SPATIAL DISTRIBUTION OF TUNA LARVAE IN THE BANDA SEA WITH RELATION TO ITS CONSERVATION

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ABSTRACT

Tuna is the single valuable export fishery commodity in Indonesia, and Banda Sea is one of the main tuna fishing ground which belongs to fisheries management area (FMA) 714. More recently, the northern part of the Banda Sea has been preserved for tuna conservation since January 2015. The reason for this restriction is due to a preliminary of tuna spawning ground was adopted based on the scientific finding. Although conservation area has been enacted, information on the distribution of tuna larvae as a key variable for establishing conservation area in the Banda Sea needs to be improved through scientific findings. This study aims to provide the information on the tuna larvae encompassing the spatial distribution and tuna larval development stage as an important input to establish tuna conservation area. Tuna larvae data collection were carried out from several onboard surveys for more than four decades. Those study consisted of 21 surveys by using three types of gears to collect tuna larvae. Total of 143 stations was sampled from these surveys and tuna larvae were found in 57 stations. The average length of larvae specimens was 7.36 ± 0.33 mm. In general, tuna larvae found in the Banda Sea were in the pre-flexion, flexion, and post-flexion stage and larvae in pre-flexion stage found in the nearshore area. We concluded that the result of this study confirmed the hypothesis that tuna might spawn in the Banda Sea. Therefore, to strengthen this finding, studies on tuna larvae should be conducted regularly to clarify properly that the Banda Sea is an important tuna conservation zone.

Keywords: Tuna larvae, Distribution, Banda Sea.

INTRODUCTION

Tuna (family *Scombridae*, tribe *Thunnini*) is the single important export fishery commodity in Indonesia and commodity with high economic value on the fishery market (Lehodey *et al*., 2018). Tuna has made a significant contribution to Indonesia and world fisheries productions, and Indonesia gradually became the first tuna production country since 2004 (Sunoko and Huang, 2014). However, issues of overfishing and illegal, unreported and unregulated fishing practices (IUUF) are still the major threat of national fish stock and its management.

Establishing a conservation area was proposed as a precautionary approach in addressing those issues particularly on sustaining spawning stocks. Starting in January 2015, Indonesia government through Ministry of Marine Affairs and Fisheries (MMAF) issued a regulation of MMAF regulation 4/2015 (Menteri

Perikanan dan Kelautan, 2015) that manages temporary closure area in the Banda Sea is part of tuna management practices in the country. The Banda Sea plays an important role as a buffer of the oceanic communication between the Pacific and Indian Oceans (Syamsudin *et al*., 2010). The Banda Sea is known as one of Indonesian important fishing grounds of commercial fishes (Tapilatu *et al*., 2018). This regulation, relies on the finding that larva tuna is abundant in some areas in the Banda Sea. Therefore, that area claimed as the spawning and breeding ground of yellowfin tuna *(Thunnus albacares).* The relationship among fish larvae abundance and its distribution with marine protected inspected in some other related studies (López-Sanz *et al*., 2009; Hitchman *et al*., 2012).

Despite the fact that the regulation has been applied since early 2015, a review study on tuna ecology in the Banda Sea revealed that very limited argument supporting the idea that tuna larva exists in the Banda Sea (Satrioajie *et al*., 2018). Moreover, only one study supports the finding that tuna larva was found in some areas near to the Banda Islands (Wagiyo *et al*., 2012). This conservation is might controversial due to limited studies, particularly major gap of the finding on presence tuna larva presence in the Banda Sea. This study aims to synthesize the information on the tuna larvae encompassing the spatial distribution and tuna larval development stage by compiling all tuna studies that were done in the Banda Sea over four decades. The finding will be significantly contributed to a better understanding of the role of Banda Sea for tuna conservation area.

MATERIALS AND METHODS

Study sites and times

Tuna (*Thunnini*) larvae distribution data were reanalyzed from several surveys that previously carried out in the Banda Sea. In total there are 21 surveys over four decades, starting from 1984 to May 2018. Tuna larva survey was first conducted in August 1984 and February-March 1985 (Soewito and Schalk, 1990), and followed by several studies in March-April 2011 (Wagiyo *et al*., 2012), and November 2013, October 2015, April, August, September and November 2017 and February, March, April, and May 2018 (present study). The compilation of the data source is shown in Table 1.

Sampling method

Different sampling methods in each survey, tuna larvae were sampled with horizontal towing that discrete depth layers, from 0-100 m, 100-300, and 0-500 m (Soewito and Schalk, 1990), vertical and horizontal towing in 150 m (Wagiyo *et al*., 2012), oblique, diagonal, and step tow, net towed horizontally and obliquely (ladder-like), in 100 m and 300 m (present study).

Samples were preserved directly after capture on either 70% alcohol or4% buffered (sodium tetraborate) formalin (Soewito and Schalk, 1990), 4% formalin (Wagiyo *et al*., 2012), and 10% buffered (sea water) formalin (present study).

Data analysis

Tuna larvae were observed under a stereomicroscope (Nikon SMZ1270i) and identified morphologically into the lowest possible taxon using available literatures (Nishikawa and Rimmer, 1987; Neira *et al*., 1998; Leis and Carson-Ewart, 2004; Kendall, 2011; Izumi *et al*., 2014). Larva stages is classified in 5 stages, yolk sac, pre flexion, flexion, post flexion, and juvenile, (Kendall, et al., 1984).

RESULTS

Total of 143 stations have been sampled from those surveys and tuna larvae found in 57 stations (Figure 1 and Table 1). Some of survey locations found tuna larvae outside the conservation area determined by (Kementerian Perikanan dan Kelautan, 2015) MMAF Regulation No 4 2015 which geographically describes within 4°0'0"S-

6°0'0"S 126°0'0"E-132°0'0"E. Seasonal observation showed that tuna larvae abundance on February-April was higher than August-November (Table 2).

Our data from surveys in November 2013 and October 2015 could not be converted to abundance unit due to limited information available (the volume of filtered waters was unknown). The average standard body length (SL) of larvae tuna was around 7.36 ± 0.33 mm. Generally, tuna larvae found in the Banda Sea were in the pre-flexion, flexion, and post-flexion stage (Figure 2). Meanwhile, tuna larvae in pre-flexion stage found in the nearshore area.

Survey on November 2013 found larvae tuna in 3 phases were pre flexion, flexion, and post flexion, on October 2015 larvae tuna in pre flexion phase was absence, and on February 2018 only pre flexion larvae was presence. The development stages of tuna larvae shown in Figure 3.

DISCUSSION

Distribution of tuna larvae depend on specific species, *Thunnus thynnus*, *T. atlanticus* and *T. obesus* mostly distributed on offshore waters (Koched *et al*., 2016, Cornic *et al*., 2018), *T. albacares* distribution mostly in offshore yet it can be found in nearshore (river plume) also (Lang *et al*., 1994, Tzeng *et al*., 1997, Cornic *et al*., 2018) *Auxis rochei* and the *Euthynnus alletteratus*, *E. affinis* larvae distribute mostly in nearshore (Tzeng *et al*., 1997, Koched *et al*., 2016, Al-Abri *et al*., 2017), and *T. alalunga* larvae showed a very scattered distribution (Koched *et al*., 2016). Some species mainly found in shallower waters between 50 and 400 m, such as *A. rochei*, *E. alletteratus*, *E. affinis*, and *Katsuwonus pelami*s (Soewito and Schalk, 1990, Boehlert *et al*., 1992, Tzeng *et al*., 1997, Koched *et al*., 2016, Al-Abri *et al*., 2017), density of larvae decreasing by increasing depth (Soewito and Schalk, 1990, Boehlert *et al*., 1992). And some species prefer in deeper waters between 400 and 800 m, such as *T. thynnus* (Koched *et al*., 2016).

Distribution and abundance of tuna larvae were influenced by physical and chemical conditions of the water mass notably sea surface temperature and salinity (Cornic *et al*., 2018). Tuna larvae higher abundance in waters with surface temperature, between 24 and 25°C (warm waters) (García *et al*., 2005, Koched *et al*., 2016, Cornic *et al*., 2018) Tuna larvae were most abundant at intermediate salinities, with values not exceeding 37.5 (Lang *et al*., 1994, Koched *et al*., 2016, Cornic *et al*., 2018).

Tuna larvae found in April to August (Tzeng *et al*., 1997, Koched *et al*., 2016, Al-Abri *et al*., 2017, Cornic *et al*., 2018) depending on specific species, larvae of *Auxis sp.* found in May to August, *Thunnus sp.* April (Tzeng *et al*., 1997). June and July to correspond with the spawning period of several tunas in the Gulf of Mexico. With larvae were present higher for *T. atlanticus* and *T. obesus* in July and for *T. albacares* and *T. thynnus* larvae in June (Cornic *et al*., 2018). Meanwhile (Lang *et al*., 1994) suggested that *T. albacares* spawning dates from 13-24 July and 22-31 August. In the southeast monsoon (August) about 60% of the larvae were from oceanic taxa, and only 30% in the northwest monsoon (Feb/March) (Soewito and Schalk, 1990). *Auxis sp*. larvae that found in May to August on whole development stage (yolk sac, pre flexion, flexion, and post flexion) and *Thunnus sp*. larvae that found in April on Pre flexion phase (Tzeng *et al*., 1997).

The development stage of larvae is also important in evaluating tuna conservation. We can estimate larval ages from the development stage of larvae, whereas proper method for estimates larval ages are using otolith microstructure, but we can use results of previous study on larval age estimates. Sagittal otolith microstructure was used to estimated larval ages (Lang *et al*., 1994). The estimate of larval ages was used to back-calculate of spawning periods.

Average body length (BL) of *T. thynnus* larvae was 2.83 mm (newly hatched), 3.54 mm (1 day old, yolk sac larva), 3.81mm (3 day old, pre flexion larva), 4.02 mm (4 day old, pre flexion larva), 5.34 mm (7 day old, flexion larva), 7.23 mm (15 day old, post flexion larva), 8.64 mm (20 day old, post flexion larva), and 13.55 mm (25 day old, juvenile) (Miyashita *et al*., 2001, García *et al*., 2006). *Auxis rochei* between 2 and 3.5 mm (2 to 4 days old) (Laiz-Carrión *et al*., 2013), *E. alletteratus* between 2 and 3.5 mm (1 to 3 days old) (Allman and Grimes, 1998), *S. sarda* smaller than 3.5 mm and between 6.6 and 7.5 mm (about 1 day old and 5 to 7 days old) (García *et al*., 2006, Sarropoulou *et al*., 2014). *T. alalunga* smaller than 3.5 mm and between 4.6 and 5.5 mm (about one day and 10 to 14 days old) (García *et al*., 2006, Sarropoulou *et al*., 2014).

CONCLUSION

This study shows that tuna larvae were found in 57 stations surrounding the Banda Sea. The larvae dispersal indicate that tuna larvae distributed within and beyond the conservation zone, as mentioned in MMAF Regulation No 4 2015. This phenomenon provides an understanding that territorial restriction is part of the area where larvae are present. Therefore, we suggest to carry out more frequent observations and provide better source of reliable data on abundance estimation and distribution tuna larvae to improve the existing conservation zone of tropical tuna in the Banda Sea. Body length (SL) of larvae tuna was 7.36 ± 0.33 mm. Tuna larvae found in the Banda Sea were in the pre-flexion, flexion, and post-flexion stage. We concluded that this result strongly supported the hypothesis that tuna might spawn in the Banda Sea within certain period. Therefore, some more studies on tuna larvae should be conducted regularly to support fisheries policy that the Banda Sea is one of the important tuna conservation areas in the country.

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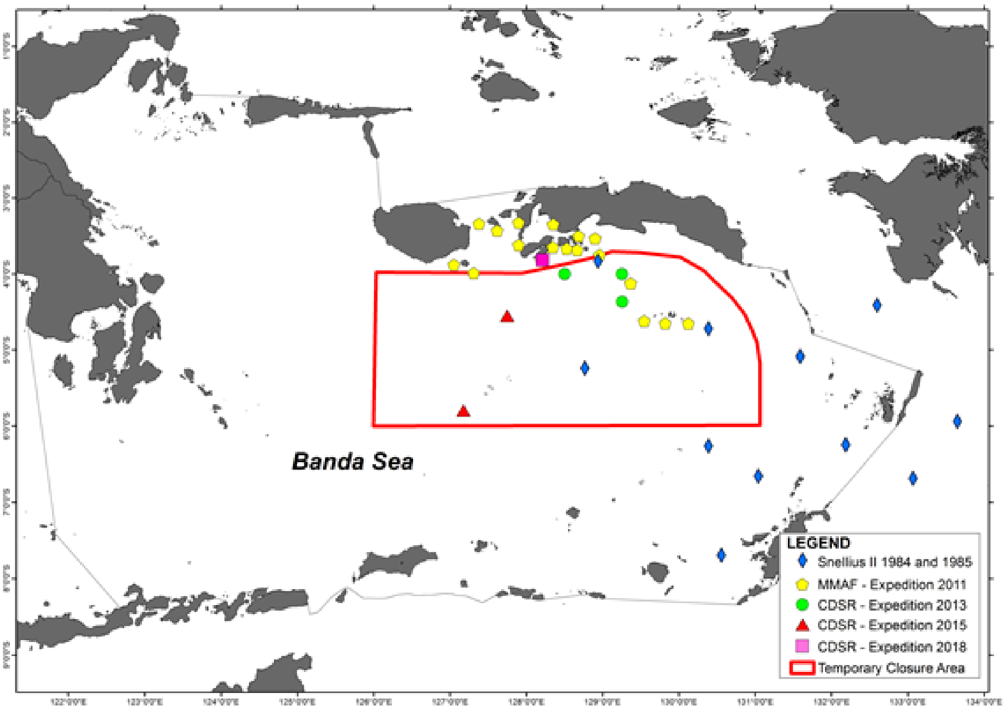


Figure 1. Survey locations which tuna larvae were collected.

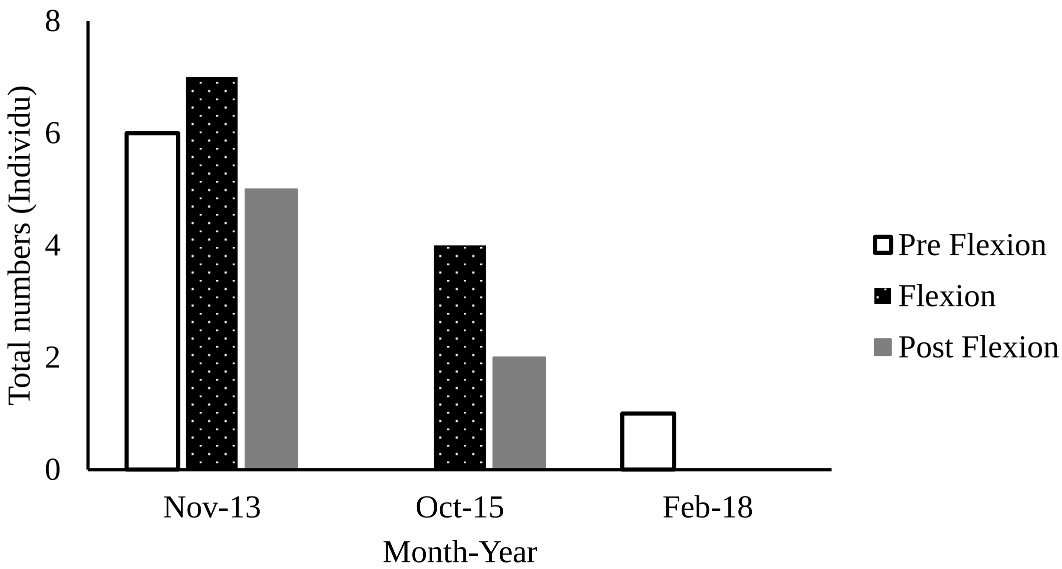
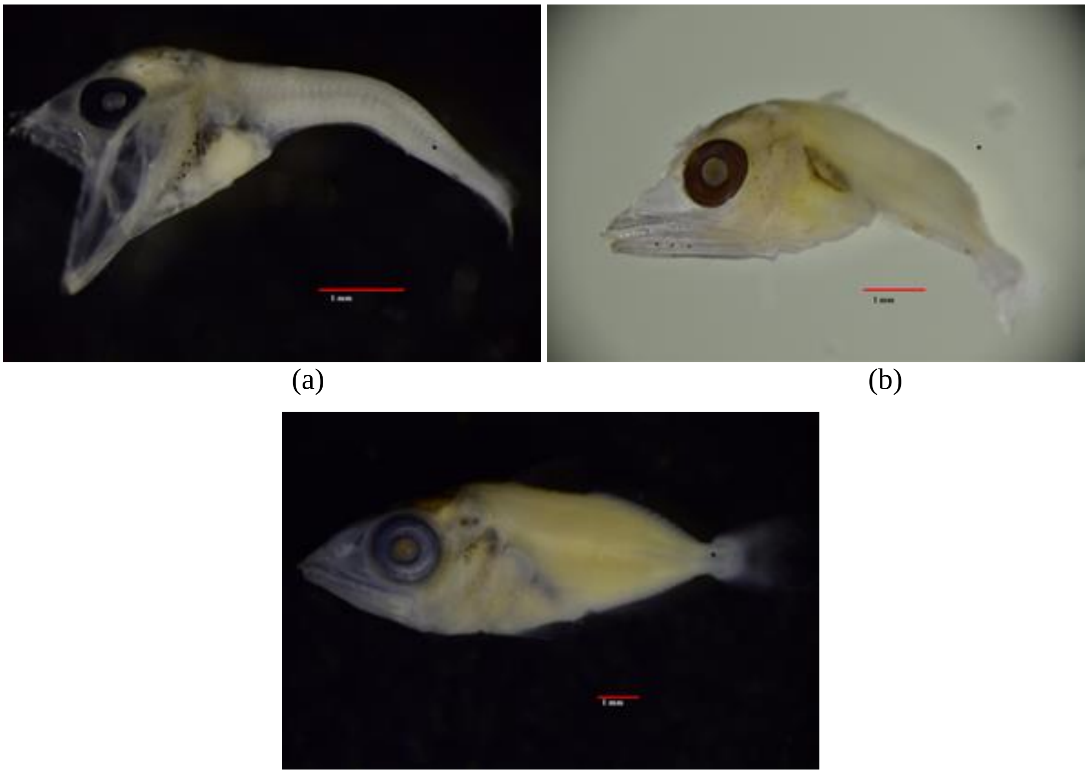


Figure 2. Tuna larvae phase found in surveys.



(a) (b)

(c)

Figure 3. Development stage of tuna larvae (a) pre flexion phase (c) flexion phase and (c) post flexion phase. Scale bar: 1 mm.

Sources: personal documentations

Table 1. Compilation of the data source used in the study with particular interest on tuna larva

Survey periods	Station number	Sampling gear	Sources
August 1984	16	RMT[a]	(Soewito and Schalk, 1990)
February-March 1985	16	RMT	
March-April 2011	18	Bongo net	(Wagiyo et al., 2012)
November 2013	4	IKMT[b]	RCDS
October 2015	2	IKMT	
February 18	1	Bongo net	

(a) Rectangular midwater trawl, (b) Isaacs Kidd Midwater Trawl (IKMT)

Table 2. Abundance of tuna larvae in each survey

Time survey	Abundance (larvae.m^{-3})	Depth (m)	Authors
August 1984	0.003	0-100	(Soewito and Schalk, 1990)
February-March 1985	0.067	0-100	
March-April 2011	0.222	0-150	(Wagiyo et al., 2012)
November 2013	21*	0-300	RCDS
October 2015	7*	0-300	
February 2018	0.018	0-100	

Remark: * number of larvae (not abundance), because the volume of filtered waters was unknown