The importance of the Banda Sea for tuna conservation area: A review of studies on the biology and the ecology of tuna

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Abstract. Tuna exploitation in the Banda Sea was started when the Indonesian government gave access to the Japanese fleet under the bilateral cooperation of the Banda Sea Agreement (BSA) in 1975-1980. Several studies were conducted afterward in revealing the magnitude of tuna resources in the Banda Sea. In this paper, we reviewed the tuna studies that were done in the Banda Sea over the periods of 1980-2017 to improve our understanding on the biology and ecology of tuna in the region as the basis for future studies. Overall, we reviewed 29 publications consisted of eight research themes; biodiversity (5), catch composition (8), fish aggregating device (FAD) (2), fishing ground (2), growth-population (3), harvest-effort strategy (4), reproduction (4), and tagging (1). The Snellius II expedition in 1984-1985 was a remarkable study covering almost whole area of the Banda Sea. The study of catch composition and biodiversity were dominant in recent decade indicating there was urgent need to manage the tuna fisheries in the Banda Sea to preserve the tuna stock. Since the Banda Sea is considered as a tuna conservation area, the future studies should be focussed on the scientific findings to support the regulation.

Keywords: Banda Sea, tuna, study

1. Introduction

Indonesia is one of the main tuna producers which contributes nearly 16% or 800,000 MT of tuna per year [1]. Most of the tuna fisheries in Indonesia are operated in the eastern regions. The Banda Sea that belongs to the Indonesian fisheries management area 714 has been known as one of the most important fishing grounds for tuna [2-4]. Over 2,000 fishing vessels ranging in gears purse seine, handline, troll line, longline, and pole and line are operating in this area and catch close to 17,000 tons of tuna and tuna-like per year [5].

Historically, tuna exploitation in Indonesia has been started prior to World War II. Foreign vessel such as Japanese tuna fleet operated around the Banda Sea, the Flores Sea, the Timor Sea and the Indian Ocean close to Sumatra and Java Island [2]. After independence in 1945, Indonesia started to cease the foreign fishing activities. This act generated an objection from the Japanese government since most of the tuna industry in the country relied on the tuna resource from Indonesia.

In order to address this issue, Indonesia and Japan made an agreement which was known as the Banda Sea Agreement (BSA). During 1968-1980, there were several phases of this cooperation

negotiating the fisheries access of the Japanese vessels to operate in the Indonesian waters [2]. Indonesia's goals were to earn foreign exchange, income, employment, technology transfer and regional development. These missions were considered to be very important during that period since Indonesia needed additional income immediately to develop its regions after the independence. On the Japanese side, the BSA gave the benefit in maintaining protein consumptions in the country through tuna supply from Indonesia. This arrangement brought about 40,000 MT tuna from the Banda Sea to Japan. During the same period, Indonesia earned about US$20 million to support the state budget. Indonesia expanded this policy by giving fishing licenses to foreign vessels from other countries even though this latter decision recently has been temporarily suspended under Ministerial Regulation of Marine Affairs and Fisheries (MAF) 56 2014 since many foreign vessels were indicated to be main actors of illegal unreported unregulated (IUU) fishing [6].

Concerning the importance of marine resources, in terms of history of marine research, there were six expeditions held in the colonial era where the Banda Sea was one of the area of interests (Table 1). Although those expeditions were more focused on the deep-sea biota and oceanographic features, the scientific findings were significant in revealing natural resources of the Banda Sea [7, 8]. There were seven expeditions conducted during five decades after the independence (Table 1) [7, 9]. Snellius II (1984-1985) was the biggest expedition ever carried out under the Indonesia-Netherlands cooperation where more than 450 scientists and technicians joined this research. This expedition covered most areas of the Banda Sea [7]. Furthermore, for the first time, tuna that belongs to the family of *Scombridae* have been found explicitly in some parts of the reports of this research. Apart from the rapid development of tuna fisheries on that period [2], this result has become a starting point concerning the importance of tuna biology and ecology studies in the Banda Sea [10, 11].

Table 1. Expeditions occurred in the Banda Sea [7, 9].

No	Expedition	Year
1	Challenger	1872-1876
2	Gazelle	1875
3	Siboga	1899-1900
4	Mortensen	1922
5	Vening-Meinesz	1927-1929
6	Snellius I	1929-1930
7	Galathea	1950-1952
8	Baruna I	1964
9	Alpha Helix	1975 and 1979
10	SEATAR	1966-1980
11	Corindon	1980-1981
12	Snellius II	1984-1985
13	Karubar	1992
14	Baruna VII	2013

Given the increase of fishing effort in the Banda Sea, Indonesian government recently has considered the exploitation level of tuna in the Banda Sea as fully-exploited [5]. A specific regulation which prohibited fishing activities in a huge closure area in the Banda Sea (126-132^{o}E, 4-6^{o}S) or almost 130,000 km^2 (20%) of the total area during the period of October – December each year was stated under MAF Ministerial Regulation No 4 2015 (Figure 1). This area was stipulated to be a spawning ground of yellowfin tuna *(Thunnus albacares)* that is one of the important tuna commodities in Indonesia [1]. Nevertheless, this regulation leads to a critic from the stakeholders that question the scientific basis of the closure area in the Banda Sea.

Some previous studies have discussed the potential impacts of this regulation on socio-economic [12] and fishing competition to other areas [6]. However, there is still a lack of information that supports the idea of spawning ground of tuna existence in the Banda Sea. Indeed, the number of tuna studies within the focus area in the Banda Sea increased after the 1990s. However, the scientific findings of those tuna studies are highly fragmented.

Reviewing tuna studies in the Banda Sea is needed to obtain better understanding on the current status of tuna stock and the potential issues. This paper reviews the scientific literature on past tuna studies and compiles empirical proofs in revealing the tuna resources in the Banda Sea. The finding of each study will be used to trace the idea of tuna spawning ground occurred in the Banda Sea and also to provide the scientific basis of closure area in the Banda Sea. In addition, we propose future studies that could be applied regarding tuna biology and ecology, to strengthen the aforementioned regulation.

2. Literature Review

We collected information of original publications of tuna studies in the Banda Sea from the last three decades. Information was derived by searching in Scopus, ISI Web of Science (Thomson Reuters), and Google Scholars using query combination "tuna banda sea" or "banda sea tuna". Some local publications, graduate theses, and reports were also used to enhance the material including the proceedings.

As it can be expected that many research on fisheries and or tuna have been done in the Banda Sea, only publications focusing on the biology and ecology of tuna were selected in this paper. From those topics, only publications that contained subject(s) such as; 1) fishing ground, 2) biodiversity, 3) reproduction, 4) catch composition, 5) fish aggregating device (FAD), 6) growth population, 7) tagging-movement and 8) harvest-effort strategy were included in the review. Overall, there were 29 publications collected where each publication, the main species, study area, observation were recorded (Table 2). Publications of the Snellius II expedition in 1990 were used as the oldest literature since the pelagic fish study was first done in this research [4, 13].

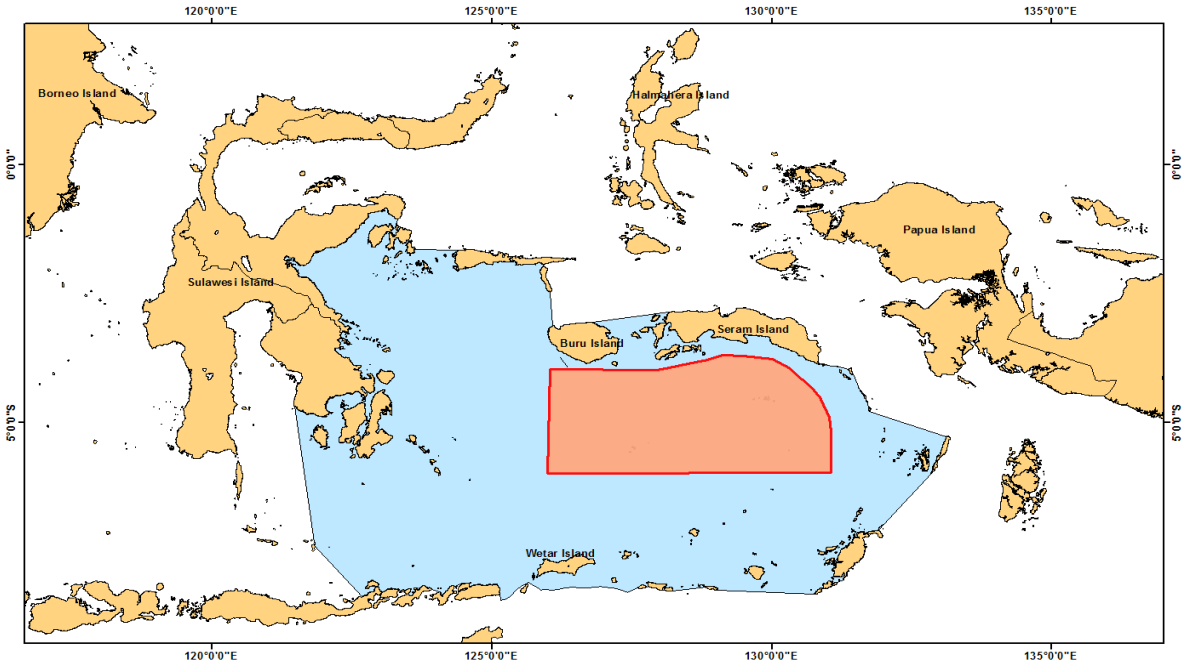

Figure 1. Study area of the Banda Sea belongs to Fisheries Management Area 714 within blue colour. The closure area is inside the red line based on Ministerial MAF 4 2015.

Table 2. Summary of tuna studies in the Banda Sea.

No	Observation	Subject	Methodology	Species	Area	Ref.
1	Fish abundance was 75% higher in the depth layer 3-100 meters during night observation.	Biodiversity	Acoustic	Pelagic fish	Whole Banda Sea	[4]
2	Fish larvae *Scombridae* was found in depth 0-100 meters during both day and night sampling.	Biodiversity	Midwater trawl	Fish larvae	Whole Banda Sea	[13]
3	Mollusks were dominant in stomach content and SKJ spawned in the whole year within peak season in June.	Reproduction	Stomach and Gonad observation	SKJ	North Banda close to South Seram Island	[14]
4	*Scombridae* was found the second highest within 26% of total larvae.	Biodiversity	Bongo net	Fish larvae	Middle Banda Sea close to Banda Islands	[15]
5	Spawning season was estimated to occur in December.	Reproduction	Onboard observer	BET	Southwest Banda Sea close to Wetar and Alor	[16]
6	Bait fish were found dominant in the stomach content and the gonad maturity did not link with fish length and age.	Reproduction	Stomach and Gonad observation	SKJ	South Seram and Nusa Laut Island	[17]
7	Range of fork length (FL) caught by longline was 104-123cm for yellowfin and 104-153cm for big eye.	Catch composition LL	Onboard observer	BET YFT	Close to Banda Islands 5-6^{o}S and 129-130^{o}E	[18]
8	Catch of pole and line was dominated by SKJ (FL 30-78cm) and followed by juvenile of yellowfin and big eye tuna.	Catch composition PL	Onboard observer	SKJ, YFT and BET	North Banda, Ambon and Buru Island	[19]
9	Mini purse seine caught 30-36% of bullet tuna.	Catch composition PS	Onboard observer	Bullet tunas *Auxis* spp	Close to Kendari	[20]
10	High abundance were found near Hatta and Gunung Api Island by 49 individual/liter and 37 individual./liter respectively.	Biodiversity	Acoustic and bongo net	Tuna larvae	North Banda Sea from Ambalau to Banda Neira	[21]
11	Tuna production was estimated 123.9-162.4kg/trip with peak season in October-December.	Harvest-effort strategy	Interview survey	Tuna	Banda Neira Island	[22]
12	Range of fork length (FL) modus caught by purse seine was 44-46cm, pole and line 40-42cm, handline 38-40cm and troll line 44-46cm.	Catch composition PS, PL, TL and HL	Port data	SKJ	Kendari	[23]
13	There were 200 fish tagged in the Banda Sea of total number 25,197 fish. FL of tagged fish were 28-65cm of yellowfin, 29-83 of SKJ and 29-58 of big eye.	Tagging-migration	Onboard observer	YFT, SKJ and BET	North Banda close to Ambon and Saparua	[24]

continued on the next page

Table 2. Continued

No	Observation	Subject	Methodology	Species	Area	Ref.
14	Range of fork length (FL) was 55-215cm and natural and fishing mortality rate were 2.4yr^{-1} and 1.79yr^{-1} respectively.	Growth-population	Enumeration	YFT	East Banda Sea 4-6^{o}S and 129-130.30^{o}E	[25]
15	There was no genetic differentiation between yellowfin caught in Ambon and North Molucca.	Biodiversity	Genetic	YFT	Ambon	[26]
16	Range of fork length (FL) of yellowfin was 87.5-177.5cm and the modus of size was 137.5cm.	Catch composition HL	Onboard observer	YFT	Banda Neira Island	[27]
17	The size (FL) of SKJ decreased over three decades 45-50.9cm (1984-1986), 42.4-48.5cm (2007-2011).	Catch composition PL	Onboard and enumeration	SKJ	Ambon, Lease Island, South Buru	[28]
18	Length and weight of SKJ caught unassociated with FADs was higher than FADs associated.	Catch composition PL	Onboard observer	SKJ	West Banda Sea close to Wawoni and Buton	[29]
19	Range of fork length (FL) caught by troll line was 20-70cm with modus 40-50cm.	Catch composition TL	Onboard observer	SKJ YFT	Kendari	[30]
20	There were 39 FADs recorded on the survey.	FAD	Interview survey	Tuna	Ambon	[31]
21	The total number of FADs in the period of 1997-2002 in the Banda Sea based on government permission was 27.	FAD	Port data	Tuna	Banda Sea (not specific)	[32]
22	The highest probability of SKJ fishing ground was estimated located in West Seram, Buano, Kelang and Manipa.	Fishing ground	Remote sensing and logbook	SKJ	Banda Sea 2-5^{o}Sand 125-131.5^{o}E	[33]
23	The criteria of size catch was >58cm.	Growth-population	Enumeration	SKJ	Ambon	[33]
24	MSY of SKJ was 33.000ton/year.	Harvest-effort strategy	Interview survey and Port data	SKJ	Banda Sea (not specific)	[34]
25	Yellowfin spawned all year within peak season in October – December.	Reproduction	Enumeration	YFT	Around Banda Islands 3-4^{o}S and 129-130^{o}E	[35]
26	By catch of tuna longline was dominated by sickle pomfret, stingray and lancet fish.	Catch composition LL	Onboard observer	Tuna	Southwest Banda Sea close to Wetar and Alor	[36]
27	Fishing ground of SKJ was predicted in east Wawonii Island.	Fishing ground	Remote sensing	SKJ	West Banda Sea close to Kendari	[37]
28	Range of fork length (FL) of SKJ was 36.54-51.30cm and maximum length (L∞) was 70.1cm	Growth-population	Enumeration	SKJ	Kendari	[38]
29	Maximum Sustainable Yield of SKJ was 180.487ton and total allowable catch was 144.390ton.	Harvest-effort strategy	Vessel logbook and port data	SKJ	North Banda Sea close to Ambon	[39]

HL = Handline, PL= Pole and line, TL= Troll line, LL= Longline, and PS= Purse Seine, SKJ= Skipjack Tuna, YFT= Yellowfin Tuna, BET= Big Eye Tuna, MSY= Maximum Sustainable Yield

3. Development of the tuna studies in the Banda Sea

In general, the number of the tuna studies in the Banda Sea increased significantly since the 1990s (Figure 2). Despite the Snellius II expedition was not specifically purposed for tuna study, it was a milestone in revealing the magnitude of marine resources including tuna in the Banda Sea. The expedition encompassed almost the whole area of the Banda Sea involving multidisciplinary of oceanography research: geological, physical, chemical, and biological [9]. Given the large area of the Banda Sea, there were only two studies that discussed the small size of potential tuna fishing grounds based on satellite imagery. They suggested that the fishing ground located close to the islands covering Ambon and Buru Islands in the north Banda Sea and Wawonii and Wakatobi Islands in the west Banda Sea [33, 37]. Two important commodities namely the skipjack (SKJ) / *Katsuwonus pelamis* and the yellowfin tuna (YFT) / *Thunnus albacares* were the most frequent subjects of the studies. There was only small number of studies concerning ~~on~~ the big eye (BE) *Thunnus obesus* and other tuna-like species such as *Auxis* sp (Table 2).

There were two publications from the Snellius II expedition related to tuna focusing on the abundance of pelagic fish including tuna and its larvae [4, 13]. Those studies were updated by Taufik et al. in 2005 and Karsono et al. in 2012, reporting the high abundance of tuna larvae around Banda Islands and Ambalau Island respectively. Those studies suggested that most tuna larvae were found in the depth layer of 0-100meters [4, 13, 15]. Meanwhile, tuna reproduction study was first studied in the first decade focussing on skipjack [14]. It was followed by another study discussing on other species BE and YFT. Those studies found that YFT and SKJ spawn throughout the year, within peak seasons in October to December [14, 16, 17, 35].

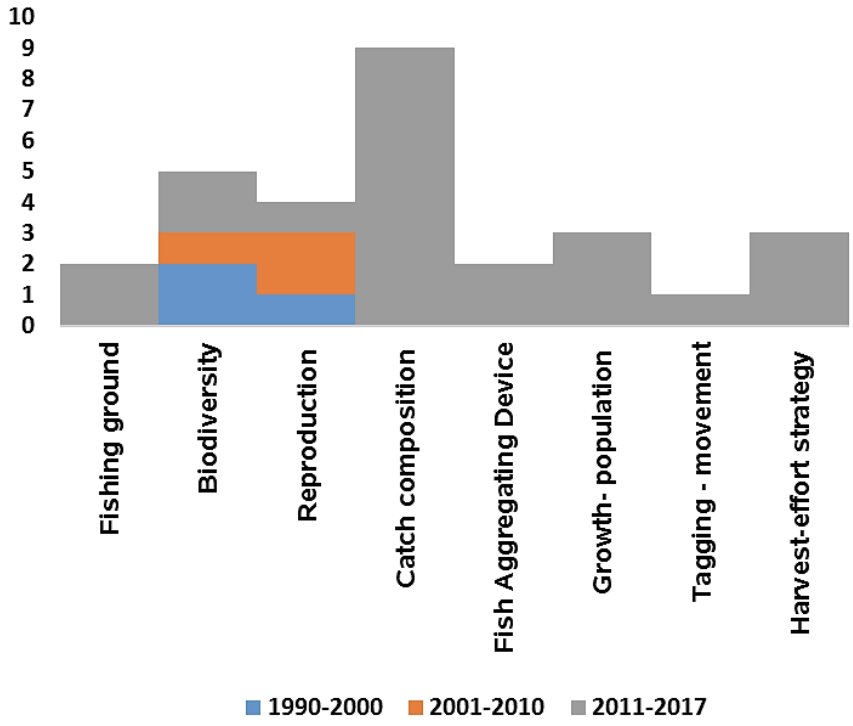

Figure 2. Computation of selected tuna subject publications in the Banda Sea in three decades.

More studies were focused on catch composition from different fishing gears and harvest control rules in the last two decades [27-30]. This indicated more concerns in revealing the fishing impact towards tuna stock [40]. Catch composition of five main tuna gears that operated in the Banda Sea was observed. Handline and longline vessels caught bigger size of YFT than troll line [18, 30]. The SKJ was the main species of pole and line fishery operated in this area [19, 28]. Some studies observed small purse seine fishery reporting that SKJ, tuna-like species such as *Auxis* spp and small pelagics fish were the dominant species. However, there were also concerns about the decrease in the size of SKJ and YFT and also the potential catching of juvenile tuna on several gears such as purse seine, longline, pole and line [18, 23, 28]. These findings were also encountered by some studies discussing the fish growth and fishing mortality of SKJ and YFT revealing that those species were caught in immature conditions [25, 33, 38].

Tuna fishery in the Banda Sea cannot be separated also from the use of fish aggregating devices (FADs). This device has been a concern on tuna sustainability of Indonesian tuna fisheries since the 2000s [41, 42]. A study in western Banda Sea reported that smaller size of SKJ was caught around this device [29]. Some descriptive studies also already reported the total number of FADs on the basis of licenses and interview survey, however, the distribution and density of FADs in this Banda Sea remain unclear [31, 32]. With regards to tuna movement, the use of archival tags to determine the migration patterns was studied in eastern Indonesia [41]. Unfortunately, there was only one paper discussing the number of fish that were tagged in the north of the Banda Sea close to the Ambon Island. Meanwhile, on the stock study, SKJ that associated with pole and fishery was used as the case study to estimate the maximum sustainable yield. From both studies, it was found that the exploitation level of skipjack around Ambon was under fished and it was suggested that pole and line fishery could be maintained [33, 39].

4. Idea of tuna spawning ground and closure area

The investigation of tuna spawning location has been approached using several variables such as larvae abundance [43-45], tuna behaviour and movement patterns [46-48], and interaction between larvae and oceanography feature such as temperature [49]. Following that schemes, several tuna larva studies have been done in the Banda Sea revealing that this larva was abundant [13, 15, 21]. However, there was no clear record that the spawning ground of tuna, particularly YFT existed in the Banda Sea. Those studies only took snapshots of the tuna larvae abundance in a short period from specific locations making it really difficult to describe the role of the Banda Sea related to the life cycle of tuna. Despite the closure period in October until December is according to the reproduction study of YFT [35], more studies are needed to sharpen the analysis, by expanding the observation from another area surrounding the Banda Sea.

The realistic reason in justifying the importance of closure area of the Banda Sea is the harvest-effort and catch composition studies. However, it should be noticed that the national tuna management plan (RPP-TCT) under Ministerial Decree MAF No. 107 2015 also did not propose a closure area as a part of the strategy in sustaining tuna stock. This regulation emphasized to control (hold) the fishing effort in the Banda Sea despite the exploitation level that was still under MSY. This concern is in line with some literature concerned on the decrease of the length of fish caught from different fishing gears and catch amount on the basis of observer and enumeration program [19, 23, 28].

5. Implication on the management and future studies

All studies showed concerns regarding the depletion of tuna resources in the Banda Sea. By contrast, we argue that the regulation of the restriction area under the Ministerial Regulation of MAF 4 2015 in the Banda Sea has a strong scientific background. Some studies indicated the finding of tuna larvae in some area of the Banda Sea. However, it is noteworthy that no study has reported tuna post-larvae or early tuna juveniles exist in some periods which suggested that this area could be considered as a conservation area for specific species.

In general, the idea of making a closure area to promote the recovery of YFT stock could potentially be beneficial. However, the decision of location choices, sizes, shapes, and closure duration (seasonal or multi-annual duration) should be carefully studied. Furthermore, the relevancy with other regulations such as Ministerial Decree MAF 69 2009 that organized the marine conservation area and Ministerial Decree MAF 58 2014 that managed the establishment of aquatic tourism park in the Banda Islands of the area should be considered carefully. In particular, knowledge of where the spawning and nursery sites are located and how these locations vary with population characteristics (abundance, age/size structure) remains highly needed.

This paper is the first to review the tuna research in the Banda Sea. Given the difficulties in obtaining reliable findings from the various studies, it can provide the urgently required insight as compiling the snapshots to the better quality of the scientific advice in managing tuna resources in the Banda Sea. We suggest the future studies should be prioritized on exploring the accuracy of regulation such as investigating the life cycle of the two main species SKJ and YFT in Indonesian waters either regularly larvae survey, advance tagging study, and genomics. Another urgent study needs to be done is to evaluate the implementation of Ministerial Regulation of MAF 4 2015 and the impact of the closure area to other aspects such as production and socio-economy.

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