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Acoustic approach for estimation of Skipjack (*Katsuwonus pelamis)* abundance in Bone Bay

R S Putri[1], I Jaya[2*], S Pujiyati[2], A Priatna[3], A Makmun[3] and A Suman[3]

[1] Department of Marine Technology, Graduate School of Bogor Agricultural University, Indonesia
[2] Faculty of Marine Science and Technology, Bogor Agricultural University, Indonesia
[3]Research Institute for Marine Fisheries, Ministry of Marine and Fisheries Affairs, Indonesia
*e-mail: indrajaya@ipb.ac.id

Abstract. Skipjack is one of the most important economical fish. As a result, skipjack stocks are vulnerable to over-exploitation. Therefore, to anticipate and to set sound management plan, it is necessary to monitor from time to time the abundance of these fish to ensure the sustainability of its resources. The purpose of this study was to determine the abundance distribution of skipjack fish based on acoustic method in Bone Bay waters. The abundance estimate of the skipjack was conducted using Split Beam Echosounder Simrad EY 60 with frequency 120 kHz. The results of this study indicated that the range of skipjack target strength (TS) was -67.0 dB to -55.3 dB, or equivalent to fish length of 8 cm to 31 cm, detected from surface to a depth of 40 m. Temporally, skipjack density during the day was more towards the surface with an average of 43 ind/1000m³ and at night in deeper waters with an average density of 36 ind/1000m³. Vertically, the highest density was detected at a depth of 5 m - 15 m with a density of 82 ind/1000m³. While horizontally, the highest skipjack density of 188 ind/1000m³ was found around Kolaka waters.

1. Introduction

Skipjack is one of fishery commodities in Indonesia which has important economic value. This makes this fish as one of the main target in fishing activities. One of Skipjack producing areas in Indonesia is Bone Bay waters. Bone Bay is a potential waters for Skipjack fishing in Eastern Indonesia. The potential abundance of Skipjack is related by the spatial and temporal pattern of biophysical distribution of the oceanographical condition in Bone Bay. The oceanography condition near the mouth of the bay (Flores Sea) is certainly different from the other area [1]. It is suspected as a trigger of the high abundance of Skipjack in this waters.

Skipjack fishing mostly use pole and line, purse seine, gillnet and handline. The skipjack behaviour that form a schooling gives the opportunity to catch Skipjack in large quantities. As the result, Skipjack's resource is vulnerable to over-exploitation. Although fishery resources are a renewable resource, the rate of recovery may be unbalanced with the rate of utilization.

In 2005-2014, Skipjack production in WPP 713 experienced an annual increase of 11.40%, with production in 2014 was 56.299 tons. Skipjack production in Indonesia in 2014 was 496.682 tons, meaning that 11% of it came from WPP 713 [2]. With the increasing of skipjack production, it is necessary to have information about the status of Skipjack’s stock. The estimation of Skipjack stock is important so that the potential of Skipjack resources can be utilized sustainably and to avoid the overfishing. One of the most effective methods for estimating fish stocks is by using the acoustic method. The principle of acoustic method is based on the echo system, that is the reflection of the emitted sound by something that prevents it [3]. The acoustic method has several advantages in estimating schooling of fish and its abundance, including information that can be generated faster and covering larger areas,

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stock estimation can be done in real time and in situ regardless of data fishery statistics, have high accuracy, can be used when other methods are unusable, and are not harmful or destructive because the frequency of sound used is not harmful to the users or the target of the survey [4].

The existence of Skipjack's schooling can facilitate the detection of Skipjack using acoustic method. The estimation of abundance of fish resources through acoustic survey generally has the same condition with other fishery survey, that is to gather data about a fisheries resource in an area. This analysis can produce information about the conditions of a fisheries resources [5]. One approach to estimate the fish abundance with acoustic methods is by measuring the target strength (TS). Measurement of fish target strength is the main parameter in estimating fish stock with acoustic method [6]. Generally, the higher the target strength of fish, the larger the size of the fish, but not always so. In addition to size, TS values are also influenced by the swim bladder in the fish, fish body shape or type of fish itself.

The purpose of this research was to estimate the density of Skipjack temporally (day and night), vertically (depth) and horizontally (spatial) using the acoustic method in Bone Bay waters, and to validate the results with the results from fishery survey. It was expected that the results of this study could provide information about the existence and abundance of Skipjack. This information could be used to support the sustainable management of Skipjack fisheries resources in the waters of Bone Bay.

2. Methods

The acoustic survey was conducted in April 2014 in Bone Bay waters and was validated using a survey on landing site in September - October 2016. The survey on landing site was conducted to collect data about the size of Skipjack in two fishing port with high Skipjack production, namely Sinjai and Luwu. The acoustic survey track that was done in Bone Bay waters was shown in figure 1.

Acoustic data was collected using Split Beam Echosounder Type Simrad EY 60 with frequency 120 kHz. Software Echoview, R, and ArcGIS 10.3 were used for acoustic data analysis. Fork Length (FL) data were obtained by following the Skipjack fishing operation by using pole and line in Bone Bay waters. In addition, FL measurement was also conducted at the fishing port in Sinjai and Luwu. FL measured using roll meter.

Acoustic data processing followed the method in [7] with the following processing steps :
Target Strength analysis and average TS are calculated by equations (1) and (2).

$$TS = 10 \log\ ts \tag{1}$$

$$\overline{ts} = \frac{\sum ts}{\text{n}} \tag{2}$$

where TS is acoustic reflection strength of fish as a single target (dB).

Scattering volume (SV) and average SV are calculated by equations (3) and (4).

$$SV = 10 \log sv \tag{3}$$

$$\overline{sv} = \frac{\sum sv}{\text{n}} \tag{4}$$

where SV is *volume backscattering strength* (dB).

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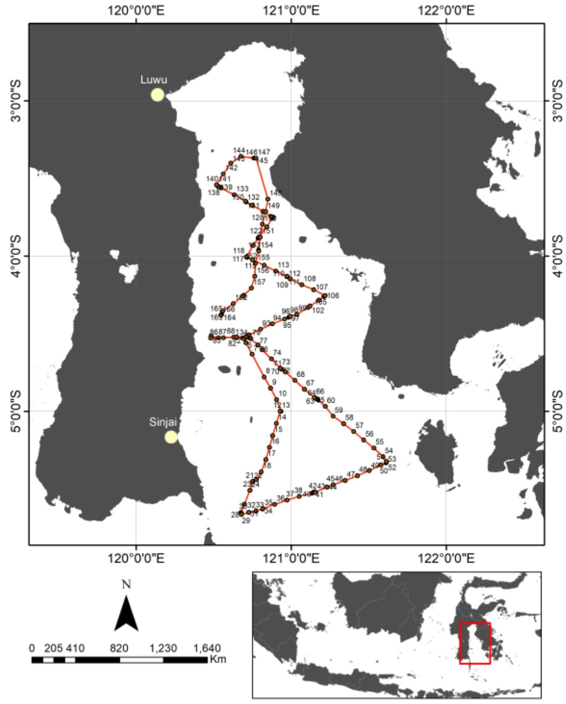

Figure 1. Figure 1 Research location and track of acoustic survey.

To obtain fish density value (ind / 1000m^3), equation (5) is used.

$$SV = 10 \log \rho + \overline{TS} \quad (5)$$

So that:

$$\rho = 10^{\frac{SV - \overline{TS}}{10}} \quad (6)$$

where ρ is density of fish (ind/1000m^3).

The prediction of TS value can be known based on the length of fish caught by using target strength of Skipjack in [8]:

$$\mathrm{TS} = 20\ log\mathrm{FL} - 85{,}08 \quad (7)$$

3. Results and discussion

3.1. Fisheries survey

The fishery survey was conducted to obtain the fork length data which was then was used in the estimation of the target strength (TS) of Skipjack. The total of samples used were 626 fishes, which were obtained from two different locations, Sinjai (406 fishes) and Luwu (220 fishes). Figure 2 showed that the dominant of fish length was ranged from 40 to 49 cm, with the total of sample was 188 and the lowest size was ≥70 cm. The catchable size of Skipjack in the waters of Bone Bay is > 47 cm in TKG IV [9]. Based on this result, it could be concluded that from the total samples, 65% of them was not eligible to catch. Skipjack production in South Sulawesi in 2015 was 21038.8 tons, 32% comes from Sinjai and Luwu [10].

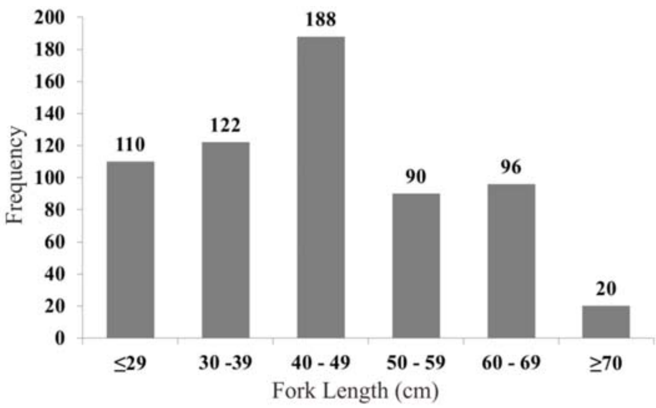

Figure 2. Fork Length composition of Skipjack from the fisheries survey.

3.2. Estimation of target strength (TS)

The Acoustic method was not able to provide definitive information on detected fish species, so the TS were predicted. Target Strength (TS) describes the ability of a target to reflect an incoming sound wave. TS is expressed in decibels (dB) [5]. TS was a function of size, shape, and presence or absence of swim bladder [11]. Based on the size of Skipjack catch in fishing port, it could be known that the range of Skipjack TS was -59 dB to -47 dB (figure 3).

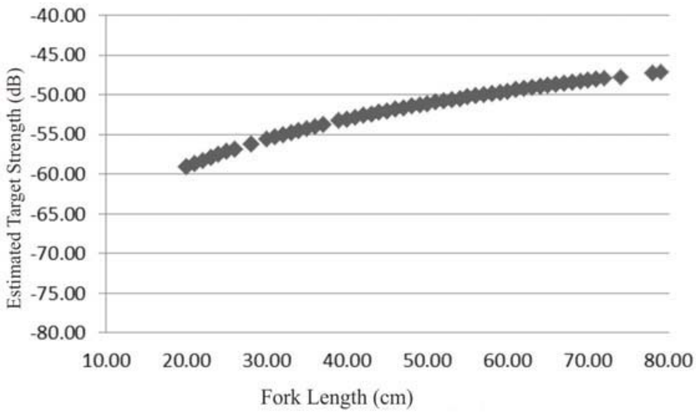

Figure 3. The relationship between FL (Fork Length) and estimated TS of Skipjack using the equation (TS=20 log FL – 85.08) [8].

The graphic relationship between FL (Fork Length) and estimated TS of Skipjack in this study indicated that the longer size of the fish, the higher its target strength (figure 3). Measuring the target strength of the same species, the target strength had a linear relationship with the length of the fish [12-13].

The length of fish is one factor that was very influential on the TS. In general, the relationship between TS and the fork length of the fish is positive, which means that the longer the fish, the higher the TS. In addition, TS values are also influenced by swim bladder, behavior and the instrument factors. Skipjack tuna is a fish that does not have a swim bladder, unlike other types of tuna fish, so the TS value of skipjack is lower than other tuna species [14].

3.3. Acoustic survey
Based on the results of acoustic survey, the obtained acoustic data was in the form of echogram. Figure 4 was an example of an echogram that indicated the existence of a fish schooling and vice versa. This reference was used in performing acoustic data analysis.

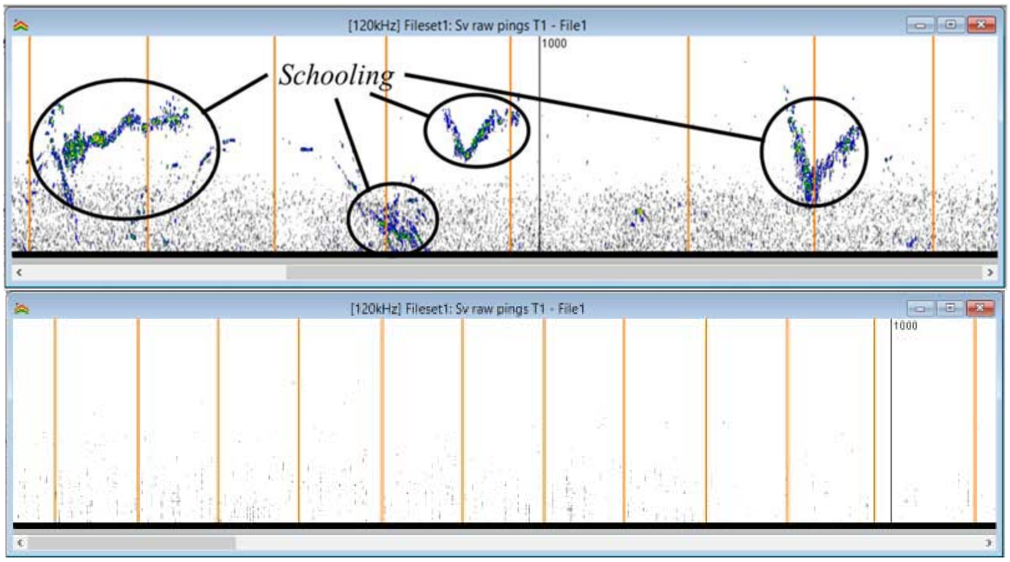

Figure 4. Echogram with an indication and no indication of fish schooling.

3.3.1. Temporal distribution. Distribution of fish in night and day tend to be different. Pelagic fish during the day is more often to form schooling as an effort to facilitate foraging, mating and spawning, to avoid or defend themselves from predators while at night is more distributed in the water column [15]. Figure 5 showed that the temporal distribution of Skipjack during the daytime was in the water column with a depth range of 7.1 m to 38.9 m, density 1 to 188 ind/1000m^3 and estimated FL was ranged from 4 cm to 76 cm. The central of Skipjack distribution was at 21.4 m depth, with a density of 43 individual and an estimated FL of 29 cm.

In the evening, Skipjack was distributed in the depth range of 11.8 m to 39.3 m with a range density 4 to 141 ind/1000m^3 and estimated FL range of 4 to 73 cm. The central of Skipjack distribution at night time was at a depth of 29.1 m with a density of 36 ind/1000m^3 and an estimated FL of 27 cm. In general, the distribution of Skipjack at night time located in deeper water while in the day was located closer to the surface of the waters. Skipjack is more active during the day time than at night because they are looking for food, its peak occurence is in the morning and mid of noon and afternoon [3].

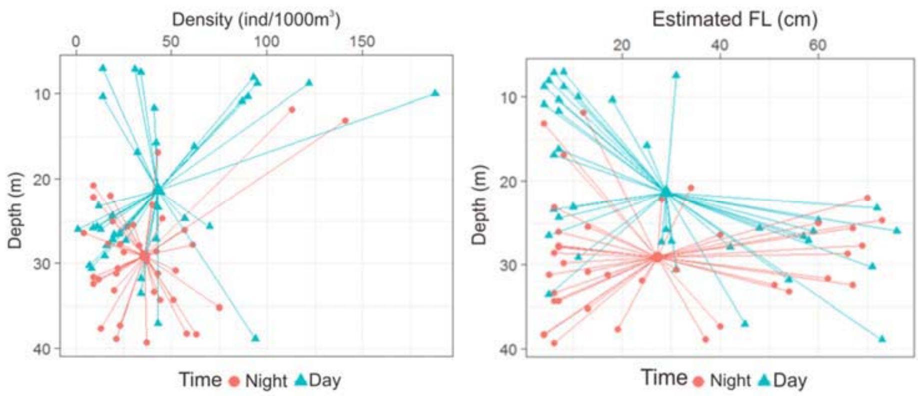

Figure 5. Skipjack distribution in the day and night.

3.3.2. Vertical distribution. Skipjack tuna is often referred as surface tuna [16], because Skipjack generally distributes in surface waters. Skipjack performs repetitive ups and downs movement in the waters, but the main distribution is in the upper layer where the water temperature is greater than 15°C [17]. Skipjack was distributed in the depth range up to 40 m, so the echo analysis was limited to a depth of 40 m. Skipjack was indicated high concentrated in the depth range up to 40 m, and used as a reference in the analysis of acoustic data conducted in this study [18].

The average target strength and density of Skipjack was then plotted in a graphic to evaluate their differences in the depth of the waters. Generally, the deeper the water, the higher the target strength due to the longer of fish size. However, in Figure 6, the target strength values was fluctuated to a depth of 40 m, this might be due to the calculated target strength was come from the average of the target strength of schooling fish that might had varying sizes. Skipjack is a tuna that has no swim bladder, so that their target strength was highly influenced by the size their body. The highest average of target strength was -55.3 dB and was occurred in the depth range of 20 m - 25 m, with the estimated FL was 31 cm.

The highest density of skipjack was 82 fish/1000m³, and was occurred in the depth of 5 m - 15 m or closer to the surface of the water (figure 6). It could be assumed that these fishes were generally small fish because their average of target strength was small (TS was -66.8 dB and estimated FL was 8 cm). Generally, the deeper the waters, the lower density of fish [19]. The highest average of target strength (-55.3 dB) as previously mentioned was estimated to be the longest fish that was detected by acoustics, with density of 29 ind/1000 m³.

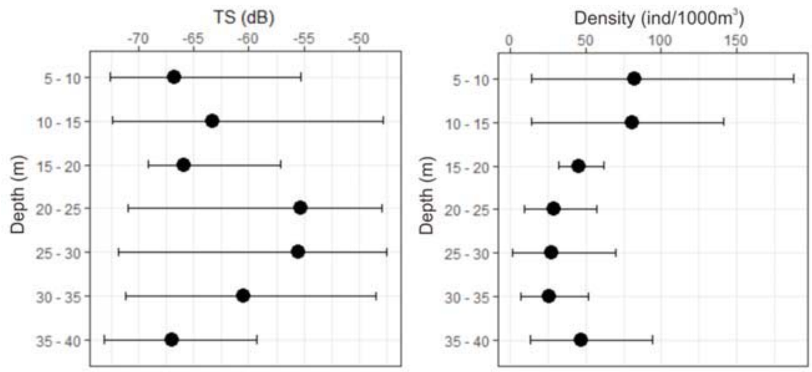

Figure 6. The relationship of depth with target strength and Skipjack density.

The estimated FL of Skipjack based on TS was then presented in table 1 to give an information about the estimated of Skipjack size vertically. Based on TS average from acoustic survey, an average of estimated FL was ranged from 8 cm to 31 cm. The overall data from estimated FL showed that the catchable fishes according to their size were distributed in the depth range of 10 m - 35 m, with size of 48.1 cm - 76.0 cm.

Table 1. Depth, $\overline{TS}$, estimated $\overline{FL}$ and density of Skipjack.

Depth (m)	$\overline{TS}$ (dB)	Estimated $\overline{FL}$ (cm)	Density (ind/1000m³)
5 - 10	-66.8	8	82
10 - 15	-63.3	12	81
15 - 20	-65.9	9	45
20 - 25	-55.3	31	29
25 - 30	-55.5	30	27
30 - 35	-60.4	17	26
35 - 40	-67.0	8	47

3.3.3. Horizontal distribution. The horizontal distribution of fish in aquatic ecosystems is complex. There are several factors that influence the distribution of fish populations, such as migration, feeding behaviour, patterns of predation, reproduction and habitat selection [20]. The skipjack density was showed horizontally (figure 7) to determine the position and the abundance of Skipjack in Bone Bay waters. Figure 7 showed that the highest density of Skipjack in Bone Bay waters was located in Kolaka waters precisely at 121°10'84,00 "E and 4°55'11,56"S, with the total density of 188 ind/ 1000m³. This might be due to high disribuition of small pelagic fish in these waters . Small pelagic fish is food source for Skipjack, thus inviting Skipjack to concentratein that waters. Skipjack generally distributed in areas with high productivity. This is due to the presence of small pelagic fish that is high in these water condition for feeding [21].

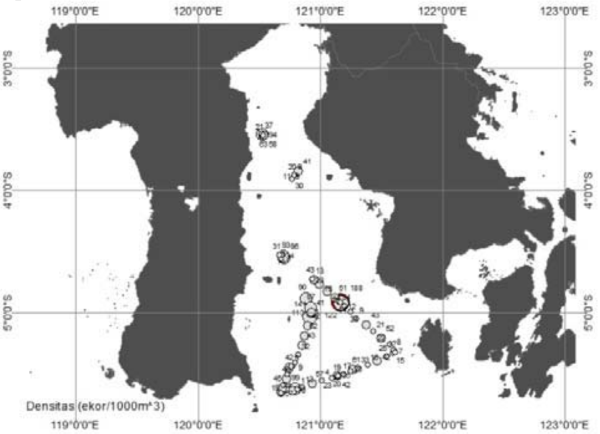

Figure 7. Map of skipjack density in Bone Bay.

4. Conclusion

The range of skipjack target strength was -67.0 dB to -55.3 dB, or equivalent to fork length of fish of 8 cm to 31 cm that was detected from the surface to a depth of 40 m. Temporally, the Skipjack density during the day was more toward the surface at 21.4 m depth with average density of 43 ind/1000m³ and at night in deeper waters at 29.1 m depth with average density of 36 ind/1000m³. Vertically, the largest density at the time of the acoustic survey was conducted was at a depth of 5 m - 15 m with a density of 82 ind/1000m³. While horizontally, the highest Skipjack density, with the total density was 188 ind/1000m³, was located in Kolaka waters or in the southern part of Bone Bay.

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