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RELATIONSHIP BETWEEN THE EXISTENCE OF TUNA TO UPPER AND LOWER THERMOCLINE AT FADs IN PELABUHANRATU WATERS, WEST JAVA

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ABSTRACT

Knowledge of fish behavior and its relationship to environmental factors is needed so that the development of fishing gear operating methods can be more effectiveThe target fish is no longer seen from the quantity of catch but rather the quality of the catch). This is done to maintain the sustainable use of fish resources. Data collection was conducted from November 24 to December 3, 2015 at Pelabuhanratu. This study aimed to determine the relationship between fish behavior and environmental factors in the upper thermocline (Zona-Up), thermocline and lower thermocline layer (Zona-Un). Observations were carried out at intervals of 6 hours: morning (6:00 - 08:00 WIB), daytime (12:00 - 14:00 WIB), afternoon (18:00 - 20:00 WIB) and evening (00:00 - 02:00 WIB) using echosounder in FADs. Acoustic recording tracks form stars around the FADs. Environmental factors were measured using the CTD Sea bird SBE 19 plus V2. The measured environmental parameters were temperature (ºC), salinity (PSU), dissolved oxygen (mg / l), chlorophyll (mg / m^3), conductivity (S / m) and seawater density (kg / m^3). The results showed that the factors that had a significant relationship between fish abundance and environmental factors in the zone-up were temperature and salinity, while the key factor in thermocline and un-zone layers was temperature.

Keywords: Underwater acoustic; yellowfin tuna; FADs; Pelabuhanratu

INTRODUCTION

Market demand for capture fisheries products, especially tuna, continues to increase. However, the export volume of tuna and neritic fish showed a decreasing trend from 226,553 tons in 2014 to 168,433 tons in 2018 ((Rahmantya, 2015; Hariono, 2019). This trend may result from the degradation of fish resource stocks, where catch decreases are due to increased fishing efforts, but the carrying capacity remains relatively the same. Nowadays, fishers no longer pay attention to the size of the fish caught. The catch is generally dominated by small-sized immature fish that can lead to recruitment overfishing. The smaller the average size of fish retained, the less likely it is for fish to reach spawning size. The impact of reduced recruitment is a decreased potential yield (Damora & Baihaqi, 2013; Davies *et al.*, 2014) and over-capture capacity or overfishing (Simbolon, 2004; Nurdin *et al.*, 2012; Hufiadi & Nurdin, 2013; Davies *et al.*, 2014).

If catching juvenile tuna continues, it can harm resource conservation where there is a decrease in the size of fish caught and opportunities for breeding (Nurdin *et al.*, 2016). The presence of fish in particular waters is strongly influenced by environmental factors and the movement of water masses that affect productivity (Amri *et al*., 2005; Amri *et al*., 2006). Changes in the environment will affect the fish and their food sources (Amri *et al*., 2006). The water layer with high productivity will affect the presence and abundance of fish (Pena, 2014) so that some fish experience a food chain process between pelagic fish (Baskoro *et al*., 2011). Knowledge of the dominant environmental factors in several layers of water is needed so that fishing gear operations can be more effective.

This study is aimed to determine environmental factors that affect the presence of fish within the above of thermocline layer, the thermocline, ,and the layer below the thermocline.The thermocline layer is essential for tuna, as these large pelagic fish inhabit the thermocline layer and the layer under the thermocline (Song *et al.*, 2007).

In the Indian Ocean, bigeye tuna are primarily caught in the thermocline layer and below the thermocline (Mohri *et al.*, 1999; Song *et al.*, 2006; Syamsuddin, 2009). Analysis of the relationship between a species and its environment is always

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crucial in ecology. Marine species are often associated with particular physical or biological habitats, so we can seek to understand the correlation of environmental variables with fish distribution and abundance patterns.

MATERIALS AND METHODS

Acoustic observation of fish around FADs was carried out between November 24 to December 3, 2015, using an echosounder on a FAD located in the waters south of Pelabuhanratu (Indian Ocean) (7^0 53.89' S and 105^0 44.08' E). Observations were made at four times of the day - morning, daytime, afternoon and night in one FAD. FAD was observed at intervals of 6 hours, in the morning (06.00 - 08.00 WIB), daylight (12.00 - 14.00 WIB), afternoon (18.00 - 20.00 WIB) and at night (00.00 - 02.00 WIB). The location of FADs sampled are shown in Figure 1.

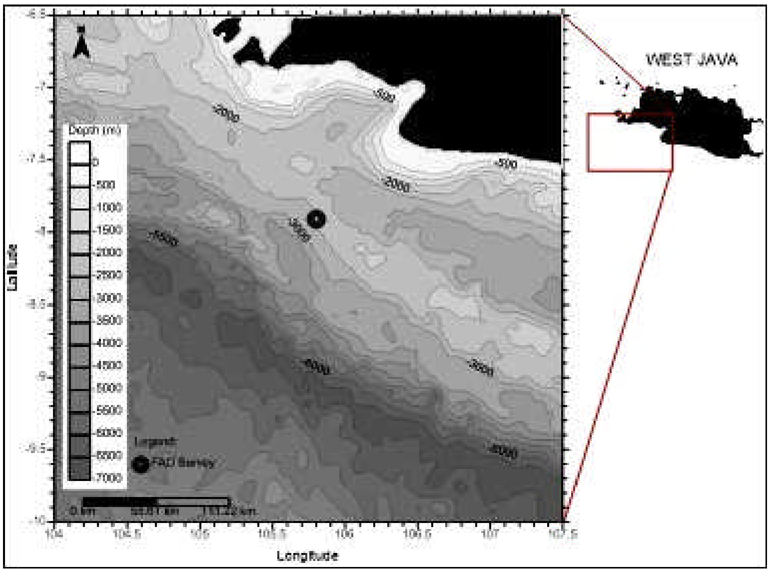

Figure 1. Locations of FADs in the Indian Ocean.

The acoustic recording track by circling star survey is shown in Figure 2 (Josse *et al.*, 1999). The track radius was 0.2-1 nm from the FADs center. Boat speed was 4-5 knots with a duration of 2-2.5 hours. Data acquisition used a portable scientific echosounder SIMRAD EY60 and a transducer with a frequency of 38 kHz on the side-mounted system (Simmonds & MacLennan, 2005). The use of low frequencies for deeper waters will be better used in stock assessments (Lee, 2012).

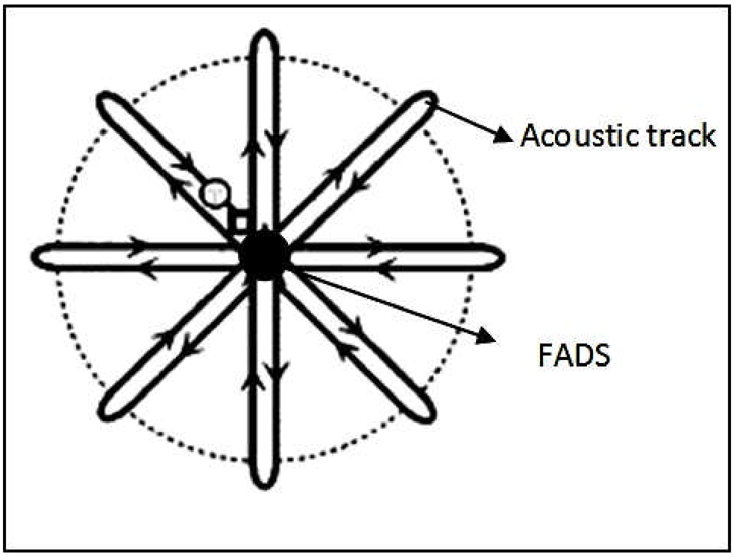

Figure 2. Acoustic track design (Josse *et al*., 1999).

Data acquisition involved recording at a depth range of 1 m to 500 m. This was adjusted to the ability of the hydroacoustic tool used. Recording data during research used ER60 software that produces raw data (files with format *.raw, *.bot, *.idx). Parameter settings echosounder system are presented in Table 1.

Table 1. EY60 parameter setting

Parameter	Value
Frequency	38 KHz
Pulse duration	1.024 ms
Power transmit	1500 watt
Sound speed	1547 m/s
Absorption Coefficient	5.72 dB/km
SV threshold	-70 dB
TS threshold	-60 dB

Acoustic data display took the form of target strength data distribution (TS) in decibels (dB) as a fish size index and backscatter power volume (SV) as density index collection of a detected fish target. The size of the fish was divided into three groups, 30-50 cm FL, 50-100 cm FL and 100-200 cm FL. To validate catch, fishing vessels operated around the FADs by carrying five types of fishing gear: troll line, hand line, vertical line, float line and kite line. Catching trials were carried out at each interval of observation. Strings were marked down the line during the fishing process to find out the depth of fish captured. Operation of most fishing gear used artificial bait with shiny colors and textures, with only vertical buoy lines using fish bait. The catch obtained was used as a fish validation of the results of acoustic measurements.

Measurement of environmental factors used CTD Sea bird SBE 19 plus V2 device deployed to a depth of 200 m. Data was collected for each change in pressure to depth. The types of environmental parameters that can be measured by the CTD Sea bird SBE 19 plus V2 include: temperature (ºC), salinity (PSU), dissolved oxygen (mg/l), chlorophyll (mg/m^3), conductivity (S/m) and seawater density (kg/m^3).

Data Analysis

Data processing used SONAR software ver.5 with an echo counting technique to obtain the echogram. Extraction results from backscatter coefficients (sA,m^2/nmi^2) and distribution of single fish target (TS) values in decibels (dB) which is a reflection index of one size of fish. The distribution of composition based on fish size was expressed as an estimated average size based on TS values expressed in units of cm (Mun *et al*, 2006; Lee & Shin, 2005; Yoon & Ha, 1998). TS values were used as a basis for resource groups because TS values for each individual may differt (Korneliussen *et al.*, 2009; Kim *et al.*, 1998). The relationship of TS and óbs (backscattering cross-section, m^2) was calculated based on Simmonds & MacLennan (2005), that TS = 10 log óbs. The results of the analysis are shown in the distribution pattern. The equation for fish density (ρ A, individual / nmi^2) is ρ A = sA / óbs. The length of fish (L) is related to óbs, namely: óbs = aL ^ b (Ma'mun *et al.*, 2017; Ma'mun *et al.*, 2018).

According to (Josse *et al.*, 2000a), the conversion value of TS to length (L) is obtained from $TS = 20\log L + A$. A is TS value for 1 cm of fish length (normalized TS). The equation TS = 25.26 log FL - 80.62 was used for the yellowfin tuna (Thunnus albacares) formulation for large pelagic fish. This equation is used as the basis for separating tuna species, assuming different species within the same fish length (L) overlapping are considered the same species. The dominant catch supports assumptions at the sampling location (Appendix 4). The estimated abundance of yellowfin (*Thunnus albacares*) in size was TS -44 to -24 dB, equivalent to a size range of 28-174 cm.

The thermocline is a transition area that displays a drastic decrease in temperature along with increasing depth (Nontji, 2002; Pickard *et al.*, 1995). The depth of the thermocline in Indian Ocean, based on inter-annual variations in global climate, found that the upper limit of El Nino events is generally more shallow (average 50.9-51.7 m) than in La Nina events (average 58.4-60.2 m). Conversely the lower thermocline limit in El Nino events was found to be deeper (average 262.9–281.8 m) than in La Nina events (average 204.5–259.6 m). The thickness of the thermocline in El Nino events was found to be generally thicker (average 211.2-230.9 m) than in La Nina events (average 144.4-201.2 m) (Kunarso *et al.*, 2012).

Zoning is carried out in 3 parts of the thermocline (Zona-Up), thermocline (Thermocline) and lower of the thermocline (Zona-Un) see Figure 3. Water hydrological data were taken using CTD SBE 19 plus V2. Vertical according to depth, includes temperature, salinity, dissolved oxygen, density and chlorophyll. The measured digital file is recorded in the form (. HEX). CTD data processing is done with SBE Data Processing software, then visualized with Matlab.

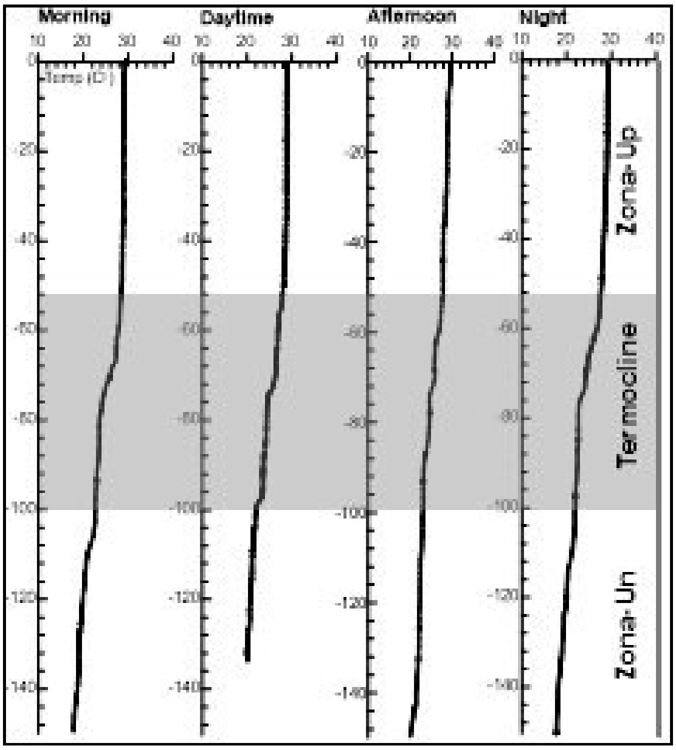

Figure 3. Zona temperature in the water column, by time of day.

The descriptive statistic for environmental parameters are displayed as median values of standard deviation expressed in Table 1. Statistical non-parametric analysis of the Generalized Additive Model (GAM) is used to see the response of variable of fish presence to environmental parameters (Hastie *et al.*, 1990; Swartzman G, 1997). GAM can analyze the relationship between responses and parameters tested without limiting the form of the relationship. The GAM package “mgcv” (version 1.7-28) is used in R programming (Wood, 2006). The results of this model can provide information about the dominant parameters of the environment for fish around the FAD. The model result can show various environmental factors that significantly explain the presence of tuna. Environmental parameter data entered into the GAM model are temperature (^{0}C), salinity (PSU), oxygen (mg/l), conductivity (S/m), chlorophyll (mg/m^3) and seawater density (mg/m^3).

RESULTS AND DISCUSSION

Result

The existence of fish in FADs

Vertical Distribution

Length of fish based on acoustic analysis is divided into three groups: fish length 30-50 cm FL, 50-100 cm FL and 100-200 cm FL. Grouping makes it easier to distinguish juvenile and adult tuna (*targetted capture*). The grouping is carried out in all four observation interval times: Morning (6:00-08:00 WIB), daytime (12.00-14.00 WIB), and afternoon (18.00-20.00 WIB) and night (00.00-02.00 WIB).

Figure 4 shows that 30-50 cm FL of tuna (juveniles) are detected at a depth of 10-150m, and are mostly found in the thermocline layer, with others found above the thermocline layer and a small part in lower layer of the thermocline. Fish lengths 50-100 cm (sub-adults) are detected at a depth of 150-300m, dominated by a depth of 250-300m. Fish length 100-200 cm (adults sought for capture) are detected at a depth of 200-500 m with dominance at depths below 300 m. Thus fish length>50 cm FL generally occur in the lower layer of the thermocline.

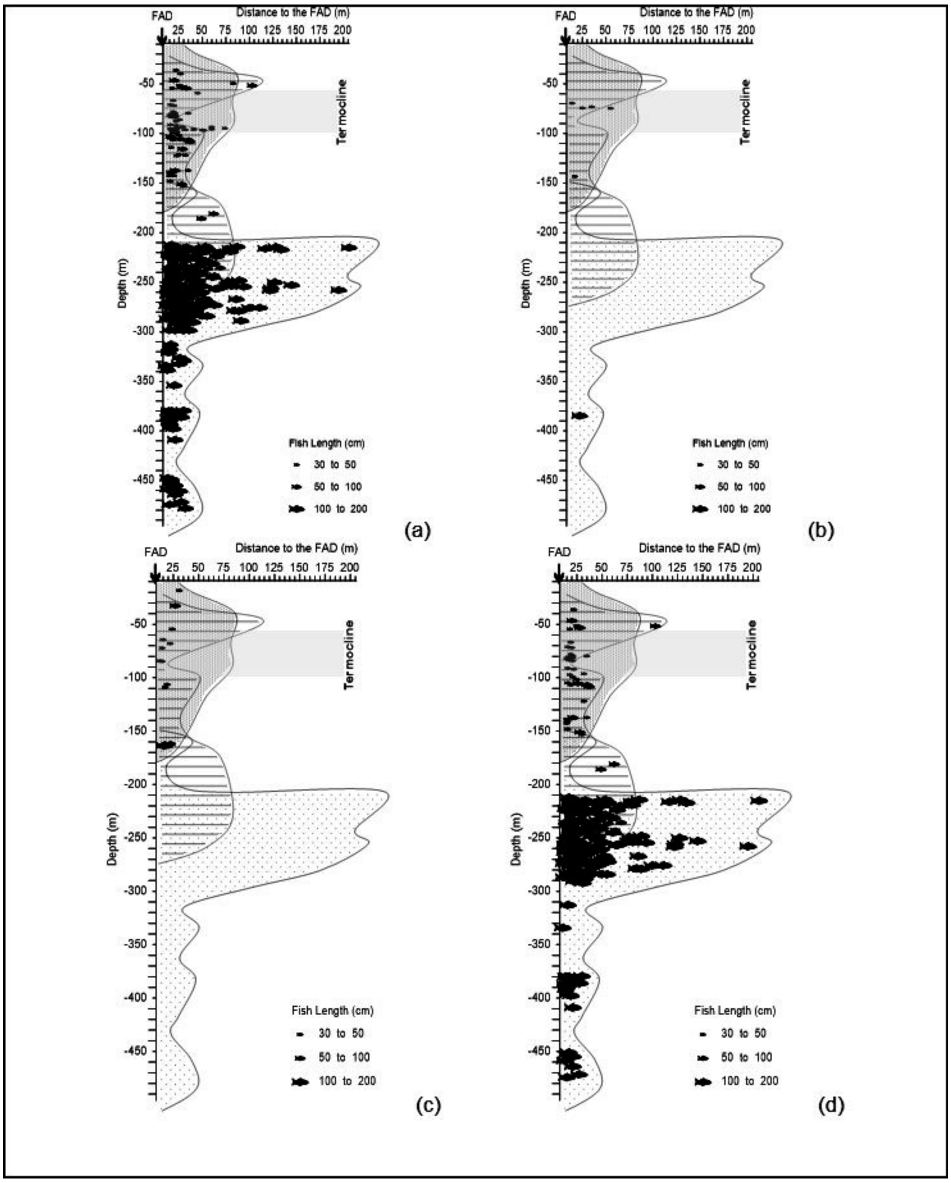

Figure 4. Vertical distribution and fish size group at the FAD (a) morning (06.00 – 08.00 WIB), (b) daytime (12.00 – 14.00 WIB), (c) afternoon (18.00 – 20.00 WIB) and (d) night (00.00 – 02.00 WIB) at 26-28 November 2015.

Horizontal Distribution

Fish horizontally distribute around FADs up to 225 m from the FAD center for groups of fish size 50-100 cm and 100-200 cm, while fish size 30-50cm occur near the FAD center. The existence of fish in FADs horizontally is supported by environmental factors, which can be seen from the pattern of fish distribution based on the time of data collection. According to Gaol & Sadhotomo (2007), the distribution and abundance of biological resources in given waters cannot be separated from the conditions and variations in oceanographic parameters. Fluctuations in environmental conditions greatly influence the seasonality of migration and the abundance of fish (Cahya, 2016). In migration periods, fish distribution is strongly influenced by current local oceanographic conditions, such as temperature, salinity, surface currents, dissolved oxygen, and other oceanographic factors (Cahya, 2016).

According to Josse *et al*. (2000), the presence of yellowfin tuna around the FADs reached a peak in the early morning, then the group of fish decreased in number during the day until the afternoon. Soon before the sunset, is the tuna is suspected schooling around FADs to find food (feeding motivation).

According to the observed pattern of fish distribution in morning and evening, fish can be found to be 225m from the center of FADs, with fish spreading around the FADs. Daytime and nighttime fish tend to occur around the center of FADs at a distance <75m (Figure5). Length of fish around FADs in day and nighttime is dominated by 30-50 cm fish (juveniles). Small groups of fish lengths 50-100Lcm and 100-200 cm were also present.

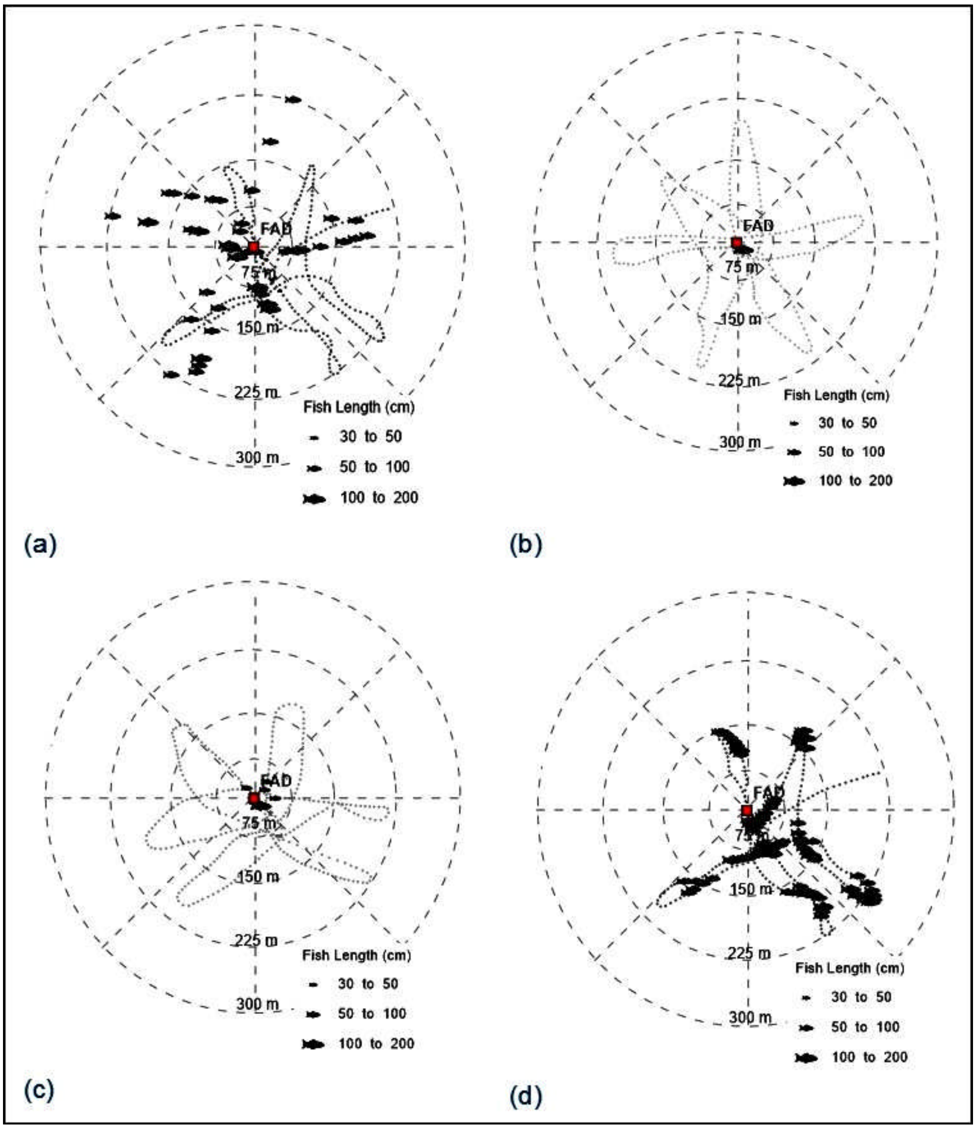

Figure 5. Horizontal distribution and fish length in FAD (a) morning, (b) daytime, (c) afternoon and (d) night.

Results showed that a significant presence of fish around FADs was found at night before morning with a peak in the early morning. At least the presence of fish in the depth of 10–200 m was alleged because fish on the surface had been captured first by other fishermen before recording. This evidence is reported by other fishers (purse seine) on FADs who arrived at the location. It is predicted that most of the tuna may have a chance to be captured at a depth 200-500 m. A data comparison of fish catch survey, the landing data (in November 2015), and acoustic data show that there is a match between size detected by acoustics and catches, especially for fish on the surface (Figure6). Catches representing fish in layers 5-20 m, are based on fishing techniques and marked lines es used during the capture process.

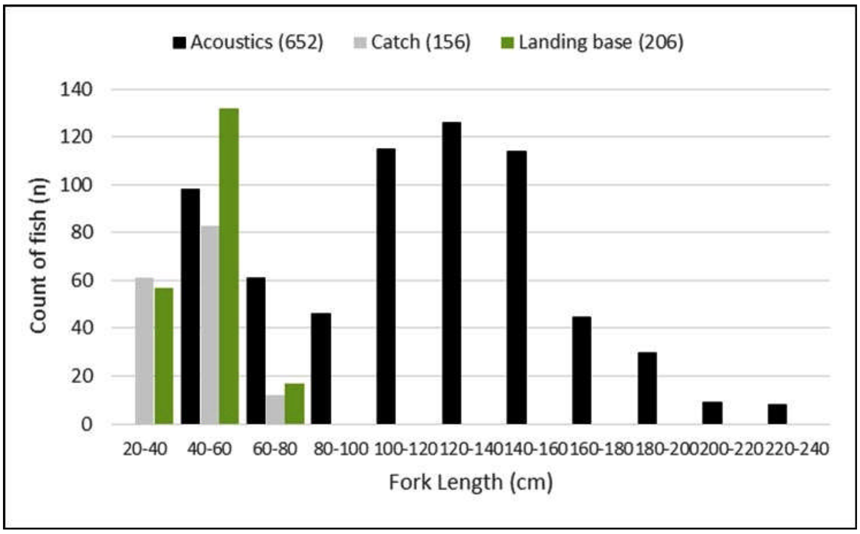

Figure 6. Length of fish in FAD from acoustics, catch survey and landed catch.

Environmental factors at FADs

Environmental parameters obtained using CTD are temperature, salinity, dissolved oxygen, chlorophyll, conductivity and density of seawater. Seawater's conductivity and density values are not shown because they have almost uniform values with the salinity profile to a depth of 200 m. Location of FADs in waters of high seas is the main factor, where both values are relatively homogeneous. The vertical distribution of environmental parameters to depth, shows the thermocline layer is at a depth between 50-100 m. As for time difference taken for ecological data it shows almost the same values by depth layer.

The chlorophyll content in upper thermocline layer (Zona-Up) has significant value fluctuations, especially at night, when high values are seen in 20-30 m water depth (Figure7). The oxygen content of water at night and in the morning shows a higher value than at other times. The salinity of the surface to lower thermocline layer shows an almost homogeneous value.

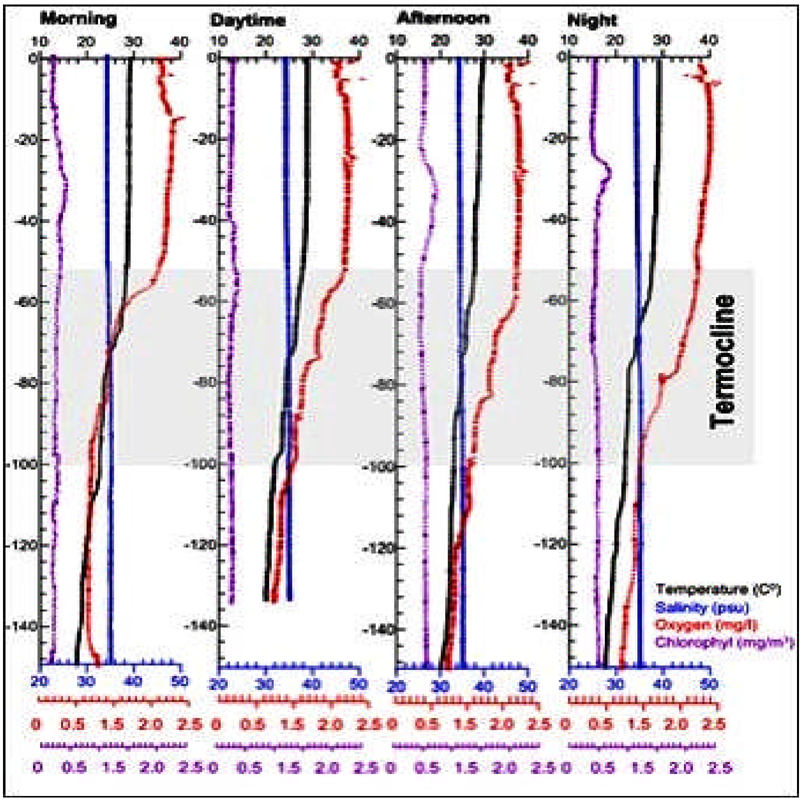

Figure 7. Vertical profile of environmental factors by layer depth and time of day.

The average value and standard deviation of environmental factors in each temperature zone show that Upper Zone has a higher value than the thermocline and Zona-Un layers. This pattern is opposite to that of salinity which increases by depth. Interesting results were seen for chlorophyll where changes and fluctuations in chlorophyll reserves from Zona-Up to Thermocline have decreased, then increased in Un-Zone (Table 2). The conductivity value is directly proportional to the decrease in temperature value as it decreases with depth. In contrast, sea air density is directly proportional to the value of salinity, as it decreases with depth.

Table 2. The average value and standard deviation of environmental factors in FADs

Time	Environmental factors (Mean±SD)					
	Temp (°C)	Salinity (PSU)	Oxygen (mg/l)	Conduct (S/m)	Chlorophyll (mg/m³)	Density (mg/m³)
Zona-Up	28,83 ± 0,37	34,34 ± 0,04	1,74 ± 0,08	5,61 ± 0,02	0,10 ± 0,09	21,62 ± 0,20
Thermocline	24,97 ± 1,83	34,91 ± 0,21	1,28 ± 0,26	5,29 ± 0,16	0,08 ± 0,08	23,26 ± 0,69
Zona-Un	19,73 ± 1,98	35,06 ± 0,09	0,77 ± 0,08	4,78 ± 0,20	0,11 ± 0,03	24,86 ± 0,46

Environmental factors are dominant for presence of fish in FADs

The model results show parameters that have a significant relationship with fish abundance and environmental factors in the Zona-Up, that is temperature and salinity, while for the Thermocline and Zona-Un-zone layers, that is temperature (Table 2). Other parameters have a weak relationship with the abundance of fish, in this case tuna in range of fish length 28-174 cm. The presence of fish in Zona-Up was found in temperature range of 28.0-28.5^{0}C and salinity 34.1-34.3 PSU with oxygen levels in the range of 1.6-1.9 mg/l, with chlorophyll concentrations between 0.2-0.4 mg/m^3. The conductivity value changed from 5.65 to 5.7 S/m and sea water density from 21.8 to 22.4 mg/m^3 (Appendix 1).

Fish abundance found in Thermocline regions with environmental characteristics with a temperature range of 26.0-28^{0}C and salinity of 35-35.2PSU, oxygen levels in the range of 1 -1.8 mg/l, and with chlorophyll concentrations between 0.15-0.3 mg/m^3. The conductivity value ranges from 5.0 to 5.2 S/m and sea water density is 21.8-23 mg/m^3 (Appendix 2).

Fish abundance in Zone-Un was found in temperature range of 20.0-22^{0}C and salinity of 35.1-35.3 PSU with oxygen levels in the range 0.8 -1 mg/l, and with chlorophyll concentrations between 0.10-0.25 mg/m^3. The conductivity values range from 4.2 to 4.6 S/m and density of seawater is 24-25 mg/m^3 (Appendix 3).

Discussion

Acoustic observations in FADs show that tuna can be detected in surface layers down to 500 m. Juvenile yellowfin tuna(30-50 cm fish) are found in the layer above the thermocline (Zona-Up) to a depth of 100 m. The abundance of juveniles at this depth is closely related to high fishing efforts, where data collection carried out on FADs observed some fleets make purse seine sets. Moreno *et al.* (2007) and Menard *et al* (2000) wrote that fish catches around FADs consisted of skipjack mixed with juvenile tuna (yellowfin) with a nearly uniform fish length of about 46 cm. The study of Josse *et al.* (2000a) using trolling gear captured juvenile fish, especially from 50 - 56 cm.

The results of this study indicate that there is a pattern of fish grouping similar to the results of a study by Josse *et al*. (2000a), which obtained three groups based on the type of aggregation, that is, deep scattering fish (150-300 m), medium fish scattering (50-200m) and shallow school (10 -150m). Small fish are found in the Zona-Up area and close to the FADs position, while large fish are in the deeper layers (Fig.4).

Acoustic detection of fish in FADs shows fish size almost the same as the landed catch, where the catch is dominated by yellowfin tuna with a fish length of 20-60 cm. The larger fish is not captured, because fishing gear is only operated up to a depth of 10-20 m. Acoustic detection records for larger fish sizes are much deeper. This information is in accordance with the catch of the troll (tonda) fishing gear which operates on the surface of the water column, where the fish caught are dominated by fish length 50-56 cm (Josse & Dagorn, 2000).

The presence of tuna around FADs reaches its peak in early morning, then the number of fish decreases during the day until night before sunset. This is possible because tuna is a type of fish with high mobility where morning to evening is time to look for food, so many fish gather around FADs as a place to find food to form trophic function at existing FADs location. Josse *et al*. (2000b) state that groups of fish exist in FADs is at the maximum point in morning after sunrise and then decreases in the afternoon until late afternoon. At night after sunset, presence of a group of fish is hardly found until the early hours and continues to increase during the morning.

The function of FADs is other than refuge, shading place, feeding ground, trophic position, meeting point, reference point, spawning ground, and cleaning the place, also function as suitable places for other pelagic fish species (Yusfiandayani, 2004; Menard *et al*., 2000a; Samples & Sproul, 1985; Gooding & Magnuson, 1967). According to Baskoro *et al*. (2011) and Simbolon (2004), FADs function as aggregators to attract fish to gather and to concentrate around the FADs location so that potential fishing areas are formed.

The existence of fish in any given location cannot be separated from environmental conditions - fish will move to look for environmental conditions that match their bodies. The results of GAM model show that the factors have a significant relationship between tuna abundance and environmental factors in Zona-Up, that is, temperature (28.0-28.5^{0}C) and salinity (34.1-34.3PSU). At the same time, for thermoclines and Zona-Un that is the temperature (20.0-26^{0}C). Tuna fish tend to have aggressive movements, so they will look for cooler conditions to lower their body temperature, which can be found in the deeper layers (Baskoro *et al*., 2011).

Skipjack tuna and yellowfin tuna have temperature preferences for warm surface temperatures (Arrizabalaga *et al.,* 2015). The level of salinity and oxygen is needed by tuna to conduct osmoregulation (physiological processes carried out in the body of fish to regulate acid concentration in the body to be balanced with the environment) (Pamungkas, 2012) and to generate the energy needed to move (Stickney & Rust, 2000). Other environmental factors are generally not directly related to the presence of tuna, but rather the process of fulfilling the body's food needs. Tuna generally consume small pelagic fish such as scad and flying fish. These small pelagic fish depend on chlorophyll-a occurrences and have a close relationship (Kasim et al, 2014).

CONCLUSION

Tuna juveniles (size 30-50cm) are detected at a depth of 10-150m, mostly found in the thermocline layer, whereas others are found above the thermocline. Fish of lengths 50-100cm (sub-adults) are detected at a depth of 150-300m. Fish of length 100-200cm (adults, sought for capture) are detected at a depth of 200-500 m. In general, fish of length >50 cm are generally in the layer below the thermocline. Horizontally the fish occur around FADs up to a distance of 225 m from the center of FADs for groups of fish 50-100cm and 100-200cm, while for fish lengths 30-50cm not far from the center of FADs. Many fish are found aggregated near the FADs at night until early morning. The model results show factors that have a significant relationship between fish abundance and environmental factors in the Zone-up, that is, temperature and salinity. At the same time, that is temperature for the Thermocline and Zone-Un.

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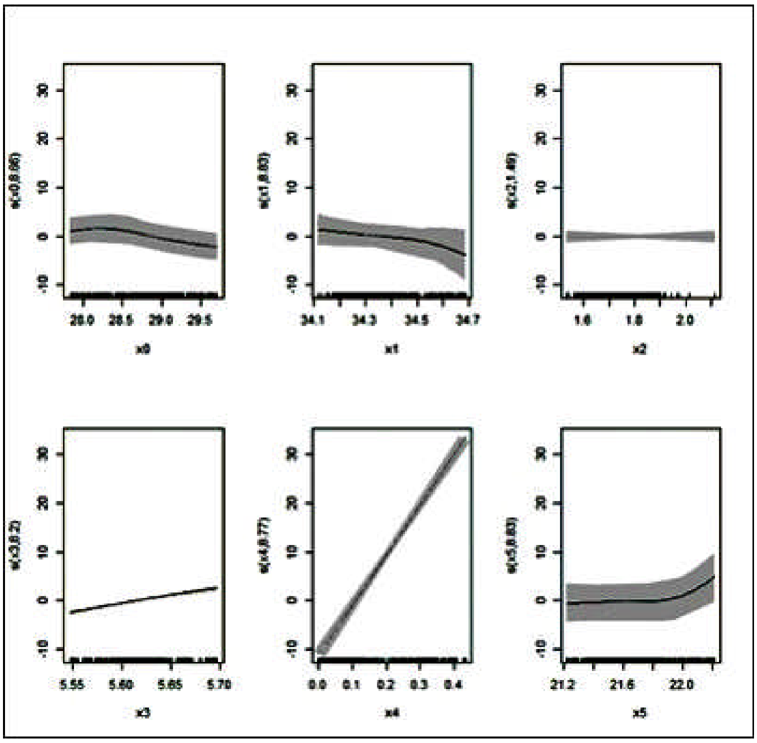
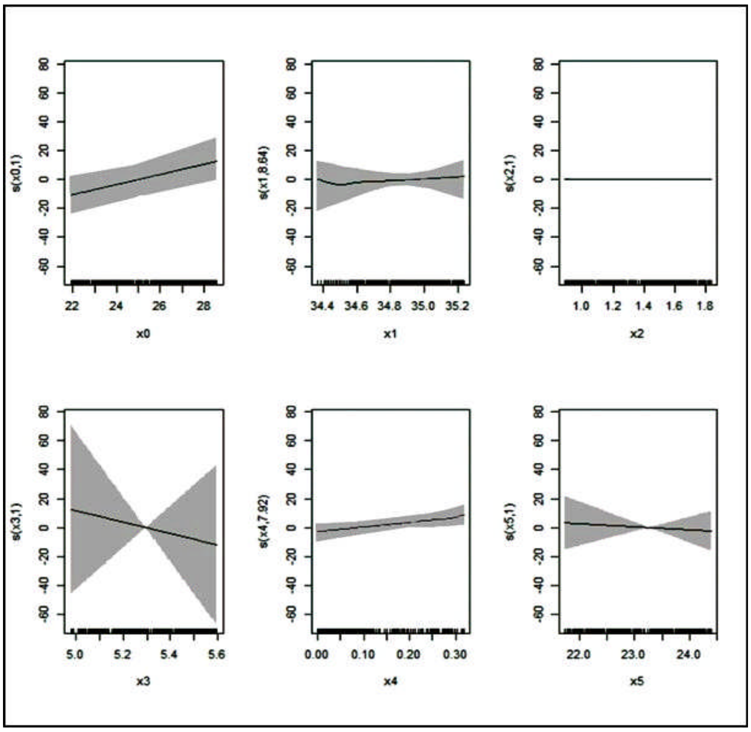
APPENDIX

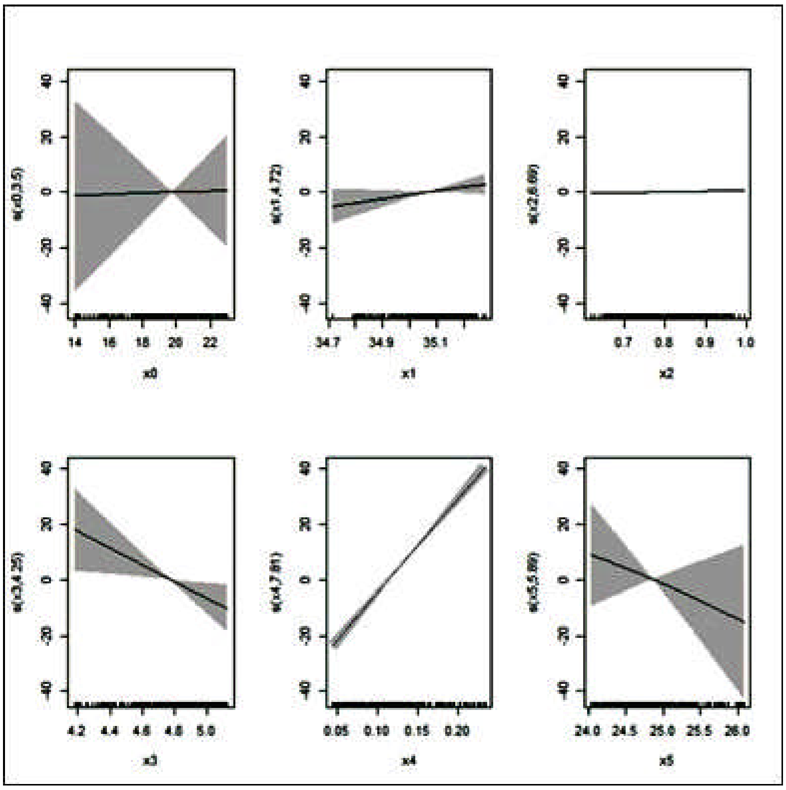
Appendix 1. Generalized additive model functions on distribution fish and environmental parameters on Zona-Up (temperature, salinity, oxygen, conductivity, chlorophyll, sea density).



Appendix 2. Generalized additive model functions on distribution fish and environmental parameters on Termocline (temperature, salinity, oxygen, conductivity, chlorophyll, sea density).



Appendix 3. Generalized additive model functions on distribution fish and environmental parameters on Zona-un (temperature, salinity, oxygen, conductivity, chlorophyll, sea density).



Appendix 4. Composition of troll line catches in FAD

No	Local/English Name	Species	Catch (kg)	%
1	Madidihang (*yellowfin tuna*)	*Thunnus albacares*	41.131	53,67
2	Cakalang (*skipjack*)	*Kastuwonus pelamis*	22.635	29,54
3	Setuhuk loreng (*stripped marlin*)	*Tetrapturus audax*	8.141	10,62
4	Tuna mata besar (*bigeye tuna*)	*Thunnus obesus*	3.293	4,30
5	Albakor (*albacore tuna*)	*Thunnus alalunga*	713	0,93
6	Lemadang (*Common dolphin*)	*Coryphaena hippurus*	694	0,91
7	Layaran (*sailfish*)	*Istiophorus platypterus*	25	0,03