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Relationship Between Sea Surface Temperature and Chlorophyll-a with the Production and Productivity of Skipjack on Bacan Island Waters

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Abstract:

Sea surface temperature (SST) and chlorophyll-a concentration level influenced on skipjack spatial and temporal distribution. Skipjack tuna fishing operation rely on its distribution information to obtain the best fishing operation efficiency. Main problem to obtain the fishing operation efficiency are the availability of data and information on oceanography condition related with the skipjack fishing. This research aim is to analyse the skipjack tuna fishing production and productivity correlation between sea surface temperature and chlorophyll-a on Bacan Island waters based on spatial and temporal (quarterly, seasonal and calendar periods). Landing data collected from landing site at Panamboang fishing port in Bacan Island for five years of time series (2008-2012). The research was conducted from July to September 2012. SST and chlorophyll-a data was downloaded from Aqua-MODIS Level-3 satellite data with 0.05 ^{0} x 0.05 ^{0} spatial resolution and 8 days of temporal resolution from January 2008 to December 2012. The result found that highest skipjack tuna production and productivity was on quarterly-IV of calendar period on 2010 of year seasonal. Skipjack tuna production and productivity has correlation with SST.

Keywords: SST, chlorophyll-a, skipjack, Bacan Island

I. INTRODUCTION

Bacan Islandwater located at Maluku Sea Waters within Indonesia Fishing Management Area (*WPP RI*) 8 or know as *WPP 715* includes Maluku Sea, Bay ofTomini and Seram Sea. This location also known as Indonesian Sea Current (ARLINDO) which is one of Indonesia sea current system connection between Indian Ocean and Pacific Ocean through eastern Indonesian water [1].When this sea current passing through Indonesian waters, ARLINDO current mixed with other oceanic materials from Indian and Pacific Ocean.These material includes its characteristics such as temperature, salinity, oxygen, chlorophyll and other tracers as indicates of water productivity [2]. As one of important ARLINDO, this area known as one of the richest nutrient for the availability of phytoplankton. On the food chain, phytoplankton eaten by small fish and then by the large fish like tuna. In addition to nutrients, another factors that affecting the skipjack distribution is the SST as reported by [3], that SST influence the skipjack distribution with the vary range temporally and spatially.

Another researchers, [4]; [5]; [6]; and [7] that changes in abundance of fish in the specific area as the result of fish in response to the changes of the environment condition. Tuna is a cosmopolitan species, their distribution and life cycle are not limited to a specific area. Therefore, any change in environment condition somewhere will affect the skipjack elsewhere.Skipjack response to environmental changes in narrow meaning but widespread in the ecological limits. Ecological limit determined by skipjack tolerances range against their environment conditions. Skipjack fishing requires the information on their distribution to make the fishing activity more efficient. Skipjack distribution can be clarified by the changes of the sea characteristics.

As reported by [8] that fishing ground is influenced by the oceanographic characteristics: chemicals, physics and biology, e.g. temperature (SST; vertical and horizontal), salinity, chlorophyll-a concentration, thermal front and upwelling phenomena. Those water characteristics phenomenon can be identify as indicator of potential fishing ground. Oceanographic characteristics information can be obtained from remote sensing tenchology.

According to [9] that upwelling can be detected by the condition of low SST and high of chlorophyll-a concentration compared to surrounding areas. Areas with high density of chlorophyll-a concentration indication of rich nutrient assumed as potential of tuna schooling ground. These SST and cholophyll-a concentration of oceanography conditions as a basic parameter to determine tuna fishing ground. For this research, fishing ground determination based on strong upwelling assumption and according to [10] research that occurrence of a strong upwelling where the SST below 26 ^{0}C with chlorophyll-a concentration above 2 mg/m. Based on a research conducted by [11] that with remote sensing technology then it can be obtained information on SST and chlorophyll-a concentration wider and more efficient rather than direct on-situ observation.

The main problem to optimize skipjack catches is data and information limitation on oceanographic characteristics to obtain the efficiency from fishing operation. Based on that condition this research is to fill gap on the analysis of

relationship between SST and chlorophyll-a as oceanographic characteristics with skipjack tuna productivity in Bacan Island, South Halmahera Regency. This research aim is to examine the skipjack tuna production and productivity and analyse the relationship between SST and chlorophyll-a as oceanographic characteristics in Bacan Island, South Halmahera Regency in seasonal and quarterly time scale of calendar periodic. Hypothesis of this research that there is a relationship between SST and chlorophyll-a concentration with skipjack tuna production and productivity.

II. RESEARCH METHODS

Research site and time

This research was conducted in Bacan Island, South Halmahera Regency from July to September 2012 on 0.855687^0-1.096369^0 S dan 127.09412^0-127.543124^0 E coordinates (Fig. 1). This site were chosen because it is a pole-and-line landing site at Panamboang fishing port, South Halmahera Regency.

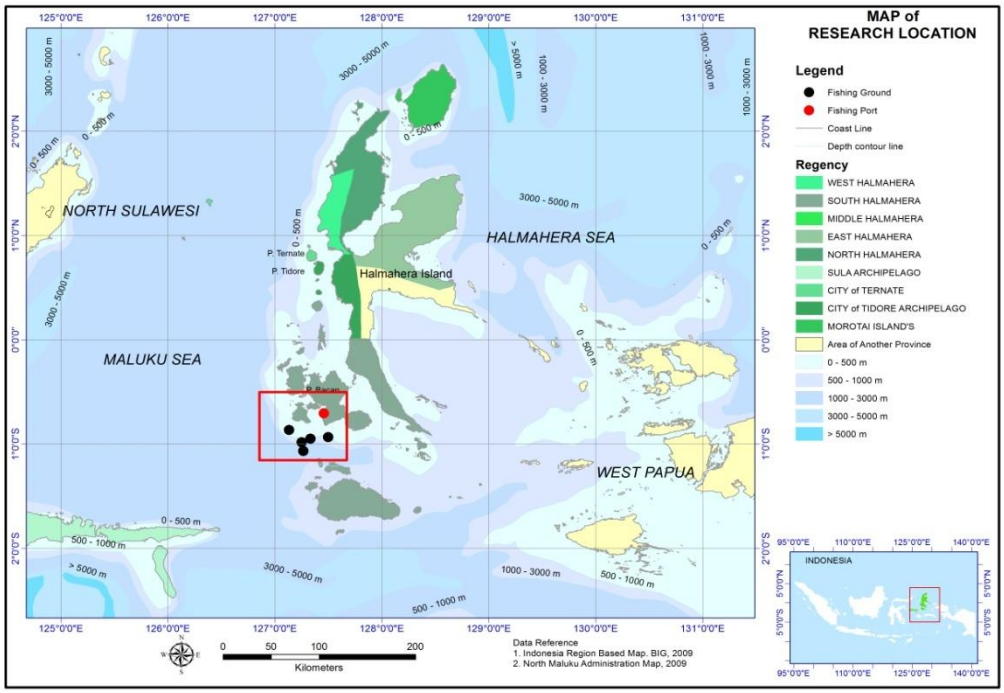

Fig 1. Research site

Data source

Data obtained for this research are: production data, fishing trip, SST and chlorophyll-a concentration. This research used explorative methods with two variable relationship analysis of skipjack production and productivity.

Time series landing and fishing trip data obtained from statistics data of Panamboang fishing port, South Halmahera Regency from 2008 to 2012. SST and chlorophyll-a concentration data obtained from Aqua-MODIS level-3 with 0.05^0 x 0.05^0 spatial resolution and 8 days of temporal coverage from January 2008 to December 2012 (Fig. 2). Satellite data downloaded from pacific islandsfisheries science center (PIFSC) of national oceanic and atmospheric administration (NOAA) – USA, data location based on skipjack fishing ground.

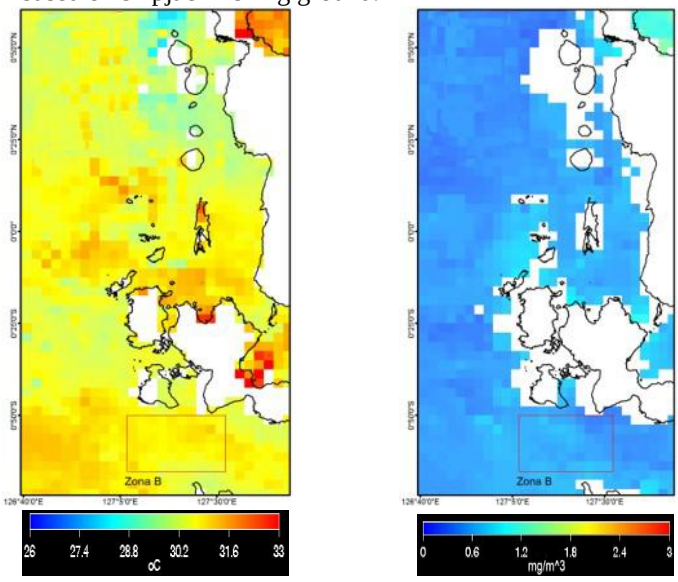

Fig 2. SST and chlorophyll-a satellite images

Data analysis

SST and chlorophyll-a concentration from each latitude and longitude were calculated on statistics parameters into quarterly data. This calculation was performed in two categories: seasonal (first quarter starts on December from the year before to February) and periodical category (first quarter starts from January to March from the same year). Statistics parameters used were mean, median, modus, variant, standard deviation, range and diversity coefficients.

Quarterly skipjack production and productivity

a) Skipjack landing data collected from Panamboang fishing port Kabupaten Halmahera Selatan with fishing ground coordinates from 0.855687^0- 1.096369^0 S and 127.09412^0- 127.543124^0 E.

b) Quarter production of skipjack from Panamboang fishing port Kabupaten Halmahera Selatan from 2008 to 2012.

$$TP_{kz} = \sum_{b}^{4} JK_b$$

Where;

TP_{kz} = the total quarter skipjack production (ton)
b = number of month based on calendar periodic / season
Jk_b = quarter skipjack production (ton)

Quarter skipjack productivity analysis procedures:

c) Fishing effort data (trip) were yearly skipjack fishing effort (trip/year).

d) Yearly skipjack fishing effort for 5 years analysed with:

$$TU_{tz} = \sum_{b}^{5} UPI_b$$

Where;

TU_{tz} = yearly skipjack fishing effort (trip)
UPI_b = monthly skipjack fishing effort (trip)
b = number of month in a year

e) Yearly skipjack quarter productivity for 5 years:

$$PK_z = \frac{TP_{kz}}{TU_{tz}}$$

Where;

PK_z = skipjack quarter productivity (ton/trip)

Partial Correlation

Partial correlation analysis were used for identify the correlation between SSP (X1) and chlorophyll-a (X2) with skipjack production and productivity using SPSS ver.15. Partial correlation analysis as follow [12]:

$$r_{y2.1} = \frac{r_{y2} - r_{12}}{\sqrt{(1 - r_{y1}^2)(r_{12}^2)}}$$

III. RESULT AND DISCUSSION

Result

Quarterly skipjack production and productivity

Skipjack production based on calendar periodical and seasonal for 5 years (2008 – 2010) in Bacan of IslandSouth Halmahera Regency shows that the highest production was in forth quarter of 2010, 521.17 tonnes (calendar periodical) and 422.37 tonnes (seasonal) and the lowest was in third quarter of 2010 was 59.89 tonnes (calendar periodical) and 63.26 tonnes (seasonal). Skipjack productivity quarterly based on calendar periodical and seasonal shows that the highest productivity was in forth quarter of 2010, 0.44 tonnes/trip (calendar periodical) and 0.36 tonnes/trip (seasonal) and the lowest was in third quarter of 2010, 0.05 tonnes/trip (calendar periodical and seasonal) (Fig. 3).

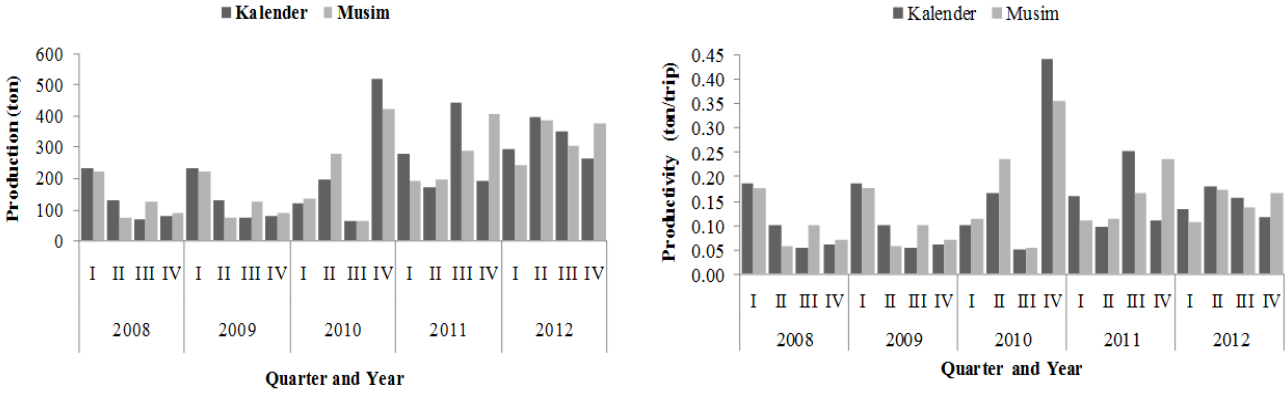

Fig 3 Skipjack production and productivity fluctuation quarterly based on calendar periodical and seasonal at Bacan of Island South Halmahera Regency for 5 years (2008 – 2012).

Sea Surface Temperature (SST)

Quarter fluctuation of SST both based on calendar periodical and seasonal (Table 1) showed that there was no significant differences between calendar periodical and seasonal categories in Bacan of Island South Halmahera Regency except for range value obtained wide range for seasonal category. Based on range statistical parameter, quarter SST alteration from 1.8 ^{0}C (calendar periodical) and 2.6 ^{0}C (seasonal) with diversity coefficient between 2.5 ^{0}C (calendar periodical) and 2.9 ^{0}C (seasonal). SST fluctuation diversity in Bacan Island was highest in seasonal category compared with calendar periodical category. Thus indicates that calendar periodical was more stable compare to seasonal category.

Table 1 SST differences (^{0}C) quarterly in Bacan of Island South Halmahera Regency for 5 years (2008 – 2012).

No	Statistics Parameters	Waters region Bacan of Island South Halmahera	
		Calendar	Seasonal
1	Mean	2,1	2,0
2	Median	2,2	2,2
3	Modus	2,7	2,5
4	Variant	0,9	0,9
5	Standard deviation	0,7	0,9
6	Range	1,8	2,6
7	Diversity coefficient	2,5	2,9

Chlorophyll-a

Quarterly fluctuation chlorophyll–a changes both in calendar periodical and seasonal category within 5 years (2008 – 2012) in Bacan of Island South Halmahera Regency (Table 2) shows that a similar trend pattern except for the diversity coefficient. Based on statistical parameter of diversity coefficient the chlorophyll-a quarterly changes with total result of 29.5mg/m^3 (calendar periodical) and 34.5mg/m^3 (seasonal). Seasonal category of SST fluctuation in Bacan Island was higher than calendar periodical category. Differences diversity of SST from calendar periodical indicates that calendar periodical more stable than seasonal category.

Table 2 Quarterly chlorophyll-a concentration changes (mg/m^3) in Bacan of Island South Halmahera Regency for 5 years (2008 – 2012).

No	Statistics Parameters	Waters region Bacan of Island South Halmahera	
		Calendar	Seasonal
1	Mean	0,2	0,2
2	Median	0,2	0,2
3	Modus	0,3	0,3
4	Variant	0,0	0,0
5	Standard deviation	0,1	0,1
6	Range	0,3	0,2
7	Diversity coefficient	29,5	34,5

Partial correlation between SST and chlorophyll-a with skipjack production

Partial correlation used statistics parameter for SST and chlorophyll-a were: mean, median, modus, variant, standard deviation, range and diversity coefficient for skipjack production in Bacan of Island South Halmahera Regency shows that no significant correlation ($p< 0.05$) result for calendar periodical category. Based on seasonal category there was a significant correlation ($p< 0.05$) for SST statistic parameter of variant, standard deviation, range and diversity coefficient, it mean that skipjack production and productivity correlated with SST changes (Table 3).The correlation was a positive correlation indicates a positive response so that the SST were a variable on skipjack abundance based on seasonal category.

Table 3 Partial correlation of statistics parameter for SST and chlorophyll-a with skipjack production in Bacan of Island South Halmahera Regency

No	Statistics analysis		Waters region Bacan of Island South Halmahera	
			Calendar	Seasonal
1	Mean	SST	0,238	0,126
		Chlorophyll-a	-0,123	-0,037
2	Median	SST	0,222	0,090
		Chlorophyll-a	-0,190	-0,022
3	Modus	SST	-0,027	0,029
		Chlorophyll-a	0,308	0,024
4	Variant	SST	0,090	0,554*
		Chlorophyll-a	-0,121	-0,162
5	Standard deviation	SST	0,142	0,533*

		Chlorophyll-a	-0,179	-0,176
6	Range	SST	0,174	0,526*
		Chlorophyll-a	-0,282	-0,117
7	Diversity coefficient	SST	0,133	0,529*
		Chlorophyll-a	-0,218	-0,181

Note: * = Significant on p <0.05

Partial correlation between SST and chlorophyll-a with skipjack productivity

Partial correlation used statistics parameter for SST and chlorophyll-a were: mean, median, modus, variant, standard deviation, range and diversity coefficient for skipjack productivity in Bacan of Island South Halmahera Regency shows that no significant correlation (p< 0.05) result for calendar periodical category. Based on seasonal category there was no significant correlation (p< 0.05) for SST statistic parameter (mean, median, modus, variant, standard deviation, range and diversity coefficient).

Tabel 4 Partial correlation of statistics parameter for SST and chlorophyll-a with skipjack productivity in Bacan of Island South Halmahera Regency

No	Statistics analysis		Waters region Bacan of Island South Halmahera	
			Calendar	**Seasonal**
1	Mean	SST	0,375	0,230
		Chlorophyll-a	-0,199	-0,078
2	Median	SST	0,310	0,211
		Chlorophyll-a	-0,231	-0,064
3	Modus	SST	0,210	0,164
		Chlorophyll-a	0,151	-0,046
4	Variant	SST	-0,097	-0,124
		Chlorophyll-a	-0,193	-0,193
5	Standard deviation	SST	-0,063	-0,157
		Chlorophyll-a	-0,253	-0,240
6	Range	SST	-0,009	-0,147
		Chlorophyll-a	-0,307	-0,241
7	Diversity coefficient	SST	-0,079	-0,164
		Chlorophyll-a	-0,273	-0,327

Note: * = Significant on p <0.05

Discussion

Differences in skipjack production and productivity within 5 years (2008-2012) in Bacan of Island South Halmahera Regency caused by the differences in the environmental conditions due to differences in seasons, in this case the difference in sea surface temperature (SST). SST affects the spread and fishing as well as the swimming layer of skipjack and other tuna species. According to [13], the temperature directly affects on spawning, larval survival, and also on the growth of tuna juvenile. Skipjack distribution at SST range of 17 – 28 ^{0}C and skipjack fishing around 19 – 23 ^{0}C [14].

Variations and dynamics of the marine environment will cause a shift in the abundance of fish periodically at particular areas that affect the state of a fishery; further stated that the SST and chlorophyll-a fluctuations were a major oceanographic factors used to determine the fishing ground and abundance of fish [15]. According [14], many factors affected on the presence and migration of tuna, such as sea surface temperature and water productivity. Distribution of pelagic fish such as tuna can be predicted from the known optimum sea surface temperature and its changes on a monthly basis.

Variability on marine environmental conditions will cause a shift in the abundance of fish periodically on an area and have an impact on the availability of fish for fishing operations {[16]; [17]; [18]}. Quarterly fluctuations in the abundance of fish in Bacan Island South Halmahera Regency indicate fish's responses to fluctuations in the change of marine environmental conditions. According [18]; [19]; and [20], environmental factors are the main factors that determine changes in the abundance of pelagic fish.

Monthly SST and chlorophyll-a fluctuations in Bacan Island were different. SST quarter fluctuations in seasonal was higher than the calendar periodical category. SPL differences indicates that the quarterl calendar periodical were more stable in comparison with seasonal category. Instability quarter SST in season category in Bacan Island related to the geographic position, where the waters in Bacan of Island South Halmahera Regency predominantly influenced the mass flow of water throughout the year from the Banda Sea and the Seram sea, despite being on the mass flow of Banda Sea and Seram seas but is also influenced by Monsoon.

During the West season (December-January-February) northwest monsoon pushing water masses from the Jawa Sea, through the Flores Sea and into the Banda Sea and surrounding area [21]. Furthermore, the circulation of the water masses of Indonesian waters were different between the West and the East monsoon season. In West season, the mass of water generally flows toward the eastern waters of Indonesia, on the contrary during the East season, water mass supplied from upwelling areas in the Arafura Sea and the Banda Sea waters will flow towards western Indonesia. The water

supply of the mass difference resulted in changes to the water conditions that ultimately affect the level of primary productivity including SST and chlorophyll-a [1].

Changes in SST tendency was caused by the wind patterns Monsoon (seasonal) that affect the ocean circulation in Indonesian waters, including conditions in the waters of Bacan Island South Halmahera Regency. According [1], the change of seasons can lead to changes in distribution patterns of sea surface temperature; further stated that during West season, the position of the sun to the earth causes the heating process of radiation and more are in the southern hemisphere, so the temperature of surface waters ranges of 29 - 37 ^{0}C and in the north equatorial temperatures range of 27 – 28 ^{0}C. In contrast on East season excessive heating to the north so that the temperature of the northern Indonesian waters will rise to 28 – 30 ^{0}C and the surface temperature in southern Indonesian waters will fall to 27 – 28 ^{0}C [1].

[22], Argued that Arlindo channel is divided into two channels, the west and the east channel. West channel where the water mass flows through the Sulawesi Sea and the Makassar basin. Most of the water mass will flows through the Lombok Strait and ended in the Indian Ocean, while others have been turned towards the east continues to Flores Sea amd to the Banda Sea and then out into the Indian Ocean through the Timor Sea. Eastern channel flows to Maluku Sea and Halmahera Sea and continue into the Banda Sea. From the Banda Sea, the water mass would flow by 2 (two) routes; a northern route through the Ombai island of Ombai strait between Alor island and Timor island, into the Sawu Sea and the Rote Strait, while the southern route through the Timor Island and the Timor East basin, between the Rote Island and continental shelf of Australia.

Water productivity is a water condition content with phytoplankton concentration. Fluctuations changes quarterly in chlorophyll-a calendar periodical and season category within 5 years (2008 - 2010) showed a similar trend of change except the statistical parameters of diversity coefficient. The changes pattern of chlorophyll-a were the same in Bacan Island South Halmahera Regency caused by the shallow waters characteristics and archipelagic close area and distance to the mainland. In shallow waters nutrients will be easily lifted to the surface layer or to euphotik layer (layer on the ocean are exposed to light) as a result of vertical mixing process (turbulence), thus the nutrients availability continues. In contrast to the deep ocean that it can only happen if upraising of water mass and it only occurs at certain locations [23].

Chlorophyll-a diversity in the seasonal category quarterly higher than the quarterly calendar periodical category in Bacan Island South Halmahera Regency within 5 years (2008 – 2012), with the result that high water productivity as reported by [24], that if the concentration of chlorophyll-a more than 0.2 mg / m^3, this indicates of the presence of the plankton tomaintain the continuity of commercial fishing operation. The distribution of chlorophyll-a in the waters is highly dependent on the concentration of nutrients. The concentration of nutrients in the surface layer is very little and will increase at thermocline layer and the layer below it. According to [25] that low concentration of nutrient on the sea surface and its concentration increases with increasing of depth and will reach a maximum concentration at depths between 500 - 1500 m. The chlorophyll-a concentration can be used as indicator of the marine productivity. Based on research by [26] that the average value of chlorophyll-a in Indonesian waters of 0.19 mg / m^3, the average concentration during a East season (0.24 mg / m^3) indicates a maximum concentration than the West season (0.16 mg / m^3).

SST fluctuations during high seasonal category (unstable) in Bacan Island South Halmahera Regency caused strong correlation between the SST with skipjack production and productivity. Reflected to the results of statistical analysis on SST seasonal category where significant with skipjack production and productivity described in statistical parameter: variance, standard deviation, range, and coefficient of diversity. Significant correlation fluctuation based on SST seasonal category showed that skipjack are tolerant in oceanographic conditions changes, which highly depended on the tolerance level of skipjack original habitat. According to [4] that fish life patterns, including skipjack can not be separated from the influence of oceanographic factors. Skipjack sensitive to temperature changes, especially feeding behaviour related to certain habits [14]. High, abnormal or unstable temperature will reduce the speed of feding behaviour. Furthermore [27], stating that the tuna migrates because; (1) any changes in the environmental factors such as temperature, salinity and currents; (2) the search of suitable area for food; and (3) the search for spawning areas.

Chlorophyll-a fluctuations changes during quarter calendar periodical and seasonal category showed a trend similar patterns of changes (stable). Chlorophyll-a stable concentration condition indicates there were no relationship between chlorophyll-a concentration level with the skipjack production and productivity in Bacan Island South Halmahera Regency. Based on the results from statistical analysis both calendar periodical and the seasonal categories to the skipjack production and productivity for all statistical parameters were used (mean, median, mode, variance, standard deviation, range, and coefficient of diversity). No direct relationship found on this analysis was due to the skipjack was not plankton eaters (herbivores) species as skipjack categoried as carnivorous species. This condition consistent with the research held by [28] that skipkjack are carnivorous fish species, because their main food source were composed of materials of animal origin. This phenomenon can be explained as an ecological process, where organisms can have a wide tolerance range on one factor and a narrow range on other factors.

IV. CONLUSION

Highest skipjack production and productivity in Bacan islandSouth Halmahera Regency was in forth quarter based on calendar periodical and seasonal category in 2010. Skipjack production and productivity has related with sea surface temperature

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