Effect of global climate (ENSO) and regional climate on the dynamics of the fishing ground and the catch in Morotai Island, North Maluku

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Abstract. Climate change impacts the El Nino and La Nina, which then affect marine organisms. El Nino Southern Oscillation (ENSO) is a phenomenon of climate pattern that involves changes in water temperature and in the atmosphere in the eastern to middle Pacific equator, impacting fluctuations in sea surface temperature, rainfall and sea level. This certainly affects regional climate and fishing activities in Morotai, facing Pacific Ocean. This study aimed to determine the effect of global and regional climate on the dynamics of fishing grounds and catch. The analysis of the global and regional climate, the condition of fishing grounds and the catch were determined using structural equation models (SEM). The global climate has an effect on regional climate and on fishing ground dynamics ($p<0.05$), but has no effect on the catch ($p=0.438$). Regional climate around Morotai Island has no effect on fishing ground ($p=0.274$) or on catch ($p=0.582$). Similarly, the fishing area had no effect on the catch ($p=0.243$).
Key Words: climate change, El Nino, La Nina, Pacific Ocean, Structural Equation Modeling (SEM).

Introduction. Global warming is a process of increasing the temperature of the earth, having an impact on climate in various parts of the world. Climate change affects various sectors of human life, including the fisheries and marine sectors. Climate change in the fisheries and marine sector causes increased sea surface temperature, increased ocean acidity, increased frequency and intensity of extreme weather phenomena, changes in rainfall patterns and freshwater runoff (triggered by the El Nino and La Nina phenomena), changes in ocean circulation patterns and increased sea level (Fox 2000; Aldrian & Susanto 2003; Bindoff et al 2007; IPCC 2007; Vermeer & Rahmstorf 2009; Nicholls et al 2007; Nicholls 2010). These changes ultimately have an impact on marine organisms (Roessig et al 2004; IPCC 2007; Chen 2008; Satria 2009; UNEP 2009). The increase in sea surface temperature is closely related to fish production in Indonesian waters. The increase in the average air temperature in the last three decades of about 0.5^{o}C due to worsening greenhouse gas emissions became one of the causes of climate change and of the decrease in the number of fish catches in the ocean (Amri 2002).

Global climate change has contributed to changing regional climate patterns and in turn, they affect fishing activities. Capture fisheries (fishing) business activities are strongly influenced by climate change because the presence, distribution, and abundance of fish that are targeted by fishermen change with the variability of the aquatic environment as a result of regional climate change (Simbolon 2019) and global climate (IPCC 2007).

El Nino Southern Oscillation (ENSO) is the global interaction of the ocean with the atmosphere, resulting in an anomaly of sea surface temperature (SST) in the equatorial Pacific Ocean (Fox 2000; Aldrian 2008; Asyakur 2010). El Nino is characterized by an increase in SST above normal (warm) in the waters of the central and eastern Pacific Ocean, usually followed by a decrease in rainfall and an increase in air temperature in Indonesia. Whereas La Nina is marked by SST in the waters of the eastern and central

Pacific Ocean, which decrease and turn cold, usually stimulating an increase in rainfall in Indonesia above normal levels (Mulyana 2002; Qian et al 2010; Yananto & Sibarani 2016).

The ENSO phenomenon has brought many impacts on the climate and the sea in Indonesia, especially in eastern Indonesia (Aldrian & Susanto 2003). Both El Nino and La Nina climate anomalies play an important role in the annual climate and usually cause shifts in climate parameters, especially changes in the amount of rainfall (Hidayat & Ando 2014). Further terms of the quantity and areas of rain are affected by wind, temperature, humidity, and atmospheric pressure (climate factors). This will certainly affect the regional climate, the dynamics of fishing grounds, and capture fisheries activities in Morotai, which faces the Pacific Ocean.

Morotai Island, as one of the territorial waters in eastern Indonesia as a whole, has regional and local characteristics. Morotai fishermen are categorized as small-scale fisheries that use fish aggregating devices (FADs) to catch pelagic fish. The target catch is tuna (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), and mackerel (*Euthynnus affinis*) have high economic value and are exportable. This fish has great potential to enter the area of FADs because they migrate from the Pacific Ocean toward the Morotai waters. Global climate change is thought to affect the dynamics of the aquatic environment, including fishing grounds, so that it will affect the catch. This study aims to determine the influence of the global climate and regional climate on the dynamics of fishing grounds and the catch in Morotai Island.

Material and Method

Description of the study sites. The research period was 9 months, starting from April to December 2017. This research was conducted in Morotai Island, North Maluku Province, which geographically is in the position of 2°00′ N - 2°40′S and 128°15′E – 129°08′E (Figure 1).

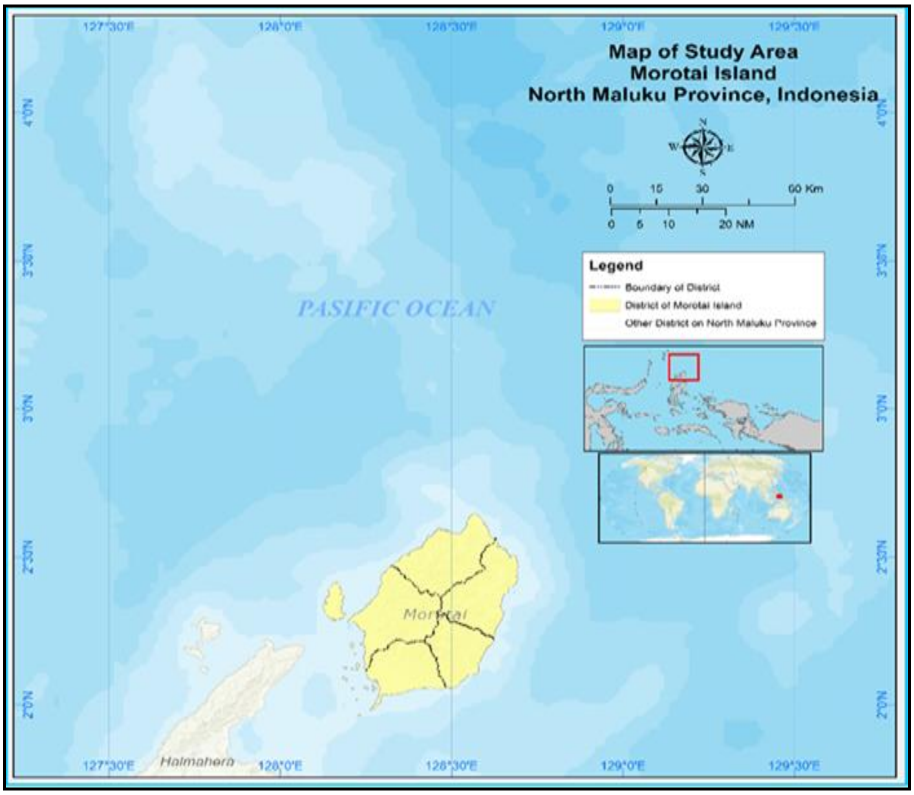

Figure 1. Research location (Source: Earth map, Indonesian Geospatial Agency).

Data source. This research was performed by using data sources in the form of Southern Oscillation Index (SOI) and Nino 3.4 values, air temperature, rainfall, wind speed, SST, chlorophyll-a concentration and the catch of tuna, skipjack and mackerel. Sources and the data collection methods are presented in Table 1.

Table 1

Type, source, and methods of data collection

No	*Data*	*Source*	*Data collection methods*
1	SOI	Australia Bureau of Meteorology (www.bom.gov.au)	Historical and documents
2	Nino 3.4	Australia Bureau of Meteorology (www.bom.gov.au)	Historical and documents
3	Air temperature, rainfall, and wind speed	Meteorological, Climatological, and Geophysical Agency (BMKG) North Maluku	Historical and documents
4	Sea Surface Temperature and Chlorophyll-a	Citra Satelit Aqua Modis (www.oceancolor.gsfc.nasa.gov)	Historical and documents
5	Catch	Fishermen	Observation and interview

Note: SOI - Southern Oscillation Index.

Data analysis. Data analysis was performed using the Structural Equation Modeling (SEM) approach by operating the Smart PLS software. Research with this approach explores the relationships between various variables identified comprehensively. This approach allows the closeness assessment of multiple relationships between variables (multiple relationships) (Juanim 2004; Narimawati, 2007). This relationship is formed in two models, namely the structural model and measurement model. The structural model is the relationship among constructs (latent/unobserved variables or variables that are not measured directly and several indicators or proxies are needed for their measurement) consisting of independent and dependent variables. The measurement model is the relationship (loading value) between the indicator (manifest variable) and the construct (latent variable) (Arbuckle 1997; Ghozali 2014). The structural model and measurement model developed in this study are presented in Figures 2 and 3.

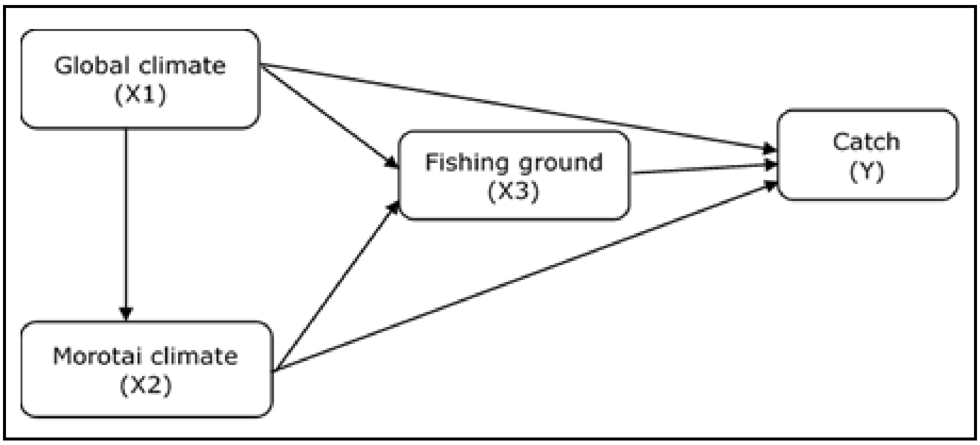

Figure 2. The structural model for research on the influence of global climate, the regional climate of fishing grounds, and the catch of Morotai fishermen using fish aggregating devices.

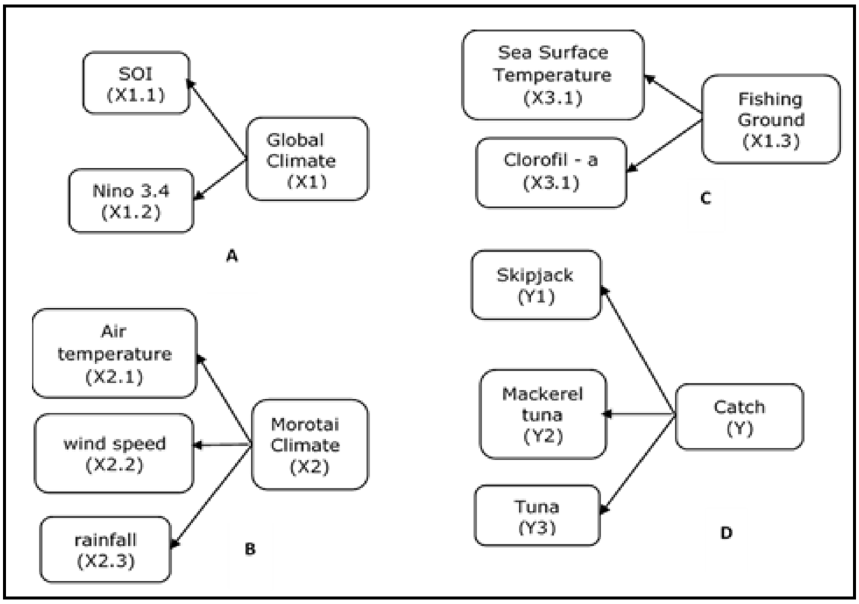

Figure 3. Measurement model for the latent variable of global climate (A), Morotai climate (B), fishing ground (C), and catch model (D).

The structural model in Figure 3 graphically depicts the structure of the causality relationship between the independent variable (X), the intervening, and the dependent variable (Y). Intervening, in this case, is a variable that theoretically affects the relationship between the independent variable and the dependent variable by an indirect relationship that cannot be observed or measured. Based on the structural model, it can be seen how the direct and indirect effects are formed. The direct effect is the influence of one independent variable on the dependent variable without going through other variables or intervening variables (Juanim 2004).

The measurement model in Figure 3 is evaluated using the conformity test measurement. The analysis process can be continued if the measurement model is valid. The latent variable measurement model and indicators developed in this study were adjusted to the objectives, including the measurement model of global climate latent variables (Figure 3-A), measurement model of Morotai climate latent variables (Figure 3-B), measurement model of fishing ground latent variables (Figure 3-C), and measurement model of catch latent variables (Figure 3-D).

Evaluation of the measurement model (outer model). The evaluation of the measurement model (the outer model) was carried out by using the validity and reliability test approaches. The validity test is conducted to determine the extent to which an instrument accurately measures the object of a research or the extent to which it could be on target. Validity is a measure that indicates the levels of legality or validity of an instrument (Sugiyono 2010). An instrument is valid if it is able to accurately measure the studied object, thus having a high validity. An invalid measuring instrument, on the other hand, has low validity. Convergent validity test parameters are known based on the output results of algorithmic smartPLS in the form of outer loading, with the criteria for actor loading >0.70 or criteria for AVE >0.5. Average Extracted Variance (AVE) value describes the amount of variance or the diversity of manifest variables that can be owned by the latent construct. In other words, the outer loading value <0.7 is considered invalid in measuring the model.

Discrimination test parameters are known from the output of the algorithm in the form of cross loading, AVE roots, and latent variable correlation. AVE values were compared with the correlation between constructs.

The reliability test is a test to ascertain whether the research data on variables is realistic or not. An indicator is reliable if the value of Cronbach alpha is higher than 0.6 and the composite reliability is higher than 0.7.

Evaluation of the structural model (inner model). The evaluation of the structural model (inner model) was carried out using the R-Square and/or F-Square approaches. The R-Square value shows the coefficient of determination or the extent to which a construct is able to explain the model. The total value of R^2 is used to calculate the Goodness of Fit (GOF). The GOF value reflects how much the dependent variable can be explained by the independent variable. An R^2 value of 0.67 indicates that the model is in a good category (Ghozali 2012). R^2 values between 0.33 and 0.67 indicate that the model is in a moderate category and an R^2 value below 0.33 indicates that the model is in a weak category.

Hypothesis test. The hypothesis test or significance test aims to determine the influence of the independent variable on the dependent variable. Significant values can be obtained by the bootstrapping procedure. The formulation of the hypothesis in the significance test was as follows: (1) H_0: the independent variable does not have a significant effect on the dependent variable, and (2) H_1: the independent variable has a significant effect on the dependent variable. The test criterion is that the significance level of H_0 is rejected if the value of t-statistical or t-count $>t\alpha$ (t-table), or p-value $<\alpha$ (0.05). Six hypotheses were built in the model (Table 2).

Table 2

Model hypotheses

Hypothesis		*H0*	*H1*
1	→	Global climate (GC) has no effect on fishing grounds (FG)	Global climate (GC) affects fishing grounds (FG)
2	→	Morotai regional climate (MRC) has no effect on fishing grounds (FG)	Morotai regional climate (MRC) affects fishing grounds (FG)
3	→	Global climate (GC) has no effect on regional climate Morotai (IR)	Global climate (GC) affects the regional climate of Morotai (MRC)
4	→	Global climate (IG) has no effect on the regional climate of Morotai (MRC)	Global climate (IG) affects the regional climate of Morotai (MRC)
5	→	Global climate (GC) has no effect on the catch (C), through the fishing ground (FG) variable	Global climate (GC) has no effect on catch (C), through the fishing ground (FG) variable
6	→	Morotai regional climate (MRC) has no effect on the catch (C), through the fishing ground (FG) variable	Morotai regional climate (MRC) has no effect on the catch (C), through the fishing ground (FG) variable

Results and Discussion. The results of smartPLS analysis show that the invalid manifestations of global and regional climate that influence the fishing grounds and catches in Morotai waters are SOI (Southern Oscillation Index), rainfall (Rain), wind speed (WS), and chlorophyll-a (CHL), with their respective values of -0.905, -0.435, 0.630, and -0.815 (Table 3, Figure 4). These four variables are invalid because the value of outer loadings is <0.7. Nino Variable 3.4 (NIN), air temperature (AT), Sea Surface Temperature (SST), production of skipjack (SP), production of tuna mackerel (MTP), and production of tuna (MTP) are valid because the outer loadings value is higher than 0.7.

The regional climate which is depicted from the air temperature variable in Figure 5 is the main indicator that explains the regional climate in Morotai, where the air temperature is one indicator of climate change. Changes in air temperature will have an impact on the ecosystem and existing organisms. Many experts predict that temperatures will increase by an average of 1.4°C to 5.8°C by 2100. The Intergovernmental Panel on Climate Change (IPCC) predicts that global temperatures are likely to increase by 1.1°C to 6.4°C in the next 90 years (IPCC 2007).

Table 3

Outer loading values

Manifest variable		*Latent variable*			
Description	*Symbol*	*Global climate*	*Morotai climate*	*Fishing ground*	*Catch*
SOI	SOI	-0.905	-	-	-
Nino 3.4	NIN	0.942	-	-	-
Rainfall	Rain	-	-	-0.435	-
Wind Speed	WS	-	-	0.630	-
Air Temperature	AT	-	-	0.846	-
Chlorophyll-A	CHL	-	-0.815	-	-
Sea Surface Temperature	SST	-	0.770	-	-
Tuna Production	TP	-	-	-	0.855
Mackerel Tuna Production	MTP	-	-	-	0.836
Skipjack Production	SP	-	-	-	0.930

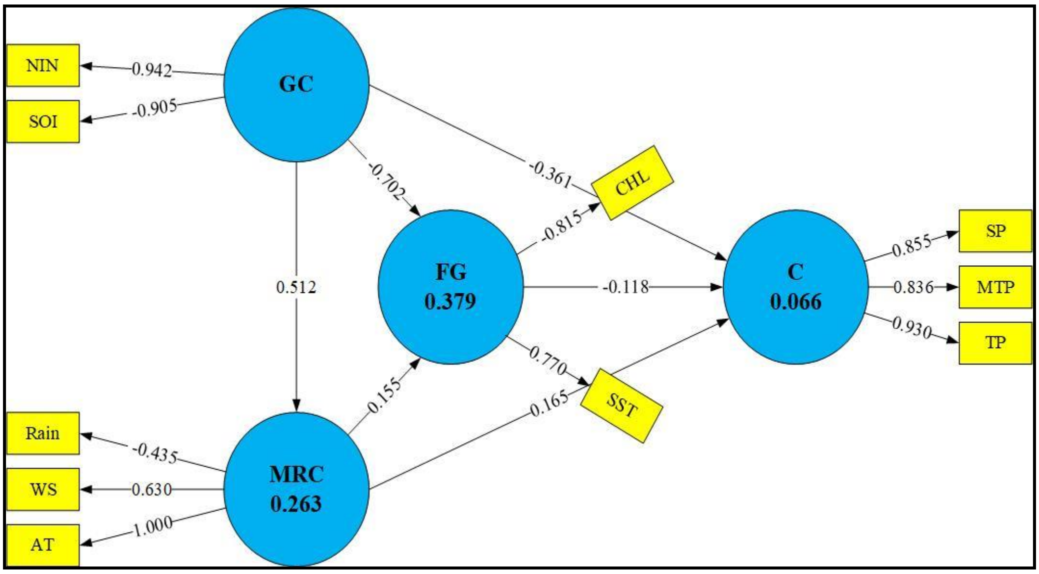

Figure 4. Measurement of the relationship between variables of global climate (GC), regional climate (MRC), fishing ground (FG), and catch (C) in Morotai.

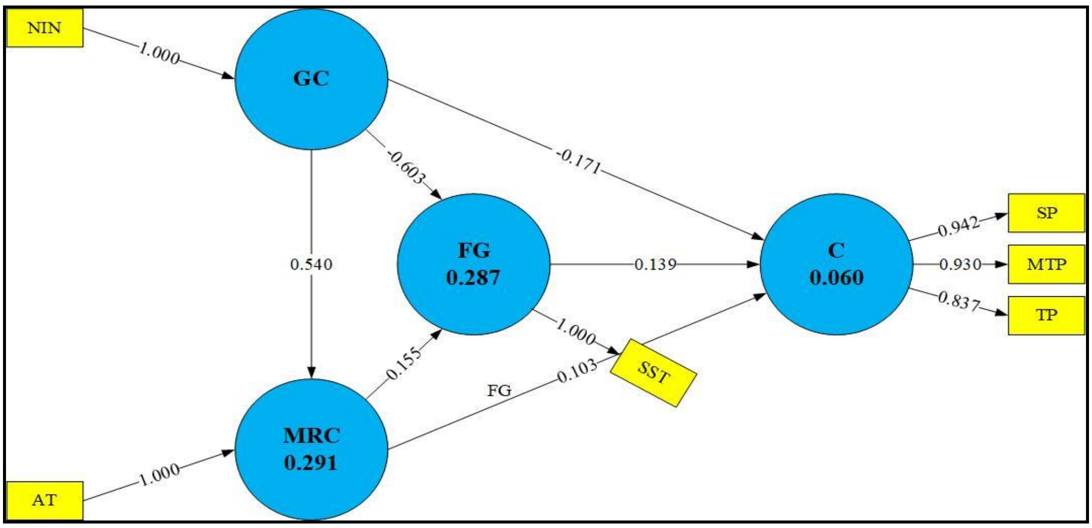

Figure 5. Relation model on variables of global climate (GC) and regional climate (MRC) to the fishing ground (FG) and catch (C) in Morotai waters.

The fishing ground depicted from the SST variable is the main indicator that explains the dynamics of the fishing grounds in Morotai waters. SST is known to have an important role in the distribution of skipjack, mackerel, and tuna. SST affects many life cycles in the ocean. Fish spawning, feeding, and nursing are also influenced by the dynamics of water temperature (Ali et al 2014).

The catch is the main indicator that explains the fish resources existing in Morotai waters, where the three types of fish (tuna, skipjack, mackerel tuna) are the Morotai Island's flagship product. The abundance and distribution of these fish are influenced by several parameters of the aquatic environment, including seawater temperature, ocean currents, salinity, and food availability.

The modeling results show that temperature is an oceanographic parameter that has a dominant effect on fish life. The optimum temperature range for the distribution of the three types of fish, however, needs to be re-observed because each type of fish has an optimal temperature range for development. Zulkhasyni (2015) states that SST spatially and temporally affects the catch of skipjack tuna.

The results of the R-Square analysis (determinant coefficient) and the significance results of the 6 structural models developed can be seen in Tables 4 and 5. The R-Square values ranged from 0.060 to 0.291, which means that the model was categorized as weak (Table 4).

Table 4

R-Square value (determinant coefficient)

	R Square	*R Square adjusted*
Fishing ground	0.287	0.262
Catch	0.060	0.010
Regional climate	0.291	0.279

Table 5

Significance test results on the structural model

No	*Hypothesis*	*Sample (O)*	*Mean (M)*	*Standard deviation*	*T-Statistics*	*P Values*	*Result*
1	GC->FG	-0.603	-0.600	0.147	(O/STADEV	0.000	Sig
2	MRC->FG	0.155	0.161	0.141	1.094	0.274	No sig
3	GC->MRC	0.540	0.524	0.116	4.663	0.000	Sig
4	FG->C	0.139	0.137	0.119	1.168	0.243	No sig
5	GC->C	-0.171	-0.187	0.220	0.777	0.438	No sig
6	MRC->C	0.103	0.109	0.187	0.550	0.582	No sig

Note: Sig - significant (p<0.05); No sig - not significant (p>0.05).

The results of the significance test on model/hypothesis-1 indicate that the global climate (GC) in the Pacific Equator has a significant effect on the fishing ground (FG) in Morotai waters. Based on the t-value (4.095), which is greater than the t-table (2.0057), and the p-value of 0.000 or less than 0.05, the hypothesis H_0 is rejected and H_1 is accepted. Climate change will greatly affect the physiology and behavior of individuals, populations, and communities. Extreme conditions with increasing water temperature, low dissolved oxygen concentration, and water pH can cause fish mortality. An environment with non-optimal conditions can reduce the metabolic rate, growth, and spawning ability of fish, and also affect life stages and affect the endocrine system and culture patterns (Roessig et al 2004). All of these changes directly affect fish populations and community structures, which in turn affect fishery stocks (Simbolon 2019).

The results of this study confirm the results of Lehoday et al (1997), who reported that climate change has several impacts on fisheries such as mackerel (*Trachurus trachurus*), and anchovy (Engraulidae family). Production of mackerel increased during 1946-1987 due to increased concentrations of phytoplankton and zooplankton (Reid et al

2001; Stenseth et al 2002). The El Nino also affected skipjack production. Nearly 70% of skipjack production in the world comes from the catch from the Pacific Ocean (Lehoday et al 1997). Skipjack tuna is very common in the warm waters of the western Pacific equatorial region. However, as a result of the El Nino event, this warm water mass shifted, so that the distribution of skipjack tuna also changed. Thus, ENSO prediction becomes important to determine potential skipjack fishing areas for the commercial tuna business.

The results of the significance test on the hypothesis/model-2 show that the regional climate in Morotai (MRC) has no effect on the fishing ground (FG) with the t-value (1.094) smaller than the t-table (2.0057) value and a p-value of 0.274, higher than 0.05. Thus, H_0 was accepted and H_1 rejected, meaning that there is no influence of the regional climate in Morotai on the fishing grounds.

The results of the significance test on the hypothesis model-3 indicate that the global climate has a significant effect on the Morotai regional climate. The calculation results show that the t-value (4.561) is greater than the t-table (2.0057) value and the p-value is lower than 0.05. Thus, H_0 is rejected and H_1 accepted, meaning that there is a significant effect of the global climate on the regional climate in Morotai.

The results of the significance test on the 4th, 5th, and 6th structural models indicate that the hypothesis H_0 is accepted and H_1 is rejected. In model-4, the t-value (1.168) is smaller than the t-table value (2.0057) and the p-value is 0.243, higher than 0.05. Thus, the fishing ground has no effect on the catch. Model-5, which describes the relationship between global climate and catch, obtained a t-value (0.777) smaller than the t-table value (2.0057), and a p-value of 0.438, higher than 0.05. This means that the global climate has not yet had a significant effect on catch in Morotai waters. Morotai regional climate has not even had a significant effect on the catch. This can be seen from the results of the significance test in the 6th model, where the t-count value (0.550) was smaller than the t-table value (2.0057) and the p-value was 0.582, higher than 0.05.

Conclusions. The conclusions resulting from this study are:

1. The variables representing global and regional climate that affect the dynamics of fishing grounds in Morotai waters are Nino 3.4 and air temperature, respectively. The characteristics of the fishing ground that are influenced by these two variables are sea surface temperature, and in the end, the catch production of skipjack, mackerel tuna, and tuna.

2. The global climate in the Equatorial Pacific, especially SOI/Nino 3.4 has a significant effect on the regional climate (air temperature) and also on the dynamics of sea surface temperature in the fishing grounds of Morotai waters.

3. Global climate change and regional climate in Morotai waters do not have a significant impact on the catch production of skipjack tuna, mackerel, and tuna. The dynamics of sea surface temperature in the fishing area does not have a significant effect on the number of catches of skipjack, mackerel and tuna because these three types of fish have a good adaptability to changes in SST.

Conflict of Interest. The authors declare that there is no conflict of interest.

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Received: 12 February 2021. Accepted: 28 March 2021. Published online: 06 December 2021.
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How to cite this article:
Muksin D., Simbolon D., Sondita M. F. A., Wiyono E. S., 2021 Effect of global climate (ENSO) and regional climate on the dynamics of the fishing ground and the catch in Morotai Island, North Maluku. AACL Bioflux 14(6):3450-3459.