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Submission Journal 3

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Kepada: Eni Kovacs

Sab, 15 Mei 2021 jam 00.24

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Impact of El Nino Southern Oscillation (ENSO), Variability on Skipjack Tuna (Katsuwonus pelamis) Catches in the Fisheries Management Area (FMA) 715, Indonesia

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Erick Nugraha

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Impact of El Nino Southern Oscillation (ENSO), Variability on Skipjack Tuna *(Katsuwonus pelamis)* Catches in the Fisheries Management Area (FMA) 715, Indonesia.

Name of the authors:

Sepri, Agus Hartoko, Suradi W. S., Abdul Ghofar, Erick Nugraha

Hereby I would like to submit the manuscript entitled "**article title**" to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.

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Corresponding author

Erick Nugraha
May 14, 2021

Impact of El Nino Southern Oscillation (ENSO), Variability on Skipjack Tuna (*Katsuwonus pelamis*) Catches in the Fisheries Management Area (FMA) 715, Indonesia

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Abstract. Marine and fisheries resources have trans-boundary nature and have great potential to be affected by global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the existence of various environmental conditions. Fluctuations in environmental conditions have many influences on the seasonal migration period and the presence of fish in one place. This study aimed to determine the variability in peak season of tuna fishing to regional climate change, El Nino and La Nina, with the aim to optimize the utilization of *K. pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Nino (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement times were performed at the end of the East season, which was from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management (FMA) 715 area. During El Nino, FMA 715 was an ideal place for *K. pelamis* fishing. The peak fishing season was in October for the period from September to November. The regional climate change triggered from the Pacific Ocean caused the unsuitable water conditions in the FMA 715 for *K. pelamis* fishing. Variability of climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for fish migration to the FMA 715 waters.
Keywords : La Nina, Salinity, Sea Surface Temperature, Climate change, Tuna fishing

Introduction. Indonesia is an archipelagic country that has a strategic position and has waters which is one of the main players in the movement of global water mass or known as the *Great Ocean Conveyor Belt*. The changes occur in the movement pattern of global water mass affect the world's climate (Trenberth 2007). Global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change touches the joints of life in the territorial area and will negatively impact to the potential, quality and quantity of marine and fisheries resources (Yáñez et al 2017). The impact of global warming on the atmosphere, for instance, is the temperature increase until 0.5°C throughout the 20^{th} century (Church and White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a characteristic that is trans-boundary (Song et al 2016) and have a great potential to be affected by global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in global environment emerge because there are climate changes characterized by warming in the atmosphere. Tuna is one of Indonesia's main export commodities (Hidayati et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the existence of various environmental conditions.

Fluctuations in environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *K. pelamis* are the availability of data sources for fishing catches and in site data. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. This information is important to be known by the *K. pelamis* fishing community in early, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards regional climate change that affected the monthly variability of *K. pelamis* catches, with the aim to increase the optimization of the *K. pelamis* fishing.

Materials and Method

Description of the study sites

The position of the each observation station were recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

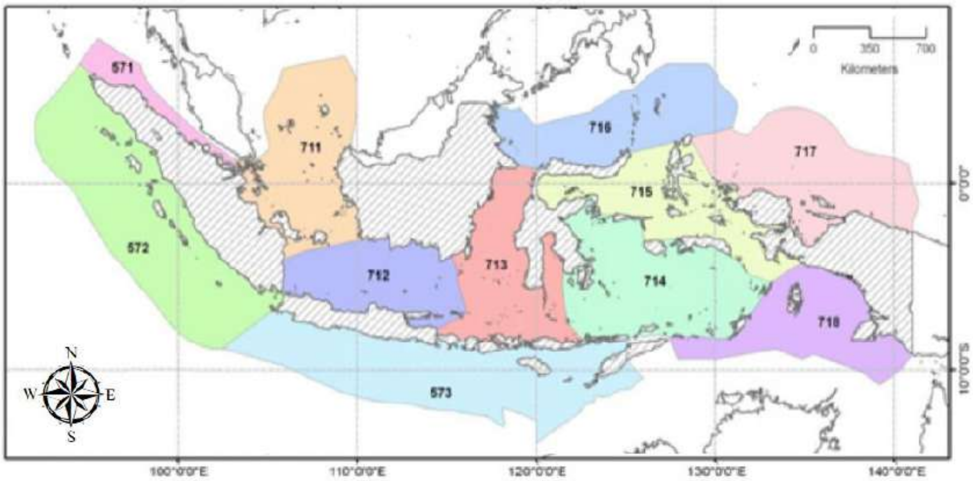

Figure 1. Map of sampling site (MMAF, 2018).

Data collection

Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using qualitatively descriptive methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and regional climate change that occurred during those periods, i.e., El Nino (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesia Meteorology, Climatology, and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement times were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

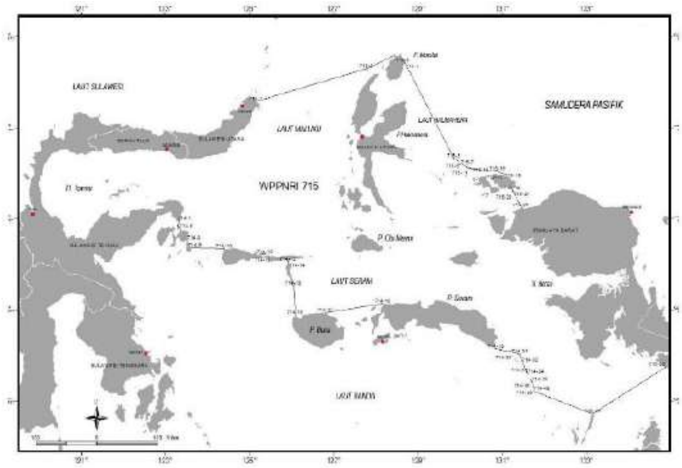

Figure 2. Indonesia Fisheries Management Area (FMA) 715

Data Analysis

Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and regional climate changes that occurred in those periods, i.e., El Nino (2015 to 2019) and La Nina (2015 to 2019)

Result and Discussion

Resources

West Papua is one of the Provinces in the Papua Island that has considerable fish resource potential and has good prospects for capture fisheries activities, especially pelagic fisheries commodities with important economic value such as tuna, *K. pelamis* and small pelagic fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O’Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on oceanographic conditions of waters, especially the water temperature which is in accordance with the tolerance of body temperature of *K. pelamis* and abundance of food. Potential fishing catch zone is strongly influenced by oceanographic factors both physical, chemical and aquatic biology including SST (Zainuddin 2011) or the distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front and up welling phenomena (Putri et al 2018).

Climate conditions

The waters of FMA 715 are areas in a tropical zone. There is a region with rainfall above 3000 mm per year in the western regions of Irian and Mindanao because it is the center of warm water pool, which results in intensive convection accompanied by a high virginity process (Wyrtki 1961). During the period of 2019 in September-November, data from Jefman station, Sorong showed the average rainfall decrease, both in the number of rainy days and the rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters from the rainy season into the summer or which is known as the transition season.

Oceanographic conditions

The eastern part of the Indonesian archipelago flows important ocean currents, known as *Arus Lintas Indonesia (Arlindo)*. This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 have characteristics that have direct influences from the Pacific water mass to the entrance the main area that goes through Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of Westward (west) water mass from the Pacific in the form of warm water mass towards the Halmahera Island which spreads in many directions, including towards the equator and Indonesian waters through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move so that they do not depend on ocean currents or the water movements caused by wind. However, the effect of ocean currents is in the formation of areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of water originating from the Northwest. This event is known as the lower current in North Guinea/North Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean occur along the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. The effect of upwelling in this area, that brings nutrients from deeper water to the surface of the water causes nutrification and plankton bloom (Kämpf & Chapman 2016).

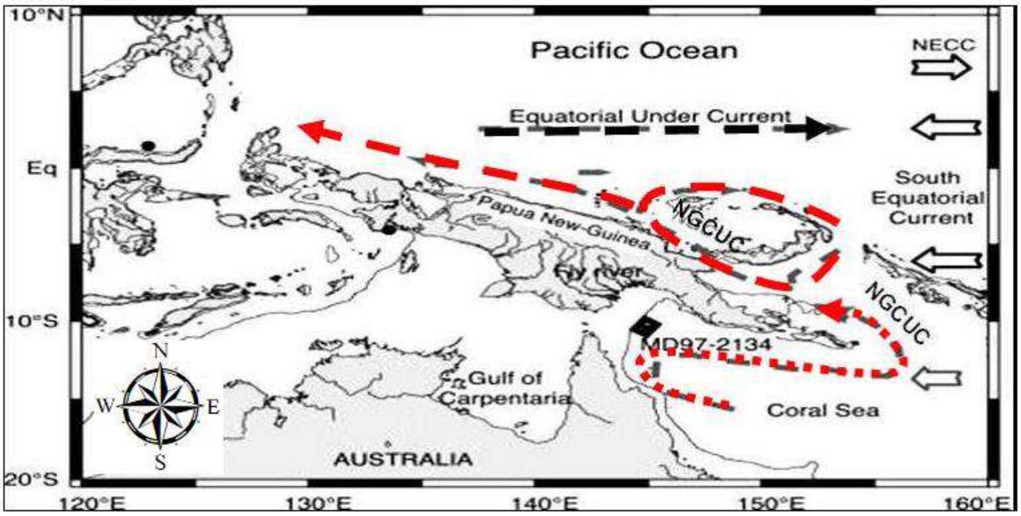

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature

The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. For temperature from Triton data which is the SST, the results show average of SST variations ranged from 28.4 to 30.6°C. The biggest catch of *K. pelamis* was in the SST range of 29 to 30°C (Nugraha et al 2020).

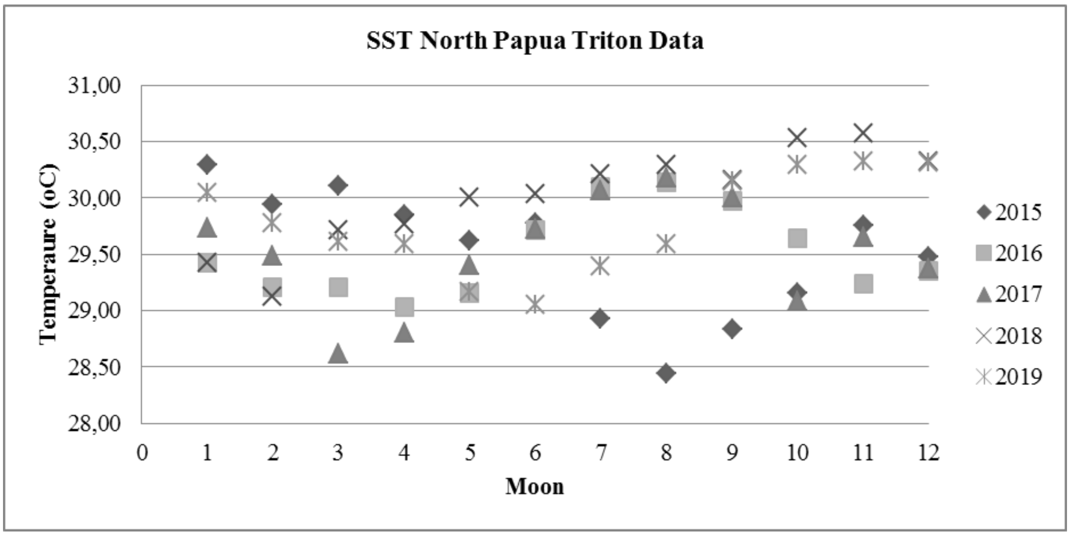

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters

Salinity

Salinity of water surface layer is influenced by wind and mosun current. In the east monsoon, a high salinity value occurs due to Arlindo currents takes in high salinity water from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The sea vertical salinity data of TRITON buoy shows temperature data obtained at various depths 1.5 m. Salinity profiles at some coordinate points in 2015-2019 in North Papua (West end Pacific) shows salinity values ranged from 33.3-34.6 psu.

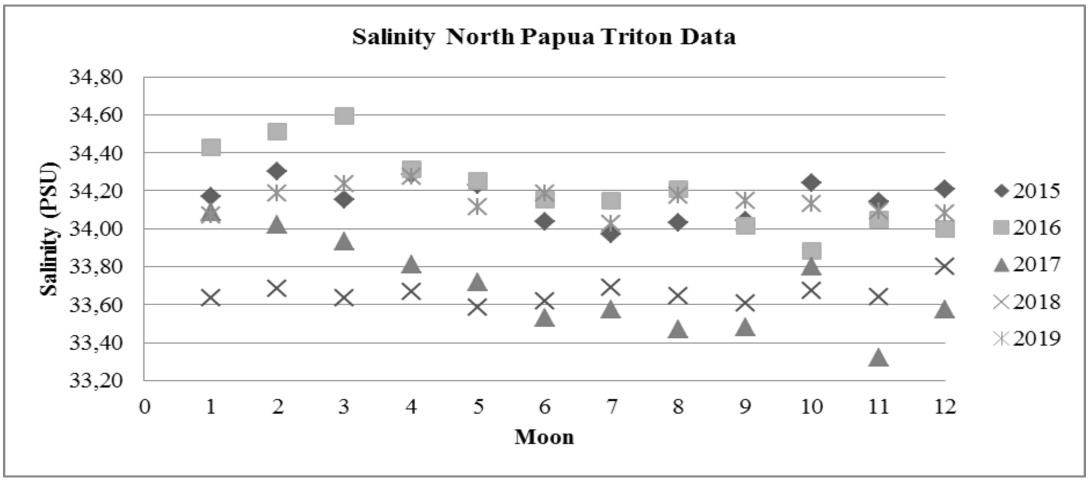

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis

In January, May to June, and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The catch of *K. pelamis* in the headwaters of Papua landed at Radios Apirja Co. Ltd., for five years is known to be the highest reached in March. It can be assumed that in March, the waters in the head of the Papua (FMA 715) were in a suitable condition and abundant food was available for *K. pelamis*, thus it was convenient by *K. pelamis* to migrate (Mugo et al 2010).

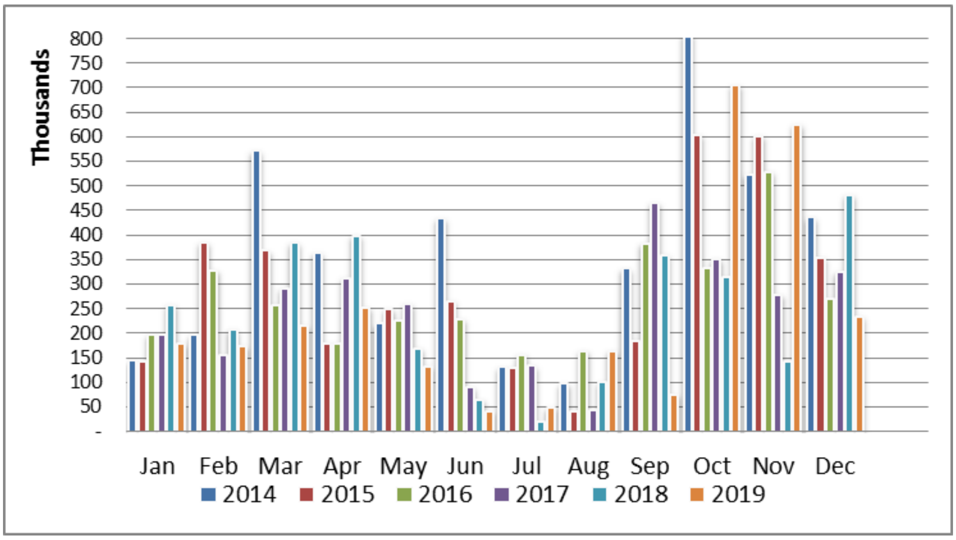

Figure 7. Catches of *K. pelamis* from 2014 to 2019

The graph of *K. pelamis* catches shows the trends of *K. pelamis* catches in the fishing period of February to May and September to December periods that are decreasing annual catches in total catches, and increasing catches in June to August, November and January, without considering other factors that affect production such as fishing fleet, size and number of catches.

***Correlation Analysis of K. pelamis catches and regional climate change*.**

The conditions of Indonesia's oceanography are influenced by global climate change, for example, the condition of rainfall on land and at sea, sea surface temperature (SST) and sea level height. Rainfall is influenced by the El Nino phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll to produce.

El Nino

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño and La Niña Years and Intensities (NOAA-NWS, 2019)

El Niño is characterized by a decrease in SST in Indonesian waters, and an increase in SST in the eastern tropical Pacific Ocean, with an increase in SST of more than 0.5°C (Sofian et al 2011). From Maret 2014 until April 2016, El Nino came to cause the regional climate to experience a prolonged dry season and it was recorded as one of the largest in history.

El Nino with moderate intensity began to be felt in October 2014, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia's internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (*Arlindo*) flowing from the western Pacific Ocean. This condition continued to grow with the strengthening of El Nino signals which became extreme in November 2015 and returned to normal conditions in May 2016 (figure 8).

El Niño's strength from june 2015 to februari 2016 El Niño to be in the weak category in March to september 2014, September 2018 to Desember 2019, while october 2014 to April 2014 in the moderate category. From june to july 2015 El Nino strength reached its peak as the strong category, and during this phase, *K. pelamis* catches were increased (Figure 7) at october 2014, 2015 and November 2015.

Normal phase

Oceanographic conditions of the FMA 715 waters returned to normal and began to form upwelling. The horizontal surface temperature in North Papua comes from the temperature flow of the water mass originating from the Northwest Pacific. This event is known as the lower current in North Guinea/North Guinea Coastal under Current (NGCUC). The displacement of the water mass from the Pacific (inflow) into the eastern islands such as Papua occurs along the Northwest monsoon wind and outflow to the Indian Ocean occurs along the Southeast monsoon wind (Hartoko 2007).

The existence of NGCUC water flow from a depth of 100 m in northern Papua then rises to the surface of the water of south Halmahera and becomes upwelling. The effect of upwelling in this area that brings nutrients from deeper water to the water surface can cause nutrification and plankton blooming (Hartoko 2009). The formation of warm water mass in the internal waters of FMA 715 is an ideal condition for the environment of *K. pelamis*. Normal phase in March to september 2014, march to augstus 2018, which catch increased but not as big as during El Nino phase.

La Nina phase

During La Nina (from June 2016 to january 2017 and June 2017 to April 2018), *K. pelamis* catches was decreased when observed in the fishing area of the western Pacific compared to the eastern and central Pacific regions. Correlation between *K. pelamis* catches in FMA 715 waters and regional climate change from the results of this study using data of SST and temperature at depth from Triton buoy in *K. pelamis* fishing season during the transition season (September to November) shows an decrease in catches.

K. pelamis in the La Nina period migrated, including Indonesia, when El Nino occurred, tuna in the Pacific moved to the East. These conclusions have proven the hypothesis that is developed in fishing communities who perform fishing activities of *K. pelamis* in FMA 715, in which in general there is a shift in the fishing season caused by climate change. This weather deviation can have a positive impact on the fisheries sector because at that time there was a migration of tuna to the territorial waters of Indonesia. (Turkington 2019) Reported that El Nino and La Niña have the potential to occur with a period of 2 to 3 years.

The possible impact of climate change on fisheries is that a decrease in catch results can occur due to the migration of targeted fish species. The migration of targeted fish from temperate (sub-tropical) to tropical climate regions and not vice versa due to climate change will decrease fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig 2004).

Conclusions

The results of this study provide recommendations that the peak season of *K. pelamis* fishing in the waters of WPP 715 can be predicted based on information on the area's climate conditions that are taking place at a certain time. This study also shows that regional climate change greatly affects inter-monthly variation at the peak of *K. pelamis* fishing season in FMA 715 waters. During El Nino, the waters of WPP 715 are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to FMA 715 waters. Therefore, regional climate change triggered from the Pacific Ocean can also cause FMA 715 waters to become unfavorable for the *K. pelamis* environment.

Acknowledgement

This research was funded by the Ministry of Marine Affairs and Fisheries Republic of Indonesia (KKP) in 2019, therefore the authors would like to thank the Research and Human Resources Agency-KKP for funding this research. Thanks also to the Marine and Fisheries Resources Surveillance Sorong and PT. Citra Raja Ampat Canning for enabling us to carry out this research.

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Received: xxxxxxxxx. Accepted: xxxx 2021. Published online: xxxxxxx.

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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Nino Southern Oscillation (ENSO), Variability on Skipjack Tuna *(Katsuwonus pelamis)* Catches in the Fisheries Management Area (FMA) 715, Indonesia. AACL Bioflux xx(x):

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Thank you for your new submission.
The editorial team will assess your manuscript and I will get back to you as soon as possible with the result.

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Thank you.

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Kind regards,
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Preliminary acceptance 2

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Authors:
Sepri, Agus Hartoko, Suradi Wijaya Saputra, Abdul Ghofar, Erick Nugraha

was preliminary accepted for publication, with revision, in volume 14 (2021) of the scientific/academic journal: Aquaculture, Aquarium, Conservation & Legislation – International Journal of the Bioflux Society.
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erick nugraha <nugraha_eriq1@yahoo.co.id>
Kepada: Eni Kovacs

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Dear Dr. Eni,
I have been paid my manuscript with USD 300.

Thank You

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Revision 2

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Eni Kovacs <ek.bioflux@gmail.com>
Kepada: erick nugraha

Kam, 17 Jun 2021 jam 02.56

Dear Dr Nugraha,

Regarding your manuscript submitted to AACL Bioflux, the editorial team has some requests prior to acceptance (please see the attachment).

Please note: Always operate corrections/additions (or deletions) in the manuscript we are sending you, by **highlighting with a bright color** (for an easy identification). We never work on the manuscript you send back, just identify the corrections and operate them on our document (to avoid any undesirable accidental operations like changed page set up, otherwise the editors have to start all the work from the beginning, and we cannot ask them to re-check every manuscript word by word to identify unmarked modifications).

Thank you for understanding!

--
Kind regards,
Editor AACL Bioflux
Eniko Kovacs

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Impact of El Nino Southern Oscillation (ENSO), variability on skipjack tuna (*Katsuwonus pelamis*) catches, in the fisheries management area (FMA) 715, Indonesia

[1]Sepri, [2]Agus Hartoko, [2]Suradi W. Saputra, [2]Abdul Ghofar, [3]Erick Nugraha

[1] Doctoral Programe in Coastal Resources Management, Fisheries and Marine Science Faculty, Diponegoro University, Semarang, Central Java, Indonesia; [2] Coastal Resources Management, Fisheries and Marine Science Faculty, Diponegoro University, Semarang, Central Java, Indonesia; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: Nugraha E., nugraha_eriq1@yahoo.co.id

Abstract. Marine and ~~fisheries~~ fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the ~~existence of various~~ environmental conditions~~.~~, ~~Fluctuations~~ whose fluctuations ~~in environmental conditions have many~~ influence~~s~~ ~~on~~ the seasonal fish migration and residence period ~~and the presence of fish in one place~~. This study aimed to determine the ~~variability in peak season of~~ tuna ~~fishing~~ catch variability in the peak season, under~~to~~ regional climate change constraints, such as El Nino and La Nina, with the aim to optimize the utilization of *Katsuwonus* ~~*K.*~~ *pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Nino (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement ~~times~~ sessions were performed at the end of the East season, ~~which was~~ from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715 ~~area~~. During El Nino, the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, ~~The~~ the peak fishing peak season was in October ~~for the period from September to November~~. The regional climate change ~~triggered~~ originating from the Pacific Ocean caused ~~the~~ unsuitable water conditions in the FMA 715, regarding the~~for~~ *K. pelamis* fishing. ~~Variability~~ The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.

Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and ~~has~~ its waters ~~which is one of the main players in the~~ are part in the oceanic movement ~~of global water mass or~~ known as the Great Ocean Conveyor Belt. The changes occuring in the ~~movement~~ pattern of the global water mass movement affect the world's climate (Trenberth 2007). ~~Global~~ The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change ~~touches the joints of~~ affects life in the territorial area and ~~will~~ negatively impacts ~~to~~ the potential~~,~~ quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming ~~on the atmosphere, for instance, is the temperature~~ increased temperatures ~~until~~ with 0.5°C throughout the 20th century (Church ~~and~~ & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a ~~characteristic that is~~ trans-boundary character (Song et al 2016) ~~and have a great potential to be affected by~~ making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al

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2017). Changes in the global environment emerge ~~because there are~~ due to the climate changes characterized by ~~warming in~~ the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayati et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the ~~existence of~~ various environmental conditions. Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus* ~~*K.*~~ *pelamis*~~-~~, are the availability of data sources for fishing catches and ~~in~~ for site ~~data~~characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. ~~This~~ The early availability of this information is ~~important to be known by~~essential for the *K. pelamis* fishing community ~~in early~~, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to ~~increase the optimization~~ optimize ~~of~~ the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station ~~were~~ was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

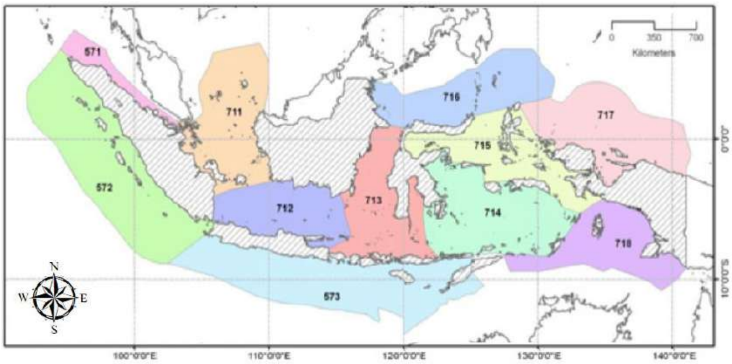

Figure 1. Map of sampling site (MMAF 2018).

~~**Results and Discussion**~~

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using ~~qualitatively~~ qualitative and descriptive methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Nino (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology~~,~~ and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement ~~times~~ sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

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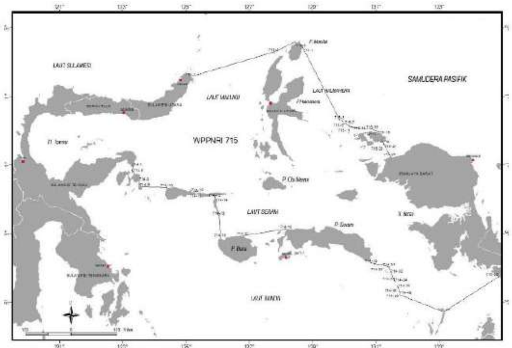

Figure 2. Indonesia Fisheries Management Area (FMA) 715.

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Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Nino (2015 to 2019) and La Nina (2015 to 2019).

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Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture ~~fisheries~~ fishery activities, especially pelagic species, among which ~~fisheries~~ fishery commodities with important economic value such as tuna, *K. pelamis* and small ~~pelagic~~ fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature ~~which is~~ (in accordance with the tolerance of body temperature of *K. pelamis* ~~-~~) and abundance of food. ~~Potential~~ The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors ~~both physical, chemical and aquatic biology~~, including the SST (Zainuddin 2011) ~~or~~ , ~~the~~ distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front ~~and~~ or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas ~~in~~ of a tropical zone, in~~.~~ ~~There is~~ a region with rainfalls above 3000 mm per year, located ~~in~~ to the west~~ern regions~~ of Irian and Mindanao. I~~because i~~t is the center of a warm water pool, which results in intensive convection accompanied by ~~a~~ high ~~virginity~~ velocity ~~process~~ currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in ~~the~~ number of rainy days and ~~the~~ in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season ~~in~~to the summer ~~or which is known as the~~ (transition season).

Oceanographic conditions. ~~The~~ In the eastern part of the Indonesian archipelago flow~~s~~ important ocean currents, known as *Arus Lintas Indonesia (Arlindo)*. This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 ~~have characteristics that have~~ are directly ~~influences~~ influenced ~~from~~ by the Pacific water mass, ~~to~~ from the entrance of the main area ~~that goes through~~consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of ~~Westward~~ westward ~~(west)~~ water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ~~effect of~~ ocean currents ~~is in the~~ form~~ation of~~ areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in ~~North Guinea/North~~New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, ~~occur along~~during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. ~~The effect of upwelling~~ Upwelling ~~in this area, that~~ brings nutrients from deeper water to the surface, ~~of the water causes~~ causing ni~~u~~trification and phytoplankton bloom (Kämpf & Chapman 2016).

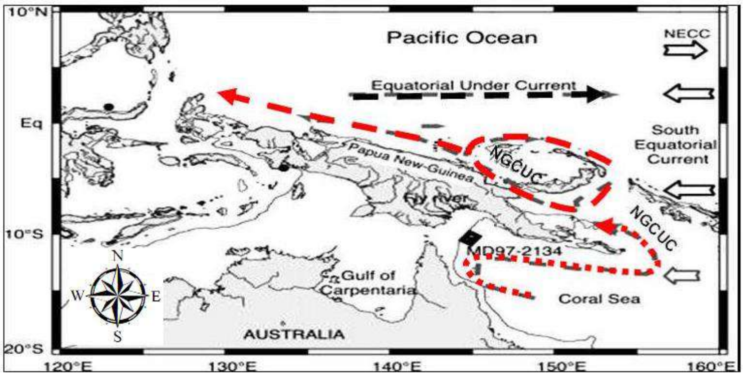

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. ~~For temperature~~ Temperature data from Triton ~~data which is the SST, the results~~ show an average of the SST variations ~~ranged~~ ranging from 28.4 to 30.6°C. The ~~biggest~~ largest catch of *K. pelamis* ~~was~~ occured in the SST range of 29 to 30°C (Nugraha et al 2020).

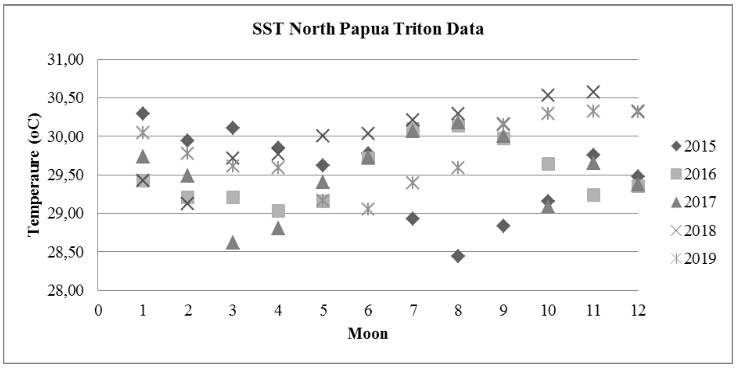

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. ~~Salinity of~~ The water surface layer's salinity is influenced by wind and ~~mosun~~ monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, ~~takes in high salinity~~ which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The sea vertical salinity data of TRITON buoy shows the temperature data obtained at various depths 1.5 m. During the period from 2015 to 2019, the ~~Salinity~~ salinity profiles at ~~some~~ certain coordinate points ~~in 2015-2019~~ in North Papua ~~(West end Pacific)~~ show~~s salinity~~ values ~~ranged~~ ranging from 33.3~~-~~ to 34.6 psu.

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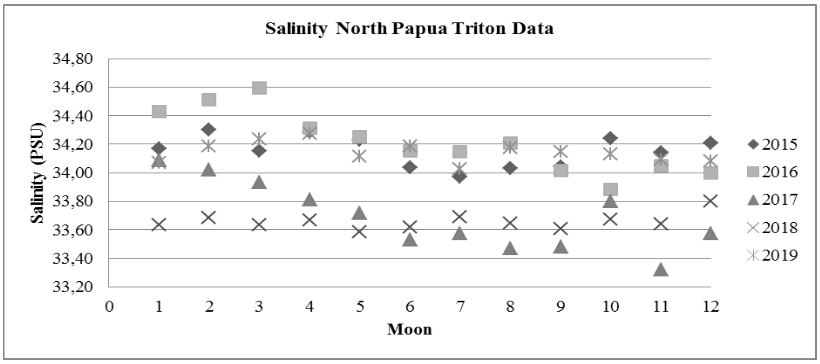

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. ~~In~~ January, May to June~~,~~ and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis*~~-~~ ~~in~~ originating from the headwaters of Papua and ~~landed~~ landing at Radios Apirja Co. Ltd.~~,~~ ~~for five years is known to be~~ reached their highest levels~~reached~~ in March. It can be assumed that in March, the waters ~~in~~ to the ~~the head of~~north of ~~the~~ Papua (FMA 715) were in a suitable condition, ~~and~~ with ~~abundant~~ food ~~was~~ available in abundance ~~for *K. pelamis*~~, ~~thus it~~ and it was convenient for ~~by~~ *K. pelamis* to migrate into (Mugo et al 2010).

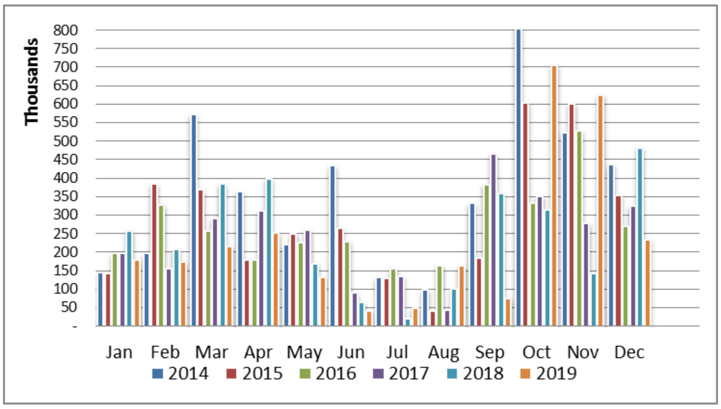

Figure 7. Catches of *Katsuwonus ~~K.~~ pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows ~~the~~ decreasing trends ~~of *K. pelamis* catches~~ in the fishing periods of February to May and September to December ~~periods that are decreasing annual catches in total catches,~~ and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example~~,~~ by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Nino phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll ~~to produce~~synthesis.

El Nino

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño and La Niña Years and Intensities (NOAA-NWS 2019).

El Niño is characterized by a SST decrease ~~in SST~~ in the Indonesian waters~~,~~ and ~~an~~ increase (of more than 0.5°C) ~~in SST~~ in the eastern tropical Pacific Ocean~~, with an increase in SST of more than 0.5°C~~ (Sofian et al 2011). From ~~Maret~~ March 2014 until April 2016, ~~El Nino came to cause~~ the regional climate ~~to~~ experienced one of the longest ~~a prolonged~~ dry seasons ~~and it was recorded as one of the largest~~ in ~~history~~History~~.~~, due to El Nino.

El Nino ~~with moderate intensity~~ began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia's internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) ~~flowing~~

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La Nina?

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El Niño
El Nino

coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Nino signals, which became extreme in November 2015 and returned to normal conditions in May 2016 (~~figure~~ Figure 8).

El Niño's strength from ~~june~~ June 2015 to ~~februari~~ February 2016 El Niño to be in the weak category in March to ~~september~~ September 2014, September 2018 to ~~Desember~~ December 2019, while ~~october~~ October 2014 to April 2014 in the moderate category. From june to july 2015 El Nino strength reached its peak as the strong category, and during this phase, *K. pelamis* catches were increased (Figure 7) at october 2014, 2015 and November 2015.

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Normal phase. Oceanographic conditions of the FMA 715 waters returned to normal and began to form upwellings.

~~The horizontal surface temperature in North Papua comes from the temperature flow of the water mass originating from the Northwest Pacific. This event is known as the lower current in North Guinea/North Guinea Coastal under Current (NGCUC). The displacement of the water mass from the Pacific (inflow) into the eastern islands such as Papua occurs along the Northwest monsoon wind and outflow to the Indian Ocean occurs along the Southeast monsoon wind (Hartoko 2007).~~

~~The existence of NGCUC water flow from a depth of 100 m in northern Papua then rises to the surface of the water of south Halmahera and becomes upwelling. The effect of upwelling in this area that brings nutrients from deeper water to the water surface can cause nutrification and plankton blooming (Hartoko 2009).~~ The formation of warm water mass in the internal waters of FMA 715 is an ideal condition for the environment of *K. pelamis*. ~~Normal~~ The normal phase could be observed ~~in~~ from March to ~~september~~ September 2014~~,~~ and from ~~march~~ March to ~~augstus~~ August 2018, ~~which~~ with an ~~catch~~ increased catch, but not as ~~big~~ significant as during El Nino phase.

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La Nina phase. During La Nina (from June 2016 to ~~january~~ January 2017 and from June 2017 to April 2018), *K. pelamis* catches ~~was~~ were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed~~from the results of this study~~, using ~~data of~~ SST and depth temperature data ~~at depth~~ from the Triton buoy. ~~in *K. pelamis* fishing season during~~ Within the transition season (September to November), the *K. pelamis* catches ~~shows~~ showed a~~n~~ decrease ~~in catches~~.

K. pelamis migrated in the La Nina period ~~migrated, including Indonesia, when El Nino occurred~~, ~~tuna in~~ moving from the Pacific ~~moved~~ to the East (including Indonesia). These conclusions ~~have proven~~ proved the ~~hypothesis that is developed~~observation of a shift in the fishing season, caused by climate change, ~~in~~ reported by the fishing communities ~~who perform fishing activities of *K. pelamis*~~active in the FMA 715~~, in which in general there is a shift in the fishing season caused by climate change~~. This weather deviations can have a positive impact on the fisheries sector, ~~because at that time there was a~~triggering migrations of tuna to the territorial waters of Indonesia. ~~(~~Turkington (2019) ~~Reported~~ reported that El Nino and La Niña have the potential to occur ~~with a~~ periodically, every ~~of~~ 2 to 3 years.

~~The~~ A possible impact of the climate change on fisheries is ~~that~~ a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration ~~of targeted fish~~ from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. T~~he results of t~~his study ~~provide recommendations~~suggests that the peak season of *K. pelamis* fishing in the waters of FMA~~WPP~~ 715 can be predicted based on information on the area's climate conditions~~ that are taking place at a certain time~~. This study also shows that regional climate change greatly affects the inter-monthly variation ~~at~~ and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Nino, these waters ~~of WPP 715~~ are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also ~~cause~~ make ~~FMA 715~~these waters~~ to become~~ unfavorable for the *K. pelamis* environment.

Acknowledgments. This research was funded by the Ministry of Marine Affairs and Fisheries Republic of Indonesia (KKP) in 2019, therefore the authors would like to thank the Research and Human Resources Agency-KKP for funding this research. Thanks also to the Marine and Fisheries Resources Surveillance of Sorong and PT. Citra Raja Ampat Canning for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Nino Southern Oscillation (ENSO), variability on skipjack tuna *(Katsuwonus pelamis)* catches in the fisheries management area (FMA) 715, Indonesia. AACL Bioflux 14(x):

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Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna (*Katsuwonus pelamis*) catches, in the fisheries management area (FMA) 715, Indonesia

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Abstract. Marine and fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the environmental conditions, whose fluctuations influence the seasonal fish migration and residence period. This study aimed to determine the tuna catch variability in the peak season,under regional climate change constraints, such as El Niño and La Nina, with the aim to optimize the utilization of *Katsuwonus pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement sessions were performed at the end of the East season, from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715. During El Niño , the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, the fishing peak season was in October. The regional climate change originating from the Pacific Ocean caused unsuitable water conditions in the FMA 715, regarding the *K. pelamis* fishing. The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.

Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and its waters are part in the oceanic movement known as the Great Ocean Conveyor Belt. The changes occuring in the pattern of the global water mass movement affect the world's climate (Trenberth 2007). The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change affects life in the territorial area and negatively impacts the potential quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming increased temperatures with 0.5°C throughout the 20th century (Church & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a trans-boundary character (Song et al 2017) making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in the global environment emerge due to the climate changes characterized by the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayat et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the various environmental conditions.

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Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus pelamis*, are the availability of data sources for fishing catches and for site characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. The early availability of this information is essential for the *K. pelamis* fishing community, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to optimize the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

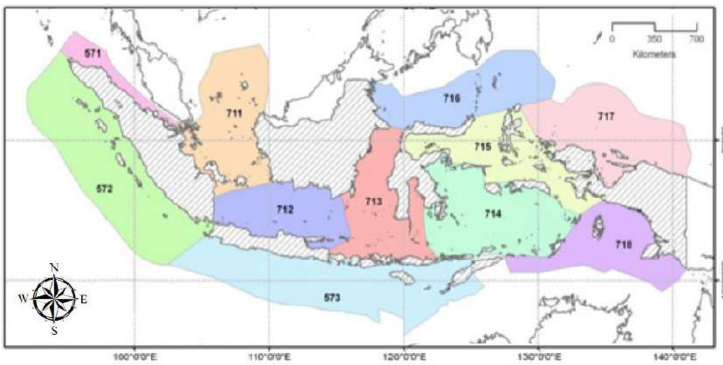

Figure 1. Map of sampling site (MMAF 2018).

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using *qualitative and descriptive* methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Niño (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

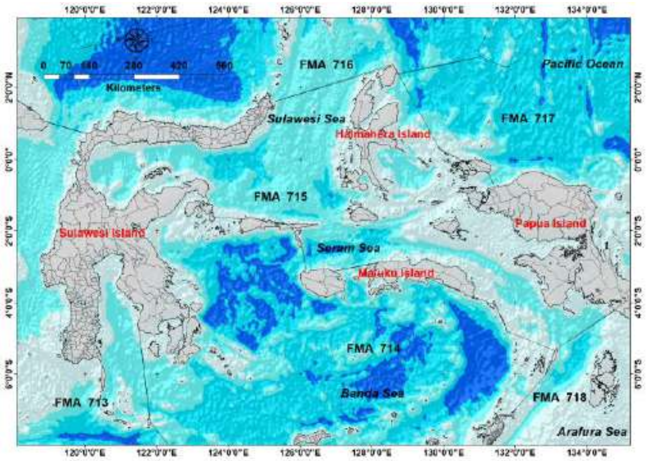

Figure 2. Indonesia Fisheries Management Area (FMA) 715 (MMAF 2018).

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Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019).

Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture fishery activities, especially pelagic species, among which fishery commodities with important economic value such as tuna, *K. pelamis* and small fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature (in accordance with the tolerance of body temperature of *K. pelamis*) and abundance of food. The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors, including the SST (Zainuddin 2011), distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas of a tropical zone, in a region with rainfalls above 3000 mm per year, located to the west of Irian and Mindanao. It is the center of a warm water pool, which results in intensive convection accompanied by high velocity currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in number of rainy days and in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season to the summer (transition season).

Oceanographic conditions. In the eastern part of the Indonesian archipelago flow important ocean currents, known as *Arus Lintas Indonesia (Arlindo)*. This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 are directly influenced by the Pacific water mass, from the entrance of the main area consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of westward water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ocean currents form areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. Upwelling brings nutrients from deeper water to the surface, causing nitrification and phytoplankton bloom (Kämpf & Chapman 2016).

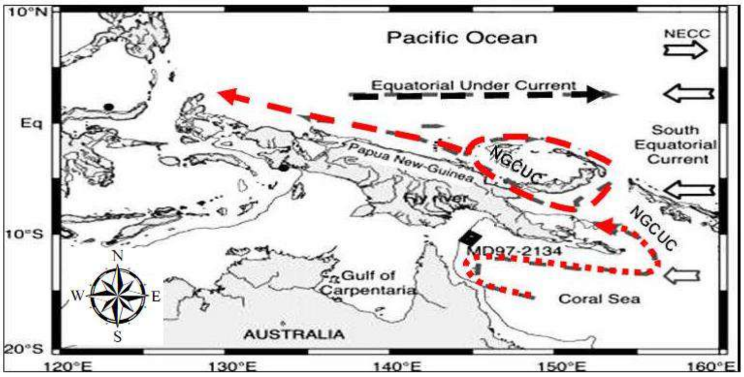

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. Temperature data from Triton show an average of the SST variations ranging from 28.4 to 30.6°C. The largest catch of *K. pelamis* occured in the SST range of 29 to 30°C (Nugraha et al 2020).

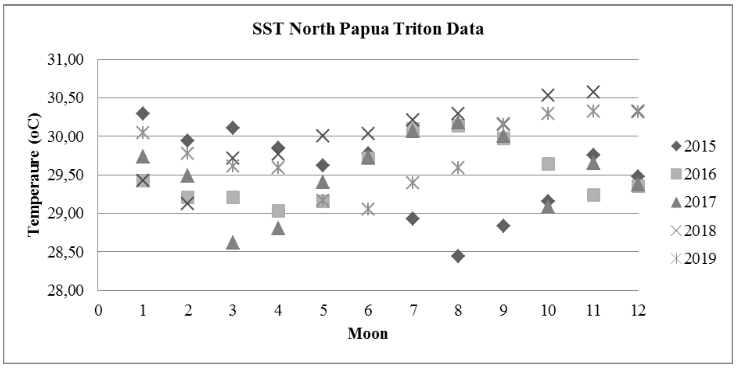

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. The water surface layer's salinity is influenced by wind and monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The vertical salinity data of the TRITON buoy shows the temperature data obtained at each depth of 1.5 m .During the period from 2015 to 2019, the salinity profiles at certain coordinate points in North Papua show values ranging from 33.3 to 34.6 psu.

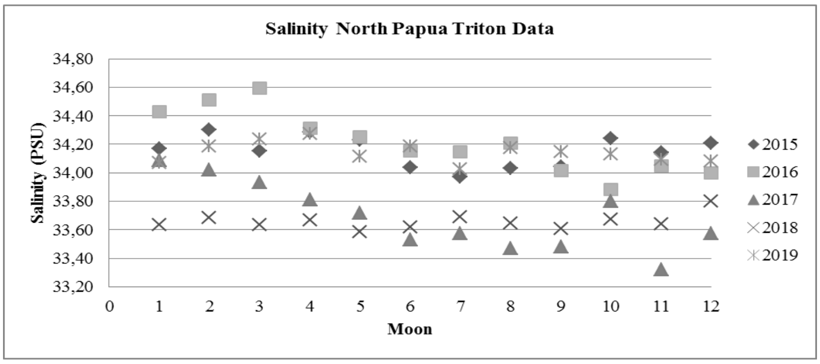

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. January, May to June and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis* originating from the headwaters of Papua and landing at Radios Apirja Co. Ltd. reached their highest levelsin March. It can be assumed that in March, the waters to the north of Papua (FMA 715) were in a suitable condition, with food available in abundance , and it was convenient for *K. pelamis* to migrate into (Mugo et al 2010).

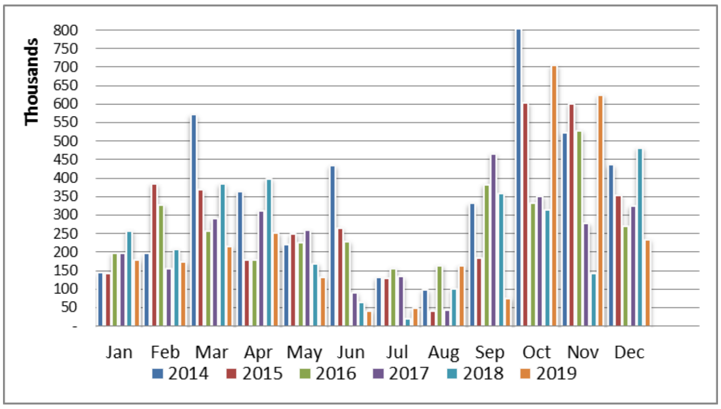

Figure 7. Catches of *Katsuwonus pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows decreasing trends in the fishing periods of February to May and September to December and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Niño phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll synthesis.

El Niño

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño Years and Intensities (NOAA-NWS 2019).

El Niño is characterized by a SST decrease in the Indonesian waters and increase (of more than 0.5°C) in the eastern tropical Pacific Ocean (Sofian et al 2011). From March 2014 until April 2016, the regional climate experienced one of the longest dry seasons in History, due to El Niño .

El Niño began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia's internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Niño signals, which became extreme in November 2015 and returned to normal conditions in May 2016 (Figure 8).

El Niño's strength from June 2015 to February 2016 El Niño to be in the weak category in March to September 2014, September 2018 to December 2019, while October 2014 to April 2014 in the moderate category. From june to july 2015 El Niño strength reached its peak as the strong category, and during this phase, *K. pelamis* catches were increased (Figure 7) at october 2014, 2015 and November 2015.

August 2015 to April 2016, El Niño was a stronger category, even reaching its peak in January 2016 (Figure 8), and during this phase, *K. pelamis* catches increased (Figure 7).

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Normal phase. The oceanographic conditions of FMA 715 returned to normal and upwellings began to form. The formation of warm water masses in the internal waters of FMA 715 is an ideal condition for the *K. pelamis* environment. The normal phase can be observed from March to September 2014 and from March to August 2018, with increasing yield catchment, but not as significant as in the El Niño phase.

La Nina phase. During La Nina (from June 2016 to January 2017 and from June 2017 to April 2018), *K. pelamis* catches were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed, using SST and depth temperature data from the Triton buoy. Within the transition season (September to November), the *K. pelamis* catches showed a decrease.

K. pelamis migrated in the La Nina period, moving from the Pacific to the East (including Indonesia). These conclusions proved the observation of a shift in the fishing season, caused by climate change, reported by the fishing communities active in the FMA 715. This weather deviations can have a positive impact on the fisheries sector, triggering migrations of tuna to the territorial waters of Indonesia. Turkington (2019) reported that El Niño and La Niña have the potential to occur periodically, every 2 to 3 years.

A possible impact of the climate change on fisheries is a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. This study suggests that the peak season of *K. pelamis* fishing in the waters of FMA 715 can be predicted based on information on the area's climate conditions. This study also shows that regional climate change greatly affects the inter-monthly variation and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Niño, these waters are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also make these waters unfavorable for the *K. pelamis* environment.

Acknowledgments. This research was funded by the Marine and Fisheries Education Centre - Ministry of Marine Affairs and Fisheries Republic of Indonesia. Thanks also to Marine and Fisheries Resources Surveillance Sorong, Citra Raja Ampat Canning Co. Ltd Sorong and MV. Cinta Bahari 09 crews for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna *(Katsuwonus pelamis)* catches in the fisheries management area (FMA) 715, Indonesia. AACL Bioflux 14(x):

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Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna (*Katsuwonus pelamis*) catches, in the fisheries management area (FMA) 715, Indonesia

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Abstract. Marine and fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the environmental conditions, whose fluctuations influence the seasonal fish migration and residence period. This study aimed to determine the tuna catch variability in the peak season,under regional climate change constraints, such as El Niño and La Nina, with the aim to optimize the utilization of *Katsuwonus pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement sessions were performed at the end of the East season, from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715. During El Niño , the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, the fishing peak season was in October. The regional climate change originating from the Pacific Ocean caused unsuitable water conditions in the FMA 715, regarding the *K. pelamis* fishing. The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.
Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and its waters are part in the oceanic movement known as the Great Ocean Conveyor Belt. The changes occuring in the pattern of the global water mass movement affect the world's climate (Trenberth 2007). The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change affects life in the territorial area and negatively impacts the potential quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming increased temperatures with 0.5°C throughout the 20th century (Church & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a trans-boundary character (Song et al 2017) making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in the global environment emerge due to the climate changes characterized by the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayat et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the various environmental conditions.

Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus pelamis*, are the availability of data sources for fishing catches and for site characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. The early availability of this information is essential for the *K. pelamis* fishing community, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to optimize the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

Figure 1. Map of sampling site (MMAF 2018).

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using *qualitative and descriptive* methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Niño (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

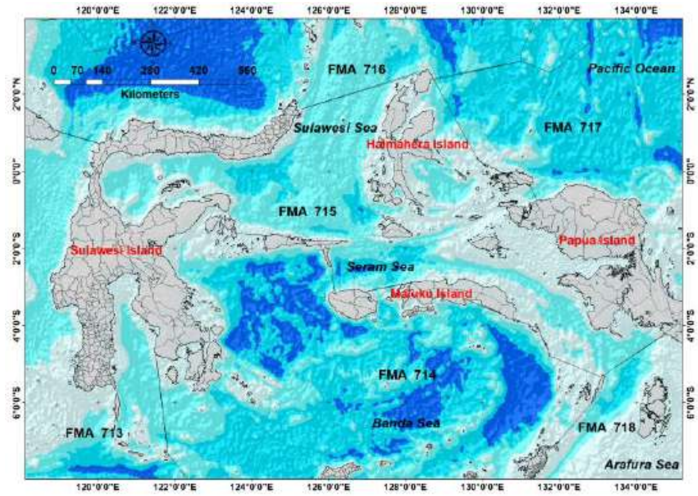

Figure 2. Indonesia Fisheries Management Area (FMA) 715 (MMAF 2018).

Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019).

Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture fishery activities, especially pelagic species, among which fishery commodities with important economic value such as tuna, *K. pelamis* and small fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature (in accordance with the tolerance of body temperature of *K. pelamis*) and abundance of food. The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors, including the SST (Zainuddin 2011), distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas of a tropical zone, in a region with rainfalls above 3000 mm per year, located to the west of Irian and Mindanao. It is the center of a warm water pool, which results in intensive convection accompanied by high velocity currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in number of rainy days and in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season to the summer (transition season).

Oceanographic conditions. In the eastern part of the Indonesian archipelago flow important ocean currents, known as Arus Lintas Indonesia (Arlindo). This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 are directly influenced by the Pacific water mass, from the entrance of the main area consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of westward water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ocean currents form areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. Upwelling brings nutrients from deeper water to the surface, causing nitrification and phytoplankton bloom (Kämpf & Chapman 2016).

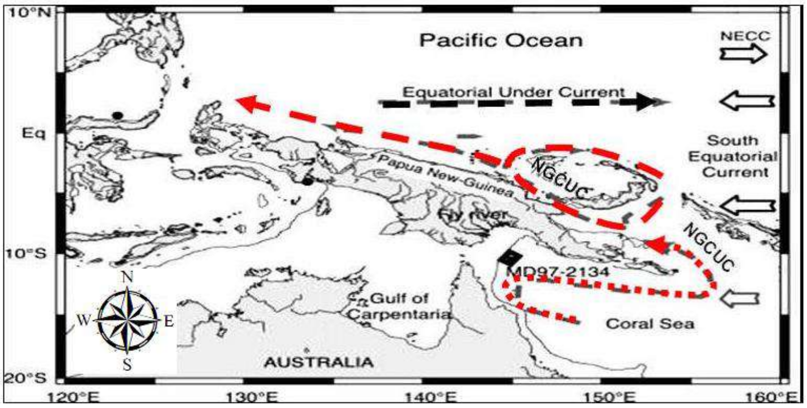

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. Temperature data from Triton show an average of the SST variations ranging from 28.4 to 30.6°C. The largest catch of *K. pelamis* occured in the SST range of 29 to 30°C (Nugraha et al 2020).

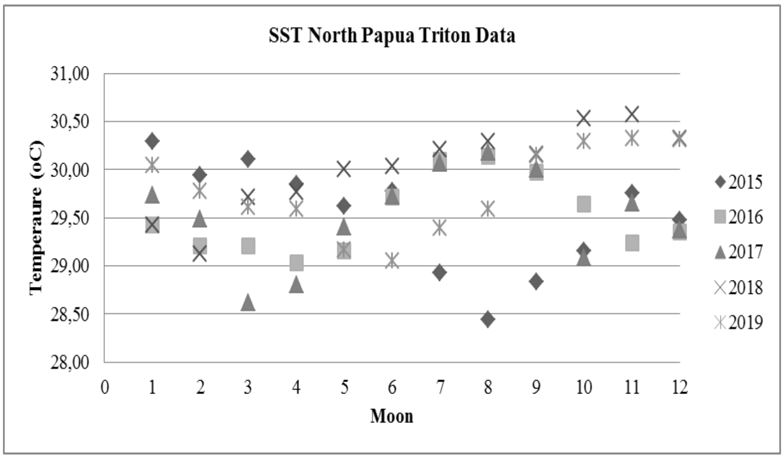

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. The water surface layer's salinity is influenced by wind and monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The vertical salinity data of the TRITON buoy shows the temperature data obtained at each depth of 1.5 m. During the period from 2015 to 2019, the salinity profiles at certain coordinate points in North Papua show values ranging from 33.3 to 34.6 psu.

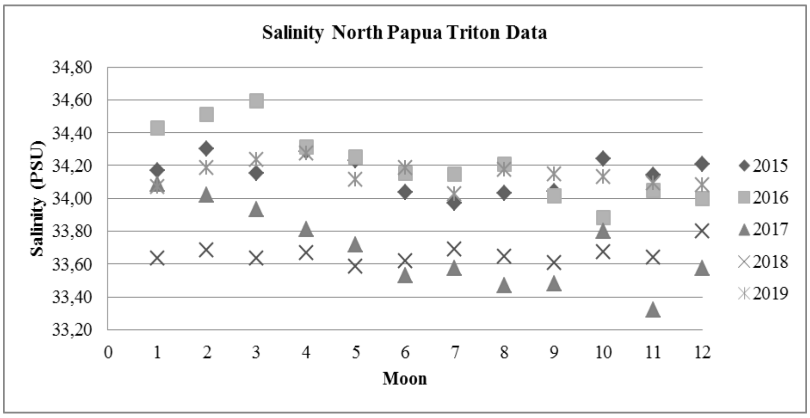

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. January, May to June and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis* originating from the headwaters of Papua and landing at Radios Apirja Co. Ltd. reached their highest levelsin March. It can be assumed that in March, the waters to the north of Papua (FMA 715) were in a suitable condition, with food available in abundance , and it was convenient for *K. pelamis* to migrate into (Mugo et al 2010).

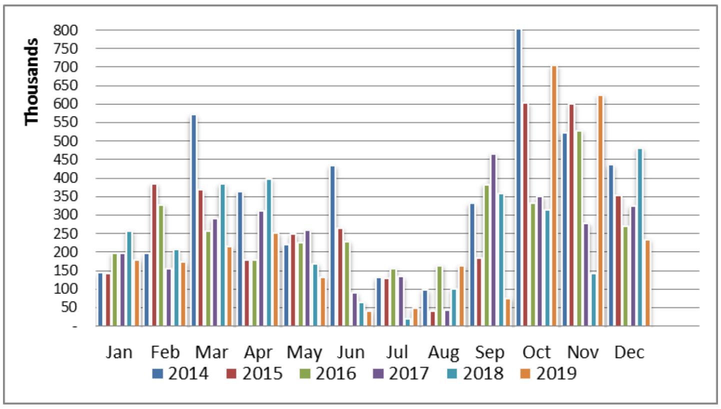

Figure 7. Catches of *Katsuwonus pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows decreasing trends in the fishing periods of February to May and September to December and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Niño phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll synthesis.

El Niño

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño years and intensities (NOAA-NWS 2019).

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El Niño is characterized by a SST decrease in the Indonesian waters and increase (of more than 0.5°C) in the eastern tropical Pacific Ocean (Sofian et al 2011). From March 2014 until April 2016, the regional climate experienced one of the longest dry seasons in History, due to El Niño.

El Niño began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia's internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Niño signals, which became extreme in November 2015 and returned to normal conditions in May 2016 (Figure 8). From August 2015 to April 2016, El Niño was a stronger category, even reaching its peak in January 2016 (Figure 8), and during this phase, *K. pelamis* catches increased (Figure 7).

Normal phase. The oceanographic conditions of FMA 715 returned to normal and upwellings began to form. The formation of warm water masses in the internal waters of FMA 715 is an ideal condition for the *K. pelamis* environment. The normal phase can be observed from March to September 2014 and from March to August 2018, with increasing yield catchment, but not as significant as in the El Niño phase.

La Nina phase. During La Nina (from June 2016 to January 2017 and from June 2017 to April 2018), *K. pelamis* catches were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed, using SST and depth temperature data from the Triton buoy. Within the transition season (September to November), the *K. pelamis* catches showed a decrease.

K. pelamis migrated in the La Nina period, moving from the Pacific to the East (including Indonesia). These conclusions proved the observation of a shift in the fishing season, caused by climate change, reported by the fishing communities active in the FMA 715. This weather deviations can have a positive impact on the fisheries sector, triggering migrations of tuna to the territorial waters of Indonesia. Turkington (2019) reported that El Niño and La Niña have the potential to occur periodically, every 2 to 3 years.

A possible impact of the climate change on fisheries is a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. This study suggests that the peak season of *K. pelamis* fishing in the waters of FMA 715 can be predicted based on information on the area's climate conditions. This study also shows that regional climate change greatly affects the inter-monthly variation and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Niño, these waters are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also make these waters unfavorable for the *K. pelamis* environment.

Acknowledgements. This research was funded by the Marine and Fisheries Education Centre - Ministry of Marine Affairs and Fisheries Republic of Indonesia. Thanks also to Marine and Fisheries Resources Surveillance Sorong, Citra Raja Ampat Canning Co. Ltd Sorong and MV. Cinta Bahari 09 crews for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna *(Katsuwonus pelamis)* catches in the fisheries management area (FMA) 715, Indonesia. AACL Bioflux 14(x):

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Impact of El Niño Southern Oscillation (ENSO), Variability on Skipjack Tuna (*Katsuwonus pelamis*) Catches, in the Fisheries Management Area (FMA) 715, Indonesia

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Abstract. Marine and fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the environmental conditions, whose fluctuations influence the seasonal fish migration and residence period. This study aimed to determine the tuna catch variability in the peak season,under regional climate change constraints, such as El Niño and La Nina, with the aim to optimize the utilization of *Katsuwonus pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement sessions were performed at the end of the East season, from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715. During El Niño , the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, the fishing peak season was in October. The regional climate change originating from the Pacific Ocean caused unsuitable water conditions in the FMA 715, regarding the *K. pelamis* fishing. The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.
Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and its waters are part in the oceanic movement known as the Great Ocean Conveyor Belt. The changes occuring in the pattern of the global water mass movement affect the world's climate (Trenberth 2007). The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change affects life in the territorial area and negatively impacts the potential quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming increased temperatures with 0.5°C throughout the 20th century (Church & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a trans-boundary character (Song et al 2017) making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in the global environment emerge due to the climate changes characterized by the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayat et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the various environmental conditions.

Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus pelamis*, are the availability of data sources for fishing catches and for site characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. The early availability of this information is essential for the *K. pelamis* fishing community, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to optimize the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

Figure 1. Map of sampling site (MMAF 2018).

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using *qualitative and descriptive* methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Niño (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

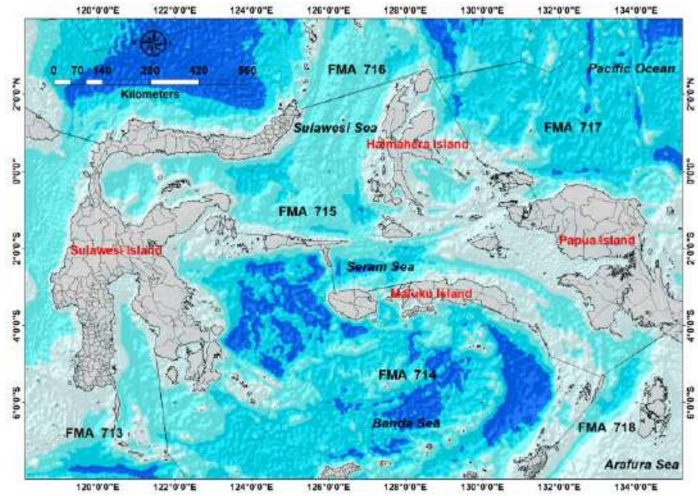

Figure 2. Indonesia Fisheries Management Area (FMA) 715 (MMAF 2018).

Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019).

Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture fishery activities, especially pelagic species, among which fishery commodities with important economic value such as tuna, *K. pelamis* and small fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature (in accordance with the tolerance of body temperature of *K. pelamis*) and abundance of food. The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors, including the SST (Zainuddin 2011), distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas of a tropical zone, in a region with rainfalls above 3000 mm per year, located to the west of Irian and Mindanao. It is the center of a warm water pool, which results in intensive convection accompanied by high velocity currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in number of rainy days and in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season to the summer (transition season).

Oceanographic conditions. In the eastern part of the Indonesian archipelago flow important ocean currents, known as Arus Lintas Indonesia (Arlindo). This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 are directly influenced by the Pacific water mass, from the entrance of the main area consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of westward water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ocean currents form areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. Upwelling brings nutrients from deeper water to the surface, causing nitrification and phytoplankton bloom (Kämpf & Chapman 2016).

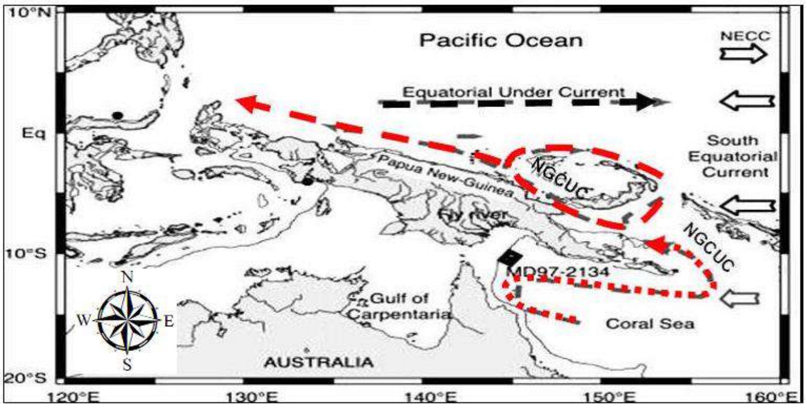

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. Temperature data from Triton show an average of the SST variations ranging from 28.4 to 30.6°C. The largest catch of *K. pelamis* occured in the SST range of 29 to 30°C (Nugraha et al 2020).

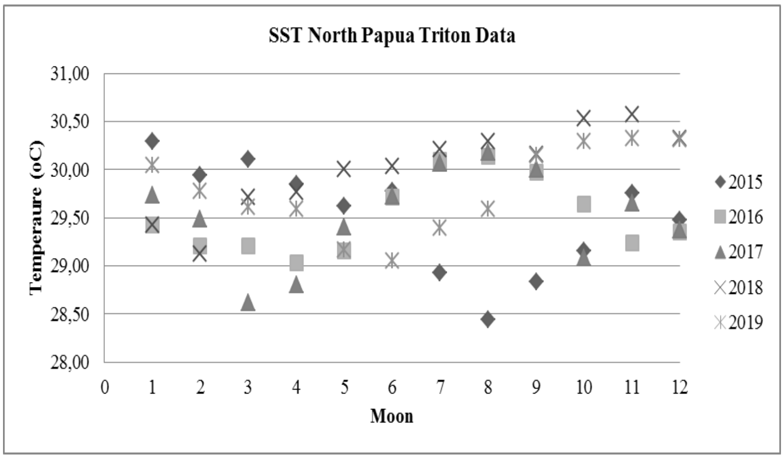

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. The water surface layer's salinity is influenced by wind and monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The vertical salinity data of the TRITON buoy shows the temperature data obtained at each depth of 1.5 m. During the period from 2015 to 2019, the salinity profiles at certain coordinate points in North Papua show values ranging from 33.3 to 34.6 psu.

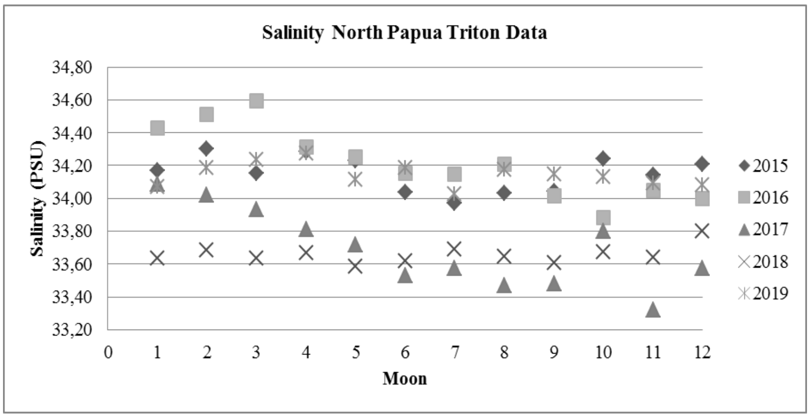

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. January, May to June and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis* originating from the headwaters of Papua and landing at Radios Apirja Co. Ltd. reached their highest levelsin March. It can be assumed that in March, the waters to the north of Papua (FMA 715) were in a suitable condition, with food available in abundance , and it was convenient for *K. pelamis* to migrate into (Mugo et al 2010).

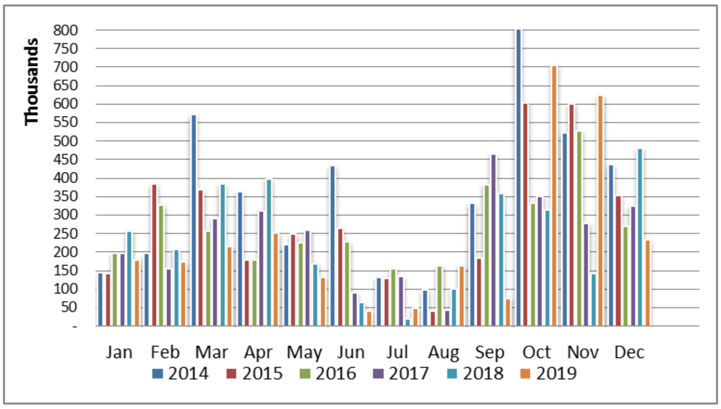

Figure 7. Catches of *Katsuwonus pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows decreasing trends in the fishing periods of February to May and September to December and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Niño phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll synthesis.

El Niño. El Niño is characterized by a SST decrease in the Indonesian waters and increase (of more than 0.5°C) in the eastern tropical Pacific Ocean (Sofian et al 2011). From March 2014 until April 2016, the regional climate experienced one of the longest dry seasons in History, due to El Niño. The year and intensity of El Niño can be seen in the table below (NOAA-NWS 2019).

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño years and intensities (NOAA-NWS 2019).

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El Niño began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia's internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Niño signals, which became extreme in November 2015 and returned to normal conditions in May 2016

(Figure 8). From August 2015 to April 2016, El Niño was a stronger category, even reaching its peak in January 2016 (Figure 8), and during this phase, *K. pelamis* catches increased (Figure 7).

Normal phase. The oceanographic conditions of FMA 715 returned to normal and upwellings began to form. The formation of warm water masses in the internal waters of FMA 715 is an ideal condition for the *K. pelamis* environment. The normal phase can be observed from March to September 2014 and from March to August 2018, with increasing yield catchment, but not as significant as in the El Niño phase.

La Nina phase. During La Nina (from June 2016 to January 2017 and from June 2017 to April 2018), *K. pelamis* catches were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed, using SST and depth temperature data from the Triton buoy. Within the transition season (September to November), the *K. pelamis* catches showed a decrease.

K. pelamis migrated in the La Nina period, moving from the Pacific to the East (including Indonesia). These conclusions proved the observation of a shift in the fishing season, caused by climate change, reported by the fishing communities active in the FMA 715. This weather deviations can have a positive impact on the fisheries sector, triggering migrations of tuna to the territorial waters of Indonesia. Turkington (2019) reported that El Niño and La Niña have the potential to occur periodically, every 2 to 3 years.

A possible impact of the climate change on fisheries is a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. This study suggests that the peak season of *K. pelamis* fishing in the waters of FMA 715 can be predicted based on information on the area's climate conditions. This study also shows that regional climate change greatly affects the inter-monthly variation and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Niño, these waters are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also make these waters unfavorable for the *K. pelamis* environment.

Acknowledgements. This research was funded by the Marine and Fisheries Education Centre - Ministry of Marine Affairs and Fisheries Republic of Indonesia. Thanks also to Marine and Fisheries Resources Surveillance Sorong, Citra Raja Ampat Canning Co. Ltd Sorong and MV. Cinta Bahari 09 crews for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Niño Southern Oscillation (ENSO), Variability on Skipjack Tuna *(Katsuwonus pelamis)* Catches in the Fisheries Management Area (FMA) 715, Indonesia. AACL Bioflux 14(x):

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Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna (*Katsuwonus pelamis*) catches, in the fisheries management area (FMA) 715, Indonesia

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Abstract. Marine and fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the environmental conditions, whose fluctuations influence the seasonal fish migration and residence period. This study aimed to determine the tuna catch variability in the peak season,under regional climate change constraints, such as El Niño and La Nina, with the aim to optimize the utilization of *Katsuwonus pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement sessions were performed at the end of the East season, from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715. During El Niño , the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, the fishing peak season was in October. The regional climate change originating from the Pacific Ocean caused unsuitable water conditions in the FMA 715, regarding the *K. pelamis* fishing. The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.
Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and its waters are part in the oceanic movement known as the Great Ocean Conveyor Belt. The changes occuring in the pattern of the global water mass movement affect the world's climate (Trenberth 2007). The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change affects life in the territorial area and negatively impacts the potential quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming increased temperatures with 0.5°C throughout the 20th century (Church & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a trans-boundary character (Song et al 2017) making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in the global environment emerge due to the climate changes characterized by the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayat et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the various environmental conditions.

Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus pelamis*, are the availability of data sources for fishing catches and for site characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. The early availability of this information is essential for the *K. pelamis* fishing community, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to optimize the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

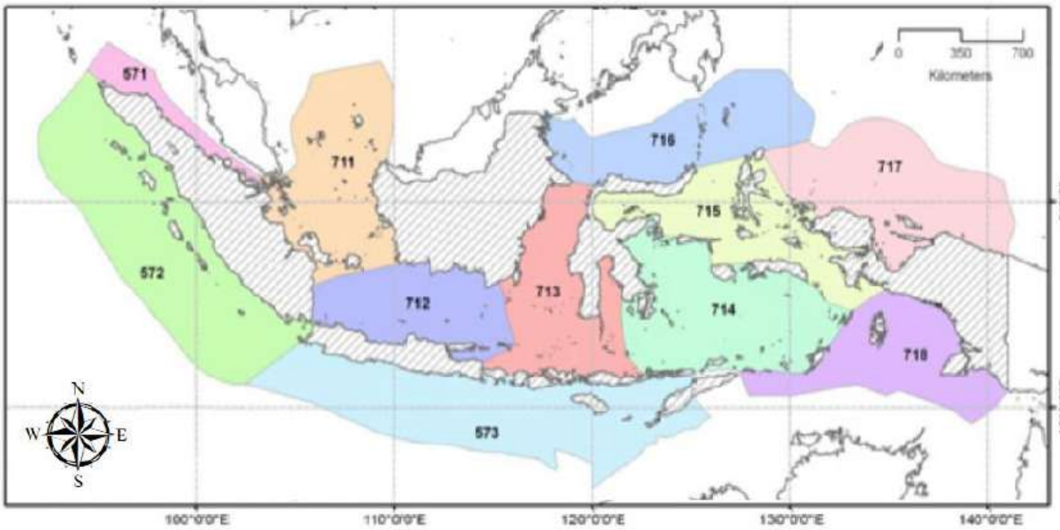

Figure 1. Map of sampling site (MMAF 2018).

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using *qualitative and descriptive* methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Niño (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

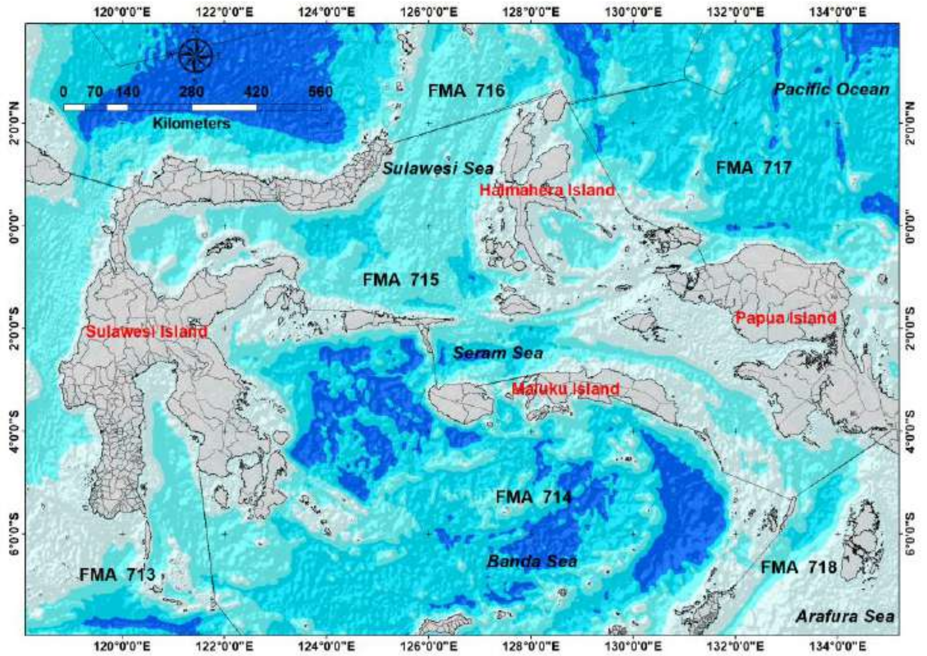

Figure 2. Indonesia Fisheries Management Area (FMA) 715 (MMAF 2018).

Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019).

Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture fishery activities, especially pelagic species, among which fishery commodities with important economic value such as tuna, *K. pelamis* and small fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature (in accordance with the tolerance of body temperature of *K. pelamis*) and abundance of food. The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors, including the SST (Zainuddin 2011), distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas of a tropical zone, in a region with rainfalls above 3000 mm per year, located to the west of Irian and Mindanao. It is the center of a warm water pool, which results in intensive convection accompanied by high velocity currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in number of rainy days and in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season to the summer (transition season).

Oceanographic conditions. In the eastern part of the Indonesian archipelago flow important ocean currents, known as Arus Lintas Indonesia (Arlindo). This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 are directly influenced by the Pacific water mass, from the entrance of the main area consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of westward water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ocean currents form areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. Upwelling brings nutrients from deeper water to the surface, causing nitrification and phytoplankton bloom (Kämpf & Chapman 2016).

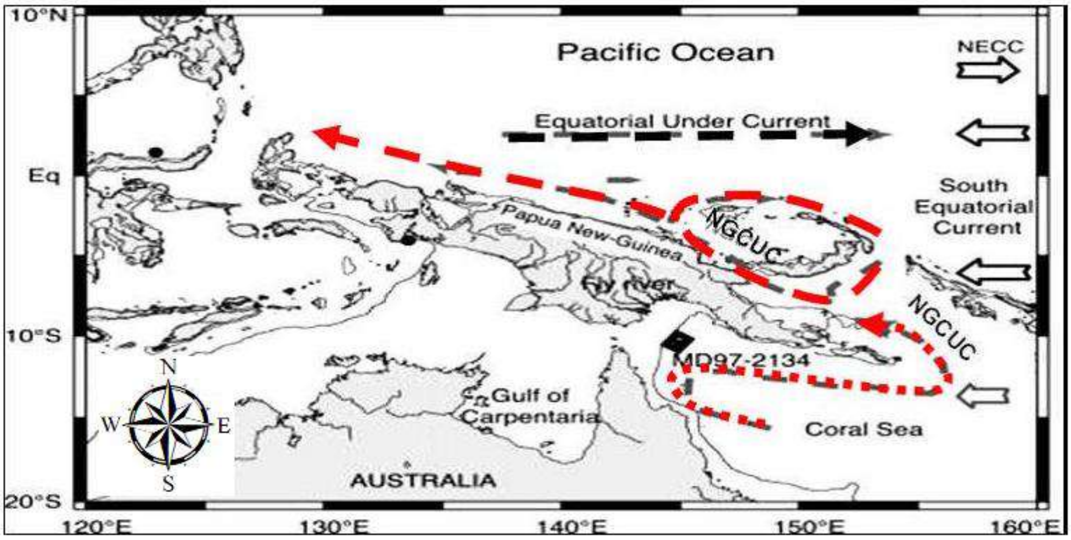

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. Temperature data from Triton show an average of the SST variations ranging from 28.4 to 30.6°C. The largest catch of *K. pelamis* occured in the SST range of 29 to 30°C (Nugraha et al 2020).

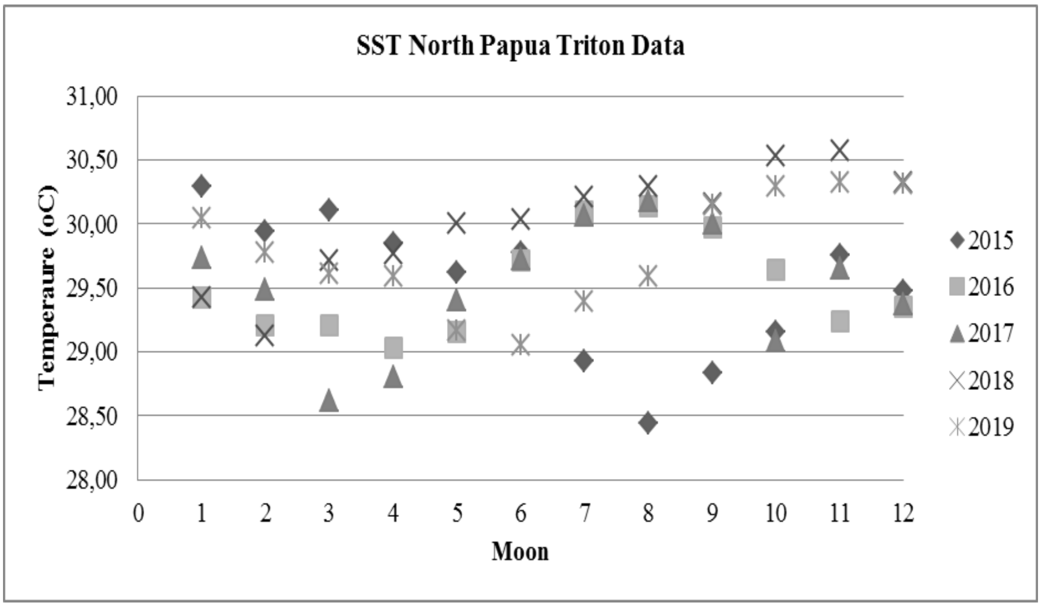

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. The water surface layer's salinity is influenced by wind and monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The vertical salinity data of the TRITON buoy shows the temperature data obtained at each depth of 1.5 m. During the period from 2015 to 2019, the salinity profiles at certain coordinate points in North Papua show values ranging from 33.3 to 34.6 psu.

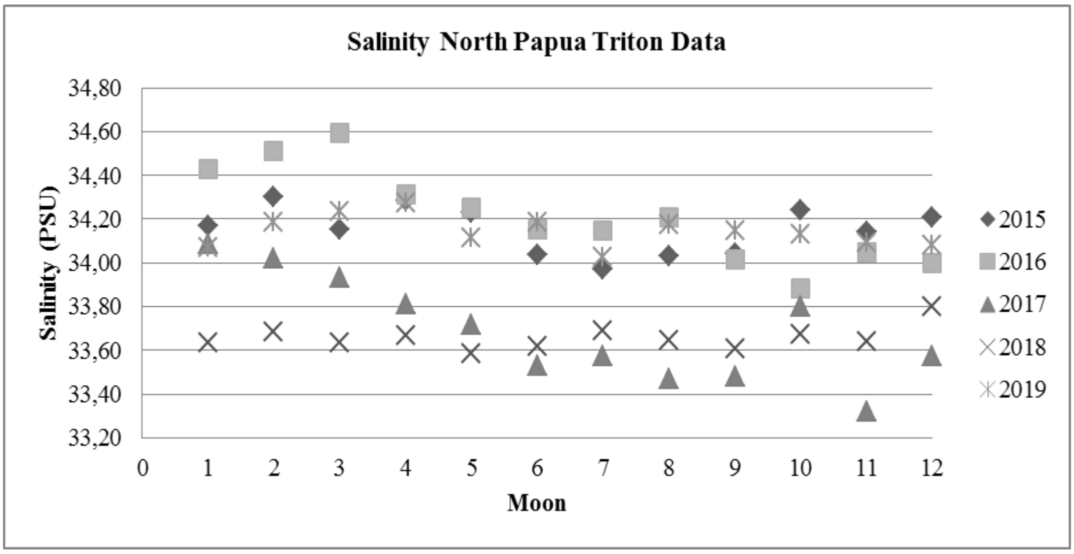

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. January, May to June and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis* originating from the headwaters of Papua and landing at Radios Apirja Co. Ltd. reached their highest levelsin March. It can be assumed that in March, the waters to the north of Papua (FMA 715) were in a suitable condition, with food available in abundance , and it was convenient for *K. pelamis* to migrate into (Mugo et al 2010).

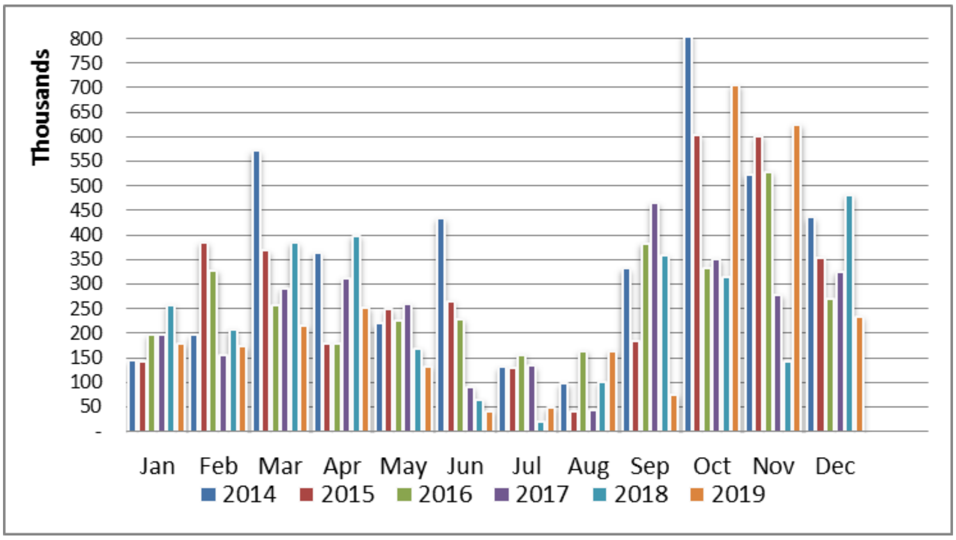

Figure 7. Catches of *Katsuwonus pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows decreasing trends in the fishing periods of February to May and September to December and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Niño phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll synthesis.

El Niño. El Niño is characterized by a SST decrease in the Indonesian waters and increase (of more than 0.5°C) in the eastern tropical Pacific Ocean (Sofian et al 2011). From March 2014 until April 2016, the regional climate experienced one of the longest dry seasons in History, due to El Niño.v The year and intensity of El Niño can be seen in Figure 8 (NOAA-NWS 2019).

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño years and intensities (NOAA-NWS 2019).

El Niño began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia’s internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Niño signals, which became extreme in November 2015 and returned to normal conditions in May 2016 (Figure 8). From August 2015 to April 2016, El Niño was a stronger category, even reaching its peak in January 2016 (Figure 8), and during this phase, *K. pelamis* catches increased (Figure 7).

Normal phase. The oceanographic conditions of FMA 715 returned to normal and upwellings began to form. The formation of warm water masses in the internal waters of FMA 715 is an ideal condition for the *K. pelamis* environment. The normal phase can be observed from March to September 2014 and from March to August 2018, with increasing yield catchment, but not as significant as in the El Niño phase.

La Nina phase. During La Nina (from June 2016 to January 2017 and from June 2017 to April 2018), *K. pelamis* catches were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed, using SST and depth temperature data from the Triton buoy. Within the transition season (September to November), the *K. pelamis* catches showed a decrease.

K. pelamis migrated in the La Nina period, moving from the Pacific to the East (including Indonesia). These conclusions proved the observation of a shift in the fishing season, caused by climate change, reported by the fishing communities active in the FMA 715. This weather deviations can have a positive impact on the fisheries sector, triggering migrations of tuna to the territorial waters of Indonesia. Turkington (2019) reported that El Niño and La Niña have the potential to occur periodically, every 2 to 3 years.

A possible impact of the climate change on fisheries is a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. This study suggests that the peak season of *K. pelamis* fishing in the waters of FMA 715 can be predicted based on information on the area's climate conditions. This study also shows that regional climate change greatly affects the inter-monthly variation and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Niño, these waters are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also make these waters unfavorable for the *K. pelamis* environment.

Acknowledgements. This research was funded by the Marine and Fisheries Education Centre - Ministry of Marine Affairs and Fisheries Republic of Indonesia. Thanks also to Marine and Fisheries Resources Surveillance Sorong, Citra Raja Ampat Canning Co. Ltd Sorong and MV. Cinta Bahari 09 crews for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna *(Katsuwonus pelamis)* catches in the fisheries management area (FMA) 715, Indonesia. AACL Bioflux 14(x):

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erick nugraha <nugraha_eriq1@yahoo.co.id> Sen, 21 Jun 2021 jam 05.43
Kepada: Eni Kovacs

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We have to correct our manuscript.
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Thank for your cooperation.

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Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna (*Katsuwonus pelamis*) catches, in the fisheries management area (FMA) 715, Indonesia

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Abstract. Marine and fishery resources have trans-boundary nature and have great potential to be affected by the global climate change. Tuna is one of the main export commodities from Indonesia. Patterns of fish life can not be separated from the environmental conditions, whose fluctuations influence the seasonal fish migration and residence period. This study aimed to determine the tuna catch variability in the peak season,under regional climate change constraints, such as El Niño and La Nina, with the aim to optimize the utilization of *Katsuwonus pelamis*. A descriptive qualitative study was conducted to investigate the direct correlation between *K. pelamis* catches during 2015 to 2019 and regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019). Sampling and measurement sessions were performed at the end of the East season, from September to December 2019. The results of this study show that regional climate change affected inter-monthly variation of the peak seasons of *K. pelamis* fishing in the fisheries management area (FMA) no. 715. During El Niño , the FMA 715 was an ideal place for *K. pelamis* fishing. During the period from September to November, the fishing peak season was in October. The regional climate change originating from the Pacific Ocean caused unsuitable water conditions in the FMA 715, regarding the *K. pelamis* fishing. The variability of the climate changes triggered by La Nina in the Pacific Ocean did not provide a favorable environment for the fish migration to the FMA 715 waters.
Key Words: La Nina, salinity, sea surface temperature, climate change, tuna fishing.

Introduction. Indonesia is an archipelagic country that has a strategic position and its waters are part in the oceanic movement known as the Great Ocean Conveyor Belt. The changes occuring in the pattern of the global water mass movement affect the world's climate (Trenberth 2007). The global warming that hits the world today causes global climate change that is irregular and has an impact on the environment as a whole (Blunden et al 2018). This global change affects life in the territorial area and negatively impacts the potential quality and quantity of the marine and fisheries resources (Yáñez et al 2017). The impact of the global warming increased temperatures with 0.5°C throughout the 20th century (Church & White 2011; Masson-Delmotte et al 2018).

Marine and fisheries resources have a trans-boundary character (Song et al 2017) making them vulnerable to the global climate change (Barange et al 2014; Monnereau & Oxenford 2017). Environmental changes that occur and have an impact on the water resources in a particular area can cause environmental changes in other areas (Duran-Encalada et al 2017). Changes in the global environment emerge due to the climate changes characterized by the atmosphere warming. Tuna is one of Indonesia's main export commodities (Hidayat et al 2019; Ningsih 2018). Fish life patterns cannot be separated from the various environmental conditions.

Fluctuations in the environmental conditions have major influences on the period of seasonal migration (Taylor et al 2013) and the presence of fish in certain places (Enders & Boisclair 2016). The main problems faced in the effort to optimize fish catches, especially *Katsuwonus pelamis*, are the availability of data sources for fishing catches and for site characterization. There is very limited data and information about oceanographic conditions that are closely related to potential fishing areas. The early availability of this information is essential for the *K. pelamis* fishing community, so that fishermen can direct their fishing activities effectively and efficiently.

This study aimed to determine the variability of *K. pelamis* catch season to regional climate changes, i.e. El Niño and La Nina. This study investigated the water sensitivity of FMA 715 towards the regional climate changes that affected the monthly variability of *K. pelamis* catches, with the aim to optimize the *K. pelamis* fishing.

Material and Method

Description of the study site. The position of the each observation station was recorded using the Global Positioning System (GPS) in FMA 715, West Papua. Fishing ground location was located in yellow colour area (Figure 1).

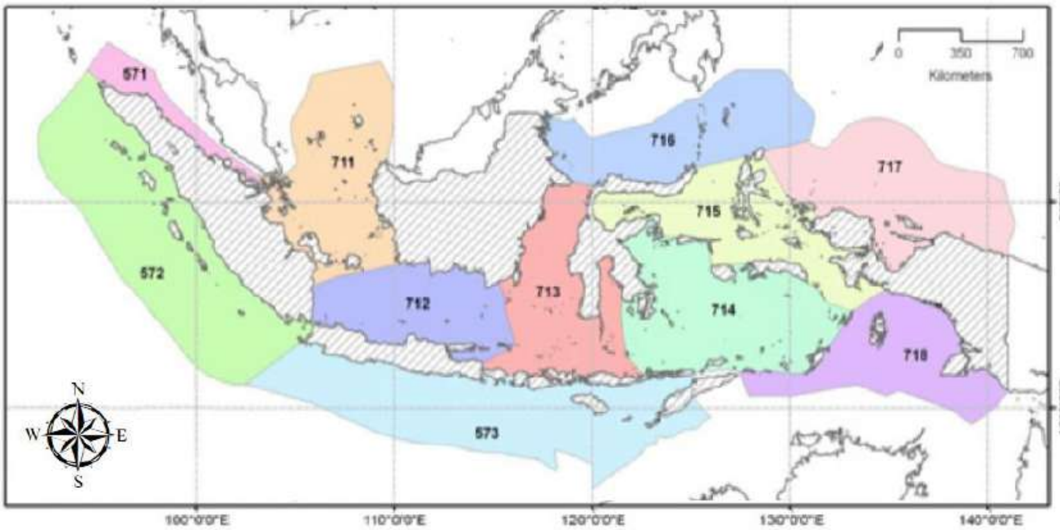

Figure 1. Map of sampling site (MMAF 2018).

Data collection. Observations and data collection on oceanographic variable factors (SST and salinity) in the FMA 715 area were carried out using satellite data and in situ data from September to December 2019, where the West Papua Province was still in the transition season from the East season. The study was conducted using *qualitative and descriptive* methods by investigating the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate change events that occurred during those periods, i.e., El Niño (2014 to 2019) and La Nina (2004 to 2019) using data from the Indonesian Meteorology, Climatology and Geophysical Agency, Jefman Sorong Station.

Sampling and measurement sessions were carried out at the end of the East season, which was between September and November 2019. Simultaneous measurement methods of the Sea Surface Temperature (SST) in the FMA 715 waters area were performed using satellite imagery and Triton buoy data.

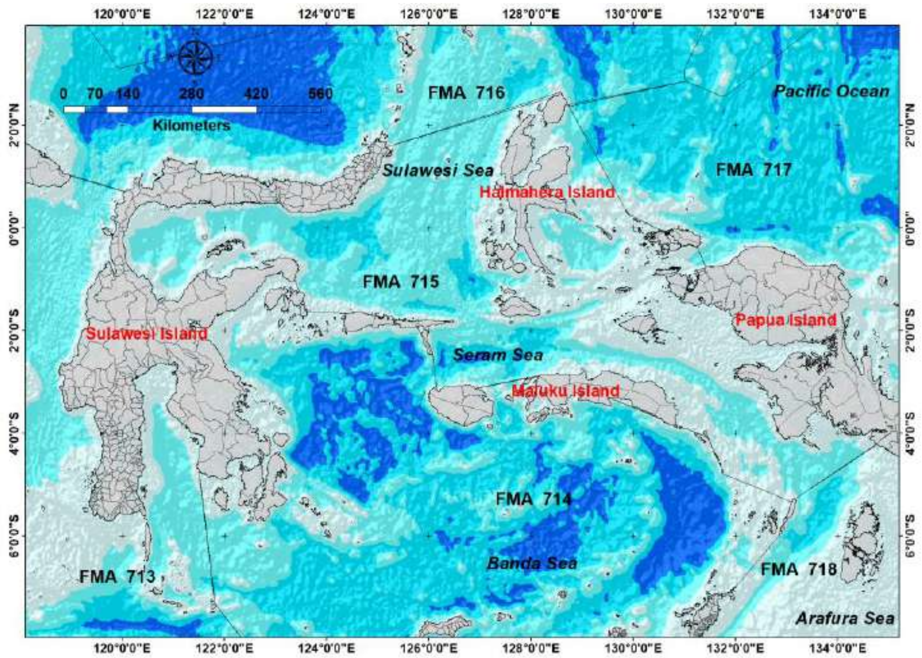

Figure 2. Indonesia Fisheries Management Area (FMA) 715 (MMAF 2018).

Data analysis. Data analysis using descriptive qualitative analysis was conducted to investigate the direct correlation between *K. pelamis* catches during 2014 to 2019 and the regional climate changes that occurred in those periods, i.e., El Niño (2015 to 2019) and La Nina (2015 to 2019).

Results and Discussion

Resources. West Papua is one of the Provinces in the Papua Island that has a considerable fish resource potential and has good prospects for capture fishery activities, especially pelagic species, among which fishery commodities with important economic value such as tuna, *K. pelamis* and small fish groups. It was recorded in 2019 that 15,825 tons of tuna were caught (Ministry of Marine and Fisheries 2012). Fishing season occurs throughout the year and moves according to food availability and temperature that can be tolerated by the fish body (Brucet et al 2012; O'Gorman et al 2016).

K. pelamis in eastern Indonesia waters are available throughout the year, especially in the Maluku Sea, Halmahera Sea, Banda Sea, Seram Sea and Sulawesi Sea (Tadjuddah et al 2017; Hidayat et al 2019). The abundance of *K. pelamis* is very dependent on the oceanographic conditions of waters, especially on the water temperature (in accordance with the tolerance of body temperature of *K. pelamis*) and abundance of food. The potential fishing catch zone is strongly influenced by oceanographic physical, chemical and aquatic biology factors, including the SST (Zainuddin 2011), distribution of horizontal (Zainuddin et al 2017) and vertical temperature, salinity, chlorophyll-a concentration and front or up welling phenomena (Putri et al 2018).

Climate conditions. The waters of FMA 715 are areas of a tropical zone, in a region with rainfalls above 3000 mm per year, located to the west of Irian and Mindanao. It is the center of a warm water pool, which results in intensive convection accompanied by high velocity currents (Wyrtki 1961). During the period of 2019 in September-November, data collected from Jefman station, Sorong, showed the average rainfall decrease, both in number of rainy days and in rain intensity. This indicates the occurrence of the seasonal transition process in the FMA 715 waters, from the rainy season to the summer (transition season).

Oceanographic conditions. In the eastern part of the Indonesian archipelago flow important ocean currents, known as Arus Lintas Indonesia (Arlindo). This current flows from the Pacific Ocean to the Indian Ocean and falls on the surface and the thermocline zone. In general, the waters of the West Papua Sea and FMA 715 are directly influenced by the Pacific water mass, from the entrance of the main area consisting of the Indonesian waters to the Indian Ocean. The effect of oceanic water mass from the Pacific Ocean is dominant in the East season.

The upwelling process in the waters of North Papua is generally caused by the flow of westward water mass from the Pacific, in the form of warm water mass towards the Halmahera Island, which spreads in many directions, including towards the equator and Indonesian waters, through the waters gate between the Halmahera and the Papua Islands (Hartoko 2007). Pelagic fish are organisms that have the ability to move, so that they do not depend on ocean currents or the water movements caused by wind. However, the ocean currents form areas known as upwelling and fronts. The horizontal surface temperature pattern in North Papua comes from the mass flow temperature of the water originating from the Northwest. This event is known as the lower current in New Guinea Coastal under Current (NGCUC). The transfer of water mass from the Pacific (inflow) into the Eastern islands such as Papua occurs along the Northwest monsoon and outflows to the Indian Ocean, during the Southeast monsoon wind (Hartoko 2007). The NGCUC water mass flows from a depth of 100 m in the North Papua, then continues to the surface of the water in the South Halmahera and becomes upwelling as shown in Figure 3. Upwelling brings nutrients from deeper water to the surface, causing nitrification and phytoplankton bloom (Kämpf & Chapman 2016).

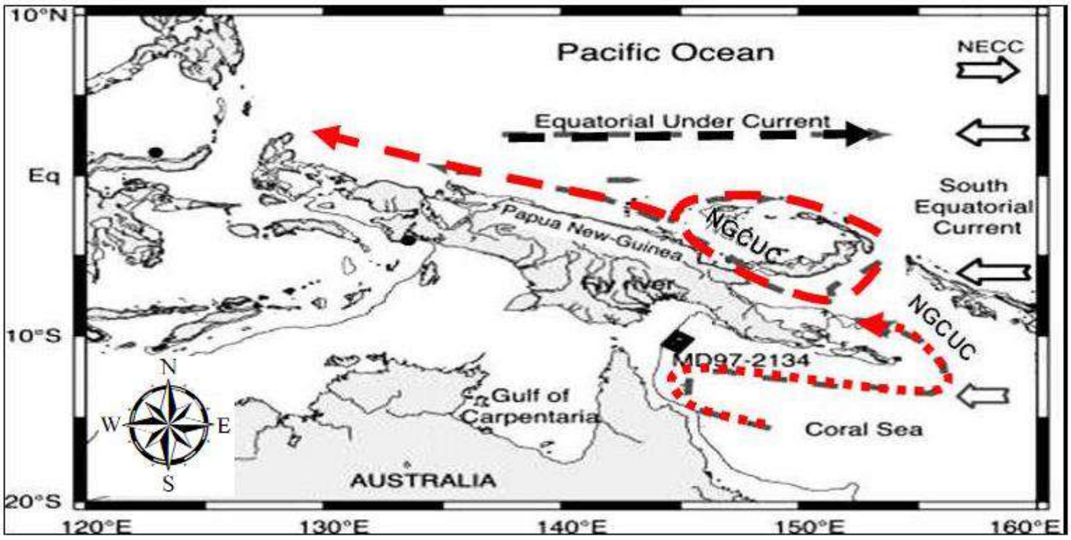

Figure 3. Current flow patterns in North Papua (Hartoko 2007).

Water temperature. The temperature of the FMA 715 waters is directly affected the Pacific Ocean. Water temperature based on vertical sea temperature data from Triton buoy was obtained at various depths 1.5 m. Temperature data from Triton show an average of the SST variations ranging from 28.4 to 30.6°C. The largest catch of *K. pelamis* occured in the SST range of 29 to 30°C (Nugraha et al 2020).

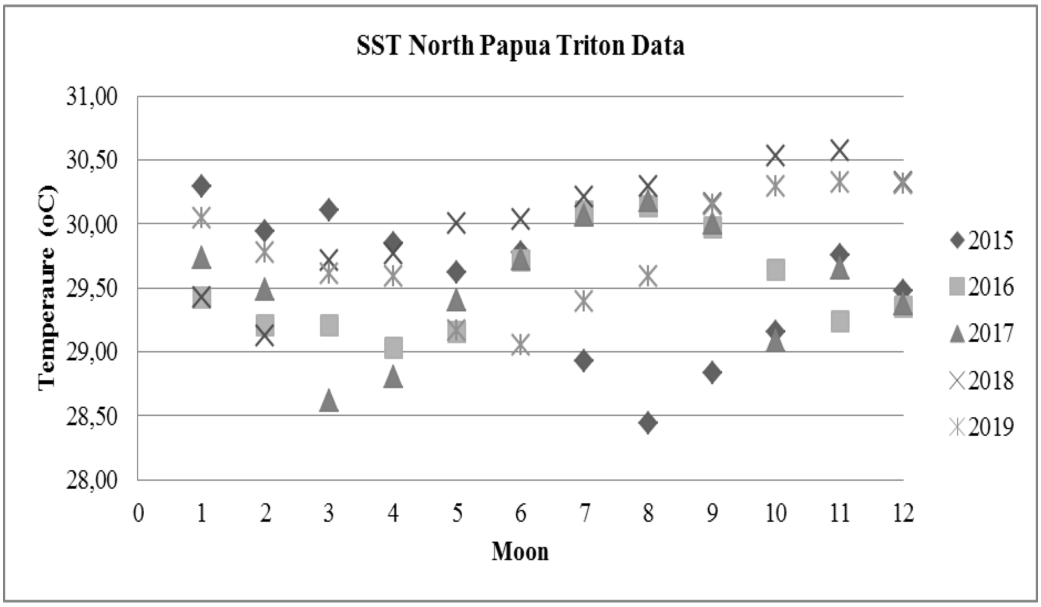

Figure 4. Sea Surface Temperature (SST) in the FMA 715 waters.

Salinity. The water surface layer's salinity is influenced by wind and monsoon current. In the east monsoon, a high salinity value occurs due to Arlindo currents, which transfer water masses from the Pacific Ocean into Eastern Indonesian (Bahiyah et al 2019). The vertical salinity data of the TRITON buoy shows the temperature data obtained at each depth of 1.5 m. During the period from 2015 to 2019, the salinity profiles at certain coordinate points in North Papua show values ranging from 33.3 to 34.6 psu.

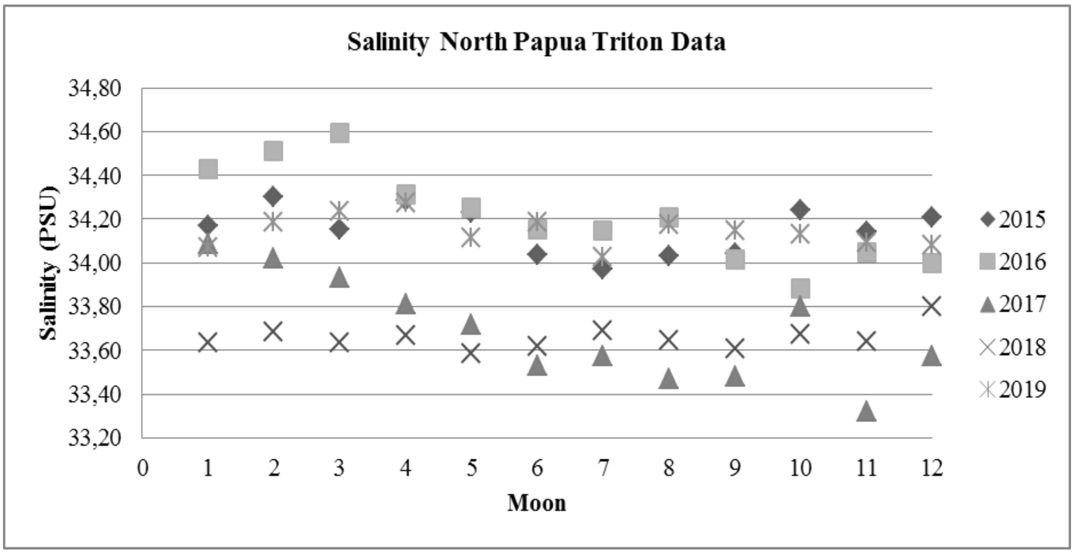

Figure 6. Salinity profiles in North Papua waters.

Catches of K. pelamis. January, May to June and September to December are not the appropriate seasons for *K. pelamis* fishing in the area of Papua. The five years catches of *K. pelamis* originating from the headwaters of Papua and landing at Radios Apirja Co. Ltd. reached their highest levelsin March. It can be assumed that in March, the waters to the north of Papua (FMA 715) were in a suitable condition, with food available in abundance , and it was convenient for *K. pelamis* to migrate into (Mugo et al 2010).

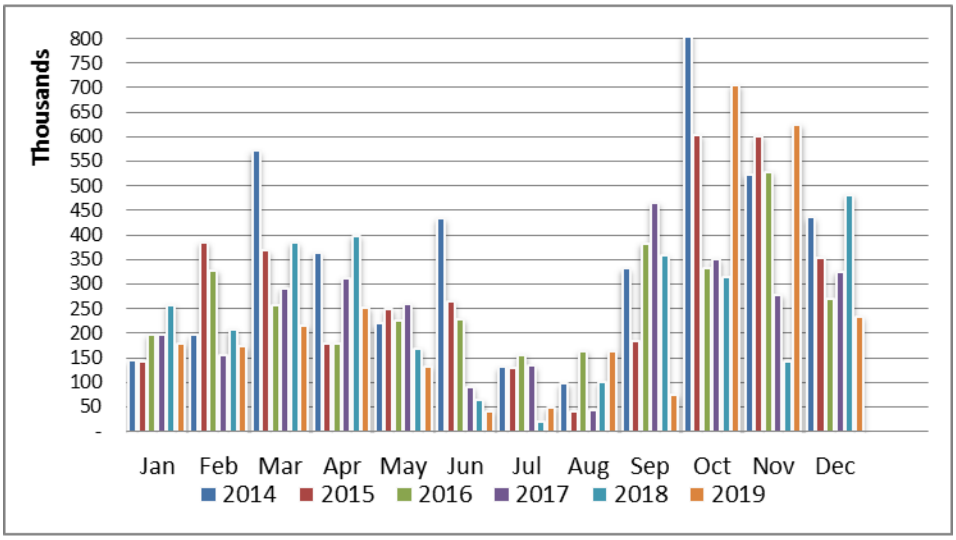

Figure 7. Catches of *Katsuwonus pelamis* from 2014 to 2019.

The graph of *K. pelamis* catches shows decreasing trends in the fishing periods of February to May and September to December and increasing catches in June to August, November and January, without considering other factors that affect production, such as fishing fleet, size and number of catches.

Correlation analysis of K. pelamis catches and regional climate change. The conditions of Indonesia's oceanography are influenced by global climate change factors, for example by the condition of rainfall on land and at sea, the sea surface temperature (SST) and the sea level height. Rainfall is influenced by the El Niño phenomenon which is predicted to affect sea surface temperature. Global warming will increase sea level (Mimura 2013) and water temperature (Brown et al 2019). The impact of the ozone layer is expected to affect the performance of chlorophyll synthesis.

El Niño. El Niño is characterized by a SST decrease in the Indonesian waters and increase (of more than 0.5°C) in the eastern tropical Pacific Ocean (Sofian et al 2011). From March 2014 until April 2016, the regional climate experienced one of the longest dry seasons in History, due to El Niño.v The year and intensity of El Niño can be seen in Figure 8 (NOAA-NWS 2019).

Running 3-Month Mean ONI values

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

WE=Weak El Niño, ME=Moderate El Niño, SE=Strong El Niño, VSE=Very Strong El Niño

WL=Weak La Niña, ML=Moderate La Niña, SL=Strong La Niña

ENSO Type	Season			JJA	JAS	ASO	SON	OND	NDJ	DJF	JFM	FMA	MAM	AMJ	MJJ
	2013	-	2014	-0.4	-0.4	-0.3	-0.2	-0.2	-0.3	-0.4	-0.4	-0.2	0.1	0.3	0.2
WE	2014	-	2015	0.1	0.0	0.2	0.4	0.6	0.7	0.6	0.6	0.6	0.8	1.0	1.2
VSE	2015	-	2016	1.5	1.8	2.1	2.4	2.5	2.6	2.5	2.2	1.7	1.0	0.5	0.0
WL	2016	-	2017	-0.3	-0.6	-0.7	-0.7	-0.7	-0.6	-0.3	-0.1	0.1	0.3	0.4	0.4
WL	2017	-	2018	0.2	-0.1	-0.4	-0.7	-0.9	-1.0	-0.9	-0.8	-0.6	-0.4	-0.1	0.1
WE	2018	-	2019	0.1	0.1	0.4	0.7	0.9	0.8	0.8	0.8	0.8	0.8	0.6	0.5
WE	2019	-	2020	0.3	0.1	0.1	0.3	0.5	0.6	0.5	0.6	0.5	0.3	0.0	-0.3

Figure 8. El Niño years and intensities (NOAA-NWS 2019).

El Niño began to be felt in October 2014, with a moderate intensity, when the western Pacific equatorial hot pool moved from the west to the central Pacific. This caused Indonesia’s internal waters to obtain a mass supply of water that is relatively cooler than the The Indonesia through Flow (Arlindo) coming from the western Pacific Ocean. This condition continued to grow with the strengthening of El Niño signals, which became extreme in November 2015 and returned to normal conditions in May 2016 (Figure 8). From August 2015 to April 2016, El Niño was a stronger category, even reaching its peak in January 2016 (Figure 8), and during this phase, *K. pelamis* catches increased (Figure 7).

Normal phase. The oceanographic conditions of FMA 715 returned to normal and upwellings began to form. The formation of warm water masses in the internal waters of FMA 715 is an ideal condition for the *K. pelamis* environment. The normal phase can be observed from March to September 2014 and from March to August 2018, with increasing yield catchment, but not as significant as in the El Niño phase.

La Nina phase. During La Nina (from June 2016 to January 2017 and from June 2017 to April 2018), *K. pelamis* catches were decreased when observed in the fishing area of the western Pacific, compared to the eastern and central Pacific regions. Correlations between *K. pelamis* catches in FMA 715 waters and regional climate change could be observed, using SST and depth temperature data from the Triton buoy. Within the transition season (September to November), the *K. pelamis* catches showed a decrease.

K. pelamis migrated in the La Nina period, moving from the Pacific to the East (including Indonesia). These conclusions proved the observation of a shift in the fishing season, caused by climate change, reported by the fishing communities active in the FMA 715. This weather deviations can have a positive impact on the fisheries sector, triggering migrations of tuna to the territorial waters of Indonesia. Turkington (2019) reported that El Niño and La Niña have the potential to occur periodically, every 2 to 3 years.

A possible impact of the climate change on fisheries is a decrease in the catch results, which can occur due to the migration of the targeted fish species. The migration from temperate (sub-tropical) to tropical climate regions (and not vice versa), due to the climate change, will decrease the fish stocks. Climate change will greatly affects the physiology and behavior of individuals, populations and communities (Walther 2010; Butler 2019). Extreme conditions with rising water temperatures, low dissolved oxygen concentrations and water pH can result in fish death. Environmental conditions that are not optimal can reduce metabolic rate, growth and ability of fish to lay eggs, and can also change metamorphosis, endocrine systems and patterns of the fish skin (Roessig et al 2004).

Conclusions. This study suggests that the peak season of *K. pelamis* fishing in the waters of FMA 715 can be predicted based on information on the area's climate conditions. This study also shows that regional climate change greatly affects the inter-monthly variation and the peak of the *K. pelamis* fishing season, in the FMA 715 waters. During El Niño, these waters are an ideal place for catching *K. pelamis*. In normal climatic conditions, the peak of the fishing season occurs from October to November. Regional climate change triggered from the Pacific Ocean does not provide a suitable environment for *K. pelamis* migration to the FMA 715 waters. Therefore, the regional climate change triggered from the Pacific Ocean can also make these waters unfavorable for the *K. pelamis* environment.

Acknowledgements. This research was funded by the Marine and Fisheries Education Centre - Ministry of Marine Affairs and Fisheries Republic of Indonesia. Thanks also to Marine and Fisheries Resources Surveillance Sorong, Citra Raja Ampat Canning Co. Ltd Sorong and MV. Cinta Bahari 09 crews for enabling us to carry out this research.

Conflict of interest. The authors declare no conflict of interest.

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Received: 06 March 2021. Accepted: 2021. Published online: 2021.
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How to cite this article:
Sepri, Hartoko A., Suradi W. S., Ghofar A., Nugraha E., 2021 Impact of El Niño Southern Oscillation (ENSO), variability on skipjack tuna *(Katsuwonus pelamis)* catches in the fisheries management area (FMA) 715, Indonesia. AACL Bioflux 14(x):

ACCEPTANCE FOR PUBLISHING

Hereby we declare our article with the title:

Impact of El Nino Southern Oscillation (ENSO), Variability on Skipjack Tuna *(Katsuwonus pelamis)* Catches in the Fisheries Management Area (FMA) 715, Indonesia.

It has gone through several editing processes and we agreed to publish it. Thank you.

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June 21st, 2021