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The impact of ENSO-IOD on *Decapterus* spp. in Pangkajene Kepulauan and Barru Waters, Makassar Strait, Indonesia

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Abstract. *Baharuddin NAI, Zainuddin M, Najamuddin. 2022. The impact of ENSO-IOD on* Decapterus *spp. in Pangkajene Kepulauan and Barru Waters, Makassar Strait, Indonesia. Biodiversitas 23: 5613-5622.* ENSO and IOD are climate variability that affects water conditions seasonally and inter-annually, including Makassar Strait, Indonesia. Research on the effect of ENSO and IOD variations on water fertility in Makassar Strait requires updating every year. This study aimed to analyze the impact of ENSO and IOD on the variability of oceanography (SST and SSC) and dynamics of the Scad (*Decapterus* spp.) production in Makassar Strait. This study used Niño3.4 Index and Dipole Mode Index data from NOAA, while SST and SSC data were obtained from the Aqua-MODIS satellite imagery from January 2015 to December 2019. For the study, data were processed using SeaDAS, ArcGIS, and RStudio software. The results indicated that the Niño3.4 Index for SST and SSC was strong, and the Dipole Mode Index for SST and SSC was low. The time-series graph showed that the El Niño event was strong, and the IOD+ was quite strong in 2015-2016, affecting the negative SST anomaly and the positive SSC anomaly. Cross-correlation analysis of the effect of the Niño3.4 Index with the SST anomaly of -0.62 and the low SSC anomaly of 0.18. The result of IOD on the SST anomaly was quite strong at -0.51, and the SSC anomaly was low at 0.07. Strong El Niño and IOD+ events were found to highly affect SST and SSC as well as influence the variation or fluctuation of Scad catch production, especially from 2015 to 2016 in the study area of Makassar Strait, Indonesia.

Keywords: Anomaly oceanographic condition, El Niño southern oscillation, Indian ocean dipole, Indonesia, Makassar strait

INTRODUCTION

Makassar Strait is a part of Fishery Management Area (FMA) 713, known as the water with a lot of fishing activity, one of the fishing objects is Scad (*Decapterus* spp.). The production of Scad in South Sulawesi in 2018 was 38125.75 tons (MMAF-RI 2021). Scad accounted was mostly caught using purse seine unit operation at night by the coastal communities of Pangkajene Kepulauan (Pangkep) and Barru Districts Waters, Makassar, South Sulawesi, Indonesia. The geographical location of the Makassar Strait is the main route for Indonesian Throughflow (ITF) and is traversed by South China Throughflow (SCTF), which is strongly influenced by the circulation system of the Pacific Ocean and the Indian Ocean caused by differences in sea level which play an important role in global circulation (Nuzula et al. 2017; Purba et al. 2021; Putri et al. 2022). Due to its geographical conditions, these waters have become potential fishing areas.

The difference in surface pressure impacts the transfer of hot water pools from two oceans and has become one of the strategic routes for global waters (Putri et al. 2022). Furthermore, the occurrence of monsoon winds, the east monsoon causing upwelling, and the west monsoon causing downwelling events that affect the variability of Sea Surface Temperature (SST), Sea Surface Chlorophyll-a (SSC), tides, and current circulation systems in the waters of the Makassar Strait (Sprintall et al. 2014; Zainuddin et al. 2017). Another cause is the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) events that occur together or separately in three to seven years (RRF 2019).

ENSO and IOD cause climate variability and affect the condition of the oceans and atmosphere, especially in areas located at the equator. The dry season will arrive sooner and stay longer if El Niño and a positive IOD (IOD+) phenomenon coexist. In contrast, El Niño and IOD- phenomena occur together, causing slightly higher rainfall and a slightly longer rainy season (Narulita 2017). ENSO and IOD can be known from the variability of SST (Susanto et al. 2012; Purwandari et al. 2019) and the variability of chlorophyll-a (Wirasatriya et al. 2017). ENSO and IOD can affect the strength of the volume, current discharge, and the eddy pattern (Susanto et al. 2012). El Niño events (ENSO) impact extreme marine environments, such as sea level and air temperature found in coral, seaweed, seagrass, and mangrove ecosystems (Holbrook et al. 2020). These two phenomena trigger weather and climate variations and can periodically affect seasonal shifts, so they play a significant positive or negative role in the amount of fishing (Arleston et al. 2016), especially pelagic fish.

Various observations have been made between oceanographic parameters SST and chlorophyll-a, which are closely related to the distribution of Scad in the Makassar Strait (Safruddin 2013; Fuadi 2018). In addition, several studies have proven that linking climate variability to pelagic fish can help predict the distribution of pelagic fish, including the distribution and abundance of tuna stocks in the Pacific Ocean, Indian Ocean, and Eastern Indonesia (Syamsuddin et al. 2016; Johnson et al. 2018; Khan et al. 2020). The effect of climate change on the distribution of Swordfish in the Eastern Indian Ocean (Setyadji and Amri 2017), the stock abundance of Lemuru in the Bali Strait is also influenced by ENSO and IOD (Saputra et al. 2017), and the dynamics of Scad related to SST variations due to the ENSO phenomenon in the Bali Strait (Arleston et al. 2016). The ENSO phenomenon has affected the fishing seasons and Catch per Unit Effort (CPUE) of some pelagic fish in Indonesia Waters (Puspasari et al. 2021). However, research on the impact of ENSO and IOD on the production of Scad in the Pangkep and Barru Waters, Makassar Strait is not yet known.

The usage of pelagic fish resources has a general and primary issue in that it is dynamic and continually changing as a result of changes in oceanographic parameters, and climate change is a worldwide phenomenon that cannot be avoided (Safruddin et al. 2018; Peck et al. 2021). The best way to analyze and describe this research is to integrate remote sensing and Geographic Information Systems (GIS) analysis and some data analysis in this study to gather, manipulate, and analyze spatial data (Manson et al. 2015). This study aims to determine the relationship between the ENSO and IOD phenomena on the variability of SST and SSC obtained from satellite imagery data and the impact on the production of Scad catch from January 2015 to December 2019 in the Pangkep and Barru Waters, Makassar Strait, Indonesia.

MATERIALS AND METHODS

Study area

The research focuses on Makassar Strait (118-120°E and 3.62-5.38°S), which is known as global transverse water (Gordon et al. 2019) and combined with the abundance of small pelagic fish such as Scad, has the largest catch production, in Makassar Strait, South Sulawesi (Anggriani et al. 2016; Najamuddin et al. 2017). Pangkajene Kepulauan (Pangkep) and Barru Districts Waters, Makassar Strait, South Sulawesi Province, Indonesia, belong to FMA 713 and have the highest production of the Scad of all pelagic fish species (Figure 1).

Procedures

Climate Index: Niño3.4 Index

Niño3.4 Index is available at the NOAA (National Oceanic and Atmospheric Administration) Climate Prediction Center (https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Niño34/). NOAA is a satellite that is used to obtain information about the physical state of the oceans and the atmosphere. El Niño, as an event of increasing SST in the central and east eastern equation of the Pacific Ocean, causes SST in Indonesia to be colder than normal. In contrast to El Niño, La Niña is an event of a decrease in SST in the equatorial region of the Pacific Ocean and causes SST in Indonesia to be warm. Both events are marked by five consecutive months Niño3.4 Index +0.5°C is defined as El Niño and La Niña -0.5°C.

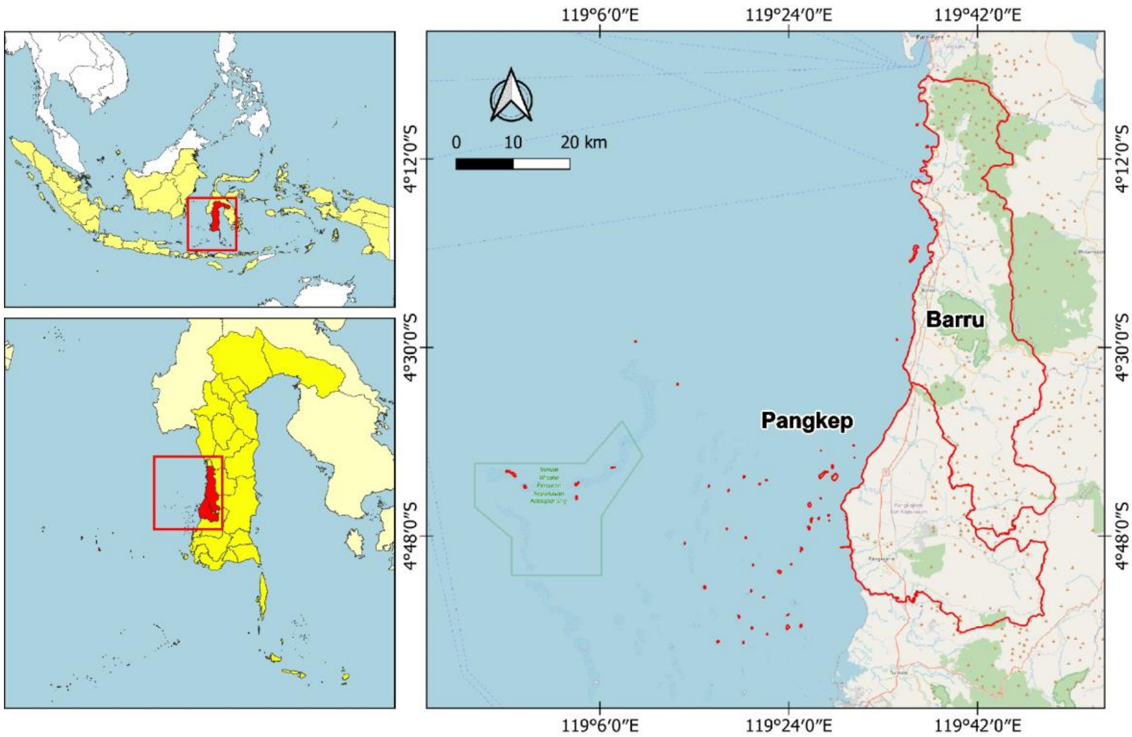

Figure 1. Map of the study area in Pangkep and Barru Waters, Makassar Strait, South Sulawesi, Indonesia

Clime index: Dipole Mode Index (DMI)

Meanwhile, the IOD intensity is represented by DMI, which is a gradient of SST anomalies between the western equatorial Indian Ocean (50-70°S and 10°S-10°N) and the southeastern equatorial Indian Ocean (90-110°E and 10°S-0°N). This index is available at the NOAA (National Oceanic and Atmospheric Administration) Climate Prediction Center (https://psl.noaa/gov/data/timeseries/DMI). Similar to the ENSO phenomenon, DMI was identified with successive events for five consecutive months. DMI +0.5°C was defined as positive IOD (IOD+), and -0.5°C was defined as negative IOD (IOD-).

Fishery data

Scad production data for this study was obtained from the Department of Marine Affairs and Fisheries of Pangkep District and Barru District. These two regencies can represent the production of Scad in South Sulawesi Province, Indonesia, which is located adjacent to the waters of the Makassar Strait, and the fishing operations may be categorized as very active. The data was obtained for the annual period from January 2015 to December 2019 with monthly temporal resolution and relatively high spatial resolution (<250 m).

Satellite remote sensing data

SST and SSC data derived from the Aqua-Moderate Resolution Imaging Spectroradiometer (Aqua-MODIS) satellite data recording level 3 at 4 km resolution monthly from January 2015 to December 2019 downloaded from NASA on the website http://oceancolor.gsfc.nasa.gov for the extent of the study area, i.e., 118-120°E and 3.62-5.38°S. Further data processing was carried out in SeaDAS7.5.3 (SeaWiFS Data Analysis System), which can be freely accessed at https://seadas.gsfc.nasa.gov/. SeaDAS is a comprehensive software package for processing, displaying, analyzing, and quality control marine color data. The value of SST and SSC distribution is required in the waters of Pangkep and Barru Regencies, Makassar Strait. The five-year monthly oceanographic data extracted in ArcGIS10.2 was used to obtain the monthly average of SST and SSC. The ArcGIS software used has a Memorandum of Understanding (MoU) between ESRI and Hasanuddin University (original ArcGIS licensed) since 2015 and has been extended to date. Furthermore, the graph was prepared using Origin 8.5.1 to analyze in time series.

Data analysis

Anomaly analysis

The anomaly method was used to evaluate the change in oceanographic conditions from January 2015 to December 2019 in Pangkep and Barru Waters, Southern Makassar Strait. Satellite imagery data identified decreasing (negative anomaly) and increasing (positive anomaly) oceanographic parameters relative to normal conditions. The equation analysis of the SST anomaly and SSC anomaly formulas was used and implemented in Microsoft Excel 2019, and a monthly time series graph for five years was created on Origin 8.5.1 software. The equation used for the calculation of anomaly oceanographic parameters (Putri and Zainuddin 2019) is as follows:

$$\delta_{ij} = T_{ij} - T_i$$

Where:

Δ_{ij}: anomaly of oceanographic parameters in a month i and year j

T_{ij}: oceanographic parameter factor in month i

T_i: oceanographic parameter factor value in a month i and year j

Relationship analysis

Cross-correlation, a correlation between two variables in the form of a time series with the same length of time and a time lag, was used to assess the association between variables using open-source RStudio 4.0.5 software. The two variables in the k-lag will be most closely related when there is a significant correlation between them. The confidence interval utilized for this analysis was 95%. If the P-value was less than 0.05, the correlation value was considered to be significant (Table 1). The cross-correlation calculation formula is as follows:

$$r_{xy} = \frac{(\sum xy) - \sum(x) \, . \, \sum(y)}{\sqrt{n(\sum x)^2 - (\sum x)^2}\,\sqrt{n(\sum y)^2 - (\sum y)^2}}$$

Where:

r: coefficient of cross-correlation;

x: input data; and

y: output data;

The analysis was carried out to determine the relationship between catch production of Scad in time series in Pangkep and Barru Waters, with Niño3.4 Index (El Niño and La Niña) and DMI (IOD+ and IOD-) as well as with SST anomaly and SSC anomaly, likewise SST and SSC with catch production of Scad using Origin 8.5.1 software and further described based on the trend that is formed.

RESULTS AND DISCUSSION

Niño3.4 Index and DMI

Based on the Niño3.4 Index and DMI from January 2015 to December 2019 (Figure 2), it is known that there is an anomaly of increasing SST (+0.5°C) and an anomaly of decreasing SST (-0.5°C). The El Niño phenomenon occurred from April 2015 to April 2016 and appeared again from October 2018 to July 2019. Meanwhile, the La Niña phenomenon happened in the Pacific Ocean from September 2017 to March 2018. In addition, during this period, there was one IOD+ incident in the Indian Ocean, from April to August 2017 and May to November 2019.

Table 1. Cross-correlation coefficient relations

Correlation value	Interpretation
0.0-0.2	Very low
0.2-0.4	Low
0.4-0.7	Strong
0.7-1.0	Very strong

Source: Wijaya et al. (2020)

Seasonal variations of SST and SSC

SST

The spatial distribution of Aqua-MODIS average SST from January 2015 to December 2019 in the Pangkep and Barru Waters ranged from 27.34-32.42° (Figure 3.A). The visual-spatial data showed that the average distribution of SST from January to May and October to December tends to be warmer, which ranges from 29.64-31.93°C, than from June to September, which ranges between 27.34-29.64°C. Likewise, the average SST in the waters around the coast tends to be warmer than in the open waters. Furthermore, the warmest average SST occurs in April, and the coldest average SST occurs in August, around 31.00°C and 29.13°C, respectively.

SSC

The spatial distribution of Aqua-MODIS average SSC from January 2015 to December 2019 in the Pangkep and Barru Waters ranged from 0.14-1.00 mg m^{-3} (Figure 3.B). The average monthly SSC distribution (January 2015 to December 2019), ranged from 0.16-1.40 mg m^{-3} in January, 0.17-1.26 mg m^{-3} in February, 0.21-1.28 mg m^{-3} in March, 0.22-1.55 mg m^{-3} in April, 0.19-1.71 mg m^{-3} in May, 0.18-1.72 mg m^{-3} in June, 0.20-1.64 mg m^{-3} in July, 0.20-1.58 mg m^{-3} in August, 0.19-1.69 mg m^{-3} in September, 0.16-1 .29 mg m^{-3} in October, 0.15-1.57 mg m^{-3} in November, and 0.14-1.06 mg m^{-3} in December.

The visual-spatial data results showed the highest distribution of SSC in the waters around the coast and the distribution of SSC decreased in open waters. The distribution of SSC in the Barru Waters was lower than the distribution of SSC in the Pangkep Waters. Barru Waters, from December to March, the distribution of SSC was quite abundant, and the distribution of SSC decreased from April to November. Meanwhile, in the Pangkep Waters, the distribution of SSC was abundant every month, but the highest distribution of SSC was in January.

Seasonal variation data of oceanographic parameters for 2015-2019 in the Pangkep and Barru Waters, Makassar Strait (Figure 4) showed that the SST ranged from 28.71-30.99°C, and SSC ranged from 0.25-0.37 mg m^{-3}. The highest SST occurred in the transitional season I (March-May) with 30.09°C, 30.99°C, and 30.18°C, respectively. The lowest SST occurred in the east season until transitional season II (June-September) at 29.63°C, 29.00°C, 28.71°C, and 29.11°C, respectively. Meanwhile, when a low SST occurred, the SSC value increased by 0.29, 0.32, 0.36, and 0.35 mg m^{-3}. SST in the east monsoon and transitional season II in the Pangkep and Barru Waters became cooler and caused an increase in SSC from normal conditions, representing an upwelling phenomenon (Figures 3.A and 3.B). Earlier studies examined the Makassar Strait, which had the average SST peak in August and the lowest upwelling area in a large range (Utama et al. 2017). SST and SSC support upwelling conditions and correlate with monsoon situations. Observations were made based on the upwelling area, occurring from May to October. Specifically for the waters of South Sulawesi, the indication of the widest peak of upwelling occurred in August at 17640 km^2 (Purba et al. 2019).

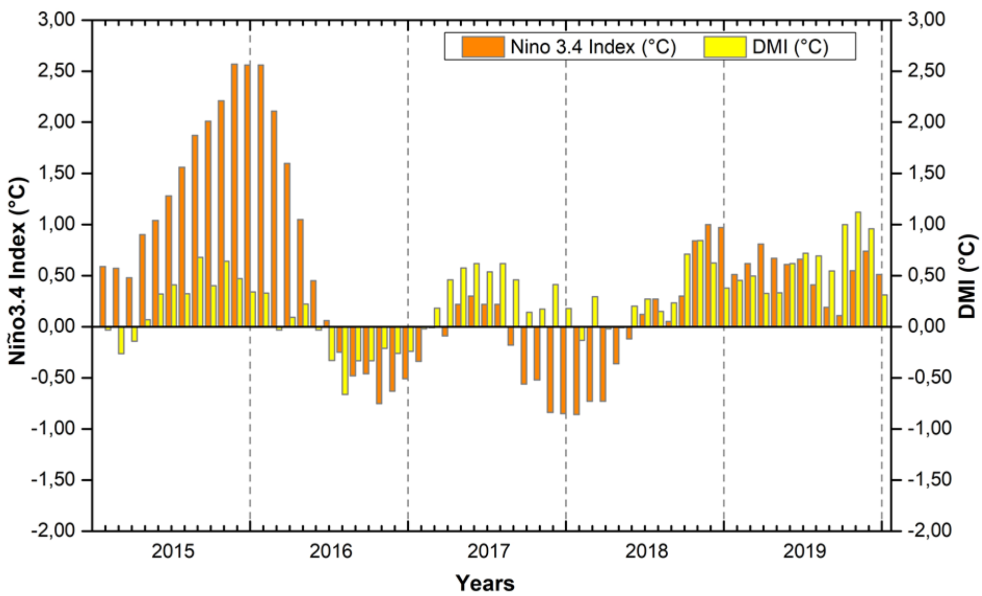

Figure 2. Niño3.4 Index and DMI data from January 2015 to December 2019

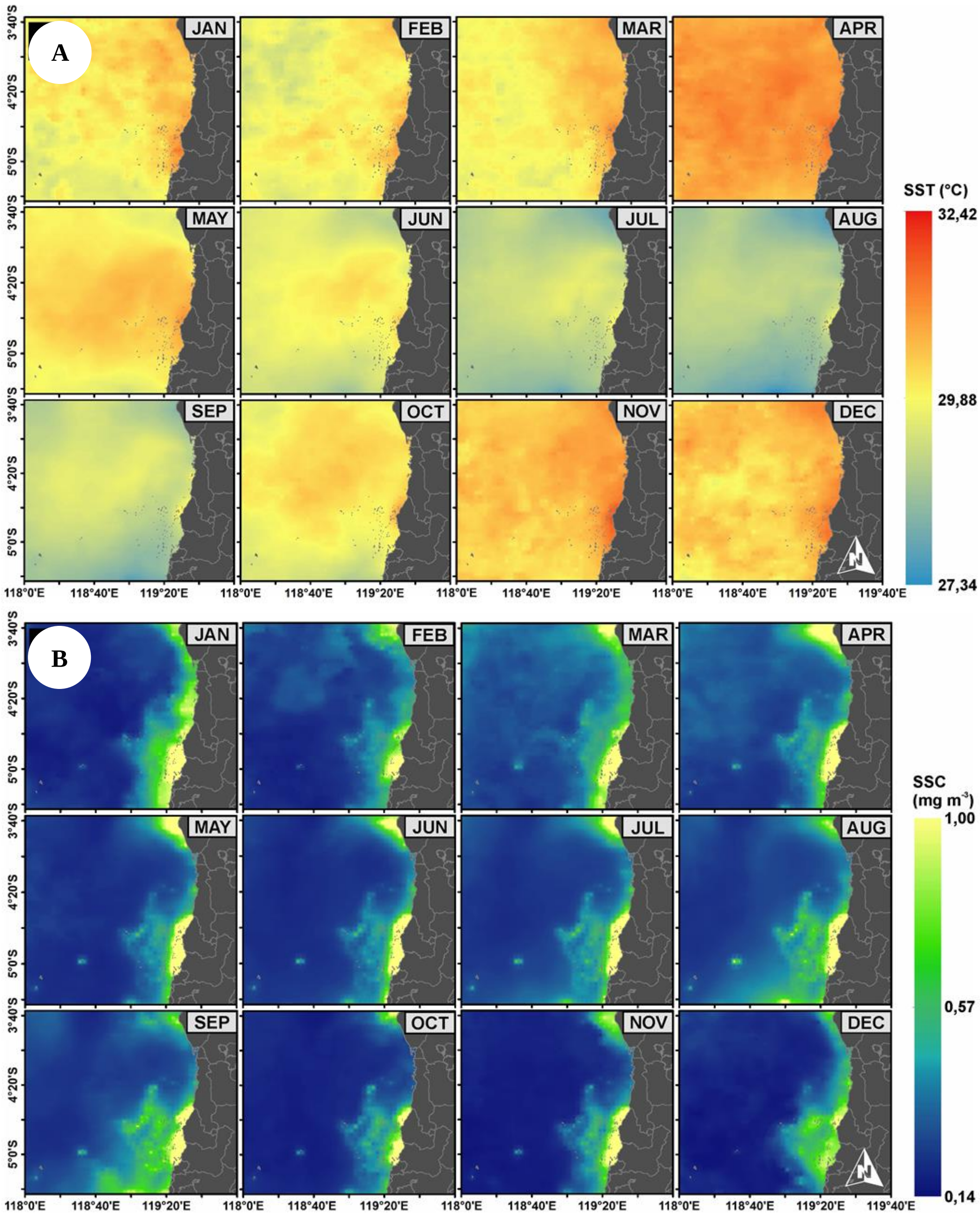

Figure 3. Map of the average monthly distribution of (A) SST and (B) SSC from 2015-2019 in the Pangkep and Barru Waters, Indonesia

Time series SST and SSC

The time-series data of SST (Figure 5.A) and SSC (Figure 5.B) were performed to determine the variation of the two oceanographic parameters every month for five years. It can be seen that there was an increase or decrease in SST and SSC in the Pangkep and Barru Waters, Makassar Strait. Both oceanographic parameters fluctuated every month. In general, the increase in SST generally occurs from November to May. Meanwhile, the SST decline began in June, and the lowest peak was in August. In general, the peak of the increase in SSC occurred in March, and the decline in SSC began to appear in April, with the peak of the decline in May.

SST in Pangkep and Barru Waters ranges from 27.82-31.50°C. The SST trend that formed the sharp slope occurred twice in 2015 and 2019. The lowest SST value occurred in April 2016, and the highest SST value occurred in August 2015. Otherwise, SSC ranges from 0.19 mg m^{-3} to 0.56 mg m^{-3}. The lowest SSC value occurred in September 2015, and the highest SSC value occurred in December 2018. The results showed that from 2015 to 2016 and from 2018 to 2019, the El Niño phenomenon occurred, which decreased SST and increased SSC, also known as an upwelling in Pangkep and Barru Waters Makassar Strait, South Sulawesi.

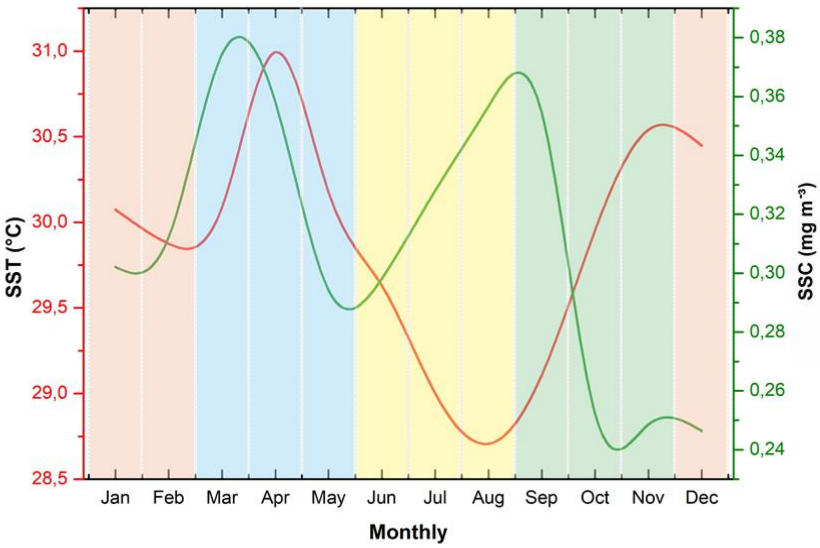

Figure 4. The seasonal SST and SSC average trend 2015-2019 in the Pangkep and Barru Waters, Makassar Strait, South Sulawesi Indonesia

Time series SST anomaly and SSC anomaly

SST anomaly (Figure 6.A) and SSC anomaly (Figure 6.B) were calculated to determine data deviations under normal conditions over five years. The calculation was carried out by subtracting the monthly SST (monthly SSC) in a certain year by the average value of the months during that period. The lowest SST anomaly (-0.5°C) occurred from June to October 2015 and 2019, with the lowest value of -1.04°C. Meanwhile, the highest SST anomaly (+0.5°C) occurred from March to November 2016, with the highest value of +1.39°C. SSC anomaly (increase or decrease from normal) did not occur significantly, or the incidence of SSC anomaly did not exceed +/-0.5°C. Only in September 2015, did the highest SSC anomaly reaches +0.21°C.

Relationship analysis

During 2015-2019, Scad production fluctuated yearly in Pangkep and Barru Waters, part of the Makassar Strait. In general, the highest production of Scad was in August and formed a normal production. However, from April 2015 to April 2016, there were extreme El Niño conditions that peaked in December 2015 at +2.56°C (Figure 7.A), having a negative impact on the SST anomaly or having a significant impact on the SSC anomaly value compared to the year before (Figure 7.B). Due to this, the output of Scad was not normally distributed; as a result, it first increased slowly before declining noticeably by 104.90 tonnes in November 2015 and then rapidly increasing by 384.40 tonnes in December 2015.

Meanwhile, from October 2018 to June 2019, there was another El Niño, and shortly an IOD+ event occurred. This had quite an impact on SST anomalies and slightly affected the production of Scad. In addition, from September 2017 to March 2018, there was a La Niña event (warm waters), and shortly, an IOD+ event (cold waters) occurred so that the SST of the Pangkep and Barru Waters was relatively stable. The study conducted in the waters in Bali Strait (Arleston et al. 2016), showed that low SST was followed by the low catch production of Scad and otherwise.

The results of the analysis (Table 2) showed that the SST anomaly in the Pangkep and Barru Waters during the ENSO event (El Niño/La Niña) has a strong relationship with a value of -0.62, with IOD (+/-) having a strong relationship with value -0.51. Meanwhile, the relationship between SSC anomalies during ENSO (El Niño/La Niña) and IOD (+/-) events is very low, with values of 0.18 and 0.07.

The analysis results (Table 3) showed that the Scad production with SST has a strong relationship with a value of -0.41, and SSC has a strong relationship with a value of 0.60) in the Pangkep and Barru Waters, Makassar Strait.

Table 2. Correlations of Niño3.4 Index, DMI, SSC anomaly, and SSC anomaly

	Niño3.4_ Index	DMI	SST anomaly	SSC anomaly
Niño3.4_Index	1.00			
DMI	0.34	1.00		
SST nomaly	-0.62	-0.51	1.00	
SSC nomaly	0.18	0.07	-0.43	1.00

Table 3. Correlations of SST, SSC, and scad production

	SST	SSC	Scad production
SST	1.00		
SSC	-0.39	1.00	
Scad production	-0.41	0.60	1.00

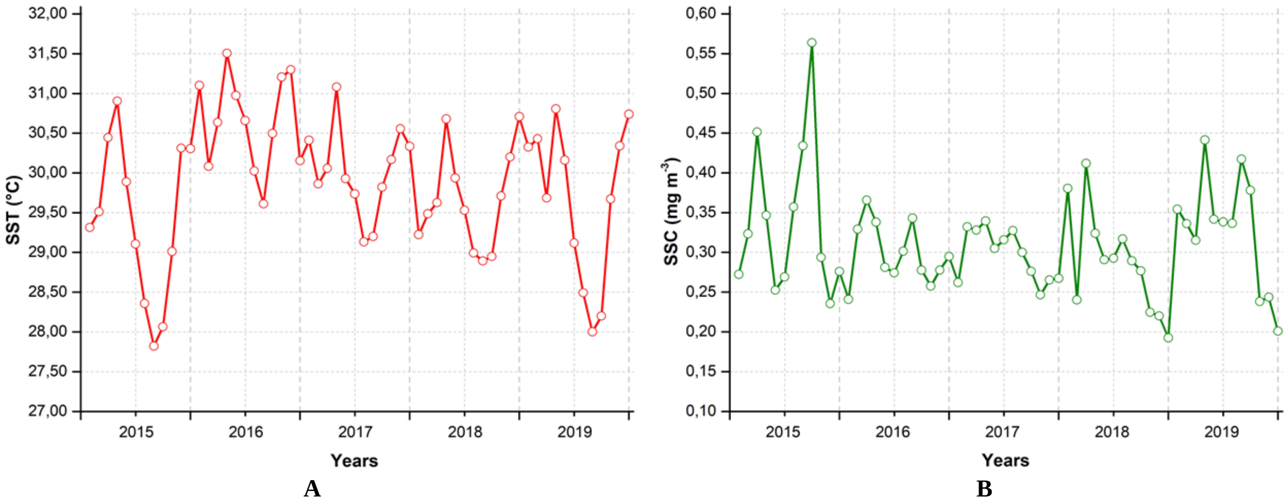

Figure 5. The time series average of (A) SST and (B) SSC from January 2015 to December 2019 in the Pangkep and Barru Waters, Makassar Strait, South Sulawesi, Indonesia

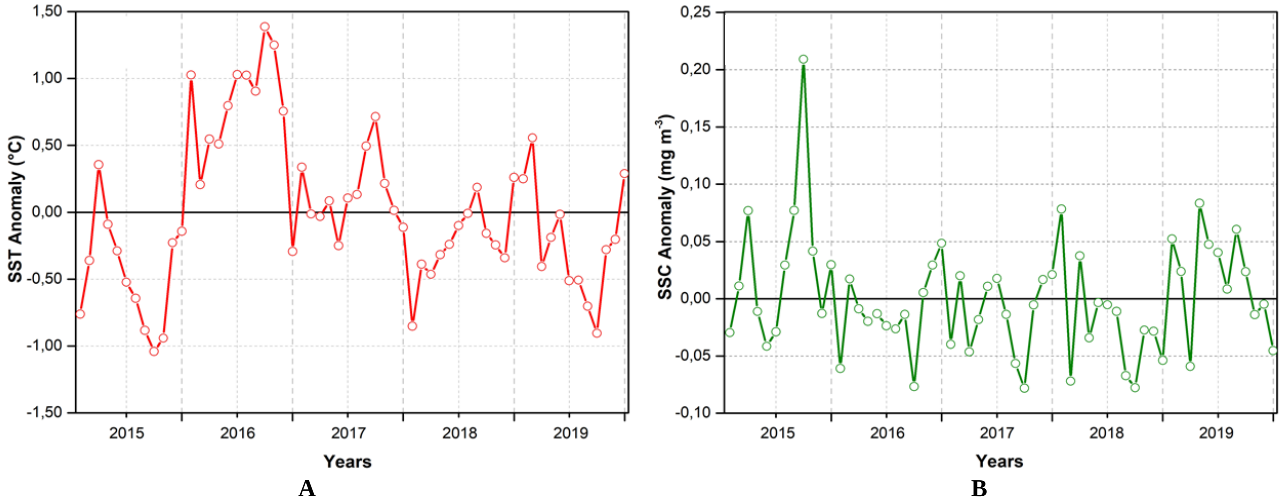

Figure 6. The time series average of (A) SST anomaly and (B) SSC anomaly from January 2015 to December 2019 in the Pangkep and Barru Waters, Makassar Strait, South Sulawesi, Indonesia

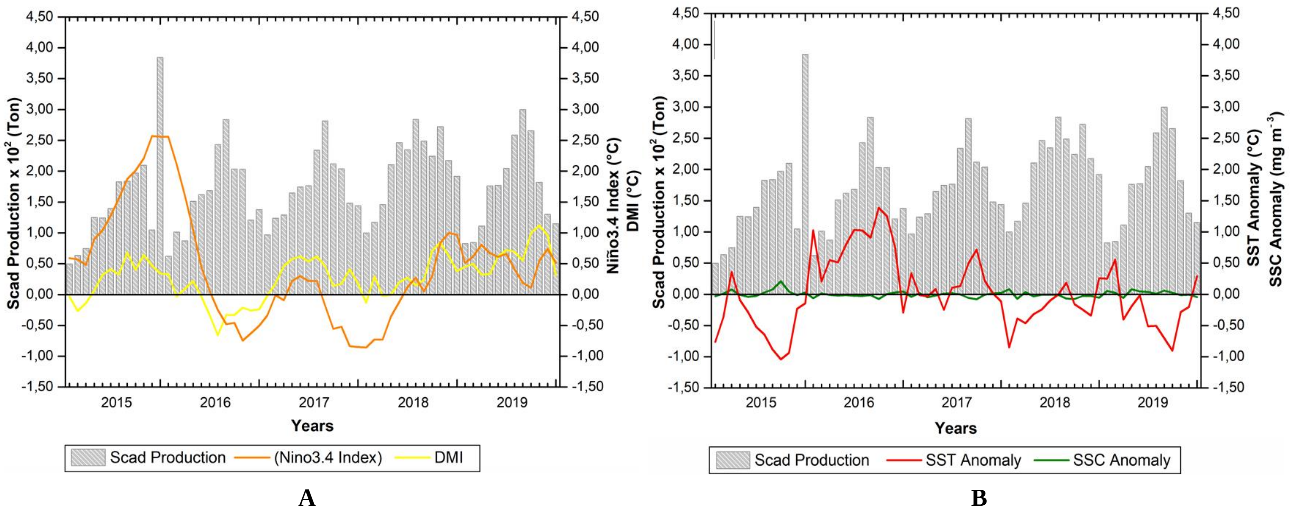

Figure 7. The time series (A) Niño3.4 Index, DMI, and scad production and (B) SST anomaly, SSC anomaly, and scad production from January 2015 to December 2019 in the Pangkep and Barru Waters, Makassar Strait, South Sulawesi, Indonesia

Discussion

Global climatic dynamics are typically linked to regional climate variability. To effectively assess events in regional and even small-scale waters, one must be aware of the atmospheric phenomena, physical, and dynamic processes that make up space and time. The influence of monsoon winds, climate change caused by ENSO and IOD, and the Indonesian Throughflow can all have an impact on the regional and temporal changes of Indonesia's SST (Hidayat et al. 2016; Martono 2016). Using time series data SST and SSC from Aqua-MODIS satellite images and their relationship to Scad production, global scale events through ENSO and IOD events may be identified and linked to water conditions in the Pangkep and Barru Waters, Makassar Strait.

This study examined IOD (IOD+/IOD-) and ENSO (El Niño/La Niña) events from January 2015 to December 2019. IOD events using the Dipole Mode Index and ENSO events using the Niño 3.4 Index can both occur simultaneously or independently. During the five years of the study, this phenomena led SST (cold) to drop and SSC to rise from the average normal state, particularly in 2015. A larger intensity of ENSO occurrences could affect SST than during IOD events, according to a study by Dewi et al. (2020). According to Nababan et al. (2016), seasonal patterns during the ENSO event (El Niño) impact the fluctuation of SST and SSC in the Pangkep and Barru Waters, Makassar Strait, making the upwelling phenomena more intense and distinct in the absence of ENSO occurrences. Strong La Niña phenomena along with IOD- induce an increase in SST and a decrease in SSC, whereas strong El Niño phenomena combined with IOD+ cause a decrease in SST with an increase in SSC (Seprianto et al. 2016; Wijaya et al. 2020). In contrast to SSC anomalies, which have a poor association, the findings of the cross-correlation analysis of ENSO and IOD on SST anomalies in the Pangkep and Barru Waters, Makassar Strait waters, reveal a substantial relationship. This is because ENSO and IOD directly affect SST, while SSC requires an SST intermediary (indirect effect).

According to monthly data on scad production in two South Sulawesi regencies (Pangkep and Barru), the scad fishing season begins in June and peaks in August (east monsoon). Meanwhile, from December to February, there was famine (west monsoon). The findings of Wahju et al. (2011) are nearly the same, with famine occurring in March and April and Scads fishing's peak season occurring in June (east season) (transitional season I). This study shows that the significant El Niño event that occurred in 2015 impacted SST, SSC, and Scad production in the Pangkep and Barru Waters, Makassar Strait. In November 2015, it saw a dramatic decline, then the following month, it experienced a sharp increase (December 2015). El Niño also happened in 2018 and had a big impact on Scad's output. As demonstrated in this study for 2016, 2017, and 2019, when neither ENSO nor IOD was present, the total monthly production of Scad was within the normal range or following the fishing season. The claim made by Lehodey et al. (2020) that an El Niño evolved concurrently with a positive phase of IOD in 2015 strengthens this research. At the end of 2015, a significant cold anomaly in the southern Indonesian region coincided with the peak intensity of both El Niño and the positive IOD. A major El Niño event in 2016 reportedly impacted the fall in CPUE values (Puspasari et al. 2021).

Because of its range from subtropics to the tropics, Scad has a high tolerance for SST (Fishbase 2021). But according to studies by Puspasari et al. (2016), Scad is particularly vulnerable to climate change because it is connected to many islands, particularly those with coral reefs. Coral reefs are a particular kind of ecosystem that is extremely susceptible to variations in seawater temperature, claim Quiin and Johan (2015). According to the RRN (2019), El Niño and La Niña can both have a significant negative influence on coral reef ecosystems. Globally, ENSO caused severe coral mortality and bleaching in the years 1982-1983; 1997-1998; 2002-2003; 2005; and 2010; this resulted in the loss of several coral species. These assertions demonstrate that the Scad captured in the Makassar Strait seas are likewise considerably impacted by climate change, as evidenced by the Scad production data for Pangkep and Barru (Figure 7).

The high Scad production during the east monsoon can be attributed to an upwelling of nutrients into the Makassar Strait's surface waters. It is characterized by a simultaneous reduction in SST and a rise in SSC. According to several studies (Inaku et al. 2011; Wibowo et al. 2020), the Makassar Strait has an upwelling phenomenon during the east monsoon that is directly related to the fishing grounds (Samad et al. 2016). The southeast monsoons' pace and direction, as well as the flow of freshwater rivers, impact on the incidence of upwelling in the southern waters of the Makassar Strait (Nababan et al. 2016). Piton and Delcroix's (2018) investigation revealed that upwelling is getting stronger due to El Niño events. Sartimbul et al. (2010) have revealed this by making a schematic of the possible impacts of climate variability on the CPUE of *Sardinella lemuru* in the Bali Strait. Climate variability (ENSO and IOD) prolongs the monsoon period and further affects SST depending on the solar intensity and other factors (e.g., currents, river runoff, wind, upwelling, etc.). Furthermore, SST affects the concentration of SSC and indirectly influences the increase in *S. lemuru*. The energy transfer time from SSC to *S. lemuru* in the food chain is around three months.

The variability of SST and SSC, which ENSO and IOD influence, demonstrates the close connection between the analysis of Scad production. According to Safruddin (2013), SST and SSC in the Makassar Strait waters have a favorable impact on Scad dispersion. SSC, which is abundant in the water, provides food for the plankton feeder Scad (Wahju et al. 2011). According to Putra et al. (2012), SSC has an indirect effect on raising CPUE Scad. Additionally, it was noted that the waters of Kendari and its surroundings had the biggest Scad capture when the SST was between 29°C and 31°C, and the upwelling mechanism resulted in a high concentration of chlorophyll-a (Hariati et al. 2010). According to a different study, SSC had a 23% impact on Shortfin Scads (Wicaksono et al. 2019).

This study concludes that the identification of ENSO and IOD from January 2015 to December 2019 showed that there were two El Niño events, one La Niña event, and two IOD+ events. ENSO and IOD significantly impact SST and SSC variability (increase/decrease). There is a strong direct relationship between ENSO/IOD with SST (SST anomaly) and indirect variability with SSC (SSC anomaly). This causes a strong and intensive upwelling phenomenon, especially when the El Niño event is strong and affects the unstable Scads production in the Makassar Strait, Indonesia. Understanding the real impact of ENSO and IOD on Scad production needs to be known to predict the level of Scad resources and as a material for consideration of marine resource management.

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