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Analysis of Sea Surface Temperature and Chlorophyll-A and Its Relationship with Catch Results Flying Fish Eggs in the Waters of the Kei Islands

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Abstract: The Kei Islands water area is quite productive in fisheries management. Environmental characteristics and oceanographic factors in a body of water will determine the potential of fisheries resources in a water body, and influence fish movement patterns and the formation of fishing areas for flying fish eggs. This research aims to examine the distribution of sea surface temperature and chlorophyll-a concentrations and analyze the relationship between sea surface temperature and chlorophyll-a concentrations with catches of flying fish eggs. The research focused on the waters of the Kei Islands, Southeast Maluku, which is an area for catching flying fish eggs. The research data was studied in the period December 2014 – November 2017. SPL and Chlorophyll-a data were downloaded from Citra MODIS-Aqua, while data on flying fish egg production was obtained from PPN Tual. The research results show that the monthly average SST distribution is between 25.03-30.42ºC, and the monthly average of chlorophyll-a varies quite widely with a range of 0.05-3.09 mg/m³. The number of flying fish egg production fluctuates every year with a production range of 36.28-81.905 kg. The peak of catching flying fish eggs occurs in June-September (eastern season and transition season II). The results of the analysis show that the correlation between SST and chlorophyll-a variables has a very dominant influence on the abundance of flying fish eggs.

Keywords: Chlorophyll-a; Flying Fish Eggs; Sea Surface Temperature

Introduction

The waters of the Kei Islands are the administrative area of Southeast Maluku Regency and Tual City which has an area of approximately 1,031.81 km2. Based on its geographical position, the waters of the Kei Islands have direct boundaries with the Banda Sea and the Arafura Sea (Teniwut et al., 2023a). The waters of the Kei Islands are located between the Republic of Indonesia State Fisheries Management Area, Banda Sea (WPP-NRI 714), and Arafura Sea (WPP-NRI 718). This condition makes the waters of the Kei Islands a quite productive water area in fisheries management (Sahetapy et al., 2020); (Teniwut et al., 2023b).

According to (Pramoda et al., 2021), the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 69 of 2016 concerning Management Plans for Flying Fish Fisheries, it is stated that administratively 15 provinces have the authority and responsibility to manage fish resources, especially flying fish, one of which is Maluku Province which includes WPP 714 and WPP 718. Based on actual conditions related to the utilization of flying fish resources, there are fishing activities specifically for flying fish and fish eggs with quite high intensity.

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The waters in the Kei Islands cover the areas around Kei Besar Island, Kei Kecil, Tanimbar Kai, Ur Island, and around Taam Island, Walir Island, and Tayando Island, which have enormous potential for fish resources and flying fish eggs. Flying fish egg resources have become a favorite for the area around these waters. Generally, fishermen who carry out fishing activities in this area are indigenous people who live in this area and are located along the coast. Fishing activities have been carried out since ancient times and are used as a regional specialty food, while many fishermen from outside Southeast Maluku carry out fishing activities for commercial activities in the domestic market and for foreign exports.

Geographically, the waters around the Kei Islands are distinctive and unique because they are directly connected to several waters, each of which has its characteristics. The relationship between these waters allows for mutual interaction so that it will influence local water conditions. Apart from the issue of interaction between waters, the condition of the waters around the Kei Islands is also influenced by seasonal factors which are expected to cause fluctuations in oceanographic parameters which can have a direct or indirect impact on the existence of existing resources. The surrounding waters that are directly connected to the waters of the Kei Islands include the Banda Sea, Seram Sea, Arafura Sea, Flores Sea, and the waters of western Papua which are predominantly influenced by the monsoon wind system.

Environmental characteristics and oceanographic factors in a body of water are generally used as the basis for determining the potential for fisheries resources in a body of water and their influence on the formation of fishing areas (Grip & Blomqvist, 2020); (Kenny et al., 2018). This shows that fish resources and flying fish eggs in a water column are very dependent on changes in oceanographic conditions. These changes will occur dynamically, affecting fish movement patterns in the water column. This is because fish will naturally look for water areas that suit their living environment so knowledge of the oceanographic conditions of the Kei Islands waters will provide a complete picture of the existence of flying fish resources and flying fish eggs, as well as determining fishing areas that can optimize fishing results.

Based on the description above, further studies are needed regarding these oceanographic environmental factors, to study the distribution of concentrations of sea surface temperature and chlorophyll-a; and analyze the relationship between sea surface temperature and chlorophyll-a concentrations with catches of flying fish eggs.

Method

The research was carried out in the waters of the Kei Islands which are included in the administrative area of Southeast Maluku Regency and Tual City (Figure 1). The research period took place between December 2014 and November 2017.

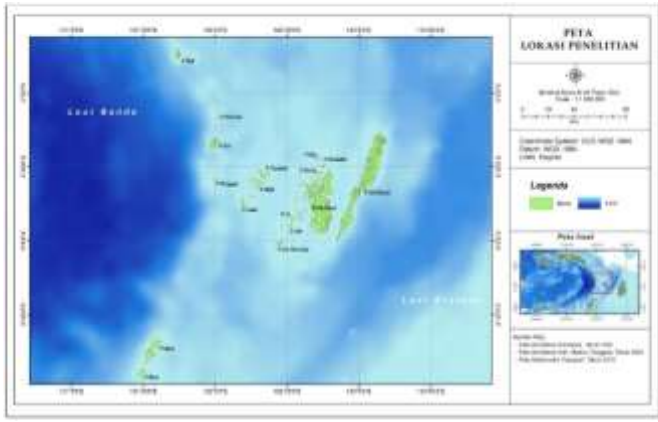

Figure 1. Map of research locations

The tools and materials used to collect data are presented in Table 2.

Table 2. Tools and materials in research

MODIS data	Utility
MODIS data	Provides SPL and Chlorophyll-a data
Tual VAT data	Providing data on flying fish egg production
Seadas	
Surfer	Software that interprets data in the form of images and graphs
Microsoft Excel	
SPSS	Software that analyzes the relationship between oceanographic data and flying fish eggs
Computer	The device downloads data, tabulates, and processes research data

SST and chlorophyll-a data are the results of recording from MODIS-Aqua Imagery. This data was accessed from the National Aeronautics and Space Administration (NASA) website: https://oceandata.sci.gsfc.nasa.gov/cgi/getfile. Meanwhile, the data for flying fish eggs was obtained from the Tual Fisheries PPN as a landing base for catches of marine resources in the WPP 714 and WPP 718 areas. Flying fish egg production data is data from 2015-2017. The SPL and chlorophyll-a data had been downloaded in NetCDF form and then cropped using Seadas 7.30

software. The data was then tabulated into monthly data and analyzed to obtain statistical values with the help of Microsoft Excel 2010 software. The monthly average SPL and chlorophyll-a data were analyzed to obtain a horizontal distribution pattern with the help of Surfer 12 software. The analyzed results were displayed in the form of images. distribution of SST and chlorophyll-a. Through pictures of the distribution of SST and chlorophyll-a, the distribution patterns and phenomena or dynamics that occur in waters such as upwelling, water masses meeting, and so on are studied.

Flying fish egg data was obtained from Tual Fisheries VAT. The flying fish egg data was then tabulated using Microsoft Excel 2010 to obtain monthly, seasonal, and annual data. These data are then interpreted in the form of images and graphs to see fluctuations in flying fish egg production on a monthly and annual basis. The relationship between oceanographic parameter variables and flying fish egg production was further analyzed to see the correlation using regression analysis with SPSS and Microsoft Excel 2010 software. Each independent variable (SPL and chlorophyll-a) was tested for its effect on the related variable (flying fish eggs). Each variable tested is classified based on monthly seasonal and annual data for each variable tested. The output of the regression analysis test is in the form of a graph that shows the correlation between each variable in each year. The results of the analysis of oceanographic variables and flying fish eggs in all observation seasons are grouped into discussions based on year (2015-2017), and will then be described descriptively.

Result and Discussion

Sea Surface Temperature

Sea surface temperature (SST) in the waters of the Kei Islands shows quite significant variations seasonally. According to (Wu et al., 2023), SST variations are caused by the interaction between sea and air and the circulation of monsoon currents. Apart from that, the movement of water masses and the process of mixing water masses that occur in the surface layer of water also influence SST (Syahdan et al., 2021), The distribution of the monthly average SST in the waters of the Kei Islands from December 2014 to November 2017 shows that the average temperature is generally lowest in August, and highest in November and December (Figure 2). The low sea surface temperature in August, which is part of the east season, is caused by the upwelling phenomenon that occurs in the waters of the Banda Sea, Arafura Sea, and the waters around the Kei Islands, while the high temperature in November and December is caused by the position of the sun which is in the southern hemisphere. receives more intense sunlight and also because the wind is weak, it reduces the release of heat into the air.

The seasonal average temperature distribution pattern shows cold sea surface water masses in the east season and warm sea surface water masses in the Kei Islands in the west season and transition season I. In general, the lowest monthly average temperature was found in August 2015, namely 25.03ºC and the highest in November 2017 was 30.42ºC. (Toyoda et al., 2021), said that the distribution pattern of sea surface temperatures in the waters of the Kei Islands during the east season (June-August) is generally very cold and reaches its lowest value in August. This is because the monsoon winds reach maximum speed and cause the process of lifting cold water masses from the deep layers to the surface layers (upwelling).

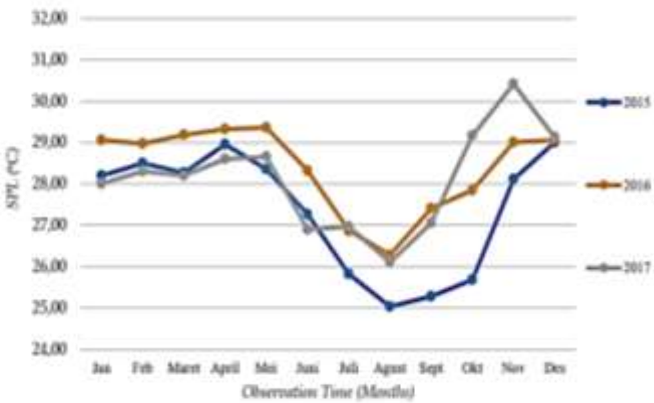

Figure 2. Distribution Pattern of Monthly Average SST

The monthly average distribution pattern of SST from 2015 to 2017 shows seasonal variations (Figure 3-5). This is closely related to the seasonal monsoon winds. However, there are visible differences between the years. This condition can be caused by the influence of climate anomalies that occur locally, regionally, or globally, in this case, ENSO. In the west season, the distribution of SST in the waters of the Kei Islands ranges between 24.21 - 30.36ºC while the monthly average SST is between 28.00 - 29.06ºC. Temporally, the distribution of sea surface temperatures shows that December is higher compared to January and February. This is because the northwest monsoon winds increase over time and reach their peak in late to early February.

Spatially, it can be seen that the distribution of sea level (SST) is higher in the western part of the Banda Sea to the southern part of Tanimbar Kei Island and the eastern part of Kei Besar Island with higher temperatures, while lower temperatures are more concentrated in the northern part of Kei Kecil Island and Pulau Big Kei. According to (Shaltout & Omstedt, 2014); (Muhammad et al., 2016); (Crespo et al., 2019), in general, the SST value in Indonesian waters ranges between 28-31ºC, with a comparison of the SST value in the east season period being much lower than the west season. The distribution of SST in the first transition season ranges from 24.37 – 30.05⁰C, with a monthly average SST range of between 28.21 – 29.37⁰C. The distribution of SST concentrations in the first transition season does not show significant differences from the SST distribution pattern in the western season. In the first transition season, the higher SST is concentrated in the western part of the Banda Sea, while the relatively lower SST is concentrated in the southern region of Tanimbar Kei Island. In general, the pattern of sea surface temperature distribution during the first transition season in the waters of the Kei Islands is still quite high. The high surface temperature is determined more by the amount of light energy received by the sea surface and the weakness of the wind.

In the first month of the transition season, the sun is near the equator so the sea surface receives quite a lot of sunlight energy. Cahyono (2010) revealed that solar activity influences changes in the temperature of the earth's surface and oceans so the position of the sun has a significant role in changes in sea surface temperature. Entering the east season, the distribution shows the dominance of cold water masses in the waters of the Kei Islands. The sea surface temperature of the Kei Islands waters ranges from 23.82 - 29.45ºC, with an average monthly temperature ranging from 25.03 - 28.33ºC. Temporally, the distribution of SST in June is seen to be in the range above 26.0ºC throughout the waters of the Kei Islands and decreases further in July and August. In July, sea surface temperatures are in the range of less than 26.0ºC and reach the lowest range in August.

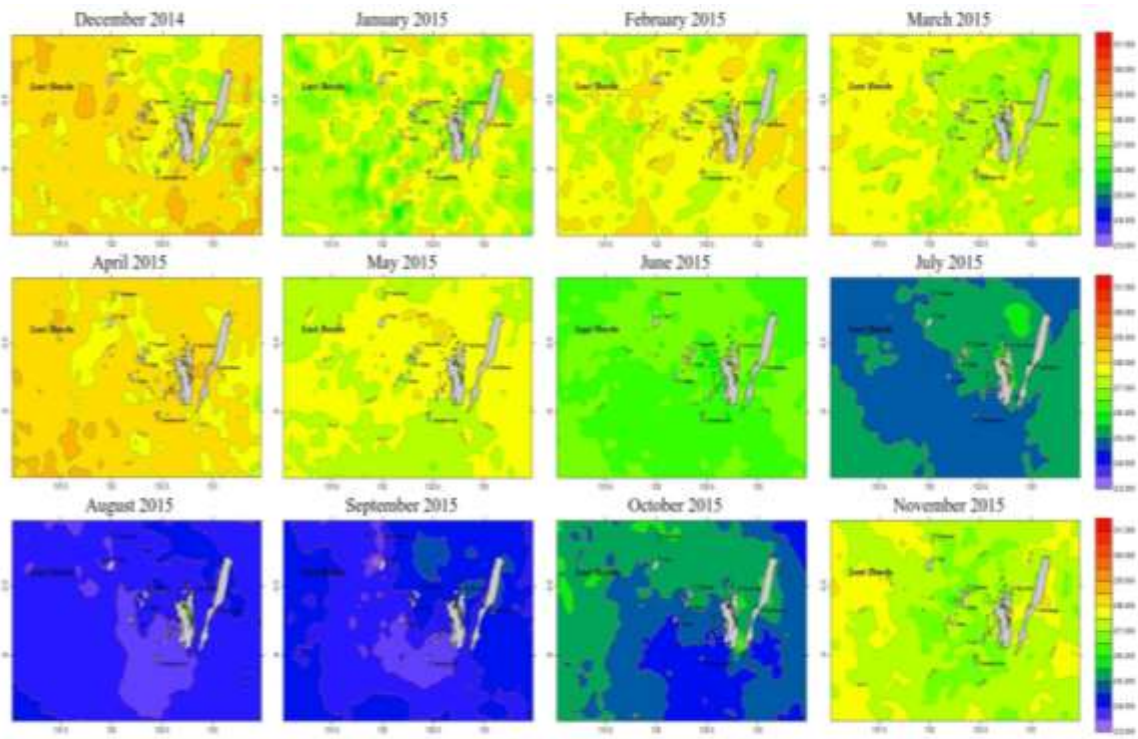

Figure 3. SST distribution pattern in 2015 in the waters of the Kei Islands

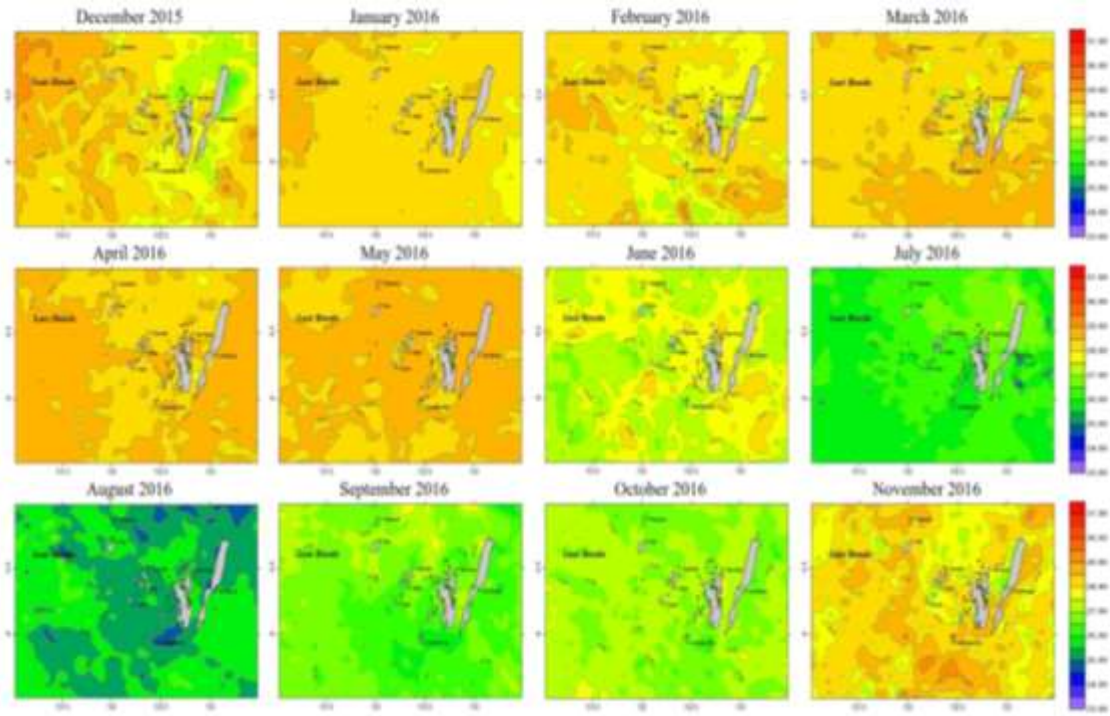

Figure 4. SST distribution pattern in 2016 in the waters of the Kei Islands

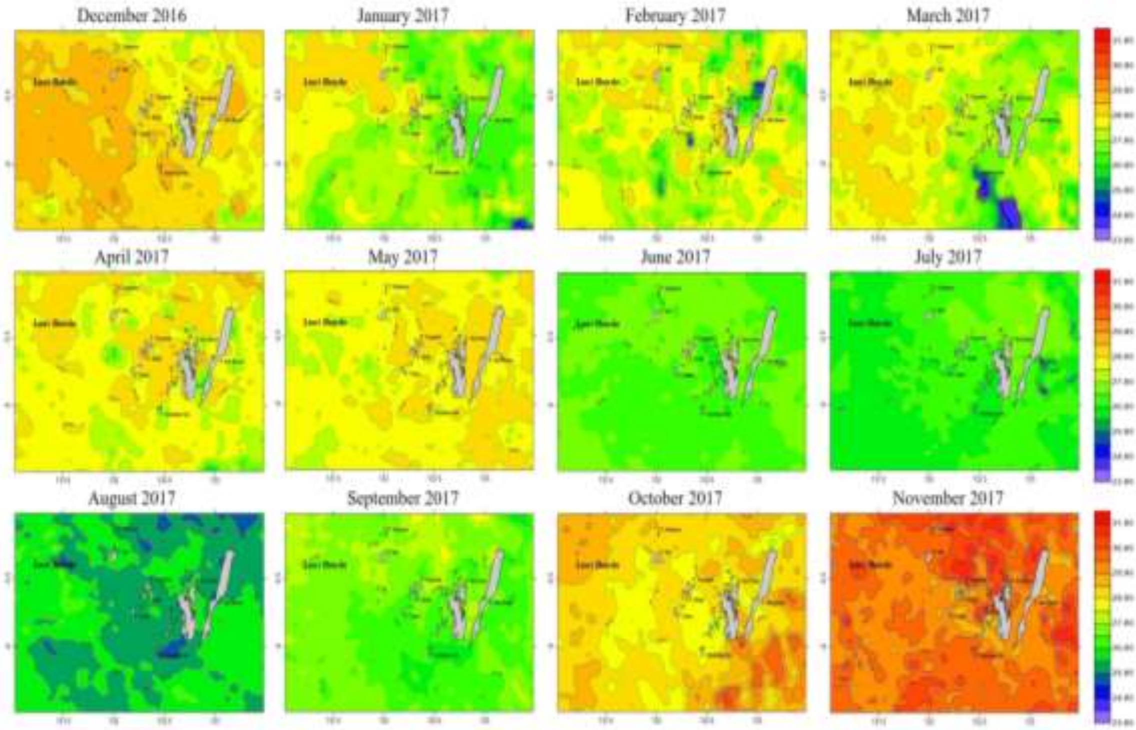

Figure 5. SST distribution pattern in 2017 in the waters of the Kei Island

The low water temperature is caused by the increasingly strong winds of the southeast monsoon, causing the water dynamics process to become more dynamic. Figure 3-5 shows that in the east season, there is a center of mass concentration of cold water in the waters of the Banda Sea, south of the Kei Islands, and waters of the western part of the Kei Islands, especially in the waters around the Kur-Tayando Islands, Tanimbar Kei waters and also in the waters northeast of the Kei Islands. The center of concentration of cold water masses indicates that upwelling is occurring in the waters of the Kei Islands. Sahuleka et al (2018) said that upwelling in the waters of the Kei Islands occurred from May to October. The upwelling phenomenon takes place in the Banda Sea, the waters of the Kei Islands, and the Arafura Sea during the east monsoon period (Ratnawati et al., 2016; Putra, et al., 2017).

In transition season II, the SST distribution in the waters shows an increase in temperature compared to the east season. The SPL range is between 23.82 - 31.96 ºC, with a monthly average SPL between 25.28 - 30.42ºC. Temporally, sea surface temperatures increase with increasing time, and surface water masses become warmer in November. The surface water is still colder in September and October when compared to November because in September and October, especially in September, the southeast monsoon still blows, although its strength is starting to weaken. This causes the waters of the Kei Islands to still occur with low-intensity upwelling. The warm water masses in November are caused by the sun's position in the southern hemisphere and the weakening of the wind.

The SST distribution pattern shows a connection with the movement pattern of flying fish. Flocks of flying fish have begun migrating to the waters of the Kei Islands to find suitable waters for the spawning ground. Generally, spawning time begins at the end of the first transition season (April and May). This condition marks the beginning of the season for catching flying fish eggs in the waters of the Kei Islands every year.

Chlorophyll-a

Chlorophyll-a is an indicator to determine the distribution and abundance of phytoplankton, therefore chlorophyll can be used as an approach to determine the fertility of waters and the availability of food which are characteristics of fishing grounds (Aufar et al., 2021; Harahap et al., 2019; Eka et al. al., 2021). The concentration of chlorophyll-a in the waters of the Kei Islands in the period December 2014 - November 2017 ranged from 0.05 – 3.09 mg/m^3 (Figure 6). The highest monthly average chlorophyll-a concentration was found in the east season (August 2015), and the lowest chlorophyll-a content was seen in the west season (December 2017).

The distribution pattern of the monthly average chlorophyll-a concentration in the waters of the Kei Islands shows that the chlorophyll-a concentration began to increase in May and reached its peak in August, then decreased although it was still categorized as quite high until October. This pattern shows similarities with the pattern of decreasing water temperature. Thus, the upwelling phenomenon that occurs when the southeast monsoon blows (May-October) has an impact on decreasing water temperature, increasing the concentration of chlorophyll-a. Deep water masses are water masses that are rich in nutrients. If the water mass is lifted to the surface layer, the upwelling phenomenon causes nutrient enrichment in the surface layer and has an impact on the density of phytoplankton.

The distribution pattern of chlorophyll-a concentrations in the waters of the Kei Islands shows seasonal and spatial variations. The waters of the Kei Islands, especially around the waters of Kei Kecil Island, are waters that have quite high primary productivity almost throughout the year.

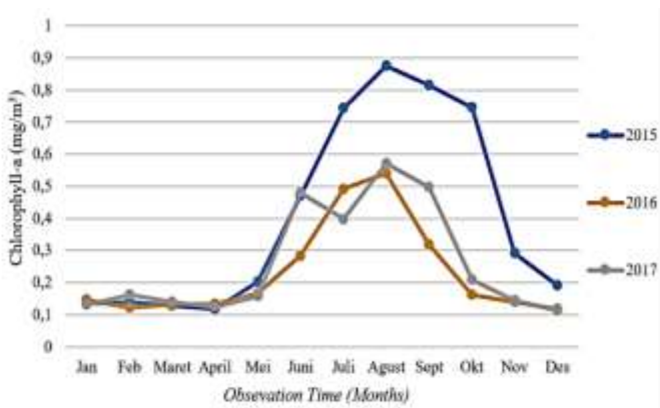

Figure 6. Monthly Average Distribution Pattern of Chlorophyll-a

The high productivity is due to the shallow waters which cause perfect mixing of water masses. Apart from that, the upwelling phenomenon that occurs when the southeast monsoon blows (May-October) has an impact on increasing nutrients in the surface layer and ultimately affects the high productivity values in the water column. Spatially, the distribution of chlorophyll-a in the western part of the waters to the south of Kei Kecil Island shows high concentrations almost throughout the year, and reaches its peak during upwelling, especially in the east season and transition season-II (Figure 7-9).

A significant increase in chlorophyll-a concentration was also seen in the transition season II in the southern part of Kei Besar Island. In western and eastern waters, an increase in chlorophyll-a concentrations is only visible in the eastern season and transition season II. An increase in chlorophyll-a concentration began to be seen in May and continued to increase until September and October. Analysis of the distribution of chlorophyll-a concentrations spatially and temporally shows that the highest concentrations of chlorophyll-a are found in the transition season-II (October), while the lowest concentrations are found in the western season (January). In the west season, the chlorophyll-a concentration ranges from 0.06-1.50 mg/m^3, with a monthly average value ranging from 0.12 – 0.19 mg/m^3.

Entering the transition season-I, the chlorophyll-a concentration value continues to increase with a range of 0.06 - 2.31 mg/m3, the monthly average chlorophyll-a concentration ranges from 0.12 - 0.20 mg/m^3. In the east season, the concentration of chlorophyll-a continues to increase, namely 0.14-3.09 mg/m^3, while the monthly average concentration of chlorophyll-a has a value of 0.28-0.88 mg/m^3. Furthermore, in the transition season II, chlorophyll-a concentrations reached maximum values in the range of 0.05-3.09 mg/m^3, and the monthly average chlorophyll-a concentrations ranged from 0.14 – 0.82 mg/m^3. The high concentration of chlorophyll-a during the east monsoon and transition season II indicates that these two seasons are periods of water fertilization.

The concentration of chlorophyll-a has increased significantly, this is thought to be the result of runoff and circulation of water masses from surrounding waters such as the Arafura Sea, the waters of the Aru Islands, and upwelling events that carry nutrients and have the potential to refresh and fertilize these waters. According to (Pusparini et al., 2017), the concentration of chlorophyll-a in the Banda Sea and Arafura Sea when the southeast monsoon blows is higher than the northwest monsoon (Simanjuntak & Lin, 2022); (Dewi et al., 2018) .

In general, it appears that the waters around the coast of the Kei Islands have high concentrations of chlorophyll-a throughout most of the year (Saragih et al., 2020); (Wirasatriya et al., 2021). The highest concentrations are found in the east season and transition season II (Elbayoumi et al., 2014); (Naik et al., 2020); (Singh et al., 2022). Spatially, the waters of the western and southern parts of the Kei Islands have very high concentrations of chlorophyll-a (Antoni et al., 2019). Chlorophyll-a can be used as an indicator to evaluate the fertility level of water. Chlorophyll-a concentration describes the amount of phytoplankton biomass in the water column. Phytoplankton are primary producers and play an important role as a food source for fish. Food availability and water fertility levels can be used to identify the distribution of fish in the sea (Laevastu and Hayes, 1981).

The concentration and distribution of chlorophyll-a generally increased in June and then decreased in October. Peak concentrations and widespread distribution of chlorophyll-a were observed in August, mainly located in the southern waters of the Kei Islands. In this period, the chlorophyll-a concentration ranges between 0.55-3.08 mg/m^3, this condition will fertilize the waters as stated by Gower (1984) that chlorophyll-a concentrations above 0.2 mg/m^3 indicate the presence and adequate plankton life to support or maintain the continuity of the development of commercial fisheries.

The optimal distribution of chlorophyll-a concentrations has proven the existence of productive flying fish egg fishing areas. Thus, the chlorophyll-a concentration value shows harmony and linearity with the production of flying fish eggs in the waters of the Kei Islands. The results of catching flying fish eggs which have the same fluctuation pattern in the concentration of chlorophyll-a in the water indicate that there is an interaction between environmental factors such as food availability. Small pelagic fish tend to congregate in areas with high plankton concentrations, as occurs along the waters of the Kei Islands.

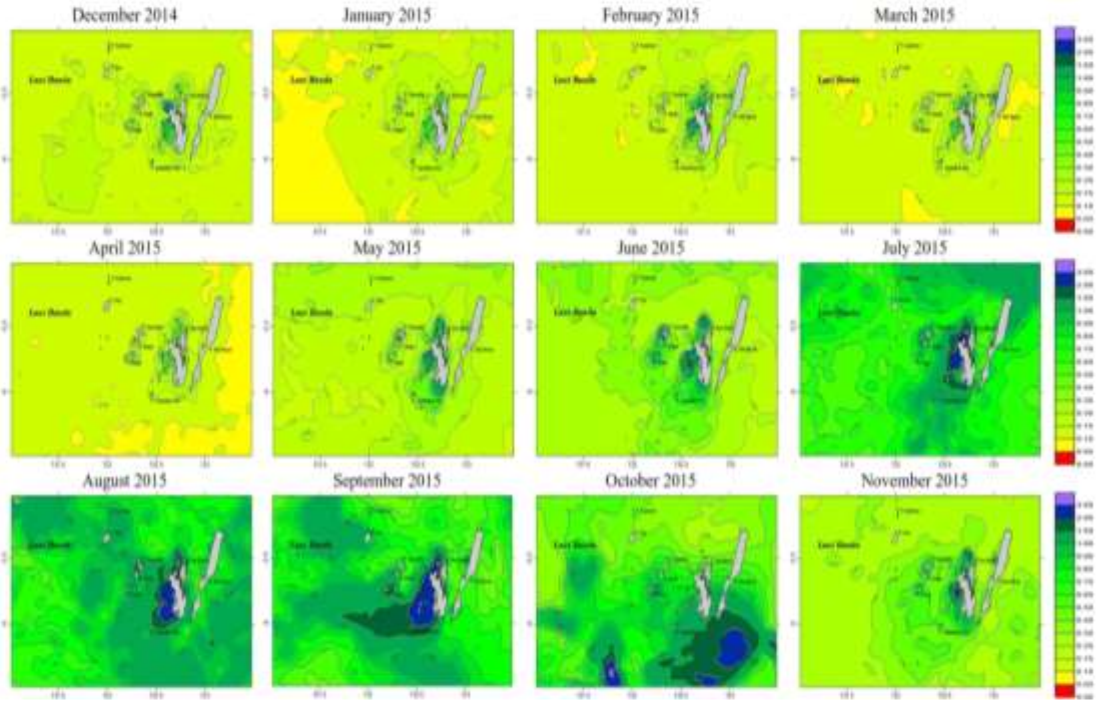

Figure 7. Chlorophyll-a distribution pattern in 2015 in the waters of the Kei Islands

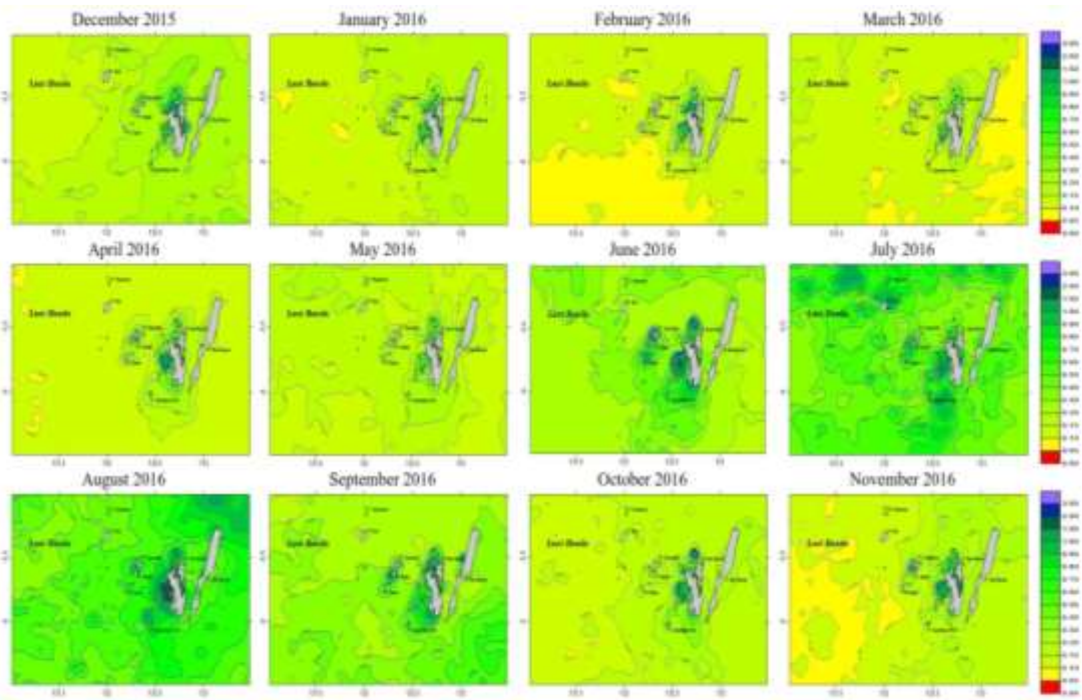

Figure 8. Chlorophyll-a distribution pattern in 2016 in the waters of the Kei Islands

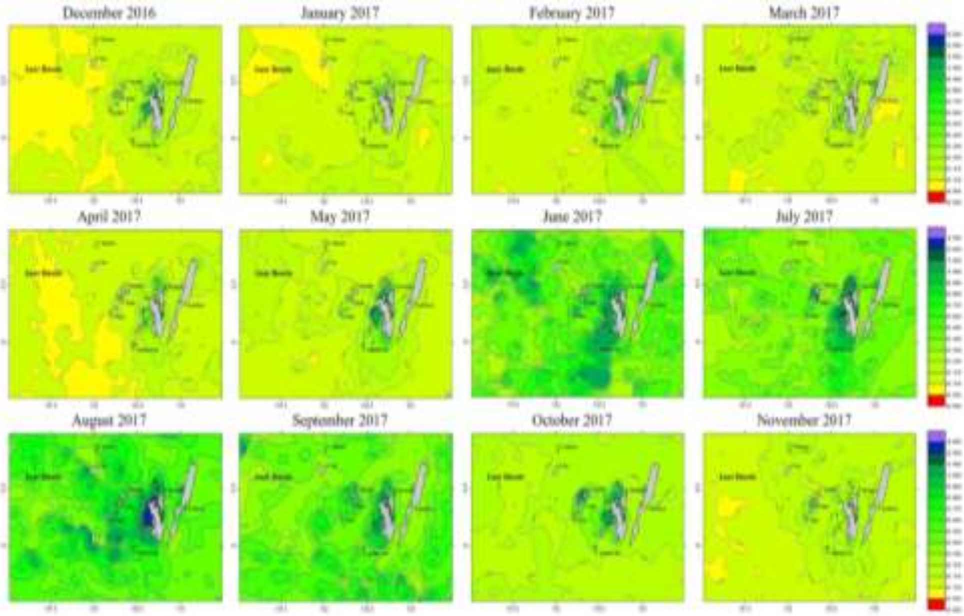

Figure 9. Chlorophyll-a distribution pattern in 2017 in the waters of the Kei Islands

Fish Egg Production

Flying fish egg production in the waters of the Kei Islands, Southeast Maluku is spread across Fisheries Management Areas (WPP) 714 and 718 which include the Arafura Sea and waters around the Kei Kecil area. This water area has become a fishing area for flying fish eggs and is a fairly large producer of fish eggs in the period 2015 to 2017. During this period, the number of flying fish egg production fluctuated from year to year, fish egg production was lowest in 2015 was 36.29 kg, and the highest production results were in 2016, namely 81.90 kg, while in 2017 production was 78.65 kg (Figure 10).

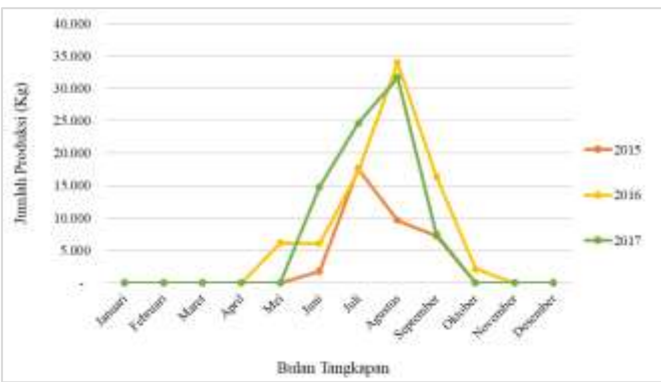

Figure 10. Production of Flying Fish Eggs in Kei Islands Waters

The catch of flying fish eggs shows that the amount of production produced is quite large every year, this has a direct impact on improving the fishermen's economy. This situation has spurred ongoing fishing activities for flying fish eggs. In general, fishermen fishing in the waters of the Kei Islands come from South Sulawesi and Southeast Sulawesi. The activity of catching flying fish eggs by local fishing communities has decreased sharply in the last 20 years. Fishing activities on a traditional scale have experienced a significant decline, with local fishermen even finding no results at all. These local fishermen need appropriate technological assistance to increase the efficiency and effectiveness of their fishing.

If studied based on the seasonal cycle, it can be seen that the production of flying fish eggs caught is generally at the end of the first transition season, the east season, up to the second transition season (May-October). Monthly production of flying fish eggs shows quite significant differences. Flying fish egg production peaks during the east monsoon. This significant production is supported by very high fishing activity in the east season. Many andon boats (flying fish egg fishing fleets) come to collect flying fish eggs even though they have to face high waves and extreme weather. The production of flying fish eggs fluctuates every year, indicating that the production of flying fish eggs in the waters of the Kei Islands is still quite productive.

The relationship between SST and chlorophyll-a with the distribution of flying fish eggs

Based on the description of flying fish egg production that has been presented above, it is known that the effective and efficient time for catching flying fish eggs in the waters of the Kei Islands takes place between June, July, August, and September (eastern season and transition season-II) throughout 2015-2017.

Fluctuations in flying fish egg production in the waters of the Kei Islands in the period 2015-2017 were caused by differences and dynamics in the oceanographic characteristics of the waters. According to (Hong et al., 2023), the dynamics of marine waters will cause a shift in fish abundance over a certain period in a water area which has an impact on the state of a fishery. Fish tend to be located or concentrated in environmental conditions according to activity, where fish environmental factors are related to biological and physical factors (Costa et al., 2022). The peak production of flying fish eggs in the east season and transition season II in the waters of the Kei Islands shows that there is a positive response of flying fish to the characteristics of seawater conditions, thereby encouraging flying fish to carry out optimal spawning. Environmental factors are the main indicators of changes in the abundance of pelagic fish in waters (Jghab et al., 2019). An overview of oceanographic parameter values that occur in June – September (eastern season and transition season II) is presented in Table 3.

Table 3. Statistical data on oceanographic parameters when catching flying fish eggs

Parameter	Year	Statistics					
		Min	Max	Average	Std	R-*Square*	Egg Production Fish
2015	SPL	23.82	29.25	26.54	3.84	0.50	36.287
	Chlorophyll-a	0.21	3.09	1.65	2.04	0.83	
2016	SPL	24.59	29.45	27.02	3.44	0.80	81.905
	Chlorophyll-a	0.10	2.67	1.39	1.82	0.89	
2017	SPL	23.82	31.96	27.89	5.76	064	78.65
	Chlorophyll-a	0.16	3.05	1.61	2.04	0.74	

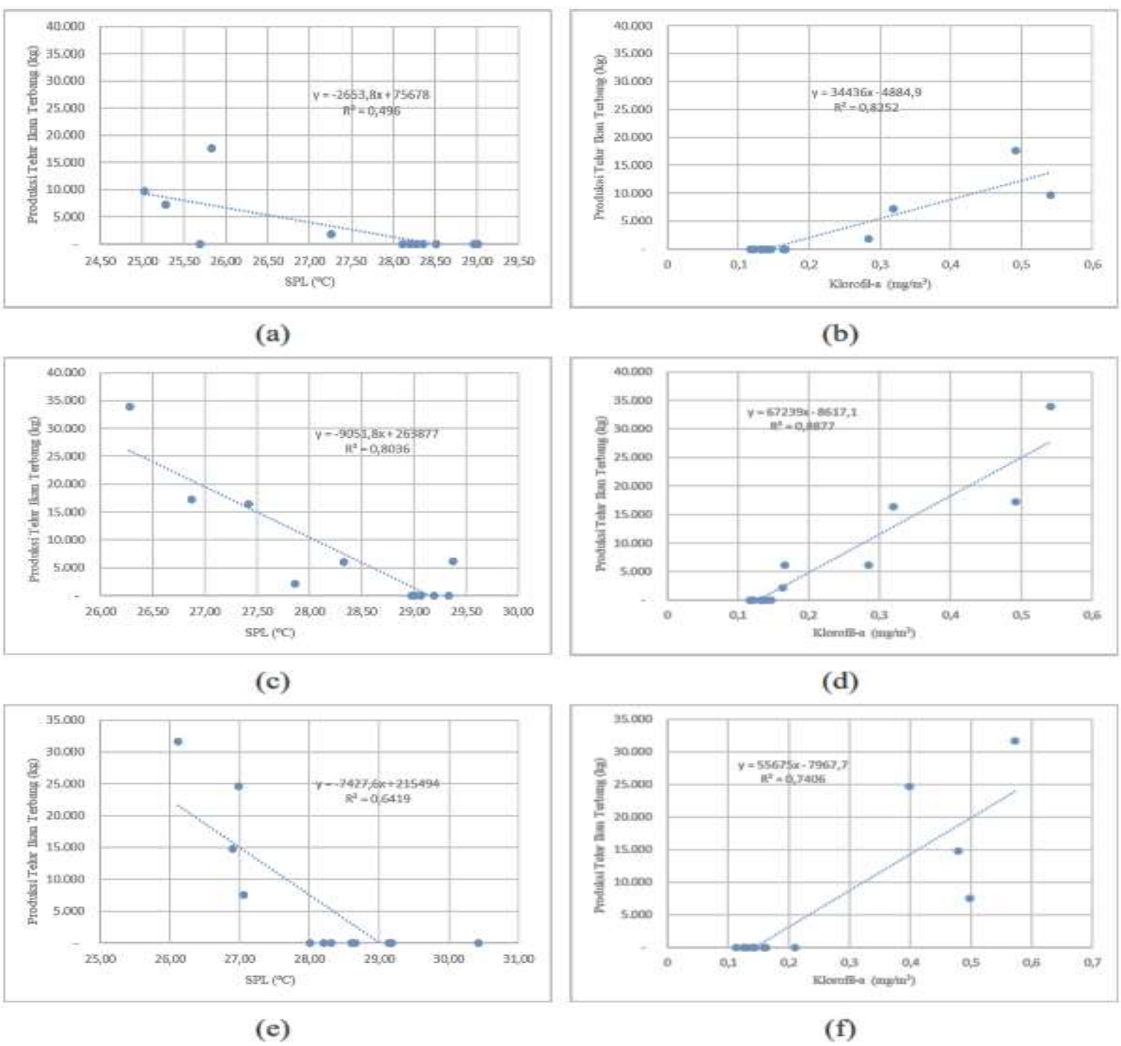

Figure 11. Relationship between oceanographic parameters and flying fish egg production in 2015 (a) SST, (b) Chlorophyll-a; 2016 (c) SPL, (d) Chlorophyll-a; 2017 (e) SPL, (f) Chlorophyll-a

The results of the regression analysis (Figure 11) show that the relationship between the SST and chlorophyll-a variables and the flying fish egg variable shows a very varied relationship based on grouping in each year. 2015 (Figures 11. a and 11. b) show that the SST correlation (0.49) has a moderate relationship. A strong correlation relationship was shown for chlorophyll-a of 0.82. A coefficient of determination approaching a value of 1 (one) and away from 0 (zero) means that the independent variables (oceanographic parameters) can provide all the information needed to predict the dependent variable (flying fish eggs). Thus, the distribution pattern of SST and chlorophyll-a shows dominance and significant influence on flying fish egg production.

Entering 2016 (Figures 11. c and 11. d), the analysis results provide a varied picture of correlation. The parameters SPL (0.80) and chlorophyll-a (0.88) show a very strong correlation. This analysis is supported by (Fadhilah et al., 2022) stating that the SST distribution and chlorophyll-a concentration can be used as indicators for the fertility of waters, and have a positive influence on fish catches. In 2017 (Figures 11. e and 11. f) you can see an SST correlation of 0.64 which is considered moderate. A strong correlation relationship is shown by the chlorophyll-a parameter of 0.74. Chlorophyll-a is the basis of the food chain which has an important role in the existence of fish in waters, so changes in the concentration of chlorophyll-a will affect the distribution of fish, especially small pelagic fish which require food in the form of phytoplankton (Nair et al., 2023). The shifting pattern of catching flying fish eggs in Kei Islands waters based on the annual cycle has a significant relationship with the temporal pattern of SST. The highest SST value in the east season was 31.96ºC (2017), while the lowest value was 23.80ºC (2015 and 2017). Generally, in the east season and transition season II, the SPL is seen to be much lower than in other seasons. The low SST is caused by an increase in water masses (upwelling) and the stirring (turbulence) of water masses generated by the southeast monsoon.

SPL has a very significant role in the value range of 0.50-0.80. This shows that cooler SST concentrations tend to have an impact on increasing the number of catches of flying fish eggs, and conversely if there is an increase in SST it will have implications for decreasing the number of catches. There is a tendency for flying fish to spawn optimally in the SPL range of 23.84-29.1ºC, this is in line with the increasing number of catches obtained in these conditions. When compared with environmental conditions in managing flying fish resources in Fak-Fak waters, SST concentrations have the same trend, where SPL concentrations range from 26.2-29.1ºC during the flying fish egg fishing season.

The chlorophyll-a content is closely related to the level of primary productivity as indicated by the large biomass of phytoplankton which is the first food chain for pelagic fish. The high chlorophyll-a content of a body of water can indicate that the water has a high level of fertility. (Syah et al., 2020), stated that chlorophyll-a is a factor that can provide a direct indication of the presence of fish food and pelagic fish migration routes. This is in line with the increase in chlorophyll-a concentration during the time (season) of catching flying fish eggs, where the highest chlorophyll-a concentration reached 3.09 mg/m^3 (2015), while the lowest value was 0.10 mg/m3 (2016).

Chlorophyll-a concentration has a very strong and very significant correlation in each fishing season, namely around ≥ 0.7. The strong correlation between flying fish egg production and chlorophyll-a concentration cannot be separated from the indication of strong upwelling which reaches a peak in July-August so that the waters will become water. According to (Maradhy et al., 2022), the average concentration of chlorophyll-a in Indonesian waters is approximately 0.19 mg/m^3, while the concentration of chlorophyll-a in Fakfak waters in June-September ranges from 0.201 - 2.13 mg/m3. Availability of sufficient food to produce fish at a higher level. This proves that the high value of chlorophyll-a is related to the production of flying fish eggs.

In general, the Kei Islands waters have become a fishing ground for flying fish eggs. Based on the results of observations, it was revealed that high-intensity flying fish egg fishing activities were taking place in areas that were centers of upwelling, both in areas near the coast and offshore. It was found that the locations for catching flying fish eggs were in the areas of Tanimbar Kei Island, Ur Island, Tayando Island, Warbal Island, and Taam Island. Fishing activities also take place in WPP 718, namely the water area between the middle of Kei Besar Island and the Aru Islands (Tual VAT data and interviews with fish egg fishermen). Besides that, the results of this research are supported (Benson et al., 2011) stated that the fishing area for flying fish eggs also takes place in the waters around the southern and western parts of Tanimbar Kei Island, as well as the northern part of Tayando Island and the waters around Kur Island. Thus, the entire territorial waters of the Kei Islands are a potential fishing area for flying fish eggs.

Flying fish tend to look for spawning grounds that have oceanographic characteristics characterized by low SST and high chlorophyll-a (Boli et al., 2019). Flying fish will also choose spawning grounds with clear waters, lots of floating objects, and the presence of Sargassum seaweed. Recently Pattorani fishermen have been assembling coconut leaves (bale-bale) as a medium for flying fish to lay their eggs so that they can directly catch flying fish eggs. Flying fish require a medium as a place to attach their eggs because the mass of flying fish eggs is heavier than the mass of seawater. The attachment of flying fish eggs to floating objects means that flying fish eggs do not sink, but can continue to float. On the other hand, this is a special way to avoid predators.

Conclusion

Based on the results of the research and discussions that have been carried out, several things can be concluded, including The characteristics of SST and Chlorophyll-a in the waters of the Kei Islands temporally show very high dynamics, thus making the waters of the Kei Islands a potential fishing ground and spawning ground for flying fish. The peak time for flying fish spawning occurs from June to September with water conditions having an SPL ranging from 23.82-31.96ºC and Chlorophyll-a ranging from 0.10-3.09 mg/m3. There is a strong correlation between SST and chlorophyll-a parameters with flying fish egg production. The peak of fish egg production is directly proportional to oceanographic dynamics which has a high level of significance. High chlorophyll-a concentration values and low SST concentrations have made the waters fertile and triggered the spawning of flying fish in Kei waters.

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Conceptualization; A. S. W. R., S. T., J. A. N. M., R. D. H., methodology.; A. S. W. R..; validation; S. T..; formal analysis; J. A. N. M.; investigation.; R. D. H.; resources; A. S. W. R; data curation: S. T.; writing—original draft preparation. J. A. N. M.; writing—review and editing: R. D. H.; visualization: I. W. S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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