# Identification of potential areas for upwelling based on characteristics of eddies event in the Bone gulf

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# Identification of potential areas for upwelling based on characteristics of eddies event in the Bone gulf

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**Abstract**. The Bone Gulf is one of the waters with massive potential for catching pelagic fish. The potential for catching fish is associated with oceanographic events in the waters. This study aims to see the potential for upwelling in the eddy occurrence areas. The spatial analysis method will be used to see the potential for upwelling in the area of the eddy occurrence and will be associated with sea surface temperature parameters and chlorophyll-a as a fertility variable. The results of this study indicate that eddy events occur every month in the Bone Gulf waters. In addition, it can be proven that every eddy occurrence is not a guarantee for the emergence of upwelling areas simultaneously. However, several eddy events with high current velocities were seen to cause a decrease in temperature in the middle of the eddy and increase the chlorophyll-a concentration in that area. In addition, the suitability of this event is also shown from the time of upwelling, which occurs several months before the peak month of fishing in the Bone Gulf. This research is expected to be the basis for the sustainable development of fisheries.

## 1. Introduction

The Bone Gulf is one of the fertile waters with abundant capture fisheries production potential [1]. This is inseparable from the geographical conditions of The Bone Gulf, which is semi-enclosed waters and close to the equator [2,3]. This type of water usually has its characteristics besides that these waters are bordered by other fertile waters such as the Flores Sea and the Banda Sea, which of course, also significantly affect the oceanographic characteristics that occur in the Bone Gulf [4,5].

Naturally, the ocean has a very dynamic nature, spatially and temporally. Various kinds of physical, chemical, and biological events look complex, forming various habitats of organisms with their respective characteristics [6]. The most important indicator that must be known to study an organism is the habitat. For the fisheries sector, habitat is usually associated with environmental conditions or oceanographic factors [7]. Hotspot areas are described as areas with high biological activity and are associated with dynamics of environmental factors so that they have an essential role in controlling the distribution and migration of marine organisms [8–10]. Several oceanographic parameters show a positive response to identifying the presence of fish in the ocean. Sea surface temperature, chlorophyll-a, and primary productivity are related to the distribution of organisms in the waters [11].

As the leading indicators in this study, sea surface temperature and chlorophyll-a are two parameters that can be used to increase capture fisheries production. Sea surface temperature is closely

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related to upwelling, downwelling, and front events, which are usually indicators of the presence of tuna species [12]. Meanwhile, chlorophyll-a is an indicator of the fertility level of the waters, which of course, is related to predation cases that occur in the waters [13–15]. In Zainuddin et al., 2017 [16] study, skipjack tuna can be identified at a concentration of 0.2 mg $m^{-3}$. Meanwhile, if it is related more, such as current speed, water surface height, or eddy distribution, it will also be closely related to water fertility which will identify the presence of fish [17–19].

Eddy event can cause upwelling and downwelling along with the occurrence of El-Nino and La-Nina [20,21]. Upwelling and downwelling events will also significantly affect the nutrient fertility level in the area where they occur [22]. With a large area and oceanographic data that makes it very difficult to predict the presence of fish using the observation method, the utilization of data through remote sensing facilities currently being developed is very effective in supporting the determination of fish hotspots in the waters. This research was conducted to see the potential for upwelling at specific locations in the waters of the Bone Gulf, which is expected to be the basis for forming a fishing calendar at this location.

## 2. Material and methods

### 2.1. Study area

The research was conducted in the waters of The Bone Gulf, using remote sensing methods. Site determination in The Bone Gulf is based on references to eddy occurrences in these waters. Spatially observations were made in two areas (sites a and b) in the Bone Gulf as shown in Figure 1.

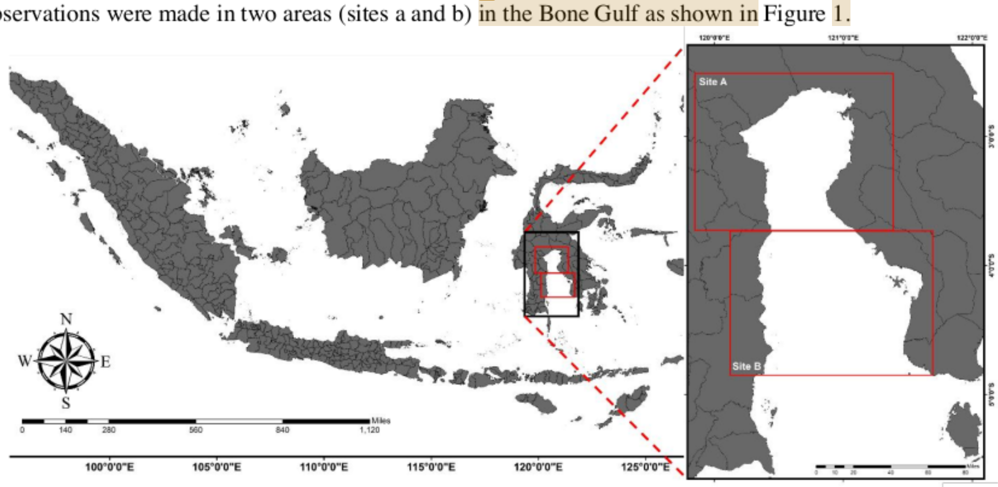


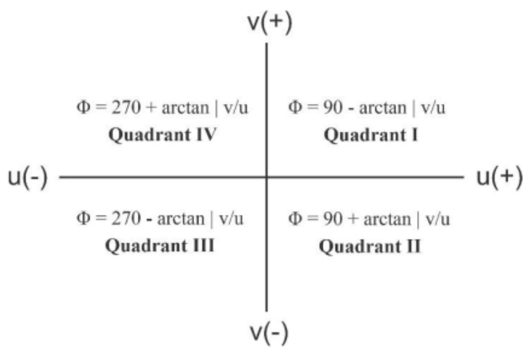

**Figure 1.** Study area at Bone Gulf.

### 2.2. Material

This study uses oceanographic time-series data from 2010 to 2019 to reference data focused on 2021. The primary data is monthly data from January to December 2021. The research location is the Bone Gulf watering with certain limits (two sites). Oceanographic data used is sea surface current data with a spatial resolution of 1/12° or 9KM and monthly temporal origin from Marine Copernicus (https://marine.copernicus.eu/), while upwelling predictor data using sea surface temperature data and sea surface chlorophyll with a spatial resolution of 4KM and monthly temporal originating from Ocean Color (https://oceancolor.gsfc.nasa.gov/). All data were processed using SeaDAS and ArcGIS applications with spatial analysis techniques.

### *2.3. Eddies event identification*

The determination of the direction of the eddies is a factor in the initial indication of the occurrence of eddies in the waters. These characteristics will separate the eddy type at the research location. Based on the characteristics of the eddies, the eddies are classified into two types: cyclonic eddies and anti-cyclonic eddies. This type of eddy also shows a difference where cyclonic eddies in southern latitudes will produce areas that have the potential for upwelling, then vice versa for anti-cyclones. In determining the direction of the current in the waters, the following formula is used:




Where:
Φ = current position
V = current velocity to longitude
U = current velocity to latitude

In addition to the current's direction, the current's speed is also very influential on the occurrence of eddy events in the waters. Current velocity will play a crucial role in the energy transfer process in the waters, which will be a variable in identifying the increase in water productivity. The average geostrophic velocity of the eddies can be calculated using the following formula:

$$c = \left(u^2+v^2\right)^{\frac{1}{2}} \tag{1}$$

Where:
c = The resultant speed of geostrophic current (cm/s)
u = Geostrophic current U component (cm/s)
v = Geostrophic current V component (cm/s)

## 3. Results and discussion

### *3.1. Characteristics of current patterns in Bone Gulf*

The current velocity in the Gulf is so slow, and the highest speed is only 0.35 m $s^{-1}$ compared to other waters in WPP-NRI 713. The current movement pattern in Bone Gulf seems to come from one source, namely the southern waters. In April, the average current flow pattern from the north of the Bone Gulf out to the south of the Bone Gulf in several areas also created a back eddy to the north at a relatively low speed of only ± 0.1 m $s^{-1}$ (Figure 2). In August, there was an increase in speed up to ± 0.25 m $s^{-1}$ and continued to increase in the following month. Then also seen in August, the intervention of current flow from the direction of the Banda Sea began to enter the waters of the Bone Gulf. In October (Figure 3), there was a change in the direction of the current in the previous month. The direction of the current came from east to west; this month, the current direction changed from west to east. In addition, in October, it was also seen that currents from the Flores Sea began to enter the waters of the

Bone Gulf, which immediately joined the vortex that formed in the middle of the waters of the Bone Gulf.

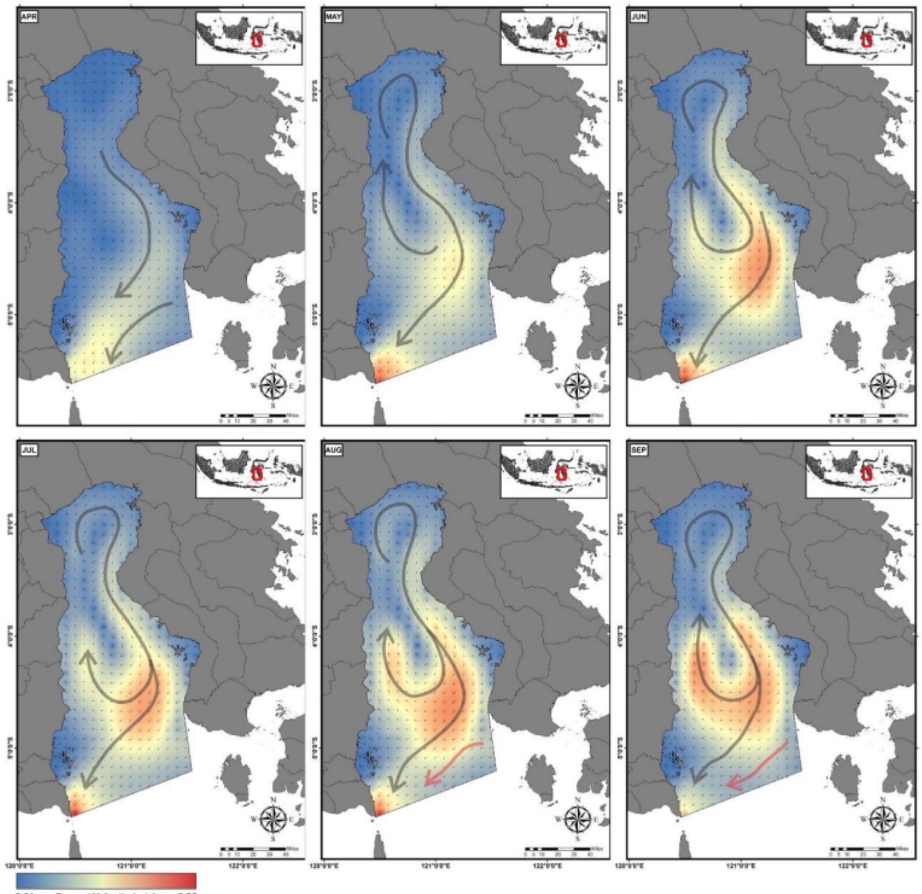



**Figure 2.** The average current movement in April – September in the Bone Gulf. The imaginary black line is the direction of the current originating from Bone Gulf, while the red is in the direction of the current originating from the Flores Sea and the waters south of Bone Gulf.

The incoming current seems to be deflected by the flow of water from the north of Bone Gulf, causing some water discharge to come out again towards the Banda Sea. This event occurred until February, and there was also a decrease in the current velocity in the eddies in the Central part of Bone Gulf. So that in March, it was seen that there were two intersecting eddies, namely the eddies caused by currents from the northern part of Bone Gulf (site a) and those originating from the Flores Sea in the Central part of the Bone Gulf (site b).

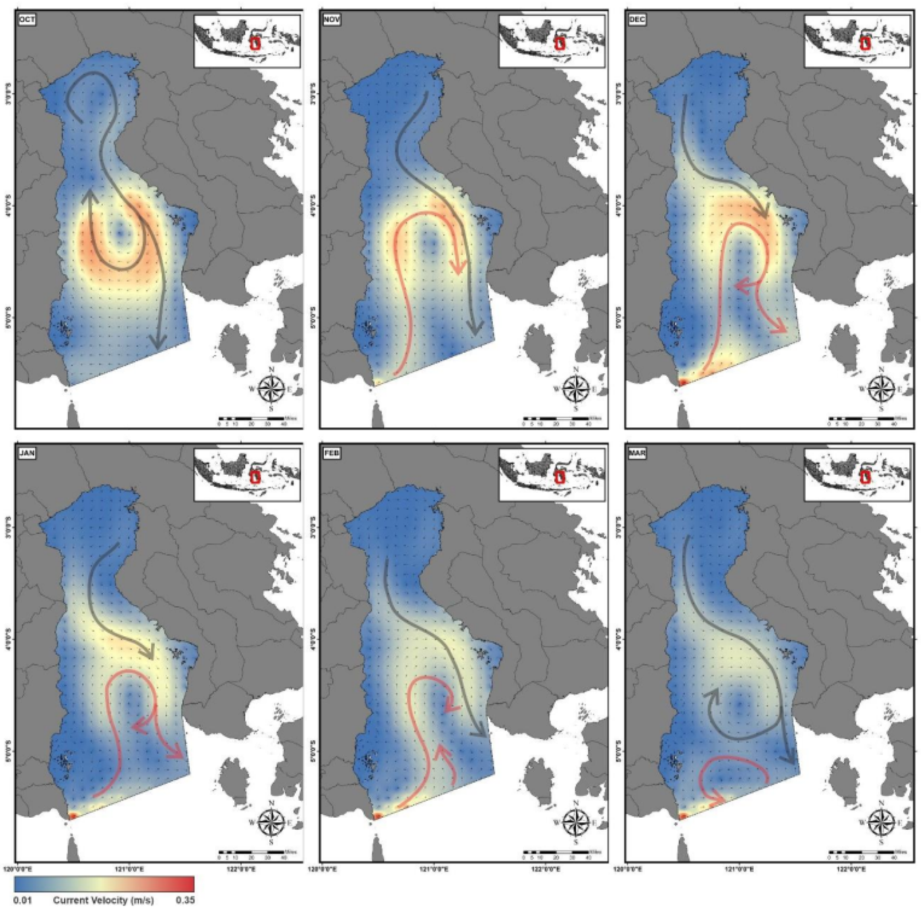



**Figure 3.** The average current movement in October – March in the Bone Gulf.

### *3.2. Eddies event relation with sea surface temperature and chlorophyll-a*

Eddy pumping, which brings beneath high-nutrient water to the surface, is the most common cause of phytoplankton blooms induced by cyclonic eddies [23]. Phytoplankton blooms have also been documented in anticyclonic eddies [24], where the upper ocean nutrients were reduced due to a weak vertical nutrient supply. As the wind picks up, eddy-Ekman pumping causes SSC levels to rise [25]. Anticyclonic eddies can boost the amount of SSC in eddies by 10% in the southeastern Indian Ocean, although the usual SSC enrichment produced by an anticyclonic eddy is significantly smaller than that produced by a cyclonic eddy [26].

The decrease in sea surface temperature in the area where the eddy occurs combined with the increase in the SSC concentration in the waters can identify upwelling events. This event can be shown in Figures 4 (site a) and 5 (site b). The eddies in these two areas are also accompanied by oceanographic characteristics supporting upwelling. This event occurs especially from July to September.

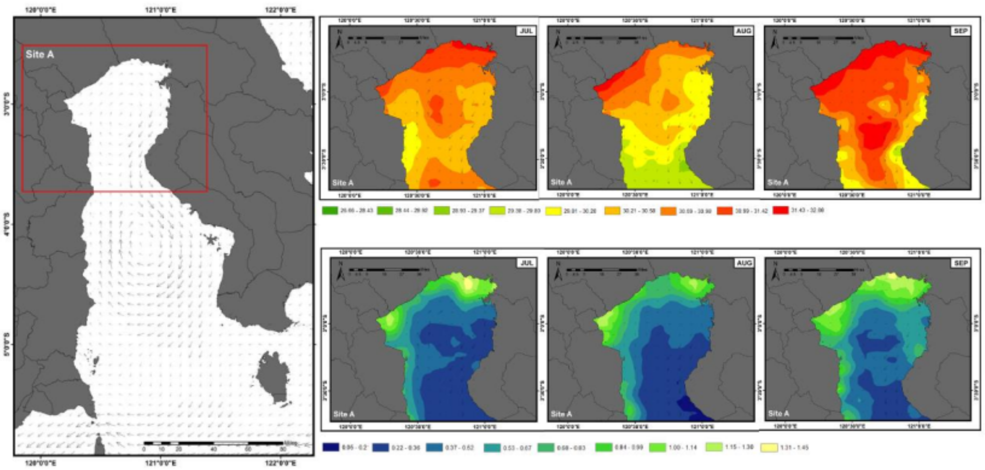


**Figure 4.** relationship of eddy event and characteristics of SST (top) and SSC (bottom) from July to September in the northern part of the Bone Gulf (site a).

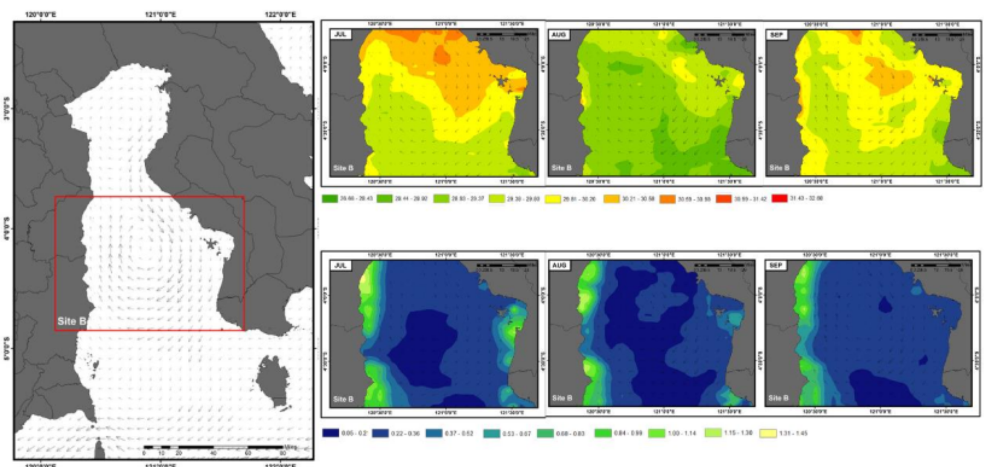


**Figure 5.** relationship of eddy event and characteristics of SST (top) and SSC (bottom) from July to September in the northern part of the Bone Gulf (site a).

### *3.3. Potential upwelling event*

Based on the spatial characteristics shown in Figures 4 and 5, an analysis of the current velocity that occurs on the value of SST and SSC concentration is also carried out with a positive focus from July to September. Observation of SST value and SSC concentration is undoubtedly closely related to the potential for upwelling. In addition, previous research data also illustrates if the value of catch fishery production in Bone Gulf reached its peak in October. The results of this study look exciting when associated with data visualization results in July and September.

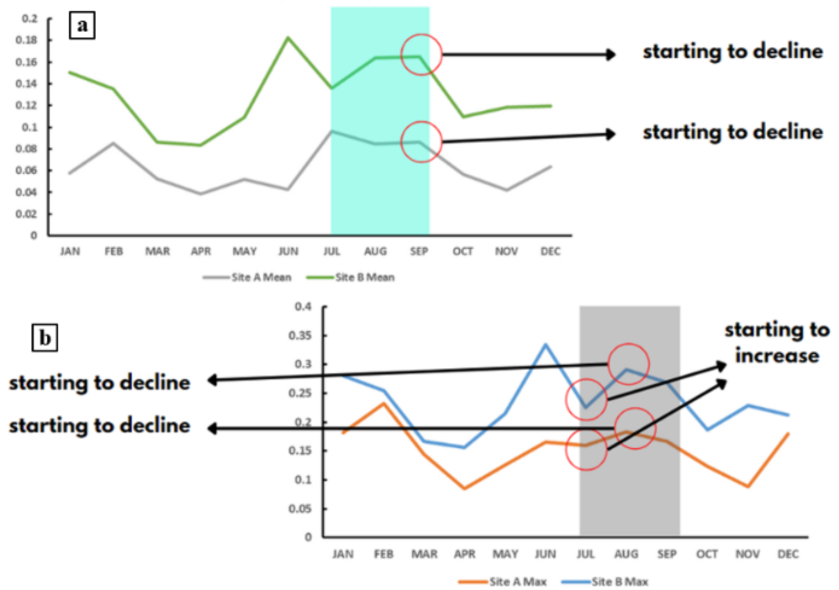



**Figure 6.** the average current velocity (a) and maximum current velocity (b) in the area of eddy occurrence in Bone Gulf in January - December 2021.

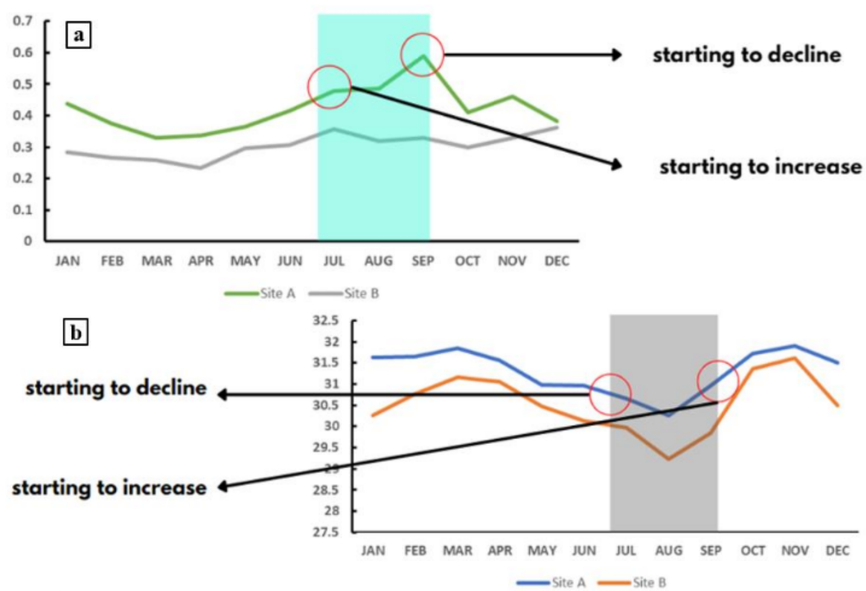



**Figure 7.** The average concentration of SSC (a) and SST value (b) in the area of eddy occurrence in Bone Gulf in January - December 2021.

The current velocity in the Bone Gulf is not as fast as in Makassar Strait. The event can be seen from the highest current velocity, which was only ±0.18 m $s^{-1}$ in January and August at site a and ±0.29 m $s^{-1}$ in August at site b. The same is also shown for the average current velocity, with the highest value of only ±0.1 m $s^{-1}$ at the site a and ±0.18 m $s^{-1}$ at site b in 2021(Figure 6).

Figure 7 shows exciting events that occurred during the month of observation focus. SSC showed a continuous increase in concentration from July to September (Figure 7a) and was followed by a decrease in SST values in the same month (Figure 7b). This characteristic shows an indication of upwelling in this region. In addition, the eddies from July to September also showed reasonably good consistency with an increasing speed from the previous month (Figure 6).

The event of a decrease in temperature value followed by an increase in nutrients was identified as one of the valid indicators to suspect the upwelling phenomenon in the waters [27–29]. In addition, the short time difference in semi-enclosed waters also confirms why the amount of capture fishery production in Bone Gulf tends to increase in October. However, this preliminary study aims to pave the way for further research in developing an analysis to find the best location and the best time to fish. So with supporting research results, it will undoubtedly have a good impact on fishers in terms of cost and effort in carrying out fishing operations and can support sustainable fishing.

## 4. Conclusions
The Eddy event is not a guarantee for the emergence of upwelling areas simultaneously. However, several eddy events with high current velocities were seen to cause a decrease in temperature in the middle of the eddy and increase the chlorophyll-a concentration in that area. In addition, this event is also shown from the time of upwelling, which occurs before the peak month of fishing in the Bone Gulf.

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