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The use remote sensing technology to determine the distribution of small pelagic fish in IFMA 713

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Abstract. This study aimed to better understand the effect of oceanographic parameters on the spatial distribution of small pelagic fish (SPF) in Indonesia Fisheries Management Area (IFMA) 713. This research is a preliminary study in identifying preferences habitat for SPF by using some oceanographic parameters (i.e. depth, sea surface temperature (SST), and sea surface chlorophyll-a (SSC)). The depth data was gained from The ETOPO2 satellite database. Furthermore, the SST and SSC data were derived from Terra/MODIS. Fish finder was used to detect and determine the position of fish schooling in the water column and provide water depth information. The In-situ data collected from June to August 2020 in Makassar Strait and Bone Gulf by followed the fishing operation by lift net gear in the Spermonde Island waters and Luwu Regency waters, respectively. The fishery data and oceanographic satellite imaginary overlay and mapped using Geographic Information System techniques. The result founded that the SPF distributions, which is dominated by anchovies, sardine, scad, and mackerel, occupied areas with range from 30.0 to 31.0 °C SST with corresponding with SSC of 0.30 to 0.50 mg/m^{-3}, and inhabit the water depth in inshore areas with the fish swimming layers mostly in maximum depth at 20 m or less based on fish finder recording display. This information is needed for the sustainable management of small pelagic fish in IFMA 713.

1. Introduction

Indonesian waters are one of the potential areas for exploiting marine fish resources in the world, this is because these waters are the migration path for pelagic fish which are economically important fish. In order to the existence of these fish resources can be used as strategic assets to be utilized for the prosperity of coastal communities and increase in state revenue from the fisheries and marine sectors. However, in developing the utilization of marine fisheries resources, there are many obstacles encountered by capture fisheries actors including monitoring changes or dynamics of the marine environment in Indonesian waters and their relationship with fish distribution and abundance [1–4].

This is an important and urgent step to be carried out immediately, especially in relation to the availability of data, information, and how to build a strongly capture fisheries information system for the utilization of this economically important fish resource. Furthermore, for utilize marine fish resources in a sustainable manner, a method with a reliable approach is needed using the latest technology and the quality of information provided is more accurate. Remote sensing technology is a method for measuring, identifying, and recording the presence of an object or information remotely. In an effort to obtain information about objects from a distance without direct contact with the object. Remote sensing technology has been applied to the world's marine fisheries industry either by using

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hydroacoustic equipment (acoustical remote sensing) or by using satellite technology (satellite remote sensing) or by combining these two technologies for optimal utilization of fishery resources [5].

In this research, a trial of the application of hydroacoustic technology was carried out to understand the distribution of economically important fish such small pelagic fish and supported by oceanographic satellite imagery data to reveal the optimum habitat of various economically important species that exist in the IFMA 713 which includes the waters of the Bone Gulf, Flores Sea, Bali Sea, and Makassar Strait. The purpose of this research is to provide information on the distribution and abundance of small pelagic fish in relation to dynamics of oceanographic factors derived from satellite remote sensing technology in the IFMA 713. This research is very important to provide data and information related to the fish abundance and distribution in spatially and temporally in the area of IFMA 713 in order to fishermen or the fisheries industry can manage the fishing calendar, including the fishing gear that will be used. This is important and needs to be done to greatly support the sustainable management of capture fisheries.

2. Research methods

The research location was IFMA 713 as shown in Figure 1. In this reseacrh, the data used consisted of two groups, namely main data and supporting data. Main data collection is done through direct observation or measurement in the field. In-situ data required are acoustic data, oceanographic parameters data, latitude and longitude position data using GPS, fishing technology, kind, size and number of catches. Fish position in the water column as well as water depth were recorded by using a fish finder 350C, Garmin. Supporting data is sourced from the NASA data base using remote sensing technology (Terra / MODIS satellites, http://oceancolor.gsfc.nasa.gov/ and ETOPO2, http://www.ngdc.noaa.gov/) were analyzed with information system techniques [6]. Supporting equipment in the form of a computer unit equipped with spatial data processing software (base map, R Program 4.0.3, SeaWiFS Data Analysis System, and ArcGIS 10.2, ocean data view 5.4.0) to process, analyzed, and visualized data.

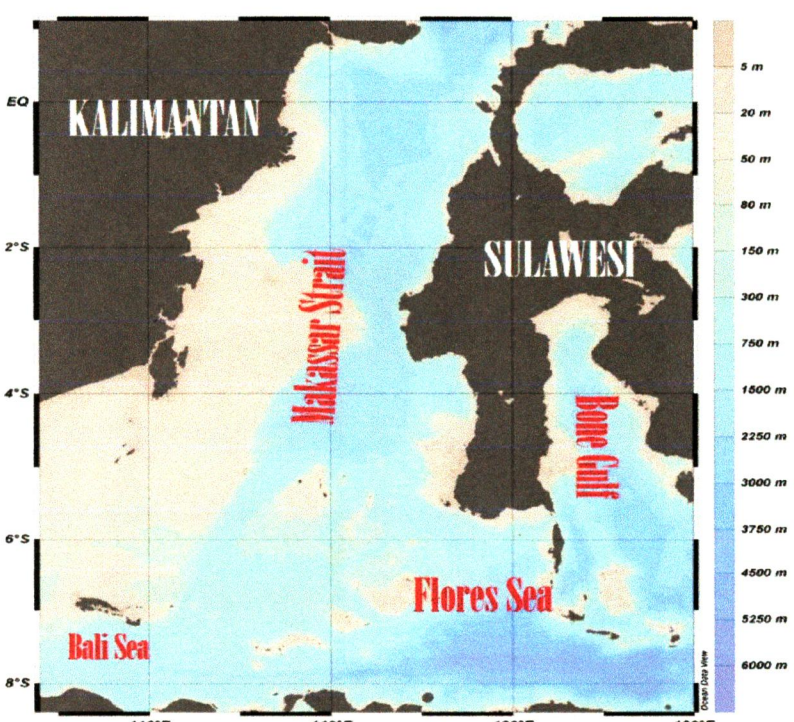

Figure 1. The Study Area of Fisheries Management Areas 713, Indonesia.

The distribution of economically important fish species is important in relation to the dynamics of the

parameters of oceanographic conditions such as water depth, sea surface temperature, and sea surface chlorophyll-a in IFMA 713 analyzed using the statistical model (Generalized Additive Model, GAM)) [6]. The results of the statistical model created will obtain the range of values for the oceanographic parameters as the preferred habitat for small pelagic fish (SPF) in the study areas.

3. Result and Discussion

3.1. Fishery and Oceanography data

Fishing activities were carried out from June to August 2020 as many as 140 trips consisting of 75 trips with a total catch of 8,461 kg in the Makassar Strait waters and 65 trips in the coastal waters of the Gulf of Bone with a total catch of 13,948 kg. The catch is SPF which is dominated by anchovies, sardine, scad, and mackerel. The fishing position is then overlaid with satellite image data which includes SST data, SSC and the depth of the waters.

The environment in which fish lifes is very dependent on the oceanographic conditions in these waters. Therefore, knowledge about the conditions and changes in oceanographic factors spatially and temporally is needed to determine the fishing area accurately. Besides being influenced by the kind of fish that is the target of the catch, the fishing ground is also determined by changes in water depth. In Figures 2 - 4, it can be seen that the fishing area spatially and temporally monthly in IFMA 713. The fishing ground of small pelagic fish generally occur in inshore areas in the Makassar Strait and in the Bone Gulf.

One of the oceanographic factors that greatly affects the distribution and abundance of fish is sea surface temperature (Figures 2 to 4). The sea surface temperature in IFMA 713 during the study was 27.33 - 32.47 °C. Based on Figures 2 - 4, it can be seen that the distribution of SST from June to August 2020 is overlaid with the fishing ground positions. Spatially, the IFMA 713 area and its surroundings have a higher sea surface temperature than other water areas. Based on the temporally, the highest SST in IFMA 713 was found in June and gradually decreased in SST until August 2020 as clearly shown in Figures 2 – 4. Water mass penetration with a relatively low temperature originates from the southern region, namely around the Flores Sea towards the north so that the contrast distribution of surface temperature is clearly visible in that area (Figure 4). Based on the results of research from various references, in general there is no fixed fishing area, always changing and moving according to the movement of environmental conditions, which naturally the fish will choose a more suitable habitat. Meanwhile, these habitats are strongly influenced by oceanographic conditions or parameters such as sea surface temperature, chlorophyll-a, water depth [6–9]. This affects the dynamics or movement of sea water both horizontally and vertically, which in turn affects the distribution and abundance of fish.

Besides from SST, the conditions of the aquatic environment with high chlorophyll-a concentrations are very influential and support the life and development of fish in certain areas, especially SPF with the main prey of plankton [6,10]. In coastal areas usually have high primary and secondary productivity so that fish abundance is found at lower tropic levels to middle tropic levels. The concentration of chlorophyll-a in the water column is highly dependent on the presence of nutrients. Nutrients have low and variable concentrations at sea level and their concentrations will increase with increasing depth and will reach maximum concentrations around the bottom of the water. The chlorophyll-a concentration range during the observation was in the range 0. 1 – 2.0 mg / m^{-3}.

The highest chlorophyll-a was found in June 2020 and the lowest occurred in August 2020 (Figures 2 - 4). High and consistent concentrations of chlorophyll-a were found every month in coastal waters throughout IFMA 713, especially around the territorial waters of Luwu Regency, Sinjai Regency, Spermonde Islands and waters of Takalar Regency and its surroundings. Where as, in the off shore area, it tends to be relatively lower SSC concentration. The high concentration of chlorophyll-a in coastal areas is influenced by the availability of sufficient nutrients for phytoplankton photosynthesis. The distribution of chlorophyll-a density in the sea varies geographically and based on water depth. These variations are caused by differences in sunlight intensity and nutrient concentrations in waters.

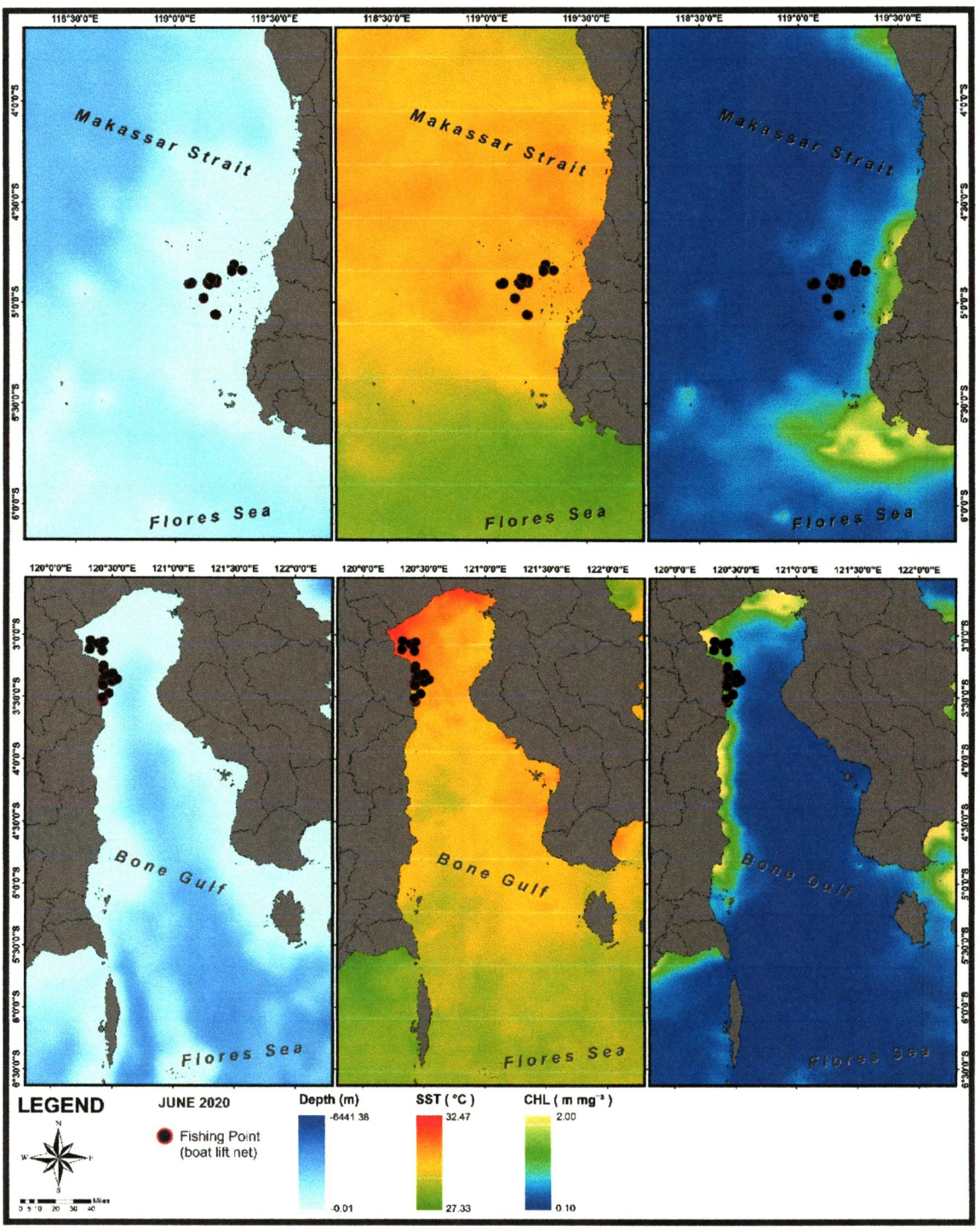

Figure 2. The depth, SST, and SSC parameters overlay with SPF fishing grounds in June 2020. The fishing grounds are in the Makassar Strait (above) and Bone Gulf (below).

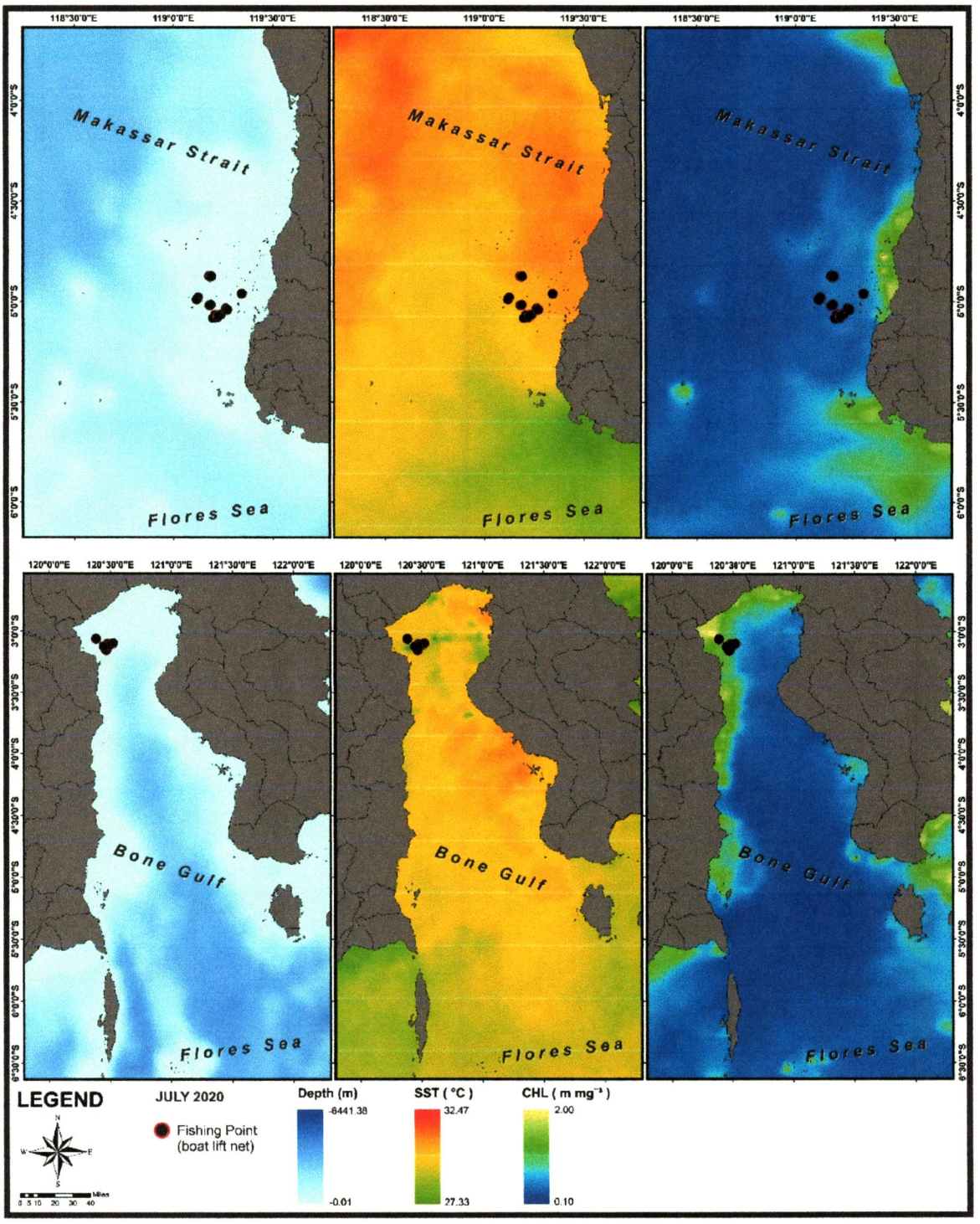

Figure 3. The depth, SST, and SSC parameters overlay with SPF fishing grounds in July 2020. The fishing grounds are in the Makassar Strait (above) and Bone Gulf (below).

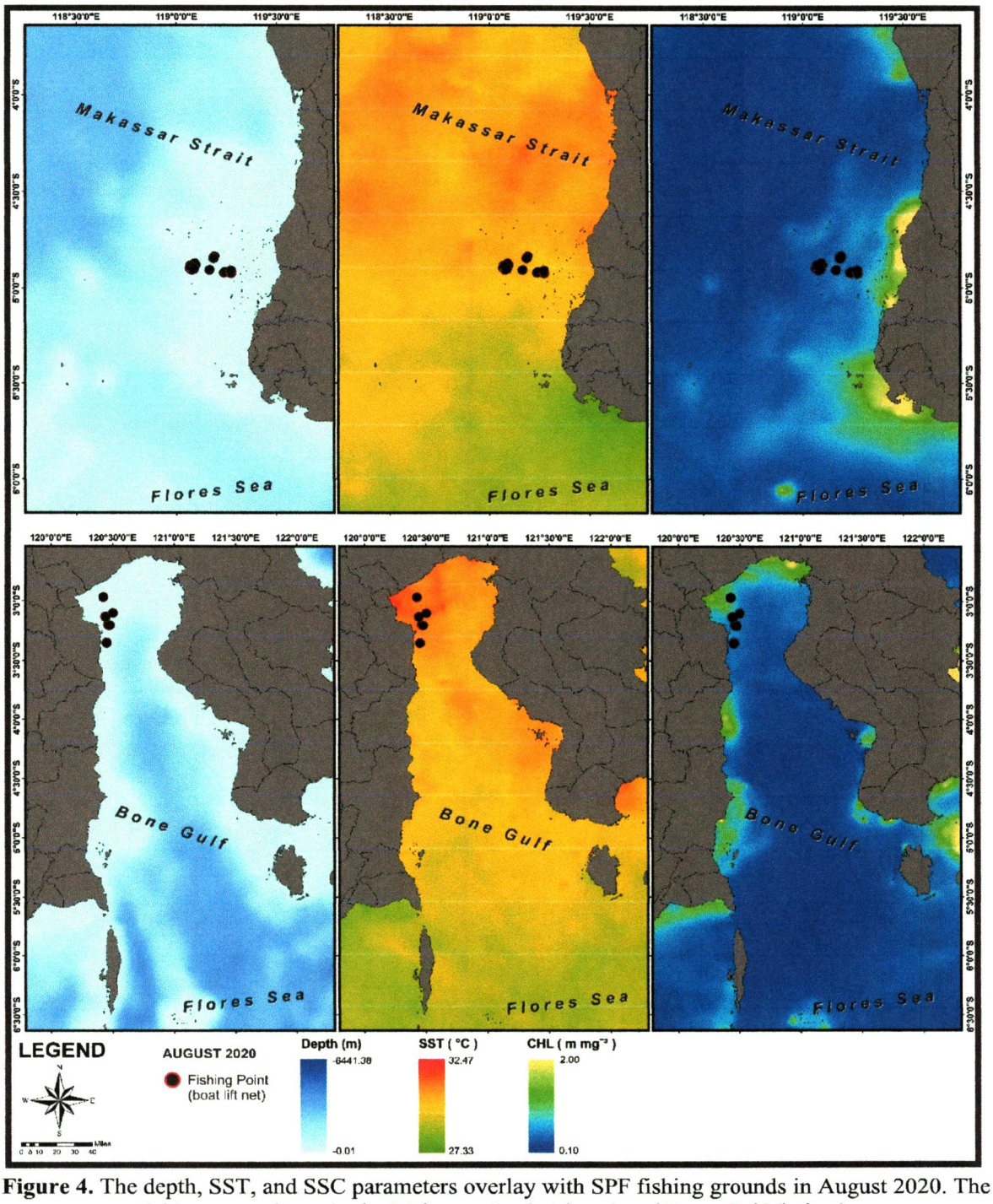

Figure 4. The depth, SST, and SSC parameters overlay with SPF fishing grounds in August 2020. The fishing grounds are in the Makassar Strait (above) and Bone Gulf (below).

The relationship between oceanographic factors and the distribution of SPF in the Makassar Strait and Bone Gulf areas as presented in Figure 5. The fishing grounds tend to be permanent, meaning that local fishermen who are traditional fishermen catch fish in relatively the same fishing area close to the fishing base, in the area around the coastal or around the island which is their fishing base locations (Figures 2-4).

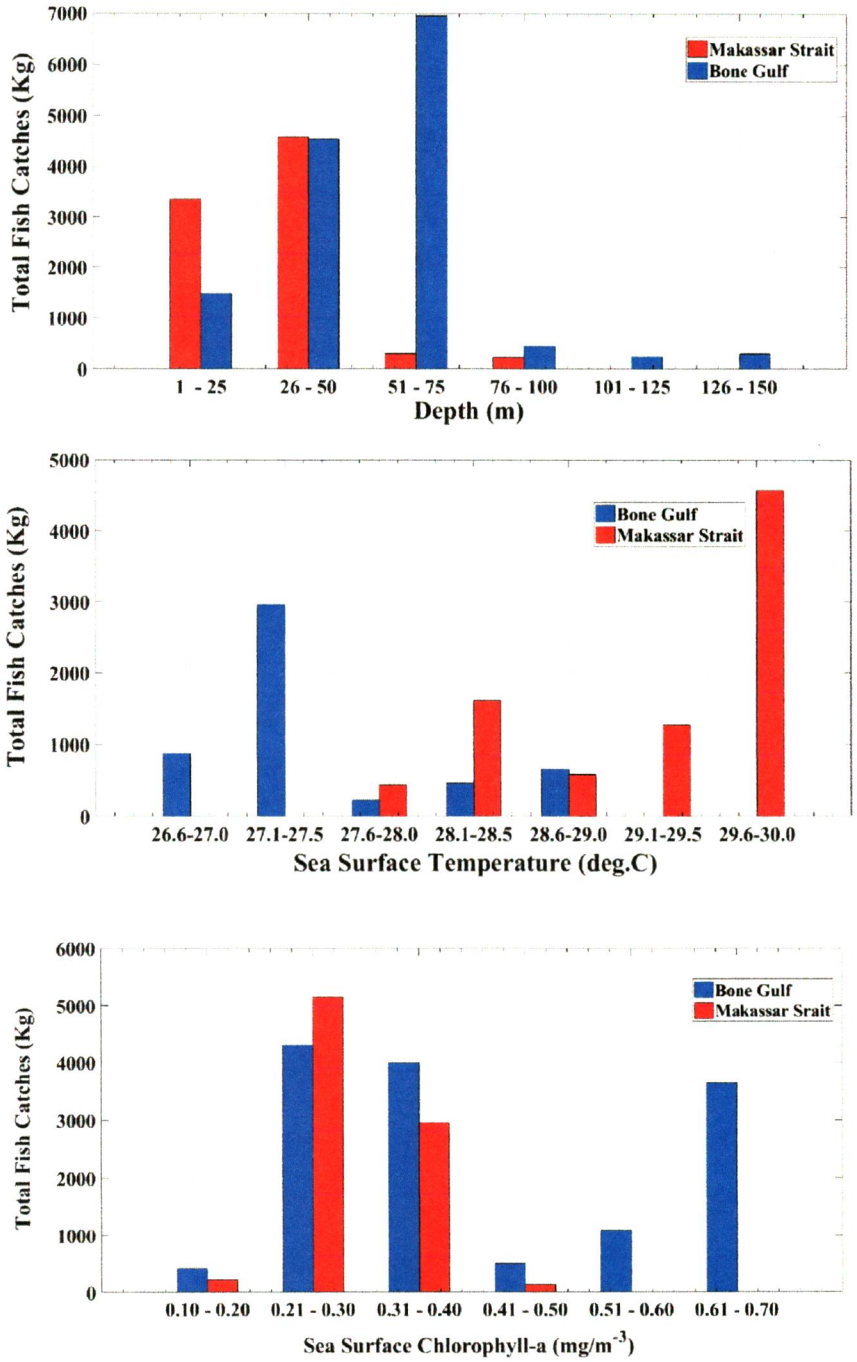

Figure 5. The relationship between Depth, SST, and SSC (from above to below) with the total fish catches of SPF in the Makassar Strait and Bone Gulf, respectively.

Small pelagic fish tend to occupy relatively deep spaces in the waters of Bone Gulf with relatively low temperatures, on the other hand in the Makassar Strait waters. However, they tend to be caught in large amounts at chlorophyll-a concentrations in the same relative range of 0.21 - 0.40 mg / m^{-3}). Furthermore, the results of Generalized Additive models to understand the effects of oceanographic condition in relation to SPF distribution are presented in Table 1.

Table 1. Results of GAM derived from SPF catches as a function of oceanographic parameters (n = 139).

Model	Parameter	CDE (%)
Catch~ s(depth)	Depth	11.6**
Catch~ s(sst)	SST	14.7***
Catch~ s(ssc)	SSC	16***
Catch~ s(depth) + s(sst) + s(ssc)	SST, SSC, Depth	16.4***

*** indicated statistical significance at the level 0.001 level

The best model was selected on the basis of the significance of predictor terms and increase in cumulative deviance explained (CDE). As showed in Table 1, all the observed oceanographic parameters have a significant effect on the distribution of SPF in the waters. The concentration of chlorophyll-a gave a greater positive effect on the presence of fish. The combination of three oceanographic parameters is the best model to predict the presence of small pelagic fish in the waters. This is because plankton is the main food for small pelagic fish [9]. The oceanographic parameters analyzed in this study played important role in the distribution. The numbers represented preferences in defining optimal habitat of the commercially important fish [4], especially for SPF distributustion and abundance in the IFMA 713.

3.2. Acoustic Data

It is well known that fish stock estimation is very important information for ecosystem-based fish resource management. Fortunately, this demand coincides with developments in the field of fisheries acoustics which are very promising in many parameter measurements in the field of fisheries and marine, including monitoring of marine environmental ecosystems [11]. The use of underwater acoustic technology has been able to detect and determine the position of fish schooling in the water column and provide water depth information [5]. Therefore, this equipment has been able to increase the effectiveness of fishing by using left net. Recording and observation activities using acoustic technology at frequency of 200 kHz are carried out prior to fishing operations in several fishing areas as shown in Figure 6.

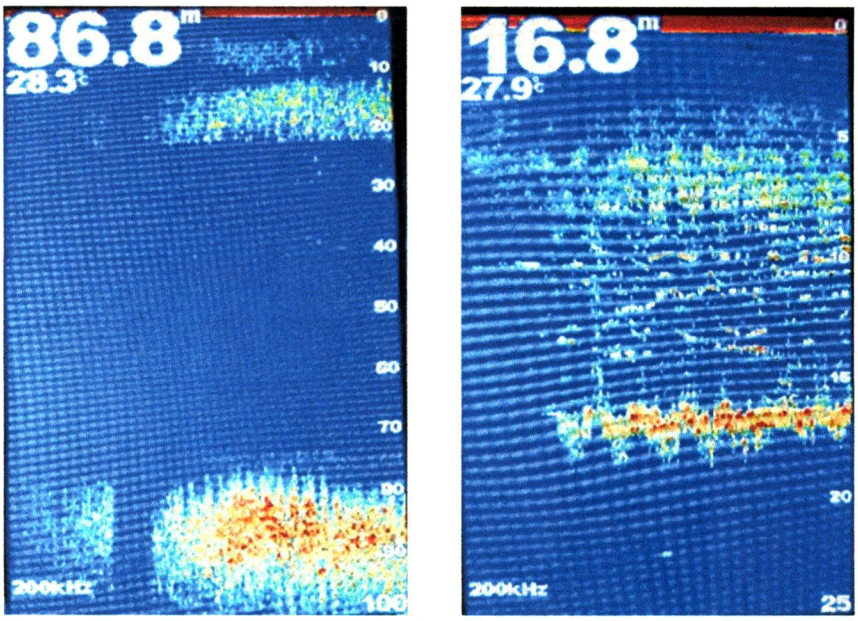

Figure 6. The echo traces of the SPF on the echogram at different depths. Fish finder recording provided information such as sea surface temperature, depth, and fish schooling positions.

Figure 6 showed that SPF distribution tends to made schooling at the depth of fewer than 20 meters from the water surface. Based on the swimming layer, it is possible for this group of fishes to be caught using various types of fishing gears such as purse seine, gill net, and lift net which the main species target is SPF.

4. Conclusion

The results above are preliminary funding in identifying preferences habitat for small pelagic fish in relation to water depth, sea surface temperature, sea surface chlorophyll-a parameters. The researches noted that the commercially important fish such as SPF distributions were relatively higher in 30.0 to 31.0 °C SST with corresponding with SSC of 0.30 to 0.50 mg/m^{-3}, and inhabit the water depth in inshore areas with the fish swimming layers mostly in maximum depth at 20 m based on fish finder recording information. This information is needed for the sustainable management of small pelagic fish in IFMA 713.

Acknowledgments

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