Seasonal changes of potential fishing ground formation for Skipjack Tuna in the Bone Gulf, Indonesia

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Abstract. Skipjack tuna (Katsuwonus pelamis) plays an important role by pole and line fishery in the Bone Gulf, Indonesia, since it has a high economic value and wide market acceptance. The purpose of this paper was to assess the seasonal changes of skipjack tuna potential fishing ground in the Bone Gulf. We used pole and line fishery and oceanographic data of sea surface temperature (SST) and chlorophyll-a derived from satellite to figure out the seasonal formation of the potential fishing areas. We developed the spatial model to determine the potential fishing ground based on different levels of oceanographic preferences. The results showed that potential fishing grounds were mostly formed in the first transition season (particularly in May) as well as the west season (especially in November), which have a good association with the specific SST and chlorophyll-a of near 30 Deg C and 0.2 mg m-3 , respectively. Most of the potential skipjack fishing ground formation developed along with the specific oceanographic signatures. It was likely that the potential seasonal changes of fishing grounds corresponded with enhanced feeding opportunity distribution pattern for skipjack schools. This suggested that these potential areas play an important for conservation and skipjack fishing management within the study area.

1. Introduction

The Gulf of Bone, located in the central Indonesian Seas, is one of the most biologically productive skipjack fishing grounds in the western Coral Triangle area [1]. The study area has specific bathymetric features (shallow waters in the northern area and deep waters in the south). In terms of biological productivity, this area is very important for several commercial pelagic species since it is strongly affected by the three ecosystem types (coral reef, mangrove, and seagrass). This area is also strongly influenced by a tropical monsoon type of climate, resulting from the Asia-Australian monsoon wind systems, which change the wind direction according to the seasons, i.e., southeast monsoon and northwest monsoon [2]. The interaction between the Asian monsoon affects the specific current circulation system, Ekman mass and heat transport, tidal mixing, wind-induced upwelling, and downwelling system and variability of surface SST and chlorophyll-a, and ocean fronts (2, 3, 5,7]. The dynamics of the physical oceanographic structures in this area results in a highly productive skipjack tuna fishing ground [4,6].

Skipjack tuna is one of the most important commercial species targeted by pole and line fishermen in the Gulf of Bone. The distribution and hotspot habitat for skipjack in the Bone Gulf have a good association with the specific Chl-a of near 0.2 mg m^{-3} as an indication of the main chlorophyll frontal position [1]. This species is sensitive to the change of Sea surface temperature (SST)[10]. SST and surface Chl-a are the two most important habitat predictors for skipjack tuna migration in the western North Pacific [11]. However, there is a critical gap of skipjack distribution and abundance for the seasonal changes of the potential fishing ground formation. Therefore, this paper attempted to map out the seasonal pattern of the potential fishing ground for skipjack tuna in the Bone Gulf.

2. Data and Methods

In this paper, we used satellite together with fishing data for the period of 2009-2015. The bio-physical oceanographic satellite data used to assess the oceanographic conditions around the fishing grounds were SST and Chl-a concentration data derived from Aqua/MODIS. The Global Standard Mapped Image level 3 binary data with NetCDF format (https://oceandata.sci.gsfc.nasa.gov/). We used the satellite images with monthly temporal resolution and 4 km of longitude and latitude spatial resolution. We processed the data using the IDL (Interactive Data Language) software package to get image data throughout the study area. The pole and line fishery data consisted of high-resolution fishing ground positions in latitude and longitude, SST fishing boat, and daily CPUE data. We compiled the daily data into monthly to match the satellite data temporal resolution. This paper divided the season into four categories, the west season (November-February), the first transition season (March-May), the east season (June-August), and the second transition season (September-October). The oceanographic data were linked to fishery data to estimate and extract SST and Chl-a at and around the fishing grounds. The optimum oceanographic preferences were described using a boxplot of all the catches more than average. The potential fishing ground was shown as habitat index where the most potential fishing zone was denoted as 1; the less potential area was indicated as 0. Monthly formation of potential fishing ground images was composited to get the seasonal illustration or changes of the main skipjack habitat. All seasonal potential fishing ground maps were created using ArcGIS software.

3. Results and Discussion

The Gulf of Bone is one of the best skipjack tuna fishing ground in Indonesia. This paper showed spatial patterns in detail, which part of the Gulf is to be the most potential fishing area. In this study, we focused on mapping the seasonal changes of the best skipjack tuna fishing zone in the Bone Gulf. We found that the oceanographic preferences constructing the skipjack tuna fishing ground formation centered at approximately SST 30 Deg C together with 0. 2 mg m-3 chlorophyll-a isopleth (Figure 1). Our results indicated that the dynamics of the important skipjack fishing grounds associated with the movement of both the preferred oceanographic data. This study found that, in general, the potential fishing zones well-formed in the west and the first transition season (Figures 2 and 3). This result is similar to the previous study, which has been conducted in Makassar Strait [9]. The development of skipjack tuna habitat during the period may link with the growth of the chlorophyll front, which provides enhanced feeding opportunity for skipjack tuna in the Gulf [1,5].

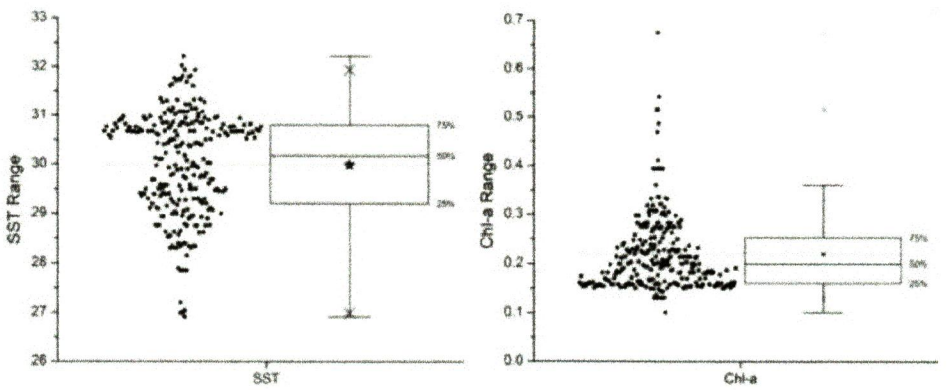

Figure 1. Boxplot illustration of the oceanographic preferences for skipjack tuna in the study area.

In the west season, the high productive tuna fishing ground developed almost throughout Bone Gulf (Figure 2). That covered the areas of 3-5.5 °S and 120.5-122° E. However, the most potential fishing areas were found in the form of Sinjai waters and moved to the Luwu waters and reached a peak in the eastern part of Bone Gulf, to be exact near Kolaka Coastal Waters. It is imperative that the movement of the fish appeared to form a clockwise pattern. It is most likely that they have a good association with the chlorophyll-a front [1]. For all-season, we found that the west season is the best time to capture skipjack tuna in the Bone Gulf with a relatively high intensity of habitat index of 0.84-1.0.

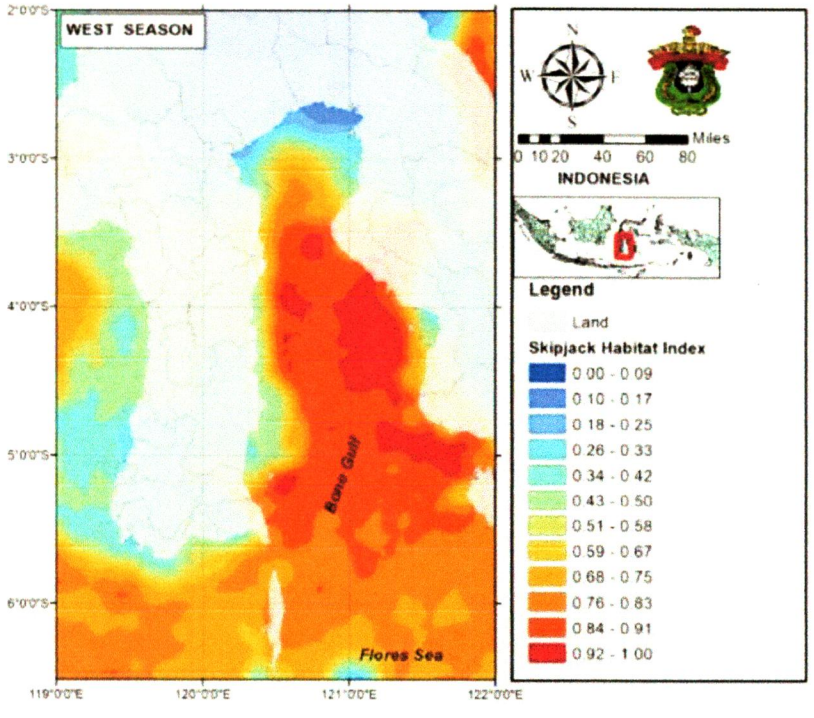

Figure 2. The spatial distribution pattern of potential fishing ground formation for skipjack tuna shown as habitat index during the west season based on satellite oceanographic preferences in relation to catching data.

During the first transition season, the potential fishing ground formed well in all locations within Bone Gulf (Figure 3). The potential fishing locations covered the areas of 3-6 °S latitude and 120.5-122° E longitude. It clearly shows that predicted potential fishing zones widely spread through the Flores Sea. The intensity of habitat index is from 0.76 to 1, implying highly potential fishing zones for skipjack tuna. This indicates that the skipjack tuna habitat experiences zonal displacement and tends to move to the south at the end of the first transition season. We estimated that during the first transition season, the chlorophyll-a front is relatively developed. It strongly corresponds with the movement of high chlorophyll-a concentration at the onset of the east season near the Flores Sea [2,3]. We believe that chlorophyll-a plays a key role in detecting tuna habitats and observing the dynamics of several physical oceanographic variables [1,8].

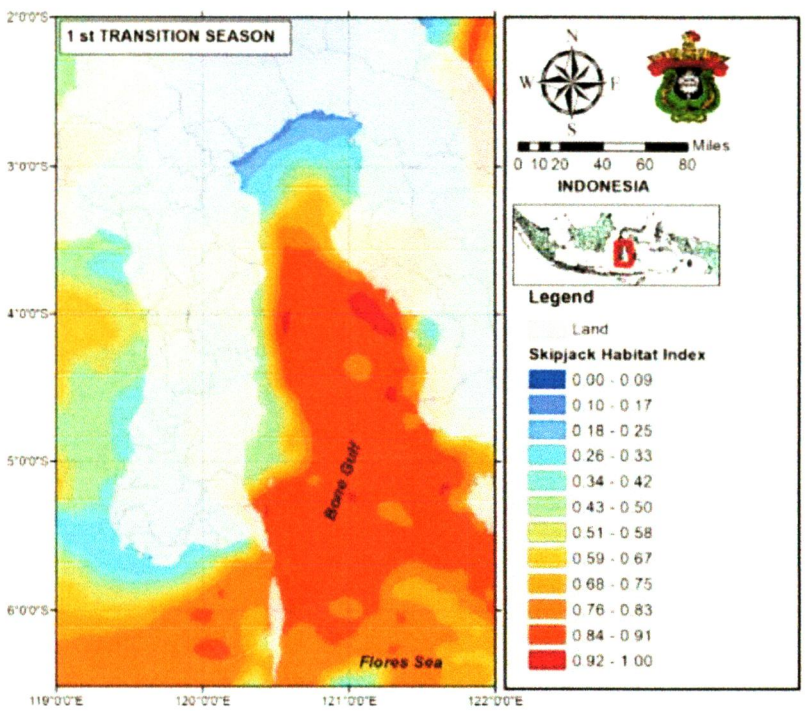

Figure 3. The spatial distribution pattern of potential fishing ground formation for skipjack tuna shown as habitat index during the first transition season based on satellite oceanographic preferences in relation to catching data.

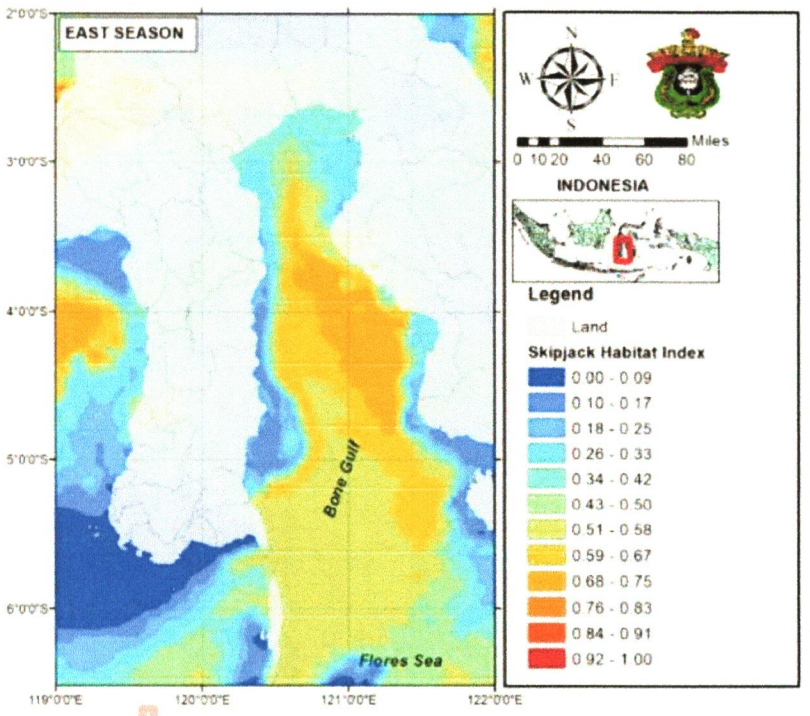

Figure 4. The spatial distribution pattern of potential fishing ground formation for skipjack tuna shown as habitat index during the east season based on satellite oceanographic preferences in relation to catching data.

It is generally seen that in the east monsoon shows that potential skipjack fishing areas are predicted to experience a significant decrease in the aspect of habitat index intensity. From the aspect of covering area potential, it tends to be relatively the same as the previous season (Figure 4). When entering this eastern season, the concentration of chlorophyll-a increases sharply so that the chlorophyll-a front is less formed. This is thought to be a potential cause of potential skipjack fishing areas in Bone Bay, which did not develop rapidly in June-August. Previous research has proven that chlorophyll-a front plays a key role in detecting the distribution and presence of skipjack tuna in the Gulf of Bone and the Flores Sea [1,5].

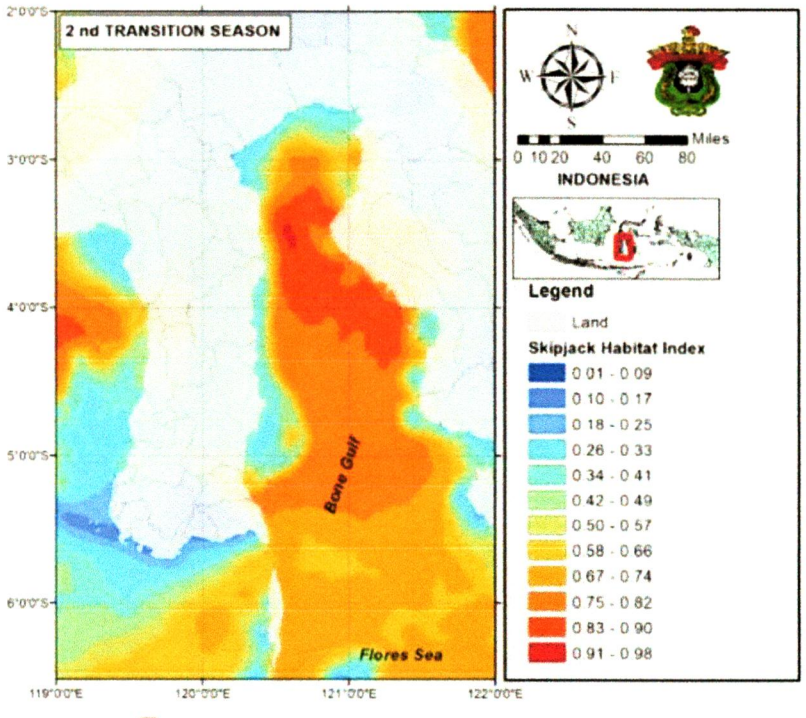

Figure 5. The spatial distribution pattern of potential fishing ground formation for skipjack tuna shown as habitat index during the second transition season based on satellite oceanographic preferences in relation to catching data.

During the second transition season (September-November), potential skipjack fishing grounds in Bone Bay re-form (Figure 5). This can be observed starting from the waters of Bulukumba, offshore Bone waters, and their development reaches peaks in the waters of Luwu, Kolaka, and northern Kolaka. The productive area has an index habitat intensity with a range from 0.75 to 1. The waters with the highest index habitat intensity are in Luwu waters. There are two main causes for the potential formation of skipjack tuna fishing during this second transition season: (1) the re-formation of chlorophyll-a front stimulating nutrient enrichment, (2) abundance of nutrients due to upwelling factors transferred from the southern part of the Makassar Strait [1,7, 12]. These two things stimulate the development of abundant skipjack fish food so that the formation of the fish habitat is formed.

As a concluding remark: base on the dynamics of space-time potential fishing ground, we found that the Persistent potential skipjack fishing ground formation in Bone Gulf located in the eastern area of the Bone Gulf, especially in May (first transition season) and November (second transition season).

Acknowledgments
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