Monsoon and temperature effects on sword fish (*Xiphias gladius)* catches in the high seas of Indian Ocean: A case study in high seas longline fishery of Sri Lanka

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Abstract

Bill fishes are normally landed as a by-catch in tuna- longline fishery of Sri Lanka. Among the five major billfish species found in the longline catches, Swordfish (*Xiphias gladius*) is dominant in terms of contribution to the total national fish production in Sri Lanka. In 2017, the production of Swordfish was 9,198mt which contributes about 46% of the total billfish catch in the country. High seas production of Swordfish was only 1,451mt where more than 90% has been harvested by longline operations. The present study was undertaken with the aim of understanding the monsoon and temperature effects on catch rates of Swordfish in high seas longline fishery of Sri Lanka. Spatial and temporal data with corresponding catch rates were obtained from the logbook data whereas Sea Surface Temperature (SST) data were obtained from ERA-interim of the European Centre for Medium-Range Weather Forecasts (ECMWF). Long line catches of Swordfish showed three distinct spatial distributions: Arabian Sea-Indian Ocean spatial cluster (ASIO) (55^0-70^0 E, 0^0-15^0 N), Bay of Bengal Region (BB) (7^0-17^0 N, 75-80E) and Sothern Indian Ocean Spatial Cluster (IO) (10^0S-5^0 N, 75^0-80^0 E). Swordfish catch rates in all three regions gradually increased during April - November while the maximum was reported from December to March during the North East monsoon prevails. Catches of Swordfish were recorded in a range of SST which varied from 27.1 to 31.2 ^{0}C. However, a clear decrease in the extent of the distribution as well as the catch rates could be observed with increased SST.

Comparatively, higher catch rates of Swordfish were observed in ASIO region followed by IO and BB regions respectively. The lowest catch rates in BB reported during many months of the year may probably be due to less productive nature of the region. Catch rates of Swordfish in both ASIO and IO clusters increased during the inter monsoon and with the onset of north east monsoon while in BB cluster highest catch rates were recorded during the first inter monsoon period.

Key Words: Bill fish, Sri Lankan Fishery, Fish distribution

Introduction

Billfish is the third largest group of fish reported in the large pelagic fish production in Sri Lanka which include three species of marlins, one species of sailfish and one species of sword fish. Although billfish are not normally targeted species, they are very common in offshore gillnet and longline catches and are considered as by-catch species(Haputhantri and Maldeniya 2011;Weerasekara and Rathnasuriya, 2016). Of the five major billfish species namely *Makaira indica*(black marlin), *Makaira nigricans*(blue marlin), *Tetrapturusaudux*(striped marlin), *Xiphias gladius*(sword fish) and *Istiophorus platypterus*(sail fish) are presently found in local commercial landings, *Xiphias gladius* is dominant in terms of the relative contribution to the total national production (Weerasekara and Rathnasuriya, 2016).

In 2017, the production of *Xiphias gladius* was 9198mt was and this contributes more than 46% of the total billfish production in the country (Figure 1). High seas production of *Xiphias gladius* has increased to 1450mtin 2017 where more than 90% was harvested by long line operations followed by gillnets.

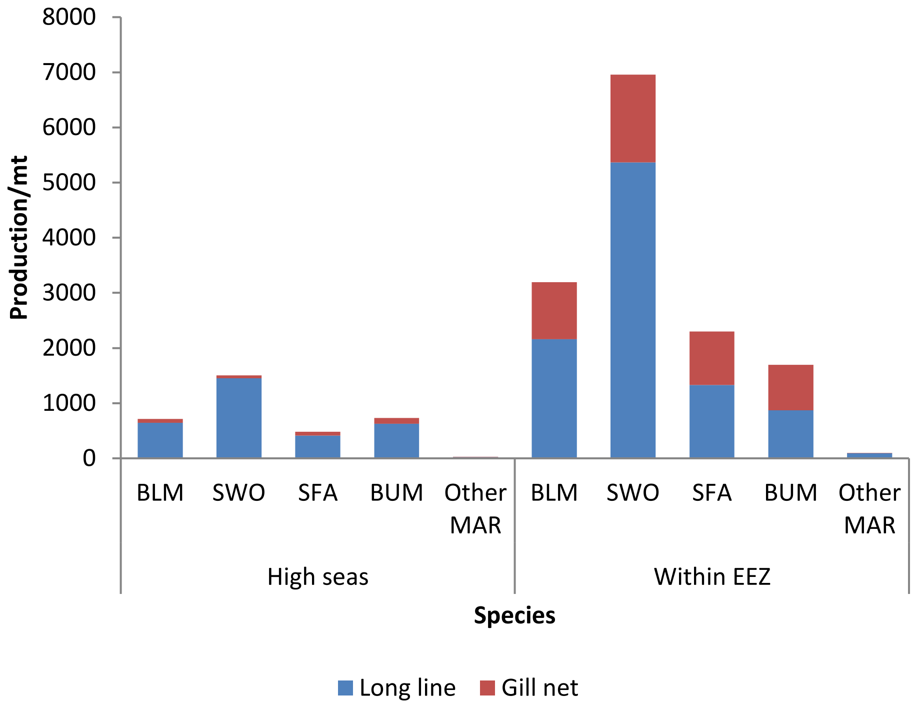


Figure 1 Bill fish production by species by gear in 2017 (PELAGOS, 2017)

Xiphias gladius is unique among teleost fishes in thermo conserving. Among the variety of oceanographic parameters, sea surface temperature (SST) has emerged repeatedly as the best single predictor of species density and richness for such species (Lee et al., 2005; Worm et al., 2005).

The present study was undertaken to understand the monsoon driven temperature effects on catches of *Xiphias gladius* in longline fishery in three different regions in Indian Ocean high seas; BB, ASIO and IO.

Materials and Methods

Logbook data and data validation

High seas logbook data in 2017maintained by Department of Fisheries and Aquatic Resources, Sri Lanka was mainly used for this study. Logbooks provide information on respective fishing operations including catch and effort data, spatial data (GPS position) with temporal information. The logbook data were validated in order to identify the data recording and data entry errors especially with regard to GPS position (Latitude and

Longitutde). The validation was done by comparing Vessel Monitoring System (VMS)data of corresponding fishing operation via tracking logs of VMS database.

Mapping of spatial distribution

Spatial distribution of sword fish was mapped using the position data obtained from logbooks during the high sea fishing operations at five grid spatial resolution. ArcGIS was used as Geographic Information System (GIS) mapping software.

Sea surface temperature data

Sea Surface Temperature (SST) data were obtained from ERA-interim of the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA-Interim is the recently published ocean data and re-analysis dataset which covers the period from 1979 to present (Uppala et al., 2005). ERA-interim has 0.75° x 0.75° grid resolution data generated by atmospheric reanalysis which consists of 6 hourly wave parameters.

Data Interpretation

Seasonal means are used throughout this study and they are constructed from the monthly means by averaging the data in December–January–February-March (DJFM) for North-East monsoon, April–May (AM) for 1stIntermonsson, June–July–August-September (JJAS) for South-West and October–November (ON) for 2nd Intermonsoon (Reddy, 2001). In this study, we focus on the year 2017 during which all the fishing data sets are available.

Results and Discussion

Spatial distribution of *Xiphias gladius*

According to Weerasekara and Rathnasuriya (2016), spatial distribution of the *Xiphias gladius* showed three distinct spatial clusters as Bay of Bengal spatial cluster (BB) (7^0-17^0 N, 75-80E), Arabian Sea-Indian Ocean spatial cluster (ASIO) (55^0-70^0 E, 0^0-15^0 N)and Indian Ocean spatial cluster (IO) (10^0S-5^0 N, 75^0-80^0 E) directing along the EEZ boundary of Maldives from the Southwest EEZ boundary of Sri Lanka. A quite similar distribution pattern was observed in year 2017 and this may be due to the favorable conditions for *Xiphias gladius* in the area.

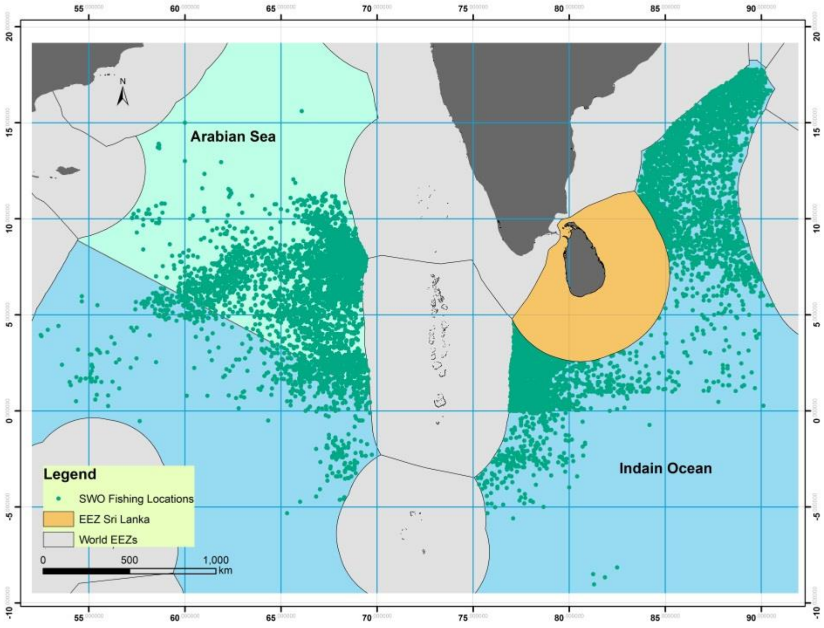


Figure 1 Distribution of *Xiphias gladius* fishing grounds in High seas of Indian Ocean

Catch per unit effort (CPUE)

Comparatively higher catch rates of *Xiphias gladius* was frequently observed from Arabian Sea-Indian Ocean spatial cluster (ASIO) while comparatively lower catch rates was observed from Bay of Bengal Region during many months of the year (table 1). This is obvious because Bay of Bengal is considered to be less productive region compared to the Arabian Sea as the wind-driven mixing is not dominant in the Bay of Bengal (Prasanna Kumar et al, 2014). Average CPUE of *Xiphias gladius* has peaked in October to November in both ASIO and IO whereas it is peaked in Bay of Bengal from April to May.

Table 1 Catch rates of *Xiphias gladius* by monsoons by major spatial clusters

Monsoon Periods / Region	Average CPUE (kg per trip)			
	NE (Dec-Mar)	1st Inter Monsoon (Apr-May)	SW (Jun-Sep)	2nd Inter Monsoon (Oct-Nov)
ASIO	153.86	92.35	118.65	176.28
BB	99.09	112.51	72.33	87.00

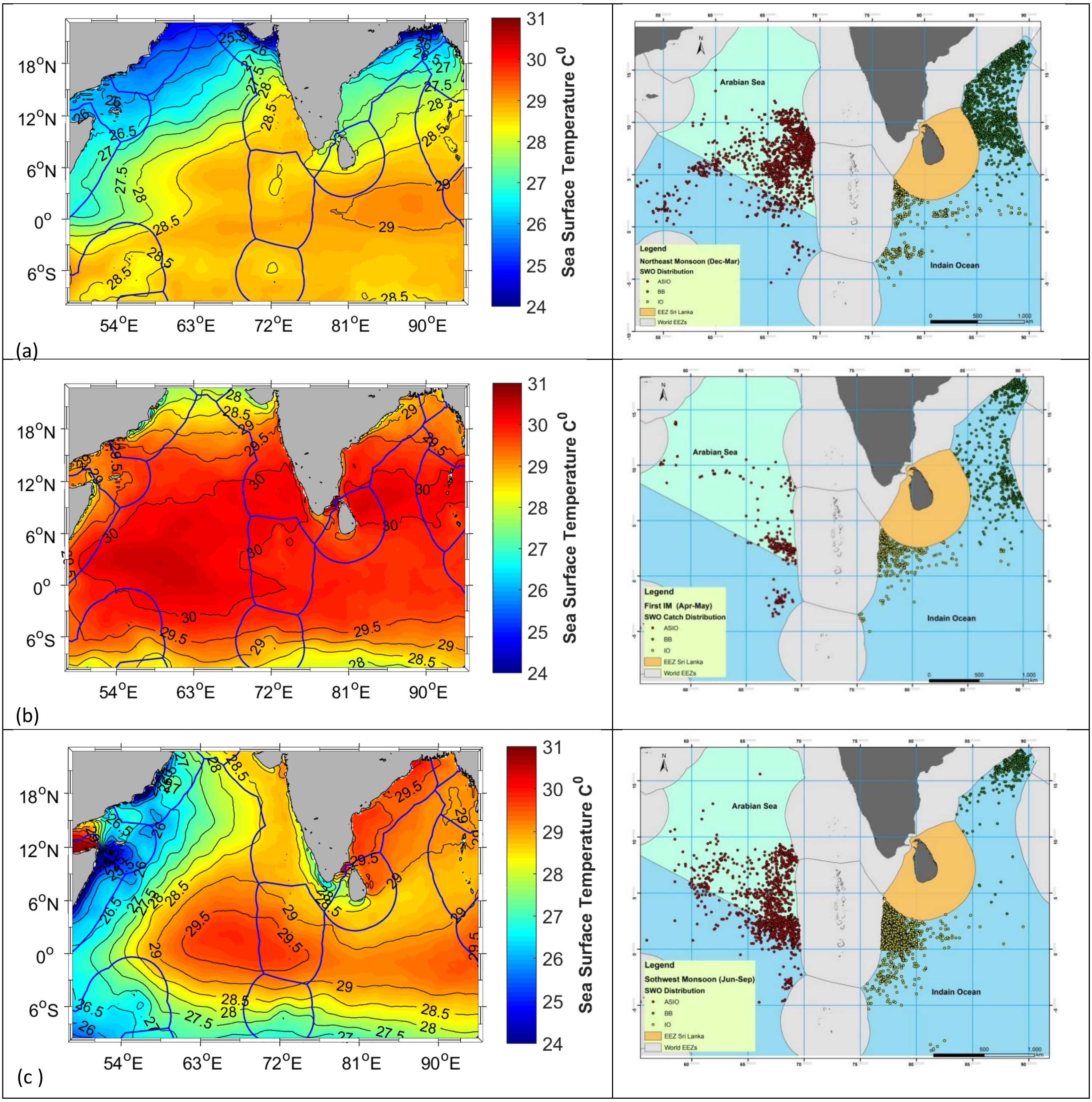
IO	84.31	90.41	109.24	152.88

Temperature effects

Temperature differences and distribution of *Xiphias gladius* were shown in Figure 2. It depicts that the spatial distribution of *Xiphias gladius* catches has declined with the increased temperature. As longline fishing operations conduct to harvest deep sea fish resources are mainly associated with thermo cline depth, the above results may probably be due to deepening of thermocline with respect to the depth of longline operations.

Sword fish are normally associated with deeper layers during day time compare to other billfishes, but it remains at the surface layer during the night time (Carrey, 1990). As Sri Lankan longliners mainly operate during the night time at the shallow depth ranges (50 -100 m) billfish are frequently caught during the night time at this depth range (Rathnasuriya et al, 2016).Generally depth penetration of hooks in Sri Lankan longline is around 65m close to buoy lines while it is about 90m in the middle of the depth penetration. However the depth of thermocline in the region can exceed that level depending on the monsoons. Further, it has also been reported increase trend in the catch rate when the long line reaches the thermocline depth (Rajapaksha, et al, 2018).

According to Rathnasuriya et al (2016), there is a weak relationship between SST and billfish CPUE while there is a strong relationship between Sea Surface Chlorophyll and billfish CPUE. Further they revealed that 27-30 ^{0}C range of SST CPUE remains approximately constant. The present study shows that catches of *Xiphias gladius* were recorded in a wide range of SST which varied from 27.1 to 31.2 ^{0}C. A decrease trend in the catch rate could be observed with increased SST especially when temperature exceeds 30 ^{0}C (Figure 3).


Sea Surface Temperature C0
18oN
12oN
6oN
0o
6oS
54oE
63oE
72oE
81oE
90oE
(a)
Arabian Sea
Indain Ocean
Legend
Northeast Monsoon (Dec-Mar)
SWO Distribution
ASIO
BB
IO
EEZ Sri Lanka
World EEZs
(b)
Legend
First IM (Apr-May)
SWO Catch Distribution
ASIO
BB
IO
EEZ Sri Lanka
World EEZs
(c)
Legend
Sothwest Monsoon (Jun-Sep)
SWO Distribution
ASIO
BB
IO
EEZ Sri Lanka
World EEZs

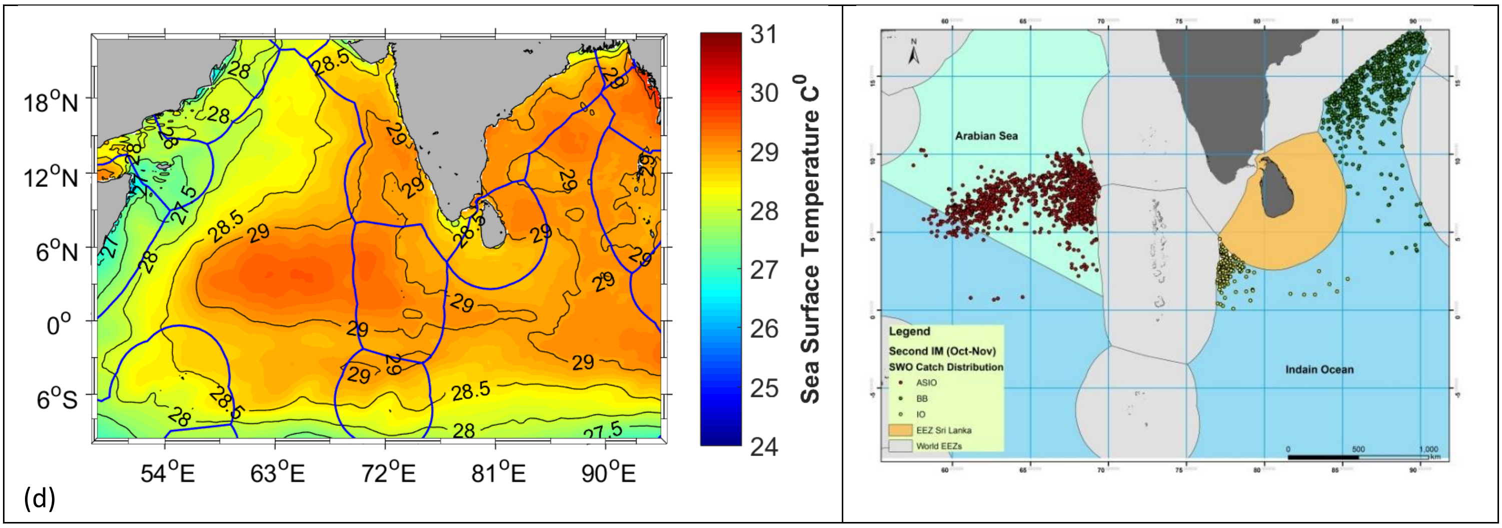
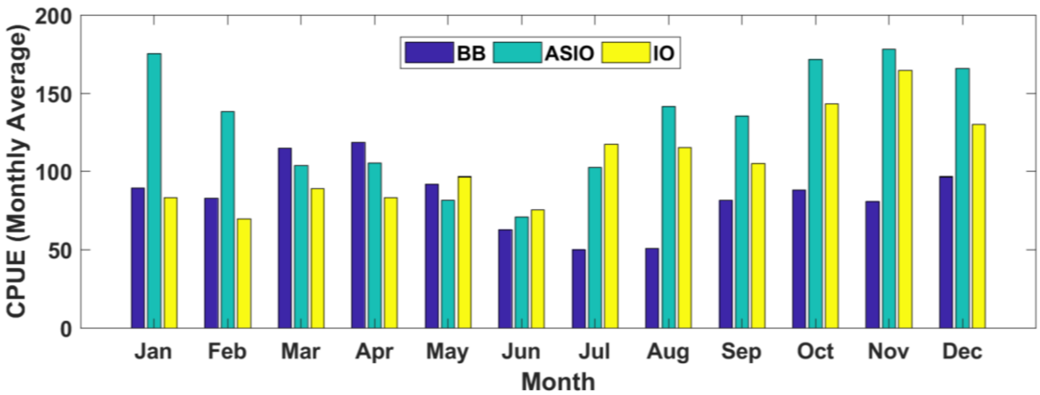
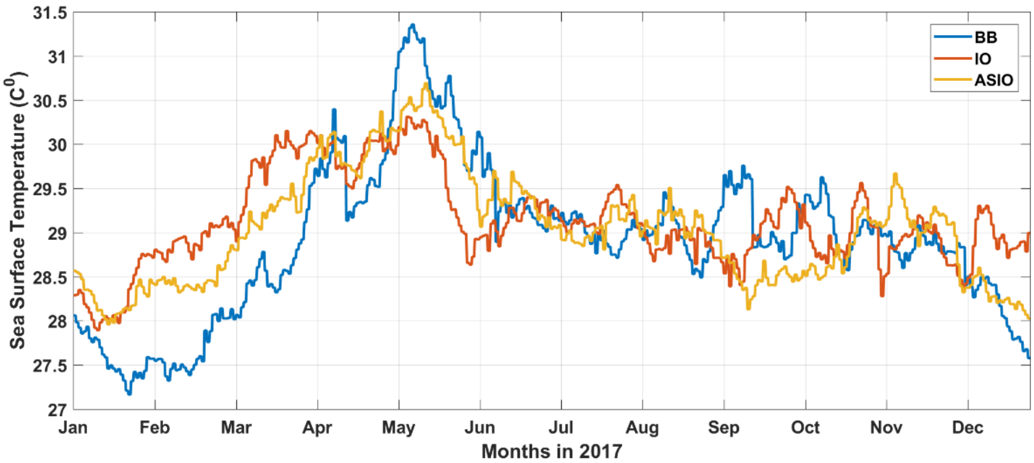


Figure 2: SST variation and spatial distribution of *Xiphias gladius* with respect to different monsoons: (a) North east monsoon (December- March) (b) First inter monsoon (April-May) (c) South west monsoon (June-September) and (d) Second inter monsoon (October-November)



(a)



(b)Figure 3: (a) Monthly variation of Average CPUE of Long line operations and (b)SST in the three high sea regions in the Indian Ocean

This study was carried out based on one year data. Therefore, a similar study needs to be carried out using time series data in order to get a comprehensive picture of the distribution of *Xiphias gladius* in the high seas of Indian Ocean. Apart from SST, other parameters such as thermocline depth, sea surface height and chlorophyll content should need to be incorporated for such studies.

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