Sword fish catch rates in relation to Sea Surface Temperature and Chlorophyll-A concentration within EEZ Sri Lanka

*Bandaranayake, K.H.K[1]., Gunasekara, S.S.[1], Bandara A.P.R.[2] and Haputhantri, S.S.K.[1]

[1]National Aquatic Resources and Development Agency, Crow Island, Mattakkuliya, Colombo 15, Sri Lanka.

[2] Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Wellamadama, Matara, Sri Lanka

*kisharabandaranayake@gmail.com

Swordfish (*Xiphias gladius*) is one of the important bill fish species landed as a by catch of tuna-longline fishery. In 2018, the production of swordfish in the longline fishery within EEZ was 5795mt which contributes about 42% of the total bill fish catch. Remarkable changes of the monthly catch rates of sword fish can be observed from different zones of the country and may probably influenced by the monsoon driven temperature and chlorophyll fluctuations. Therefore, the present study was undertaken to understand temperature and chlorophyll a effects in the CPUE variations of swordfish within EEZ, Sri Lanka. The values of Sea Surface Temperature (SST) and Sea Surface Chlorophyll a (SSC) were obtained from remote sensing data while catch rates were based on 2016longline fishery data of log books. A Generalized Additive Model (GAM) was fitted for describing the relationships between oceanographic parameters and sword fish catch rates. The result of GAM shows that the relationships between swordfish catch rates and two oceanographic parameters are significant at 0.05 level ($p<0.01$). The higher catch rates of swordfish were observed from the areas where SST varied between 28.8-30.6 °C and SSC ranged from 0.11-0.16mgm^{-3}.However the strongest relationship was observed between SST and swordfish CPUE. The GAM results show that space-time factor also has more influence on swordfish catch rates where high catch rates are primarily associated in productive areas of Sri Lankan EEZ.

Keywords: sword fish, CPUE, environmental parameters

Introduction

Sword fish (*Xiphias gladius*) is an important bill fish species unique among the other teleost species in thermo conserving and has shown their habitat preference in relation to different oceanographic parameters (Worm et al, 2005). The species is considered as oceanic and epipelagic with varying horizontal distribution (Nakamura, 1985).

Sword fish is mainly recorded as a by catch in tuna long line fishery in Sri Lanka (Haputhantri and Maldeniya 2011; Weerasekara and Rathnasuriya, 2016) where major contribution has made from EEZ of the country than high seas (Bandaranayake et al, 2018).In 2018, the total production of swordfish in longline fishery was 5795mt which contributes about 42% of the total bill fish catch (PELAGOS, 2018). However, a remarkable change in the monthly catch rates of sword fish could be observed temporary and spatially in different zones of the country and this might probably be due to the monsoon driven temperature and chlorophyll a fluctuation.

As the influence of SST and Chlorophyll-a on distribution and migration of sword fish is poorly documented in SL waters, the present study was carried out with the aim of investigating the relationships between sword fish catch rates and oceanographic parameters within EEZ of Sri Lanka.

Methodology

Logbook data and Data validation

Fishery data with regard to sword fish catches of long line fishing fleet were obtained from the fisheries logbooks of DFAR. Fishing positions in logbooks were validated with Vessel Monitoring System (VMS) data with 0.3 degree accuracy (Gunasekara and Rajapaksha., 2016). The Catch per Unit Effort (CPUE) in this study was expressed as number of fish per 100 hooks per fishing trip. A total of 515 swordfish non-zero catch records within EEZ of SL obtained from January to August 2016 was used for this analysis.

Oceanographic parameters

Sea Surface Temperature (SST) and Sea Surface Height (SSH) data were obtained from GLOBAL_ANALYSIS_FORECAST_PHYS_001_015 product of the COPERNICUS Marine Environment Monitoring Service (http://marine.copernicus.eu/). Sea Surface Chlorophyll (CHL)

8-day composite data was downloaded from Globcolour website relating to the area of interest. This CHL composite uses merged data of SeaWiFS (NASA), MODIS (NASA), MERIS (ESA), OLCI-A (ESA), VIIRS (NOAA/NASA) and which are freely available. *GlobColour data (http://globcolour.info) used in this study has been developed, validated, and distributed by ACRI-ST, France.*

Relationship between oceanographic parameters and swordfish catch rates

A generalized additive model (GAM) was applied to identify the relationships between three oceanographic parameters (predictor variables) swordfish CPUE (response variable). The relationships between oceanographic parameters and the CPUE are mostly expected as non-linear. Once the shape of the relationships between the response variable and each predictor was identified, the appropriate functions were used to parameterize these shapes in the GAM model. The shapes resulting from the GAM were reproduced as closely as possible using the stepwise GAM. The CPUE as a function of oceanographic variables were included in the analysis using GAM by Equation:

$$ln(CPUE) = a + s(SST) + s(SSC) + s(SSH) + e \quad (1)$$

Where a is a constant, s(.) is a spline smoothing function of the variables (SST, SSC, SSH) and e is a random error term. GAM is a nonparametric generalization of multiple linear regressions which is less restrictive in assumptions of the underlying statistical data distribution (Hastie and Robert, 1990). The GAM has no analytical form, but explain the variance of CPUE more effectively and flexible. A logarithmic transformation of the CPUE was used to normalize asymmetrical frequency distribution. The analysis was conducted using the mgcv package in R statistical software (version 3.4.1) (Wood, 2011).

Inclusion of spatial parameter in GAM

In addition to the inclusion of above-mentioned oceanographic parameters, the fishing position data in the form of (Lat, Lon) was included in the best fitted GAM model.

Results

The spatial distribution of fishing grounds depicted that sword fish catches were mostly concentrated to northeast and southwest parts of the country (Figure 1). However limited fishing activities can be observed in the south east part of the country due to the rough sea conditions. Therefore, fish abundance influenced by oceanographic factors cannot be predicted based on fishery dependent data for the south east part.

The frequency of fishing grounds indicates that sword fishes tend to concentrate in specific ranges of favorable oceanographic conditions. Monthly averages of environmental parameters; SST and SSC followed a general pattern mainly with the influence of the south-west and north-east monsoonal patterns during the study period (Figure 2 and 3). The fishable area for sword fish in relation to SST is primarily range between 28.8-30.6°C while the respective value for SSC is in between 0.11-0.16mgm^{-3}. Negative skewed catch frequencies of billfish within the range of SSC showed that more catches tend to arise from water with relatively low concentration of Chlorophyll (Figure 4).

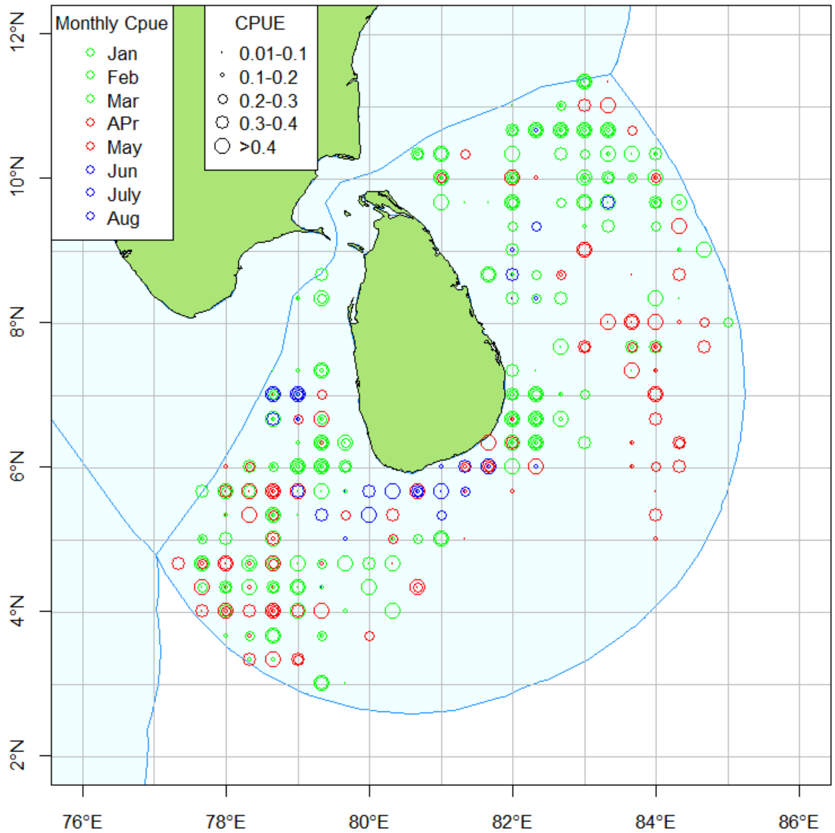
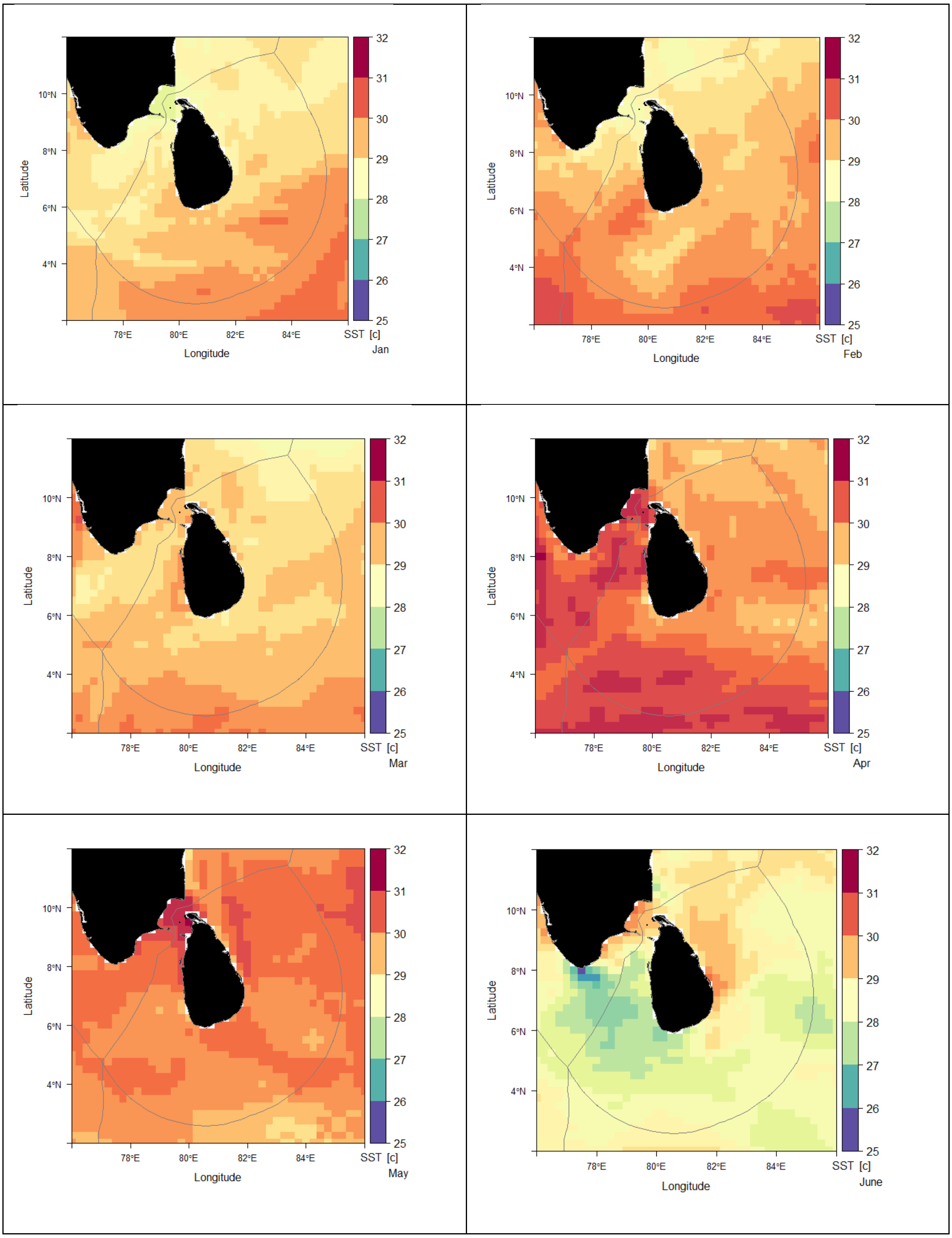


Figure 1: Spatial distribution and abundance of Sword fish (*Xiphias gladius*) within EEZ of Sri Lanka (number of fish per 100 hooks per fishing trip)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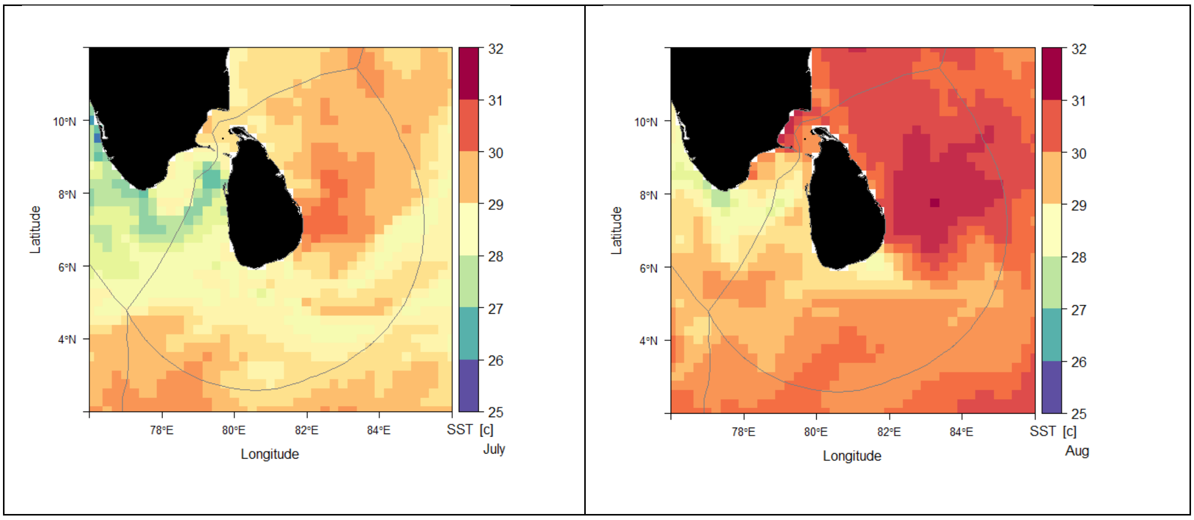
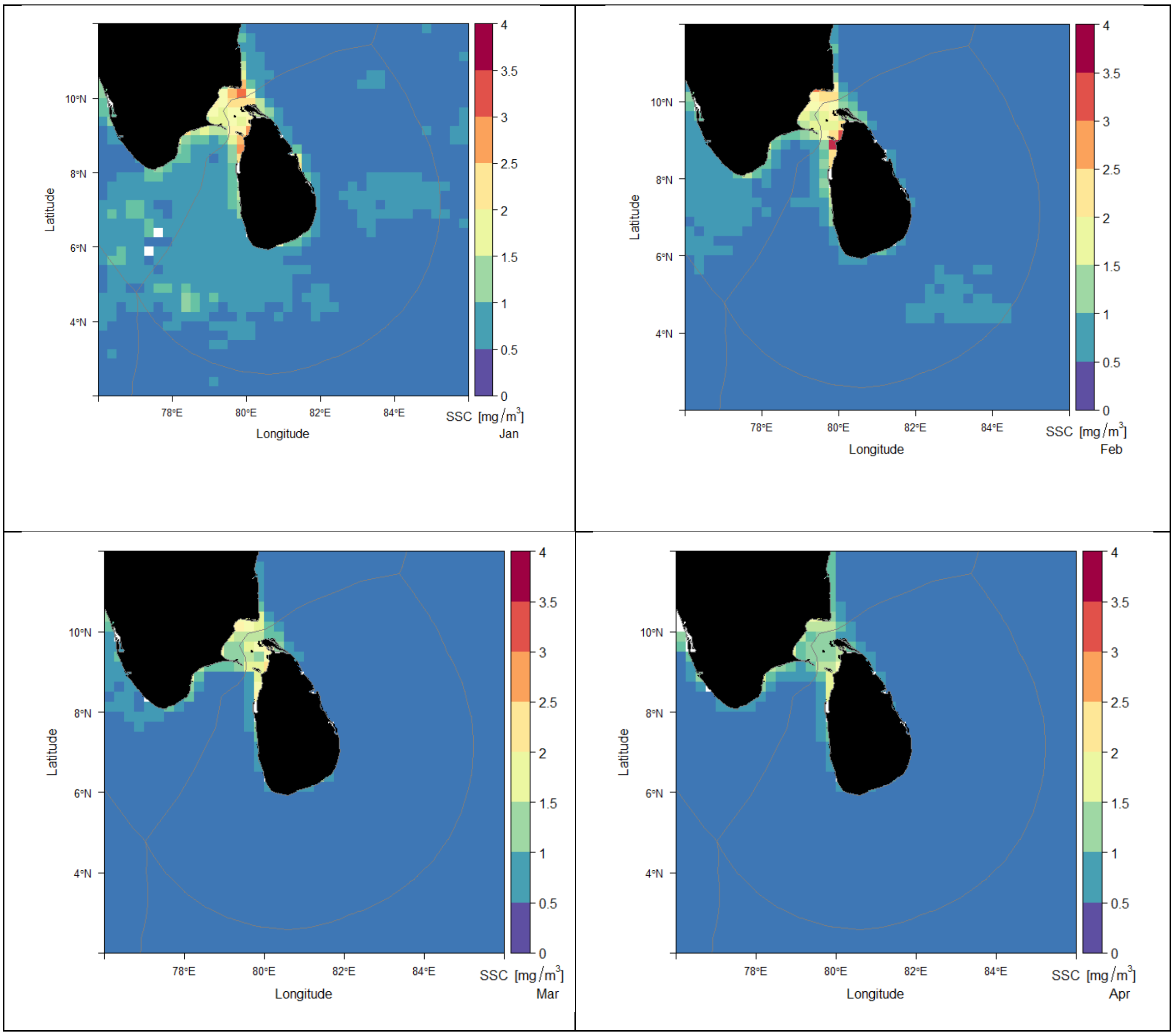


Figure 2 Spatial Distribution of SST within EEZ Sri Lanka



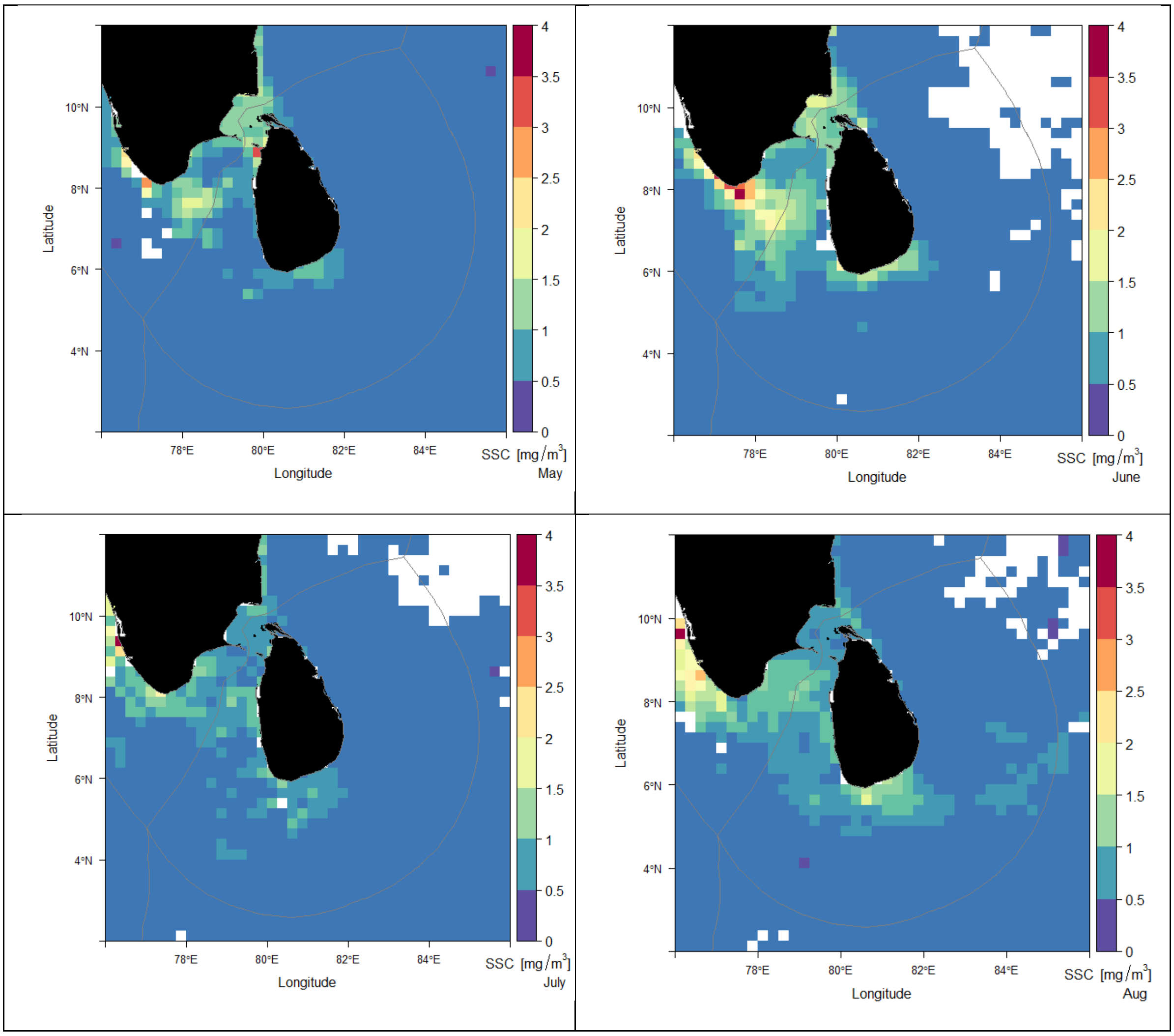


Figure 3 Spatial Distribution of SSC within EEZ Sri Lanka

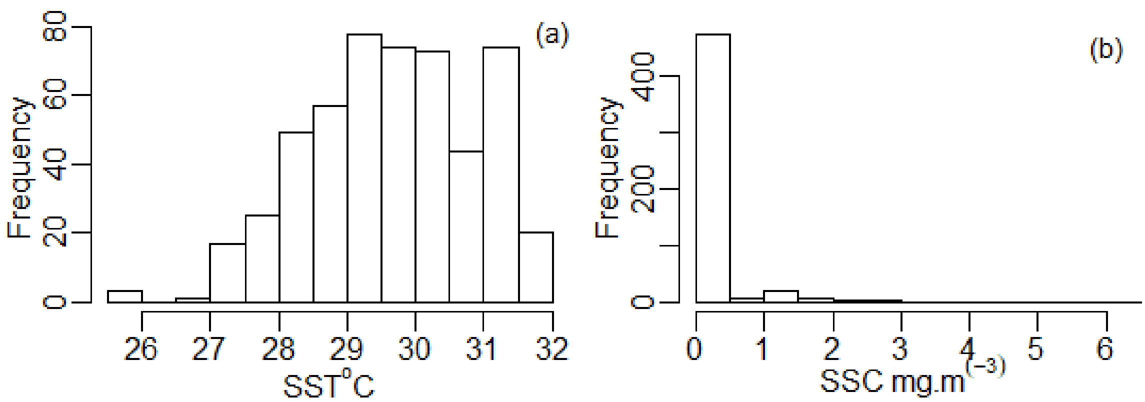


Figure 4: Frequency of sword fish caught (a) Sea Surface Temperature (SST) (b) Sea Surface Chlorophyll (SSC)

GAM results showed that two oceanographic parameters; SST and SSC were significant at 0.05 level (p<0.01) and influence the average catch rates of sword fish. Underline relationships between (SST and swordfish catch rates) and (SSC and swordfish catch rates) were non-liner (Figure 5). In general, a declining trend in the abundance (CPUE) of swordfish could be observed with increased SST.

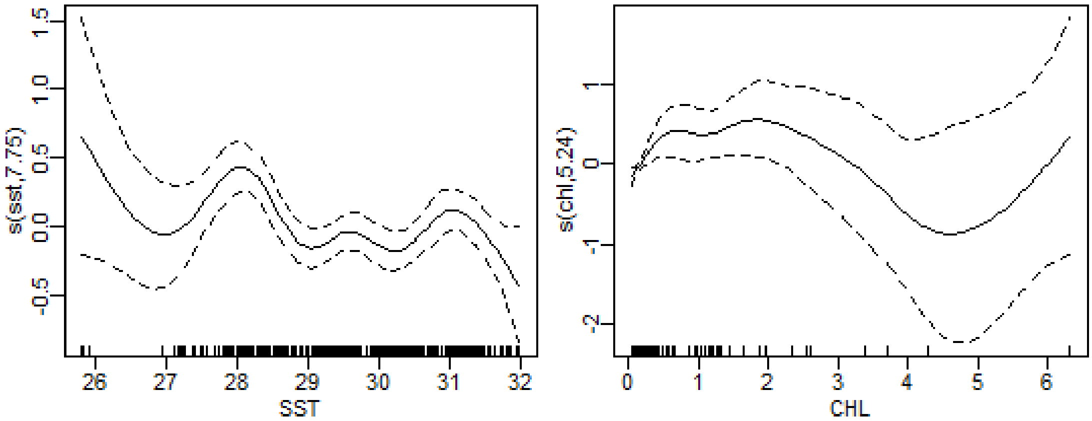


Figure 5: Generalized Additive model (GAM) derived effect of oceanographic variables (a) Sea Surface Temperature (SST), (b) Sea Surface Chlorophyll (SSC) on swordfish CPUE (log transformed). Dashed lines indicate 95% of the confidence intervals. The relative density of data points is shown in rug plots along the x axis.

SST and SSC explained 7.39% and 4.14% of the total deviance respectively (Table 1). However, SSH explains only 0.04% of the deviance. The best fitted GAM model which comprised of SST, SSC and (Lat, Lon) explained 22.4% of the deviance.

Table 1: Single predictor GAM fitted for swordfish CPUE (For each predictor, the percentage of deviance and the generalized cross validation (GCV) scores are given)

Parameter	% deviance	GCV score
SST	7.39	0.5527
SSC	4.14	0.5664
SSH	0.04	0.5809
SST + SSC+ (Lat, Lon)	22.4	0.5158

GAM results showed that space-time factor also has more influence on swordfish catch rates where high catch rates were primarily associated in the South west and east coasts of the country (Figure 6). South west is a well-known productive area mainly during the south west monsoon.

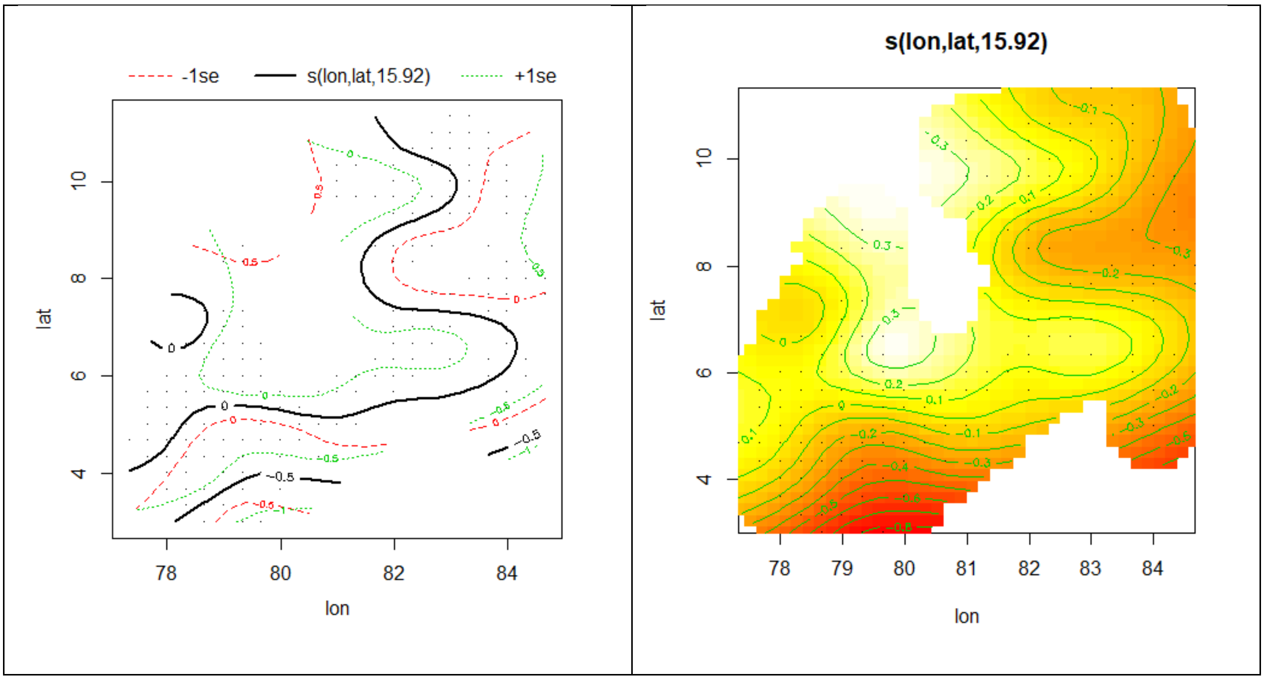


Figure 6 Spatial Distribution of Sword fish catches within EEZ, Sri Lanka (January- August 2016)

Discussion and Conclusion

Satellite remote sensing data in a higher temporal resolution has a great capability to provide the required environmental data that can be used as an indicator for the abundance of swordfish and thereby helps to reduce searching time of vessels in this particular fishery. Very limited studies have been focused on bill fish varieties in Indian Ocean in determining their availability with respect to oceanographic factors (Rathnasuriya et al, 2016). The present study includes limited fishery data of sword fish for a shorter period of time with respect to main environmental factors to develop the GAM model. However, the data collected for a longer time period will improve the precision and accuracy of the model.

Sword fish are normally associated with deeper layers during day time compare to other billfishes, but remain at surface layer during the night time (Carrey, 1990). As Sri Lankan longliners mostly operate during the night time (except few longliners operates during the day time on the new moon days) at the shallow depth ranges (50 -100 m) where billfish are frequently found in this layer.

In the present study a declining trend in the catch rates of swordfish were observed with increased SST. Bandaranayake et al in 2018 revealed a similar trend where catch rate of sword fish in high seas have been decreased with increased SST. According to Rathnasuriya et al, (2016), SST and SSC for billfish have been explained only less than 2%. But in the present study, SST and SSC explained a substantial deviance of sword fish catch rates: 7.39% and 4.14% respectively. The species-specific nature of environmental preference determined by the spawning and feeding behavior could show a better relationship than the billfish as a group of fish. However, SSH in the present results explained only 0.04% and this is negligible. Further, space-time factor explains a largest portion of the variance of catch rates and play the most significant role in the sword fish prediction. As an overall it can be concluded that the combination of two environmental factors; SST and SSC together with space time factor is important in predicting Sword fish catch rates.

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