Abstract

Use port sampling and logbook data for the analysis of catch rates of Skipjack Tuna (*Katsuwonus pelamis*) in gillnet fishery of Sri Lanka

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Fourteen years port sampling data (2005-2018) and three years logbook data (2016 - 2018) in the gillnet fishery of Sri Lanka was used to analyze the catch rates of skipjack tuna. Skipjack tuna is the main target species in the Sri Lankan gillnet fishery. All gillnet catches including the catches made by popular gear combinations operated in the gillnet fishery (gillnet–longline and gillnet-ringnet) were considered under the port sampling. Five vessel types operated in the tuna fishery have caught skipjack tuna. Year, month, boat type, gear type, trip duration (in days) and number of net panels used per fishing operation were incorporated for the analysis. Fishing location (5° square) obtained from fisheries logbooks with regard to gillnet fishing operations made during 2016 – 2018 was also considered for this audit. The logbook data exists at present only for multiday fishing vessels. The skipjack tuna Catch Per Unit Effort (CPUE) was estimated in terms of catch in kg per boat per trip. Gamma based Generalized Linear Models (GLMs) were fitted to determine the relationship between above mentioned explanatory variables and CPUE for two data sets separately. Around 1.3% of the total operated vessels which contained zero catches of skipjack tuna in the port sampling data were excluded for the analysis. The GLM model fitted to port sampling data explain around 48% of the total deviance and vessel type was found to be the most important parameter. Inclusion of 5° square fishing zones for GLM modeling may help only to slightly improve the GLM results.

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Introduction

Sri Lanka tuna fishery is a multi-species and multi-gear fishery conduct throughout the year. Gillnet, ringnet (mini purse seiners) and longline could be considered as the main fishing gear use in the tuna fishery of Sri Lanka. In addition, other gears such as handline, pole & line and trawl line are seasonally operated targeting tuna and tuna like species. The gillnet could still be considered as the main fishing gear use in tuna fishery but, this gear is progressively being replaced by other popular gears such as longline and ringnet. In gillnet fishery, gear combinations are frequently used targeting tuna and tuna like species. Popular gear combinations use in the gillnet fishery are gillnet- longline and gillnet-ringnet, Skipjack tuna (*Katsuwonus pelamis*) is the main target species in gillnet fishery. The total tuna production of Sri Lanka in 2016 was 70 460 t, of which skipjack tuna contributed more than 50% of the total tuna production (PELAGOS, 2016). Skipjack tuna is mostly consumed locally and sometimes used for producing dry fish and Maldive fish. The aim of the present study was to analyze the catch rates of skipjack tuna in the gillnet fishery of Sri Lanka and to examine the influence of the spatial, temporal and operational parameters to change the catch rates.

Materials and methods

Fisheries data

Fisheries data used for this analysis were mainly obtained from the port sampling programme conducted by the National Aquatic Resources Research and Development Agency (NARA) and Department of Fisheries and Aquatic Resources (DFAR), Sri Lanka. The port sampling is mainly conducted at the major large pelagic fish landing sites and fishery harbours in Sri Lanka. The skipjack tuna landed by the fishing vessels operated during the period January 2005 – December 2018 with above described gears were considered for this audit. At the field, the unloaded skipjack tuna catches by fishing vessels were monitored with other parameters: vessel type, used gear/ gear combination, trip duration in days and number of net panels used per fishing trip etc. For the data collection, enumerators were stationed by NARA and DFAR at the major ports and fish landing sites.

In addition to port sampling data, fisheries logbook data of DFAR from January, 2016 to December, 2018 was used for this audit. Multiday fishing vessels engage in tuna fishery (three types of vessels) provide log sheets to DFAR after completion of respective fishing trips.

Preparation of spatial and temporal maps of gillnet fishing operations

Fisheries logbook data were used for preparation of spatial and temporal maps of the gillnet fishing operations. The Arc GIS software 10.4.1 was used for map preparation.

Selection of parameters for port sampling catch rates analysis

The gear type (GT) which included gillnet (GN) and main gear combinations used in gillnet fishery (i.e. gillnet–longline (GL) and gillnet-ringnet(GR)) was considered as one operational parameter for the catch rate analysis of skipjack tuna. The vessel type (VT) is also considered as another fishing operation related parameter. Five vessel categories were operated during this period potentially targeting skipjack tuna (Table 1).

Table 1. Classification of fishing vessels in Sri Lanka operated during 2005-2012 period potentially targeting skipjack tuna

Class	Fishery	Category	Description
1	Costal Fishery	UN1	5.5 - 7.2 M (17' - 21') FRP dinghy Outboard engine - 8-40 HP (usually 15 - 40 HP) may have GPS Single day boats - assumed to be fishing in COASTAL WATERS
2	Costal Fishery	UN2A	8.8 - 9.8 mm (28' - 34') displacement hull. FRP or wooden. Inboard engine (single) - 40 HP No ice box or insulated fish hold, no gear hauler, or acoustic equipments but, may have GPS Single day boats - assumed to be fishing in COASTAL WATERS

3	Offshore/ deep sea fishery	UN2B	8.8 - 9.8 m (28' - 34') displacement hull. FRP wooden. Inboard engine (single) - 40 HP Insulated fish hold - no gear hauler, may have GPS/sounder/fish finder Multi-day boats-assumed to be fishing in OFFSHORE/ DEEP SEA WATERS
	Offshore/ deep sea fishery	UN3A	9.8 - 12.2 m (34' - 40') displacement hull. FRP wooden. Inboard engine (single) - 60 HP - Insulated fish hold and may have gear hauler/GPS/sounder/fish finder Multi-day boats-assumed to be fishing in OFFSHORE/ DEEP SEA WATERS
4	Offshore/ deep seafishery	UN3B	12.2 m - (40' - 50') displacement hull. FRP or wooden Inboard engine (single) - 60 + HP Insulated fish hold and may have freezer facilities. Gear hauler/GPS/sounder/fish finder Multi-day boats-assumed to be fishing in OFFSHORE/ DEEP SEA WATERS

Other two fishing operation-related parameters considered for this analysis are trip duration (TD) and number of net panels used per fishing operation (NP). Apart from that, “year” and “month” were included as temporal parameters.

Selection of parameters for logbook catch rates analysis

For the analysis of logbook data, spatial data (GPS fishing locations) were classified into 5° squares (latlong5). Only the log book data relating to gillnet fishing operations (the two gear combinations were excluded) was considered. Also, logbook provides information on vessels with regard to multiday fishing operations i.e., fishing operations carry out by UN2B, UN3A and UN3B vessels.

GLM model fitting

Two Generalized Linear Models (GLMs) (McCullagh and Nelder, 1989) were fitted for two data sets (port sampling data and logbook data) separately. The skipjack tuna CPUE was expressed in terms of catch in kg per boat per trip. All zero-catch rates of skipjack tuna which was around 1.3% of the total were excluded for the analysis. When zero values were eliminated, distribution of the positive values was approximately lognormal and a gamma distribution was found to be appropriated. Accordingly, a gamma based GLM was fitted using "log" link function to determine the relationship between the five explanatory variables and skipjack tuna CPUE for port sampling data. For logbook data, year, month, VT and latlong5 were taken into consideration as categorical explanatory variables and skipjack tuna CPUE as the response variable. The models were fitted using R statistical software (R Development Core Team, 2018).

Results

Nominal CPUE data of port sampling: 2004- 2018

The nominal CPUE of skipjack tuna in the gillnet fishery of Sri Lanka has considerably varied over the period (Figure 1). The highest catch rates were reported in 2018 whereas the lowest catch rates were reported in 2015. As a whole, the catch rates during 2014 – 2016 had considerably dropped but, it has largely recovered after 2016.

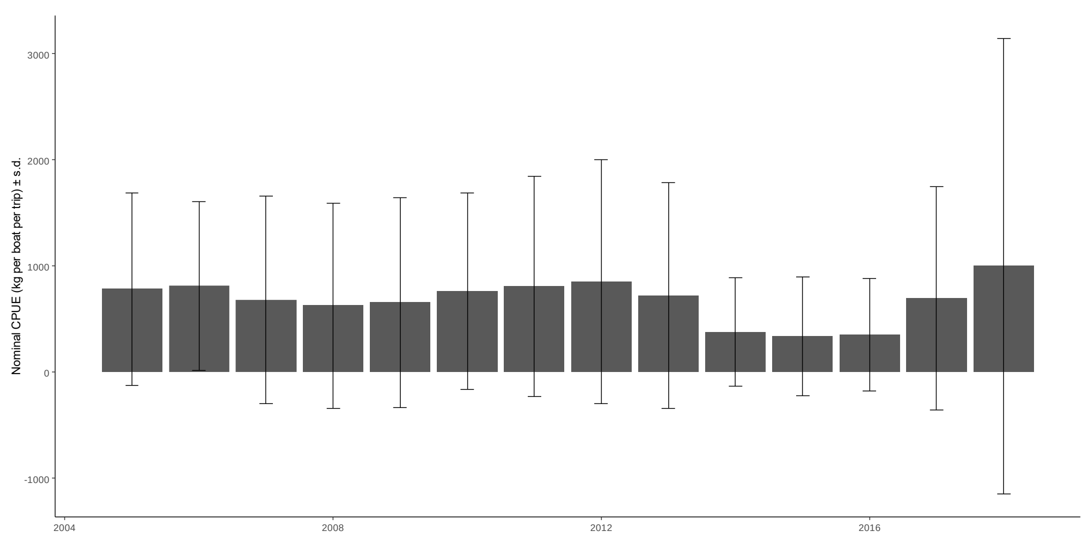

Figure 1: Variation in nominal CPUE of skipjack tuna in gillnet fishery of Sri Lanka during 2004- 2018. The error bars refer to the standard errors

Spatial and temporal distribution of fishing grounds

The fishing grounds of skipjack tuna mostly concentrated within EEZ of Sri Lanka during 2016-2018 (Figure 2). In addition, high sea fishing operations were conducted mainly in the Arabian Sea, Bay of Bengal and Sothern Indian Ocean.

The geographical area of skipjack tuna fishing grounds has not considerably changed annually but, some variations in the distribution pattern of the fishing effort could be observed during the three-year period (Figure 3).

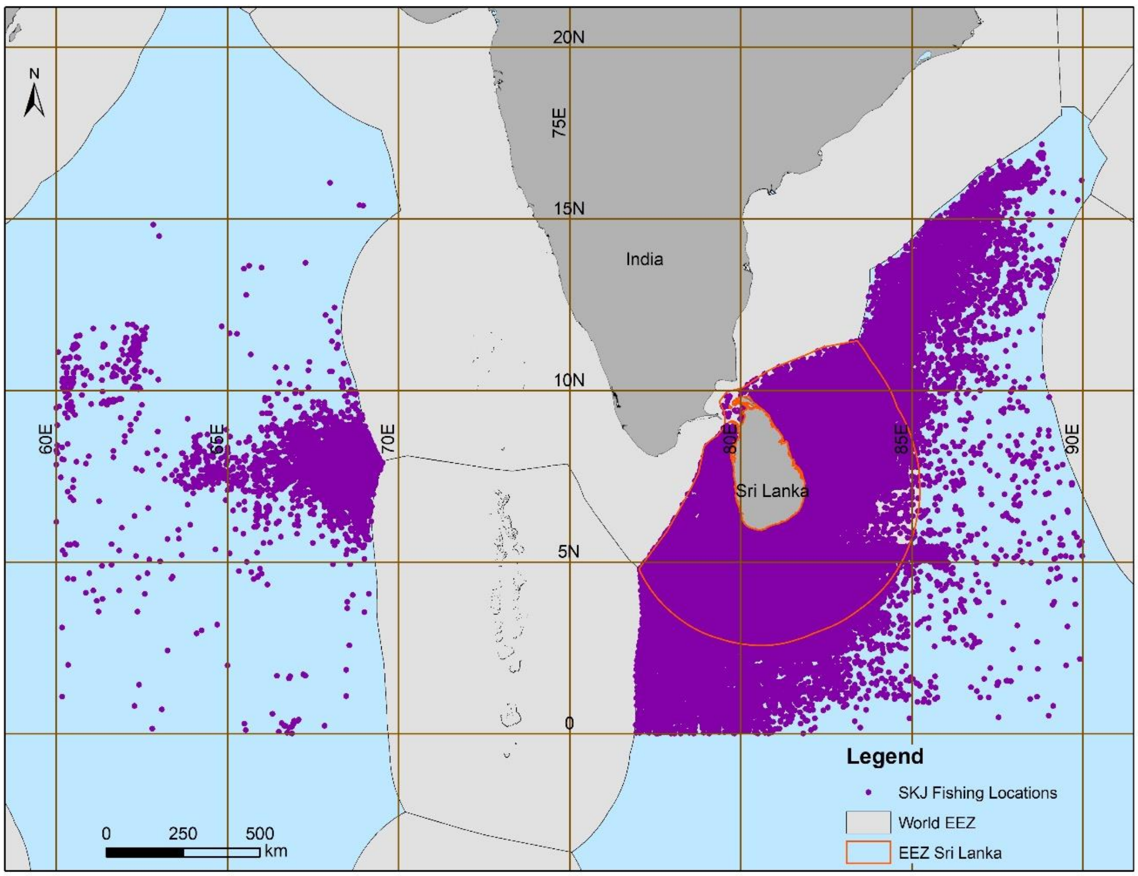

Figure 2: Spatial distribution of skipjack tuna fishing grounds: 2016 - 2018

Fishing operations targeting skipjack tuna has mostly been conducted within the EEZ of Sri Lanka though out the year but, high sea fishing operations in all three regions mentioned above were largely conducted during the 1st quarter of the year (Figure 4). In rest of the three quarters, fishing operations in high seas were mostly carried out in the Southern Indian Ocean Region.

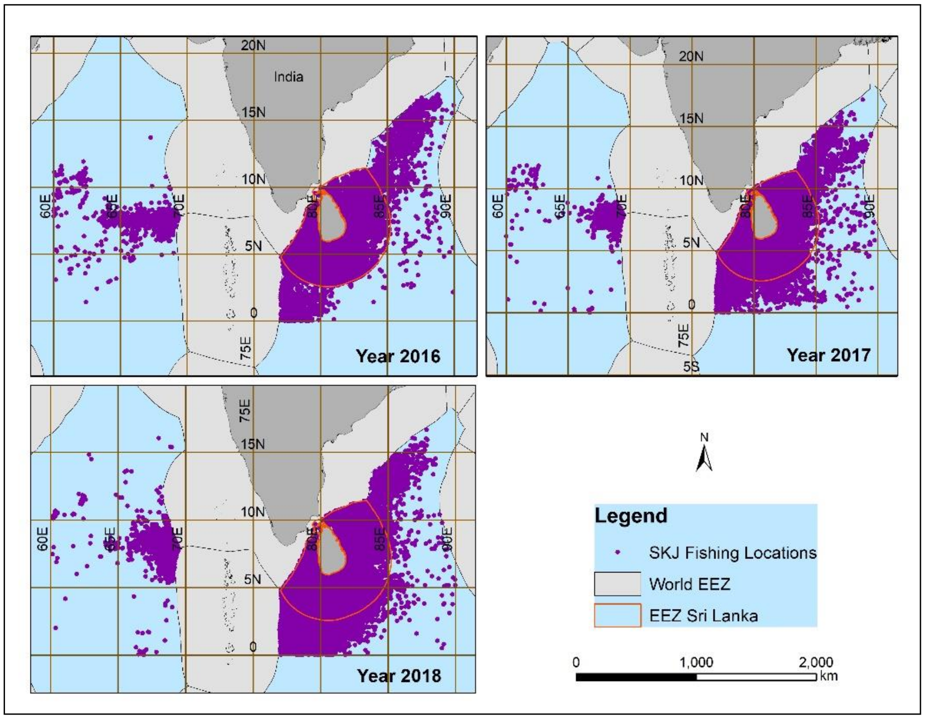

Figure 3: Annual variation of skipjack tuna fishing grounds: 2016 - 2018

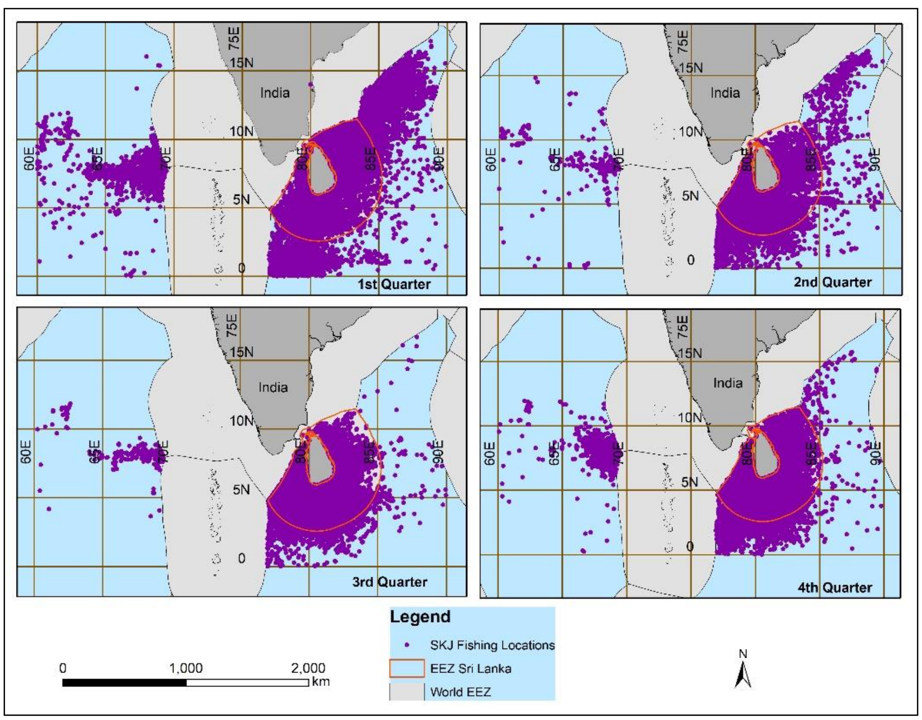

Figure 4. Seasonal variation of the skipjack tuna fishing grounds

GLM for logbook data

The analysis of deviance for gamma-based GLM model fitted to non-zero CPUE of skipjack tuna (logbook data) shows that all main effects are significant at 0.001 (Table 1). The model explained only 19.2% of the deviance and most of which is explained by the vessel type (VT) and latlog5 (10.7% and 3.9% respectively). However, the deviance explained by latlong5 was considerably low. One of the possible reasons for this may be due to the practice of skippers who normally record their fishing locations only at one time per day, which was found to be insufficient for reliable reporting.

Table 1. Analysis of deviance table for gamma-based GLM model fitted to logbook skipjack tuna catch rates (VT- Vessel type, latlong5 - 5° squares)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			187822	276518		
Year	2	6988.7	187820	269530	1533.39	< 2.2e-16 ***
Month	11	5927.6	187809	263602	236.47	< 2.2e-16 ***
VT	2	29558.6	187807	234043	6485.47	< 2.2e-16 ***
latlong5	35	10691.8	187772	223351	134.05	< 2.2e-16 ***
Sig. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						

GLM for port sampling data

The analysis of deviance for gamma-based GLM model fitted to non-zero CPUE of skipjack tuna (port sampling data) shows that all main effects are significant at 0.001 (Table 2).However, the fitted GLM model explains 47.9% of the total deviance. The two main effects, VT and TD explain 35.4% and 9.4% of the total deviance respectively.

Table 2. Analysis of deviance table for gamma-based GLM model fitted to port sampling skipjack tuna catch rates (VT- Boat type, GT- gear type, TD – trip duration and NP- no of net pieces)

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL			4874	9346.5		
year	13	287.3	4861	9059.3	19.2572	< 2.2e-16 ***
month	11	95.1	4850	8964.1	7.5359	5.363e-13 ***
VT	4	3202.8	4846	5761.4	697.78	< 2.2e-16 ***
GT	2	20.4	4844	5741.0	8.8890	0.0001402 ***
TD	1	847.3	4843	4893.7	738.410	< 2.2e-16 ***
NP	1	22.5	4842	4871.2	19.6157	9.678e-06 ***
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1						

Conclusion

The catch rates analysis provide a considerable knowledge on the variation of skipjack tuna CPUE in the gillnet fishery of Sri Lanka. Gillnet fishing operations targeting skipjack tuna are largely conducted within the EEZ of Sri Lanka. High sea fishing operations are mainly conducted in three regions: Arabian Sea, Bay of Bengal and Sothern Indian Ocean but, a considerable variation in spatial and temporal distribution of high sea fishing grounds was observed. The results of GLM fitted to port sampling data have been encouraging since the model explained around 48% of the total deviance. Inclusion of spatial data obtained from fisheries logbooks for GLM modeling does not seem to be adequately contributed for improving the results.

Acknowledgements

The relevant staff members of National Aquatic Resources Research and Development Agency (NARA), Department of Fisheries and Aquatic Resources (DFAR) and Ministry of Fisheries and Aquatic Resources Development (MFARD) of Sri Lanka who assisted in port sampling data collection, data entry and data analysis are acknowledged.

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