Received: 1 October 2017
IOTC-2017-WPTT19-45

Relationship between skipjack tuna *(Katsuwonus pelamis)* Catch Per Unit Effort (CPUE) and fishing operation related parameters: A case study in gillnet fishery of Sri Lanka

S.S.K. Haputhantri

Marine Biological Resources Division, National Aquatic Resources Research & Development Agency, Crow Island, Mattakkuliya, Colombo–15.

Abstract

The fishing operations in tuna fishery of Sri Lanka are conducted by single day and multiday fishing crafts and fishing activities are taken place from coastal waters up to the high seas. Gillnet is the main fishing gear used in tuna fishery of Sri Lanka. Mostly multiday fishing boats use this fishing gear. Gillnet is sometimes operated as a supplementary fishing gear in longline fishery. The popular gear combinations operated with gillnets are gillnet-longline (GL), gilllnet-handline (GH) and gillnet-ringnet (GR). The key target species in gillnet fishery is skipjack tuna (*Katsuwonus pelamis*). Skipjack tuna landed by Sri Lankan fishing vessels were monitored from January 2005 – December 2012 at the major tuna landing sites and fishery harbours in Sri Lanka. The unloaded skipjack tuna catch by the vessels was recorded. Other parameters in relation to fishing operations were also recorded: boat type, gear type, trip duration and number of net panels used. A Gamma based Generalized Additive Model (GAM) was fitted using log link function to describe the relationship between skipjack tuna CPUE and fishing operation related parameters. The fitted GAM model explains 75.4% of the deviance. Catch rates of skipjack tuna increased in association with increases in trip duration and increases in gillnet panels. Results from this case study can have few management implications.

Introduction

Sri Lanka is one of the oldest and most important tuna catching island nations in the Indian Ocean. Both semi-industrial and artisanal fishing crafts are engaged targeting tuna and tuna like species. The tuna fishery has gradually developed over the last seven decades. At the beginning, fishing activities mostly took place in the shallow coastal waters. However, at present, there is a wide distribution in the tuna fishing fleet from coastal waters up to high seas. Around 1600 fishing boats have currently been registered for fishing operations in high seas. The fish landed by the vessels engaged in tuna fishery mainly comprise of tuna and tuna like species. The catch is dominated by skipjack tuna (*Katsuwonus pelamis*) and this particular species has contributed around 55% to the total landings made by fishing vessels engaged in targeting tuna and tuna like fish (PELAGOS, 2014). Around 85% of the total skipjack tuna landed in 2014 were caught by gillnets (PELAGOS, 2014). The aim of the present study is to find out the relationship between catch rates of skipjack tuna and fishing operation related parameters in the gillnet fishery of Sri Lanka.

Materials and Methods

Fisheries data

The fisheries data used for this analysis was obtained from the port sampling programme conducted by the National Aquatic Resources Research and Development Agency (NARA), Sri Lanka. The sampling programme was conducted at the major tuna landing sites and fishery harbours in Sri Lanka. The skipjack tuna landed by the fishing vessels operated during the period January 2005 – December 2012 with above described gears (i.e., gillnet, gillnet-longline (GL), gilllnet-handline (GH) and gillnet-ringnet (GR)) were considered for this audit. The unloaded skipjack tuna catch by the fishing vessels was recorded with other parameters: boat type, used gear/ gear combination, trip duration and number of net panels used per fishing trip etc. For the data collection, enumerators were stationed by NARA at the major ports and fish landing sites.

Selection of fishing operation related parameters

Gear type (gillnet (GN) and three gear combinations (gillnet–longline (GL), gilllnet-handline (GH) and gillnet-ringnet (GR)) was \considered as one parameter. The vessel type was considered as another fishing operation related parameter. Five vessel categories were operated during this period targeting skipjack tuna (Table 1). Two more parameters, trip duration (TD) and number of net panels (NP) used for fishing operation were also considered.

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 sea fishery	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

Generalized Additive Models (GAM)

The GAM was proposed by Hastie and Tibshirani (1990) for the purpose of fitting nonparametric functions describing the relationship between a transformation of the mean response and the continuous predictors. A GAM is a non-parametric generalization of multiple linear regression and generalized linear models, in which a link function is related to predictor variables by arbitrary smooth functions of the predictors. They are non-parametric regression methods, which model the dependent variable as an additive sum of unspecified functions of covariates.

Model fitting

The vessels which brought zero catch of skipjack tuna were not considered. Monthly average Catch Per Unit Effort (CPUE) of skipjack tuna was estimated in terms of skipjack tuna catch in kg per boat per fishing trip. In GAM modelling, it was assumed that response variable (CPUE) follows a Gamma distribution (Haputhantri, 2016). GAM model was fitted using a “log” link function to determine the relationship between the explanatory variables and monthly average CPUE. GAM was constructed in R (version 3.1.0) software (R Development Core Team, 2016), using the GAM function of the mgcv package (Wood 2006), with CPUE as the response variable with gear type, craft type, trip duration and net panels used as predictor variables.

Results and discussion

The trip duration of a multiday fishing craft ranged from 2 – 60 days. The average trip duration for UN2B, UN3A and UN3B fishing crafts were 7, 13.4 and 19.7 days respectively. The lowest average trip duration of 6.3 days for multiday boats was reported for UN2B boats operated with gillnet whereas the highest average trip duration of 22 days was reported for UN3B operated with longline – gillnet gear combination. Most gillnet boats have used 20- 60 gillnet panels for a fishing trip (Figure 1).

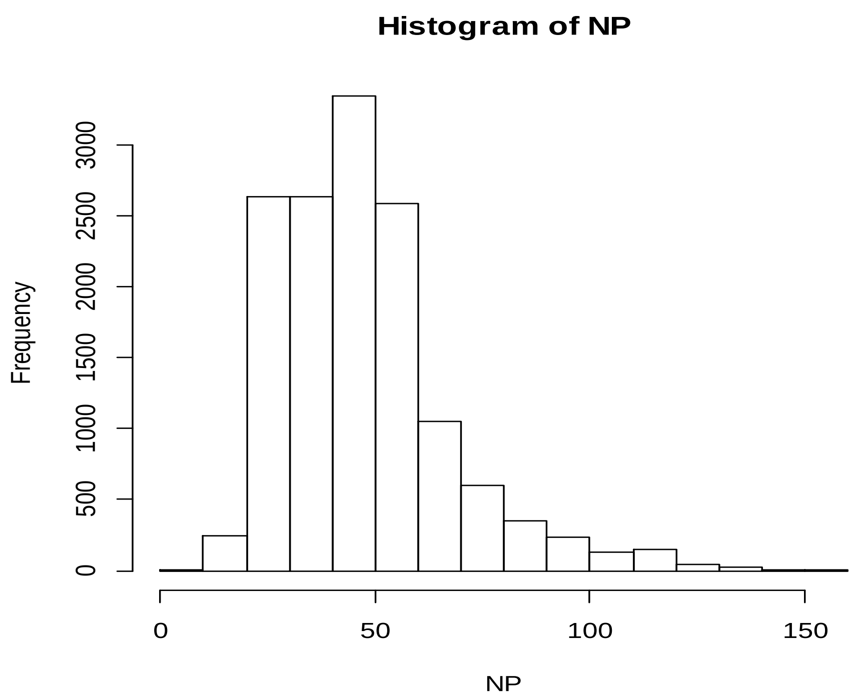

Figure 1. Histogram of net panel usage for a fishing trip

The histogram of non-zero CPUE of skipjack tuna for the vessels operated in tuna fishery during 2005-2012 was skewed (Figure 2).

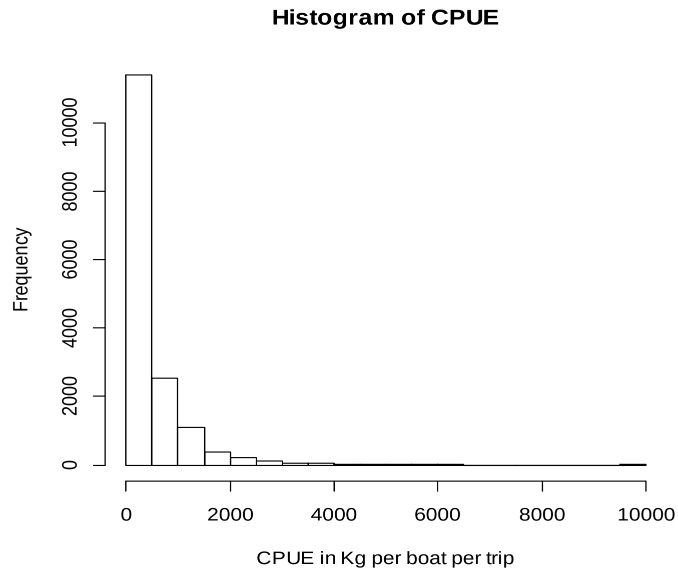

Figure 2. Histogram of non-zero Catch Per Unit Effort (CPUE) of skipjack tuna

The annual average non-zero CPUE of skipjack tuna was higher during 2005 – 2006 compared to rest of the period (Figure 3).

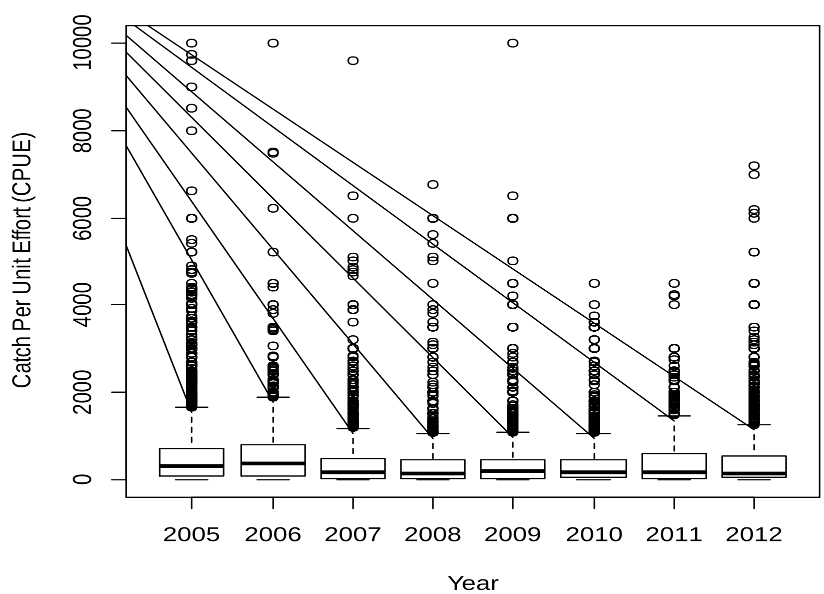

Figure 3. Annual variation in non-zero Catch Per Unit Effort (CPUE) of skipjack tuna: 2005-2012

Among the vessels operated in tuna fishery of Sri Lanka, the highest average non-zero CPUE of skipjack tuna was reported by UN3B type vessels (Figure 4). When compared with other gears, average non-zero CPUE of skipjack was highest for longline-gillnet combination (Figure 5).

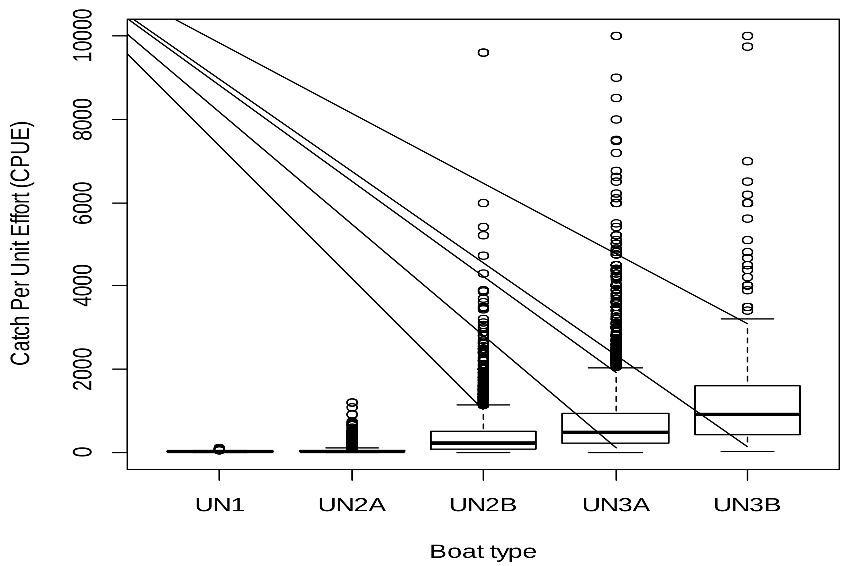

Figure 4. Boat type wise variation in non-zero Catch Per Unit Effort (CPUE) of skipjack tuna: 2005-2012

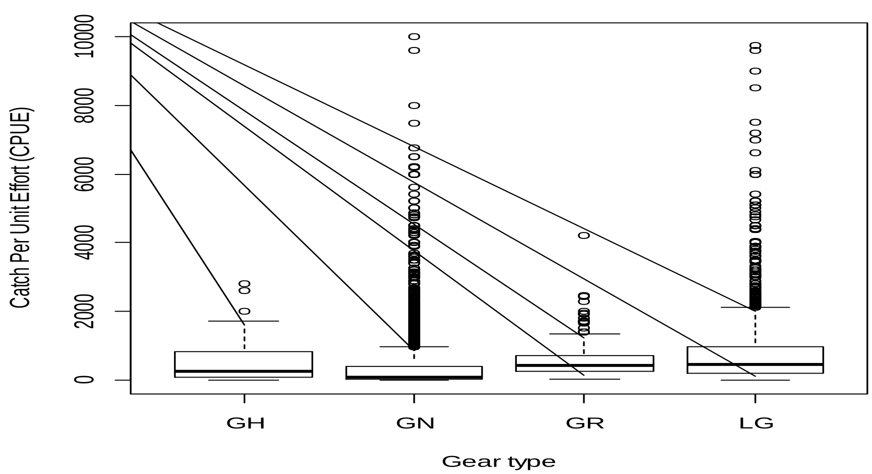

Figure 5. Gear-wise variation in non-zero Catch Per Unit Effort (CPUE) of skipjack tuna: 2005-2012

The results of this study show that catches of skipjack tuna are linked to gear type and boat type. Moreover, catches are linked to trip duration and gillnet panels. Catch rates of skipjack tuna increased in association with increases in trip duration and increases in gillnet panels (Figure 6).

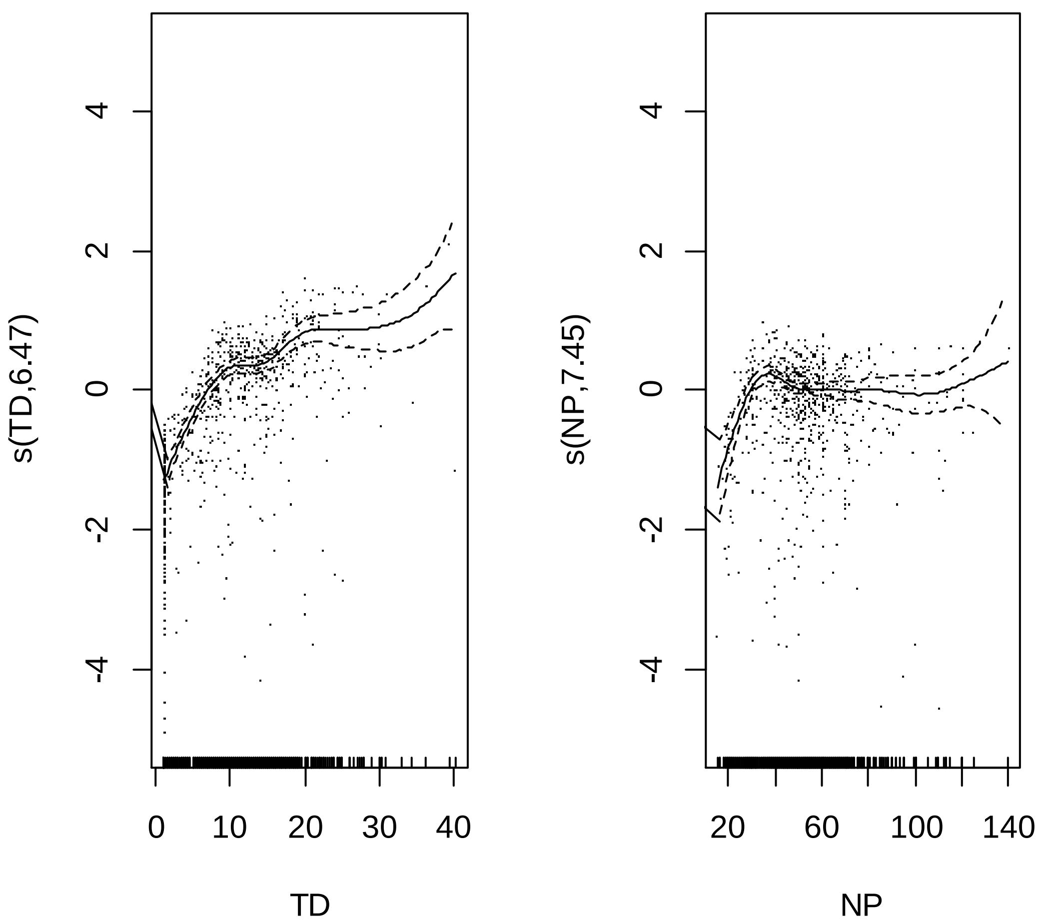

Figure 6. Modeled effect of trip duration (TD) and net panels used (NP) on non-zero CPUE of skipjack tuna. The solid line shows the fitted GAM function and the black-dotted line indicates 95 % confidence intervals. Relative density of data points are indicated by the rug plot on the x-axis

Two smooth terms in the GAM model was highly significance (P-values <0.001). The GCV (Generalized Cross Validation) score and deviance explained by the model were 0.36 and 75.4% respectively. Low GCV value and higher deviance were evidence for the best fitting of the model.

Conclusion

This case study provides preliminary insights into the relationship between catch rates of skipjack tuna and fishing operation related parameters. Results from the study can have few management implications. Some management tools which will be based on fishing input control could be attempted for the fisheries management in a situation where resources are subjected to heavy fishing and output control measures are difficult to implement.

Acknowledgements

The support given by the staff members of the Marine Biological Resources Division, National Aquatic Resources Research and Development Agency (NARA) is highly appreciated.

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