Applying Generalized Linear Models (GLM) for the analysis of catch rates of Skipjack Tuna (*Katsuwonus pelamis*) in gillnet fishery of Sri Lanka

S.S.K. Haputhantri and S.J.W.W.W.M.M.P Weerasekera

Marine Biological Resources Division, National Aquatic Resources Research & Development Agency (NARA), Crow Island, Mattakkuliya, Colombo–15, Sri Lanka.

Abstract

Thirteen years port sampling data (2005-2017) 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 gillnet fishery. All gillnet catches including the catches made by popular gear combinations operate in gillnet fishery (gillnet–longline, gillnet-handline and gillnet-ringnet) were considered for this study. Five vessel types which were operated during this period in the tuna fishery of Sri Lanka have caught skipjack tuna. Fish landing data and biological data of key species in gillnet fishery are collected during the port sampling. Accordingly, the unloaded skipjack tuna catches made by the vessels are recorded and these data with other data relating to fishing operations are also recorded and entered into the national database (PELAGOS). Year, month, boat type, gear/ type, trip duration (in days) and number of net panels used for fishing operation were considered for this analysis. A monthly series of skipjack tuna Catch Per Unit Effort (CPUE) in terms of catch in kg per boat per trip was derived from the catch data. A Gamma based Generalized Linear Model (GLM) was fitted to determine the relationship between the explanatory variables and monthly average CPUE. All zero-catch rates of skipjack tuna were excluded for the analysis. All main effects and their first order interactions were taken into consideration. The fitted GLM model explains 83.8% of the deviance and the vessel type was found to be the most significant factor for determining the catch rates of skipjack tuna. Among the first order interactions, year : month was found to be the key explanatory variable. The fitted GLM model comprises of main effects only explains 65.5% of the deviance.

Introduction

Tuna fishery resources in Sri Lanka mainly comprise of skipjack tuna (*Katsuwonus pelamis*) followed by yellowfin tuna (*Thunnus albacores)* and big eye tuna (*T. obsesus*) respectively. These species are mostly caught in offshore and high sea areas. However, a small proportion of above oceanic tuna species is caught within the continental shelf too and therefore has been included in the coastal fish production. The total tuna production of Sri Lanka in 2014 was 89,603Mt and this included neritic tuna production too (PELAGOS, 2014), of which skipjack tuna contributed more than 54% of the total tuna production. Skipjack tuna is mostly consumed locally and sometimes used for producing dry fish and maldive fish.

A wide range of gear is used in the tuna fishery. Gillnet, longline and ringnet are the main gears used for catching tuna and tuna like species. Skipjack tuna is the key target species in the gillnet fishery. Gillnets are sometimes operated as gear combinations and most popular gear combinations in the gillnet fishery are gillnet-longline, gillnet-handline and gillnet-ringnet. Around 85% of the total skipjack tuna landed in 2014 were caught by gillnets (PELAGOS, 2014). The aim of the present study was to examine the relative influence of selected temporal and operational factors to change the catch rates of skipjack tuna (*Katsuwonus pelamis*) in the gillnet fishery of Sri Lanka.

Materials and methods

Fisheries data

Fisheries data used for this analysis were 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 2017 with above described gears were considered for this audit. At the field, the unloaded skipjack tuna catches made by the fishing vessels were recorded with other parameters: boat 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.

Selection of temporal and operational parameters for catch rate analysis

The gear types which included gillnet (GN) and main gear combinations used in gillnet fishery (i.e. gillnet–longline (GL), gilllnet-handline (GH) and gillnet-ringnet (GR)) was considered as one operational parameter for the catch rate analysis of skipjack tuna. The vessel type 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
	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

3			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

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

GLM model fitting

A monthly series of skipjack tuna CPUE (Catch Per Boat Per Trip) was derived from the catch data. All zero-catch rates of skipjack tuna 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 Generalized Linear Model (GLM) was fitted using “log” link function to determine the relationship between the five explanatory variables and monthly average CPUE. In the first case, all main effects and their first order interactions were taken into consideration. Secondly, only main effects were considered for 2nd GLM model The models were fitted using R statistical software (R Development Core Team, 2015).

Results

More than 99% of CPUE comprised of non-zero CPUE values. The frequency distribution (histogram) of non-zero CPUE was skewed (Figure 1).

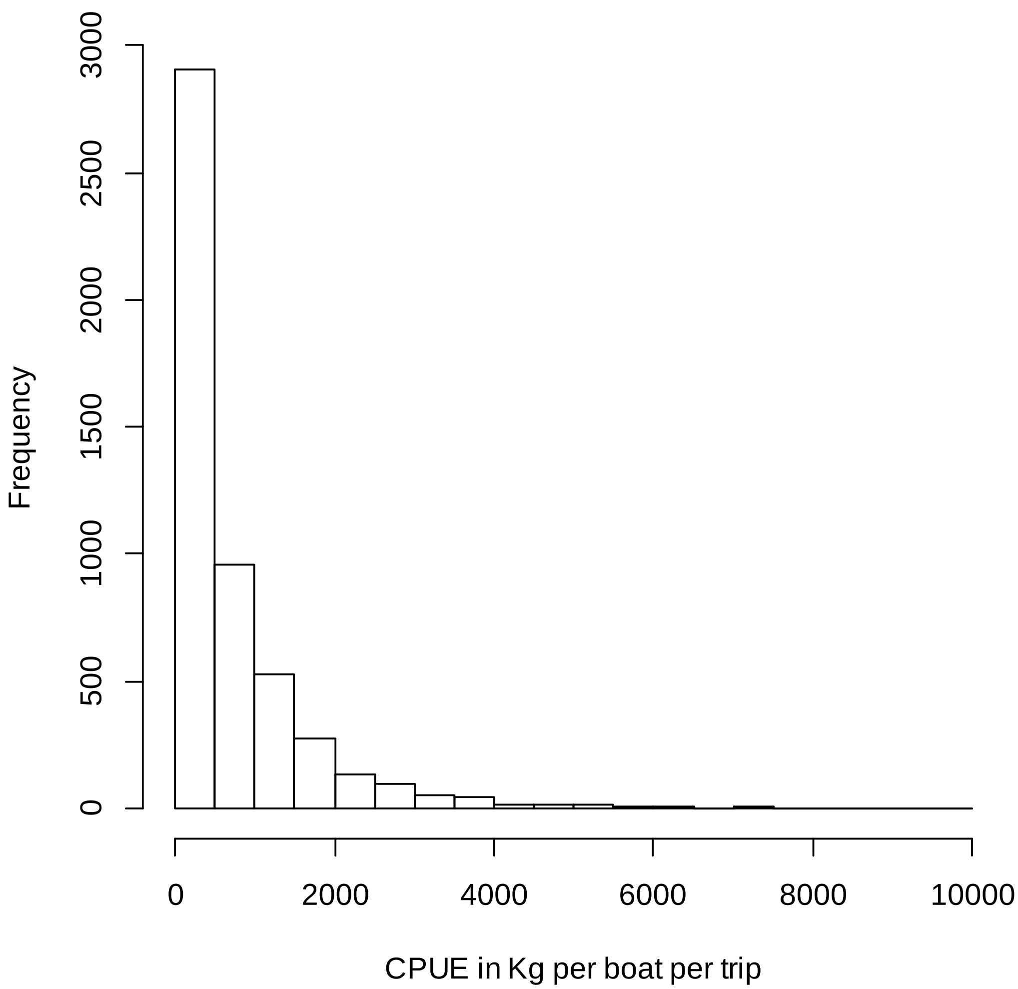

Figure 1. Histogram of non-zero CPUE of skipjack tuna in gillnet fishery

The number of net panels used per fishing operation has a wider range but, most vessels have used 20-50 net panels (Figure 2).

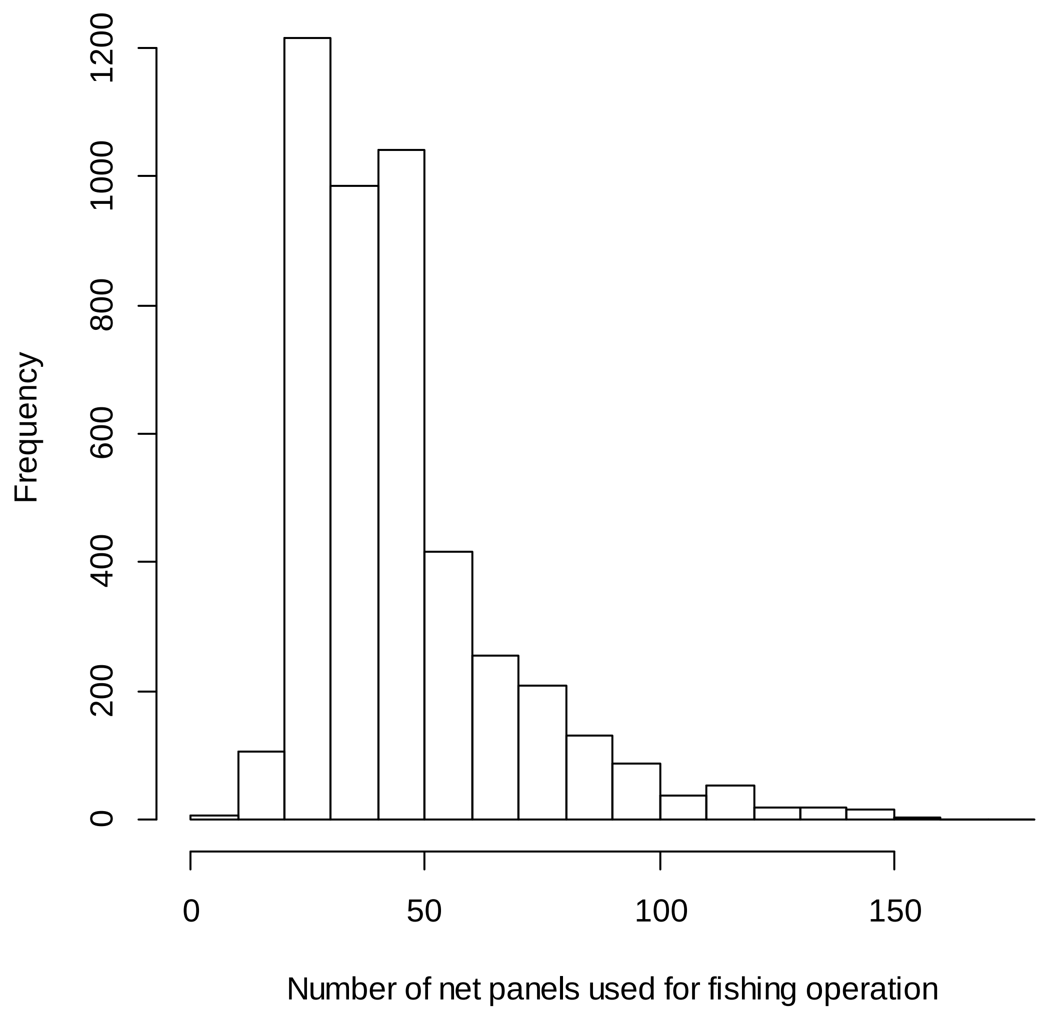

Figure 2. Distribution of the net panels used for fishing operations

A considerable variation in the mean annual CPUE could be observed during 2005-2017 and mean annual CPUE has increased considerably in 2017 after the drop in three consecutive years since 2014 (Figure 3).

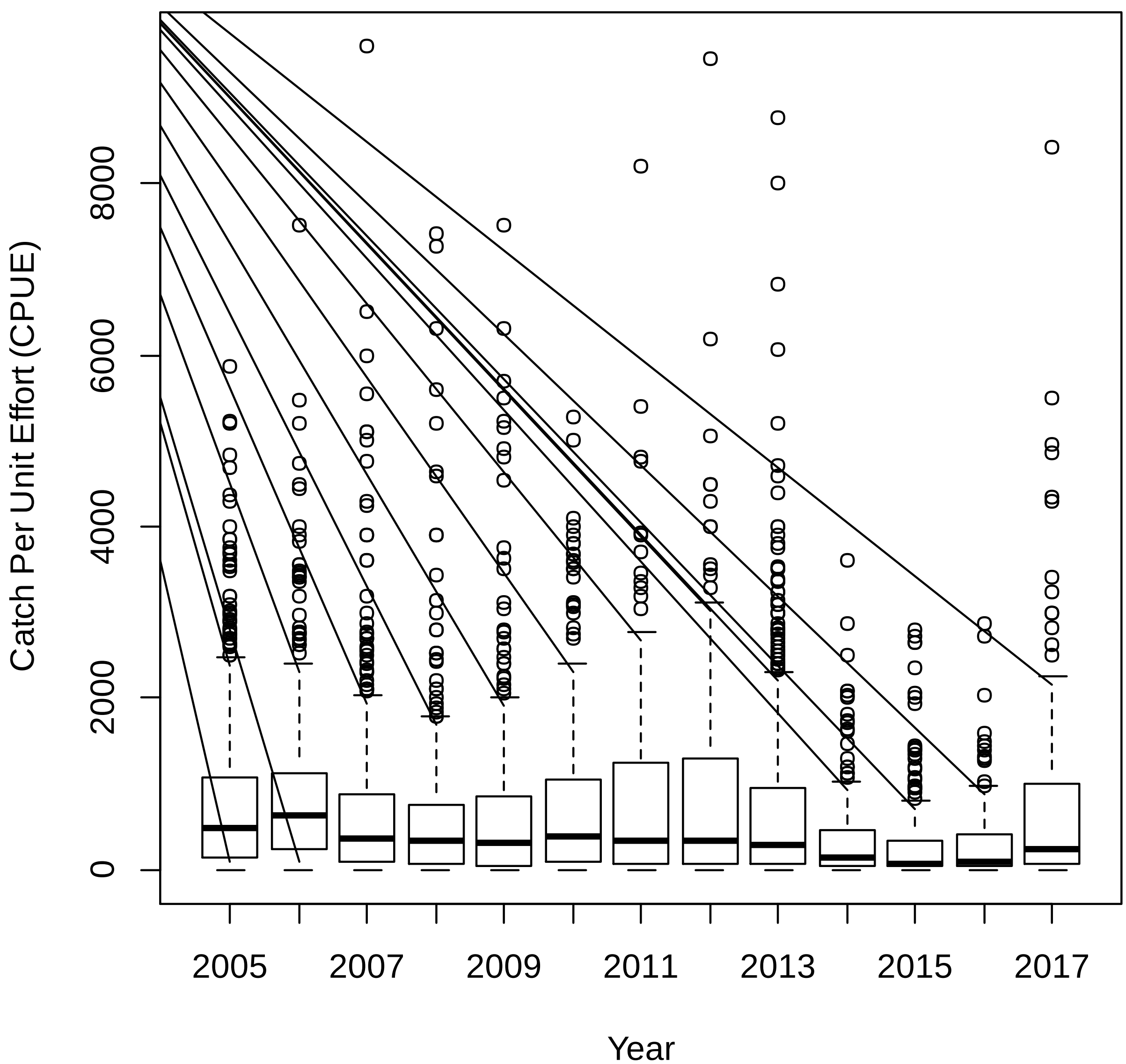

Figure 3. Box plot to show the annual variation in CPUE of skipjack tuna: 2005-2017

A remarkable monthly variation in the mean CPUE could be observed (Figure 4). In general, monthly average CPUE is comparatively higher from October to March than other months of the year.

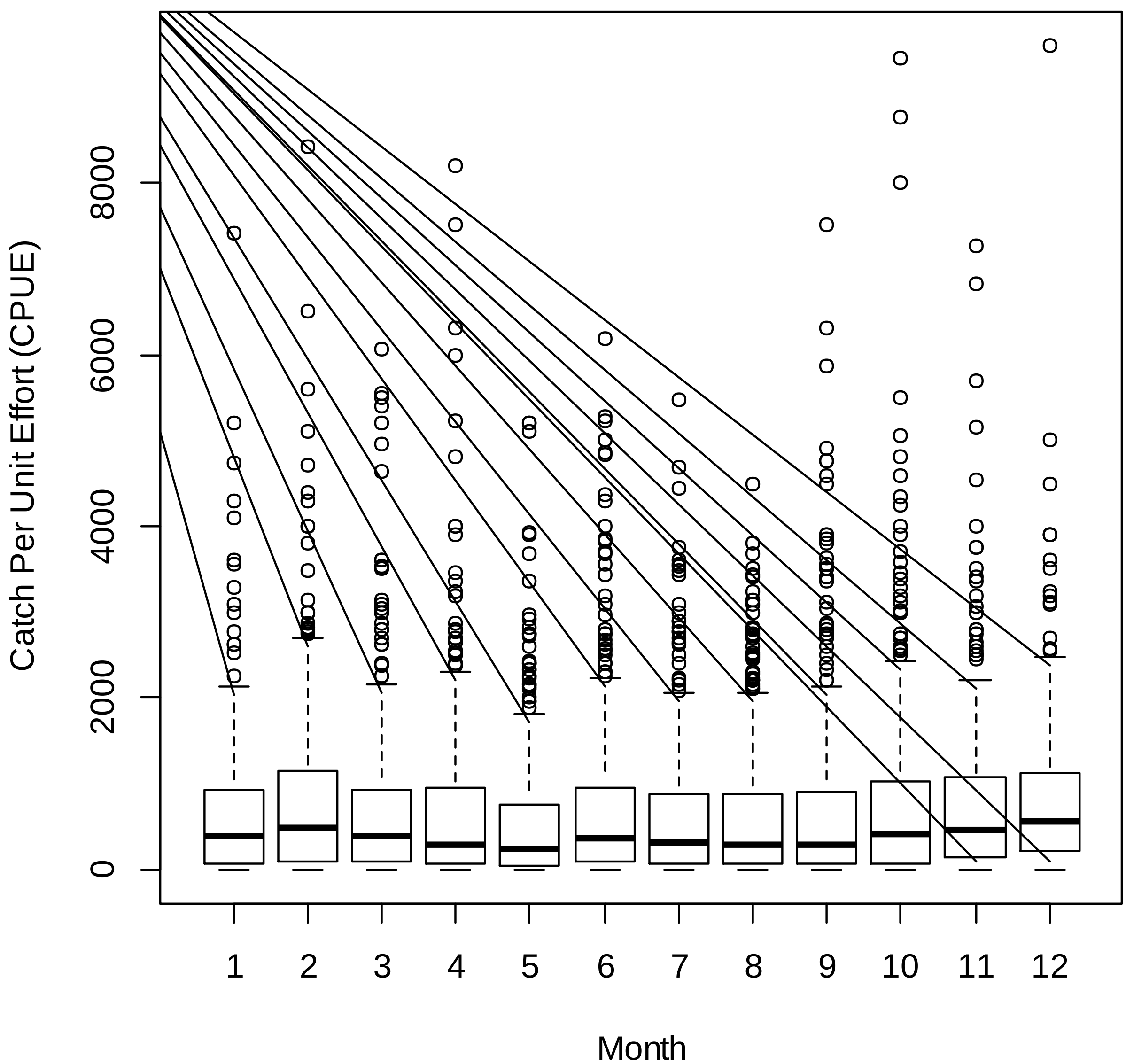

Figure 4. Monthly variation in average CPUE of skipjack tuna

Among different gear types operated targeting skipjack tuna, the average CPUE was highest for gillnet – ring net gear combination whereas it was lowest for fishing crafts operated with gillnet along (Figure 5).

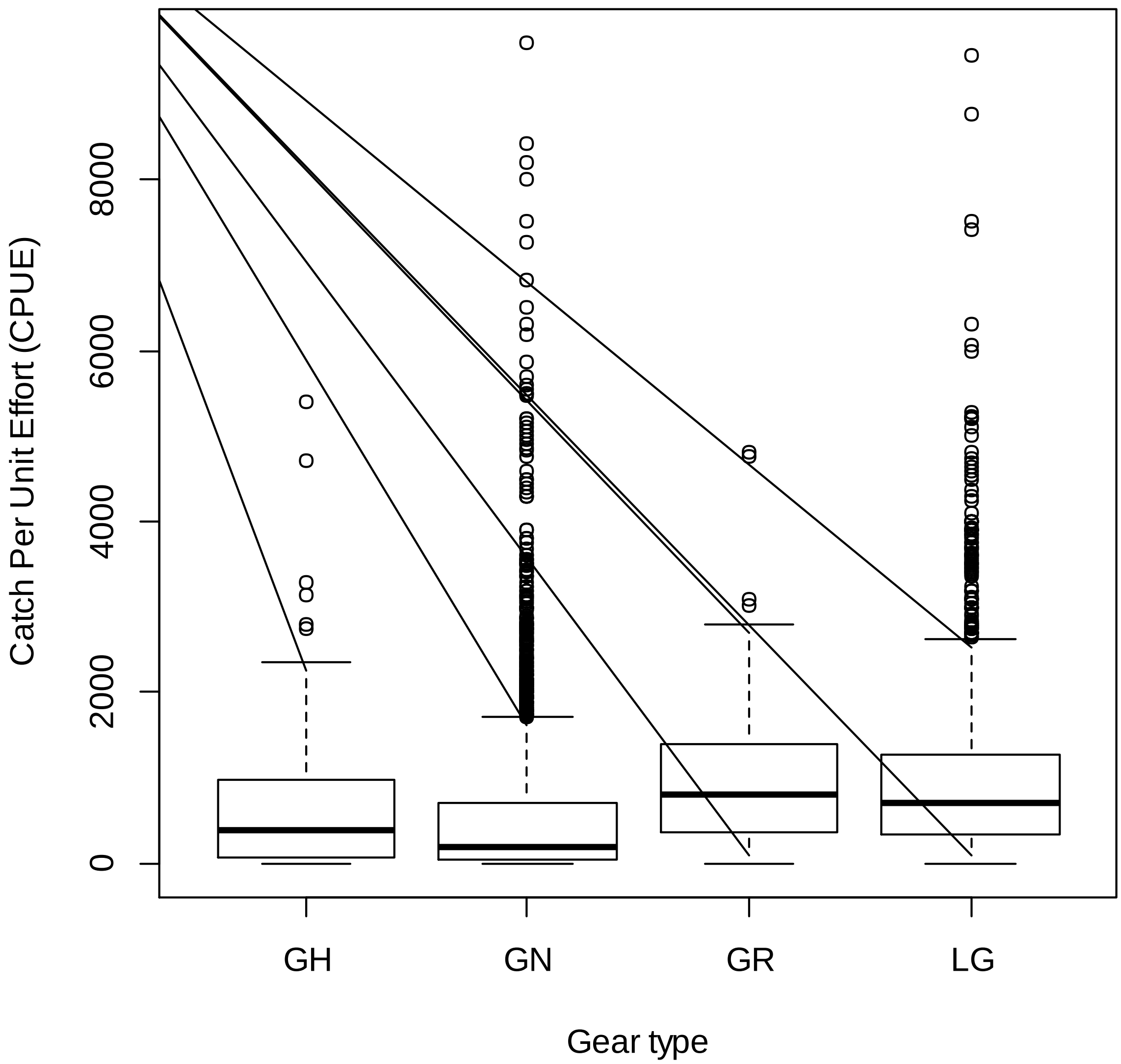

Figure 5. Gear wise variation in the CPUE of boats operated targeting skipjack tuna

A remarkable variation in the CPUE of skipjack tuna could be observed with respect to different craft types (Figure 6). The average CPUE was highest for UN3B multiday fishing crafts whereas it was lowest for UN1 single day boats.

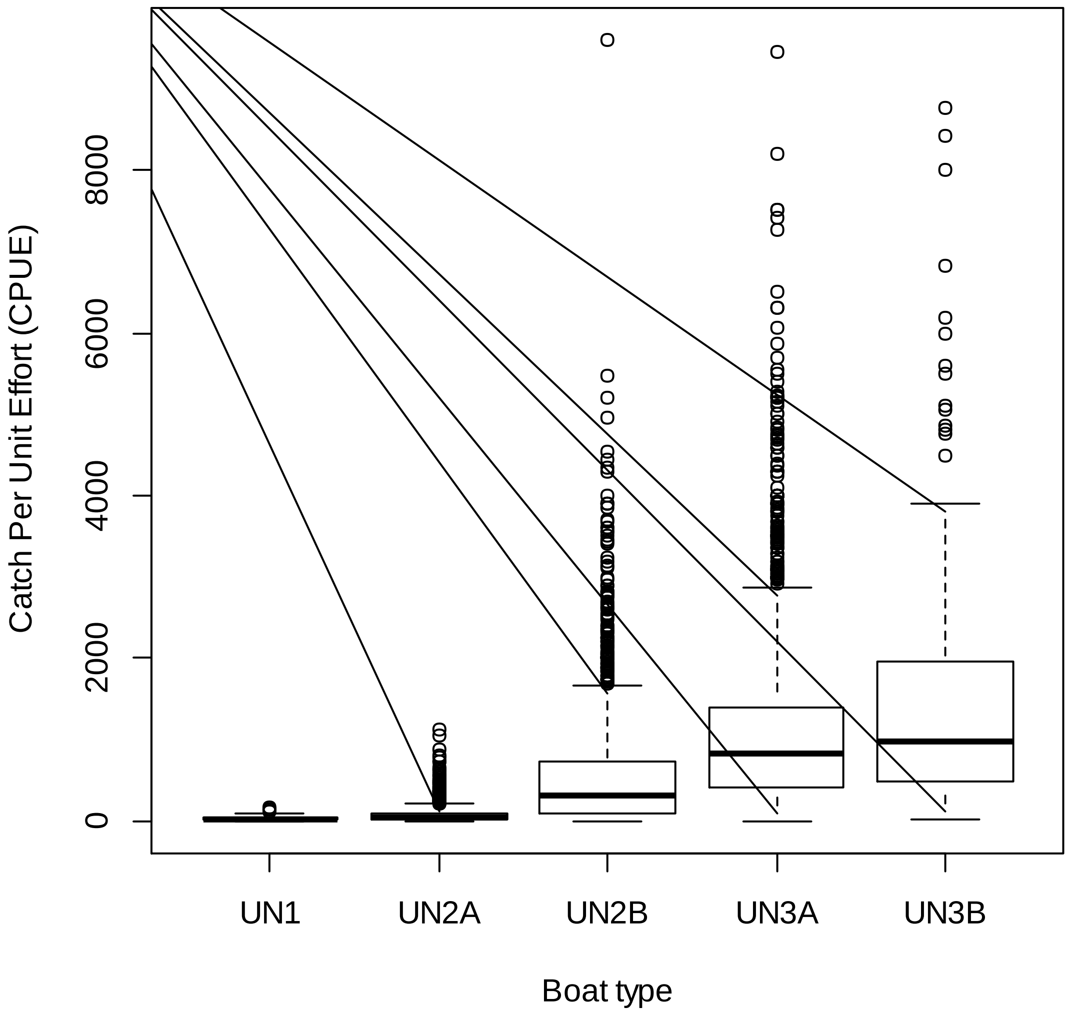

Figure 6. Fishing craft wise variation in CPUE of skipjack tuna

GLM results

The analysis of deviance for gamma-based GLM model fitted to skipjack tuna CPUE shows that all main effects and some first-order interactions are significant ($p < 0.05$) (Table 2). When considering the interaction between year and month for example, meaning the monthly variation in catch rates is not the same in all years. The model explained 83.8% of the deviance, most of which is explained by the difference between the vessel type (50%). However, the variation in ln (CPUE) explained by net panels is very small (0.2% only) in comparison with other main effect factors. Also, it may be important to notice that year: month interaction explains 6.7% of the total deviance.

Table 2. Analysis of deviance table for gamma-based GLM model (main effects and first order interactions only) fitted to skipjack tuna catch rate data (BT- Boat type, GT- Gear Type, TD- fishing trip duration, NP- number of net panels used per fishing operation)

Source	d. f .	Deviance	% explained	Residual d. f.	Residual Deviance	F value	Pr (F)
Null				909	1211.91		
Year	12	47.86	3.9	897	1164.05	13.29	< 2.2e-16 ***
Month	11	28.81	2.4	886	1135.24	8.73	2.463e-14 ***
BT	4	605.63	50.0	882	529.61	504.62	<2.2e-16 ***
GT	3	5.33	0.4	879	524.28	5.92	0.0005614 ***
TD	1	103.13	8.5	878	421.15	343.70	<2.2e-16 ***
NP	1	2.52	0.2	877	418.63	8.41	0.0038899 **
year:month	125	81.48	6.7	752	337.15	2.17	1.103e-09 ***
year:BT	41	42.31	3.5	711	294.84	3.44	3.822e-11 ***
year:GT	23	12.91	1.1	688	281.93	1.87	0.0085903 **
year:TD	12	17.25	1.4	676	264.68	4.79	1.700e-07 ***
Year:NP	12	6.81	0.6	664	257.86	1.89	0.0328244 *
month:BT	43	21.66	1.8	621	236.20	1.67	0.0053835 **
month:GT	33	14.37	1.2	588	221.83	1.45	0.0521125 .
month:TD	11	5.56	0.5	577	216.27 .	1.68	0.0730193

month:NP	11	4.02	0.3	566	212.25	1.21	0.2720814
BT:GT	10	1.77	0.1	556	210.48	0.59	0.8219151
BT:TD	3	4.54	0.4	553	205.94	5.03	0.0018842**
BT:NP	4	4.28	0.4	549	201.66	3.57	0.0069166**
GT:TD	3	2.26	0.2	546	199.40	2.51	0.0578203.
GT:NP	3	0.82	0.1	543	198.57	0.91	0.4330578
TD:NP	1	1.79	0.1	542	196.79	5.96	0.0146505*
Total Explained		1015.11	83.8				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The 2nd GLM model comprises of only main effects explains 65.5% of the deviance (Table 3).

Table 3. Analysis of deviance table for gamma-based GLM model (main effects only) fitted to skipjack tuna catch rate data (BT- Boat type, GT- Gear Type, TD- fishing trip duration, NP- number of net panels used per fishing operation)

Source	d. f .	Deviance	% explained	Residual d. f.	Residual Deviance	F value	Pr (F)
Null				909	1211.91		
Year	12	47.86	3.9	897	1164.05	8.9	2.994e-16 ***
Month	11	28.81	2.4	886	1135.24	5.8	3.335e-09 ***
BT	4	605.63	50.0	882	529.61	337.9	< 2.2e-16 ***
GT	3	5.33	0.4	879	524.28	3.9	0.008035 **
TD	1	103.13	8.5	878	421.15	230.1	< 2.2e-16 ***
NP	1	2.52	0.2	877	418.63	5.6	0.017867 *
Total Explained		793.28	65.5				

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Conclusion

This catch rates analysis provided substantial knowledge on the variation of the CPUE of skipjack tuna in the gillnet fishery of Sri Lanka. The GLM results have been encouraging since the model explained more than 83% of the total deviance. Inclusion of spatial data for GLM modeling may help for further improving the results. The analysis could be further extended for the standardization of skipjack tuna CPUE in the gillnet fishery of Sri Lanka.

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.

References

1. McCullagh, P. and J.A. Nelder, 1989. Generalized Linear Models. 2nd ed. Chapman & Hall, London, 509 pp
2. PELAGOS, 2014. Large pelagic database of Sri Lanka. National Aquatic Resources Research and Development Agency (NARA). Sri Lanka.
3. R Development Core Team 2015. *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0.