Temporal and operational effects on frigate tuna *(Auxis thazard)* Catch Per Unit Effort (CPUE): A case study in tuna fishery of Sri Lanka

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Abstract

Frigate tuna (*Auxis thazard*) is a key species found in neritic tuna fish landings in Sri Lanka. Ladings of frigate tuna mostly come as a by-catch in the fishery conduct targeting tuna. Four single gears (gillnet, pole & line, ringnet and trolling line) and three gear combinations (gillnet-handline, gillnet-ringnet, gillnet-longline) catch frigate tuna in a relatively larger proportion than other gears operate in tuna fishery. Among the highly diverse fishing operations, catch rates of frigate tuna could vary with respect to different temporal and operational parameters. The aim of the study was to find out the influence of such parameters on the variability of catch rates of frigate tuna. Two temporal parameters (year and month) and three fishing operation related parameters (boat type (BT), gear type (GT) and duration of fishing trip (TD)) were used for this audit. Port sampling survey data of January, 2005 to December, 2017 were obtained from the large pelagic fishery database (PELAGOS) of National Aquatic Resources Research & Development Agency (NARA). A Gamma based Generalized Linear Model (GLM) was fitted to describe the relationship between frigate tuna monthly average CPUE and temporal & fishing operation related parameters. The fitted GLM model explains 71.5% of the total deviance and the vessel type was found to be the most significant factor for determining the catch rates of frigate tuna. Among the first order interactions, year:month was the key explanatory variable followed by year:gear type.

Keywords: Tuna fishery, *Auxis thazard*, Generalized Linear Model

Introduction

Frigate tuna (*Auxis thazard*) is a key species in neritic tuna production in Sri Lanka (Perera *et al*. 2014, Bandaranayake *et al*. 2015, Haputhantri 2016) and which accounts more than 40% in total neritic tuna production (Haputhantri 2016). Frigate tuna mostly come as a by-catch in tuna fishery mainly from four single gears (gillnet, pole & line, ringnet and trolling line) and three gear combinations (gillnet-handline, gillnet-ringnet, longline-gillnet) (Haputhantri 2016). Among different gear and gear combinations which catch frigate tuna, ring net represents highest catch per unit effort (CPUE) as it mainly targets either free fish schools or flotsam associated fish schools. According to Haputhantri (2016), CPUE varies with boat type and the fishing area.

The aim of the present study is to find out the relationship between catch rates of Frigate tuna (*Auxis thazard*) and temporal & operational parameters in tuna 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 frigate tuna landed by the fishing vessels operated during the period January 2005 – December 2017with above described gears (i.e., gillnet (GN), pole and line (PL), ringnet (RN), trolling line (TL), gillnet-longline (GL), gillnet-handline (GH) and gillnet-ringnet (GR)) were considered for this audit. The unloaded frigate tuna catch by the fishing vessels was recorded with other parameters: boat type (BT), used gear/ gear combination (GT) and trip duration (TD). For the data collection, enumerators were stationed by NARA at the major ports and fish landing sites.

Selection of parameters

Gear type (gillnet (GN), pole and line (PL), ringnet (RN), trolling line(TL), gillnet-longline (GL), gillnet-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 in tuna fishery of Sri Lanka (Table 1). Trip duration (TD) was used as the 3rd fishing operation related parameter. In addition, 'year' and 'month' were used as temporal parameters.

Table 1. Classification of fishing vessels in Sri Lanka operated during 2005-2017 period potentially targeting frigate tuna

Class	Fishery	Fishing vessel 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 m (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
4	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
5	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

Generalized LinearModel (GLM)

The Generalized Linear Model (GLM) (McCullaghand Nelder, 1989) is a generalization of the linear regression model such that non-linear, as well as linear, effects can be tested for categorical predictor variables, as well as for continuous predictor variables, using any dependent variable, the distribution of which follows several special members of the exponential family of distributions (e.g., gamma, Poisson, binomial, etc.), as well as for any normally-distributed dependent variable. Moreover, the dependent variable values are predicted from a linear combination of predictor variables, which are "connected" to the dependent variable via a link function.

GLM model fitting

A monthly series of frigatetuna CPUE (Catch Per Boat Per Trip) was derived from the catch data. All zero-catch rates of frigatetuna 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, agamma based Generalized Linear Model (GLM) was fitted using “log” link function to determine the relationship between the five explanatory variables and monthly average CPUE. All main effects and their first order interactions were taken into account. The models were fitted using R statistical software (R Development Core Team, 2015).

Results

GLM results

The analysis of deviance for gamma-based GLM model fitted to frigate tuna data shows that all main effects are significant ($p < 0.05$) (Table 2). Among the first-order interactions, six interactions are significant ($p < 0.05$) i.e., year:month; year:BT; year:GT; month:TD; BT:GT and GT:TD (Table 2). The model explained 71.5% of the total deviance, most of which is explained by the difference between the vessel types (10.3%) followed by gear type (7.5%). The interaction between year and month was highest in terms of percentage explained of the deviance (18.4%) which shows that the monthly variation in catch rates is not the same in all years. The main effects and first order interactions explain 45.2% and 26.2% of the deviance respectively.

Table 2. Analysis of deviance table for the gamma-based GLM fitted to frigate tuna (*Auxis thazard*) catch rate data (BT- boat type, GT- gear type, TD – duration of fishing trip)

Source	d. f .	Deviance	% explained	Residual d. f.	Residual Deviance	F value	Pr (F)
Null				891	1246.41		
Year	12	71.98	5.8	879	1174.43	9.5023	< 2.2e-16 ***
Month	11	26.08	2.1	868	1148.35	3.7552	3.740e-05 ***
BT	4	128.55	10.3	864	1019.80	50.9092	< 2.2e-16 ***
GT	9	93.47	7.5	855	926.33	16.4516	< 2.2e-16 ***
TD	1	13.41	1.1	854	912.92	21.2372	5.317e-06 ***
year:month	124	229.68	18.4	730	683.25	2.9341	< 2.2e-16 ***
year:BT	43	57.91	4.6	687	625.33	2.1335	7.922e-05 ***
year:GT	62	89.02	7.1	625	536.32	2.2743	8.815e-07 ***

year:TD	12	7.12	0.6	613	529.20	0.9394	0.507098
month:BT	44	37.55	3.0	569	491.65	1.3519	0.071588
month:GT	80	64.14	5.1	489	427.51	1.2701	0.071092
month:TD	11	16.42	1.3	478	411.09	2.3640	0.007638**
BT:GT	23	39.69	3.2	455	371.40	2.7338	3.618e-05 ***
BT:TD	4	4.51	0.4	451	366.89	1.7876	0.130237
GT:TD	9	11.74	0.9	442	355.15	2.0658	0.031268 *
Total Explained	449	891.27	71.5				

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