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Evaluation of the effect of lunar cycle, monsoon and spatial differences on billfishes

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ABSTRACT

Information on the abundance of resources in time and space is a prerequisite for the success of any fishing operation. Billfishes form a major constituent of Tuna longline fishery around Andaman & Nicobar Islands. The present study is an attempt to evaluate the effect of the lunar cycle and monsoon on the catch rate of billfishes. The study is based on tuna longline survey carried out by M.V. Blue Marlin, survey vessel attached to the Fishery Survey of India, Port Blair around A&N Islands. Catch rates recorded at different latitudes showed that billfishes are more abundant in upper latitude of the region.

The results of the present study indicated that there is a significant effect of the lunar cycle on the catch rate of billfishes occurring in the Andaman and Nicobar waters. However, it has been observed that the monsoon effect has no significance on the catch rates. Downward trend of year wise catch rate noticed during the study period warrant strict management measures. The effect of monsoon and the lunar cycle on Billfishes caught by tuna longline and the likely reason for that were elucidated in the text.

Key words: moon phase and fishes; seasonality and fishes; Oceanic resources; Tuna abundance; Andaman tuna fishery; Tuna environment

Introduction

Tidal water movements and lunar cycle play a major role in feeding, spawning and migratory movements of the fishes (Carey and Robinson, 1981; Luecke and Wurtsbaugh, 1993; Milar *et al*., 1997: Taylor, 1984). Many commercial and recreational fishermen believe that the lunar cycle has an influence on fishing activity. Italian driftnet fishermen know very well the effects due to different moon phases on commercial catches (DI Natale and Mangano, 1995). However, the findings of scientific studies on the effect of the lunar cycle on fishery of large pelagic fishes are at variance (Agenbag *et al*.,2003; Bigelow *et al*., 1999; Draganik and Cholyst, 1988; Hussein *et al*.,2002; Kearney, 1977; Lowry *et al*., 2007; Moreno *et. Al.*,1991; Nakamura and Rivas, 1974; Neves dos Santos and Garcia , 2005; Ortega-Garcia *et al*. 2008; Poisson *et al*.,2010; Ponce-Diaz *et al*.,2003; Render and Allen, 1987; Thomas and Schulein, 1988).

In India, Mohan and Kunjikoya (1987) studied the effect of the lunar cycle on bait- fish and tuna catches of pole and line fishery at Minicoy Island (Lakshadweep), south-west coast of India. They had not done any statistical analysis to substantiate their findings. Except the said solitary study, no attempt has been made to understand the lunar effect on the fishery of tuna and other large pelagic fishes in Indian waters.

John & Somvanshi (2000); John *et al.* (2005)and Somvanshi *et al*. (2008) provided information on spatial variation and seasonality in catches of the longline fishery around Andaman & Nicobar (A & N) Islands. The above study lack statistical significance test and not made any attempt to correlate the effect of the monsoon and the lunar cycle on longline caught pelagic fishes.

Billfishes form a major constituent of the tuna longline fishery (Sajeevan and Rajashree, 2012) but very limited information is available on their distribution and abundance. Information on abundance in time and space will definitely improve the efficiency of fishing operation and help in the effective exploitation of resources. Hence, an attempt has been made to understand the composition and abundance of billfishes inhabiting in the area. Analysis of the effect of spatial difference, effect of monsoon and the lunar cycle on billfishes occurring in Andaman & Nicobar waters was the major objective of the study.

Materials and methods

M.V. Blue Marlin, survey vessel attached to the Fishery Survey of India (FSI), Port Blair, A & N Island have carried out an exploratory tuna longline survey around A&N Islands since 1989. The resource survey data collected by the vessel during the period January 2006 to December 2008 was used for this study. Three hundred and two sets of multifilament tuna longline gear with five 3.6 sun hooks per basket were operated around the A & N Islands between the Latitudes (Lat.) 06^0N and 14^0N. 625 hooks baited with either frozen sardines or mackerels were normally shot in the morning before sunrise and hauled in after providing five to six hours of immersion time.

Billfishes caught by the gear were identified up to species level and the numbers of specimen per species caught were recorded separately for further calculations. Catch per unit effort (CPUE) was estimated in catch rate as number of fishes caught (successful hooks) per 1000 hooks. Spatial (geographical) variations of the catch were estimated by determining aggregate catch rate of fishes caught from each 1^0 Lat.

Month-wise aggregate catch rates were estimated to understand the difference in fish abundance in time. Subsequently, the effect of monsoons on the billfishes was estimated by grouping the months into Pre-monsoon (January to April), Monsoon (May to August) and Post monsoon (September to December) periods following Somvanshi & Varghese (2005). Aggregate catch rates recorded during these periods in each year were utilized to understand the effects of the monsoon on billfishes.

Lunar days since January 2006 to December 2008 were mined from the Indian tide tables published by the Surveyor General of India, Govt. of India (GOI, 2005, 2006, 2007). The lunar periodicity in each month was pooled into three periods according to the lunar phase as a new moon period, the waxing & waning period and full moon period. New moon period refers to new moon day ±3 days, full moon period refers to full moon day ±3 days and the in between periods were pooled as the waxing & waning periods. Aggregate catch rates recorded during these lunar phases in each season and year was separately estimated to evaluate the lunar cycle effect on billfishes.

Standard statistical procedures (Courtney *et al.*, 1996; McDonald, 2009) were followed and the statistical significance of the effects was analyzed following general linear model using SYSTAT-13 software.

Results

Species composition

Billfishes constituted 8% by number of the total fishes caught during the period of study. This forms nearly one third of the target species (Yellowfin Tuna) of tuna longline fishery. Among the billfishes caught, Indian sailfish *Istiophorus platypterus* (Shaw & Nodder 1792) dominated the group with 46% followed by sword fish *Xiphias gladius*

(L.1758) – 40%, blue marlin *Makaira mazara* (Jordan & Snyder 1901) - 11% Black marlin *Makaira indica* (Cuvier 1832)-2% and striped marlin *Tetrapturus audax* (Philippi 1887) with 1%.

Effect of spatial difference

Latitude wise aggregate catch rates recorded during the survey are furnished in Table I. As shown, the highest catch rate for all fishes was recorded from Lat. 11^0 N, followed by Lat. 09^0 N. The maximum catch rate in the case of billfishes was obtained from Lat. 09^0 N. In general, the catch rate of billfishes was more in upper latitudes (Andaman waters) and catch rate from lower latitudes (Nicobar waters) was of less than 0.5.

Effect of monsoon on catch rate

Better aggregate month wise catch rates were recorded during January and June, followed by September. However no specific trend was observed during the study period. Monthly catch rates were pooled according to the season and analyzed the effect of the monsoon on Billfishes catch rate. The result is furnished as Fig. 1. As shown in Fig. 1., better aggregate catch rates were recorded during monsoon period followed by pre monsoon period.

Effect of lunar cycle on catch rate

Aggregate catch rates obtained during the new moon period, waxing &waning period and full moon period are shown in Fig.2. As shown in Fig 2., aggregate catch rates of billfishes were more during full moon days, followed by waxing & waning period. Precisely, lower catch rates were obtained during the new moon period.

Statistical significance of lunar and monsoon effect

Result of general linear model ANOVA is furnished as Table II. As revealed from the Table. II, statistical analysis established the variation in the catch rates of billfishes, according to the lunar cycle. However statistical test showed that there is no significant difference in the catch rates of billfishes recorded during different seasons of monsoon. Moreover no cumulative effect of season and lunar cycle was found significant in the case of billfishes.

Year-wise aggregate catch rate during the study period shown a declining trend towards the later years (Fig.3), statistical test shown significant difference in the aggregate catch rates recorded in time. Turkey's Honestly- Significance –Difference test of aggregate catch rates showed that the full moon catch rate is significantly different from the catch rate recorded during new moon period (Table III). Moreover, the lunar cycle effect on Billfishes catch rate was found significant throughout the study period.

Discussion

Catch rate in space and time

All the five Billfishes species reported from Indian continent are abundantly available in Andaman and Nicobar waters. A comparative study of the changes in the species composition of tuna longline fishery around Andaman & Nicobar Islands since 1989 showed a reduction in the contribution of Yellowfin tuna and pelagic sharks towards the total catch during recent years (John & Somvanshi, 2000; John *et al*., 2005). However, the contribution of billfishes towards the total catch is continued to be around 8% throughout these years.

As shown in Table I aggregate catch rate of billfishes was more in higher latitudes especially in Andaman waters. John & Somvanshi (2000) and John *et al*. (2005) also reported similar phenomena and hence the result of the present study is in agreement with their findings. Fig.3 showed that the aggregate catch rates are showing a decreasing trend towards the recent years. Decrease in catch rate even in the absence of a targeted Billfish fishery is to be taken cautiously. Hence an in-depth study on the status of billfishes stock of the Andaman Sea is the need of hours.

Effect of monsoon and lunar cycle on catch rate

The present study showed that aggregate catch rates for billfishes were slightly more during the monsoon period. However, no statistical significance was established to support the variation in catch rates during different season. The combined effect of annual and seasonal fluctuation was significant. Large scale annual fluctuation of catch rate recorded during the study period may be the reason for this phenomenon. The results indicate that monsoon effect is less significant on the catch rate of billfishes.

Better catch rates for billfishes were recorded during the full moon and catch rates of billfishes were comparatively poor during new moon days. Billfishes generally prey on surface organisms and hence remain at surface layers during most of the time as a part of their feeding strategy. This feeding strategy may be the reason for better catch rate during full moon period. The bright moonlight during full moon night will result in aggregations of the prey organism at the surface layers; meantime there will be aggregation of these organisms at bottom during day time. Vice versa phenomena happen during the new moon period. Less abundance of prey organisms in the surface layer during the day time of full moon period may lead to attraction of Billfishes towards the bait fishes and hence lead to better hooking rate. In contrast, the abundance of natural food organisms in the surface layers during new moon days may result in less attraction towards the bait fishes, and hence results in a poor catch rate of billfishes during new moon days.

An exhaustive search of literature indicated that except Mohan and Kunjikoya (1987), no studies have been carried out to understand the effect of the lunar cycle on tunas, tuna like fishes and other large pelagics in Indian waters. Hence the present study is the premier one in establishing the significant effect of the lunar cycle on the catch rate of billfishes.

A comparative statement of results of studies on the effect of the lunar cycle on Billfishes caught by the tuna longline fishery and other hooking methods is furnished in Table. IV. The available literature showed disparate data on the effect of lunar cycles on the fishes caught by tuna longline.

Findings of Bigelow *et al*. (1999); Neves dos Santos and Garcia (2005) and Poisson *et al*. (2010) are in agreement with the results of the present study**.** However, results of Ortega-Garcia *et al*. (2008) and Ponce-Diaz *et al*. (2003) contradict with the present study. Variation in the time of operation, geographical variation, differences in groups of fish categories, changes in the fishing methods, variation in sampling strategy, fluctuation in the environmental and physiological parameters, abundance of prey and differences in the feeding strategy may be the reasons for this variation of results.

The results of the present study indicate the abundance of Billfishes in Andaman waters and provided the distribution pattern of fish in time and space. Better hooking rates recorded during the full moon periods indicated that lunar cycle plays a significant role in the catch rate of Billfishes. Meantime results suggest that monsoon doesn’t play a significant role in the hooking rates. The results of the present study will help the researchers to set the course for future research on billfishes and may lead to formulating an exploitation strategy aimed at a viable and sustainable Billfish fishery.

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Table 1**.** Latitude-wise aggregate catch rate during 2006-08.

Latitude	Catch rate in one fish per thousand hooks		Latitude	Catch rate in one fish per thousand hooks	
	Total	Bill fish		Total	Bill fish
06^0 N	6.37	0.00	11^0 N	8.61	0.77
07^0 N	7.79	0.38	12^0 N	7.52	0.52
08^0 N	8.41	0.49	13^0 N	5.29	0.53
09^0 N	8.58	0.92	14^0 N	4.11	0.69
10^0 N	6.7	0.72	**Average**	7.39	0.63

Table 2. Effect of Monsoon and Lunar cycle- General linear model -Analysis of variance table

Source	Type III Sum of Square	Degrees of freedom	Mean square	F-Ratio	p- value
Year	66.501	2	33.250	37.502	0.000*
Season	5.580	2	2.790	3.147	0.116
Lunar cycle	25.260	2	12.630	14.245	0.005*
Season*lunar cycle	4.284	4	1.071	1.208	0.397
Year*season	17.905	4	4.476	5.048	0.040*
Year*lunar cycle	2.446	4	0.611	0.690	0.625
Error	5.320	6	0.887		

* Significant at 5% level

Table 3. Turkey's Honestly- Significance –Difference test of catch rates of lunar cycle

Lunar cycle	Lunar cycle	Difference	p- value	95% confidence interval	
				Lower	Upper
New moon	WANNING &WAXING MOON	-1.183	0.111	-2.587	0.221
New moon	FULL MOON	-2.585	0.004*	-3.989	-1.181
Wanning &waxing moon	FULL MOON	-1.402	0.092	-2.847	0.043

* Significant at 5% level

Table 4**.** Results of studies on effect of lunar cycle on Billfishes

Area of study	Species	Time of fishing (Day/ Night)	Significant (YES/No/ Not tested)	Author/s
Gulf of Mexico	Billfishes	Day	Not tested	Nakamura and Rivas (1974)
Hawaii	Swordfish	Night	YES	Bigelow *et al.* (1999)
Mexico	Striped marlin	Day	No	Ponce-Diaz *et al*. (2003)
Portuguese	Swordfish	Night	YES	Neves dos Santos and Garcia (2005)
Australia	Black marlin	Day	YES	Lowry *et al*. (2007)
	Blue marlin		No	
	Striped marlin		No	
Mexico	Striped marlin	Day	No	Ortega-Garcia *et al.* (2008)
Reunion Island	Swordfish	Night	YES	Poisson *et al.* (2010)
Andaman and Nicobar Islands	Billfishes	Day	YES	Present study

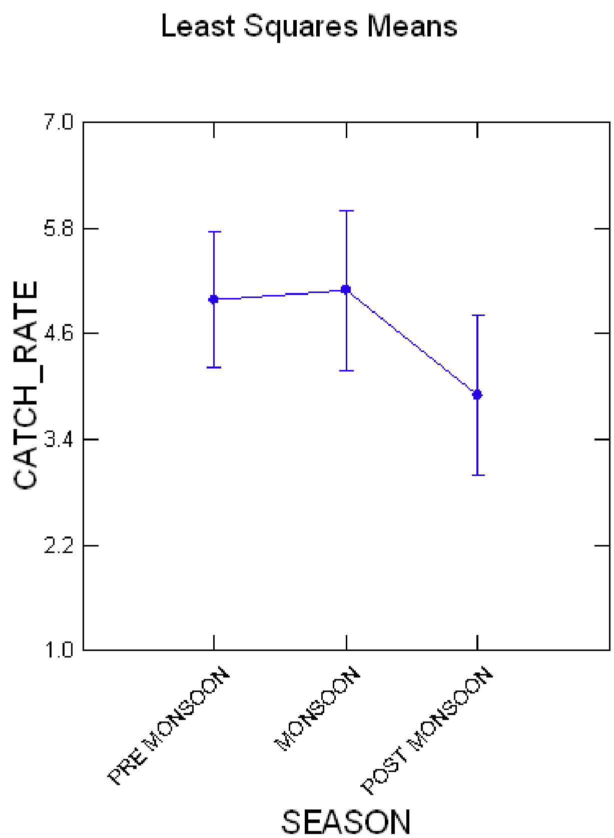

Fig.1. Effect of Monsoon on Billfishes catch rate

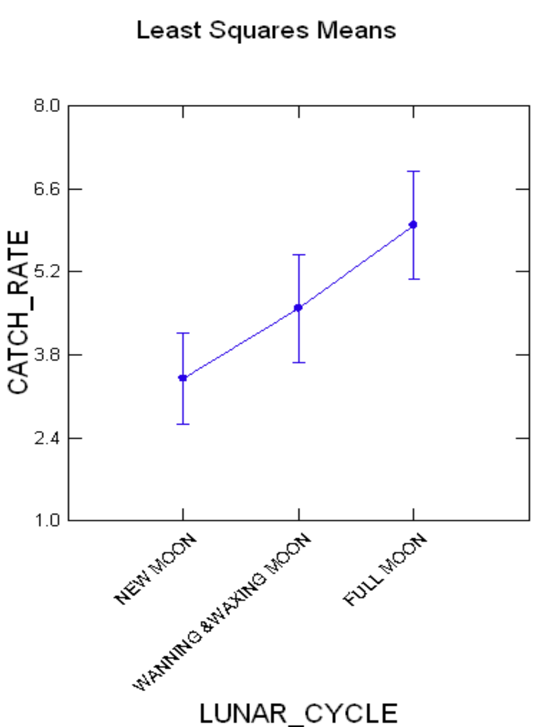

Fig.2. Effect of lunar cycle on Billfishes catch rate

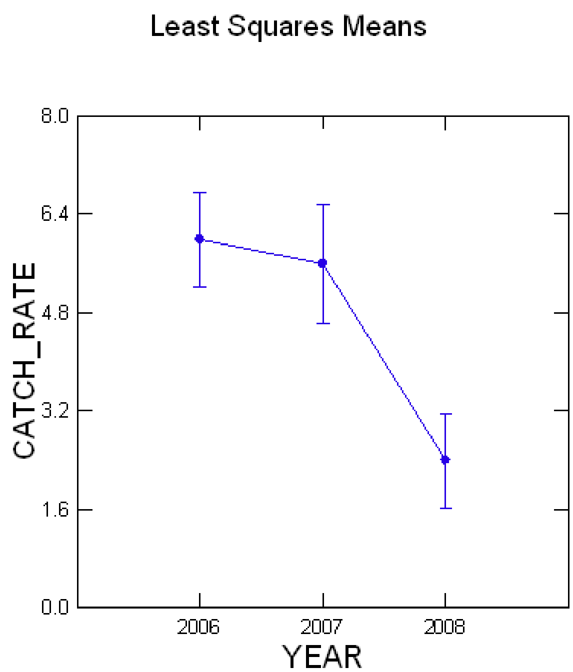

Fig.3. Billfishes catch rate year wise from 2006-08