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The optimum fishing day is based on moon

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Abstract
A research study found that fish and prawn prefer light whereas shrimp may not. There is a vertical movement of fish movement is found owing to light as on moon lit days when the fish catch may become more considering the fact the fishing efforts and gear remaining similar in all days of lunar periodicity. Estuarine fishes in Sundarban Rivers are caught more during such dates. Optimum fishing days may also determined by the intensity and duration of moon lit in total night hours.

Keywords: Catch model, Lunar periodicity, Optimum fishing day

1. Introduction
Estuaries play an important role in fish production. Due to mixing nature of the estuarine water quality of fresh water and marine, all the three types of water inhabitant fishes form the estuarine fisheries. Fishes from freshwater or marine environment migrate to estuarine zone for breeding, to fulfill the physiological need in life history and nourishment. This horizontal migration of the fishes are controlled by physical, chemical and biological factors. Another type of migration occurs among the residential estuarine fin fishes and shell fishes called as vertical migration. This vertical migration plays a significant role in estuarine fish catch enhancement by bringing fish stocks in the netting operation area. In case of vertical migration of fin fishes and shell fishes, physical factors are found to be very much influential than the chemical and biological factors. Among the physical factors light is known to play a dominant role in this phenomenon.

From the work of Thorrold *et al.* (1944) [7], it is understood that onshore winds bear a significant relationship with the larval abundance in the coastal areas. Luecke *et al.* (1993) [4] have clearly indicated the influence of moonlight and day light on hydro-acoustic estimates and pelagic fish abundance. On the other hand Yousif and Aglen (1999) [8], stated the importance of physical factors on pelagic fish distribution. The lunar periodicity is seemed to play an important role for fish catch enhancement both in open environment water resources. A variation of nocturnal estuarine fish assemblage in Serpentine Creck, Queensland during full and new moon phase was recorded by Quinn and Kojis (1981) [6]. Goldman *et al.* (1983) [3] have found significant relationship between fish eggs and larval abundance with moon phase in the Great Barrier Reef, Australia. In Lake Tanganyika (Africa), the better catch of lamps is dependent on moon age only (Mukirania, 1988) [5]. From their observations on a Canadian oligotrophic lake, Gaudreau and Boisclair (2000) [2] explained the migration and catch abundance of fishes. In the Nyanza Gulf of lake Victoria, Asila (2002) [1] has noted that the vertical migration of Nile perch between bottom and surface layer is totally controlled by the brighter and darker phase of the day; whether it is moonlight or sunlight. Understanding the importance of lunar periodicity on fish catch abundance in the open water resources, it was planned to conduct a study on the estuarine fish catch abundance during different phases of moon in the estuaries of Sunderban, West Bengal, India. The basic objectives of the study were: (i) to record variation in fish (fin fish and shell fish) catch in the selected estuaries during moon phase days, (ii) to develop predictive models for shell fish and fin fish catch with moon phase-days for the studied estuaries and (iii) to forecast optimum fishing days based on the conducted study to make estuarine fishing operation economic.

2. Materials and Methods
The study was conducted during the years 1994 to 1997 on six estuaries (Thakuran, Matla, Bidyadhari, Saptamukhi, Jhelum and Hooghly) located in the Gangetic delta of Sunderban in

West Bengal, India. Daily fish catch for a period of ten days each from twelfth day after full moon to sixth day after new moon and twelfth day after new moon to sixth day after full moon was recorded from the randomly selected fish landing centres per estuary. The catches of fin fishes and shell fish (prawn) were recorded separately. For analysis all the collected data were pooled. For statistical analysis of the data, Least Square Technique (LST) are applied. Both linear and cubic equations are developed. The cubic equations ($z = Z + e$, $Z = B_0 + B_1T + B_2T^2 + B_3T^3$, e being the error) have been been obtained. The optimum fishing days (T) and predicted fish catch (Z) are also obtained.

3. Results and Discussion

It was a fact that the number of fishing vessels, number fishermen, number of nets, fishing efforts – 'crafts and gears' remained the same for all the ten fishing days. As was mentioned earlier that some fishes migrate to estuary either from sea and a few from fresh water and such migration is seasonal i.e., during the breeding season only and not throughout the year. Variations of fish catch during the days of full moon to new moon or during the days of new moon to full moon are mainly not because of horizontal migration. Variations of fish catch during the days of full moon to new moon or new moon to full moon are, mainly, due to vertical migration of fishes. The vertical movement of fishes is due to lunar periodicity. Maximum fish abundance is observed (i) on the third day after the full moon in each data set and (ii) on the third day after the new moon in each data set. Model I and Model II represent the (maximum) catch equations over lunar days using linear and cubic functions respectively. The above two models are generated for prawn (Table I) and finfish (Table II) separately. Also are presented the graph plots indicating the observed and expected or predicted fish and prawn catch figures.

Table 1: (Prawn)

Year	Day Type	Model Name	R-square	DF	Parameter Estimates	F-stat	Significance	Optimum Value at 3 degree
1994	A	Linear (1 Degree)	0.1558	8	B_0 = 6984.47 B_1 = 326.970	1.48	0.2590	T=7.0 Z=11800.686
		Cubic (3 Degree)	0.9123	6	B_0 = 6094.47 B_1 = -1034.04 B_2 = 644.958 B_3 = -54.3978	20.81	0.0014	
	B	Linear (1 Degree)	0.2251	8	B_0 = 6278.87 B_1 = 437.861	2.32	0.1659	T=7.0 Z=12097.481
		Cubic (3 Degree)	0.9061	6	B_0 = 6613.10 B_1 = -2004.04 B_2 = 876.998 B_3 = -68.3972	19.30	0.0017	
1995	A	Linear (1 Degree)	0.1231	8	B_0 = 5726.67 B_1 = 273.788	1.12	0.3202	T=7.0 Z=10099.394
		Cubic (3 Degree)	0.9116	6	B_0 = 5140.33 B_1 = -1248.21 B_2 = 662.237 B_3 = -54.6737	20.61	0.0015	
	B	Linear (1 Degree)	0.1936	8	B_0 = 5287.80 B_1 = 375.291	1.92	0.2033	T=7.0 Z=10545.08
		Cubic (3 Degree)	0.9205	6	B_0 = 5276.07 B_1 = -1695.46 B_2 = 787.581 B_3 = -62.5488	23.16	0.0011	
1996	A	Linear (1 Degree)	0.0848	8	B_0 = 5399.13 B_1 = 221.085	0.74	0.4142	T=7.0 Z=9292.2626
		Cubic (3 Degree)	0.8512	6	B_0 = 4732.27 B_1 = -1155.84 B_2 = 618.798 B_3 = -51.5167	11.44	0.0068	
	B	Linear (1 Degree)	0.1895	8	B_0 = 4707.53 B_1 = 371.467	1.87	0.2086	T=7.0 Z=9932.311
		Cubic (3 Degree)	0.9209	6	B_0 = 4518.93 B_1 = -1568.21 B_2 = 763.358 B_3 = -61.2644	23.28	0.0011	
1997	A	Linear (1 Degree)	0.0962	8	B_0 = 4880.00 B_1 = 208.273	0.85	0.3382	T=7.0
		Cubic (3 Degree)	0.9230	6	B_0 = 3733.17	23.97	0.0010	

					B_1 = -632.954 B_2 = 484.754 B_3 = -42.6098			Z=8440.277
	B	Linear (1 Degree)	0.2184	8	B_0 = 4147.60 B_1 = 371.291	2.24	0.1733	
		Cubic (3 Degree)	0.9244	6	B_0 = 3653.87 B_1 = -1151.06 B_2 = 649.009 B_3 = -53.2898	24.46	0.0009	T=7.0 Z=9119.488

N.B. A: Twelfth day after full moon to sixth day after new moon,
B: Twelfth day after new moon to sixth day after full moon.

Table 2: (Fin fish)

Year	Day Type	Model Name	R-square	DF	Parameter Estimates	F-stat	Significance Level	Optimum Value at 3 degree
1994	A	Linear (1 Degree)	0.0341	8	B_0 = 3843.93 B_1 = 7077.58	0.28	0.6097	
		Cubic (3 Degree)	0.8160	6	B_0 = 3811.53 B_1 = -873.399 B_2 = 363.007 B_3 = -28.9270	8.87	0.0127	T=7.0 Z=5563.118
	B	Linear (1 Degree)	0.1821	8	B_0 = 3279.47 B_1 = 207.642	1.76	0.2216	
		Cubic (3 Degree)	0.9254	6	B_0 = 3533.00 B_1 = -1197.32 B_2 = 496.622 B_3 = -38.4998	24.81	0.0009	T=7.0 Z=6280.806
1995	A	Linear (1 Degree)	0.0349	8	B_0 = 2862.87 B_1 = 69.2788	0.29	0.6051	
		Cubic (3 Degree)	0.8805	6	B_0 = 2555.90 B_1 = -664.583 B_2 = 322.811 B_3 = -26.7273	14.74	0.0036	T=7.0 Z=4554.093
	B	Linear (1 Degree)	0.1562	8	B_0 = 2377.53 B_1 = 179.485	1.48	0.2584	
		Cubic (3 Degree)	0.9148	6	B_0 = 2613.53 B_1 = -1135.08 B_2 = 464.846 B_3 = -36.0412	21.49	0.0013	T=7.0 Z=5083.293
1996	A	Linear (1 Degree)	0.0331	8	B_0 = 2488.47 B_1 = 67.9515	0.27	0.6151	
		Cubic (3 Degree)	0.8752	6	B_0 = 2297.37 B_1 = -763.164 B_2 = 343.00 B_3 = -27.9116	14.03	0.0040	T=7.0 Z=4188.543
	B	Linear (1 Degree)	0.1306	8	B_0 = 2158.33 B_1 = 166.630	1.20	0.3050	
		Cubic (3 Degree)	0.8938	6	B_0 = 2072.13 B_1 = -918.206 B_2 = 424.154 B_3 = -33.9740	16.83	0.0025	T=7.0 Z=4775.151
1997	A	Linear (1 Degree)	0.0367	8	B_0 = 2003.93 B_1 = 35.9394	0.30	0.5961	
		Cubic (3 Degree)	0.6992	6	B_0 = 2230.27 B_1 = -575.485 B_2 = 199.386 B_3 = -15.0078	4.65	0.0524	T=7.0 Z=2824.113
	B	Linear (1 Degree)	0.3541	8	B_0 = 1378.27 B_1 = 179.461	4.39	0.0696	
		Cubic (3 Degree)	0.9027	6	B_0 = 2101.47 B_1 = -1010.67 B_2 = 347.315 B_3 = -24.9557	18.56	0.0019	T=7.0 Z=3485.41

N.B. A: Twelfth day after full moon to sixth day after new moon,
B: Twelfth day after new moon to sixth day after full moon.

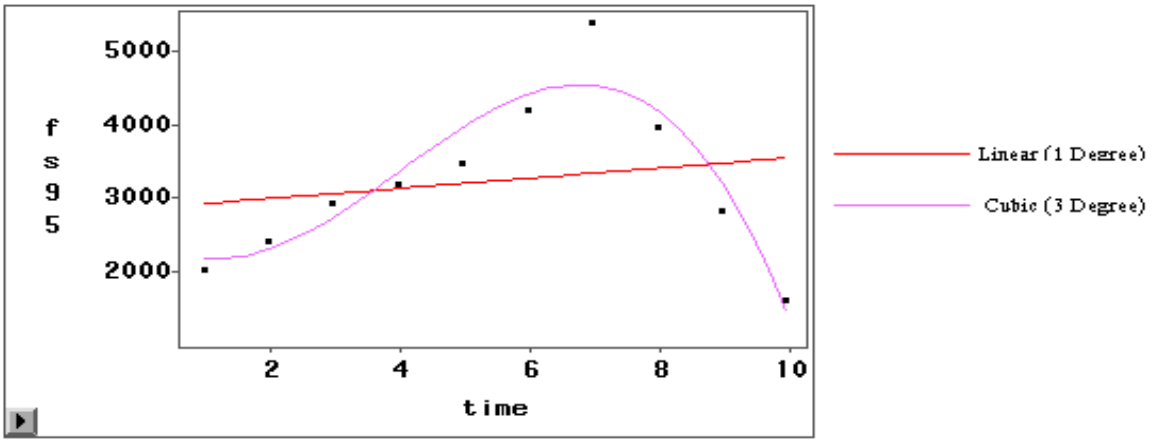

Fig 1: Fish Catch Regression Result - Twelfth day after full moon to sixth day after new moon (Year 1995)

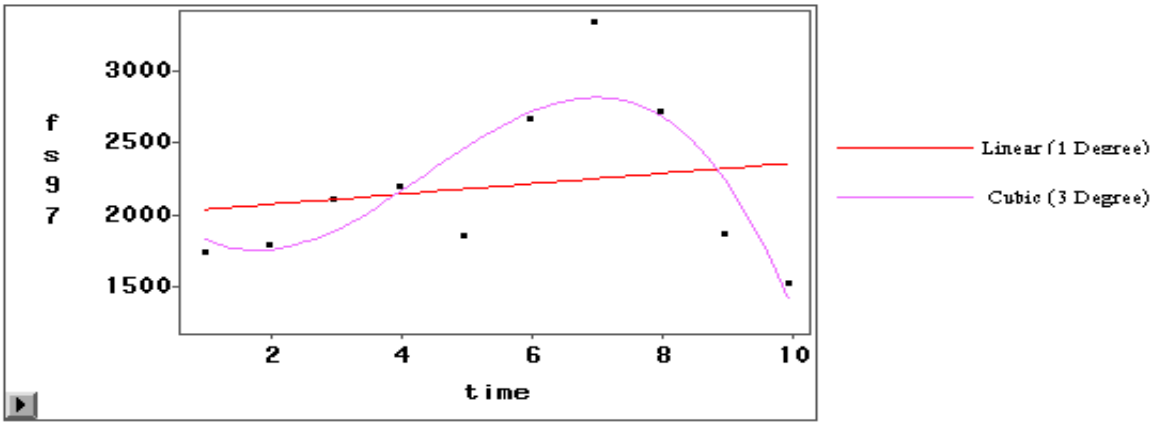

Fig 2: Fish Catch Regression Result - Twelfth day after full moon to sixth day after new moon (Year 1997)

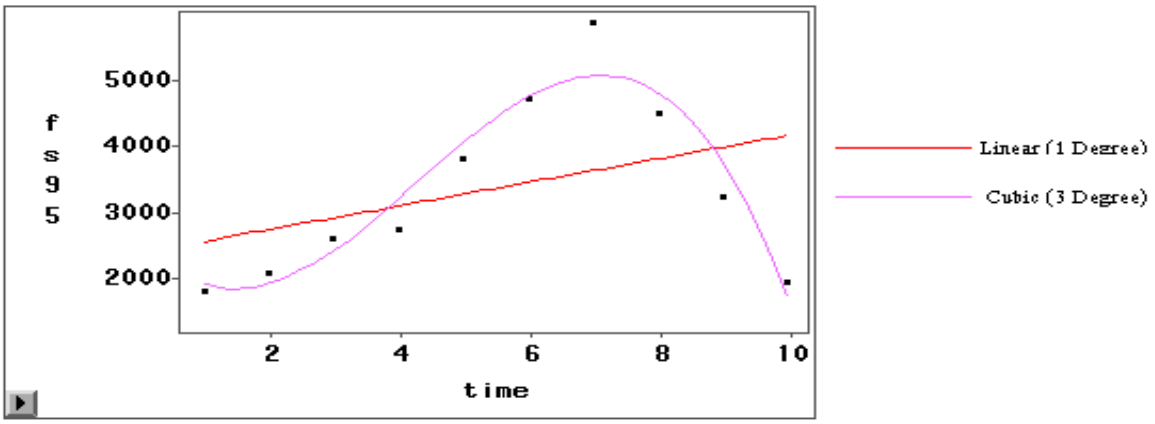

Fig 3: Fish Catch Regression Result - Twelfth day after new moon to sixth day after full moon (Year 1995)

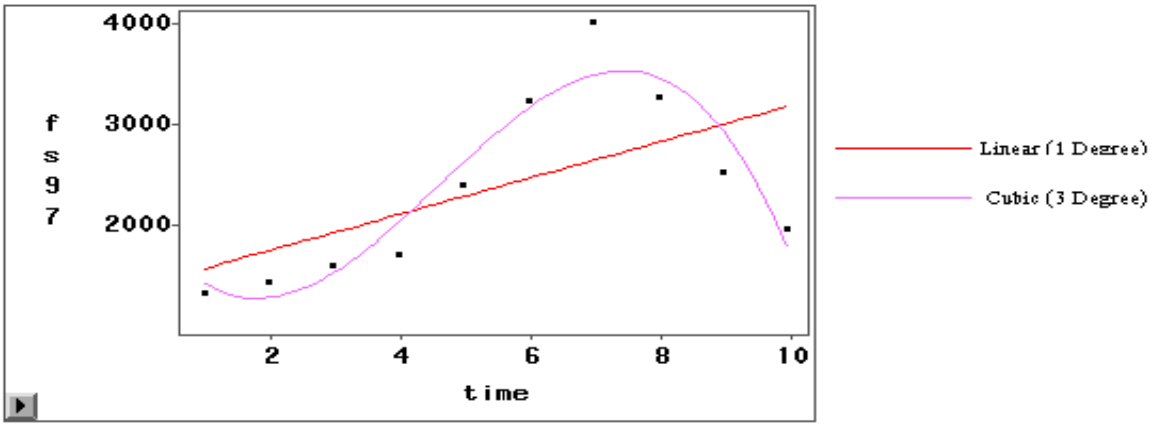

Fig 4: Fish Catch Regression Result - Twelfth day after new moon to sixth day after full moon (Year 1997)

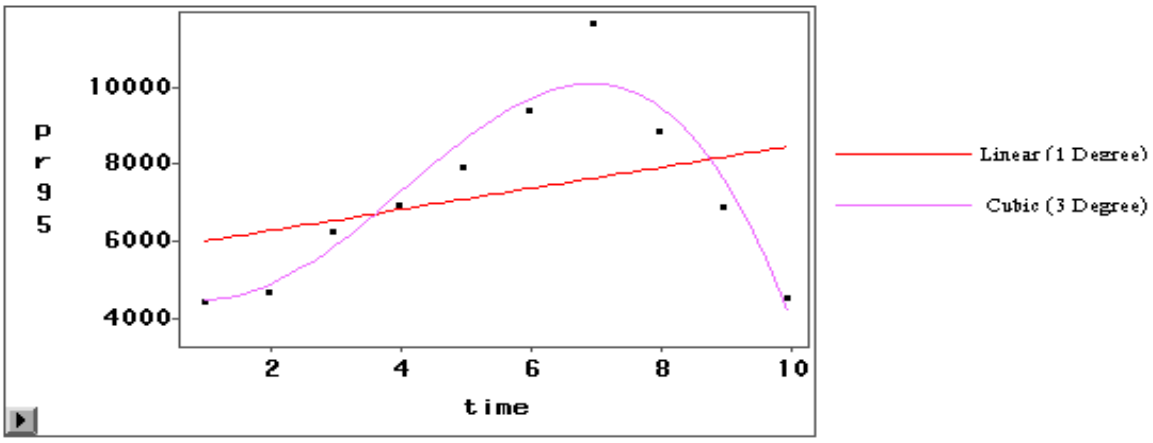

Fig 5: Prawn Catch Regression Result - Twelfth day after full moon to sixth day after new moon (Year 1995)

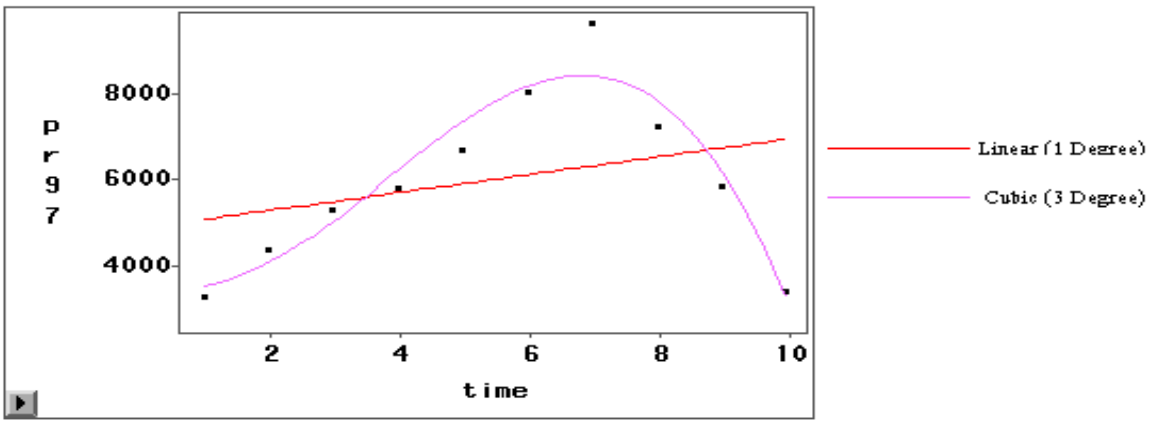

Fig 6: Prawn Catch Regression Result - Twelfth day after full moon to sixth day after new moon (Year 1997)

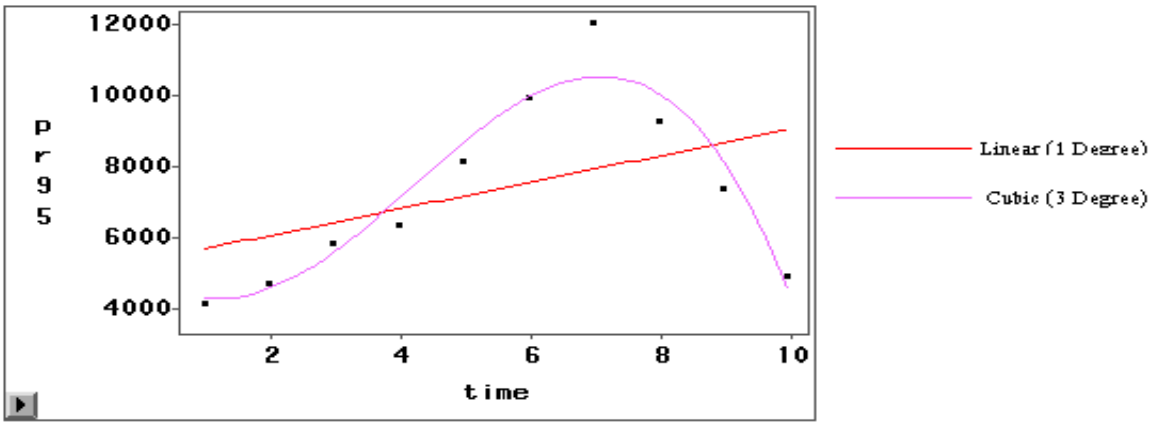

Fig 7: Prawn Catch Regression Result - Twelfth day after new moon to sixth day after full moon (Year 1995)

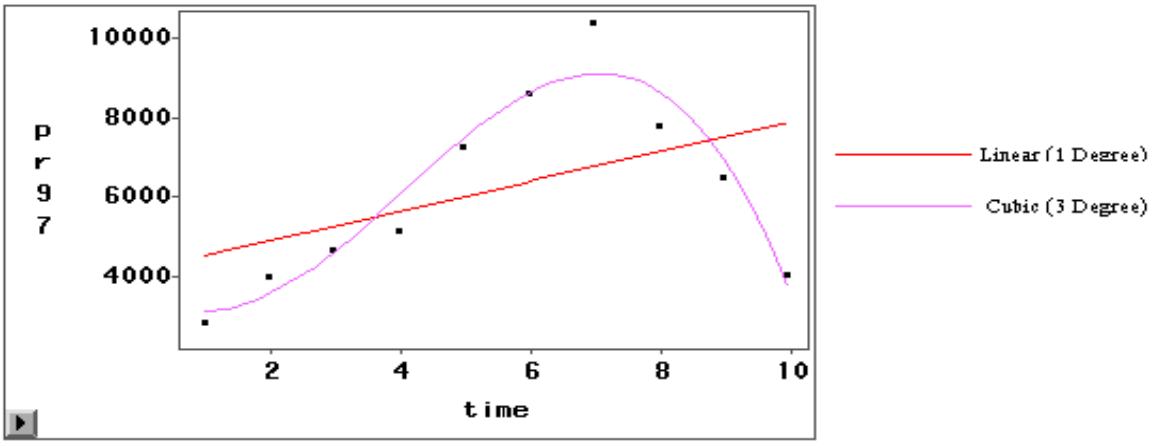

Fig 8: Prawn Catch Regression Result - Twelfth day after new moon to sixth day after full moon (Year 1997)

It is observed from the model that abundance of fishes and prawn in the netting zone i.e., Up to the water depth from where the fishing is done is maximum on the third days (optimum days) after full moon and after new moon because of vertical distribution and movement of fishes across the water depth. Whether it is advisable to catch fish or not to catch fish during those optimum days depend on fish stock available in six rivers. No such variation in shrimp catch is found against lunar periodicity. The findings obtained under the investigation confirm the existence of variation of prawn and fish catch under lunar periodicity and it is shown that such variation can be adequately modeled with the help of cubic equations. Further, the optimum fishing day and the corresponding (optimum) prawn catch and (optimum) fish catch can be predicted by using the generated equations.

Fin fish and prawn catch variation due to moon phases were found to be similar in respect of trend among the sampling centres and all the years studied. Finfish and prawn catch variation of the two moon phases are found to be similar in nature. Linear equation indicates that there is increasing trend of finfish and prawn catches from the twelfth day after full moon to six day after new moon (A) and similar trend from twelfth day after new moon to six days after full moon (B). Whereas cubic equation indicates the gradual peak in fin fish and prawn catch on both the moon phases represented as 'A' and 'B'. 'T' indicates the days when maximum fish catch is obtained in two moon phases of 'A' and 'B'. 'Z' indicates the maximum daily fish catch in moon phases, 'A' and 'B'. Finally, it is seen that the fits generated by the cubic equation are extremely good with values of R^2 greater than .80 in most cases.

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