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## Observations on the food preferences, growth parameters and biological aspects of *Coryphaena hippurus* Linnaeus, 1758 exploited through the longline survey operations along the West coast of India

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### Abstract

*Coryphaena hippurus* exploited through the longline survey operations during the period 2005-2015 were analysed the data in the present study. Occurrence of this species reported in the oceanic waters of West coast of India in the depth range 1000-4000m during tuna longline operations in the coast. The size range (fork length) of the species was between 25 cm and 135 cm with an average length of 92 cm. The frequency occurrence of food and preference of food by area and season were identified in the order of preference as fin-fishes (60%), crustaceans (20%) and cephalopods (11%). Length-wise, area-wise, sex-wise and season-wise food preferences were presented. The growth parameters estimated in the study were asymptotic length ( $L_{\infty}$ ) 135cm, growth coefficient (K) 0.35cm/year and initial condition parameter ( $t_0$ ) -0.124. The natural mortality (M) value recorded in the study was 0.57 and the total mortality (Z) was 0.95. Size at first maturity observed as 35 cm. Sex ratio observed as 1.12:1. Maximum contribution of matured females reported in the month of July and November. Two peak spawning seasons were observed during May-August with a maximum in July and the other from October-January with a highest in November.

**Keywords:** *Coryphaena hippurus*, frequency occurrence, asymptotic length, growth coefficient, mortality, size at first maturity

### 1. Introduction

The dolphin fish *Coryphaena hippurus* belongs to the family Coryphaenidae and is one of the important dominant species of the by-catch in the tuna longline operations occurring along the coast of India besides artisanal catches. This species is found in tropical and sub-tropical waters of the world oceans [1]. Merten *et al.* [2] and Gatt *et al.* [3] reported that the species *Coryphaena hippurus* is a highly migratory, large oceanic species having a wide distribution in tropical and sub-tropical waters of the Pacific, Atlantic and Indian Oceans and known to occur within a few miles off the coast when wind blows steadily. The distribution of this species generally limited by the 20 °C isotherm [4]. Whereas, it was reported along the east coast of United States that, the species caught through archival tags can tolerate 16 °C and prefer surface water temperature between 27.2 °C and 28.9 °C [5]. The catch rates and abundance influenced by inter-annual and seasonal temperature changes. The dolphin fish is being exploited in the world oceans in industrial, artisanal and recreational fisheries. In the Atlantic Ocean, the species is exploited on commercial basis [4, 6] and recreational fishing contributes more in this ocean. In the Pacific Ocean, maximum portion exploited in Mexico for sport fishing and recreational fishing, as the industrial fishing for commercial exploitation prohibited [7, 8]. In the Mediterranean Sea, around Maltese islands adult dolphin fish are mostly caught as by catch along with Sword fish and Bluefin tuna in the longline operations whereas, juveniles were caught by the surrounding nets. In the same region, Fish Aggregating Devices (FAD) is used for targeting dolphin fish [9]. In the Mediterranean Sea, this species is mostly exploited by using Fish Aggregating Devices (FADs) as this species having the tendency to attract and aggregate near natural and artificial floating objects [10]. The estimated annual average catch of this species in India was 7,975 t [11]. In India, this species is being exploited by the traditional/ artisanal sector only.

The study of growth is the quantitative aspect of development and it is one of the many ways in which the individual species or a population responds to changes in the food supply with adjustment of breeding rates and food intake [12]. Growth rate affects the time to sexual maturity which is reflected in the age composition of the adult part of the population and in the reproduction rate. The von Bertalanffy growth equation has been commonly used for assessment of fish growth [13]. The fish tends to mature according to a fixed proportion of length to their asymptotic size. The larger the asymptotic size, larger is the size at first maturity also and for a given family of fish, the ratio between length at first maturity and asymptotic length is constant [14]. Feeding is one of the attributes of an organism, since the energy required for all the physical activities is fulfilled by the food [15]. Knowledge on the relationship between the fishes and the organisms constituting their food is essential for the prediction of the abundance of the species leading to sustainable exploitation of the stocks. Understanding of variation in the food and feeding habits help to recognize fluctuations in the availability of fish in space and time. Most of the fishes are highly adaptable in their feeding habits and utilize the most freshly available food [16]. *C. hippurus* is a top predator in the pelagic ecosystem [17]. Significant contributions on the aspects of biology and stock assessment have been done in the Pacific and Atlantic oceans. Along the Indian coast these studies are very limited, except a few Benjamin and Kurup [18] on the stock status of the dolphin fish along the Kerala coast based on the data collected from the fish landing sites, diet and consumption rates of dolphin fish in the eastern part of Arabian Sea by Varghese *et al.* [19] and fishery, diet composition and reproductive biology of dolphin fish off Karnataka coast based on commercial landings by Rajesh *et al.* [12]. This study would be the first attempt in the oceanic waters of the west coast of India in the depth range of 1000-4000m and the study examined the food preferred by the species in time and space and also evaluated the growth parameters. The information of the biological aspects and their correlation is essential for understanding the population parameters for predicating the abundance of the species, which in turn would be helpful to draw the exploitation strategies.

## 2. Materials and Methods

Length frequency data collected from the tuna longline survey vessels of Fishery Survey of India deployed along the west coast of India during 2005-2015 was used in the present analysis. The growth parameters have been estimated by using von Bertalanffy growth equation.

$$L(t) = L_{\infty} [1 - e^{-k(t-t_0)}]$$

Where  $L_{\infty}$  is interpreted as mean length of very old fish, also called asymptotic length,  $K$  is curvature parameter which determines how fast the fish approaches  $L_{\infty}$  and  $t_0$  the initial condition parameter, determines the point in time, where fish has zero length.

GIS software was used for area-wise distribution and their occurrence in the west coast were drawn and plotted. The species caught in these areas were measured for fork length and monthly measurements were then classified into the length groups or class intervals of 5cm. The length of *Coryphaena hippurus* ranged from 25cm to 135cm with a sample size of 348. The Growth parameters were estimated as per FISAT-II programme developed by Gayanilo *et al.* [20]. The natural mortality ( $M$ ) was estimated as per Pauly's  $M$  empirical formula [21] and the total mortality rate ( $Z$ ) was by

Pauly's catch curve method [22]. For analysis of food and feeding habits of *Coryphaena hippurus*, condition of the gut and intensity of feeding was determined by the degree of fullness of the stomach and was expressed as full,  $\frac{3}{4}$ ,  $\frac{1}{2}$ ,  $\frac{1}{4}$  trace and empty. From the total number of fish examined, monthly percentage of occurrence of food was determined. Food items were identified to the species level and wherever identification of food up to species level was not possible owing to the advanced digestion, such items expressed as semi-digested food. The total number and frequency of occurrence of prey item in the stomach of *C. hippurus* were correlated during the study. Stomach content analysis methods determined by Pillai [23], Natarajan & Jingran [24] and Somvanshi [25] were followed for estimation of status of the gut and occurrence methods.

A total of 164 female specimens of dolphin fishes were examined for maturation and spawning process. The length range of the female fish samples ranging from 30-125 cm used for the study. For the majority of fish species from tropical and sub-tropical regions, five stages of maturity have been suggested by Qasim [26]. These maturity stages were classified as, Stage I- Thread stage; Stage II- Immature stage; Stage III- Maturation stage; Stage IV- Nearly ripening stage; Stage V- Ripe/Spawning stage. The two stages, i.e. stage I and stage II were grouped together as immature and stage III, IV and V were clubbed, considering the developed or matured stage. The size at which 50% of the fish were matured was considered to be the size at first maturity of the respective species.

## 3. Results

### 3.1. Distribution and occurrence

Distribution and occurrence of *C. hippurus* reported in this study was between Latitude  $8^{\circ}$ - $22^{\circ}$ N/Longitude  $66^{\circ}$ - $75^{\circ}$ E (West coast of India) in the depth zone of 1000-4000m (Fig 1). In this region, temperature ranges between  $24^{\circ}$ - $31^{\circ}$  C with an average temperature of  $26^{\circ}$  C. The study under report found that, the species inhabits in this environment.

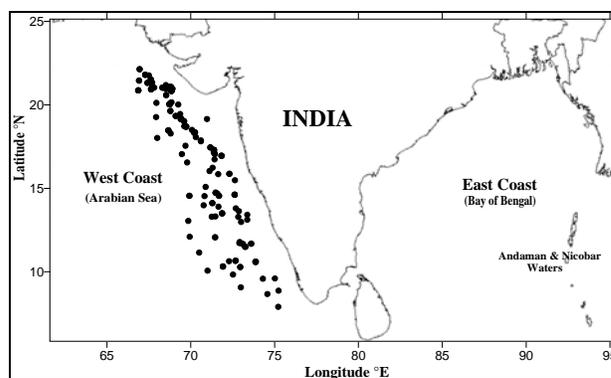


Fig 1: Sampling stations of *Coryphaena hippurus* along the West-coast of India

### 3.2. Seasonal abundance

Month-wise observations indicate that, the dolphin fishes were mostly found in all months with a peak during October to November (Fig. 2) and moderate during March to May. During monsoon seasons, dominance of males observed and females are abundant in post monsoon period.

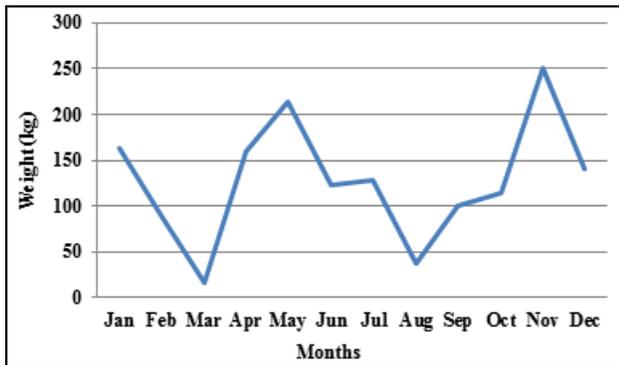


Fig 2: Seasonal abundance of *Coryphaena hippurus* during the year

### 3.3. Length-weight relationship

The length (cm)–weight (g) relationship on 164 females ranging from 35 cm to 125 cm (0.500g to 18000 g) and 184 males ranging from 27.5 cm to 135 cm (0.700g to 15000g) was found to be.

Males  $W = 0.3227L^{2.1286}$  ( $r = 0.9423$ )

Females  $W = 0.2059L^{2.234}$  ( $r = 0.9471$ )

Combined  $W = 0.2701L^{2.1707}$  ( $r = 0.9432$ )

The logarithmic form can be represented as follows:

Males :  $\ln W = -0.491 + 2.1286 \ln L$

Females:  $\ln W = -0.686 + 2.234 \ln L$

Combined:  $\ln W = -0.568 + 2.1707 \ln L$

From the above observation, it was found that the value of exponent 'b' was slightly higher in the females ( $b = 2.234$ ) than in the males ( $b = 2.1286$ ). The value of 'b' for combined samples was found to be 2.17. The value of 'b' in all the cases is not closed to 3 as per the cube law. This indicates that, the growth of this species is allometric (Fig. 3 and 4).

The correlation coefficient 'r' calculated was 0.95 for females and 0.94 males and 0.94 for combined samples in *C. hippurus* indicating a high degree of association between the length and weight in both sexes.

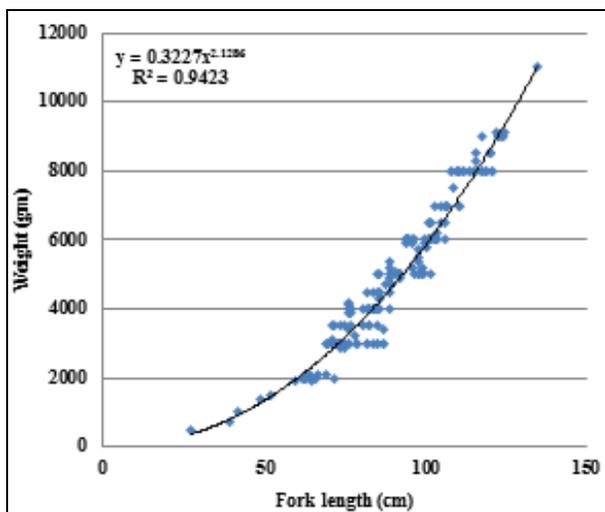


Fig 3: L -W relationships for male samples of *Coryphaena hippurus*

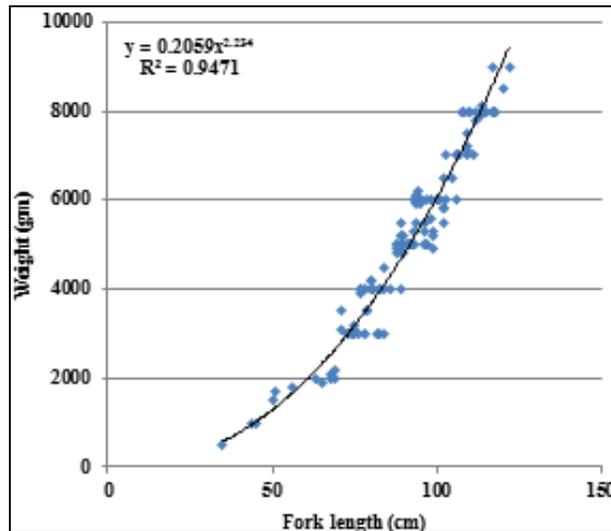


Fig 4: L -W relationships for female samples of *Coryphaena hippurus*

### 3.4. Growth parameters

The values obtained for Growth co-efficient (K), asymptotic length ( $L_{\infty}$ ), and the initial condition parameter ( $t_0$ ) on von Bertalanffy growth equation are 0.35/year and 135cm and -0.124 respectively. Total (Mortality (Z) estimated as 0.97 by using length converted catch curve (Fig. 5). While, natural mortality (M) 0.56 was calculated based on pauly's Mempirical equation. Fishing mortality (F) was 0.39, derived from  $F = Z - M$ . Fishing mortality (F) on length frequency data was analysed by using Virtual Population Analysis (VPA). M/K value 1.6 was obtained in the study. The results indicate that the fishing mortality in the size group 115-125cm was maximum (Fig. 6). Annual recruitment pattern revealed that this species has two recruitment peaks in a year (Fig. 7). October month showed the highest peak (18%) and the lowest in April (12%).

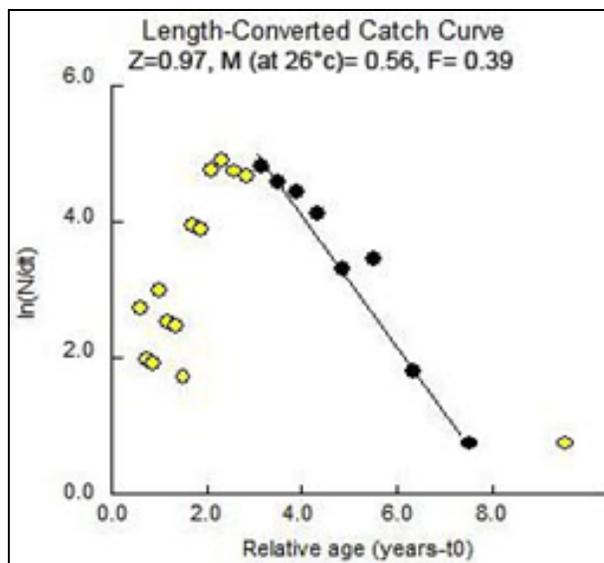


Fig 5: Length converted catch curve of *Coryphaena hippurus*

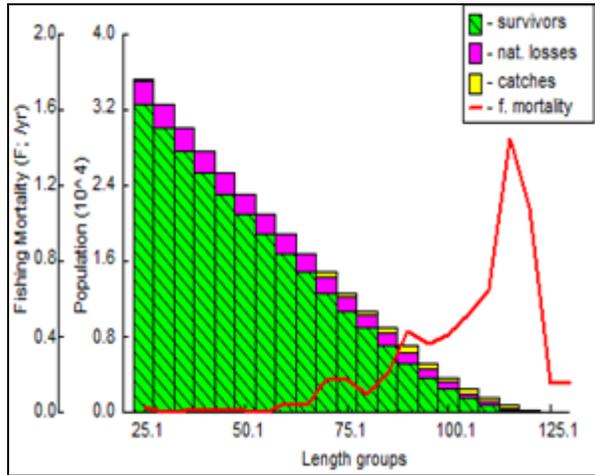


Fig 6: Length-structured Virtual Population Analysis (VPA) of *Coryphaena hippurus*

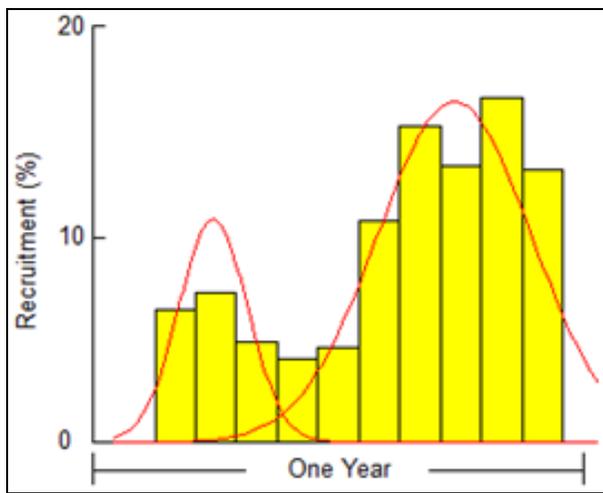


Fig 7: Annual recruitment pattern of *Coryphaena hippurus*

### 3.5. Food and Feeding

#### 3.5.1. Quantitative Analysis

A total of 348 samples of *C. hippurus* were analysed for gut content analysis. From the observation, it was found that 40% guts were found to be empty followed by 1/4 (24%), full (20%), 1/2 (14%), 3/4(2%). Dolphin fishes are believed to be visual predators and primarily feed during the day time [17]. Juanes and Conover [27] have made observation that, high percentage of empty stomachs is normal among large fishes which prey mainly on other fishes.

The food composition of *C. hippurus* indicates that, the highest preferred food by this species identified in the order of preference as fin-fishes (60%) followed by Crustaceans (20%) and cephalopods (11%). Semi-digested and miscellaneous foods (9%) were also observed in the gut of this species. Month-wise occurrence of food further differentiated to Quarter-wise method, to have better understanding of food preferences in response to the environmental changes during pre-monsoon, monsoon and post-monsoon periods. Month-wise feeding intensity indicates that, the feeding intensity is observed high in the month of November followed by July whereas; the feeding intensity is low in the month of March. Quarter-wise intensity of feeding revealed that highest intensity was found in 4<sup>th</sup> quarter i.e. Oct-Dec and the lowest intensity in 1<sup>st</sup> quarter (Jan-Mar). Season-wise food

observations show that, food contents were observed maximum during the monsoon, which clearly indicates that this species feed actively during the monsoon season (Fig. 8-11).

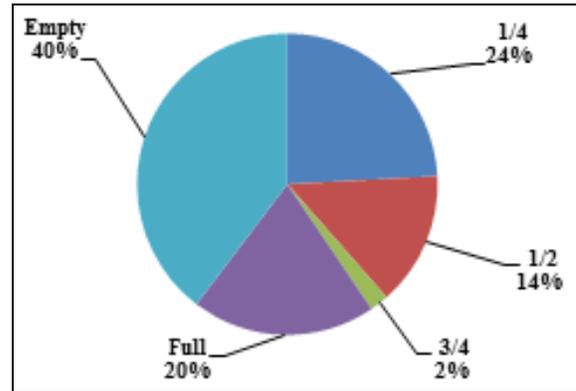


Fig 8: Percentage-wise stomach fullness of *Coryphaena hippurus*

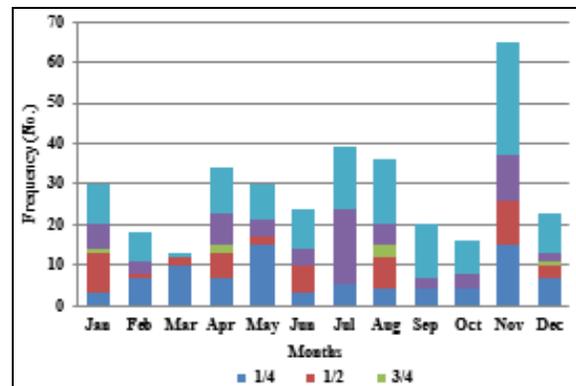


Fig 9: Month-wise stomach fullness of *Coryphaena hippurus*

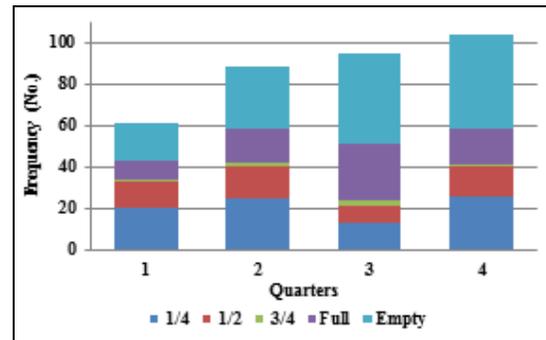


Fig 10: Quarter-wise stomach fullness of *Coryphaena hippurus*

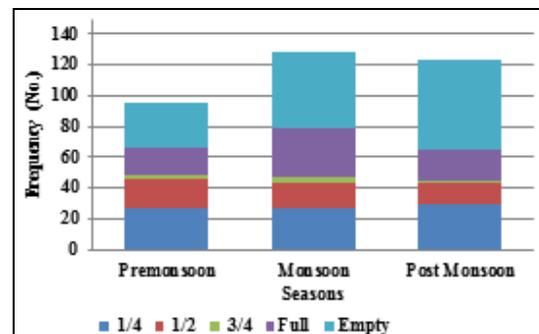


Fig 11: Seasonal stomach fullness condition of *Coryphaena hippurus*

### 3.5.2. Qualitative analysis

Length-wise food preferences and the intensity shows that, the species at the length range 95-100cm are actively fed and have full condition of the gut, whereas, the species at length range 25-30cm either poorly fed or empty. Size-wise, category-wise food preference reveals that, 90-105 cm class group voraciously feed on finfishes. The 30-35 cm up to 120-125 cm class group was found with maximum empty stomachs and most of the fishes in this length group, attaining towards maturity.

The major food preferred by the species in the stomachs identified as *Exocoetus monocirrhus*, *Rastrelliger kanagurta*, *Decapterus russellii*, *Decapterus curoides*, *Epinephelus diacanthus*, *Elagatis bipinnulata*, *Megalaspis cordyla*, *Trichiurus trichiurus*, *Seriolina nigrofasciata*, *Sardinella longiceps*, *Nemipterus japonicus*, *Katsuwonus pelamis*, sea horse (*Hippocampus sp.*) and scombroids, puffer fishes, among the teleosts fishes. The cephalopods dominated by *Loligo duvaucelli* followed by octopus. Crabs species were *Charybdis cruciata* and *Charybdis smithi* observed among the crustaceans. The qualitative analysis revealed that semi-digested matter and some miscellaneous foods were also found in the gut of this species (Fig.12-17).

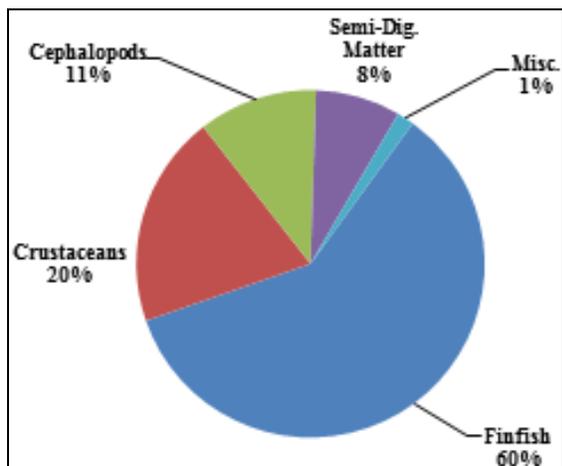


Fig 12: Category-wise gut contents of *Coryphaena hippurus*

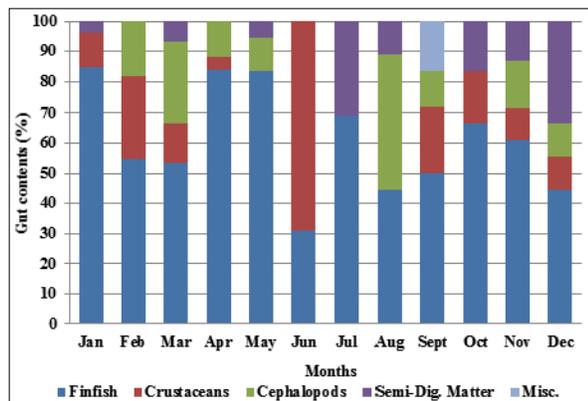


Fig 13: Month-wise, Category-wise gut contents of *Coryphaena hippurus*

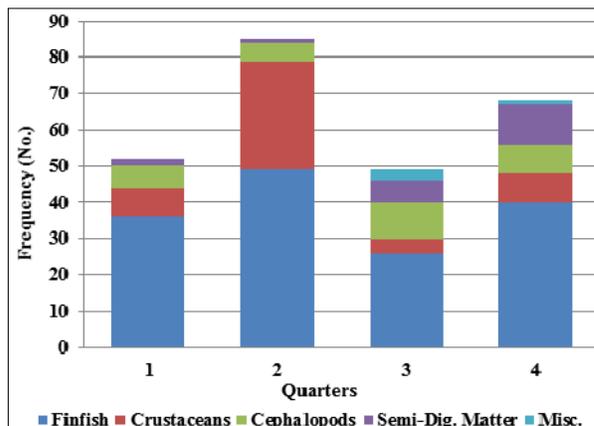


Fig 14: Quarter-wise, Category-wise gut contents of *Coryphaena hippurus*

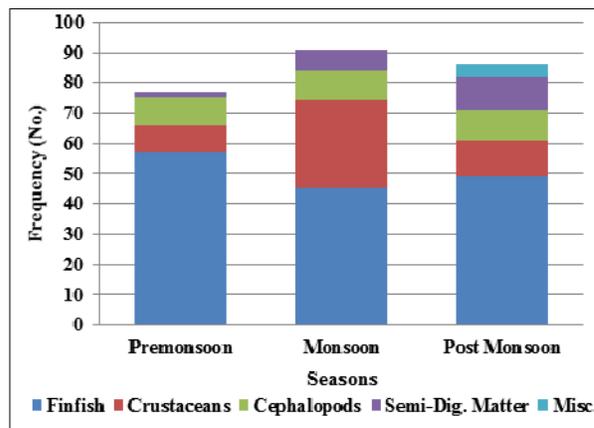


Fig 15: Seasonal food preferences in the gut of *Coryphaena hippurus*

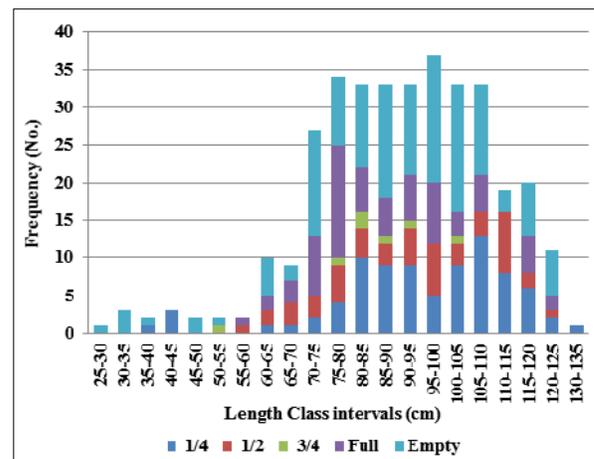


Fig 16: Size-wise stomach condition of *Coryphaena hippurus*

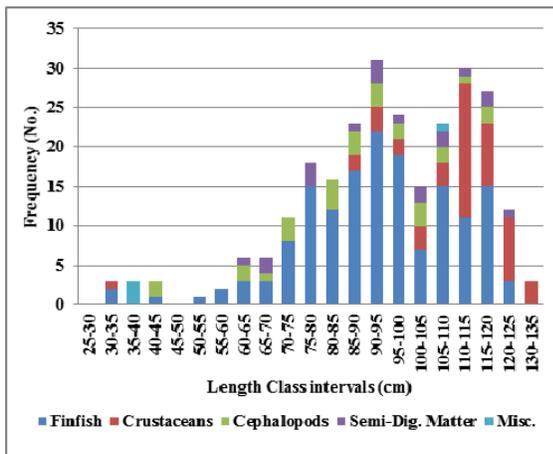


Fig 17: Size-wise, Category-wise food preferences by *Coryphaena hippurus*

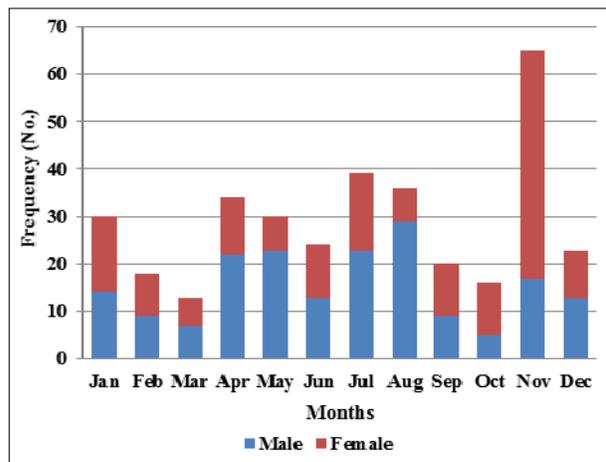


Fig 18: Month-wise male female ratio of *Coryphaena hippurus*

### 3.6. Reproductive Biology

#### 3.6.1. Sex ratio

In the present analysis, out of 348 dolphin fishes, 184 males and 164 females were observed. Male to female Sex ratio recorded was 1.12:1, which indicates, slight dominance of males in the fishery. About 70% females found to be mature, attained stage III and above and remaining 30% females were found as immature. Month-wise male to female ratio reveals that, males were slightly dominated over females in all the months except in the month of November where, females fully dominated over males (74%). Size at first maturity observed at 35cm (FL).

#### 3.6.2. Maturity and Spawning

Month-wise percentage occurrence of different maturity stages in the gonads of *C. hippurus* shows that the matured females were highlighted in the month of July, November and January. From the quarter-wise male to female ratio, it was observed that, males were dominated in all the quarters except in the 4<sup>th</sup> quarter (Oct-Dec) where it shows that females were dominated over males. Quarter-wise percentage occurrence of different maturity stages in gonads of *C. hippurus* shows that, the maximum matured females were observed in 3<sup>rd</sup> quarter i.e. July-September. The III stage maturing females were found more in the 4<sup>th</sup> quarter followed by 1<sup>st</sup>, 3<sup>rd</sup> and 2<sup>nd</sup> quarters. Season-wise male to female ratio emphasized that, the males were found to be dominated over females in pre-monsoon and monsoon seasons while in the post-monsoon season, females were found to be more dominant over males. Season-wise maturation revealed that, in monsoon as well as post-monsoon season the maturing females were found to be more. Overall, in all the seasons, nearly 71% females were found to be matured. In length group-wise observation, it is found that, males were dominated over females in all size class except 90-95 cm where, females were fully dominated over males (74%). Length group-wise percentage occurrence in different maturity stages of gonads of *C. hippurus* shows that from 35-40 cm onwards the females shows maturing gonads while 75-80cm and 90-95 cm class group shows fully mature gonads. The length at first maturity or 50% maturity was observed at 35-40cm class group. Presence of matured females observed throughout the year which indicates that this species spawns throughout the year. Two peak spawning seasons reported in the study, one from May-August with a maximum in July and the other from October to January with a highest in November (Fig. 18-25).

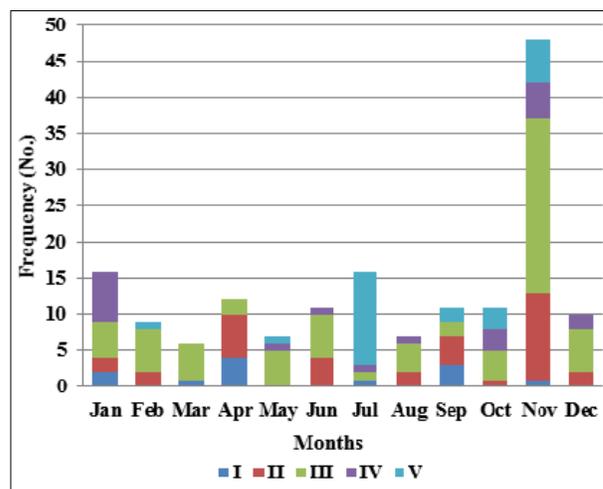


Fig 19: Month-wise percentage occurrence in different maturity stages of gonads of *Coryphaena hippurus*

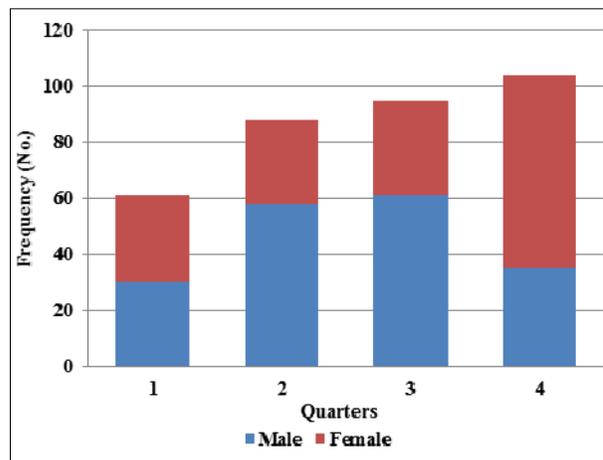


Fig 20: Quarter-wise male female ratio of *Coryphaena hippurus*

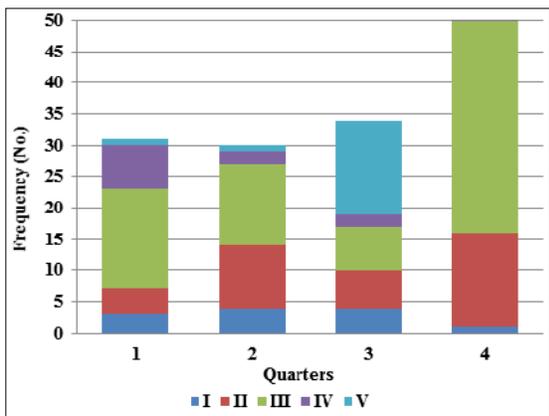


Fig 21: Quarter-wise percentage occurrence in different maturity stages of gonads of *Coryphaena hippurus*

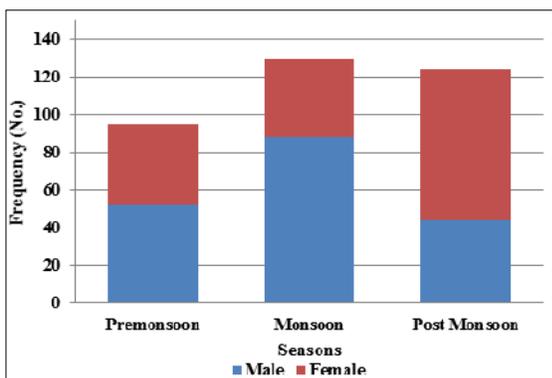


Fig 22: Season-wise male female ratio of *Coryphaena hippurus*

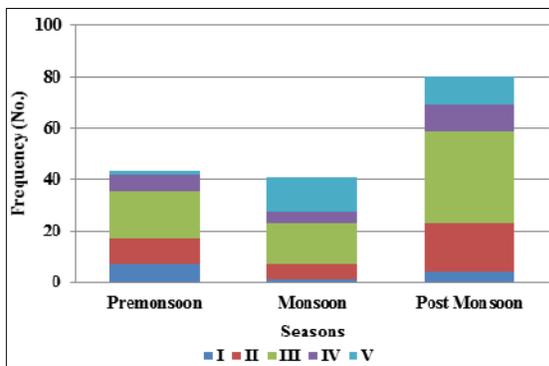


Fig 23: Season-wise Percentage occurrence in different maturity stages of gonads of *C. hippurus*

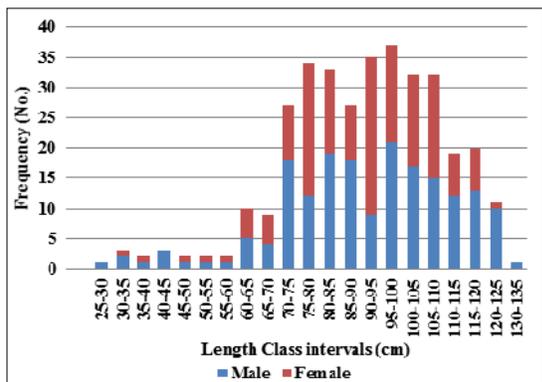


Fig 24: Length group-wise male female ratio of *Coryphaena hippurus*

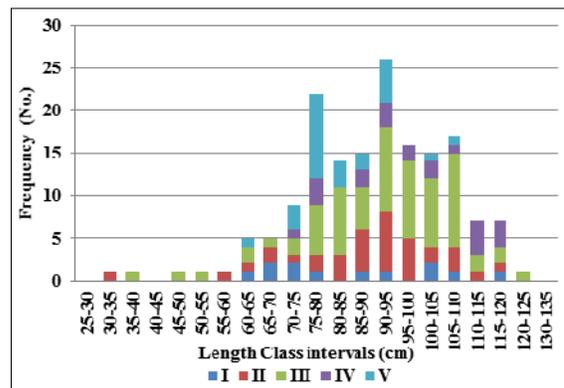


Fig 25: Length group-wise percentage occurrence in different maturity stages of gonads of *C. hippurus*

4. Discussion

Though, the *C. hippurus* fishery in Indian waters did not receive much importance, but its contribution is recognized in commercial landing. The length-weight and growth pattern parameters of *C. hippurus* showing allometric (differential) growth, it has similar results were observed by Rose and Hassler [28], Rivera and Appeldoorn [29]. The Correlation coefficient ( $R^2$ ) values for males, females and combined sexes are 0.95, 0.94 and 0.94 are almost similar to the results of Gatt *et al.* [3] in Maltese waters. The present study also indicates high degree of co-relation between length and weight. The growth coefficient (K) value obtained in the present study is 0.35 per year which is analogous to the value of 0.36 per year reported by Guzman *et al.* [30] along Pacific Panama and close to the value 0.40 obtained by Benjamin and Kurup [18] along the Kerala coast of India and 0.41 by Patterson and Martinez [32] in Equador. Natural mortality (M) value obtained in present study is 0.56 and M/K ratio is 1.6 which is very close to the values of K 0.52 and value of M/K 1.44 derived by Guzman *et al.* [30]. Food preferences of the species under study are in the order of preference as fin fishes followed by crustaceans and cephalopods. The study of food and feeding habits of *C. hippurus* caught in the depth range from 1000 m to 4000 m along the west coast of India is almost similar and is consistent with the works done by Palko *et al.* [4] and Castriota *et al.* [9]. Reproductive study revealed the presence of matured females observed throughout the year, which indicates that, this species spawns throughout the year. Two peak spawning seasons reported in the study. This phenomenon is also supported by the studies of Lasso and Zapata [31] in the Pacific coast of Columbia and Panama and Rajesh *et al.* [11]. In India, the species *C. hippurus* is presently exploited by artisanal sector only below 100m depth. As the importance of the dolphin fish fishery is increasing in Indian waters and this species also found to be occurring beyond 500m depth as revealed through the exploratory surveys, it is imperative to understand the biological aspects of this species occurring in the oceanic waters.

5. Conclusion

The results of the present study indicated that, *C. hippurus* distributed all along the west coast with highest concentration in the Northern part of the west coast. Month-wise occurrence revealed that October and November months' dominance of *C. hippurus* observed during the study period. The allometric growth pattern and M/K ratio 1.6 indicates moderate feeding and considerable high growth. Most preferred food by this species is finfishes followed by crustaceans and cephalopods.

40% of empty stomachs were seen in our samples, which may be due to stress while caught in the gear as a result, the partially digested food might have been gorged out. Highest percentage of mature females was observed during July and November which may indicate two peak spawning seasons. This species spawns was observed throughout the year in the study area. Indicators of this study may be contributing to understand the *C. hippurus* fisheries in Indian peninsula which may derive strategies for sustainable increase in production and management based on prey, predator observation, growth, maturation and spawning for wellbeing of the fishermen.

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