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Length-weight relationship, feeding traits and nutritional value of mahi mahi (*Coryphaena hippurus*) in the south-eastern Arabian Sea

K. Assana¹, R. Mridula¹, K.M. Rajesh^{2*} and T.A. Shaik³¹Department of Fisheries Resources and Management, College of Fisheries, Mangalore-575 002, India²ICAR-Central Marine Fisheries Research Institute, Mangalore Research Centre, Mangalore-575 001, India³Department of Aquatic Animal Health Management, College of Fisheries, Mangalore-575 002, India*Corresponding Author Email : rajeshmkm3@rediffmail.com

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Abstract

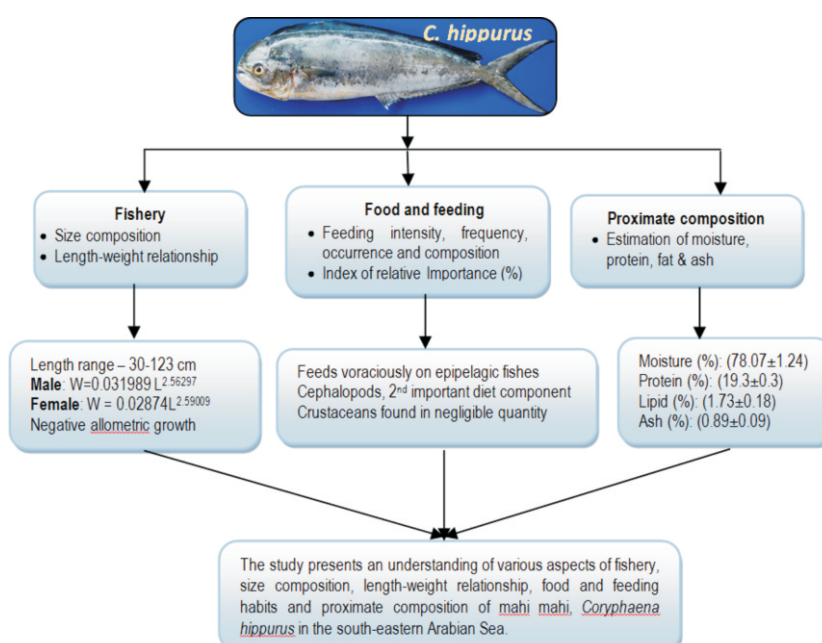
Aim: The present study was conducted to investigate the length-weight relationship, food and feeding behaviour and proximate composition of an oceanic epipelagic fish, *Coryphaena hippurus* landed along Karnataka, south-eastern Arabian Sea.

Methodology: Length-weight relationship, feeding and proximate composition of *C. hippurus* was studied for a period of one year. The size composition, feeding intensity, frequency, occurrence and index of relative importance (IRI) was determined for each diet component in the stomach. Monthly proximate composition in the dolphin fish was estimated.

Results: The fork length of the specimens of *C. hippurus* collected along Karnataka coast ranged from 30- 123 cm and fishes having length range from 33-73 cm represented 79% of the total fish sampled. The estimated *b* values of *C. hippurus* for both males and females were less than 3 which indicated negative allometric growth; the fish grows faster in length than weight. The most dominant item recorded in the gut of *C. hippurus* was pelagic and mesopelagic teleosts. Cephalopods (squids, cuttlefish and octopus) were the second important food constituent while crustaceans consisting of crabs and shrimps formed very less quantity.

Interpretation: Information on length-weight relationship, feeding behaviour and proximate composition of mahi mahi would be useful for developing suitable management plans for the conservation and judicious exploitation of this commercially important resource.

Key words: Dolphin fish, Food and feeding, Index of relative importance, Karnataka, Proximate composition



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Introduction

Coryphaena is the only genus in the family Coryphaenidae comprising of two species *C. hippurus* and *C. equiselis*. *C. hippurus*, an epipelagic highly migratory species generally known as mahi-mahi, dolphin fish or Dorado is a well-known food and game-fish with cosmopolitan distribution occurring worldwide in tropical and subtropical seas (Gatt et al., 2015). It is typically found in pelagic habitats, where they form schools and have a tendency to aggregate near natural and artificial floating objects (Castriota et al., 2007). Dolphin fish is considered as an economically important fish species all along its distributional areas as they support artisanal, recreational and commercial fisheries (Olson and Galvan-Magana, 2002).

From the ecological perspective, dolphin fish plays an important role, as it is a highly pelagic fish species located at the top portion of the food chain, contributing to the balance of the marine ecosystem. Growth rates of this fish can be as high as 4 mm per day, but vary considerably (Oxenford and Hunte, 1983) depending on location and season (Oxenford, 1999). The remarkable fast growth rate and high turnover of this species has probably made it less susceptible to the act of overfishing as compared to other long-lived slow maturing fishes (FWRI, 2008) and are included under the category 'least concern' in the IUCN Redlist (Collette et al., 2011). In trophic terms, *C. hippurus* is a top predator in the pelagic ecosystem (Massuti et al., 1998), and fishing activities may provoke top-down consequences on pelagic food resources, new insight on this topic can provide useful ecological information, which can also be exploited for an ecosystem approach to pelagic fish management.

Dolphin fish is an important part of the pelagic food web and ecosystem with a feeding strategy that is more opportunistic rather than selective. It removes considerable amount of tertiary production from an ecosystem by consuming approximately 5-6% of its body weight per day (Olson and Galvan-Magana, 2002). Extremely diverse prey array was recorded from the gut of this species from different parts of the world according to the season and geographical location. Hence, region specific studies provide knowledge on ecology and biology of the resource which is essential for its judicious management and conservation. However, the detailed study on food and feeding habits and proximate composition of this economically important fish species in Indian waters are meagre. Therefore, an investigation was initiated to study the length-weight relationship, food and feeding habits and proximate composition of *C. hippurus* in the south-eastern Arabian Sea.

Materials and Methods

Specimens of *C. hippurus* landed by various gears (trawls, purse seines, long lines and gillnets) were collected on weekly basis from August 2017 to May 2018 from two major

fishing harbours along Karnataka Coast located at Mangalore and Malpe. The collection of sample could not be done during June and July due to the monsoon fishing ban for the operation of mechanised fishing vessels. Specimens were preserved in an insulated icebox and shifted to the laboratory of the Mangalore Research Centre of Central Marine Fisheries Research Institute (CMFRI, Mangalore, India) for further analysis.

Fork length (FL) and body weight of 77 males and 270 female *C. hippurus* were measured to the nearest 0.1 cm and 0.1 g accuracy, respectively. The length-weight relationship (LWR) was estimated by the formula of Le Cren (1951).

$$W = a(FL)^b$$

where, W is the total body weight (g), FL is the fork length (cm), a is a coefficient related to body weight and b is an exponent. Analysis of covariance (ANCOVA) was used to compare the length-weight relationship of males and females (Snedecor and Cochran, 1967).

Food and feeding habit was studied based on the analysis made on 347 fishes after careful dissection. Stomachs taken out from the individual fishes were classified for the fullness of the stomach based on the visual observations as empty, trace, one-fourth full, half full, three-fourth full and full. The total weight of the content in the stomachs was recorded and prey items were broadly categorized into fishes, crustaceans and cephalopods. Weight of each prey item was recorded separately and ranking was given to various food items found in the stomach using points method. The prey items present in the stomach were identified up to the generic/species level following the keys and identifying descriptions (Froese and Pauly, 2017) and the numbers of identified food items were counted. Partially digested and unidentified remains of fish were grouped as unidentified fish remains. The index of relative importance (IRI) of each diet component in the stomach was determined following the protocol of Pinkas et al. (1971) on the basis of three indices: wet weight percentage of each food item (%W) to the total weight of all the food items in the gut; percentage of the number (%N) of each food item to the total number of all identified food items; and frequency of occurrence (%F) of each food item to the total number of guts examined. The IRI was calculated as: $IRI = (\%N + \%W) \times \%F$. Proximate composition of fish (Protein, fat and Ash content) was determined by following the method of AOAC (2010).

Results and Discussion

The fork length of *C. hippurus* specimens collected along Karnataka coast ranged between 30 and 123 cm and the fishes having length ranging from 33-73 cm represented 79% of the total fish sampled (Fig. 1). Among the different length class, the length range from 59 to 63 cm represented 12.6% followed by the length range of 49-53 cm (11.8%), 64-68 cm (9.9%), 54-58 cm (8.5%), 74-78 cm (8.5%) and 30-33 cm (8.3%). Modal lengths were 63

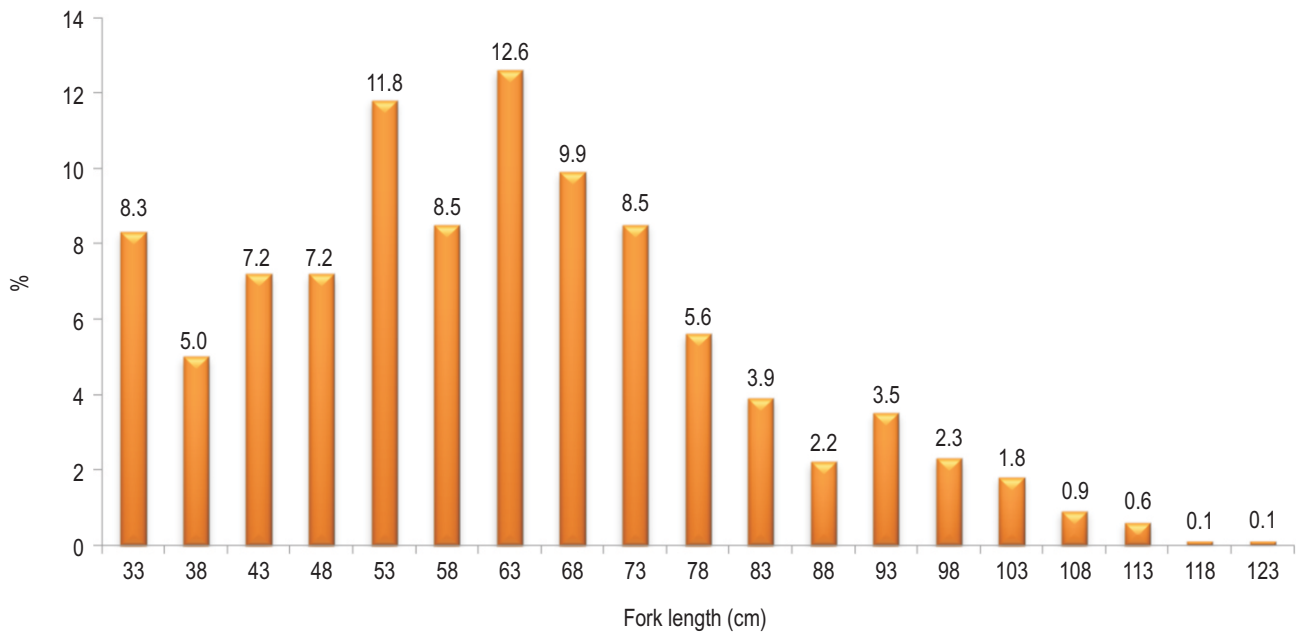


Fig. 1 : Size composition of *C. hippurus* collected during 2017-18 in south-eastern Arabian Sea along Karnataka Coast.

and 53 cm and the estimated annual mean length was 74.2 cm. The fork length range recorded in the present study is almost similar to the previous reports from east coast of Taiwan (Chuen-Chi Wu *et al.*, 2001) and west coast of India (Vinod Kumar *et al.*, 2017) where a size range of 26.5-139 cm and 27.5-135 cm were recorded, respectively. In contrast, a higher length range of 41.7-177 cm FL was reported from the Eastern Pacific Ocean (Olson and Galvan-Magana, 2002).

The LWR for male and female *C. hippurus* are given in Fig. 2. The estimated b values of *C. hippurus* for both males and females were less than 3 which indicated negative allometric growth; the fish grows faster in length than weight. The estimated allometric coefficient b did not differ significantly between the sexes and was found within the normal expected range of 2.5–3.5 for teleosts (Froese, 2006). The LWRs of *C. hippurus* in the present study is in agreement with the previous published information from the Eastern-Pacific Ocean (Olson and Galvan-Magana, 2002), Central Mediterranean (Gatt *et al.*, 2015) and West coast of India (Vinod Kumar *et al.*, 2017).

Of the 347 guts of *C. hippurus* analysed, only 191 (55.56%) had food in varied quantity and 156 (44.44%) were having empty stomachs. Twenty eight fishes (8.02%) were having trace (very less) amount of food, 75 fishes (21.49%) with one-fourth quantity, 39 fishes (11.17%) with half, 10 fishes (2.87%) having three-fourth and 41 (11.75%) fishes were having full food content in their stomach. The higher percentage of empty stomach observed in *C. hippurus* in this study is in line with the previous observations with 50.3% and 40% empty stomachs from Eastern-Pacific Ocean (Olson and Galvan-Magana, 2002) and

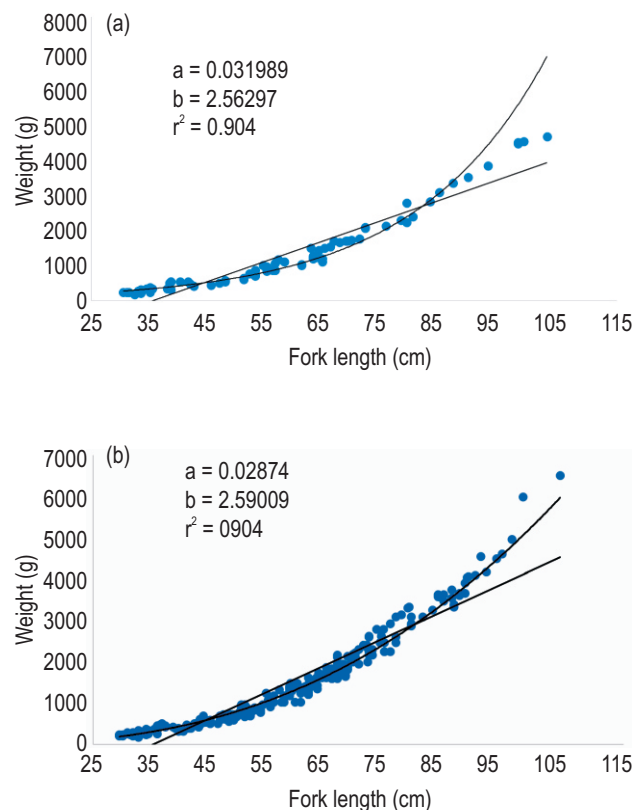


Fig. 2 : Length-weight relationship of *C. hippurus* (a) male and (b) female collected during 2017-18 in south-eastern Arabian Sea along Karnataka coast.

west coast of India (Vinod Kumar et al., 2017), respectively. Incidences of higher proportion of empty stomachs is a characteristic of piscivorous fishes (Juanes and Conover, 1994) and lesser quantity of food in the stomach and higher proportion of empty stomachs could be attributed to the high calorie content of the diet which demands limited intake of food items (Rajesh et al., 2019).

The prey of *C. hippurus* belonged to three major taxonomic group such as fishes, cephalopods and crustaceans (Table 1). The most dominant food item by frequency of occurrence (72.13%), weight (88.10%), number (78%) and % IRI (91.22%) was teleosts followed by cephalopods (24.59%, 9.49, 21% and 8.4%, respectively, in terms of occurrence, weight, number and IRI) and crustaceans (3.28%, 2.41%, 1.0% and 0.34 % in terms of frequency of occurrence, weight, number and IRI, respectively). The results of this study indicated that *C. hippurus* like other pelagic fishes predate opportunistically on several prey items (Oxenford, 1999). The study has shown that % IRI was high

for teleosts (91.22%) compared to cephalopods (8.44) and crustaceans (0.34). Predominance of teleosts in the diet of dolphin fish has been reported from Eastern-Pacific Ocean (Olson and Galvan-Magana, 2002) and along the coast of Rio De Janerio, Brazil (Pimenta et al., 2014). Almost half of the (48.86%) teleosts consumed were in the form of semi-digested matter, as the fishes caught in gillnet and longline stays alive for long time and during this period the digestion of prey item continues (Boggs, 1992).

The result of IRI indicated that this carnivorous fish gives preference to the pelagic and mesopelagic fish species such as *Decapterus russelli*, *Bregmaceros* sp., *Priacanthus* spp., *Rastrelliger kanagurta*, *Encrasicholina devisi*, *Lagocephalus inermis*, *Saurida* sp. and *Sardinella longiceps*. The predatory activity of dolphin fish plays an important role in the pelagic system in transferring energy between epipelagic and mesopelagic environments in the marine food web (Castriota et al., 2007). Epipelagic fishes as common prey item in the

Table 1 : Frequency, number, weight and Index of relative importance (IRI) of food items in the diet of *C. hippurus* collected during 2017-18 in south-eastern Arabian Sea along Karnataka Coast

Diet components	% Frequency	% Weight	% Number	Index of Relative Importance (IRI)	% IRI
Fish (Pooled)	72.13	88.10	78.00	1509.60	91.22
Partially digested unidentified fish	24.59	43.29	14.00	808.58	48.86
<i>Decapterus russelli</i>	13.11	15.48	19.67	460.94	27.85
<i>Priacanthus</i> spp.	3.28	7.21	10.67	58.60	3.54
<i>Bregmaceros</i> sp.	4.92	0.45	11.33	57.95	3.50
<i>Rastrelliger kanagurta</i>	3.28	5.18	8.33	44.31	2.68
<i>Saurida</i> sp.	3.28	4.50	1.67	20.22	1.22
<i>Encrasicholina devisi</i>	4.92	1.72	1.67	16.64	1.01
<i>Odonus</i> sp.	3.28	3.56	1.33	16.05	0.97
<i>Epinephelus diacanthus</i>	1.64	2.69	3.67	10.42	0.63
<i>Lagocephalus inermis</i>	1.64	2.20	3.33	9.07	0.55
<i>Sardinella longiceps</i>	1.64	0.62	0.67	2.10	0.13
<i>Megalaspis cordyla</i>	1.64	0.94	0.33	2.09	0.13
<i>Apogon</i> sp.	1.64	0.05	0.67	1.17	0.07
<i>Trichiurus lepturus</i>	1.64	0.16	0.33	0.81	0.05
<i>Atul mate</i>	1.64	0.06	0.33	0.65	0.04

Table 2 : Proximate composition of *C. hippurus* collected during 2017-18 in south-eastern Arabian Sea along Karnataka coast

Months	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
Aug.17	77.83	19.30	1.92	0.95
Sep.	80.10	18.00	0.9	1.0
Oct.	78.07	18.50	2.1	0.83
Nov.	78.07	19.00	2.1	0.83
Dec.	76.83	20.20	1.77	1.20
Jan.18	77.90	19.64	1.64	0.82
Feb.	80.35	18.20	0.90	1.20
Mar.	77.80	19.80	1.30	1.10
Apr.	77.02	20.00	2.30	0.68
May	76.80	20.50	2.40	0.30
Mean ± S.E.	78.07±1.24	19.3±0.29	1.73±0.18	0.89±0.09

stomachs of dolphin fish indicates that it feeds at surface as well as in the columnar waters (Brewton *et al.*, 2016).

Of the major diet components, cephalopods (squids, cuttlefish and octopus) were the second most important food constituent of dolphin fish (Table 1). Squids represented the major portion (7.24% of IRI) of cephalopods compared to cuttlefish (IRI of 1.01%) and octopus (IRI of 0.13%). The possibilities of squids being consumed by this species during their diel vertical migrations towards the surface at night was reported by Brewton *et al.* (2016). Crustaceans consisting of crabs and shrimps formed very less quantity as diet and the results of previous studies are in agreement with present observations and reported the minor role of cephalopods and crustaceans as diet components of dolphin fish (Olson and Galvan-Magana, 2002; Pimenta *et al.*, 2014).

Monthly variations in muscle proximate composition of *C. hippurus* are presented in Table 2. The moisture content (%) fluctuated from 76.80 (May) to 80.35 (February) with mean values of 78.07 ± 1.24 . The values obtained in the present study are comparable with the moisture content (%) estimated for dolphin fish caught in the Pacific Ocean with its range from 77.8-80.3 with the mean values of 79.3 (Boiteanu, *et al.*, 2014).

The ash content (%) was maximum during December and February (1.2) and minimum during May (0.3) with an average value of 0.89. The findings of this study indicated that the mean ash content (1.4%) recorded for dolphin fish is high in Pacific Ocean (Boiteanu *et al.*, 2014). The muscle composition of *C. hippurus* revealed that the protein content varied between 18.0% (September) to 20.5% (May) with mean value of 19.3% indicating that the fish can be considered as a good table fish (Viji *et al.*, 2015). The value recorded in the present study is slightly higher compared to the protein content of dolphin fish ($18.0 \pm 0.9\%$) harvested from Pacific Ocean (Boiteanu *et al.*, 2014). Protein content of the muscle varies widely depending on factors such as feeding habits and availability of food, fasting, migration etc.

The lipid content varied from 0.9% (September) to 2.4% (May), with an average value of 1.73% which was significantly high compared to the dolphin fish caught from Pacific waters (0.9%) (Boiteanu *et al.*, 2014). The difference in the lipid content could be due to the fish caught from different locations with varied environmental conditions.

The inverse relationship of moisture content with lipid and protein recorded for dolphin fish is in conformity with the observations of earlier investigation (Winfre and Stickney, 1981). The possible factor such as size, sex, maturity stage can affect the differences in proximate composition of marine fish.

The comprehensive information on length-weight relationship and feeding behaviour of dolphin fish would be a

useful tool for subsequent population studies and stock assessment as it is a pre-requisite for developing suitable management plans for the conservation and cautious exploitation of this commercially important resource. Proximate composition estimated for different season provides an update to food composition database and would be useful for the consumer in choosing the fish based on their nutritional values.

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