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Fishery, diet composition and reproductive biology of the dolphinfish *Coryphaena hippurus* (Linnaeus, 1758) off Karnataka, south-west coast of India

K. M. RAJESH, PRATHIBHA ROHIT AND E. M. ABDUSSAMAD*
Research Centre of ICAR-Central Marine Fisheries Research Institute, Hoige Bazar, Mangalore - 575 001 Karnataka, India
**ICAR-Central Marine Fisheries Research Institute, Ernakulam North P.O., Kochi - 682 018, Kerala, India*
e-mail: rajeshmkm3@rediffmail.com

ABSTRACT

Fishery, diet composition and reproductive biology of the dolphinfish *Coryphaena hippurus* (Linnaeus, 1758) landed along Karnataka Coast during 2013-15 were studied. The estimated average landing of the species in India during the study period was 7975 t of which Karnataka contributed 2.73% (218 t). The fish is mainly exploited by gillnet and also by troll lines operated from trawlers. A few stray specimens were also landed by purse seines. The fork length (FL) was in the range of 32-128 cm and fishes in the length range (FL) of 55-90 cm dominated the catch, contributing 79.8% of the total landings. The most dominant prey item, in terms of occurrence (70.57%) and weight (83.18%) were finfishes followed by cephalopods (19.62% by occurrence and 13.66% by weight) and crustaceans (7.01% occurrence and 1.32% by weight). The index of relative importance (IRI) values were 85.3, 13.39 and 0.68% respectively for fish, cephalopods and crustaceans respectively. Sex ratio (1:2.05) indicated dominance of females in the fishery. Presence of mature and spent specimens throughout the year suggests that the species spawns all through the year. Peak spawning period was from June to September. This coincided with gradual increase in gonadosomatic index (GSI) values ahead of May which reached a peak during August-September.

Keywords: *Coryphaena hippurus,* Diet composition, Dolphinfish, Karnataka, Reproductive biology

Introduction

The genus *Coryphaena* under the monogeneric family Coryphaenidae comprises only two species *viz., Coryphaena hippurus* (Linnaeus, 1758) and *C. equiselis* (Linnaeus, 1758) which are commonly called mahimahi or dolphinfishes. These are highly migratory, large oceanic species having a wide distribution in tropical and subtropical waters of the Pacific, Atlantic and Indian Oceans and known to occur within a few miles off the coast when wind blows steadily (Merten *et al.,* 2014; Gatt *et al.,* 2015). They generally occur along with large oceanic pelagic fishes and support important commercial fisheries in several regions (Losso and Zopata, 1999; Olson and Galven-Magana, 2002). These fishes have a tendency to aggregate near natural and artificial floating objects (Wickham *et al.,* 1973). Fishermen in the Mediterranean Sea make use of the aggregating tendency to their advantage and attract them using fish aggregating devices (FAD's) moored offshore, which are then caught with surround nets (Castriota *et al.,* 2007). However, the remarkable fast growth rate and high turnover of this species has probably made dolphinfishes 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). Dolphinfishes are apex predators and feeds on fishes, crustaceans and molluscs. It removes considerable amount of tertiary production from an ecosystem and consume approximately 5-6% of its body weight each day (Olson and Galven-Magana, 2002; Guzman *et al.,* 2015).

Occurrence of dolphinfishes in India is reported from all maritime states except West Bengal and the resource forms an important component of the fish landings of Gujarat (37%), Daman and Diu (16.7%), Kerala (14.3%) and Tamil Nadu (11.9%). The estimated annual average catch for the country during 2013-15 was 7975 t with Karnataka contributing 2.73% (218 t) occupying sixth position among the maritime states. Fishery in Karnataka comprised only single species, *C. hippurus* and was observed throughout the fishing season with peak landing between August and October. Dolphinfishes are mainly caught as bycatch in gears targeting seerfish, tunas, barracudas and billfishes. They also formed part of the purse seine catch using light as fish attractant, which recently started operating in deeper waters off Karnataka.

Studies on the fishery, diet composition, reproductive biology and stock status of dolphinfish are available from Mediterranean waters, Eastern Pacific Ocean, Tyrrhenian seas, Australian waters and northern coast of Rio de Janeiro, Brazil (Massuti *et al.,* 1998; Oxenford, 1999; Olsan and Galvan Magana, 2002; Castroita *et al.,* 2007; Newman, 2013; Pimenta *et al.,* 2014; Gatt *et al.,* 2015; Guzman *et al.,* 2015). However, no comprehensive report is available on the fishery, diet composition and reproductive biology of dolphinfishes from Indian waters. Benjamin and Kurup (2012) reported on the stock status of the species along Kerala Coast based on their collections made at Cochin, Munambam and Neendakara fishing harbours. The present study for the first time investigated the fishery, diet composition and reproductive biology of the dolphinfish *C. hippurus* from Karnataka coast.

Materials and methods

Data on *C. hippurus* landed during 2013-2015 by different commercial fishing vessels were obtained from the data bank of National Marine Fisheries Data Centre (NMFDC) of ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI), Kochi. Fortnightly samples were collected for biological studies from Mangalore and Malpe landing centres of Karnataka from gillnet and hook and lines, as majority of the dolphinfish was landed on a regular basis by these gears. The fork length (FL) of 953 fishes was measured to the nearest cm. Diet composition and reproductive biology was studied based on observations from a total of 256 fishes. Monthly collections were made thoughout the year, except during the monsoon months of June and July when there was a ban on the operation of mechanised fishing units. Stomachs from individual fishes were carefully dissected out and preserved for further detailed analysis. Based on the absence or presence of food, the stomach fullness was visually classified into six categories as: full, three-fourth full, half full, one-fourth full, trace and empty. Total weight of the stomach contents was recorded and food items were divided into broad prey classes *viz*., fishes, molluscs and crustaceans. The weight of each prey item was taken separately.

Point's method (Hyslop, 1980) was used to provide weightage to different food items in the stomach. The keys and identification characteristics as described in Smith and Heemstra (1986) and Fischer and Whitehead (1974) were followed to identify the prey up to genus/species level. The index of relative importance (IRI) of each food item in the diet was determined following Pinkas *et al*. (1971).

Based on the macroscopic appearance of the ovary and testes in the body cavity, maturity stages of females and males were classified with suitable modification as per the ICES scale described by Lovern and Wood (1937). The homogeneity of male and female distribution was determined by Chi-square test using monthly sex ratio. The gonadosomatic index (GSI) was calculated using the equation:

GSI = [Gonad weight/ (body weight - gonad weight)]*100

Results and discussion

Fishery

Along Karnataka Coast, dolphinfishes are exploited mainly by crafts operating gillnet (43%) and also by troll lines operated from trawlers (37%), purse seines (14%) and other indigenous gears (6%) such as ringseines and shoreseines. The landings of trawls, gillnets, purseseines, ringseines and shoreseines confirms the extent of distributional availability of dolphinfish very close to the coast and in deeper areas. Similar type of wide distributional abundance from within a few miles of the coast to offshore deeper waters has been very well documented in tropical and subtropical waters (FAO, 1994; Collette, 1999). Similarly, exploitation of the dolphinfish by different gears such as purse seines (Olson and Galvin- Magana, 2002) in Pacific Ocean, longlines (Gatt *et al.,* 2015), drifting longlines, troll lines and surrounding nets (Castriota *et al.,* 2007) in Mediterranean waters have been reported. The estimated annual catch of dolphinfish in Karnataka during 2013-2015 ranged between 136.3 t (2013) and 307.1 t (2014), with a mean of 209.3 t and accounted for 2.7% of the country's dolphinfish catch (7975 t).

Seasonal abundance

Dolphinfish was landed in all months with peak during September and October (Fig. 1) and moderate landings during August and November. Minimum catch was recorded during June-July as the fishing ban is imposed on the operation of mechanised boats. Minimal catch was recorded by a few motorised units operating gillnets during June-July.

Length distribution

The fork length (FL) ranged from 32 to 128 cm but fishes having 55 to 90 cm FL dominated the catch (79.8%) (Fig. 2). Modal lengths were at 80 and 60 cm and the estimated annual mean length was 74.2 cm. Similar length ranges of 45-127.5 cm (Rose and Hassler, 1974), 35.8-147.9 cm (Perez *et al.,* 1992), 40-120 cm (Oxenford, 1985) and 35.8-132.3 cm (Perez and Sadovy, 1991) have been reported from North Carolina, Puerto Rico, Barbados and Puerto Rico respectively. However, Benjamin and

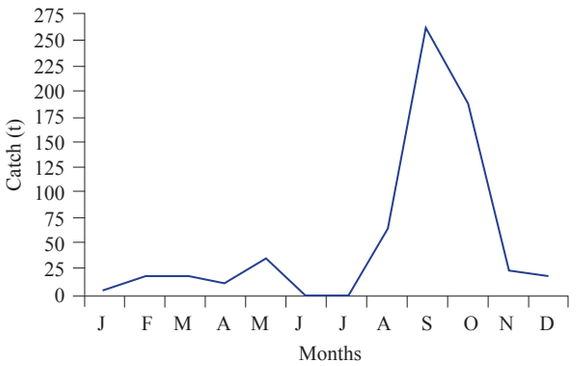

Fig. 1. Monthly trends in landings of *C. hippurus* in Karnataka during 2013-2015

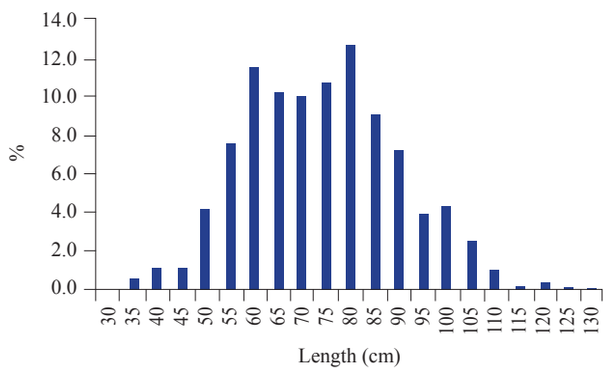

Fig. 2. Length frequency distribution of *C. hippurus* landed in Karnataka during 2013-2015

Kurup (2012) have reported a higher length range of 55-185 cm for dolphinfish in the Arabian Sea off Kerala. The size frequency distribution recorded in our study is comparable with other studies conducted in North Pacific Ocean (Ditty *et al.,* 1994), Eastern tropical Pacific (Zuniga *et al.*, 2008), Central Mediterranean (Gatt *et al.,* 2015) and Pacific Panama (Guzman *et al.,* 2015).

Food and feeding

Among the 256 guts of dolphinfish analysed, 122 (48%) were empty, 45 (17%) full, 41 (16%) trace, 35 (14%) were half full and 13 (5%) were three-fourth full. Dolphinfishes are believed to be visual predators and primarily feed during day time (Massuti *et al.,* 1998). The higher numbers of empty stomach recorded here could be due to the collection of samples from multiday gillnets and trawls operating during night time. Juanes and Conover (1994) too have made similar observations and opined that high percentage of empty stomachs is normal among large fishes which prey mainly on other fishes.

Prey items were mainly represented by three major taxonomic groups *viz*., fishes; crustaceans and cephalopods. The most dominant prey item, both by occurrence (70.57%) and weight (83.18%) were teleosts followed by cephalopods (19.62% by occurrence and 13.66% by weight) and crustaceans (7.01% by occurrence and 1.32% by weight). The % IRI values were 85.3, 13.39 and 0.68 respectively for fish, cephalopods and crustaceans (Table 1). Results indicate that *C. hippurus* like other large pelagic fishes feed opportunistically on several prey items (Oxenford, 1999). Predominance of fishes in the diet of dolphinfish has been pointed out in earlier studies carried out in Mediterranean waters (Massuti *et al.,* 1998), Eastern Pacific Ocean (Olson and Galvan-Magana, 2002), Tyrrhenian seas (Castriota *et al.,* 2007) and along the coast of Rio De Janerio, Brazil (Pimenta *et al.,* 2014).

The most important teleost prey items were the pelagic and mesopelagic fish species *viz., Decapterus russelli, Encrasicholina devisi, Lagocephalus inermis, Trichiurus lepturus, Sardinella longiceps, Scomberomorus commerson* and *Megalaspis cordyla* (Table 1). This is an indication of energy transfer between the epipelagic and mesopelagic environments through the food web, which emphasised the importance of the dolphinfish predatory activity in the whole pelagic system (Castriota *et al.,* 2007). Fishes were generally present in a highly digestible condition and unidentifiable remains accounted for the highest percentage among prey items (%F = 17.76, %N = 19.47, %W = 22.41 and %IRI = 27.54) (Table 1).

Cephalopods were the second most dominant diet found in the gut following fishes. Among cephalopods, *Loligo* sp. was the predominant prey (15.42% by occurrence, 10.18% by number, 12.84% by weight and 1.14% by IRI) followed by *Sepia* and *Octopus* (Table 1). Crustaceans comprising shrimps and crabs formed only very less quantity. Prey importance varied according to the area and availability of food organisms. Fish as the main diet component and the minor role of cephalopods and crustaceans in the diet of dolphinfish has been documented (Massuti *et al.,* 1998; Olson and Galvan-Magana, 2002; Castriota *et al*., 2007; Pimenta *et al.,* 2014).

Reproductive biology

Sex ratio

Of the 256 dolphinfishes analysed, 84 were males (32.81%) and 172 females (67.19%). Male to female ratio was 1:2.05, which indicated dominance of females in the fishery. Monthwise, female dominance was evident throughout the year (Table 2).

Dominance of females was noticeable in almost all the months (Table 2). Such sexual differentiation with dominance of females may be attributed to the migration undertaken for the purpose of spawning. Similar dominance of female dolphinfish in the fishery has been

Table 1. Index of relative importance (IRI) of food items in the diet of *C. hippurus*

	% Frequency	% Number	% Weight	Index of relative importantance	%IRI
Fish (Combined)	70.57	80.08	83.18	2303.22	85.3
Decapterus russelli	21.03	19.03	32.07	1074.39	39.79
Partially digested fishes (Unidentified)	17.76	19.47	22.41	743.67	27.54
Encrasicholina devisi	10.75	26.99	5.80	352.39	13.05
Lagocephalus inermis	5.61	2.21	10.12	69.14	2.56
Trichiurus lepturus	4.21	1.33	4.25	23.47	0.87
Sardinella longiceps	4.21	2.21	2.31	19.02	0.70
Scomeromorus commerson	1.40	6.64	0.05	9.38	0.35
Megalaspis cordyla	1.40	0.44	2.64	4.33	0.16
Hemiramphus sp.	1.40	0.88	1.72	3.65	0.14
Nemipterus japonicus	1.40	0.44	1.03	2.07	0.08
Epinephelus sp.	2.80	4.42	1.84	17.56	0.09
Ablennes hians	1.40	0.44	0.78	1.71	0.06
Cephalopods (Combined)	19.62	11.95	13.66	361.4	13.39
Loligo sp.	15.42	10.18	12.84	354.88	13.14
Octopus	2.80	1.33	0.73	5.77	0.22
Sepia sp.	1.40	0.44	0.09	0.75	0.03
Crustaceans (Combined)	7.01	3.53	1.32	18.17	0.68
Shrimps	4.21	2.65	0.59	13.64	0.51
Crabs	2.80	0.88	0.73	4.53	0.17

Values are means of three years (2013-2015)

noticed and reported from other parts of the world (Table 3) and is more of a temporary behaviour and not due to sexual differentiation during conception or selective mortality of a particular sex (Oxenford, 1999). This is clearly reflected by the Chi-square test (Table 2) which also did not indicate significant difference in distribution of males and females during different months.

Length at first maturity

Out of the 256 specimens collected 250 (97.7%) were found to be mature and had attained stage III and above. Among the 6 immature fishes, 4 males (45-48 cm FL) and 2 females (42 and 45 cm FL) were in stage II of gonadal maturity. The smallest mature male and female observed were at 47 and 49 cm FL respectively. About 90% of the fishes observed in the study measured above 55 cm FL. This may be because of the dominant catch of the species by gillnets. However, more number of smaller fishes needs to be observed for the accurate determination of minimum size at maturity. Beardesly (1967) observed maturation of female dolphinfish at about 35 cm, 50% at 45 cm and 100% at 55 cm FL. The males matured at slightly larger size (42.7 cm FL) as compared to females.

Table 2. Monthly sex ratio of *C. hippurus* landed in Karnataka during 2013-2015

Months	Sex ratio (Female/male)	Chi-square value
January	1.18	1.846
February	1.89	0.038
March	2.14	0.010
April	2.20	0.018
May	1.71	0.140
August	3.17	0.881
September	2.89	0.800
October	2.71	0.409
November	1.91	0.035
December	1.44	0.654

*$p \leq 0.05$

Gonadosomatic index (GSI)

The GSI values ranged from 0.89 to 1.74 for male and 1.61 to 6.32 for female fishes. Higher GSI values were recorded during August and September (Fig. 3) indicating high reproductive activity during these months.

Table 3. Overall sex ratios reported for dolphinfish from different parts of the world

Location	Sex ratio (M:F)	Reference
Virgin Islands	1:1.9	Mather (1954)
North Carolina	1:1.9	Rose and Hasler (1974)
Puerto Rico	1:3.0	Erdman (1976)
Florida current	1:1.8	Oxenford (1985)
Barbados	1:3.0	Oxenford (1985)
Gulf of Mexico	1:1.2	Bentivoglio (1988)
Puerto Rico	1:2.3	Perez *et al.* (1992)
Maltese waters, Central Mediterranean	1:1.5	Gatt *et al.* (2015)

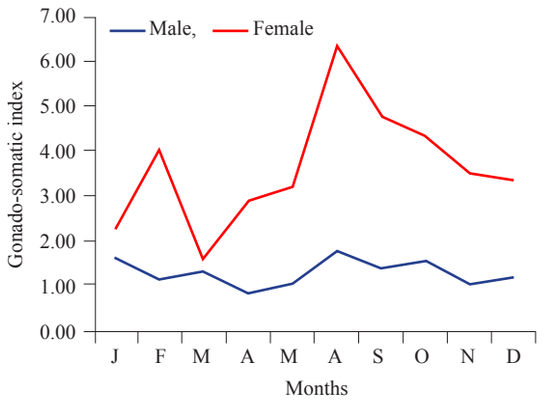

Fig. 3. Monthly mean gonadosomatic indices (GSI) for male and female *C. hippurus*

The presence of mature and spent specimens throughout the year suggests that dolphinfish spawns all through the year. However, the peak spawning period recorded during June to September coincides with gradual increase in GSI value ahead of May, with peak values in August-September which gradually reduced thereafter. The protracted multiple spawning behaviour of dolphinfish is very well documented (Palko *et al.,* 1982; Oxenford, 1985; Perez and Sadovy, 1991). The occurrence of dolphinfish larvae all through the year in the Florida Current (Powles and Stender, 1976 and Schekter, 1982) and Gulf of Mexico (Ditty *et al*., 1994) indicates year round spawning. Continuous spawning was reported in dolphinfish broodstock caught from the Florida Current kept in captivity for several months.

C. hippurus is a pelagic predator, feeding mainly on pelagic and mesopelagic fishes. Such piscivorous diet indicates energy transfer between the epipelagic and mesopelagic systems in the marine foodweb. The presence of mature and spent specimens throughout the year suggests that dolphinfish spawns all through the year with a peak during June to September and it coincided with the higher GSI values recorded during the same period. This comprehensive account on the major biological characteristics of *C. hippurus* is the first of its kind from Indian waters, that would form basic information for future studies and also for the management, conservation and judicious exploitation of the species.

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