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Reproductive biology and feeding habits of the common dolphinfish *Coryphaena hippurus* (Linnaeus, 1758) off Saurashtra coast, India

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ABSTRACT

The present study analysed reproductive biology and feeding habits of the common dolphinfish *Corphaena hippurus*, along the Saurashtra coast of India. The study is based on an investigation of 295 specimens caught using drift gillnet at Veraval. The samples were collected on a monthly basis between March 2015 and February 2016. The sex ratio was 1:1.75 with a significant dominance of females in the population. The size at maturity for females was 593 mm FL (fork length). Absolute fecundity of the individuals ranged from 1,07,813 to 15,50,400 having ova diameter range of 0.3-1.96 mm. *C. hippurus* spawned throughout the year with its reproductive activity peaking in April and December. Thus the dolphin fish has an extended spawning season; during which it laid eggs almost continuously. A total of 128 stomachs of *C. hippurus*, whose FL ranged from 380 to 1250 mm were examined during the one year period of this study. Tunas were found to be the common dietary component of the dolphinfish.

Keywords: *Coryphaena hippurus*, Fecundity, Reproduction, Sex ratio, Spawning season

Introduction

Coryphaena is the only genus in the family Coryphaenidae, which comprises of two species *viz., C. hippurus* and *C. equiselis* (Gibbs and Collette, 1959). *C. hippurus*, also known as common dolphinfish, dorado and mahi-mahi is a well-known pelagic food fish. It is one of the most exciting offshore game fish and often seen in open ocean too. Though it is popularly known as dolphinfish, it is not at all related to dolphins and distantly related to perch. Though it lands all along the Indian coast, its major contribution comes from Gujarat, Daman and Diu (54.2%; CMFRI, 2014). *C. hippurus* is a highly migratory pelagic species found in extensive areas of the world's oceans. It lives in tropical and subtropical areas of the Atlantic, Indian and Pacific Oceans and is believed to migrate seasonally to warm areas (Palko *et al.,* 1982). Common dolphinfish supports important recreational and commercial fisheries in the Caribbean, south-eastern United States, East Africa, Taiwan, Japan, China, Hawaii and thus is a shared resource among multiple countries.

Studies on the feeding habits and reproductive biology of *C. hippurus* are available from Mediterranean waters, Eastern Caribbean Sea, Eastern Pacific Ocean, eastern Arabian Sea, Karnataka coast of India and Pacific coast of Ecuador (Massuti *et al.,* 1998; Oxenford and Hunte, 1999; Olsan and Galvan Magana, 2002; Varela *et al.,* 2017). However, in India, limited research has been done on the feeding and reproductive biology of the species. Only two studies on diet of dolphinfish have been carried out in India; one from eastern Arabian Sea (Varghese *et al.,* 2013) and one from Karnataka coast (Rajesh *et al.,* 2016). Additionally, Benjamin and Kurup (2012) have reported on the stock status of the species along Kerala coast. Moreover, there is no information available on the reproductive biology and food and feeding habits of *C. hippurus* from the coast of Saurashtra. Hence, the present study was conducted to learn about the feeding and reproductive biology of the species along Saurashtra coast, Gujarat.

Materials and methods

Study area and specimen collection

The present study was conducted off the Saurashtra coast of Gujarat during the period March 2015 to February 2016. The specimens for biological analyses were collected from identified gillnetters who operated from the Veraval Fishing Harbour (20º 53' N; 73º 26' E) situated in Gir-Somnath District of Gujarat, India. The multiday gillnetters carry out fishing voyages extending from three to seven days based on the endurance of the fishing vessels. Specimens were caught using drift gillnet off the coast of Saurashtra.

Biological data

A total of 308 specimens (110 males and 198 females) were collected monthly between March 2015 and February 2016. *Chi*-square analysis was performed to determine whether the sex ratio by body size (length) and by month deviated from 1:l (Sokal and Rohlf, 1981). Maturity was observed based on the stages given by Beardsley (1967) who described five maturity stages (I-immature, II-early maturing, III-late maturing, IV-ripe and V-spent) for females and two stages (I-immature or resting and II-mature) for males, based on visual appearance. Fecundity was calculated following the gravimetric method after preserving the ovaries in 5% formalin (Fecundity = Total weight of the ovary (g) x Total number of eggs in the sub sample of the ovary/Weight of sub sample of the ovary). Relative fecundity (Fecundity per gram bodyweight) was also calculated. Gonadosomatic Index (GSI) was determined using the formula, GSI = Gonad weight (g)/Total bodyweight (g) ×100) (Kume and Joseph, 1969).

Diet analysis

The diet was assessed using the Index of Relative Importance (IRI) based on percentage occurrence by number (% N), percentage frequency of occurrence (% F) and percentage occurrence by weight (% W) of prey items (Pinkas *et al*., 1971). The IRI was considered in the present study as it takes into account the frequency of occurrence as well as the number and volume of each food item, which provides a definite and measurable basis for grading different food items. The feeding intensity was assessed based on the distension of the stomach and the volume of food contained in it. The stomach distension was classified as full, ¾ full, ½ full, ¼ full and empty.

Results and discussion

Sex ratio

Of the total 295 *C. hippurus* studied, 188 were females and 107 were males. The overall male to female sex ratio was 1:1.75, which indicated dominance of females in the fishery. Monthwise, female dominance was evident throughout the year (Table 1). Significant difference of sex ratio from 1:1 (p value < 0.05) was noticed in the months of January, March, April and December (Table. 2). The differences in sex ratios might be due to the differential fishing resultant to the differences in migration pattern of sexes to and from the fishing grounds. However, the actual pattern of the spawning migration with regard to the spatial and temporal aspects and its effect on the fishery can be understood only by further studies. Female dominated disparity in the overall sex ratio has been observed in earlier studies also from North Carolina waters, Central-East Atlantic, east coast of Taiwan, Brazil, Mediterranean waters and south-west coast of India (Rose and Hassler, 1974; Castro *et al.,* 1999; Chi Chuen *et al.,* 2001; Santos *et al.,* 2014; Gatt *et al.,* 2015; Rajesh *et al.,* 2016).

Table 1. Sex ratio of *C. hippurus* during different months

Month	Sex ratio	*Chi*-square value	p value
Mar.	1:2	5.00	0.0253*
Apr.	1:2.58	8.3953	0.0038*
Sept.	1:1.35	1.0426	0.3072
Oct.	1:1.30	0.5333	0.4652
Nov.	1:1.22	0.4000	0.5271
Dec.	1:2.2	4.5000	0.0339*
Jan.	1:4.4	10.7037	0.0011*
Feb.	1:1.21	0.2903	0.5900

*denotes significance at 5% level

Gonadosomatic index (*GSI*)

GSI value of *C. hippurus* was the least in October and it was moderate in November to March and September (range 2.32 to 2.73). The value of GSI reached its peaks in April (3.94) and December (3.73) (Fig. 1). This suggests that the ovaries were very much in ripe condition and ready for spawning in April and December, thereafter the GSI level in the population remained at a lower level. Rajesh *et al.* (2016) reported higher values of GSI for *C. hippurus* during the months of August and September. Lasso and Zapata (1999) observed higher values of GSI of the species during the months of April, December

Table 2. Monthly variations in the average fecundity and relative fecundity

Month	Ovary stages	Average fecundity	Average relative fecundity	Fecundity range
Mar.	III & IV	7,88,682	188	7,10,220 - 8,37,108
Apr.	II, III & IV	9,13,278	285	5,50,400 - 15,50,400
Sept.	III & IV	40,50,80	130	2,68,160 - 5,42,000
Oct.	IV	2,02,100	66	2,02,100
Nov.	II & III	4,81,570	181	1,07,813 - 8,55,327
Dec.	II, III & IV	7,22,404	206	2,97,230 - 13,37,330
Jan.	II, III & IV	3,17,440	126	2,50,880 - 3,84,000
Feb.	III & IV	3,49,689	126	1,36,956 - 5,92,280
Annual	II, III & IV	5,75,391	176	1,07,813 - 15,50,400

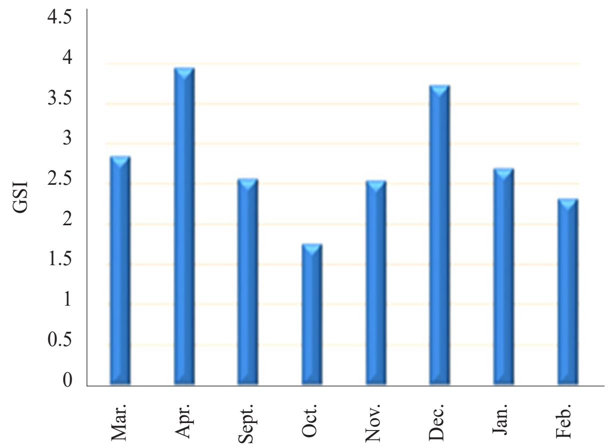

Fig. 1. Monthly mean GSI of *C. hippurus*

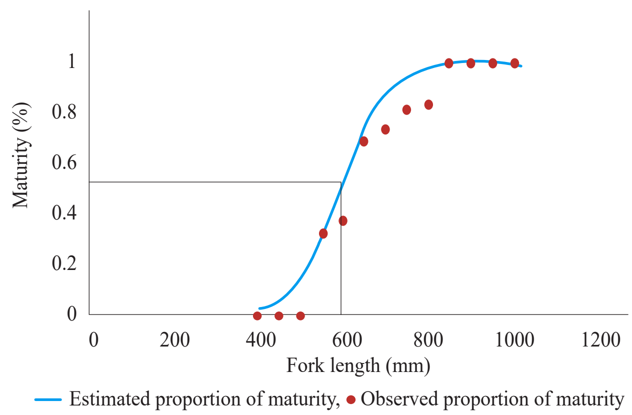

Fig. 2. Length at maturity of *C. hippurus*

and October-November. However, Santos *et al.* (2014) observed that the GSI value of the fish reached the highest in February and April respectively.

Fecundity

The absolute fecundity of *C. hippurus* ranged from 1,07,813 to 15,50,400. Monthly average fecundity of the species ranged from 2,02,100 during October to 9,13,278 in April (Table 2). The annual average relative fecundity was 176 and annual average absolute fecundity was estimated as 5,75,391. The estimated relative fecundity was the highest in April (285) and the lowest in October (66). The absolute fecundity range of *C. hippurus* recorded in the present study (1,07,813-15,50,400) was different from that (1,39,636-5,49,540) recorded by Chatterji and Ansari (1982). However, it is much closer to the results of Beardsley (1967) *i.e.,* 80,000-10,00,000. Fishes are known to exhibit wide variations in fecundity; even among individuals of the same species, depending upon the size and distribution range (Bagenal, 1957). An increase in the size of population and decline in food resources may also result in decreased fecundity of a species (Jobling, 1996). Numerous other factors like difference in stocks of fish, nutritional status (Gupta, 1967), racial characteristics (Das, 1977), time of sampling and maturation stage and changes in environmental parameters (Bhuiyan *et al.*, 2006) have also been reported to affect the fecundity; both within the species and between fish populations.

Length at first maturity

Fifty percent of the females of *C. hippurus* in the studied samples attained sexual maturity at a fork length (FL) of 593 mm (Fig. 2) and the individuals of this size were observed in all the months. Twenty five percent of fish matured when they attained 550 mm (FL) while 75% matured at 700 mm (FL). Length at first maturity reported from Majorcan waters (western Mediterranean; Massuti and Morales-Nin, 1997) has been 545 mm FL, which is almost same as the findings of the present study. The length at maturity (Lm) reported from Florida was 450 mm FL for females and 427 mm FL for males (Beardsley, 1967).

Diet analysis

A total of 128 stomachs of *C. hippurus* ranging in size from 380 to 1250 mm FL were examined during the present study. Analysis of the ontogenetic variation in the feeding intensity is depicted in Table 3. Most of the examined specimens were with empty stomachs. Dolphinfishes are believed to be visual predators and primarily feed during day time (Massuti *et al.,* 1998). Rajesh *et al.* (2016) have made a similar observation and stated that the higher numbers of empty stomachs recorded could be due to the collection of samples from multiday gillnets operating during night time. There was no fish with empty stomach in 1000 mm FL group. The highest proportion (52.38%) of empty stomachs was observed in 400 mm FL group. The percentage of stomach with trace, one-half and three-fourth stomach contents were very low (Table 3). Fish with empty stomachs (52.38%) in this study were higher than those reported from the eastern Arabian Sea (30.25%; Varghese *et al.,* 2013); eastern Caribbean (11%; Oxenford and Hunte, 1999), south-eastern United States (16%; Manooch *et al.,* 1984), North Carolina (17%; Rose and Hassler, 1974) and Japan (21%; Kojima, 1961).

The percentage of empty stomachs were highest (80%) in October and lowest (28.57%) in April (Table 4). Stomach with trace, one-half and three-fourth contents were very low in all the months except March, April, November and December. Stomachs with trace contents were 16.66% in March and 18.75% in December. Stomachs with one-half contents were 6.66 and 9.37% in November and December respectively. Stomachs with three-fourth contents were 3.57% in April. Since the breeding started in April and December, the fishes may be feeding voraciously for energy reserves in these months

Table 3. Variations in the feeding intensity (%) in different length classes of *C. hippurus*

Fork length class (mm)	No. of samples	Stomach condition					
		Empty	Trace	One-fouth	One-half	Three-fourth	Full
400 - 600	21	52.38	9.52	19.04	4.76	0.0	14.28
600 - 800	67	49.25	25.37	11.94	0.0	1.49	13.43
800 - 1000	33	36.36	12.12	18.18	9.09	0.0	24.24
1000 - 1200	2	0.0	0.0	0.0	0.0	0.0	100

Table 4. Monthly variations in feeding intensity (%) of *C. hippurus*

Month	No. of samples	% Distribution of feeding intensity					
		Empty	Trace	One fourth	One half	Three fourth	Full
Mar.	12	66.66	16.6	0.00	0.00	0.00	16.66
Apr.	28	28.57	3.57	42.85	0.00	3.57	21.42
Sep.	9	55.55	0.00	33.33	0.00	0.00	11.11
Oct.	5	80.00	0.00	0.00	0.00	0.00	20.00
Nov.	15	60.00	0.00	20.0	6.66	0.00	13.33
Dec.	32	37.50	18.75	18.75	9.37	0.00	15.62
Jan.	14	50.00	0.00	28.57	0.00	0.00	21.42
Feb.	13	53.84	0.00	38.46	0.00	0.00	07.69
Annual	128	54.01	4.87	22.74	2.00	0.44	15.91

of breeding, resulting in lesser percentage of fishes with empty stomachs and higher percentages of fishes with more stomach distension. The percentage of full stomachs was low in all the months except January, March, April, October and December.

The most frequent food items observed in the diet of *C. hippurus* was unidentified fish in almost all the months, except in October (Table 5). Among identifiable dietary components, tuna were more frequent in all months except in January, February, October and November. Similar observations have been reported indicating dominance

Table 5. Monthly variations of IRI (%) in the dietary components of *C. hippurus*

Prey groups	Months								Annual average
	Mar	Apr	Sept	Oct	Nov	Dec	Jan	Feb	
Unidentified fish	8.95	37.32	79.36	-	38.13	45.65	35.93	88.19	47.65
Semi digested Shrimp	-	-	-	-	-	2.24	8.18	-	5.21
Partially digested semi solid material	-	-	-	-	-	22.17	-	-	22.17
Tuna spp.	78.92	4.82	10.96		-	10.55	-	-	26.31
Ribbon fish	-	7.63	-	-	-	4.68	-	-	6.16
Priacanthus hamrur	-	-	-	-	25.31	-	-	-	25.31
Polynemus sp.	-	-	-	4.71	-	-	-	-	4.71
Flying fish	-	-	-	-	14.87	-	-	9.36	12.11
Mackerel	-	-	-	-	-	4.22	26.99	-	15.60
Harpodon nehereus	-	-	-	-	-	1.28	10.08	2.45	4.60
Sole fish	-	4.54	-	-	-	-	-	-	4.54
Horse mackerel	-	-	5.53	-	-	-	-	-	5.53
Croakers	-	-	-	-	-	4.22	-	-	4.22
Decapterus spp.	-	-	-	-	-	2.29	-	-	2.29
Cuttle fish	7.72	0.29	-	-	-	-	-	-	4.00
Uroteuthis sp.	-	45.37	-	-	-	1.61	18.80	-	21.93
Nautilus spp.	4.39	-	-	-	-	-	--	4.39	
Squilla	-	-	4.14	-	-	-	--	4.14	
Octopus/*Amphioctopus*	-	-	-	-	2.64	-	--	2.64	
Passerine bird	-	-	-	5.28	-	-	--	5.28	
Wild almond seeds	-	-	-						

of tuna in the diet of dolphinfish along Gujarat coast (CMFRI, 2014).

Semi-digested shrimp, mackerel, *Harpodon nehereus*, *Uroteuthis* sp., cuttlefish, lizardfish, croaker, *Decapterus* sp., flying fish and ribbonfish were also present in the stomach of *C. hippurus*. In our study, the prey items identified were mainly epipelagic species, which indicate that *C. hippurus* is a surface water feeder. However, the occurrence of deep water species of squids and cuttlefish among the stomach contents suggests that dolphinfish in the Arabian Sea also feed in deeper waters or when these prey species come to the surface during night. Our observations are similar to those reported earlier, which suggest that *C. hippurus* feed in the surface waters and occasionally during the night (Rothschild, 1964; Shcherbachev, 1973; Oxenford and Hunte, 1999; Olson and Galvan- Magana, 2002; Varghese *et al.,* 2013). Some hitherto unknown food items *viz.,* sole fish, horse mackerel, squilla, *Polynemus,* passerine bird, wild almond seeds, octopus and *Priacanthus* spp. also appeared in the stomach contents of the specimens studied. Occurrence of passerine bird and wild almond seeds among the stomach contents in our study indicates non-selective and voracious feeding behaviour of *C. hippurus*. These observations are similar to the earlier reports made by Gibbs and Collette (1959); Rose and Hassler (1974) and Manooch *et al.* (1984).

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