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Pufferfish fishery along the Kerala coast and biology of the smooth-backed puffer, *Lagocephalus inermis* (Temminck & Schlegel 1850)

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Original Article

Abstract

The puffer fish fishery along the Kerala coast with some biological aspects of the dominant and less studied species, *Lagocephalus inermis* is described from Cochin, Kerala. The annual average puffer fish landing in Kerala during 2012-2016 ranged between 188 t in 2016 to 747 t in 2013, with an average annual landing of 400 t. Peak landing was observed during post-monsoon season. The length of *L. inermis* ranged from 85 to 415 mm with a mean size of 275 mm. Males dominated throughout the study period (1:0.84), with the sex ratio not significantly different from the expected value. The spawning activity was found to be higher during the pre-monsoon period. The present study found that these species are essentially carnivores preying on a wide variety of small pelagic fishes, crustaceans and molluscs. The significance of the emergence of puffer fishes in the coastal waters of Kerala is discussed in this paper.

Keywords: *Lagocephalus inermis, Kerala coast, reproductive biology, food and feeding*

Introduction

Puffer fishes are members of the family Tetraodontidae, which includes 29 genera and over 200 species that live in tropical and subtropical coastal waters (Froese and Pauly, 2019). These fishes, as the names "blowfish" and "globefish" suggest, have a peculiar tendency to expand their body as a form of self-defence against their predators. They occur at a depth range of 20 to 200 m and serve as demersal mid-level carnivores. The greatest diversity of puffer fish is known from the Indo-west Pacific Ocean (Matsuraa, 2014). Puffer fishes are highly poisonous and contain tetrodotoxin, a potent and strongest neurotoxin that can kill adults by delaying sodium channels in nerve membranes (Alshawy *et al*., 2019). This compound is 100 times more toxic than cyanide (Santhanam, 2017; Tamele *et al*., 2019). The liver, gonads, intestines, skin and occasionally the muscles (Torda *et al.,* 1973) of puffer fish cause tetrodotoxin, poisoning, which leads to 60 per cent fatality in individuals who consume it, according to Ellenhorn and Barceloux (1988). The toxicity of puffer fishes is due to the toxin synthesised by bacteria *Pseudomonas* and *Actinomyces*, which are found in puffer fish habitats. Nevertheless, puffer fish or fugu are considered a delicacy in countries like Japan and result in an average of 70 hospitalisation and 10% fatality rates annually due to its consumption. As a result, in East Asian countries, the high demand for puffer fish has caused population declines of 75 to 95% due to overexploitation, resulting in these fishes being listed as "Conservation Concern" on the IUCN Red List.

Along the Kerala coast, puffer fishes are primarily caught by multiday trawlers (78%), followed by seines, gill nets, and hook and lines (Mohammed *et al*., 2013; Anju *et al*., 2019). Since 2000, puffer fish landings have increased to 2,000 t in less than five years, The highest contribution to the puffer fish fishery is by smooth-backed puffer (*L. inermis*), followed by fat puffers, *Arthron* sp., porcupine fish and *Diodon* spp. (Mohamed *et al.,* 2013; Raphael *et al.,* 2017). Padate *et al.* (2022) have studied the proliferation of the pufferfish *Lagocephalus spadiceus* (Richardson, 1845) in nearshore waters off Goa, the west coast of India.

The higher abundance of pufferfishes along Kerala has resulted in several fishery-related issues. For instance, the species of puffer

fish, especially *L. inermis* once they enter a fishing net, can cut through nylon nets, causing severe damage (Mohamed *et al.*, 2013). Additionally, while inside the nets, they bite at random on other catches, particularly valuable squids and cuttlefish, reducing their economic worth. The cost of repairing the nets and catch loss is estimated at millions of rupees. However, puffer fishes have been recognised as a food species in many markets along Kerala after the removal of skin and gut either for local consumption or for export to other places. According to Mohamed *et al.* (2013), the increase in puffer populations occurs due to top-down predator control in marine ecosystems. Padate *et al.* (2022) stated that the increased abundance of *L. spadiceus* in the coastal water of Goa is a clear indication of the alteration of demersal fish community structure due to indiscriminate fishing, which may be aggravated due to its voracious feeding behaviour. Several pieces of literature are available on various aspects of pufferfishes (Naik and Jalihal, 1998; Joshi, 2004; Simon and Mazlan, 2008; Thomas *et al.*, 2009; Basusta *et al.*, 2013; Sirisha and Rao, 2013; Mastuura, 2014., Salahi *et al.*, 2015; Bilge *et al.*, 2017; Padmavathi *et al.*, 2017; Anju *et al.*, 2019, Devi and Abraham, 2019; Saha and Thomas, 2020; Devi and Ayyappan, 2021; Padate *et al.*, 2022). However, there is a lack of information on the biology of the dominant species, smooth-backed puffer, *L. inermis,* from the Kerala coast.

Material and methods

The annual average catch and effort data maintained for the smooth pufferfish *L. inermis* by the Fisheries Resource Assessment Division of ICAR-CMFRI, Kochi, is used to study the trend in the fishery of this resource. Samples for biological investigation were collected from Munambam Fisheries harbour (Lat:-10°10'48"N. long 76°10'12" E) in Cochin, Kerala, during 2012-2016. A total of 418 fish (218 males and 200 females) varying in length from 147 to 385 mm were randomly selected for the study. The length and weight of the samples were measured to the nearest millimetres (mm), and grams (g) and length-weight relationship (LWR) were estimated using the methods of Le Cren (1951) and Froese (2006). The linear regression on the log-transformed equation of cube law was used to estimate the regression parameters 'a' and 'b' of the LWR.

$$\text{Log } W = \log a + b \log L.$$

Analysis of covariance (Snedecor and Cochran, 1967) was done to test for the significant difference in regression coefficients between the sexes. Bailey's t-test (Zar, 2005) was used to test the significance of the 'b' value from the expected value of 3.

$$t = \frac{b - ß}{S_b}$$ where ß is equal to 3.

b = regression coefficient of log-transformed data, sb = standard error of b

Investigations were carried out on the food and feeding, reproduction and maturation of the fish. Maturity stages were determined based on the external appearance and extent of gonads in the body cavity. Fishes with different maturity stages were classified as immature, and mature and spent to estimate the spawning season (Saha *et al.,* 2020). The sex ratio was calculated following Snedecor and Cochran (1967). The test of homogeneity was performed using the chi-square test on monthly samples. Since no difference was observed in the food and feeding habits between both sexes, the data on food and feeding were combined and presented here. Based on three indices such as the percentage of the wet weight of each food item to the total wet weight of all food items identified (%W), the percentage of the number of each food item to the total number of all food items identified (%N) and frequency of occurrence of each food item in the total number of stomachs examined (%F), the relative importance of each prey items was calculated using Index of relative importance (Zacharia and Abdurahiman, 2004; Radhika *et al.*, 2020).

Results and discussion

Puffer fishes contributed to 1.52% of the marine fish landings of Kerala during 2012-2016, with annual average landings of 2,001t. The annual puffer fish landings showed wide fluctuations, ranging between a maximum of 7,47 t in 2013 and a minimum of 188 t in 2016 (Fig. 1). Along the Kerala coast, puffer fishes were landed by seines, gill nets, and hook and lines but primarily caught by multiday trawlers of 18-24 m OAL with engine horse power ranging between 220-360 hp. The cod-end mesh size of trawl nets, which landed puffer fishes, ranged between 35-40 mm and are operated at a shallow depth of 20-60 m along the Cochin coast. The smooth-backed puffer, *L. inermis,* was the dominant species contributing 99% to the puffer fish fishery along this coast.

L. inermis were landed throughout the years (2012-2016), with peak landings seen during the October-January months (post-monsoon). The monthly average landings during the study period ranged from 40 t in June to 411 t in October (Fig. 2). Catch rate also showed a similar trend, with a minimum value in June (0. 8 kg/h) and a maximum in October (2.0 kg/h). Mohammed *et al.* 2013 reported that the main season for puffer fish fishery on the Kerala coast is the post-monsoon period (October to January), followed by pre-monsoon (February-May) and monsoon (June -September).

The total length of *L. inermis* in the fishery ranged between 85 to 385 mm with a mean size of 275 mm (Fig.3). The maximum

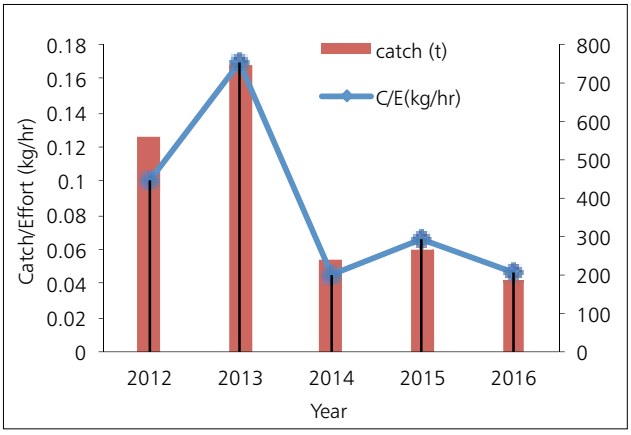

Fig.1. Catch and catch rate (CPH) of puffer fish landed by trawlers in Kerala during 2012-2016

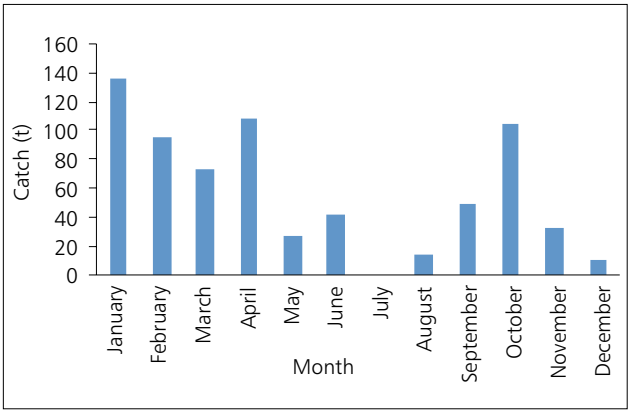

Fig. 2. Monthly average landing of puffer fish in Kerala during 2012-2016

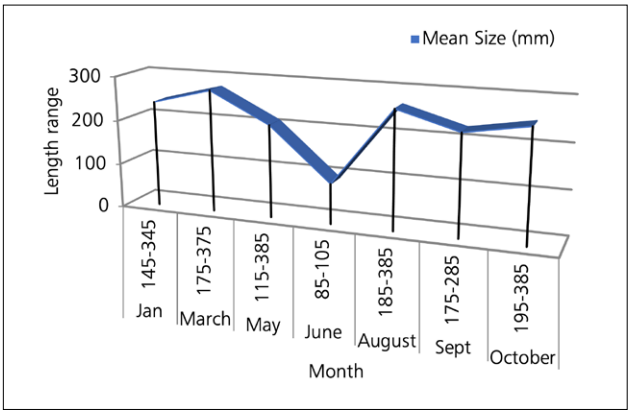

Fig. 3. Monthly average length range and mean size of *L. inermis* in Cochin during 2012-2016

number of fish, with a maximum mean size of 264 mm, was recorded in March, followed by August (264 mm) and October (249 mm). In the case of males, the length range was between 147 to 330 mm and weight ranged from 53 to 442g while in females, the length ranged between 155 to 385 mm with weight ranging between 61 to 451g.

The LWR was separately estimated for males and females as follows:

Male : Log W = -9.8847+ 2.80Log L
Female : Log W = -10.0784+ 2.84Log L

The corresponding parabolic equation can be expressed as follows:

Male $= 0.000050 \text{ X } L^{2.80}$
Female $= 0.000049\text{X } L^{2.84}$

The analysis of covariance (ANCOVA) revealed no significant difference in the regression coefficients of males and females ($P>0.01$); hence the data were pooled, and a common relationship was established for both sexes (Fig. 4).

Log W = -10.0200+ 2.824 Log L
$W = 0.000044\text{X } L^{2.82}$

The slope (b) values estimated for *L. inermis* were 2.80 and 2.84 for males and females, respectively, which indicate a negative allometric ($b<3$) growth pattern in this fish. Similar results were obtained by (Salahi *et al.*, 2015; Padmavathi *et al.*, 2017; Anju *et al.*, 2019; Saha *et al.*, 2019) for *L. inermis* at different places along the Indian coast. Naik *et al.* (1998), while investigating the biological characteristics of *L. spadiceus* along the Konkan coast, found a negative allometric growth pattern, and the estimated b values were in the range of 2.61 and 2.49 for males and females, respectively. The slope values calculated for different species of *Lagocephalus* from Iskenderun Bay off the coast of Turkey (Basusta *et al.*, 2013) showed comparable results with the present study.

The percentage occurrence of different maturity stages in males and females was calculated for different months (Fig. 5). The spawning activity in these fishes was observed to start during

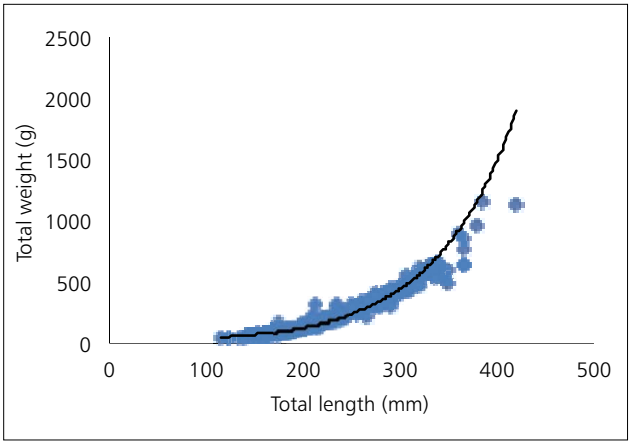

Fig. 4. Pooled parabolic length-weight relationship of *L. inermis*

the pre-monsoon period, as evidenced by the highest occurrence of fishes in advanced stages of gonadal development during January-May and September-October in post-monsoon period with peak spawning observed during March and October. The highest percentage of fish with immature, developing or recovering gonads was observed in August, September and October, respectively. Naik *et al.* (1998) observed that *Lagocephalus* spp. off the south Konkan coast breeds twice a year, once during February-March and another between September and November. The present study indicates that *L. inermis* breed twice a year with two peaks, one in pre-monsoon and another in post-monsoon months along the Kerala coast. According to Saha and Thomas (2020), the GSI estimated for *L. inermis* was highest during August, which indicates its peak spawning season. Naik and Jalihal (1998) observed that *L. spadiceus* breeds during September-November and February-March months along the Konkan coast.

Table 1 summarises the findings of the month-wise sex ratio of *L. inermis* collected during the study period. The overall male-to-female sex ratio was 1:0.84, which did not significantly differ from the expected value ($x^2 = 2.39254$, $P > 0.05$). The monthly sex ratio results show male dominance throughout the year,

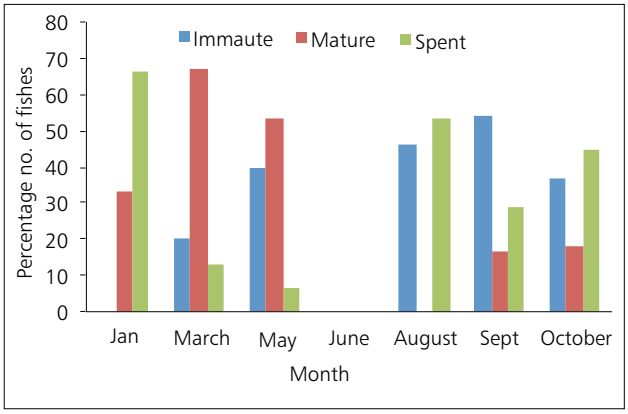

Fig. 5. Monthly average maturity stages of *L. inermis* (females) in the coastal water of Cochin, Kerala

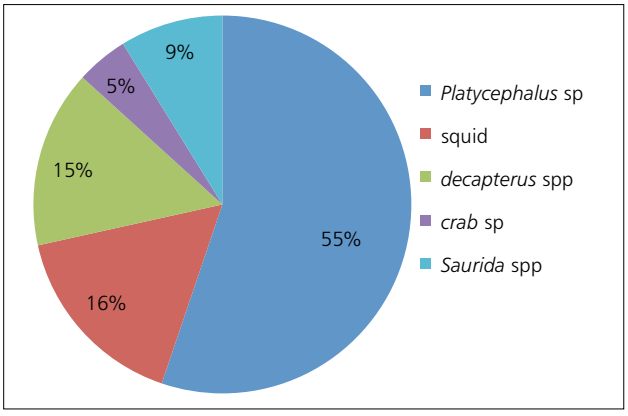

Fig. 6. Index of relative importance (%IRI) of each prey item found in the diet of *L. inermis* in the coastal waters of Cochin, Kerala

except October (1:1.1). Changes in sex ratio are likely as a result of factors such as differential growth between sex, behaviour, diverse strategies for reproduction, migration as well as other environmental conditions (Saha and Thomas, 2020). Naik and Jalihal (1998) found equal dominance of both sexes throughout the study period along the south Konkan coast.

The current study shows that *L. inermis* is a highly carnivorous fish and feeds on a wide variety of prey items (Fig. 6). The most dominant food items of *L. inermis* consisted of flatheads and squid, while other food items were *Decapterus*, *Saurida* spp. and crabs. It was estimated that flatheads spp. formed 55% of the diet of *L. inermis* followed by squid (16%), *Decapterus* spp. (15%), *Saurida* spp. (9%) and crab (5%). From the limited studies available on food and feeding of puffer fishes from Indian waters (Naik and Jalihal, 1998; Joshi, 2004), it can be inferred that *Lagocephalus* is an essential carnivore feeder which preys upon a wide variety of species such as *Stolephorus* spp., *Secutor* spp., *Acetes* spp., *Sepia* spp., molluscans, squilla and crustacean larvae.

Padate *et al.* (2022) stated that intensive mechanized fishing has caused marked alterations in coastal marine ecosystems

Table 1. Monthly sex ratio of *L. inermis* from Cochin

Month	Total no. of fishes observed	No. of unsexed fishes	Observed Male	% of males	Observed Female	% of females	M: F	Chi ^{2} test
January	59	-	37	0.627	22	0.373	1:0.59	0.191675
February	34	-	19	0.559	15	0.441	1:0.79	0.847892
April	88	44	29	0.659	15	0.341	1:0.52	1.33E-13
June	6	6						
July	27	3	13	0.542	11	0.458	1:0.85	0.993968
September	46	1	18	0.400	27	0.600	1:1.50	0.055125
October	66	1	31	0.477	34	0.523	1:1.10	0.289063
Total	326	55	62	1.419	124	2.736	1:0.84	0.396287

resulting in the proliferation of low-value, nuisance species such as *L. spadiceus* in the coastal waters of Goa. Similarly, the pufferfish, *L. imermis,* has recently proliferated along the Kerala coast and has become the cause of fishermen's woes by causing damage to fishing nets and causing physical damage to other fish caught in the net. The present study provides new information on the fishery and biology of the less studied species of *L. inermis viz,* the season of abundance, food and feeding and maturation. It will throw more light on the reason for its emergence and form the basic information when alterations in coastal marine ecosystems and species emergence and interaction will be studied in the future.

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