

Biological observations on the pufferfishes of south Konkan coast with special reference to the net-damaging species *Lagocephalus spadiceus* (Osteichthyes, Tetraodontidae)

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Initial observations on destruction of fishing gear by pufferfishes, along the south Konkan coast, indicated that out of the 7 species inhabiting the region 4 occur in fairly good numbers, but only *Lagocephalus spadiceus* (Richardson, 1845) causes large-scale damage. Biological studies were, therefore, conducted in order to understand the possible reasons which induce only certain species to damage the nets. While net-damaging species are essentially meat or flesh eaters, the non-damaging forms predominantly feed on hard molluscan shells. Both sexes of *L. spadiceus* exhibited almost similar growth rate and are homogeneously distributed for major part of the year, excepting post-monsoon breeding season. It matures at around 9 cm size and breeds twice in a year—once during February-March with smaller (9 to 15 cm) females and again from September to November with larger (11 to 28 cm) females. The two breeding seasons coincide with the peak net-damaging periods.

The pufferfishes (family Tetraodontidae) have been causing large-scale destruction of fishing gear along the south Konkan coast of Maharashtra (west coast of India) since 1984. Initial observations indicated that the puffers are instinctive biters but the extent of net-damage appeared to vary from species to species and season to season within a same species. However, excepting a few stray accounts dealing with food and feeding habits and early developmental stages of a couple of species¹⁻³, hardly any attempt has been made to study the overall biology of puffers, especially in India where they have never been food fishes⁴⁻⁹. Detailed investigations were, therefore, conducted with a view to understand the biological characteristics of certain species of puffers that damage the nets.

Materials and Methods

Material for the present investigation was obtained from regular fortnightly collections made either from trawl or rampan landings (depending on availability). Out of the 7 species of puffers inhabiting the south Konkan coast, only 4 species

viz. *Lagocephalus spadiceus* (SL 25-265 mm), *L. lunaris* (SL 53-214 mm), *Chelonodon patoca* (SL 21-175 mm) and *Arothron immaculatus* (SL 32-232 mm) could be collected in fairly good numbers while the remaining 3 species viz *A. reticularis* (50-354 mm), *C. fluviatilis* (84-106 mm) and *Takifugu oblongus* (78-166 mm) appear to be only seasonal visitors. Special emphasis is given to *L. spadiceus* which is mainly responsible for the menace.

Puffers lack true stomach, but a small constriction in the region where the bile duct joins the alimentary canal probably represents the junction of stomach and intestine¹. In the present study, the undigested (and hence easily identifiable) material from the anterior part of intestine was also considered as gut content. The condition of stomach was classified as full, 3/4 full, 1/2 full, trace or empty¹⁰⁻¹². Gut contents were analysed by wet gravimetric method^{13, 14}. The total weight of a category is expressed as percentage of overall weight of stomach contents. Both monthly and annual percentages were calculated. The stomach contents of individuals collected in trawl

have been compared with those procured from rampan catches to find out changes in feeding habits, if any, due to different habitats.

Since puffers do not exhibit sexual dimorphism, sexes had to be determined based on gonadal observations only. Testes are milky-white whereas ovaries are pinkish-red in small specimens but granular and yellowish in larger individuals. The length-weight relationship was initially calculated separately for males, females and indeterminants using Le Cren's ¹⁵ formula $W = a L^b$ or its logarithmic form $\log W = \log a + b \log L$, where W and L represent weight and standard lengths while a and b are the constants.

Sexes were determined by dissecting the specimens and examining the gonads. The smallest specimens collected during peak spawning season and exhibiting well developed gonads were considered to be representing the first maturity stage. Fecundity was estimated gravimetrically by counting mature eggs from the ovary and raised to the total weight of the ovary. It was observed that there was no significant variation in the development of ova in different parts of ovary. The number of eggs were counted from ovaries of 10 fully mature females varying in SL from 130 to 230 mm. In all 151 ovaries, at different maturity stages, were examined for ova diameter studies. The size of ova, gonadosomatic indices (GSI) and relative condition factors (Kn) have been used to corroborate breeding season as determined by natural spawning shoals. The ova diameter was determined by calibrating ocular micrometer. The GSI was calculated by using the formula

$GSI = \text{gonad weight} / \text{body weight} \times 100$. The Kn values were determined by employing the formula $Kn = W / w \times 100$, where 'W' is observed weight and 'w' is calculated weight by using logarithmic formula ¹⁵.

Results and Discussion

Food and feeding

In view of limited number of specimens in several species, it was not possible to draw any plausible conclusions based on quantitative analysis, excepting in *L. spadiceus* which seems to exhibit two intensive feeding peaks in a year—one during November-December and another during February-March (Table 1). Qualitative analysis could, however, be carried out in all the 7 species. A total of 9 major food items could be recognised and their percentage occurrences are given in Table 2. It is clearly seen that the net-damaging species belonging to the genus *Lagocephalus* are essentially meat eaters, thriving mainly upon the flesh of fish, crustaceans and soft molluscs like squids and cuttle fishes. Their sharp, inwardly bent and scissor-like canine teeth not only help them in easily slicing, cutting and tearing the flesh, but also enable them to inflict large-scale damage to the fishing gear. On the other hand, the non-damaging species like *Chelonodon patoca*, *Arothron immaculatus* etc predominantly feed on hard shells of bivalve or gastropod molluscs. Their heavy, strong, straight and blunt teeth are ideally suited in easily crushing even hardest of molluscs shell by their pounding or hammering action. Such teeth

Table 1—Monthly percentage of *Lagocephalus spadiceus* in various conditions of feeding

Month	Guts examined (no)	Condition of stomach				
		Full	3/4 Full	1/2 Full	1/4 Full	Trace
Oct. 91	13	—	7.70	15.38	76.92	—
Nov.	31	19.35	16.13	6.45	54.84	3.23
Dec.	20	15.00	20.00	30.00	30.00	5.00
Jan. 92	41	4.88	—	60.98	7.32	26.82
Feb.	29	20.69	—	24.14	51.72	3.45
March	22	13.64	—	36.36	36.36	13.64
April	23	8.70	—	34.78	52.17	4.35
May	25	4.00	—	48.00	48.00	—
June	20	—	—	—	100.00	—
July	17	—	—	100.00	—	—
Aug.	21	—	—	61.90	38.10	—
Sept.	39	43.59	—	25.64	30.77	—

Table 2—Annual percentage of food items in different species of puffers of south Konkan coast

Food items	<i>Lagocephalus uspadiceus</i>	<i>Lagocephalus ucouanaris</i>	<i>Chelonodon patoca</i>	<i>Chelonodon fluvialis</i>	<i>Arothron immaculatus</i>	<i>Arothron reticularis</i>	<i>Takifugu oblongus</i>
Fish remains	57.98	74.69	47.50	46.67	45.31	12.5	83.87
Crab remains	7.25	17.84	4.93	—	2.29	15.0	—
Prawn remain	6.49	—	—	—	1.07	—	—
Sand	6.09	4.62	19.19	—	18.11	20.0	—
Molluscan shell	0.77	—	11.58	—	21.86	30.0	—
Algal matter	2.87	2.84	11.20	53.33	6.86	15.0	16.33
Sepia remains	17.67	—	5.60	—	4.50	7.5	—
Squilla remains	0.63	—	—	—	—	—	—
Crustacean larvae	0.25	—	—	—	—	—	—

are not effective in tearing fishing webs and as such they do not damage fishing gear. The unusually large percentage of sand might be possibly due to the gasping action of puffers as they are being dragged ashore during rampan operations. It can be clearly seen (Table 3) that the amount of sand is nearly 4-times more in the specimens collected by rampans (21.62 %) than those procured from trawlers (5.67 %). Fishes form the main diet of the two net-damaging species viz. *L. spadiceus* and *L. lunaris* during most part of the year. While prawns (73.68 %) as well as soft decapod molluscs (82.20%) dominate the food of *L. spadiceus* in July and October-December respectively, crab (28.0 %) and other crustaceans (41.66 %) constitute the major bulk of food during May-June in *L. lunaris*. Among the non-damaging species, while an inverse relationship exists between consumption of hard molluscan shells and sand material in case of *C. patoca*, another species *A. immaculatus* seems to consume large amount of sand in order to facilitate crushing and grinding of shells in view of its poorly developed, premaxillary and pharyngobranchial denticles.

Length-weight relationship

Sexwise statistical analysis of length-weight relationship in *L. spadiceus* yielded the following equations:

Table 3—Comparison of stomach contents of individuals of *Lagocephalus spadiceus* collected from trawlers with those obtained from rampan (shore-seine) catches

Food items	Individuals collected from trawlers (%)	Individuals obtained from rampan catches (%)
Fish remains	42.88	13.51
Crab remains	20.70	16.22
Algal matter	13.23	37.84
Molluscan shell	10.90	10.81
Sepia remains	6.62	—
Sand	5.67	21.62

Males: $\log W = 2.6106 \log L - 1.0703 (B_1)$

Females: $\log W = 2.4976 \log L - 0.9507 (B_2)$

Indeterminants: $\log W = 1.7312 \log L - 0.4719 (B_3)$

The analysis of covariance¹⁶ revealed that the slopes B_1 , B_2 and B_3 were not equal. However, SNK test showed that while there is no significant difference between B_1 and B_2 , it was found that B_3 differed significantly from both B_1 and B_2 . It was, therefore, necessary to derive a separate regression equation for the adults (males + females) of *L. spadiceus* as under:

$$\log W = 2.5534 \log L - 1.0106$$

Table 4—Proportion of males and females and sex ratio in monthly samples of *Lagocephalus spadiceus* during 1991-92

Month	Total number of specimen	Males	Proportion of males (%)	Females	Proportion of females (%)	Ratio of male : female
Oct. 91	14	2	14	12	86	1 : 6.0
Nov.	46	22	48	24	52	1 : 1.10
Dec.	35	25	71	10	29	1 : 0.40
Jan. 92	85	47	55	38	45	1 : 0.80
Feb.	104	51	49	53	51	1 : 1.03
March	92	38	41	54	59	1 : 1.42
April	100	46	46	54	54	1 : 1.17
May	7	1	14	6	86	1 : 6
June	3	2	67	1	33	1 : 0.50
July	8	3	38	5	62	1 : 1.66
Aug.	63	29	46	34	54	1 : 1.17
Sept.	47	32	68	15	32	1 : 0.46

Application of Students' 't' test revealed that the regression co-efficient of males, females and indeterminants deviate distinctly from 3, thereby indicating that *L. spadiceus* does not follow the conventional relationship and apparently grows at a much slower rate than the cube of its length.

Sex ratio, maturity and fecundity

The proportion of males as well as sex ratio during each month and size-groups of *L. spadiceus* revealed that by and large both sexes occur in equal numbers almost throughout the year with an average ratio of 1: 1.02 (Tables 4, 5). Chi-square analysis showed that there is significant deviation from the 1: 1 ratio in October (due to preponderance of females) besides September and December (due to preponderance of males). As far as sex ratio in relation to different size groups are concerned (Table 5), it is seen that males generally outnumber the females up to 95 mm, while in higher size groups the females exhibit preponderance. Incidentally, 95 mm is the approximate size when both males and females attain first maturity. The characteristic features of

 Table 5—Sex ratio in relation to length in *Lagocephalus spadiceus* during the year 1991-92

Size range (mm) SL	N	Male	Female	Ratio of male:female
45-54	4	4	0	1:0
55-64	25	13	12	1:0.92
65-74	43	23	20	1:0.75
75-84	128	73	55	1:0.80
85-94	112	62	50	1:1.12
95-104	68	32	36	1:12
105-114	51	17	34	1:2
115-124	38	14	24	1:1.75
125-134	22	8	14	1:1.75
135-144	29	16	13	1:0.81
145-154	22	12	10	1:0.83
155-164	17	6	11	1:1.83
165-174	14	7	7	1:1
175-184	8	4	4	1:1
185-194	6	2	4	1:2
195-204	2	1	1	1:1
205-214	6	1	5	1:5
215-224	2	0	2	0:2
225-234	2	1	1	1:1
235-244	3	1	2	1:2
245-254	1	0	1	0:1
255-265	1	1	0	1:0
	604	298	306	1:1.02

different maturity stages of gonads of *L. spadiceus* are depicted in Table 6. The variation in ova size during different months are given in Fig. 1A. It is seen that immature eggs less than 150 micron occur only in May while those bigger than 200 micron occur during all months of the year. Ova larger than 700 micron were found to occur in October and February.

The percentage frequency of the number of females in various stages of maturity is expressed quantitatively in Table 7. It is seen that maturity stages III and IV occur throughout the year, with highest percentage of IV stage being in October. Fully mature fishes in stage V are found to be quite common in the catches of November and February-April. Minimum size at which fully

Table 6— Characteristic features of different maturity stages of gonads as found in *Lagocephalus spadiceus*.

Stage	Female	Male
I (immature)	Pinkish, occupying 1/4 th to 1/2 body cavity; ova irregular and transparent.	Whitish, ribbon-shaped, occupying 1/2 body cavity.
II (maturing-I)	Yellowish, occupying 1/2 to 2/3 rd body cavity; ova round, and completely filled with yolk.	Whitish, occupying 2/3 rd body cavity.
III (maturing-II)	Yellowish, occupying 2/3 rd to 3/4 th body cavity; ova round and completely filled with yolk.	Whitish, occupying 2/3 rd to 3/4 th body cavity.
IV (matured)	Yellowish, occupying nearly entire body with some ova visible out side; yolk vacuolated; perivitelline space present.	Creamy white, occupying the entire body cavity.
V (oozing)	In the oozing stage.	In the oozing stage.
VI (Spent)	Flaccid, with blood vessels prominent all over the surface—occupying not more than 1/2 the body cavity.	Flaccid, occupying about 1/2 body cavity.

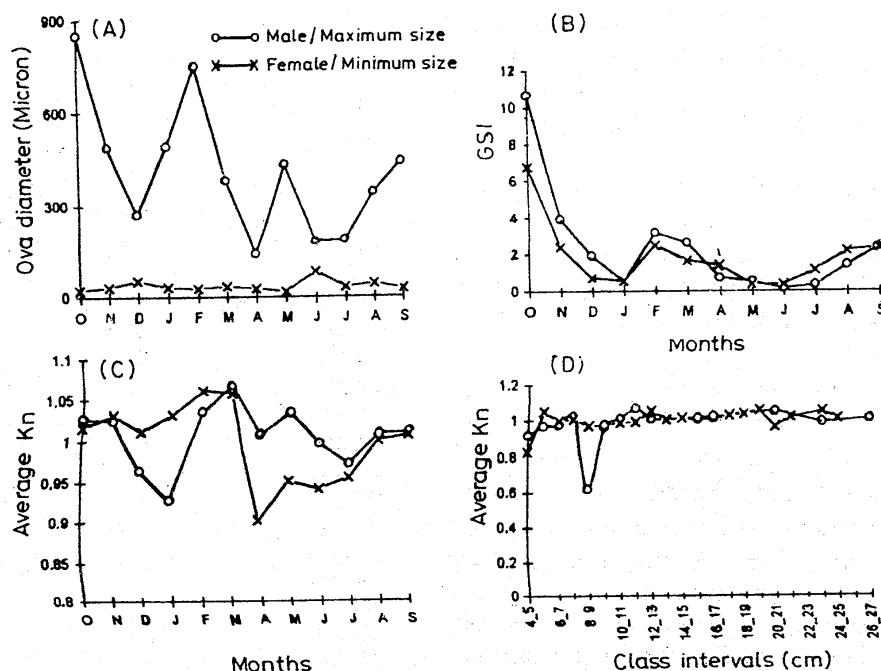


Fig. 1—Monthly variations(1991-92) in *Lagocephalus spadiceus*: (A) ova diameter, (B) average GSI values, (C) average K_n (relative condition values) and (D) K_n at different class intervals

Table 7— Percentage frequency of the number of females of *Lagocephalus spadiceus* in the various maturity stages during 1991-92. Numbers in parenthesis indicate ranges of standard lengths of females

Months	No. of females examined	Percentage of maturity stages					
		I	II	III	IV	V	VI
Oct. 91	12	—	33.33 (10.5-15.6)	16.66 (18-18.2)	50.00 (16.6-24.2)	—	—
Nov.	20	—	25.00 (12.7-16.8)	15.00 (15.8-16.8)	35.00 (16.4-20.5)	15.00 (18—21.2)	10.00 (24.5-27.5)
Dec.	10	—	30.00 (15-17.5)	30.00 (15-18.2)	40.00 (15-18.8)	—	—
Jan. 92	14	—	28.57 (6.8-8)	28.57 (8.5-9.5)	42.85 (15-18.8)	—	—
Feb.	26	—	15.38 (4.8-10.5)	07.69 (10.7-10.8)	38.46 (10.5-11.6)	30.77 (10.8-12.5)	—
March	12	—	—	22.22 (10.6-11.8)	33.33 (10-12.2)	25.92 (11.7-12.8)	14.81 (13.2-14.8)
April	12	—	—	58.33 (10.6-1.8)	16.66 (10.3-11)	16.66 (11-12.2)	08.33 (14.7)
May	06	66.66 (6.1-8.3)	33.33 (8-10.2)	—	—	—	—
June	01	—	—	100.00 (8.6)	—	—	—
July	03	—	—	66.66 (11.1-12.5)	33.33 (12.8)	—	—
Aug.	06	—	50.00 (12.4-14.5)	33.33 (15.0-16.7)	16.66 (18)	—	—
Sept.	14	—	28.57 (10.8-15.2)	35.71 (15.5-17.3)	35.71 (15.8-21.2)	—	—

mature ovaries (of stage IV) and spent ovaries (of stage VI) can be noticed are 95 mm (in January 1992) and 132 mm (in March 1992) respectively. This observation indicates possible breeding during February-March and October-November.

The monthly average GSI values for both males and females are plotted in Fig. 1B. High GSI values are indicated once during September-November and again in February-March. The mean K_n values of males and females for all sizes during one year and also for each 1 cm size-group are depicted in Fig. 1 C, D. In both males and females, high K_n values were obtained in September-November and February-March, thereby suggesting spawning of *L. spadiceus* during those months.

It has been suggested that the point of inflexion on a curve, showing the diminution of 'K' with increasing length, is a good approximate indication of the length at which sexual maturity is attained¹⁷.

In the present study a steep fall in the K_n values, in both sexes, was observed at 9 cm size (Fig. 1D), indicating attainment of first maturity at that size. This is further corroborated by the fact that the size of the smallest female (Table 7) which is in the IV stage of ovarian development found in pre-spawning month (i.e. January) is 9.5 cm.

The fecundity in *L. spadiceus* was found to vary from 0.75 to 3.5×10^5 .

Based on 10 fully mature females, regression equation for computing fecundity was derived as:

$$y = -157754.0236 + 18083.8315x$$

From the above results, it can be surmized that:

(1) While net-damaging puffers are essentially meat or flesh eaters, the non-damaging forms predominantly feed on hard molluscan shells.

(2) Fecundity in the net-damaging species *L. spadiceus* ranges from 0.75 to 3.5×10^5 .

(3) *L. spadiceus* matures at around 9 cm size and breeds twice in a year—once during February-

March with smaller (9 to 15 cm) females and again from September to November with larger (11 to 28 cm) females.

(4) The above two breeding seasons coincide with the peak net-damaging period along the south Konkan coast.

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References

- 1 Kulkarni A V, *Studies on alimentation and rate of digestion in some of the teleosts of Bombay*, M.Sc. thesis, University of Bombay, India, 1958.
- 2 Kuthalingam M D K, Luther G & Joel J J, *Indian J Fish*, 20 (1973) 240.
- 3 Thangaraja M, *Indian J Mar Sci*, 13 (1984) 199.
- 4 Munro I S R, *Mem Queensland Mus Brisbane*, 12 (1945) 136.
- 5 Uno Y, *J Tokyo Univ Fish*, 41 (1955) 169.
- 6 Merckens P J, *Het Aquarium*, 29 (1958) 106.
- 7 Targett T E, *Mar Biol*, 49 (1978) 83.
- 8 Targett T E, *Fish Bull*, 77 (1979) 292.
- 9 Kishida S & Yamada U, in *Fishes of the east China sea and yellow sea*, edited by O Okamura, (Nagasaki Seikai, RFRL, Japan) 1986, 431.
- 10 Pillay T V R, *Proc natn Inst Sci, India*, 20 (1954) 187.
- 11 Sarojani K K, *Indian J Fish*, 1 (1954) 67.
- 12 Luther G, *Indian J Fish*, 9 (1962) 604.
- 13 Parker R R, *J Fish Res Bd Canada*, 20 (1963) 144.
- 14 Hyslop E J, *J Fish Biol*, 17 (1980) 411.
- 15 Le Cren E D, *J Anim Ecol*, 20 (1951) 201.
- 16 Zar J H, *Biostatistical analysis*, (Prentice-Hall, Inc., Englewood Cliffs, N. J., USA) 1974, pp. 620.
- 17 Narasimham K A, *Indian J Fish*, 17 (1972) 90.