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Population structure and reproductive biology of selected sciaenid species along the fishing grounds of Goa, west coast of India

Dinesh T. Velip and
Chandrashekher U. Rivonker*

Department of Marine Sciences, Goa University, Goa 403 206, India

The present hypothesis on reproductive migration pattern between two species of sciaenids is based on the data collected with the help of the single-day commercial trawl with a fishing effort of 181 h along the fishing grounds of Goa, west coast of India. The observations on abundance revealed that between the two species (*Johnius borneensis* and *Otolithes ruber*) that formed bulk of the catch, a significant inverse trend in catch was observed. The pattern of migration based on the examination of female gonadal status suggested *J. borneensis* to be a continuous spawner and was evidenced by continuous occurrence of gravid and spent females and their juveniles. On the other hand, the rare occurrences of gravid females of *O. ruber* from the study area suggest that the species spawns away from the coast or might migrate to some potential spawning grounds. Further, an assessment of fecundity and the ova distribution pattern pro-pounded higher fecundity in *O. ruber* compared to *J. borneensis* with multiple spawning in both the species.

Keywords: Fecundity, population, spawning, Sciaenidae.

THE fishing grounds off Goa support an array of vertebrate and invertebrate fauna^{1,2}. Of these, the sciaenids are one of the most diverse and commonly occurring teleostean faunal groups contributing to around 10% of the total demersal catches of Goa³. Published literature from this region² revealed that these constituted 18% and 23% of the demersal fish assemblages of Marmugao and Aguada bay respectively, in terms of their abundance. In recent years, the demersal fishery of the region is subjected to increased fishing pressure through bottom trawlers for commercial exploitation. Moreover, large-scale mortality of juveniles owing to the use of reduced mesh sizes in trawl net influences the occurrence and abundance of commercially important demersal fauna.

Reproduction and recruitment is a species-specific biological process crucial for the continued existence and proliferation of population. Studies pertaining to reproductive biology and spawning behaviour are essential for a complete understanding of population dynamics^{4,5}. Moreover, reproductive rate determines the resilience

*For correspondence. (e-mail: curivonker@gmail.com)

capacity and sustainability of a species in response to environmental changes and anthropogenic activities. Further, recruitment success is also an important component of population dynamics, governed by freshwater runoff into estuaries, status of habitat and low fishing pressure⁶⁻⁸. Published literature⁹⁻¹¹ suggests extensive research on the reproductive biology of sciaenids from Indian waters. An attempt is made here to assess the sciaenid community from the nearshore fishing grounds of Goa with the following objectives: (1) to illustrate the sciaenid community structure based on species composition and abundance; and (2) to assess the abundance and reproductive biology of two major species forming bulk of the sciaenids of trawl catches of Goa.

The study area comprised potential fishing grounds off Goa, central west coast of India between 15°29'07.6"N

and 15°34'44.3"N lat., and between 73°38'10.5"E and 73°46'03.1"E long. (Figure 1). The prevailing substratum is of mixed sand-silt type interspersed with submerged rocky patches¹². These waters receive ample quantity of nutrients and freshwater from the adjacent Mandovi estuary¹³. It is subjected to strong seasonal upwelling during south-west monsoon period, resulting in marked differences in hydrographic regimes and productivity, thus contributing to rich fishery in the region². It also serves as nursery grounds for juveniles of several marine teleost species².

The samples were collected on-board single-day commercial shrimp trawler along the fishing grounds off Goa, central west coast of India down to 30 m depth (Figure 1) with a total sampling effort of 181 h incorporating 100 trawl hauls. The sampling period extended from November

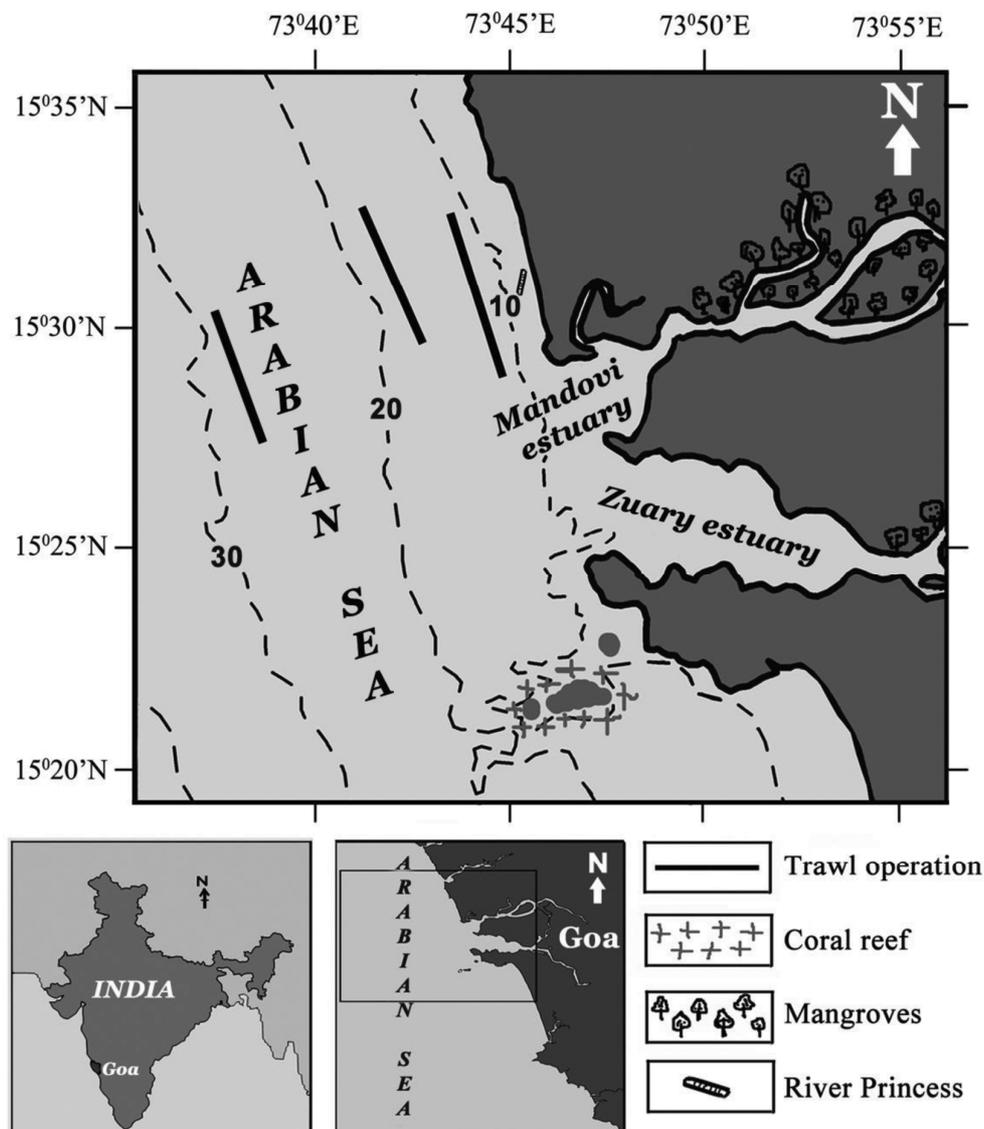


Figure 1. Map of the study area indicating trawl operations.

RESEARCH COMMUNICATIONS

Table 1. Maturity stage-wise average total length, weight of fish, weight of gonad, fecundity, ova diameter and gonado-somatic index (GSI) of *Johnius borneensis* and *Otolithes ruber*

Maturity stage	Total length (cm)	Weight of fish (g)	Weight of gonad (g)	Fecundity	Ova diameter (mm)	GSI
<i>Johnius borneensis</i> (N = 21)						
Mature	14.69 ± 1.49	39.84 ± 10.35	1.19 ± 0.37	63.38 × 10 ³ ± 24.66 × 10 ³	0.32 ± 0.05	2.98 ± 0.42
Fully mature	15.13 ± 1.05	42.60 ± 10.59	2.11 ± 0.85	80.04 × 10 ³ ± 27.75 × 10 ³	0.37 ± 0.11	4.96 ± 1.44
Spent	13.78 ± 2.16	30.58 ± 12.15	0.71 ± 0.27	43.17 × 10 ³ ± 15.59 × 10 ³	0.29 ± 0.06	2.33 ± 0.40
Overall	14.70 ± 1.47	39.26 ± 11.17	1.49 ± 0.83	66.67 × 10 ³ ± 27.43 × 10 ³	0.33 ± 0.09	3.70 ± 1.49
<i>Otolithes ruber</i> (N = 26)						
Mature	18.25 ± 2.58	62.43 ± 25.93	2.19 ± 0.53	105.11 × 10 ³ ± 17.07 × 10 ³	0.33 ± 0.04	3.74 ± 0.87
Fully mature	19.44 ± 1.85	78.07 ± 25.30	3.35 ± 1.06	123.88 × 10 ³ ± 51.81 × 10 ³	0.44 ± 0.13	4.34 ± 0.80
Spent	16.98 ± 0.87	46.80 ± 04.88	1.11 ± 0.61	57.23 × 10 ³ ± 30.09 × 10 ³	0.32 ± 0.04	2.35 ± 1.30
Overall	18.60 ± 2.19	67.24 ± 25.67	2.56 ± 1.15	106.41 × 10 ³ ± 43.92 × 10 ³	0.38 ± 0.11	3.81 ± 1.11

2010 to May 2013 with an exception of two months legislative ban (June–July). A trawl net with 20 m head and foot rope lengths and mesh sizes of 25 mm at mouth, 15 mm in middle and 9 mm at cod end was towed at a speed of about 2–3 knots for an average of 5–6 h daily. The geographical position of sampling stations was recorded with a 12-channel GPS and the corresponding depth was obtained from the Naval Hydrographic Chart no. 2022. The species, *Johnius borneensis* and *Otolithes ruber* were selected on the basis of their higher abundance and continuous occurrence in trawl catches for the detailed analysis of biological parameters including trophic dynamics and reproductive studies (gonadal maturity, fecundity, ova diameter). For analysis or estimation of abundance, the raw data, i.e. abundance of respective species or group from five sub-samples of each trawl haul were computed as

$$X = (x_1 + x_2 + x_3 + x_4 + x_5)/5,$$

where x denotes the abundance of a species or group in a sub-sample. The data was thereafter standardized to 60 min trawl in view of the variability in trawling duration (hours) throughout the study and subsequently extrapolated to the total trawl catch.

Before dissection, the fish samples were thoroughly washed and identified to the species level using conventional taxonomic keys^{14–16}. Thereafter, the specimens were weighed to the nearest 0.1 g using an electronic balance and their total lengths measured using a scale to the nearest 0.1 cm. Subsequently, the specimens were dissected and the gonads were examined visually following Devadoss⁹ and Bhusari¹⁷ and the maturity stages were recorded (Table 1). The gonads were then weighed using an electronic balance to the nearest 0.001 g and preserved in Gilson's fluid¹⁸.

Gonado-somatic index (GSI) is the ratio of fish gonad weight to body weight and was calculated following June¹⁹ and Yuen²⁰ as

$$\text{GSI} = (\text{weight of gonad}/\text{weight of fish}) \times 100.$$

Random gonad samples belonging to mature, fully mature and spent females ($N = 21$ for *J. borneensis* and $N = 26$ for *O. ruber*) from the third fishing season (October 2012–May 2013) were chosen for analysis of fecundity and ova diameter. The preserved gonads were washed thoroughly in 70% alcohol¹⁸ with intense care, dried with blotting paper and weighed to obtain the total weight of eggs. The fecundity was then analysed by weighing and counting 0.01 g of dried eggs under the compound microscope using counting chamber in triplicate to obtain the average number of eggs in the gonads. The absolute fecundity was then calculated using the formula given by Bagenal²¹ as

$$\text{Fecundity } (F) = (\text{total weight of ovary}/\text{weight of enumerated eggs}) \times \text{number of enumerated eggs}.$$

Moreover, diameters of 150 random ova were measured from each ovary using an ocular micrometer.

The family Sciaenidae is one among the most speciose and dominant demersal fish families occurring along the region^{1,2}, contributing to around 10% of the total demersal fish production of Goa³. During the present study, it consisted of 7 genera and 15 species, which contributed 2.97% of the total trawl catch and 10.33% of the teleostean fauna in terms of their abundance. Among the fifteen species observed during the present study, two species namely, the sharpnose hammer croaker (*Johnius borneensis* Bleeker, 1851) and tiger tooth croaker (*Otolithes ruber* Bloch and Schneider, 1801) representing 46% and 11% respectively of the total sciaenid catches (Figure 2) in terms of their abundance were studied in detail owing to their higher abundance and continuous occurrence in trawl catches. The probable reasons for higher abundance of these two species could be habitat heterogeneity with favourable niches, higher fecundity, and their food preferences along with wider diet spectrum. Moreover, these species are permanent residents along the region². Other sciaenids represented 43% to the total sciaenid catches in terms of their abundance (Figure 2); and consisted of *Otolithes cuvieri* (14%),

J. coitor (7%), *J. elongatus* (5%), *Pennahia macrophthalmus*, *J. belangerii* and *J. amblycephalus* (4% each), *J. dussumieri* (3%), *Kathala axillaris* (1.17%), *Pennahia anea* (0.58%), *Protonibea diacanthus* (0.54%), *Dendrophysa russelii* (0.35%) and *Johnius macropterus* and *Paranibea semiluctuosa* (0.24% each).

Abundance of total sciaenids did not show any significant trend ($R^2 = 0.384$); however it showed trivial increasing trend from the first to the third fishing season. Among the sciaenids, the species *J. borneensis* is one of the most commonly occurring and abundant sciaenid species observed during the present study along the region. Analysis of monthly abundance revealed an inverse trend between *J. borneensis* and *O. ruber* with an overall increasing trend in the case of former species (Figure 3 a) and an overall decreasing trend observed in the case of latter species (Figure 3 b). *J. borneensis* showed higher abundances during December and May throughout the study period. However, it showed consistent higher abundance from February 2013 to May 2013. On the other hand, *O. ruber* was abundant during the months of December and March–May throughout the study period. The mean abundance (number hr^{-1}) observed for *J. borneensis* and *O. ruber* was 255 ± 281 and 64 ± 48 respectively. The higher abundance of sciaenids during this period (December–May) can be attributed to recruitment of new juveniles as evidenced by predominance of their juveniles in sub-samples.

Females of *J. borneensis* and *O. ruber* were found throughout the study period (Figure 3). The juveniles/immature females of both species were found abundantly during October–December and February–May suggesting a prolonged/continuous spawning activity. The continuous and abundant occurrence of mature (gravid) and spent females of *J. borneensis* (Figure 3 a) in the study area indicates that the majority of their spawning process takes place in near shore coastal waters with peak spawning from November to April. These observations have been validated by the continuous occurrence of their juveniles from the study area. Further, published literature²² also reported November–June as the spawning period for *J. borneensis* in Kakinada region whereas Muthiah²³ reported June–July and October–November as spawning period for *J. borneensis* in Bombay waters. On the other hand, the mature (gravid) and spent females of *O. ruber* occurred rarely (November–December, February and April; Figure 3 b) in the study area, suggesting occasional spawning activity in the nearshore coastal waters. One of the reasons for lower occurrences of mature and spent females of *O. ruber* in the study area could be its reported spawning season which extends from June to October^{9,24} along the west coast of India, which corresponds to the monsoon fishing ban along the study area²⁵ followed by prevailing rough weather conditions along the coastal belt during August–September, thus hindering the sampling process.

The observations made on the fecundity and ova diameter of *J. borneensis* ($N = 21$), and *O. ruber* ($N = 26$) revealed that the former species exhibited lower fecundity and ova diameter ($66.67 \times 10^3 \pm 27.43 \times 10^3$; 0.33 ± 0.09 mm) compared to the latter one ($106.41 \times 10^3 \pm 43.92 \times 10^3$; 0.38 ± 0.11 mm; Table 1). Published literature^{9,10} also reported fecundity ranging from 43810–179.65 $\times 10^3$ numbers of eggs for *O. ruber* and 9253–151.69 $\times 10^3$ numbers of eggs for *J. borneensis*^{11,17}.

The ova distribution pattern (mature, fully mature and spent females) of both the species (Figure 4) revealed unimodal distribution of ova in mature and spent females (Figure 4 a, c, d, f) with a mode at 0.30–0.35 mm and a distinct bimodal distribution was observed in fully mature/ripe females (Figure 4 b and e) with primary mode at 0.30–0.35 mm in both species and secondary mode at 0.50–0.55 mm and 0.55–0.60 mm in *J. borneensis* and *O. ruber* respectively. In these species (*J. borneensis* and *O. ruber*), once the ova has been ovulated from the ready batch (0.45–0.80/0.45–70 mm), the ova from the intermediate or smaller size class (0.30–0.45/0.20–0.40 mm) transforms into a new ready batch for spawning as a result of asynchronous development of ova. This sequential event continues till the last batch of eggs shed-off indicating a multiple/intermittent spawning process and this has also been reported in many other teleostean species^{26,27}.

It is noteworthy to mention here that *O. ruber*, in spite of being a multiple or continuous spawner and having higher fecundity compared to *J. borneensis*, was observed to have low abundance during the present study. It is connotative from the above observations that the species *O. ruber* spawns away from the coastal waters probably in less productive offshore waters. However, the continuous occurrence of their juveniles from the study area indicates migration to the productive coastal waters which serves as potential nurseries² as this species is found to feed upon zooplankton (51% index of relative importance (IRI)), small teleosts (23% IRI) and prawns (19% IRI).

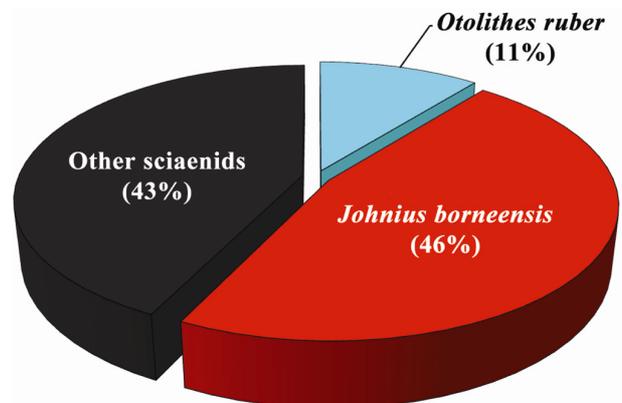


Figure 2. Species composition and percentage contribution of family Sciaenidae occurring along the region.

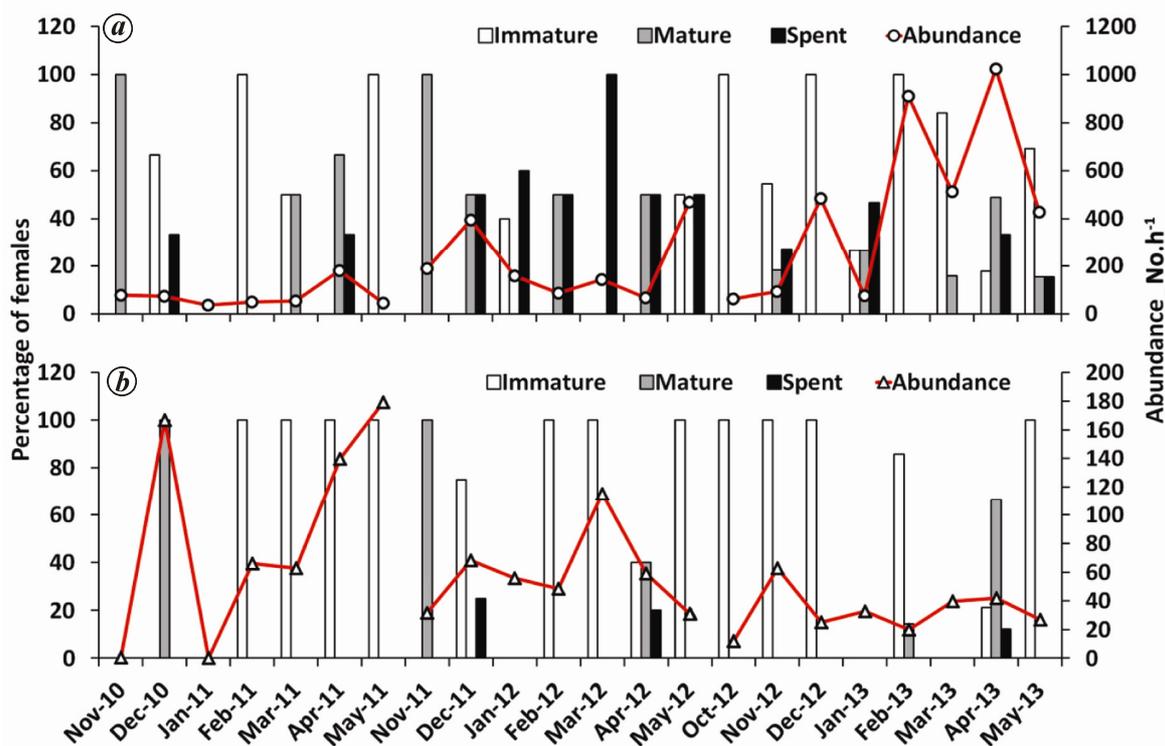


Figure 3. Monthly variation in abundance (h^{-1}) and percentage of immature, mature and spent females of (a) *Johnius borneensis* and (b) *Otolithes ruber*.

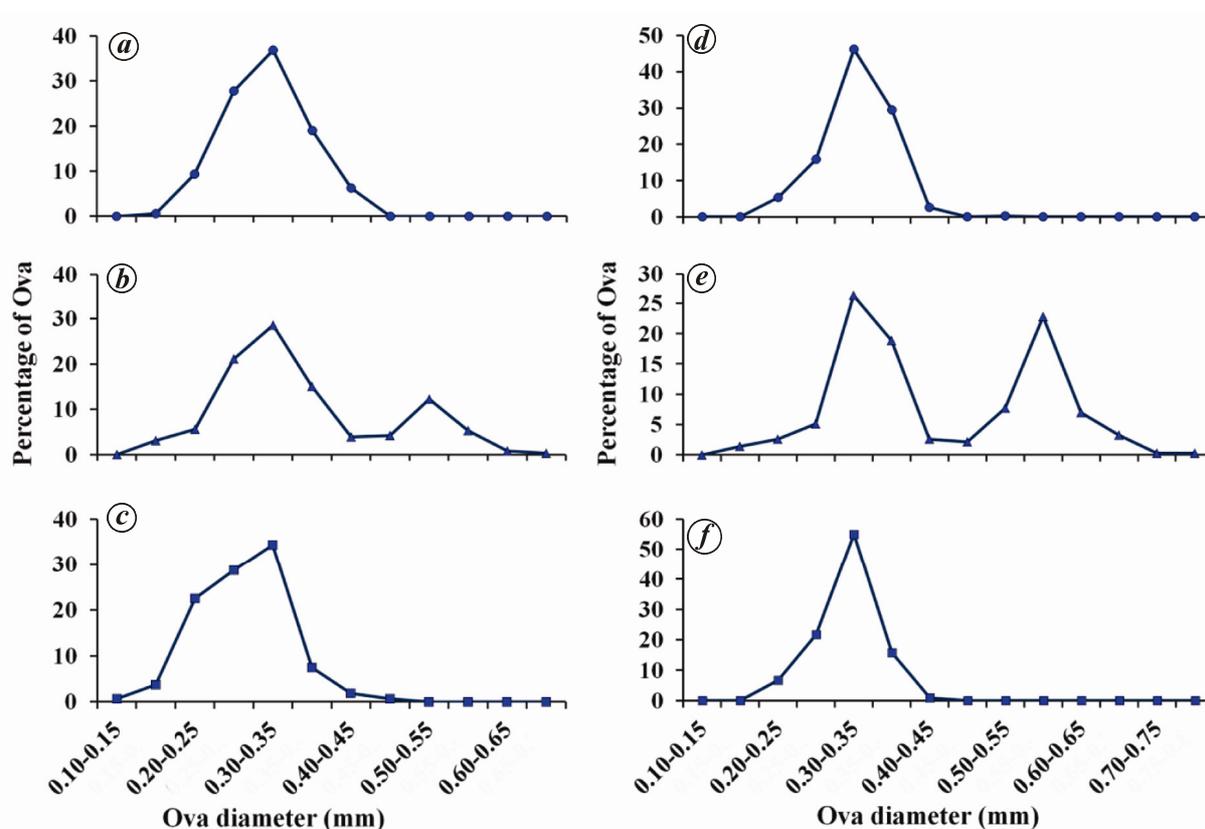


Figure 4. Percentage ova distribution plot of *Johnius borneensis*. a, Mature; b, fully mature; c, spent females and *Otolithes ruber*; d, mature; e, fully mature; f, spent females.

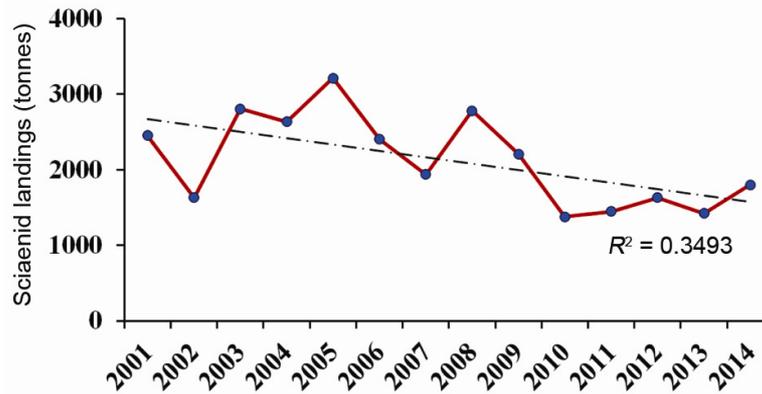


Figure 5. Sciaenid landings (in tonnes) along Goa coast from 2001 to 2014. Source: refs 33, 35.

During this process there might be some mortality of their larvae and juveniles due to starvation and predation by potential predators^{28,29} and hence low survival rate, leading to reduced species abundance in the study area. In contrast, *J. borneensis* spawns in productive coastal waters which also serve as good nurseries³⁰, leading to high survival rate of juveniles and this might be responsible for its increased abundance compared to *O. ruber* along the region. Moreover, the higher dietary breadth in *J. borneensis* ($B = 0.34$) might have favoured their increased abundance^{31,32} as compared to *O. ruber* ($B = 0.21$). Secondly, there is also a possibility of migration of gravid females of *O. ruber* to the deeper offshore waters or some other potential spawning grounds for spawning as reported in other finfishes^{33,34} and hence the lower occurrences of their gravid and spent females from the study area.

Further, an analysis of sciaenid landings along the Goa coast displayed an overall decreasing trend^{33,35} ($R^2 = 0.349$) (Figure 5), attributed to the combined effect of elevated exploitation and resultant by-catch generation and coastal anoxia. In recent years, high demand for fish and consequent intensification in fishing efforts for elevated yields/catch along with the by-catch have made the sciaenid fishery of Goa highly vulnerable to sustained fishing pressure. Apart from this, the seasonal anoxia occurring over the western Indian continental shelf³⁴ results in mortality of fish larvae and juveniles of sciaenids³⁶ as the anoxic period coincides with the spawning period of sciaenids³⁷ and may also compel some of the sciaenid species to migrate to other places³⁸. The anoxic conditions or hypoxia is widely reported to affect some of the aspects of fish population such as reproduction and development³⁹, larval survivorship, quality and fitness of juveniles³⁹, biodiversity loss⁴⁰, relocation of fish populations⁴⁰, etc. Therefore, the situation necessitates continuous monitoring of trawl catches and its by-catch coupled with studies pertaining to eco-biological aspects and population dynamics of sciaenids for sustainable exploitation and management of sciaenid fishery along the region.

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***Fragilariopsis* sp. bloom causes yellowish-brown waters off Alappuzha, south-central Kerala coast, India, during the mud bank-upwelling phase**

R. Jyothibabu^{1,*}, N. Arunpandi¹, C. Karnan¹, L. Jagadeesan¹, T. M. Manojkumar¹, K. K. Balachandran¹ and S. W. A. Naqvi²

¹CSIR-National Institute of Oceanography, Regional Centre, Kochi 682 018, India

²CSIR-National Institute of Oceanography, Dona Paula, Goa 403 004, India

Mud banks (Chakara) of Kerala are calm coastal waters that form in several isolated stretches along the coast usually during the southwest monsoon (SWM) period (June–September). They are characterized by the damping of incident waves, generating localized calm sea environment conducive for fishing activities, while the high monsoon waves create hostile environment in the rest of the region. Here, we present the scientific basis of the yellowish-brown discoloration of water column that occurs off Alappuzha, Kerala annually during the peak and late SWM associated with coastal upwelling-mud bank event. The discoloured waters that occur off Alappuzha associated with these events are locally known as ‘pola vellam’, which is nothing but diatom blooms. In 2014, pola vellam was actually caused by the bloom of *Fragilariopsis* (= *Fragilaria*) sp.; hereafter *Fragilariopsis*, which was

*For correspondence. (e-mail: rjyothibabu@nio.org)