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Length-weight relationship, reproductive biology and diet of the Javelin grunter *Pomadasys kaakan* (Cuvier, 1830) (Family: Haemulidae) from western Bay of Bengal

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Abstract

This study provides the first report on the length-weight relationship, reproductive biology and diet of *Pomadasys kaakan* (Cuvier, 1830) from western Bay of Bengal. Specimens for the study were collected from two locations, Visakhapatnam and Puri, with 301 fishes collected from the former and 153 from the latter. The mean size of *P. kaakan* at Visakhapatnam was 38.7 cm total length (TL) and 32.07 cm TL at Puri. The length-weight relationship indicated negative allometric growth in the species from both locations. The length at first maturity for female fish was estimated to be 31.5 cm TL at both locations. Our study indicated spawning throughout the year with peaks in February-April and July-August for *P. kaakan* in the study area. Analysis of diet indicated that in the study region, the species had divergent feeding habits. At Visakhapatnam, teleosts (unidentified finfish, eels and silverbellies) were dominant diet items whereas crustaceans (crabs and shrimps) were the dominant diet components of *P. kaakan* at Puri. The close similarity in size distribution and reproductive biological parameters from the two regions points towards the possibility of a single stock of the species in the study region.

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Introduction

Information on basic biology of a fish species (reproduction, diet and growth) is critical for effective management and sustainable utilisation of the species. Information on reproduction and diet form inputs in ecosystem models as well as in the development of mariculture protocols. The Javelin grunter, *Pomadasys kaakan* (Cuvier, 1830) is a marine species which is a prized food fish and is grown in mariculture systems. The species is a member of the family Haemulidae (Order: Perciformes) which has 137 valid species distributed across the world's oceans (Fricke *et al.*, 2023). *P. kaakan* is a tropical fish distributed in the Indo-Pacific region from the Persian Gulf to Australia (Froese and Pauly, 2022). It contributes to commercial fisheries in several countries/regions across its distribution range including Kuwait (Al-Husaini *et al.*, 2001), Iran (Valinassab *et al.*, 2006), Persian Gulf (Falahatimarvast *et al.*, 2012), India (Ramani *et al.*, 2010) and Australia (Garrett, 1996). In Kuwait, this species is the most important haemulid and is caught in commercial trap, trawl, gillnet and hook and line fishery (Al-Husaini *et al.*, 2001). The species formed 10.7% (761.6 t) and 3.0% (164.8 t) of Kuwait's landed catch during 1987-1988 (Al-Husaini *et al.*, 2001). In Iran, the capture fisheries production of the species was 9869 t in 2019 (FAO, 2021). In the Persian Gulf. the species is commercially important and is captured using trawl nets, gillnets, longlines and traps (Bianchi, 1985). In Indonesia, the fishery of the species is comprised mainly (90%) of individuals that have spawned at least once, indicating a low risk of overfishing (Mous *et al.*, 2018). On the other hand, the fishery in Iran has been reported to be above the maximum sustainable level with annual spawning potential ratio less than the threshold value of 0.2 (Vahabnezhad *et al.*, 2021).

P. kaakan has been studied widely with respect to abundance, reproductive biology, age and growth from various locations across its distribution range. In trawl surveys carried out to estimate abundance of demersal resources in the Persian Gulf and Oman Sea, *P. kaakan* was the third-most abundant commercial species (Valinassab *et al*., 2006). The species formed 4.69 and 9.81% of total biomass in the Persian Gulf and Oman Sea, respectively (Valinassab *et al*., 2006). In the Gulf of Carpentaria in Australia, the species was the sixth-most abundant fish caught during daytime trawl surveys (Blaber *et al*., 1990). *P. kaakan* showed significantly higher catch rates during daytime trawling as compared to nighttime trawling and showed highest catch rates at intermediate depths (Blaber *et al*., 1990). Studies on reproductive biology of the species from the northern Persian Gulf indicated that *P. kaakan* had a prolonged spawning season extending from January to August in the region with multiple spawning as evidenced by the polymodal distribution of ova diameter frequencies (Falahatimarvast *et al*., 2012). An extended spawning season was also noted in a study from Gulf of Carpentaria, Australia (Garrett, 1996) where *P. kaakan* males were estimated to mature in their third year whereas female fish were estimated to do so in their third or fourth year (Garrett, 1996). Spawning aggregations of the species have been reported from the Great Barrier Reef Marine Park (Russell and Pears, 2007) as well as northern Queensland (Szczecinski, 2012) in Australia. The age of *P. kaakan* was estimated to be 13 years (Garrett, 1996) from the Gulf of Carpentaria and up to 36 years from Kuwait waters (Al-Husaini *et al*., 2001). The von Bertalanffy growth parameters (L_{∞}, k) estimated for the species from Australian waters ranged from 74.6 cm and 0.178 (Szczecinski, 2012) to 75.6 cm and 0.243 (Garrett, 1996). *P. kaakan* has been reported as a K-selected species due to its slow rate of maturation and vulnerability to high fishing pressure (Szczecinski, 2012). *P. kaakan* is also known to be a benthic crustacean feeder (Annisa *et al*., 2018).

In India, *P. kaakan* supports commercial fisheries (Ramani *et al*., 2010) where it is caught using a number of fishing gears including trawl nets, gillnets, hook and line and *dol* net across the country. It is a prized fish in the domestic markets known for its good taste and white meat and is often sold as low-cost alternative to seabass *Lates calcarifer* (Muktha, M., *pers. obs*.). Surveys along the east coast of India indicated the presence of good fishing grounds for *Pomadasys* spp. in the region (Sekharan *et al*., 1973; Reuben *et al*., 1987). Currently there are no species-specific management measures for *P. kaakan* in India and it is subjected to the generic annual trawl ban only (east coast: April-June, west coast: June-July). Though a commercially important species in the country, information on the biology and diet of *P. kaakan* is lacking from India. Hence, we carried out this investigation to study the reproductive biology and diet of *P. kaakan* from Indian waters, off western Bay of Bengal, along the east coast of India. Updated information on *P. kaakan* would aid in the development of species-specific management strategies in the future as well as be inputs for ecosystem-based models in the region.

Materials and methods

Study area and data collection

This study was carried out at two locations along western Bay of Bengal along the east coast of India; Visakhapatnam in the state of Andhra Pradesh and Puri in the state of Odisha (Fig. 1). Specimens of *P. kaakan* were collected once weekly from Visakhapatnam Fishing Harbour (17.6962°N, 83.3009°E) during 2018-2019 and Puri (19.8135°N, 85.8286°E) during 2021 (Fig. 1). At Visakhapatnam Fishing Harbour as well as Puri, *P. kaakan* were landed by fishing vessels operating trawl nets, gillnets and hooks and lines. Trawls are operated mostly within the 100 m depth zones whereas gillnets and hooks and lines are operated from nearshore areas to farther offshore areas in the study region. At Visakhapatnam, we collected 301 fish specimens across all fishing gears; analysis was carried out on the pooled specimens to reduce the influence of size selection by any particular fishing gear, though there was no evidence of significant size selection in any of these gears. A total of 153 fish specimens were collected from Puri. Once the specimen was brought to the laboratory, the total length (TL) was measured from tip of snout to the distal end of the caudal fin (nearest cm) using a digital Vernier Caliper. Total body weight (BW) was measured to the nearest gram, using a digital weighing balance.

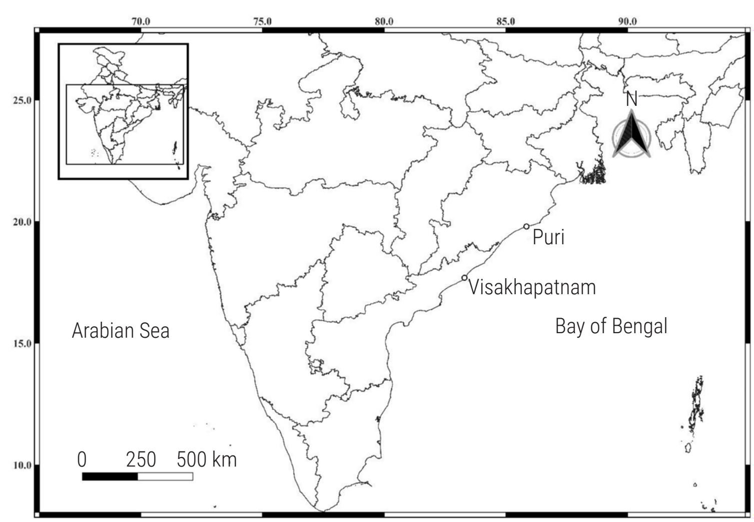

Fig. 1. Map of the study area along the east coast of India, off western Bay of Bengal with Visakhapatnam and Puri marked with open dots

The fish was then dissected and (measured for length and weight after removing the gonads). Sex was noted from the gonads. For assessing the patterns of reproductive cycles and breeding season, the Gonado-somatic Index (GSI) was calculated as follows: GSI =GW/W× 100, where GW is the weight of the gonad in g and W is the weight of the individual in g (Biswas, 1993). Maturity stages were assigned based on the macroscopic view of a fresh smear of the female gonad viewed under a trinocular microscope. Oocyte diameter was measured for the group of largest oocytes seen in the ovary; the unit was in μm (equivalent to 10^{-4} cm) from gonad samples of fish collected at Visakhapatnam. Oocyte diameter measurements were taken from a single gonad sample of each maturity stage. The diameter was noted at x40 magnification for all stages except stage I which was measured at x100 magnification. Stage I oocyte diameter values were converted to x40 magnification values for comparison with other stages. Classification of female gonadal maturity stages were based on a 7-stage classification with Stage I being immature, Stage II either being virgin developing or recovering, Stage III and IV maturing, Stage V mature, Stage VI ripe and/or running and Stage VII being spent fish (based on Antony Raja, 1966).

The stomach was dissected out and checked for fullness (Jayabalan and Ramamoorthi, 1985). All empty stomachs were counted and the Vacuity Index (Preciado *et al*., 2014) was calculated as the percentage of empty stomachs in all stomachs analysed. The individual diet contents were separated out, identified to the genus level, counted, and weighed separately, wherever possible. Unidentifiable diet contents in the form of liquid or paste were recorded as "digested matter". Where a fish or shrimp was not identifiable to the genus level it was noted as "semi-digested fish" or "semi-digested shrimp". One stomach was spoilt in the Visakhapatnam samples and was excluded from the analysis. Hence a total of 300 stomachs were analysed at Visakhapatnam and 100 at Puri for diet contents.

Data analysis

The length-weight relation was derived using the logarithmic form of the standard equation $W=a*L^b$ (Le Cren, 1951) where W is body weight in g and L is total length of the animal in cm. Sex-wise significance of length-weight relationship was tested using the ANOCOVA test (Snedecor and Cochran, 1967). Sex-wise size differences were tested with the Student's t-test at 5% level of significance. Sex ratio was estimated for overall data as well as month-wise and size-wise and tested for significance using the Chi-square test at 5% level of significance. The proportion of mature individuals was estimated for size classes of 5.0 cm range. From these proportions, the length at first maturity (L_{m50}), was estimated using the logistic equation as given by King (2007):

$$P= 1/ (1+\exp [-r\times(TL-L_{m50})])$$

where, P is the proportion of mature individuals in a length class, TL is the total length of fish in cm, r (intercept) and L_{m50} (slope) are two parameters of the logistic model.

Fullness of stomach was studied using the quarterly scale proposed by Braccini *et al.* (2005) which runs from 0 to 4 as follows; 0: empty; 1: 0-25% full; 2: 26-50% full; 3: 51-75% full and 4: 76-100% full. A Chi-square test was used to test for significant differences in the occurrence of fullness of stomach for pooled data and data disaggregated by months, sex, and size. The Index of Relative Importance (Pinkas *et al*., 1971) was estimated from the diet contents as %IRI = (%N + %V) × %F, where N is the total number of prey items, V is the volume (replaced by weight here) and F is the frequency of occurrence of each prey item.

Results

Size distribution

A total of 301 specimens of *P. kaakan* were collected from Visakhapatnam during 2018-2019 of which 148 were females, 148 were males and 5 were indeterminate. From Puri, 153 specimens were collected of which 78 were females and 75 were males. The TL of fishes collected at Visakhapatnam ranged from 18.4-58.8 cm with an average TL of 38.7 cm (SE=4.98) (Table 1). From Puri, the size range of *P. kaakan* during 2012 was 9.6-50.3 cm with an average of 32.07 cm (SE=0.59) (Fig. 2). Mean sizes of male fish and female fish were not significantly different both at Visakhapatnam (two sample t-test, $p>0.05$) and Puri (two sample t-test, $p>0.05$). Total body weight (BW) ranged from 101-2501 g with an average of 890.7 g (SE=30.1) at Visakhapatnam and at Puri it ranged from 16.8-1840 g with an average of 531.65 g (SE=26.53).

Length-weight relationship

The length-weight relationship for male and female *P. kaakan* differed significantly (ANOCOVA, $p<0.05$) at both locations, necessitating different length-weight relationship for males and females. The resultant length-weight relationships were as follows:

Visakhapatnam: Males; $W = 0.041 (L)^{2.69}$ ($r^2 = 0.98$); Females; $W = 0.025 (L)^{2.84}$ ($r^2 = 0.98$)

Puri: Males; $W = 0.033 (L)^{2.78}$ ($r^2 = 0.98$); Females; $W = 0.035 (L)^{2.75}$ ($r^2 = 0.97$)

The slope of the length-weight relationship was significantly different from the isometric value of 3 for both male and female *P. kaakan* (t-test, $p<0.05$) for both study locations, indicating allometric growth in the species. Since both male and female b-values were

Table 1. Size and weight of *P. kaakan* studied at Visakhapatnam and Puri

Particulars	TL in cm (Average in parenthesis)		BW in g (Average in parenthesis)	
	Visakhapatnam	Puri	Visakhapatnam	Puri
Males	22.0-53.8 (38.8)	9.6-50.1 (30.68)	170-1906 (855.3)	16.8-1840
Females	20.7-58.8 (39.2)	14.3-50.3 (32.40)	118-2501 (951.1)	56.5-1823
Indeterminate	18.4-23.8 (21.6)	-	101-201 (154.8)	-
Total	18.4-58.8 (38.7)	9.6-50.3	101-2501 (890.7)	16.8-1840

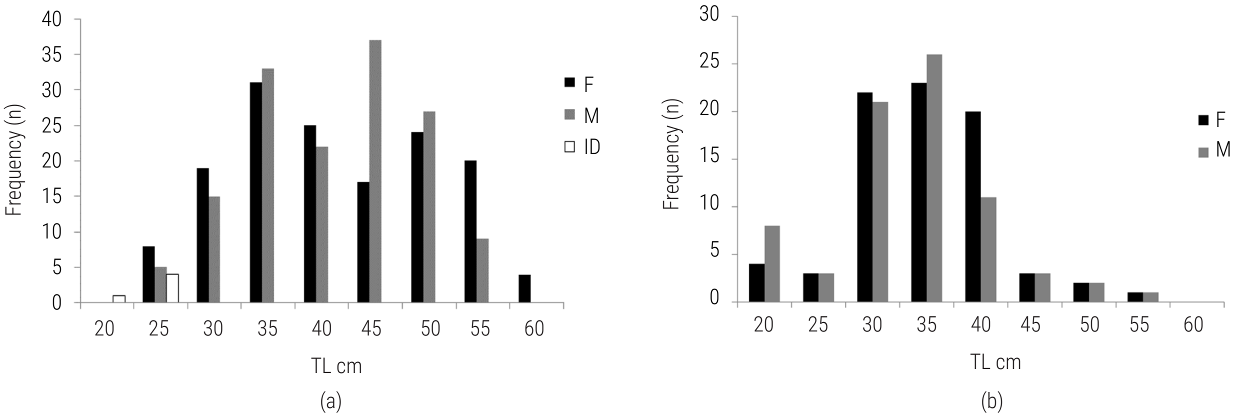

Fig. 2. Size distribution of *P. kaakan* at (a) Visakhapatnam; (b) Puri

less than 3, it indicated negative allometric growth in *P. kaakan* in the western Bay of Bengal. This is the second study to report on the length-weight relationship of *P. kaakan* from India; the only other study on the length-weight relationship for this species from India was from Chilika Lagoon where positive allometric growth was reported with the average b estimated to be 3.134 (Karna *et al*., 2020). However, the study from Chilika Lagoon was based on a restricted size range of 3.0-16.5 cm TL which might have impacted the values of b in the length-weight relationship. Studies from other regions have reported values of b in *P. kaakan* to be 2.892 (Persian Gulf; Raeisi *et al*., 2011), 2.94 (Iran; Saberi *et al*., 2017), 2.93 (Iran; Paighambari *et al*., 2018) and 2.85 (Australia; Garrett, 1996) indicating negative allometric growth in the species. Thus, despite differences in fishes sampled by region, season, fishing gear and environment, the species has consistently shown negative allometric growth indicating that *P. kaakan,* across its distribution range in the western and eastern Indian Ocean, increases more in length than in width as it grows (Froese, 2006). Negative allometry *i.e.* b<3 can also be seen when the fish in smaller sizes were nutritionally better off than the larger-sized fishes (Froese, 2006).

Sex ratio

The sex ratio was 1:1 (F: M) at Visakhapatnam and 1.04:1 at Puri, which were not significant (Chi-square test, p>0.05). The size-based sex ratio indicated significant deviation only in the 40.0-45.0 cm size class at Visakhapatnam which was biased towards male fish and >50.0 cm size classes which were biased towards female fish. Month-wise sex ratio indicated significance only in the month of June at Visakhapatnam, when the sex ratio was biased towards female fish. There was no significance either in size-based or monthly sex ratio at Puri. Sex ratios can point to the presence of either sex-specific aggregations or vulnerability of a specific sex to a specific fishing gear based on their morphology and/or behaviour (Kendall and Quinn, 2013). In a study from Australia on *P. kaakan*, sex ratios favouring males in sizes below 20.0 cm TL were observed which progressively became female biased as the fish grew in size (Bade, 1989). A possible change in sex of fish was mooted as an explanation however, without corresponding proof in histology of gonads (Bade, 1989). Female-biased sex ratios from both commercial and recreational fisheries were reported from Queensland, Australia (Szczecinski, 2012) which was attributed to the possibility of spawning aggregations in the study area. There are other reports also on the possibility of spawning aggregations in *P. kaakan* in the Great Barrier Reef, Australia (Russell and Pears, 2007). Female biased sex ratios have also been reported from the northern Persian Gulf (Falahatimarvast *et al*., 2012). Sex ratios in our study varied only for two size classes and for one month indicating that for most of the sizes and most part of the year, the fishery did not encounter sex-specific aggregations of *P. kaakan* in the study area. It could also indicate that sex-specific spawning aggregations are not formed in the study area. None of the studies from western Indian Ocean have suggested the presence of spawning aggregations for the species. Hence, with the current results of this study we cannot confirm the possibilities of sex-specific aggregations or spawning aggregations for the species along western Bay of Bengal using sex ratio information for *P. kaakan*. Moreover, this result also indicates that there might not be sex-specific vulnerability in *P. kaakan* to the fishing gears used in the study region.

Reproductive biology

P. kaakan is a gonochorist fish with separate male and female individuals. The L_{m50} for female *P. kaakan* was 31.5 cm TL (~ 0.44 kg body weight) at Visakhapatnam and Puri (Fig. 3). In *P. kaakan* L_{m50} was reached at 53.5% of maximum size. The smallest fish with a running Stage VI ovary was of size 27.6 cm TL at Visakhapatnam and 25.9 cm at Puri. The L_{m50} of female *P. kaakan* estimated in this study (31.5 cm TL) was within the range of values reported for the species from across its distributional range. The L_{m50} for the species reported from Iranian waters of the Persian Gulf was 47.7 cm TL (Falahtimarvast *et al*., 2012) and from Persian Gulf and Oman Sea was 48.0 cm Fork Length (Vahabnezhad *et al*., 2021) whereas from Australia it was 46.3 cm Length at Caudal Fork for female *P. kaakan* (Garrett, 1996). On the lower end, an L_{m50} of 29.0 cm TL was reported from Indonesia for the species (Mous *et al*., 2018). Only 22.0% and 33.0% of female fish sampled at Visakhapatnam and Puri respectively, were smaller than the L_{m50} size, indicating that majority of female fish caught by the fishery have spawned at least once in their lifetime. This points towards a relatively healthy fishery as a fishery is considered very much at risk if the contribution of immature fish is beyond 50% (Froese *et al*., 2016).

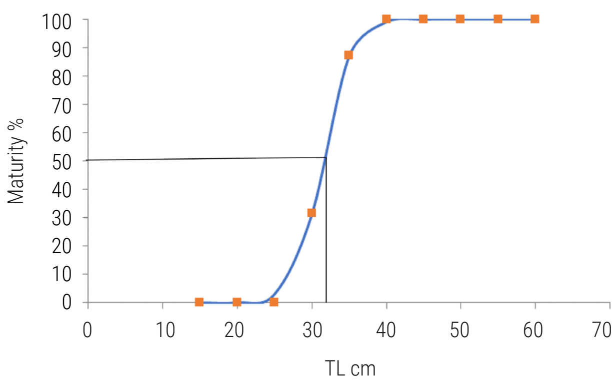

Fig. 3. Length at first maturity (L_{m50}) of female *P. kaakan* in the western Bay of Bengal

P. kaakan oocytes in stage I had an average diameter of 17.8 μm (no. of oocytes measured, n=4). By stage III, the average diameter had increased to 302.96 μm (n=7) registering an increase of 1601% in diameter values. By stage IV the average diameter had increased to 424.59 μm (n=7) and stage VI oocytes measured 549.34 μm (n=9) on average (Fig. 4). Stage II and V oocytes could not be measured due to lack of suitable gonad samples. There was a significant increase in oocyte diameter from Stage I to III which then increased at a slower rate in higher stages (Fig. 4). The ratio of oil globule diameter to oocyte diameter in hydrated oocytes was on average 0.243 and the volume of oil globule formed ~1.56% of egg volume (Table 2). There was an inverse relation between oil globule diameter and oocyte diameter with a correlation coefficient of -0.312, indicating that larger oocytes generally had smaller oil globules. The eggs of *P. kaakan* had a single oil globule whose volume range as percentage of egg volume was 1.55% which fell

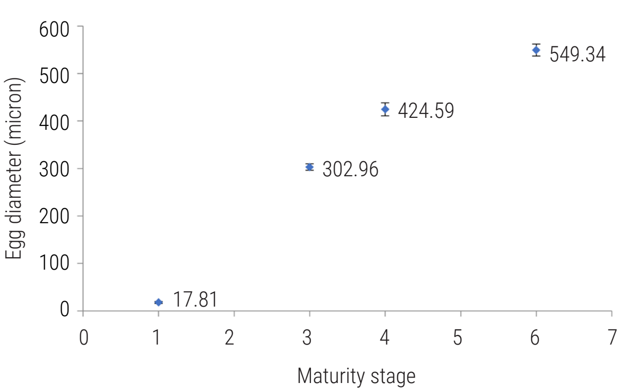

Fig. 4. Average oocyte diameter (μm) per maturity stage of *P. kaakan*

within the limits of those reported from other marine fish. The average of oil globule volume as percentage of egg volume has been reported to be 2%, with this value never exceeding 9% in marine fish (Baras *et al*., 2018). Our study is the first one to report on oil globule sizes and volume in *P. kaakan* along western Bay of Bengal.

P. kaakan ovaries exhibited batch-wise maturation of oocytes with multiple oocyte stages within a gonad. Thus, it is expected that all the hydrated oocytes of a stage VI ovary (Fig. 5) would be spawned at one stretch followed by another spawning event after a time period, when the next batch of oocytes would be ready for spawning. Females with running gonads (Stage VI) were seen in February, March, July, August, September, and November during the study period at both Visakhapatnam and Puri. Peak GSI values (average) were seen in August (2.98) and April (2.92) for female fish at Visakhapatnam (Fig. 6) and during October (1.28) and September (1.19) at Puri. For males, peak GSI values were seen in July (0.81) and February (0.71) at Visakhapatnam and in February (0.5), December (0.35) and August (0.27) at Puri. Stage V ovaries were seen in almost all the months of sampling at both locations. These observations indicated possible spawning throughout the year with peaks in February-April and July-August for *P. kaakan* in the study area. Batch-wise spawning resulting in multiple spawning events over a year is common in tropical and subtropical fishes (McEvoy and McEvoy, 1992). Prolonged spawning season extending from January to August has been reported in this species from Iranian waters of the Persian Gulf (Falahtimarvast *et al*., 2012). The same authors reported multiple spawning in the species from the polymodal distribution of oocyte sizes. Multiple spawning is a particularly important feature for species which are likely candidates for mariculture, provided other parameters like ease of spawning in controlled conditions and larval rearing is met. Thus, based on its spawning frequency, *P. kaakan* seems to be a promising candidate for mariculture in the region whose culture prospects may be explored further.

Diet

Of the 300 *P. kaakan* stomachs studied at Visakhapatnam, 128 were empty resulting in a vacuity index of 42.7% and at Puri, 44 stomachs were empty of the 100 stomachs analysed, resulting in a vacuity index of 44%. The rest of the stomachs were not empty with at least some trace of digested matter in them. With respect to fullness of stomach, 0 was the highest (42.7%) and 4 was the least (9%) at Visakhapatnam. At Puri too, 0 was the highest (44.0%) and 4 was lowest (5.88%). The Chi-square test of non-empty stomachs indicated significant differences (p<0.05) between the frequencies for each class of fullness of stomach, both at Visakhapatnam and Puri.

Table 2. Oocyte diameter and oil globule diameter in Stage VI *P. kaakan* ovaries

Oocyte diameter (μm)	Oil globule diameter (μm)	Ratio of oil globule to oocyte diameter	Volume of oil globule to egg volume (%)
685.462	136.818	0.1996	0.795
651.276	139.118	0.214	0.975
615.557	155.963	0.253	1.63
596.498	140.793	0.236	1.31
593.587	126.27	0.213	0.96
562.663	131.409	0.234	1.27
531.741	175.724	0.330	3.61
523.306	139.296	0.266	1.89

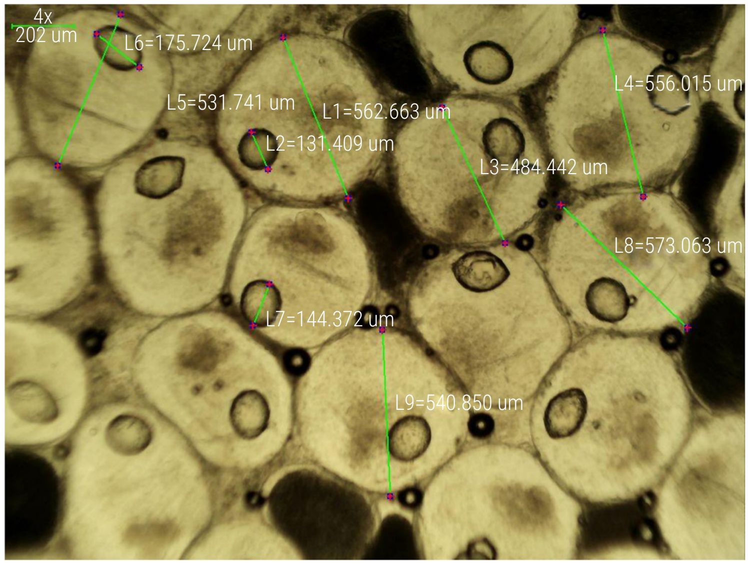

Fig. 5. Fresh smear of Stage VI ovary of *P. kaakan* (14 March 2019; TL 45.8 cm; BW 1282 g)

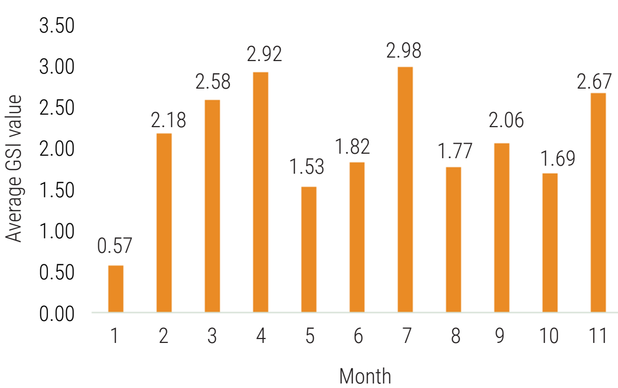

Fig. 6. Monthly average GSI values of female *P. kaakan* at Visakhapatnam

The %IRI indicated that teleost fish (cumulative %IRI = 62.36) was the dominant diet group, followed by crustaceans (cumulative %IRI = 35.87) and molluscs (cumulative %IRI = 1.77) at Visakhapatnam. At Puri, crustaceans (%IRI=57.75) and teleosts (%IRI=42.24) were the diet groups; no molluscs were seen in the diet of *P. kaakan* at Puri. Unidentified fish (%IRI = 57.03), crabs (%IRI = 24.06) and shrimps (%IRI = 6.23) were the dominant prey items of *P. kaakan* at Visakhapatnam. At Puri, crabs (%IRI=46.43), unidentified fish (%IRI=38.05) and shrimps (%IRI=9.18) were the dominant prey items. Unidentified fish could be both baitfish as well as prey fish. However, there was no way to distinguish between the two. In addition to unidentified fish, other teleosts found in the diet included eels, silverbellies (*Leiognathus* spp.), ribbonfish (*Trichiurus lepturus*, *Lepturacanthus savala*), threadfin breams (*Nemipterus japonicus*, other *Nemipterus* spp.), sardines (*Sardinella* spp.), goatfish (*Upeneus* spp.), anchovies (*Stolephorus* spp.), lizardfish (*Saurida* spp.) and Apogonids (Table 3). The crustacean diet contents included crabs, shrimps, *Acetes* spp. and stomatopods. At Puri the identified teleosts in the diet of *P. kaakan* were eels, sardines and silverbellies; shrimps and crabs were in semi-digested form and could not be identified to the genus level. The cumulative %IRI of the fishes identified up to genus level as listed above was only 5.28 at Visakhapatnam and 2.14 for Puri. Thus, if unidentified fish were set aside (to reduce the confounding effects of bait) in the Visakhapatnam samples, then crustaceans would be the dominant diet group of *P. kaakan* at both locations.

A size-wise analysis of %IRI also indicated that for most size groups unidentified fish was the dominant diet item at Visakhapatnam. Only in two size groups 25-30 cm TL and 30-35 cm TL did crustaceans *i.e.* shrimps and stomatopods dominated the diet items at Visakhapatnam. Invariably for all size groups at Visakhapatnam, finfish and a crustacean group dominated the diet (Fig. 7) except in the largest (55.0-60.0 cm TL) and smallest (up to 25.0 cm TL) size groups. In these two size groups, diet was dominated by unidentified fish and squid at Visakhapatnam. On the other hand, at Puri crustaceans dominated the diet in all size groups except the 30-35 cm TL size group, in which teleosts dominated (Fig. 8).

P. kaakan exhibited a divergent feeding nature as seen from the results of our study. At Visakhapatnam it exhibited a piscivorous nature whereas at Puri the species was a crustacean feeder. The result from Visakhapatnam was in contrast to earlier reports which have indicated that the species feeds mainly on crustaceans. The results from Puri on the other hand were in conformity with earlier

Table 3. Diet contents (finfish) with %IRI values of *P. kaakan* stomachs studied at Visakhapatnam

Diet item	%IRI	Diet item	%IRI
Unidentified fish	57.03	*Saurida* spp.	0.083
Eels	3.08	*Harpadon* spp.	0.081
Leiognathus spp.	0.55	*Trichiurus* spp.	0.077
Stolephorus spp.	0.447	*Pentaprion* spp.	0.071
Upeneus spp.	0.397	*Grammoplites* spp.	0.051
Sardinella spp.	0.338	*Nemipterus* spp.	0.027
Apogon spp.	0.110	*Bregmaceros* spp.	0.017

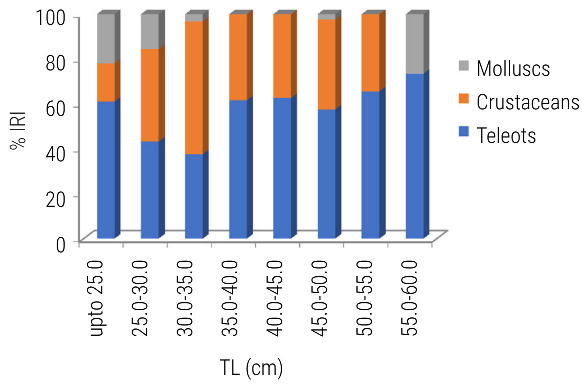

Fig. 7. Size-wise cumulative %IRI (by diet group) for *P. kaakan* at Visakhapatnam

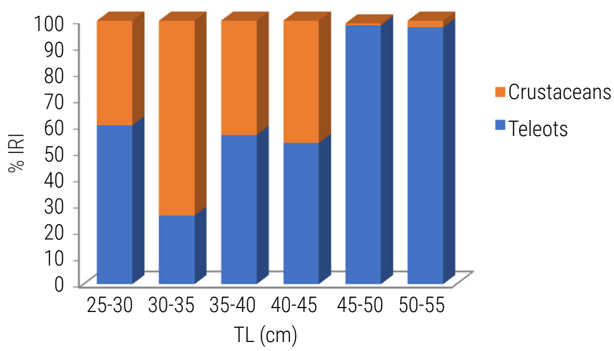

Fig. 8. Size-wise cumulative %IRI (by diet group) for *P. kaakan* at Puri

studies on the diet of *P. kaakan*. From the Persian Gulf, the main diet contents of *P. kaakan* was reported as crustaceans particularly crabs and shrimp, followed by fish and molluscs (Valinassab *et al*., 2011). Small shrimps were reported as the dominant diet item in *P. kaakan* from eastern Johor Strait, Singapore (Hajisamae *et al*., 2003). Dominance of crustaceans especially crabs and shrimps in *P. kaakan* diet has been reported from Australia as well (Bade, 1989). In our study too, if unidentified fishes were removed, the next highest diet constituents were from the crustacean group at Visakhapatnam. The high occurrence of fish in *P. kaakan* diets seen in Visakhapatnam samples in our study might be due to the confounding effects of bait fish. Small fish, predominantly scads, anchovies, small-sized mackerel, and ribbonfish are used as baits in hooks and lines in the study area for fishing (Muktha, M. and Sen, S. *pers. obs*.). Most of the identified teleost prey items which appeared to be non-bait fish (larger sized or not cut into regular pieces), like *Nemipterus japonicus*, *Leiognathus* spp., *Upeneus* spp., *Saurida* spp. and eels as well as the crustaceans (crabs and shrimps) were those associated with demersal habitats. This pointed towards the demersal/sea-bottom feeding nature of *P. kaakan* though comparing our results with earlier studies indicated that the diet of *P. kaakan* showed wide variations region-wise.

This study is the first to report on the reproductive biology of *P. kaakan* from India and provides information on the reproductive biology and diet of the species from western Bay of Bengal from two locations, Visakhapatnam and Puri which are separated by nearly 450 km. The similarity in length-weight relationship, length at first maturity and spawning season between these two locations indicate the possibility of a single stock of *P. kaakan* in the study region. The idea of a single stock needs to be explored further with genetic stock identification studies and if confirmed, can be used to map the spatial boundary of *P. kaakan* stock in the region. An effective and improved stock assessment rests on defining the stock correctly including its spatial scope and structure (Cadrin, 2020), which in turn can lead to impactful management measures to ensure sustainability of the species.

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References

Al-Husaini, M., Al-Ayoub, S. and Dashti, J. 2001. Age validation of nagroor, *Pomadasys kaakan* (Cuvier, 1830) (Family: Haemulidae) in Kuwaiti waters. *Fish. Res.*, 53: 71-81.

Annisa, C. A., Rahardjo, M. F., Zahid, A., Simanjuntak, C. P. H., Asriansyah, A. and Aditriawan, R. M. 2018. Diet and feeding habits of the Javelin Grunt, *Pomadasys kaakan* (Cuvier, 1830) in Pabean Bay, West Java. *Gadjah Mada University Fisheries Journal* 20(1): 31-40. https://doi.org/10.22146/jfs.31498 (In Indonesian).

Antony Raja, B. T. 1966. On the maturity stages of Indian oil-sardine, *Sardinella longiceps* Val., with notes on incidence of atretic follicles in advanced ovaries. *Indian J. Fish*., 13(1&2): 27-47.

Bade, T. M. 1989. *Aspects of the biology of grunts (Teleostei: Haemulidae) from North Queensland waters*. Ph. D thesis, James Cook University, Australia, 228 p.

Baras, E., Arifin, O. Z., Slembrouck, J., Subagja, J., Kristanto, A. H. and Legendre, M. 2018. Oil globule size in fish eggs: A matter of biome and reproductive strategy. *Fish Fish.,* 19(6): 996-1002. https://doi.org/10.1111/faf.12307.

Bianchi, G. 1985. *FAO species identification sheets for fisheries purposes, field guide to the commercial marine and brackishwater species of Pakistan.* Food and Agriculture Organisation of the United Nations, Rome, Italy, 200 p.

Biswas, S.P. 1993. *Manual of methods in fish biology*. South Asian Publishers. Pvt. Ltd., New Delhi, India, 157 p.

Blaber, S. J. M., Brewer, D. T., Salini, J. P. and Kerr, J. 1990. Biomasses, catch rates and abundances of demersal fishes, particularly predators of prawns, in a tropical bay in the Gulf of Carpentaria, Australia. *Mar. Biol*., 107: 397-408.

Braccini, J. M., Gillanders, B. M. and Walker, T. I. 2005. Sources of variation in the feeding ecology of the piked spurdog (*Squalus megalops*): Implications for inferring predator–prey interactions from overall dietary composition. *ICES J. Mar. Sci.,* 62(6): 1076-1094. https://doi.org/10.1016/j.icesjms.2005.04.004.

Cadrin, S. X. 2020. Defining spatial structure for fishery stock assessment. *Fish. Res.,* 221: 105397. https://doi.org/10.1016/j.fishres.2019.105397.

Falahatimarvast, A., Poorbagher, H. and Lokman, P. M. 2012. The reproductive biology of *Pomadasys kaakan* (Osteichthyes: Haemulidae) in the northern Persian Gulf. *Cah. Biol. Mar.,* 53: 25-34.

FAO 2021. .*FISHSTAT, License No. CC BY-NC-SA 3.0 IGO.* https://www.fao.org/fishery/statistics-query/en/capture. (Accessed 05 November 2021).

Fricke, R., Eschmeyer, W. N. and Fong, J. D. 2023. *Species by family/subfamily*. http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp.Electronic version (Accessed 25 January 2023).

Froese, R. and Pauly, D. 2022. *FishBase. World Wide Web Electronic Publication*. (Accessed 18 August 2022).

Froese, R., Winker, H., Gascuel, D., Sumaila, U. R. and Pauly, D. 2016. Minimizing the impact of fishing. *Fish Fish.,* 17(3): 785-802. https://doi.org/10.1111/faf.12146.

Froese, R. 2006. Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. *J. Appl. Ichthyol.,* 22: 241-253 https://doi.org/10.1111/j.1439-0426.2006.00805.x.

Garrett, R. N. 1996. *Biology and harvest of tropical fishes in the Queensland Gulf of Carpentaria gillnet fishery*. *Final Report FRDC Project No. 92/145*. Department of Primary Industries Queensland and Fisheries Research and Development Corporation, Australia, 119 p.

Hajisamae, S., Chou, L. M. and Ibrahim, S. 2003. Feeding habits and trophic organisation of the fish community in shallow waters of an impacted tropical habitat. *Estuar. Coast. Shelf Sci.,* 58: 89-98. https://doi.org/10.1016/S0272-7714(03)00062-3.

Jayabalan, N. and Ramamoorthi, K. 1985. Food and feeding habits of the silverbelly, *Gazza minuta* (Bloch) in Porto Novo waters. *Indian J. Mar. Sci*., 14: 110-112.

Karna, S. K., Mukherjee, M., Ali, Y., Manna, R. K. and Suresh, V. R. 2020. Length–weight relations of fishes (Actinopterygii) from Chilika Lagoon, India. *Acta Ichthyol. Piscat.,* 50(1): 93-96. https://doi.org/10.3750/AIEP/02640

Kendall, N. W. and Quinn, T. P. 2013 Size-selective fishing affects sex ratios and the opportunity for sexual selection in Alaskan sockeye salmon *Oncorhynchus nerka*. *Oikos,* 122(3): 411-420.

King, M. 2007. *Fisheries biology: Assessment and management*. Fishing News Books, Oxford, UK, 341 p.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.,* 20: 201-219.

McEvoy, L. A. and McEvoy, J. 1992. Multiple spawning in several commercial fish species and its consequences for fisheries management, cultivation and experimentation. *J. Fish Biol.,* 41 (Supplement B): 125-136.

Mous, P. J., Gede, W. and Pet, J. S. 2018. *Length-based stock assessment of a species complex caught in deepwater demersal fisheries targeting snappers In Indonesia Fishery Management Area WPP 718*. The Nature Conservancy Indonesia Fisheries Conservation Program AR_718_210418, 125 p.

Paighambari, S. Y., Daliri, M., Pouladi, M. and Arefi, H. M. 2018. Length–weight relationships of four marine fish species in the Gulf of Oman (Konarak, Iran). *J. Appl. Ichthyol.,* 34: 1007-1008. https://doi.org/10.1111/jai.13637.

Pinkas, L., Oliphant, M. S. and Iverson, I. L. K. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters. *Calif. Fish Game,* 152: 105.

Preciado, J. A. R., Amezcua, F., Bellgraph, B. and Madrid, J. V. 2014. Feeding habits and trophic level of the Panama grunt *Pomadasys panamensis*, an important bycatch species from the shrimp trawl fishery in the Gulf of California. *Sci. World J.*, 2014: 1-7.

Raeisi, H., Daliri, M., Paighambari, S. Y., Shabani, M. J., Bibak, M. and Davoodi, R. 2011. Length-weight relationships, condition factors and relative weight of five fish species of Bushehr waters, Northern Persian Gulf. *Afr. J. Biotechnol.,* 10(82): 19181-19186. https://doi.org/ 0.5897/AJB11.2650.

Ramani, K., Ammini, P. L., Srinivasan, J., Haja Najeemudeen, S., Beena, M. R., George, K. P., Seynudeen, M. B., Subbaraman, G., Anandan, K., Khambadkar, L. L., Augustine, S. K., Pugazhendi, D., Rudhramurthy, N., Subramani, S., Seetharaman, S., Kather Batcha, S. and Sankaralingam, S. 2010. An overview of marine fisheries in India during 2007. *Mar. Fish. Inf. Serv. T&E Ser.,* 203: 1-4.

Reuben, S., Rao, G. S., Luther, G., Rao, T. A., Radhakrishna, K., Sastry, Y. A. and Radhakrishna, G. 1987. An assessment of the bottom-trawl fishery resources of the northeast coast of India. In: *Proceedings of the National Symposium on Research and Development in Marine Fisheries Sessions I & II 1987*, *CMFRI Bull.,No.* 44, ICAR-Central Marine Fisheries Research Institute, Kochi, India, pp. 59-77.

Russell, M. and Pears, R. J. 2007. *Workshop summary: Management and science of fish spawning aggregations in the Great Barrier Reef Marine Park*, 12-13 July 2007. Museum of Tropical Queensland, Townsville, Australia. Great Barrier Reef Marine Park Authority, Townsville, Australia,14 p.

Saberi, M., Paighambari, S. Y., Darvishi, M. and Shilsar, G. F. 2017. Length–weight relationships of six fish species from the coastal waters of Jask, Iran. *J. Appl. Ichthyol.,* 33:1226-1228. https://doi.org/ 10.1111/jai.13326.

Sekharan, K. V., Muthu, M. S., Rao, K. V., Rao. V. R., Mojumder, P. and Reuben, S. 1973. Exploratory trawling on the continental shelf along the north-western part of the Bay of Bengal. In: *Proceedings of the Symposium on Living resources of the seas around India*, ICAR-Central Marine Fisheries Research Institute, Kochi, India, Mandapam Camp, Tamil Nadu, India.

Snedecor, G. W. and Cochran, W. G. 1967. *Statistical methods*. Oxford and IBH Publishing Co., Calcutta, India, 593 p.

Szczecinski, N. 2012. *Catch susceptibility and life history of barred javelin (Pomadasys kaakan) in north-eastern Queensland, Australia*. Masters (Research) thesis, James Cook University, Australia, 86 p.

Vahabnezhad, A., Hashemi, S. A., Taghavimotlagh, S. A. and Daryanabard, Gh 2021. Length based spawning potential ratio (LBSPR) of javelin grunter, *Pomadasys kaakan* (Cuvier, 1830) in the Persian Gulf and Oman Sea. *Iran J. Fish. Sci.,* 20(6): 1560-1572. https://doi.org/10.22092/ijfs.2021.125375.

Valinassab, T., Daryanabard, R., Dehghani, R. and Pierce, G. J. 2006. Abundance of demersal fish resources in the Persian Gulf and Oman Sea. *J. Mar. Biol. Ass. UK,* 86: 1455-1462.

Valinassab, T., Jalali, S., Hafzieh, M. and Zarshenas, G. A. 2011. Evaluation of some feeding indices of *Pomadasys kaakan* in the Northern Persian Gulf. *Iran. J. Fish. Sci.,* 10(3): 497-504.