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Biological observations of *Salmostoma novacula* fishery of a protected reservoir in India

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Abstract

Feeding and breeding biology of a prominent indigenous fishery of Peechi Reservoir (protected reservoir) was assessed using 300 specimens in this study. Catch composition studies identified *Salmostoma* sp. as the major species contributing to the reservoir fishery. With the help of mitochondrial CO1 gene, the species was identified as *Salmostoma novacula.* The feeding biology of the fishes was studied using index of preponderance (IOP), gastro-somatic index (GaSI) and relative gut length (RGL). IOP of *S. novacula* revealed that zooplankton dominated the gut of the species to the tune of nearly 70.82%. The mean RGL and GaSI of *S. novacula* was estimated at 1.42 (1.42±0.25) and 4.22 respectively. The indices used for reproductive study were size at first maturity, sex ratio, gonado-somatic indices and fecundity. The size at first maturity for *S. novacula* was found to be 13.0 cm. The sex ratio and relative fecundity were estimated at 1.2:1.0 and 8500-8833 nos. per gram body weight of fish. The study indicated that the fishes mature during March to August and exhibit spawning activity in September. The paper emphasises a need for enforcing minimum legal size and restricted monsoon fishing for sustained fisheries in this reservoir.

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Introduction

Tropical countries like India are bestowed with huge reservoir resources which were initially envisioned for hydro-electric power generation, tourism, irrigation and drinking water supply. Later, recognition of reservoirs as an alternate fish production centre in the country necessitated the development of various fishery enhancement strategies in these aquatic systems. Implementation of any fishery enhancement activity in a reservoir requires an investigation on fish diversity, distributions, habitat requirements and life histories of the concerned fisheries. Further, knowledge on key population characteristics (feeding and reproduction) of the dominant fish species of the concerned ecosystem is essential for the assessment and formulation of prudent management policies for fish stocks (Trindade-Santos and Freire, 2015).

Legal pluralism associated with management of reservoirs often make the fisheries of a system vulnerable. Similar management hurdles in reservoir fisheries were observed in Peechi and Pothundi reservoirs in Kerala, India. Multiple stakeholders' namely public works, irrigation, forest and fisheries departments of Kerala Government were involved in the management of the reservoir. The present study taken up in Peechi Reservoir in Thrissur District of Kerala, India focused on bringing out appropriate reservoir-based fishery management measures in protected ecosystems, based on the biology (feeding and reproductive) of the dominant fishery of the ecosystems.

Materials and methods

The study was conducted in Peechi Reservoir in Kerala, Peechi (Fig. 1) which is an artificial tropical lake situated in Thrissur District and is geographically located between 10.5060N, 76.394^{0}E and 10.55^{0}N, 76.391^{0}E. The reservoir with a water spread area of 12,500 ha was built across Manali River and is encompassed in Peechi-Vazhani Wildlife Sanctuary. The fisheries and allied activities

Fig. 1. Satellite image of Peechi Reservoir

of the reservoir were practiced through Peechi SC/ST Co-operative Society, Reg. No. FR-748, Peechi Reservoir, Thrissur. The fishery activities associated with the reservoir include stocking of indigenous fishes such as *Etroplus suratensis, Clarias dussumeri* and *Tor khudree,* capture of wild indigenous fishes and recapture of stocked fishes. Being a wildlife sanctuary, the stocking of cultivable fishes such as Indian major carps are not permitted in this reservoir.

Catch composition studies of Peechi Reservoir were carried out during 2016-2018 to identify the major indigenous single species which formed a fishery in the reservoir. The fish specimens after identification were used for molecular analysis and biological studies. The whole genomic DNA extraction (Miller *et al.,* 1988) was carried out using the salting out method. The CO1 gene was amplified using universal primer pair (Ward *et al.* 2005): Multiple alignment of DNA sequences of the COI gene was done using CLUSTAL W in Bioedit software 7.0.5.2 (Hall, 1999). DNA sequence information of COI gene was translated to amino acid sequences using MEGA 7 (Kumar *et al.,* 2016).

For biological studies, 300 specimens of the selected species were collected from Peechi Reservoir. Total length and weight were measured using a measuring board and balance respectively. The gut and gonad of fish specimens collected were stored in separate vials in 5% formalin and analysed for feeding and reproductive biological studies. The data collected were pooled and analysed month-wise. Feeding biology studies included determination of gastro-somatic index and Index of preponderance. Gastro-somatic index (GaSI) was calculated using the following formula (Desai, 1970):

GaSI = Weight of the stomach x 100 / Total weight of the fish

The index of preponderance (IP) was estimated to identify the most preferred prey of the fish selected for the study following Pinkas *et al.* (1971) as:

$IP = (ViOi / \sum_{i=1}^{i=n} ViOi)\ \%$

where, Vi is volume of prey in the gut and Oi is the occurrence of prey in the gut.

Reproductive biological studies included estimation of spawning season, size at first maturity, gonadosomatic index, fecundity and sex ratio. The sex was determined macroscopically (through dissection). Maturity and spawning seasons were studied using 106 female specimens. Developmental stages were determined based on ICES (International Council for Exploration of the Seas) scale (Wood, 1930). Size at first maturity was determined based on the examination of the maturity stages. Female specimens in stage III and above were considered as mature for the present study. Fecundity of the fishes was estimated using gravimetric method (Hunter and Goldberg, 1980; Murua *et al.,* 2003) by examining a total of 5 (five) mature ovaries of fishes.

Fecundity = No. of ova in the sample x Total ovary weight / Weight of sample

Relative fecundity *i.e.* no. of eggs per gram of body weight (unit body weight or ovary weight) was obtained by dividing absolute fecundity with total weight of the fish.

Results

Catch composition

Species composition studies in Peechi Reservoir (Fig. 2) indicated that Dam sardine *Salmostoma novacula* (Fig. 3) was the indigenous fishery contributing to nearly 14.05% of the catches throughout the year. *S. novacula* is a cheap protein source available throughout the year. The species meets the daily protein requirement of fisher families associated with the reservoir. The species is in high demand in the reservoir as it fetches ₹200 per kg.

Molecular identification

The 617 base pair CO1 sequence obtained was homology searched in NCBI-GenBank using BLAST and the species was identified as *Salmostoma novacula* and the sequence was submitted to GenBank with the Accession No. KF429839.1.

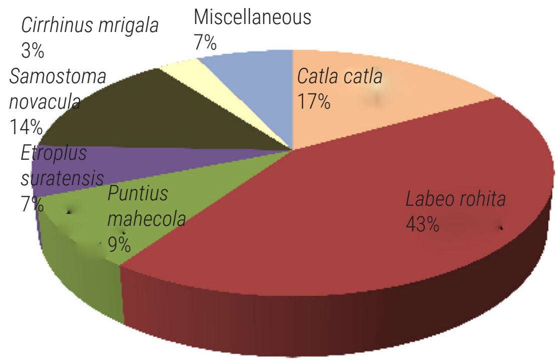

Fig. 2. Catch composition of Peechi Reservoir

Length-weight relationship (LWR)

The estimated LWR of *S. novacula* in Peechi Reservoir indicated the growth rate to be 2.93±0.051 SE (R^2 = 0.9309) suggesting negative allometric growth (Fig. 4).

Feeding biology

Index of preponderance of major group of prey species (Fig. 5) in the gut of *S. novacula* showed that zooplankton (calanoid copepod and nauplii) dominated the gut of the species to the tune of nearly 70.82% followed by phytoplankton (23.92%), vegetation (2.41%), ciliates (2.67%) and digested organic matter (0.18%). Among the zooplankton, calanoid copepod (68%) was the dominant item contributing to the food of the fish, followed by filamentous algae (22%), ciliates (5.4%), diatoms (4.84%) and vegetation (4.55%). The major diatoms encountered in the gut included *Gonatozygon* sp., *Staurastrum* sp., *Desmidium* sp. and *Closterium* sp.

Season-wise representation of the gut contents (Fig. 6) showed that vegetation was dominant in the diet of the species during pre-monsoon season (26.54%) followed by filamentous algae (26.54%) and dinoflagellates (20.85%). Calanoid copepod dominated the gut content during post-monsoon and monsoon at 51.19 and 71.62% respectively.

The mean relative gut length estimated from 25 specimens was 1.42 (1.42±0.25 SD). The mean gastro-somatic index of *S. novacula* was 4.22 indicative of the weight of the stomach across the year. Month-wise GaSI (Fig. 7) showed that August had the highest GaSI (5.1±0.23) followed by May (4.8±1.1). The lowest GaSI was seen in Dec (2.32±0.39) and March (3.2±1.1).

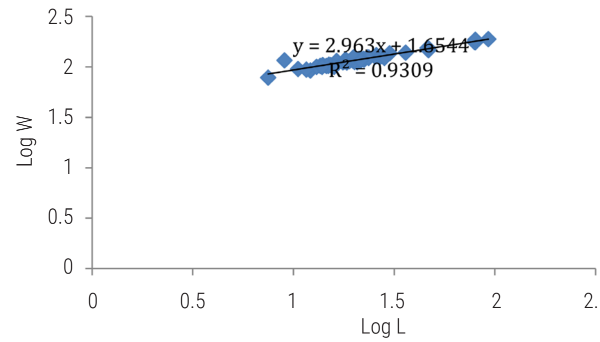

Fig. 4. Length-weight relation of *S. novacula*

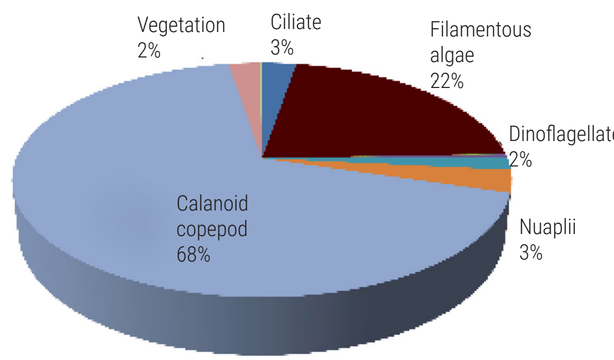

Fig. 5. Index of preponderance of prey items in the gut of *S. novacula*

High GaSI values were recorded in the monsoon (June to September) and post-monsoon seasons (October to November). This may be attributed to the availability of preferred food (calanoid copepod) during these seasons. The low GaSI values as observed in Fig. 7 is concurrent with the pre-monsoon season which is characterised by reduced availability of the preferred food.

Reproductive biology

The size at first maturity based on examination of 291 females in the maturity stage of III and above was estimated to be 13.0 mm (Fig. 8).

S. novacula in Peechi Reservoir showed spawning activity in concurrence with monsoon and post-monsoon seasons. Fig. 9 indicated that GSI is increased from March (3.14) to August (4.41), relating to the maturing period of the fish. A sudden dip in GSI (Fig. 9) in September (2.71)

Fig. 3. *Salmostoma novacula* (Valenciennes, 1840)

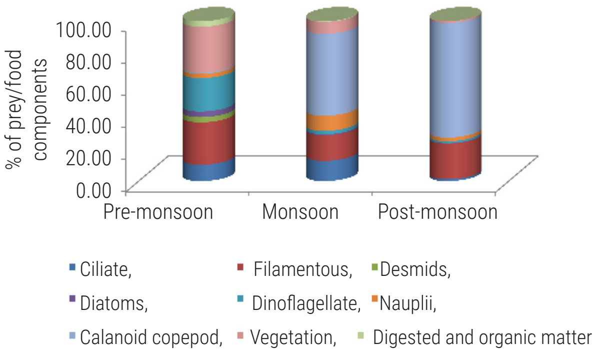

Fig. 6. Season-wise index of preponderance of prey species in the gut of *S. novacula*

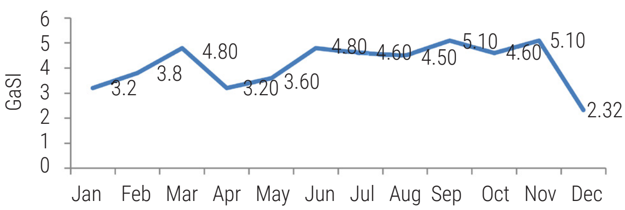

Fig. 7. Month-wise gastro somatic index (GaSI)

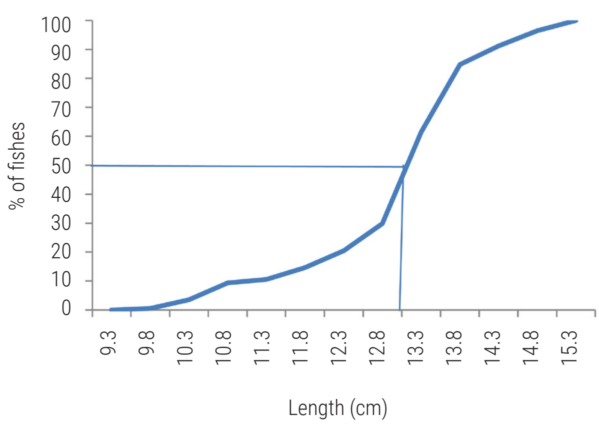

Fig. 8. Size at first maturity of *S. novacula*

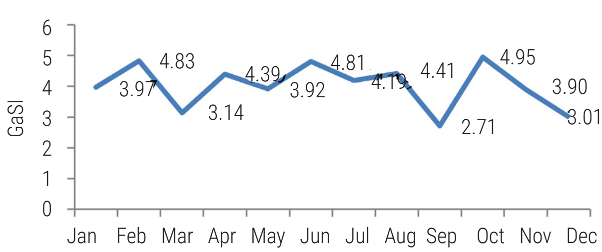

Fig. 9. Gonadosomatic index of female *S. novacula*

indicated that the species exhibited spawning activity during August to September (in accordance with monsoon season). The estimated mean sex ratio was found to be 1.2:1.0. The absolute fecundity ranged from 28,050 to 42,120 nos. of eggs for the ovary weighing between 0.3 to 1.1 g. The relative fecundity ranged from 8,500-8,833 nos. per gram weight of fish. Studies by Dewan and Saha (1979) showed that the absolute fecundity ranged from 7,146 to 33,997.

Discussion

Length-weight relationship

The well-being of fishes are assessed using the relationships between morphometric characters of the individual fishes (King, 2007) such as length-weight (LWR) relationships (Moutopoulos and Stergiou, 2002; Kara and Bayhan, 2008; Froese *et al.,* 2011). In the present study, the LWR indicated that the b value (2.93±0.051 SE) of *S. novacula* was significantly lower than 3 and hence the species displayed negative allometric growth, which was similar to the observations in a previous study on this fish in Yamuna in Allahabad (Masud and Singh, 2015). However, studies by Islam *et al.* (2016) on similar species in reservoirs such as *Salmophasia bacaila* (b= 2.755) and *S. phulo* (b=3.22) indicated negative and positive allometric growth respectively, indicating that the growth pattern of reservoir fishes is probably highly influenced by environmental conditions.

Feeding biology

The study of food and feeding habits of fishes help in understanding various aspects such as the preferred food items and the food spectrum overlapping with that of co-existing fishes (Basudha and Vishwanath, 1999), the trophic interactions in aquatic food webs (Vander Zanden *et al.,* 2000) and in determining the niche in the ecosystem.

The index of preponderance of *S. novacula* in Peechi Reservoir showed that the fish has specificity towards calanoid copepod and it is the most preferred food of the fish. But feeding biology studies on similar species, *S. untrahi* indicated the preference of fish towards insects and their larvae to the tune of 55.4% followed by vegetative matters (18.5%). Season-wise estimate of index of preponderance indicated the predominance of calanoid copepod during monsoon and post- monsoon seasons. Similar observations on the gut composition of the species were recorded in *S. untrahi* by Kiran *et al.* (2004). Studies by Peyami (2018), however indicated the predominance of insects (41.5%) and vegetable matter (29.25%) during monsoon season. The seasonal variation in food habits of fishes is dependent on the changes in the composition of food organisms at different periods of the year. The mean relative gut length of *S. novacula* of 1.42 indicated omnivorous feeding behaviour.

GaSI estimates indicated that the fishes exhibited high feeding intensity during August and October. The mean gastro-somatic index (GaSI) of *S. novacula* was more in monsoon (4.72) compared to post-monsoon (3.72) and pre-monsoon (3.9). This may be due to the availability of more food during monsoon season in the reservoir. Similar results were reported by Kiran *et al.* (2004).

Reproductive biology

Fish reproductive biology is crucial for fishery management (Jakobsen *et al.,* 2009), especially in developing countries such as India, where managers rely on size at first maturity and the onset and duration of spawning season for managing fisheries (Dias-neto, 2011). The success of reproductive activities depends on the match between spawning season and the best conditions for larval survival (Cushing, 1990; Lowerre-Barbieri *et al.,* 2011). Hence, it is fundamental to have basic biological data in order to conduct a reliable management system.

Maturity ogive of a fish is an important population attribute directly related to the reproductive potential of the population. The size at first maturity for *S. novacula* in Peechi Reservoir was found to be 13 cm (Fig. 9). Knowledge on the maturity ogive is significant in exploited fish populations because it determines the spawning biomass upon which conservation measurements are usually based.

The gonadosomatic index (GSI), may be identified as the best predictor of spawning period (Tsikliras *et al.,* 2013). The study indicated prolific breeding pattern of *S. novacula* in Peechi Reservoir with high GSI at 4.95 in the month of October. Other breeding peaks were observed in the months of June and February with GSI values 4.81 and 4.83 respectively. Similar spawning pattern in *P. mahecola* was reported by Selvaraj (2000) where mature fishes were available during January-May and October-December indicating two spawning peaks in the population. Studies by Peyami (2018) indicated from similar observations made on the maturity and breeding season of *S. bacaila* that the fish breeds during June to early September.

Fisheries management in a reservoir should be based on the spawning activity of the major fishery resource. The spawners may be excluded from fishing inventories during monsoon season (August to September). Mesh sizes of 40 mm and above should be insisted upon in this reservoir to avoid growth overfishing. Strict enforcement of mesh size regulation and restricted monsoon fishing would ensure sustenance of the fishery. Identification of allied fishery activities as alternate livelihood options for these fishers would reduce attrition of fishers from reservoir fisheries.

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