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Reproductive biology of the flathead grey mullet, *Mugil cephalus* (Linnaeus, 1758) from Krishna Estuarine Region, East Coast of Andhra Pradesh, India

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Abstract
The present study was aimed to establish the information on reproductive biology of the flathead mullet in the coastal waters near Krishna estuarine region based on biological sampling between September, 2005 and August, 2006. The following aspects of reproductive biology namely maturation, ova-diameter studies, gonado-somatic index, spawning season and fecundity of *Mugil cephalus* were presented and significant observations were recognized. This study has contributed to the updating of reproductive parameters of *M. cephalus*. This will strengthen the basis of biological knowledge for the management of the species.

Keywords: Fecundity, spawning season, Gonado-somatic index and *M. cephalus*

1. Introduction
Fishes of the family *Mugilidae* represents one of the major commercial resources of tropical and warm temperate estuaries [1, 2] and their ecological function in food webs is of the greatest importance [3, 4]. In the past, mugilids were believed to be the most abundant species in almost all the estuaries along the Indian coast and hence formed a very important species for the local fishery. Unfortunately, after extensive land reclamation of lagoons and brackish water lakes together with the constant pollution from agriculture and upstream industries and high fishing pressure, the status of mugilids is now fragile. At least one species, flathead grey mullet, *Mugil cephalus* L. 1758, is becoming endangered and rare [5]. The mullets form one of the important fisheries of the estuaries and coastal waters of India constitute less than 0.3% of the total marine landings. *Valamugil seheli* being the largest species among mullets has many desirable features, which make them suitable for aquaculture. There are only few reports on biology of *Mugil parsia* [6], biology ad fishery of grey mullets [7], embryonic and larval developmental studies of *Liza macrolepis* [8] fecundity of the grey mullet [9], some aspects of biological studies on *Liza tade* [10, 11] on the reproductive biology of mullet inhabiting Indian waters.
An increase in understanding the reproductive biology of mugilids is essential to determine the parameters to be used in age-structured models of stock assessments. Moreover, knowledge of spawning season and fishing location are instrumental in establishing time and area closures to protect essential fish habitats along with modification of fishing gear to enhance the survival of heavily exploited species [12]. All grey mullets are abundant in estuaries and inshore waters, where they spend most of their life, but they spawn in marine waters [13]. The reproductive cycle of a few grey mullet species in some of the estuaries and lagoons has been analyzed [14, 15]. In Indian waters, revisions of the taxonomy and biology of *M. cephalus* (Linnaeus, 1758) and grey mullets *Mugil tade* was studied by [6, 16, 17] and food and feeding habits of the grey mullet *Mugil macrolepis* and age growth studied by [19]. From world waters reproduction of *M. cephalus* and *M. curema* from a coastal Lagoon in the Gulf of Mexico [18]. Present aim of the study described their maturation; ova-diameter studies, gonado-somatic index, spawning season and fecundity of *Mugil cephalus* were presented.

2. Materials and Methods
An observation reported in this work was based on the examination of specimens collected from Krishna Estuarine Region, East Coast of Andhra Pradesh. After measuring the total length and weight of each specimen, the belly was cut open to note the sex, colour and general

appearance of the gonads which were then weighed to the nearest 0.1 g and preserved in 10 percent formalin. Observations on the maturation of gonads in adults, and the determination of the spawning season has been carried out mainly on the basis of examination of the ovaries, since the male gonad (testis) did not show identifiable changes during maturation. Ova diameters were taken on the ova collected from anterior, middle and posterior regions of the left ovary. Ova were teased out on a micro slide in the same medium in which they were preserved and measured under the compound microscope with the help of an ocular micrometer at a fixed magnification. At this magnification one micrometer division (md) in the ocular micrometer is equivalent to 0.02 mm.

The ova diameter studies were carried out by measuring 70 ova from each ovary (stage III and IV) in 50 individuals in the length range 14-30 cm Total length.

Gonado-Somatic Index (GSI) was calculated in females during the period of study. The Gonado-Somatic index or coefficient of maturity: Fecundity was estimated from this data by using the following equation [21]:

$$\text{Fecundity} = \frac{\text{Ovary Weight}}{\text{Weight of the sample}} \times \text{No. eggs}$$

Fecundity is defined as the number of ripening, ripe eggs found in the ovaries prior to spawning [22]. It is estimated to study the differences between stocks of fish [23] Fecundity can be used to identify a particular stock [22].

3. Results and Discussion

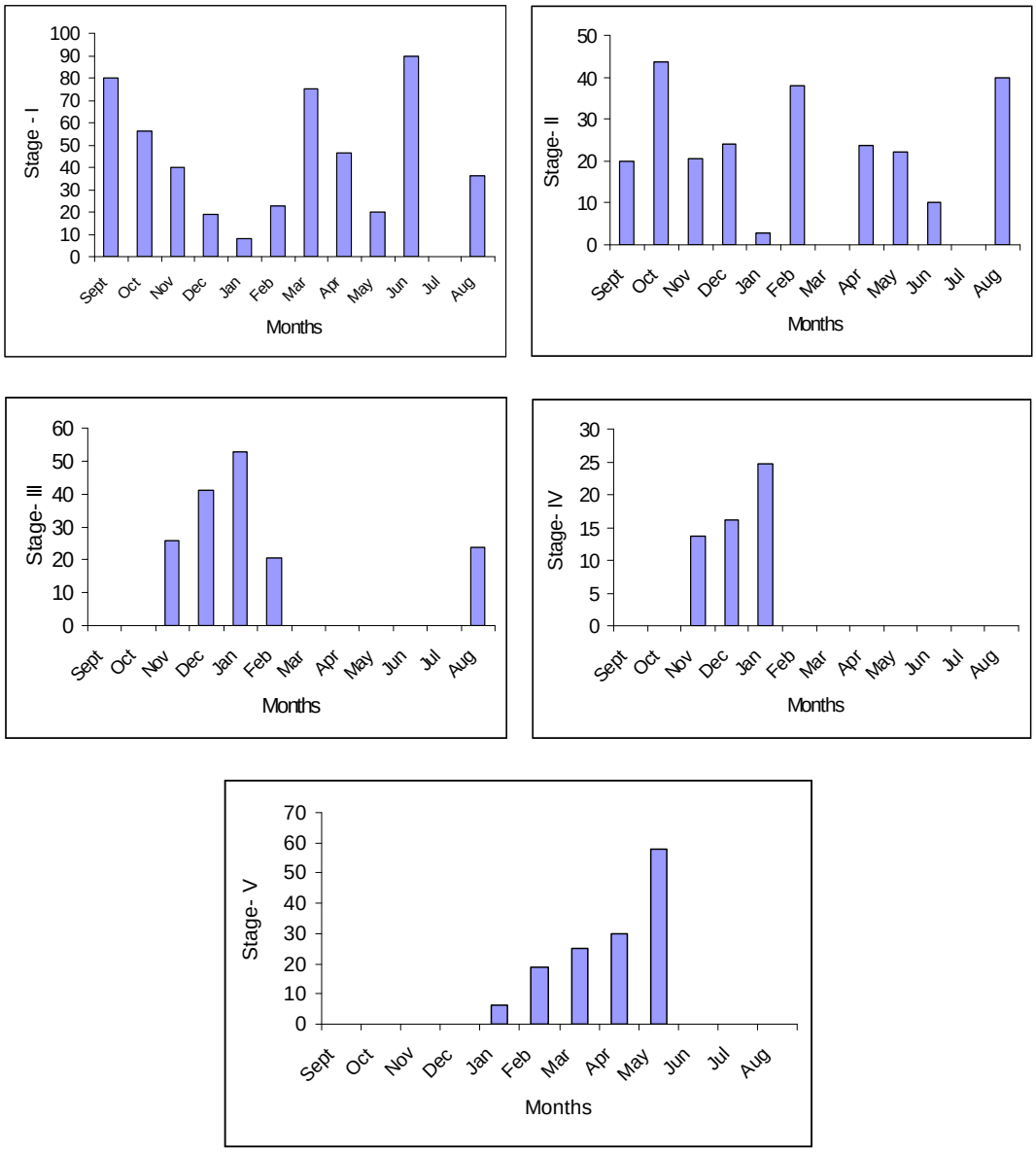

Fig 1: The monthly percentage distribution of different maturity stages

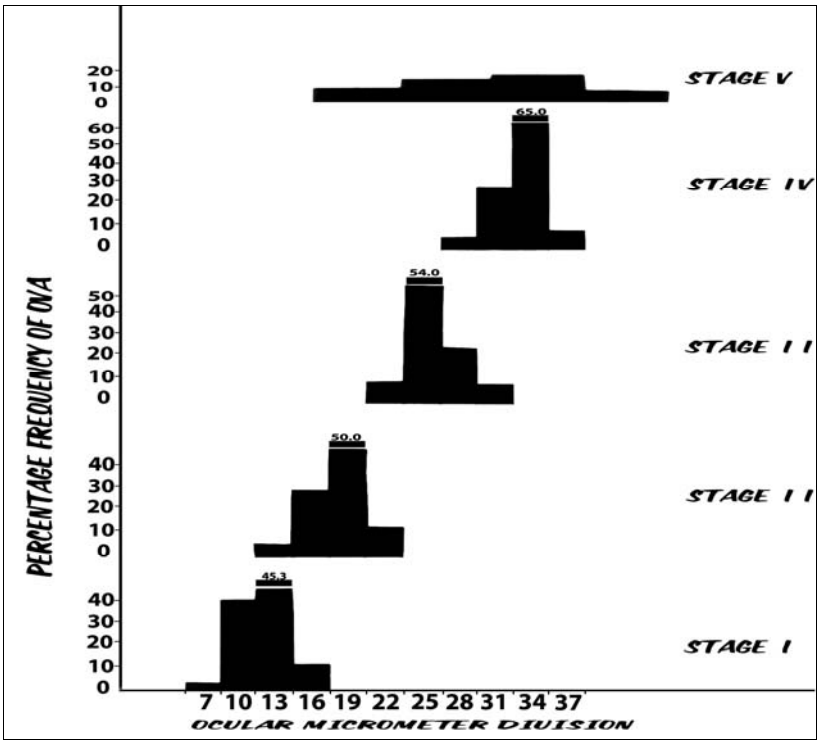

Fig 2: Size progression of ova of *Mugil cephalus* in different maturity stages

4. Development of Ova to Maturity

The percentage frequency distribution of ova diameters in different stages of maturity are represented (Figure.1 and 2). In stage I the ova are smaller in size, irregular in shape and measure in size (diameter) between 0.12 and 0.32 mm. In the ovaries in maturing stage, the ova range in size between 0.26 and 0.44 mm. In mature stage the size of ova varies between 0.44 and 0.62 mm. few ripe ova present in the mature ovary range between 0.56 and 0.74 mm. in diameter.

In the present study the frequency distribution of ova diameters in the mature ovary exhibit a single group of ova that are released in a single spawning act [24, 25, 26]. The same frequency distribution of oocyte diameter is of unimodal type [27, 28]. Mullets show a non-intermittent spawning, which is an indication of unimodal type of ova diameter frequency distribution [29].

5. Length at first maturity

Estimation of minimum length of the fish at first maturity in a fish stock helps in the determination of the spawning stock. Maturation of gonads starts before the spawning season and the ova become ripe. The size at which the fish becomes mature varies among different fish stocks. Length at first maturity in a species is determined on the basis of the minimum length at which 50 per cent of individuals in the stock become mature and spawn during the spawning season. This method was earlier adopted by in *Sardinella caerulea* the maturity stages were studied [31]; studies in biology of *Setipinna phasa* from Ratnagiri [32]. Studies in biology of *Opisthopterus tardoore* from Ratnagiri; from Andhra Pradesh in *Mystus cavasius* [33], maturity and spawning in the murrel, *Channa punctata* (Bloch, 1793) from Guntur, Andhra Pradesh [34], biology of *Mystus Vittatus* (Bloch) from Guntur, Andhra Pradesh [35], Spawing biology of *Nemipterus delagoae* [36].

The present study on the minimum size at first spawning in the stocks of *M. cephalus* from the Krishna estuarine region is based on 220 individuals collected from the fish landing centre. Studies on the spawning season of *M. cephalus* show that the mature individuals migrate to the off-shore areas for the purpose of spawning from December to January. Females with maturing, mature and ripe ovaries were utilized in the study. In the samples collected, individuals measuring less than 13 cm were with immature gonads, the smallest female with mature gonads was observed to belong to 13cm group. Females larger than 18cm are with mature gonads. The percentage frequency of mature individuals in each length group during maturation season was presented in figure- 3. 50 percent of the individuals in the 16cm length group are with mature gonads and hence 16cm length group was considered as the minimum size at maturity in this stock.

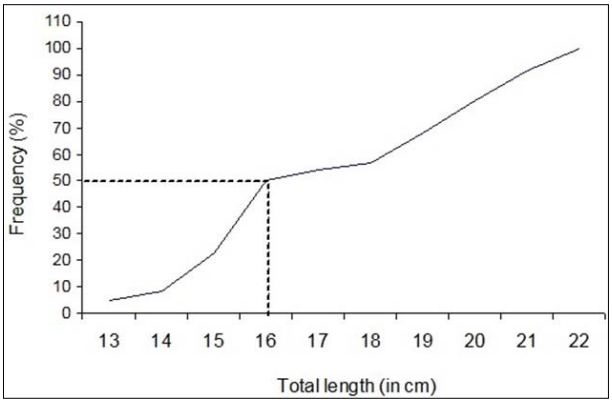

Fig 3: Percentage frequency distribution of mature females in different length groups

6. Gonado-Somatic index

The present study is based on gonad weights of fish collected from 132 female individuals in the size range 13.4 to 30.5cm TL. The average monthly values of Gonado – Somatic index in adults during different months during the period of study are presented in figure-4. In the present study the Gonado-

Somatic index (GSI) values were considerably low (0.32 to 3.8) from February to September, with the lowest value in the month of March. During this month the gonads are in spent condition as the fish are known to spawn from January onwards. The development of gonads in the female fish commences from October and the Gonado-Somatic index was ranged from 8.1 to 11.5 percent from October to January. The maximum value of Gonado-Somatic index was recorded in December. The Gonado-Somatic index from January onwards showed a decline indicating the beginning of spawning.

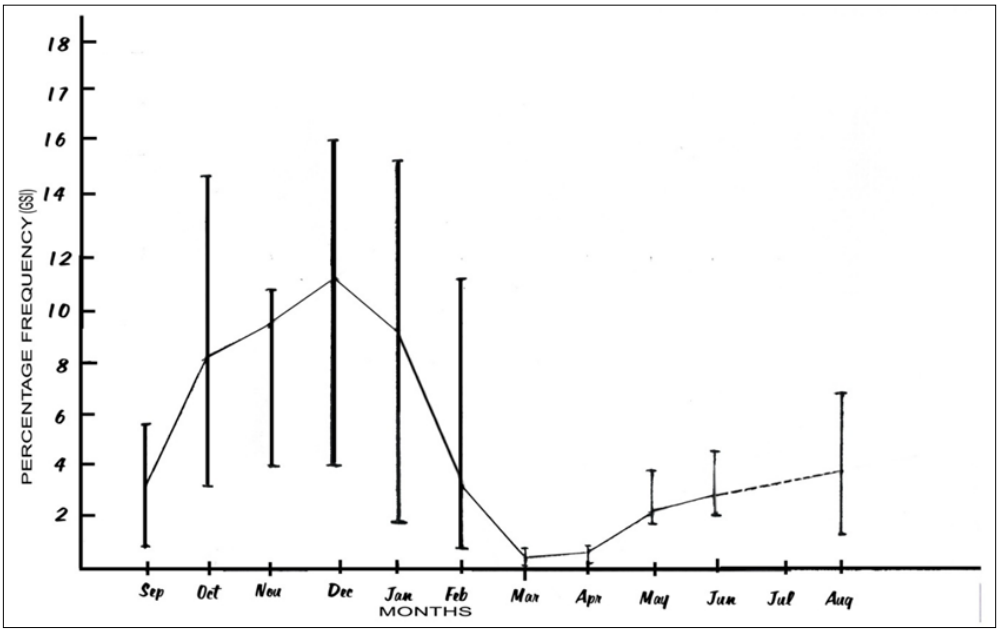

Fig 4: Gonado-somatic index (GSI) in females during different months

7. Spawning

Spawning behaviour of mullets have been studied earlier [37] from South Africa; [38] from Newzeland; [39] from Texes, USA. In Indian waters previous studies carried out various studies on taxonomy and collection [40] biology [41], distribution, breeding [42], and feeding habits of mullets [43, 44]. *Mugil cephalus* is known to mature in coastal waters and migrates into in the deeper oceanic waters for the spawning. Hence in the present area of study only few specimens with ripe gonads were collected. Presence of a single group of ripe ova indicates that the ova develop synchronously [45, 28] in the ovary and they spawn in a single spawning act.

8. Spawning season

In the present study spawning season of *M. cephalus* is determined based on indirect evidence collected from the studies on the stages of maturation and Gonado-Somatic index in the samples during different months. From late January, in the coastal waters, individuals with spent gonads started appearing in catches. In the month of February number of individuals with spent gonads increased in number and reached a peak. In March few individuals with spent gonads were noticed. The above data indicates that individuals of *M. cephalus* after becoming mature migrate to the oceanic waters; spawn and the spent individuals migrate back into near coastal waters in this region. From the above evidence on the stages of maturation of ovaries, and the Gonado-Somatic Index it can be concluded that spawning takes place in this region during late January and February. In South African waters *M. cephalus* was known to spawn two times in a year suggests that *M. cephalus* may spawn more than once during a long spawning season [37, 39], the temperature optimal for spawning for *M. cephalus* was between 19.5 to 22 ºC in Korean waters [46]. In Hong Kong waters *M. cephalus* spawns during full moon period at the end of November and December [47]. In Indian waters the breeding of *M. cephalus* takes place during the post-monsoon period [43]. *M. cephalus* spawns on the sandy grounds in Florida Bay [48]. In the species of *M. cephalus* has prolonged spawning season extending from September to February [49]. The present study shows that the spawning takes places from late January till the end of February.

9. Fecundity

In the present study fecundity in *M. cephalus* was estimated in adult females in length ranges from 14.0 to 30.5cm TL whereas in weight ranged from 28 to 248g. Absolute fecundity in these specimens ranged from 0.4 to 5.2 million. In one specimen of 30cm TL weighing 248g absolute fecundity was estimated to be at 8.2 million. Earlier studies on fecundity of *M. cephalous* from India show that in Lake Pulicat the fecundity ranged between 0.43 and 4.71 million in the specimens in the length range from 22 to 50cm TL. A comparison of present data with the earlier studies on fecundity from Lake Pulicat show that the stocks of Interu mangrove swamp exhibit higher fecundity. Similar observations has been made out previously by several authors on the fecundity of *M. cephalus* from India [40, 50, 51, 52, 20, 53, 54, 55, 34, 56, 57, 28, 59, 60].

10. Sex-Ratio

Knowledge of the sex-ratio in a fish population during different months or seasons is essential to know their relative abundance in the spawning stocks. The sex-ratio of a fish stock may also reveal differential fishing [59], affecting the stocks and also differences in growth rate of the two sexes [60]. The adolescent and adult fish migrate in to offshore regions after the maturation of gonads for spawning. After spawning

they migrate back in to coastal waters and enter the water bodies near the estuary. The migratory behaviour of the stocks accounts for the changes in the sex- ratio in the samples. Earlier studies on sex- ratio of *M. cephalus* in the Lake Pulicat show that the sex ratio 1.56: 1 indicating the preponderance of males.

Recently in Gulf of Mexico lagoon [18] observed in the two species of *Mugil*, the sex-ratio between males and females in 1: 1.1. The sex-ratio observed in the present study is 1.99: 1.

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