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Maturation profile and fecundity of the exotic *Oreochromis niloticus* in the River Yamuna, India

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Abstract

The knowledge on the reproductive biology of fish*Oreochromis niloticus* (Linnaeus, 1758) in riverine condition is meagre in the Indian sub-continent which is necessary for the development of an appropriate fishery management protocols for the rivers. In this context, the gonadal maturation profile and fecundity of *O. niloticus* was studied. Mature, spawning and spent females recorded in almost all the months of the year evidenced multiple and prolonged breeding behaviour. An overall sex ratio (M/F) of 1: 1.08 observed was statistically non-significant from expected 1:1 ratio (χ^2=6.994219, p=0.8642) indicating that males and females were statistically equal in number. The absolute fecundity ranged from1192 to 4760 with mean of 2590 eggs from ovary weighing between1.91 g to 28.89 g. Monthly changes in gonado-somatic index (GSI) revealed that fish bred throughout the year except in July and August, but at peak between October-November and March-June. Size at first maturity of male was estimated as 229.6 mm with confidence limit of 235.9 and 223.6 mm and for female as 238.1 mm with confidence limit of 244.7 and 231.7 mm, respectively.

Key words

Fecundity, Gonado-somatic Index, Maturity, *Oreochromis niloticus*, Yamuna

Introduction

Information on different aspects of reproductive biology of the fish species is required to determine its resilience capacity, sustainable exploitation and understanding the population dynamics aimed at successful management of any fishery (King,1995). Nile tilapia, a species of Cichlidae family is rapidly spreading in the Ganga river system (Singh *et al*., 2010; Anon, 2011). Among 112 genera of the family Cichlidae known globally (Nelson, 2006). There are three genera reported from India, two are exotics viz. *Oreochromis, Pterophyllum* and one endemic to the peninsular India namely *Etroplus*. Nile tilapia *Oreochromis niloticus* native to Nilo-Sudanian ecoregion of Africa (McAndrew, 2000) is widely distributed globally with presence in at least 85 countries (Lowe *et al*., 2012). Unauthorised introduction of Nile tilapia *Oreochromis niloticus* in India is reported to have taken place, sometime back in 1980's. Hydrological alteration of the riverine habitat from highly fluviatile to stagnant water, ability to tolerate extreme environmental conditions, fast growth, successful reproductive strategies and omnivorous feeding habit have favoured Nile tilapias to be successful invasive species (Peterson *et al*., 2004; Bwanika *et al*., 2006;Grammer *et al*., 2012). Introduction of exotics is recognised as the most serious threat only next to the habitat modification, posing threat to the native fish species. The appearance of tilapia in catches from river Yamuna at Allahabad was observed since July 2005 (Masud and Tyagi, 2007), reached to 36.3 t in 2010 (Anon., 2011) has changed the fishery scenario dramatically in river Yamuna.

Extensive studies on the various aspects of reproductive biology of *O. niloticus* have been carried out in different parts of the world. Studies on reproductive biology from abroad includes that of Gómez-Marquez *et al.* (2003) and Peterson *et al.* (2004) from Mexico, Komolafe and Arawomo (2007) from Nigeria, Njiru *et al*. (2006) in lake Victoria from Kenya. The knowledge base on the reproductive aspects of *O. niloticus* is lacking from the Indian

sub-continent which is fundamental in the study of biology, population dynamics and for the development of an appropriate fishery management of the river Yamuna.The present work was undertaken to investigate the reproductive season, sex ratio, fecundity and size at first maturity of *O. niloticus* in the river Yamuna to add to the existing knowledge of species which would further help in the management of fishery and river.

Materials and Methods

Study area : Fish specimens examined during the present study were collected regularly from the catches landed at Sadiapur landing centre located on the bank of river Yamuna in Allahabad of Uttar Pradesh, India.Global positioning system (GARMIN, GPSmap76CSx) was used to locate the sampling site. River Yamuna originating from lower Himalayas in Yamunotri meets river Ganges at Allahabad after traversing a distance of 1376 km. River Yamuna exhibit large seasonal variation in discharge with manifold increase during monsoon and extremely low during non-monsoon.Allahabad has humid sub-tropical climate with three defined seasons namely winter (November-February), summer (March-June) and monsoon (July-October). The average temperature ranges between 9-42 ºC with average annual temperature being 26 ºC. Total average annual precipitation is 1027 mm. The mean values of certain water quality parameters like dissolved oxygen, total alkalinity, total hardness, total dissolved solids, chloride, specific conductance and pH were 8.1, 138.9, 13.4, 193.5,69.4 ppm, 357.2 µmhos cm^{-1} and7.6 respectively.

Sampling procedure : A total of 399 fish specimens with 192 males and 207 females were collected randomly during October, 2011 to September, 2012 at monthly intervals. Their weights were measured to nearest gram and lengths to mm. Length and weight of males, ranged between 155-385 mm and 90-1272 g while that of females ranged from 155-345 mm and 86-790 g respectively. The specimens were dissected, their sex noted, gonads and livers removed and weighed to nearest mg. Gonads were preserved in specimen bottles containing 4% formalin. Statistical analysis ($\chi 2$) tested a null hypothesis of 1 male: 1female with significance set at α=0.05. Gonadosomatic index (GSI) was calculated using the formula: GSI = (weight of the gonad/ Total body weight) *100. Gravimetric method was used for estimation of fecundity. Fecundity (F) and ova diameter were determined from preserved ovaries after separation of ova by using Gilson's fluid by counting the number of oocytes (O_i) in weighed sub-sample (W_i)from three segments (anterior, middle and posterior) of each ovary with accuracy of 0.001g tissue using the formula: Absolute fecundity$(F)=[(\sum O_i/W_i)/n]*W_{ovary}$.To know the nutritional state of fish, Hepato-somatic index (HSI) was calculated on monthly basis following Busacker *et al*. (1990). Maturity stages were assigned as I-VI based on the macroscopic appearance of gonads (Witte andVan Densen,1995). Fish at I to III maturity stages were treated as immature and IV to VI as mature.

Results and Discussion

Among the collected samples, females ranged in weight from 86 to 790 g and in length from 155 to 345 mm, while males ranged from 94 g to1272 g in weight and 155 mm to 385 mm in length respectively. Maximum weight of the testes and ovaries was 10.89 g and 28.89 g respectively. Length frequency distribution of *O. niloticus* of river Yamuna, during October 2011 to September 2012 is depicted in Fig. 1 and the largest percentage of Nile tilapia (82%) was found to be within the length of 270 mm.

Maturity stages and spawning season : In the present study, IV to VI stage of maturity occurred from September to June. Majority of mature and spawning females (stages IV, V) were observed during October to November and April to June (>20%) with maximum being in April (67%), November and October (43%), low in February (9%) and September (8%) and almost nil in July and August. In addition, maximum percentage of spent female was observed during January and June (33%). Hence, peak breeding period was between October-November and between March–June.Thus the spent, mature and maturing female, found in almost all months, indicate multiple and prolonged breeding habit (Fig. 2). Messina *et al*. (2010) observed highest percentage

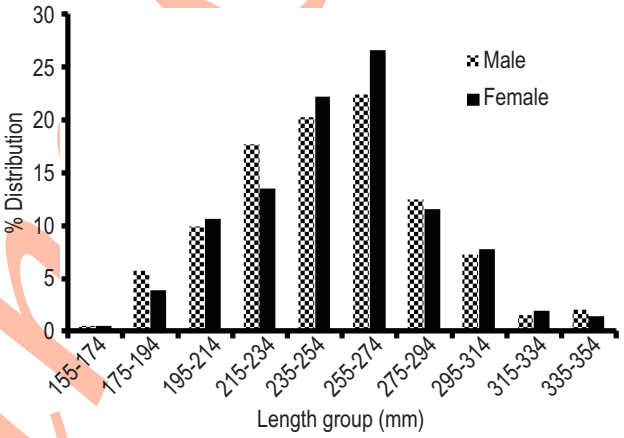

Fig.1 : Length frequency distribution of male and female *O. niloticus* from river Yamuna at Allahabad

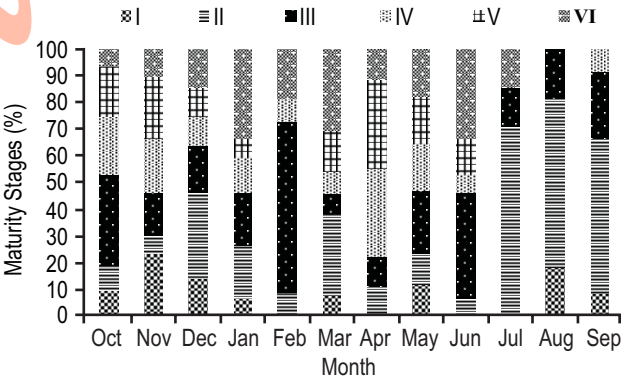

Fig. 2 : Reproductive patterns of female *O. niloticus* collected from October 2011 to September 2012 in an river Yamuna at Allahabad

occurrence of mature and spawning stages in blue tilapia during January, February, March and May when water temperature ranged between 25ºC and 28.3 °C.

During July and August, mean GSI values for both the sexes were observed to be very low (Fig. 3). In January and February too, both sexes showed low mean GSI but maximum GSI values were found to be higher in February for male (0.31) and in January for females (3.52), indicating the occurrence of matured individuals. Several peaks of mean GSI values were found in October, November, April and May. In both sexes, individuals with maximum GSI occurred in almost all month other than July and August, indicated prolonged and multiple breeding behaviour with peak being between October-November and March-June. Maximum weight of testes and ovary was 10.89 g (November) and 28.89 g (April) but maximum GSI observed in both sexes in April were 1.81 and 4.15%, respectively. HSI values were found to be highest in the month of February(2.1%), just before the peak period of spawning followed by December (2.06%) when maximum percentage of gorged and full stomachs occurred (Fig. 4).The lowest value of HSI was noted in August when GSI value was lowest (0.6%). Therefore, HSI changed according to variations in the feeding habits and reproductive behaviour. The monthly mean condition factor for male and female ranged from 1.9 to 2.3 and 1.8 to 2.2 respectively (Alam *et al*., 2015).When the values of condition factor were lower, GSI values were higher in October, May and June respectively. It may possibly be due to low feeding intensity and peak breeding season.

The absolute fecundity ranged from1192 to 4760 with mean of 2595 as compared to1505-5559 eggs of the fish ranging in total length from 235-325 mm in Lake Chila from Veracruz (Basurto-Origel, 1994), 30-2603 eggs of fish ranging in total length from 79.9-349 mm in the coastal Mississippi watershed (Peterson *et al*., 2004), 104-373 eggs of fish ranging in total length from 125-209 mm in Coatetelco Lake, Mexico (Gómez-Marquez *et al.,* 2003), 243–847 eggs in total length from 140–220 mm range in Emiliano Zapata Dam, Morelos, Mexico (Peña-Mendoza *et al.,* 2005) and 73-1810 eggs in size range from 188-297 mm total length from Opa Reservoir in Nigeria (Komolafe and Arawomo, 2007), respectively.The highest average fecundity was observed in females of 345 mm TL weighing 720 g and lowest in females with 220 mm TL weighing 224 g. Fecundity varied among similar sizes, especially within the larger size class of tilapia (Coward and Bromage, 1999), might be due to differential abundance of food items.

Relationship between fecundity and total length (Fig. 5a), body weight (Fig. 5b) and ovary weight (Fig. 5c) of fish were $F = 9.7421TL^{1.6667}$, $F = 65.897W^{0.5994}$, F = 1787.6+76.672 OW respectively. Positive correlations were observed between fecundity and total length, fecundity and total weight and fecundity and ovary weight of fish. Messina *et al*. (2010) reported no relationship between fecundity and total weight and between fecundity and standard length. Higher fecundity of an individual within the population ensures its relative stability through continuous recruitment thereby representing an adaptive response of species in an altered and environmentally impaired condition of the river Yamuna.

A total of 192 male and 207 female specimens collected randomly represented sex ratio (M/F) of 1:1.08. This was statistically non-significant from expected 1:1 ratio (x^2=6.994219, p=0.8642) indicating that males and females are statistically equal in number which is in agreement with findings by Gómez-Márquez *et al*. (2008). The proportion of female was higher from May to November. In nature, male and female sex ratio is expected to be 1:1. Any deviation from this ratio may indicate dominance of one sex over the other. The monthly male-female sex ratio also did not differ significantly (Table 1) from the expected 1: 1 ratio (χ2-test; p>0.05). This proportion leads to reduced recruitment required for the population recuperation since all tilapia invasions must have come from small number of individuals (Gómez-Márquez *et al*., 2007).

Table 1 : Ratio of male (M) and female (F) *O. niloticus* from October 2011 to September 2012 in river Yamuna at Allahabad.

Months	Male (M)	%	Female (F)	%	Ratio (M/F)
October	21	39.62	32	60.38	1: 1.52
November	25	45.45	30	54.55	1:1.2
December	32	53.33	28	46.67	1:0.88
January	15	50.00	15	50.00	1:1
February	14	56.00	11	44.00	1:0.79
March	16	55.17	13	44.83	1:0.81
April	14	60.87	9	39.13	1:0.642857
May	12	41.37	17	58.63	1:1.416667
June	11	42.31	15	57.69	1.363636
July	11	44.00	14	56.00	1.272727
August	10	47.62	11	52.38	1:1.1
September	11	47.83	12	52.17	1:1.09
Total	192	48.12	207	51.88	1.08

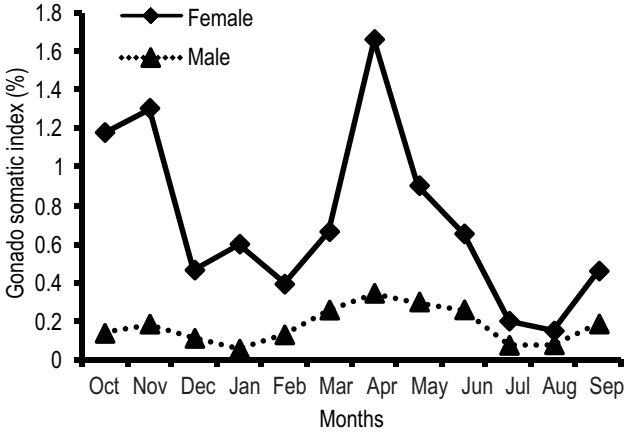

Fig. 3 : Monthly variation in gonado somatic index of male and femal *O. niloticus* in river Yamuna at Allahabad

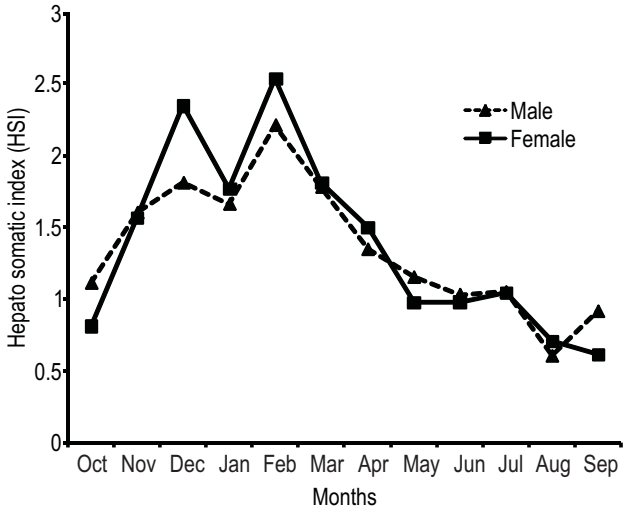

Fig. 4 : Hepato somatic index (HSI) for male and female *O. niloticus* in waters of the river Yamuna at Allahabad

The smallest spawning male and female were 205 mm and 200 mm TL. Size at first maturity of male was 229.6 mm TL with confidence limit of 235.9 and 223.6 mm while that of female was 238.1 mm TL with confidence limit of 244.7 and 231.7mm. Differential maturation of male and female has been suggested to be possibly due to different growth rates between sexes (Zhang *et al*., 2013). Njiru *et al*. (2006) reported the size at first maturatity as 308.1 mm and 345.6 mm for male and female respectively. Rainy season is known to be peak breeding period in Lake Victoria (Witte and Van Densen, 1995). River Yamuna during monsoon (July-September) has high flow with fast moving currents, an unfavourable condition for breeding of Nile tilapia. *O. niloticus* showed a well-defined reproductive strategy in river Yamuna like in Lake Victoria (Njiru *et al*., 2006).

The mature, spawning and spent females were recorded in almost all months of the year indicating multiple and prolonged breeding behaviour. Multiple spawning behaviour has an edge in highly stressed environments (Njiru *et al*., 2006) of the river

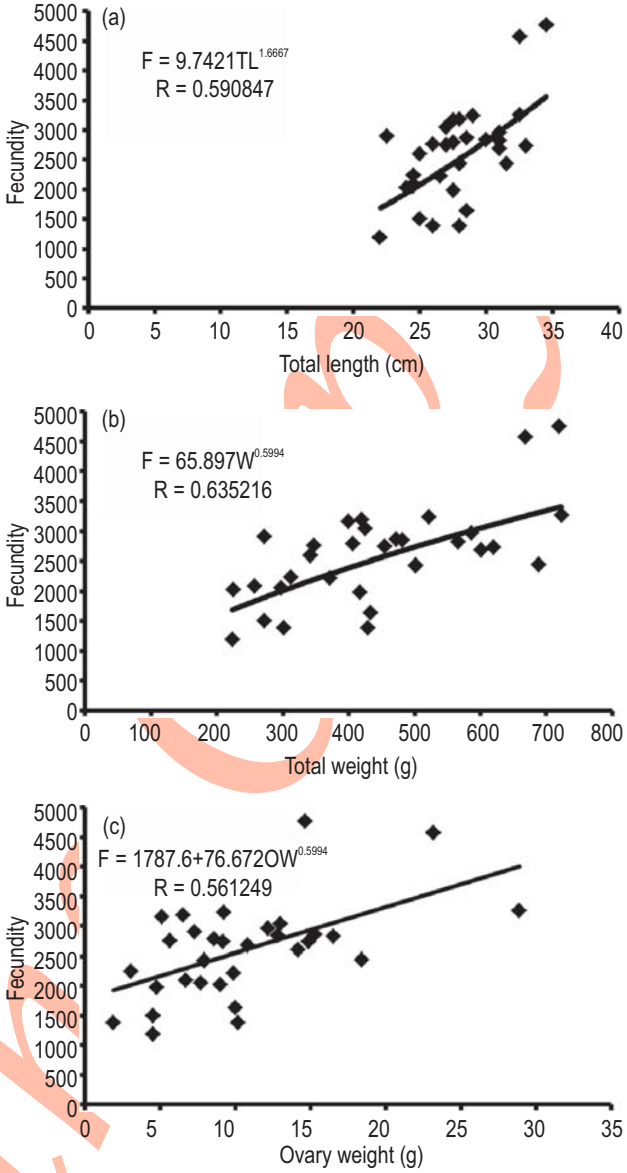

Fig. 5 : Graph depicting relationship between fecundity and total length (a), fecundity and total weight (b) and fecundity and ovary weight (c) of *O. niloticus*

Yamuna which reduces the risk of wiping out a reproductive run. Length at first maturity was (male=229.6 mm TL, female=238.1 mm TL) comparatively lower than Nile tilapia from Lake Victoria (Njiru *et al*., 2006), where mean size at first maturity was 308.1 and 345.6 mm for male and female respectively. The estimated fecundity too increased from 30-2603 oocytes in fish measuring 79.9–349 mm in the Mississippi watersheds (Peterson *et al*., 2004) to1192 to 4760 with mean 2595 eggs of 220-345 mm TL in this study. Early maturation, multiple and prolonged breeding behaviour and increased fecundity could be some of the strategies to maximise reproductive success (Njiru*et al*., 2006), possibly connected with common responses of a population to environmental stress, signifying that Nile tilapia has acclimatised

well to river Yamuna (Zhang *et al*.,2013).In the present study, size at first maturity for male and females in river Yamuna was found to be lower than population in the lakes of Africa signifying relatively rapid maturation in riverine systems. Nile tilapia in river Yamuna most probably exhibits 'r' selected life history trait to adapt and maximise fitness.These reproductive traits may offer the species a competitive lead over the native species to further invade and spread in the Yamuna river system.

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