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Research Article

Impact of Climate Deviation on Reproductive Profile of Nile Tilapia, *Oreochromis niloticus* (Linnaeus, 1758) from the Tons River, India

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Keywords: Nile tilapia; *Oreochromis niloticus*; Reproductive profile; Sex ratio; Fecundity; Tons river

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Abstract

Nile tilapia, *Oreochromis niloticus* is among the leading farmed species around the world as well as a powerful invader in many countries globally. Studies were undertaken during the period from February 2019 to January 2020 from the lower stretch of the Tons River at Prayagraj, Uttar Pradesh, India. During the sampling period, 683 fish specimens of Nile Tilapia, *Oreochromis niloticus* (336 males and 347 females) were collected and studied for evaluation of sex ratio and sex structure. The sex ratios of male and female fishes were very close and reported 1.0:1.03 in the stock. The male ratio was higher in the small size group of fish with 81 to 200 mm size groups and 411 to 470 mm size group. The sex structure of males and females was observed at 49.19% and 50.81%, respectively in the case of stock. The female proportion was recorded as a minimum with 37.50% in the 441-470 cm size group and highest with 54.84% in the 381-410 mm size group. However, the male proportion was reported lowest at 45.16% in the 381-410 mm size group and highest at 62.50% in the 441-470 mm size group. In the present findings, *O. niloticus* was found to reach maturity starting below 138 mm of total length, taking individual fish. The fishes breed in the months of March to June and September to November of the year. The number of eggs per individual ranged from 393 to 4338 in the size of fish varied from 138-452 mm. The reported fecundity and sex ratio of *O. niloticus* indicated that the climatic condition or environmental condition of the Tons River was most suitable. The environmental condition (especially temperature) of the Tons River at Prayagraj is slightly warm compared to the Ganga River which is very favourable for *O. niloticus*. The water current velocity of the Tons River is very poor. Both parameters are very helpful for the stability of *O. niloticus* in the Tons River at Prayagraj. The high fecundity of *O. niloticus* in the Tons River at Prayagraj could probably be a result of a combination of different causes such as climatic conditions, habitat structure, food abundance, water quality, and quality of food. Therefore, the present study aimed to update the information on the sex ratio, sex structure, and fecundity of *O. niloticus* with respect to climate from the Tons River, India.

Introduction

Nile tilapia, *Oreochromis niloticus* is a commercially and economically important fish species globally and plays an important function in tropical and subtropical aquatic ecosystems with respect to fish productivity [1-9]. It is found in the commercial fishery in the Ganga, Tons, Yamuna Ken, and Paisuni rivers with *Cyprinus carpio* [10-14]. In general, *O. niloticus* is well-known for its plasticity in survival (for example, tolerates a wide range of environmental conditions and ability to feed at different trophic levels, lowest dissolved oxygen need), feeding nature, fast growth, tolerance, high resistance to diseases, easily breeds and size at first maturity [15-20]. Undoubtedly, *O. niloticus* is one of the leading farmed species in the world and comparatively low cost of production.

In the Indian riverine system, the *O. niloticus* niche overlaps with *Cirrhinus mrigala*, *Labeo calbasu*, and *Cyprinus carpio* fishes. *O. niloticus* tends to quickly gain a competitive advantage because of its hardy nature and feeding plasticity due to these features. *O. niloticus* is the most common invader fish species globally [5,21-23] and also an invader in India and has become the dominant species (by-catch or landing) in many rivers of the Ganga river system, India [24,25].

Knowing fish reproductive biology is vital for fisheries management and conservation, and for fulfilling the knowledge

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gap in fundamental fisheries research [1,3,12,23]. Segmented studies on the various aspects of the reproductive biology of *O. niloticus* have been carried out in different parts of the world [1,3,12]. The knowledge base on the reproductive aspects of *O. niloticus* is lacking from the Tons River Indian Thus, the present study of sex ratio, sex structure, breeding season, and fecundity of *O. niloticus* from the Tons River, which is an entirely very new home for the fish. The study would help the fishery managers and planners in the management of the riverine fisheries in the Ganga basin, India. Record and assessment of the present research work is also necessary to formulate informed decisions about restoration and management of the fishery and rivers.

Materials and methods

The Tons River is essentially a hilly stream water body arising in the Kaimur hills of the Vindhyan range, India. Its banks are lined by deep ravines and the bed is rocky. The Tons River lies between latitude 24° 0' to 25° 16' 54" North and longitude 80° 26' 45" to 82° 04' 57" East. It is a tributary of the Ganga River. The sample was collected from February 2019 to January 2020 from the Sirsa fish landing centre at Prayagraj, Uttar Pradesh, India. Fishes were collected using a variety of methods including gill nets, drag nets, cast nets, and hook and lines.

During the course of the present study, 683 fish specimens of *O. niloticus* (336 male and 347 female) in the length ranges between 82 to 463 mm were examined for the estimation of sex ratio and sex structure. The female fishes were identified by microscopic examination of the gonads as they show sexual dimorphism only in the breeding season. The numbers of fish samples were segregated on the basis of their sex (male and female) to determine the percentage composition of each sex in different size groups. This helped to understand the distribution of sexes in different size groups. Their sex ratio (M:F) was computed for each size group.

The Absolute Fecundity (AF) of individual females was determined gravimetrically [26], with the number of ripe oocytes counted from triplicates (anterior, middle, and posterior) of the 1 gm sub-sample of the ovary. Twenty-seven ripe female fishes were used for the estimation of fecundity in the present study. To obtain representative samples of the whole gonads, 3 gm eggs were taken from the posterior, middle, and anterior of both lobes of the ovary. The 3 gm ripe eggs were counted and then divided by 3 for obtaining of 1 gm egg number. The total number of ripe eggs in the ovary was estimated by multiplying by 1 gm egg number. The fecundity was estimated by following the formula-

Fecundity = Total weight of ovary × Number of 1 gm ripe eggs

Results and discussions

During the course of the present study, 683 fish specimens of *O. niloticus* (336 male and 347 female) in the length ranges between 82 to 463 mm were examined for the estimation of sex ratio and sex structure. Present sample numbers are standard for all studies because the present fish is an exotic species for the Tons River. The size composition of *O. niloticus* fishes varied from 82 to 463 mm (total length). The recorded largest size of *O. niloticus* was indicated by the well-stable fish species from the Tons River at Prayagraj, Uttar Pradesh, India. The maximum total length of *O. niloticus* in the catches indicated its increasing colonisation success in the river Tons. The maximum length of fish is a good indicator of the health of stock in the riverine ecosystem [27,28]. The reported sex ratio (1.0:1.03) of males and females was much closer to the naturally expected ratio (1.0:1.0). The Present sex ratio is a good indicator of a healthy and stable stock of *O. niloticus* from the Tons River.

Sex ratio

The sex ratio of male and female fishes of *O. niloticus* in stock was reported 1.0:1.03 from the Tons River. The present sex ratio of the stock is most important for healthy and heavy recruitment. Male ratio was higher in small size group fishes with 81-110, 111-140, 141-170, and 171-200, mm size groups, and also in higher size groups 441-470 and 441-470 mm (Table 1). The sex ratio was reported 1.0:0.78, 1.0:0.85, 1.0:0.88, 1.0:0.93, 1.0:0.71, and 1.0:0.06 in size groups of fishes 81-110, 111-140, 141-170, 171-200, 441-440 and 411-470 mm, respectively (Table 1). The oral incubation behaviour (female, eggs, and larvae) is responsible for the higher male proportion of *O. niloticus* in the Tons River in the case of small-size fishes. After spawning in the nest made by a male fish, the young fry or eggs are carried in the mouth of the mother for a period of 12 days. During the oral incubation behaviour period, female fish's movement is limited. The female proportion was estimated higher in 201-230, 231-260, 261-290, 291-320, 321-350, 351-380 and 381-410 mm size group of fishes and sex ratio was 1.0-1.11, 1.0-1.10, 1.0-1.12, 1.0-1.05, 1.0-1.12, 1.0-1.09 and 1.0-1.21, respectively (Table 1).

The sex ratio is a fundamental parameters used in age-structured models in stock assessments of fishes. The sex ratio

Table 1: Sex ratio of *Oreochromis niloticus* from the Tons River at Prayagraj, Uttar Pradesh, India.

SN	Size groups (mm)	Male	Female	Sex ratio (M:F)	Pooled	Total % of the stock
1	81-110	09	07	1.0:0.78	16	2.34
2	111-140	20	17	1.0:0.85	37	5.41
3	141-170	26	23	1.0:0.88	49	7.17
4	171-200	31	29	1.0:0.93	60	8.78
5	201-230	37	41	1.0:1.11	78	11.42
6	231-260	51	56	1.0:1.10	107	15.67
7	261-290	40	45	1.0:1.12	85	12.44
8	291-320	39	41	1.0:1.05	80	11.71
9	321-350	34	38	1.0:1.12	72	10.54
10	351-380	23	25	1.0:1.09	48	7.03
11	381-410	14	17	1.0:1.21	31	4.54
12	411-440	07	05	1.0:0.71	12	1.76
13	441-470	05	03	1.0:0.6	08	1.17
	Total	336	347	1.0:1.03	683	

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is helpful in understanding the recruitment pattern of fish in the population. Theoretically, the expected ratio of males to females should be 1.0:1.0 [29-31]. The sex ratio of most fish species in the wild tends to be 1:1, but deviations can occur and seasonal variations are very common [32-33]. It was also reported a slightly higher proportion of female *O. niloticus* in the case of stock from the Yamuna River, India [12]. The sex ratio is influenced by several factors, including mortality, longevity, and growth rate, these in turn lead to differences in the catch rate [34]. The sex ratio in the spawning population and in the various age and size groups varies with the species, reflecting the relationship of that species to its environment [35-41]. It was reported that the sex ratio was 1:1 of *O. niloticus* from Khashm El-Girba Reservoir and Atbara River, Eastern Sudan [42]. It was observed that of the 316 *O. niloticus* examined 148 (46.8%) were males and 168 (53.2%) females and overall male-to-female ratio of 1:1.14 in Geray Reservoir, Ethiopia [43].

Sex structure

The sex structure of males and females was observed at 49.19% and 50.81%, respectively in the case of stock of *O. niloticus* from the Tons River, India (Table 2). The female proportion was reported as a minimum with 37.50% in the 441-470 cm size group and highest with 54.84% in the 381-410 mm size group (Table 2). However, the male proportion was recorded as a minimum with 45.16% in the 381-410 mm size group and highest with 62.50% in the 441-470 mm size group of fishes.

The sex structure is also adaptive to the food supply, which thereby influences the reproductive rate and the variability of the offspring [44-46]. It was reported that the 624 fishes of *O. niloticus* were caught with 272 females (43.59%) and 352 males (56.41%) and the sex ratio was 1:1.29 (females: males) in Emiliano Zapata dam Morelos, Mexico [47]. It was estimated that the *O. niloticus* had a sex structure of 121 females (54.8%) and 100 males (45.3%) in the upper Kabompo River, northwest of Zambia [38].

Table 2: Sex structure of *Oreochromis niloticus* from the Tons River at Prayagraj, Uttar Pradesh, India.

SN	Size groups (mm)	Male	Percentage	Female	Percentage	Pooled	% of stock
1	81-110	09	56.25	07	43.75	16	2.34
2	111-140	20	54.05	17	45.95	37	5.41
3	141-170	26	53.06	23	46.94	49	7.17
4	171-200	31	51.67	29	48.33	60	8.78
5	201-230	37	47.43	41	52.56	78	11.42
6	231-260	51	47.66	56	52.34	107	15.67
7	261-290	40	47.06	45	52.94	85	12.44
8	291-320	39	48.75	41	51.25	80	11.71
9	321-350	34	47.22	38	52.73	72	10.54
10	351-380	23	47.92	25	52.08	48	7.03
11	381-410	14	45.16	17	54.84	31	4.54
12	411-440	07	58.33	05	41.67	12	1.76
13	441-470	05	62.50	03	37.50	08	1.17
	Total	336	49.19	347	50.80	683	

Breeding seasons

The environmental condition (especially temperature) of the Tons River at Prayagraj is slightly warm compared to the Ganga River which is very favourable for *O. niloticus*. The water current velocity of the Tons River is very poor. Both parameters are very helpful for the stability of *O. niloticus* in the Tons River at Prayagraj. The frequency of temporal variation between ripe males and females was similar. The smallest spent female fish was recorded with a 141 mm total length. The fishes breed in the months of March to June and September to November of the year. A lot of spent fishes were recorded in this period. A current study indicated that the *O. niloticus* breeds two times per year. The first breeding season was reported long with 4 months and the second was short with 3 months. *O. niloticus* was caught at various stages of gonad development and reproduction in almost all months. However, their frequency varied with the month of capture. The seasonal pattern of gonad development for both sexes was almost similar.

Generally, Tilapia species in temperate areas have very short breeding seasons and are limited to some months only, but in tropical countries, their breeding seasons are extended, and in most cases throughout the year [48,49]. It was recorded that the breeding period of *O. niloticus* occurred from April to July and the spawning of oocytes began at the end of July [50].

Fecundity

The portion of the ovary was removed before being stored in formalin and this had to influence the results. A total of 27 ripe female fishes were utilized for the estimation of the fecundity of *O. niloticus* from the Tons River, India. The total length of ripe female fishes varied from 138 to 452 mm and the weight of gonads fluctuated between 3.27 to 34.74 gm, respectively (Table 3). In the present findings, *O. niloticus* was found to be mature starting below 138 mm of total length, taking individual fish. The number of eggs per individual ranged from 393 to 4338 in size of fish 138-452 mm, respectively (Table 3). The high fecundity of *O. niloticus* in the Tons River at Prayagraj could probably be a result of a combination of different causes such as climatic conditions, habitat structure, food abundance, water quality, and quality of food. The number of ripe eggs increased with the ovarian weight and size of fishes. The number of eggs is closely related to the size of fishes compared to the weight of the gonad. Fecundity was linearly related to the weight of the gonad. Fecundity was also directly related to the total length of fishes. The water temperature varied from 17.8 to 29.6 °C and the mean value was recorded as 24.23 ± 4.73. The dissolved oxygen concentration fluctuated between 4.7 to 6.2 mg/l while the mean value was reported 5.76 ± 0.97. The average pH value was recorded at 7.92 ± 0.32 and the value fluctuated between 7.6 to 8.3. The nitrate varied from 0.42 to 1.6 mg/l and the mean value was recorded as 1.17 ± 0.68. The fecundity of *O. niloticus* indicated that the climatic condition of the Tons River is most suitable for *O. niloticus*.

The fecundity of fish is directly associated with the growth and climatic conditions. It was estimated fecundity was between 241 to 709 eggs/fish in 125-209 mm size of fishes at Coatetelco

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Table 3: Fecundity of *Oreochromis niloticus* fishes from the Tons River at Prayagraj, Uttar Pradesh, India.

SN	Total length of fishes (mm)	Weight of Gonads (gm)	Number of eggs
1	138	3.27	393
2	150	6.39	426
3	164	8.09	756
4	170	10.32	1029
5	181	11.92	1311
6	187	12.03	1386
7	196	12.32	1446
8	203	13.98	1578
9	216	14.23	1833
10	228	14.82	2055
11	248	15.92	2418
12	253	16.12	2649
13	272	18.43	2751
14	281	19.12	2813
15	293	20.00	2859
16	316	20.48	2911
17	329	21.58	3069
18	345	22.43	3159
19	356	26.87	3543
20	365	27.02	3759
21	383	27.49	3801
22	390	29.43	3789
23	405	31.62	4008
24	416	32.03	4065
25	418	32.70	4098
26	428	33.46	4161
27	452	34.73	4338

Lake, Morelos, Mexico [48]. It was reported that the relative fecundity of *O. niloticus* ranged from 3 to 9 oocytes per gram of body weight, with a mean of 6 oocytes/gm at Peele reservoir, Nakanbé River Basin, Burkina Faso [50]. It was observed mean fecundity for *O. niloticus* was 1422.24 ± 91.103, Zambia [51]. It was estimated that the relative fecundity varied from 0.29 to 6.8 (mean 2.77 ± 0.13) eggs/g of females in brackish water, in Iran [52]. It was recorded that the fecundity of *O. niloticus* varied from 149 to 2797, for fish weighing between 36 and 975 gm in 1995, and from 178 to 1898, for fish weighing between 78 and 501 gm in 1996 from man-made lakes of Cˆote d'Ivoire [53].

In riverine ecosystems, sex ratio and fecundity also varied from season to season and year to year with respect to water flow, photoperiod, temperature, richness of fish species, size of fishes, age of fishes, stock of exotic fishes, availability of food and fishing pressure [12,34,38,43,54-60]. Due to the low concentration of heavy metals in the riverine ecosystems, it is also helpful for successful and healthy recruitment [61-66]. More and more detailed studies on the sex ratio, sex structure, breeding season, and fecundity as well as other aspects of biology (for example age and growth, food and feeding, length-weight relationship) of different fish species should be explained for sustainable management of fish biodiversity and stock of the Tons river, Uttar Pradesh, India.

Conclusion

It may be concluded that the reported sex ratio of male and female fishes in stock is 1.0:1.03 which is very close to 1.0:1.0 (for example naturally expected sex ratio, male and female) and healthy condition and creates a chance for heavy recruitment. The fecundity and breeding frequency of *O. niloticus* also indicated that the climatic condition of the Tons River is most suitable and forms a favorable environmental condition for heavy recruitment. The number of eggs per individual ranged from 393 to 4338 in size of fish 138-452 mm, respectively. The fecundity of *O. niloticus* from the Tons River is higher compared to other places in the world. The reported maximum size of *O. niloticus* indicates that the present fish powerfully invaded from the Tons River, Uttar Pradesh, India.

Recommendations

A population dynamic study should be necessary for the estimation of the fishing pressure of the present fish species from the Tons River.

The food and feeding patterns of the present fish species should be studied.

Ethical xonsiderations

This research work was conducted only on dead fish that were fished by fishermen community/fishers. The fish samples were collected from the fish market (Sirsa landing centre) at Prayagraj, Uttar Pradesh, India, thus it did not need ethical approval.

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