Invasion, Biology and impact of feral population of Nile tilapia (*Oreochromis niloticus* Linnaeus1757) in the Ganga River (India).

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**ABSTRACT**

In this study, we aimed to determine the dispersion area and population characteristic of *Oreochromis niloticus* (i.e., the abundance, length-weight, food and feeding, gastro somatic index (GaSi), sex ratio, gonado somatic index (GSI) and fecundity) which has formed a feral population in the Ganga River, the largest one in the country. Water parameters were studied in relation to *Oreochromis niloticus* between years 2008 and 2012. Abundance of *O. niloticus* in the fishery of the river was observed. Condition factor for feral *O.niloticus* was calculated which ranged from 2.07-3.64 during successive years. The gut content analysis revealed the presence of over 80% bacillariophyta and cyanophyta comprising of the phytoplankton; crustaceans and rotifera were the primary groups of zooplankton. Calculated GaSi ranged from 7.05 to 11.41 at different sampling sites. Sex ratio indicated the presence of more females than males, indicating an increased propagule pressurs. GSI was ranged from 0.27-3.90 in different catches. High fecundity was observed at locations where the fish had high abundance, indicating an increased spawning potential of the feral fish. The change in dynamics of the fishery was a consequence of increased yield of *O.niloticus* in the river attracting attention to conserve native germplasm facing threats of shifting from their natural habitats.

1. Introduction

Tilapia, a native to Africa [1] and Middle East [2] has emerged as one of the most internationally traded food fishes in the world [3]. There are about 70 species of tilapias, most of them are native to Western rivers of Africa. Of these, eight species mainly Nile tilapia (*Oreochromis niloticus*, Linnaeus 1757 ), Mozambique tilapia (*O. mossambicus*, Peters 1852), Blue tilapia (*O.aureus*, Steindachner 1864), *Tilapia urolepis* (O. hornorum, Trewavas 1966) Gallilee tilapia (*Sarotherodon galilaeus*, Hasselquist 1757) Black-chinned tilapia (*S.melanotheron*, Ruppel, 1852) Redbreast tilapia (*Tilapia rendalii*, Boulenger 1896) Redbelly tilapia (*T. zillii*, Ge vais 1848) are
used in aquaculture worldwide [4]. Of these species, Nile tilapia is a relatively large cichlid fish [5], which is introduced to several countries where its populations exist outside its natural range e.g. Brazil, Australia, Bangladesh, Sri Lanka, India [3,6]. World tilapia production has been booming during the last decade, with output doubling from 830,000 tonnes in 1990 to 1.6 million tonnes in 1999, 3.23 million in 2011 [7] and estimated to increase 8.89 million metric tons by the year 2020 [8]. Commercially, tilapias are the second most important Group of wild-captured fish, after carps, with a global capture (harvest reaching) 769,936 tonnes metric tonnes in 2007[4]. China is by far the largest consumer and producer (about 46% of global production) of tilapia, with a production estimated at 1.15 million tonnes in 2009 and is estimated to reach 1.5 million tons in 2012 [9]. Typical size of tilapia sold in the Asian market is between 450 to 680G (1.0 to 1.5 lb). It is sold live as well as fresh, frozen as whole, frozen fillets, gutted, gutted and scaled, skinless and boneless. The United State is the world’s single largest importer of tilapia [10].

The *O.niloticus* was introduced to India during late 1987 [6]. The aquaculture of *O.niloticus* expanded in the southern region of the country especially by private entrepreneurs. During 1995, Vorion Chemicals Ltd. Chennai claimed high production of hybrid red tilapia popularly called as golden tilapia [11]. However, the production collapsed for some unknown reason [6]. Culture of *O.niloticus* particularly in Andhra Pradesh, Orissa and West Bengal is now gearing up and the fish is now distributed to many states particularly the coastal areas. Cultivated tilapias are typically hybrids between the *O.niloticus* and other closely related species native to Africa [12]. *O.niloticus* are one of the easiest and profitable fish to farm, in part because they are omnivorous and can be fed a diet derived exclusively from plants[3]. *O.niloticus* and other fish that feed on vegetable materials offer a much more ecologically sound and environmentally friendly means of providing humankind with an abundance of nutritious and delicious fish.

Escapement of tilapia from aquaculture facilities due to recurring floods or inadvertent releases frequently happened. However, recent occurrence of tilapia in the fishery of the Ganga River system has been a concern. It was interesting to see a considerable size of *O.niloticus* in the fishery of the Ganga River system particularly in an area where tilapia culture is hardly practiced. This scenario prompted us to study its population characteristics i.e., the abundance, size range, food and feeding, GaSi, GSI, maturity, and breeding. The study was undertaken under two perspectives; the former was to ascertaining the colonization of the escape *O.niloticus* through natural population in the Ganga River system and the latter was to assess its possible impacts on the local fishery and the fish diversity.

2. Methods and materials

2.1 Location. The study area covered approximately 450 km of the river stretch of the middle Ganga flowing along the districts of Kannauj, Kanpur, Unnao, Allahabad, Mirzapur, Varanasi, Ghazipur and Ballia districts of Uttar Pradesh. Data was collected from fish landing areas of Mehdighat in Kannauj, bridge area and Tiwarighat in Kanpur, Shuklaganj in Unnao, Daraganj and Jhunsi in Allahabad, Adalhat and Pakka ghat in Mirzapur, Saraimohana and Ramnagar in Varanasi, Dadri ghat in Ghazipur and Ganga ghat in Ballia district (Figure 1).
2.2 Physico-chemical analysis. Atmospheric and water temperatures were recorded at sampling sites using digital thermometer with accuracy of ± 0.05 °C. Water pH, dissolved oxygen (DO), conductivity were determined using a water quality analysis kit (WTW Multi340i-SET, Germany). The value of COD was determined by remixing the water sample for two hours in the presence of mercuric sulphate, 0.025N potassium dichromate and sulphuric acid digested with silver sulphate (a catalyst). Refluxing was followed by titration of sample with 0.01N ferrous ammonium sulphate in the presence of ferroin indicator. After comparison with a blank set, COD was estimated as follows:

\[\text{COD (mg/L)} = \frac{(B-A) \times N \text{ of ferrous Ammonium Sulphate} \times 1000 \times 8}{\text{Volume (ml) of sample taken}}\]

Where,  A was volume (ml) of titrant with sample: B was volume (ml) of titrant with blank sample:  N was normality of ferrous ammonium sulphate. Silver sulphate was used to neutralize the effect of chlorides as it gets converted in the stable mercuric chloride. Some volume of added potassium dichromate was utilized to oxidize the chemical present in the water; only rest of the potassium dichromate was titrated. Ferroin indicator was prepared by adding 1.485 gm of 1/10 phenenthrodein and 0.695 gm of ferrous sulphate in 100 ml of distilled water.

Biochemical oxygen demand was estimated by the incubation of samples in dark at 20˚C for five days, proceeded by the addition of phosphate buffer which was prepared by dissolving 8.5 g KH₂SO₄, 21.75 g K₂PO₄, 33.4 g Na₂HPO₄.7H₂O and 1.7g NH₄Cl in distilled water of volume 1 lit. After incubation in BOD incubator, samples were analyzed by a modified Winkler’s Method. A blank set (un-incubated) of sample was also analyzed to find out the differences. The BOD was further calculated as follows:

\[\text{BOD (mg/L)} = (\text{DO} – \text{DO}_5) \times \text{dilution factor}\]

Where DO = volume of oxygen in blank set; DO₅ = volume of oxygen in incubated set.

2.3 Fish sampling. Fish samples were collected from the landing centers on quarterly basis during 2008 to 2012. Fishermen generally used multi-meshed gill nets of mesh size 8.5–50 mm as well as dragnets for fishing. From commercial catches, fishes were collected at the landing centers and were identified, measured (fork length, Total Length nearest cm), and weighed (g) using portable digital balance. Keys for identification of fish species [13] and FAO identification sheet as [4]. From the total catch, the abundance index of O.niloticus was calculated using the following formula:

\[\text{AI} = \frac{n(k) \times 100}{N}\]

Where:

AI = abundance index,

n(k) = number of tilapia caught at each study site.

N = number of all the fish species caught at that site.

2.4 Biometric studies. Total length (cm) of each fish was taken from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board. Body weight was measured to the nearest gram using a portable digital balance [14].
Parameters of the length-weight relationship of identified fish species were estimated using the equation [15, 16].

\[ W = aL^b \]  

where,

- \( W \) = Weight of fish (g)
- \( L \) = Length of fish (cm)
- \( a \) = \( y \)-intercept or the initial growth coefficient
- \( b \) = Slope or the growth coefficient.

The values of constants a and b was estimated after logarithmic transformation of Eq. (1) using least square linear regression [17] to give:

\[ \log W = \log a + \log bL \]

In length-weight relationship the growth coefficient ‘b’ of the fish should be close to 3.0. It may range between 2.4 and 4.0 [18]. Prior to regression analysis of \( \log W \) on \( \log L \), log-log plots of length and weight values were performed for visual inspection of outliers [16,19,20] and condition factor (K) calculated as follows:

\[ \text{Condition Factor (K)} = \frac{100W}{L^3} \]

Where \( W \) is the observed total weight for each specimen,
\( L \) is the observed standard length for each specimen and
\( K \) is the condition factor.

2.5 Gut content analysis. The intestines of tilapia captured from different sampling station were cut and fixed in 5% formalin for gut content analysis. Gut contents were thoroughly washed into a Petri dish and examined under microscope. The diet and feeding habits of \( O.\text{niliotcs} \) were determined based on the gut contents and examined by using compound microscope (olympus model no. CX41). Relative abundance of a particular item of food was expressed as total number of food items in the sample. Different taxa of the food items were identified, counted, and gastro somatic index (GaSI) was also calculated by using following formula [21,22].

\[ \text{GaSI} = \frac{\text{Total weight of gut (including food contents)}}{\text{weight of fish}} \times 100 \]

2.6 Gonado somatic index (GSI). The observation on the sex of collected \( O.\text{nilioticus} \) from different sampling station was made after macroscopically. Examining the fish and the sex ratio percentage was calculated. The gonads of sexed male and female were dissected out, weighed and GSI was calculated following the formula [23].

\[ \text{GSI} = \frac{\text{Gonad weight}}{\text{Total weight}} \times 100 \]

Fecundity was measured volumetrically by weighing the eggs present in ovary as per formula-
Fecundity = number of eggs in one gm of ovary × total weight of ovary (g)

2.7 Statistical Analyses. All data were presented as mean ± SD. Data obtained from the experiment were subjected to one way analysis of variance (ANOVA) test using the Statistical Package for the Social Sciences (SPSS), version 8.1. The correlation coefficients between the quality parameter pairs of the water samples were calculated by the application of Pearson correlation analysis. Parameters were analysed statistically (at 5 %) and significance was calculated by student’s ‘t’ test.

3. Results

The physico-chemical parameters of the river water during the study period are presented as mean ±SD (Table1). Temperature was recorded to range from 17±2 to 30±1.1, while pH values varied from 5.4±1.3 to 7.2±1. Electrical conductivity ranged between 384±42 μmho/cm to 1256±22 μmho/cm. No clear seasonal or temporal changes of EC in the river water was observed. TDS value ranged between 61±56 to 1014±28.8 mg/L. Total hardness ranged between 220±12.82 to 422±21 mg/L. While alkalinity ranged between 131±20 to 460±16 mg/L. Temporal variations of alkalinity in river water was recorded during the study period at different locations (Table 1). Dissolved oxygen ranged between 4.6±2.1 to 8±1 mg/L. Low dissolved oxygen was observed at Kanpur and BOD value in the river water ranged from 1.6±1.1 to 4.6±3.0 where as COD value ranged between 2.9±1.1 to 8.6±2.8 mg/L (Table 1).

The abundance of the *O. niloticus* ranged from 7–12% during 2008 at different sampling locations. However it increased to 9–24.6% during 2012. The size of the fish ranged from 14 cm to 19 cm in length and 70 to 250 g in weight in year 2008 and 12 to 28 cm in length and 60 to 610 g in weight by the year 2012. The *O. niloticus* included high proportion of large fish weighing 450-600 g and the small fishes were in low proportion. The condition factors (K) for *O. niloticus* ranged from 2.07 to 3.64 (Table 2). The recorded data on the occurrence of *O.niloticus* for the years 2008 to 2012 revealed that catch of *O.niloticus* increased successively during this period (Figure 3). Gonadal examination of *O.niloticus* in different catches revealed that immature, maturing, and mature fishes were available. Mature males were found at smaller size while mature females were bigger in size and sex ratio revealed slight variation 1.11 : 1 for female and male in 2008 and 1.31:1 for female and male in 2012 as expected against Mendelian sex ratio 1:1(Table 2). Observation of sex ratio revealed that female individual increased from 2008 to 2012. Gonads of examined specimens revealed varying gonado-somatic index (GSI) i.e 0.27 to 3.90 at different locations of the river. The calculated absolute fecundity ranged between 632 to 6262 and it increased through successive years as the weight of fishes increased. The gonado somatic index (GSI) and fecundity over time scale is presented in Table 2. The important fish biodiversity of the Ganga River collected from different sampling station were identified and commercially important fish diversity were grouped as Indian major carps (IMCs), minor carp, catfishes, miscellaneous, and exotic fishes. The Indian major carps was comprising of *Catla catla, Cirrhinus mrigala* and *Labeo rohita* constituting 4.5% to 9 % of the total catch. The IMCs included high proportion of large fish weighing 3–7 kg and the small fishes were in low proportion. The catch of *Labeo rohita* was remarkably low. It was also observed that there was a 2% to 3 % decline in catch of IMCs over the years during the study period. The minor carps in the total catch were mainly represented by *Labeo bata*, *L.calbasu, Cirrhinus reba, Puntius sophore*, and *P. conchonius* and they constituted 4.5%–6%. Catfishes in general were represented by *Sperata aor, S.seenghala, Walloago attu, Bagarius bagarius,Rita rita, Clupisomagarua* and constituted 9%–11% of the total catch. Other miscellaneous fishes were
Gonialosa manmina, Salmophasiab acaila, Glossogobius giuris, Ailia coila, Johniu scoitor, Mastacembelus armatus and Anabas testudineus representing 9.5%–14% of total catch. *O.niloticus* was present in all the catches from the Ganga River except Kanpur and Kannauj (Figure 3). Trophic spectra of examined specimens of *O.niloticus* revealed that there was similarity in the ingested food at different locations. Gut content analysis of *O.niloticus* collected from all sampling locations had both phytoplankton and zooplankton. By number, phytoplankton was the most abundant up to 70%. Two phytoplankton groups, bacillariophyta and cyanophyta comprised over 80% of the phytoplankton in the gut of all species (Figure 2). Crustaceans and Rotifera were the primary groups of zooplankton in fish guts. Feeding intensity as gastro somatic index (GaSi) ranged between 7.05 to 11.41 (Table 2).

4. Discussion

*Oreochromis niloticus* was introduced into India during 1987 for aquaculture purpose and now it contributes more than 7.17% in total inland fish production [24]. Results of this study delineated increased abundance of *O.niloticus* in the fishery the fish has now established feral population in the Ganga River. *O.niloticus* grows normally above 16°C; loses activities below 16°C and begins to die at 10°C [25]. Nile tilapia are notorious with their resistance against bad water quality conditions [26]. *O.niloticus* are more tolerant than most commonly farmed freshwater fish to high salinity, high water temperature, low dissolved oxygen, and high ammonia concentrations [27]. Although we found no significant variation in water quality by latitude of sampled areas but combination of long life span and high variability in life history traits such as variation in biometry, GSI, fecundity in response to locations and time scale may aid thriving of escapee *O.niloticus* in the river. *O.niloticus* has been variously reported to be a plankton feeder and they are considered filter feeders. It was found that it feed on aquatic weeds, due to omnivorous nature [28]. Gut content analysis confirmed that the fish had high preference towards plant materials. High value of feeding intensity or gastro somatic index (GaSi) also showed that it fed more intensely on planktons. Observed sex ratio showed higher number of females which helped the fish to colonize rapidly during successive years. The relatively high fecundity observed in our study may indicate the improved spawning potential of the feral population of *O.niloticus* after it successfully established in river. Our data showed that the fecundity of *O.niloticus* generally increased with the length and weight of the fish and it was probably the size which favourably affected the increased number of eggs by an individual. However variations in fecundity were noticed between fish of similar length or weight [29]. Gonadal development of *O.niloticus* has been reported to be continuous in females and the results of the present study also supported wild spawning of *O.niloticus* in the Ganga River. Since *O.niloticus*, is known to exhibit early sexual maturity, rapid colonization and wide environmental tolerances, these attributes have been considered to help the fish to successfully spread into new environments of the Ganga River. Nile tilapia develops its own ecology for its survival and repopulating by competing with other fishes as was confirmed by the biology, ecology, reproduction, food and feeding of feral *O.niloticus*.

Significant negative effects of *O.niloticus* on the piscine diversity have been reported [30,31]. *O.niloticus* in India has already been reported to cause sharp decline in the catches of endemic fishes [24,30]. The declining trend of Indian major carps in the Ganga River and increasing appearance of *O.niloticus* in the fishery is a warranting situation of biological invasion threatening ecological integrity. The fishery of the Ganga River is now subjected to the threats of pollution by sewage and industrial wastes, deforestation, excessive use of fertilizers, pesticides, and water development programmes [32-34]. Consequently, the catches of local fish species have been
adversely affected [35] but invasion of exotic *O. niloticus* in the fishery of the Ganga River has been recent further aggravating the threats to the indigenous fish diversity including environmental problem [36]. International organizations such as world watch institute consider bio invasions as the second greatest threat to biological diversity [37], the first being habitat degradation, when an exotic species establishes itself and proliferate over time and spread to new areas. *O. niloticus* adapt, in to newer areas exploiting local resources and suppressing native species [38]. Exotic fish introductions have been reported to impact the fish biodiversity and have provided significant warnings of the various effects on environment posing threats to the community trophic structure disrupting biological integrity [28,30,39-41]. It has also been realized that the nature and extent of such changes being complex remains unpredictable. Exotic species may become invasive and are capable of decreasing biodiversity through competition, predation and habitat degradation of wild populations in short or long course of time [24,28,30,39]. The problem of repopulating *O. niloticus* in degrading water of the river has come up to population faster. This would not only influence the human but might induce either more adaptability of the biota living in it or might cause damage to various species which would not be able to adapt to such fast ongoing change. The adverse impacts on the wild population due to *O. niloticus* have been assessed in the Ganga River and it is a big concern to the conservation biologists. Its rapid spread and colonization in the Ganga is understood to cause dramatic ecological disruptions at the community and ecosystem levels. The results of this study highlights that the *O. niloticus* has established in the Ganga River as a pest through naturally breeding populations which is now becoming the source for secondary invasions at other places. The result of this study indicated that ecological conditions in the Ganga River were homogenizing by the increasing population of *O. niloticus* which could be of great threat to the ecological integrity for this mighty river sustaining rich fish biodiversity. Understanding the fundamental niche of invasive species facilitates our ability to predict both dispersal patterns and invasion success and therefore provides the basis for better-informed conservation and management policies.

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References.


Figure1: Map showing sampling locations
Table 1: Physico-chemical parameter analysis of Ganga River

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kannauj</th>
<th>Kanpur</th>
<th>Unnao</th>
<th>Allahabad</th>
<th>Mirzapur</th>
<th>Varanasi</th>
<th>Ghazipur</th>
<th>Ballia</th>
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<tr>
<td>Temperature (°C)</td>
<td>19±2-27±3.2</td>
<td>17±2-29±3.1</td>
<td>18±1-27±3.5</td>
<td>17±3.2-28±1.6</td>
<td>19±1.1-26±2.1</td>
<td>20±1.2-27±2.1</td>
<td>18.2±2.1-30±1.1</td>
<td>18±2.6-29±1.6</td>
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<td>EC (µmho/cm)</td>
<td>501±72.2-1222±31.6</td>
<td>504±71.2-1230±31.4</td>
<td>498±72-1200±40</td>
<td>501±68-1198±45</td>
<td>482±56-1152±26</td>
<td>472±59-1142±36</td>
<td>396±45-1256±22</td>
<td>384±42-1226±21</td>
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<td>TDS (mg/L)</td>
<td>815±11.6-902±28.2</td>
<td>915±11.3-1014±28.8</td>
<td>918±9.7-999±40.2</td>
<td>851±15-901±31</td>
<td>812±27-1002±32</td>
<td>852±20-1011±34</td>
<td>611±56-940±30</td>
<td>621±46-1012±36</td>
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<td>pH</td>
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<td>6.8±2.2-7.2±1</td>
<td>6±2.8-6.8±1.1</td>
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<td>5.6±1.2-6.5±1.2</td>
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<td>DO (mg/L)</td>
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<td>5.1±1.1-6±2.0</td>
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<td>6.8±1-8±1</td>
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<td>BOD (mg/L)</td>
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<td>138±8.9-398±20</td>
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<td>238±24-305±35</td>
<td>226±22-325±22</td>
<td>241±24-311±17</td>
<td>239±22-322±27</td>
<td>352±70-412±25</td>
<td>222±60-422±21</td>
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Table 2: Catch contribution and biometry of *Oreochromis niloticus* captured from the Ganga River

<table>
<thead>
<tr>
<th>Year</th>
<th>Abundance (%) of <em>O.niloticus</em></th>
<th>Length Range (cm)</th>
<th>Weight Range (gm)</th>
<th>K-Value</th>
<th>GaSI</th>
<th>Sex Ratio</th>
<th>GSI</th>
<th>Fecondity of different weight fish (Above 150-500 g)</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>Male</td>
<td></td>
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<tr>
<td>2008</td>
<td>7.12</td>
<td>14-19</td>
<td>70-250</td>
<td>2.55-3.64</td>
<td>7.14-9.72</td>
<td>1.11</td>
<td>1</td>
<td>0.27-1.15</td>
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<td>2009</td>
<td>6.52-13.5</td>
<td>16-22</td>
<td>85-320</td>
<td>2.07-3.00</td>
<td>9.10-8.96</td>
<td>1.17</td>
<td>1</td>
<td>0.70-1.80</td>
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<tr>
<td>2010</td>
<td>7.32-17.4</td>
<td>13-24</td>
<td>65-370</td>
<td>2.67-2.95</td>
<td>7.05-10.71</td>
<td>1.21</td>
<td>1</td>
<td>0.49-2.60</td>
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<tr>
<td>2011</td>
<td>8.6-19.5</td>
<td>14-24</td>
<td>70-440</td>
<td>2.55-2.89</td>
<td>8.79-9.26</td>
<td>1.26</td>
<td>1</td>
<td>0.51-3.17</td>
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<td>2012</td>
<td>9.24-6</td>
<td>12-28</td>
<td>60-610</td>
<td>3.07-2.54</td>
<td>8.86-11.41</td>
<td>1.31</td>
<td>1</td>
<td>0.86-3.90</td>
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Figure 2: Food items present in the gut of *O.niloticus* from the Ganga River

Figure 3: Abundance index of *O.niloticus* in the Ganga River over time scale