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# BENTHIC MACRO-INVERTEBRATE FAUNA AND "MARINE ELEMENTS" SENSU ANNANDALE (1922) HIGHLIGHT THE VALUABLE DOLPHIN HABITAT OF RIVER GANGA IN BIHAR - INDIA

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**Abstract**
From the main channel of River Ganga 95 invertebrate taxa have been recorded in the endangered Gangetic Dolphin (*Platanista gangetica*) habitat over an observation period of ten years. Mollusks, Annelids and Arthropods are the dominating benthic groups that constitute the detritivores, filter-feeders and sediment feeders, scrapers/grazers and herbivores. The benthic sediment fauna is rich in diversity and high in abundance. This enables carnivores to occupy a large variety of specialized ecological niches. The qualitative faunal composition of Ganga resembles in general large European rivers with similar representation of taxa. Twelve taxa of marine-originated families were identified, but none of them can be classified as invasive or non-indigenous species. Only two taxa are certainly recognized as non-indigenous neozoans, whereas the remaining fauna shows pristine and stable ecological conditions. In this aspect River Ganga differs from regulated large rivers, where faunal change has largely replaced the original species inventory. Despite the heavy pollution in parts of the river, the original composition of biological diversity is still persisting in the middle reaches of the Ganga. This provides hope for the survival of the Gangetic Dolphin.

***Key words:*** Aquatic, invasive species, functional feeding groups, Gangetic Dolphin

## Introduction

The Ganga is the largest river among the rivers originating from the Himalayan region in northern India. The river section in Bihar is one of the few natural and free-flowing large rivers in south Asia. It is a water resource for one of the world's most fertile plains with pristine river morphology. This river is an irreplaceable unique habitat for the endangered Gangetic dolphin, *Platanista gangetica*

*gangetica* (Roxburgh 1801) and many other endemic and endangered species.

The benthic fauna studied included all groups of taxonomic units to provide comparable results regarding diversity of different habitat-types. Reference data were available for several invertebrate groups only through Datta Munshi *et al.* (1988), Sharan & Sinha (1988), Sinha (1988) and Subba Rao (1989) from the localities near Patna. Systematic investigations have been conducted for several gastropods e.g. Stenothyridae and Physidae (Sinha & Sharma 2001; Sinha *et al.*, 2003), bivalves (Nesemann *et al.*, 2003, Nesemann *et al.,* 2005) and Annelids (Nesemann *et al.*, 2004).

Although throughout most of its range the Gangetic dolphin is declining because of river developments, pollution, deliberate killing and entanglement in nets (Smith and Braulik, 2008) all along the study area there is a good habitat. Five to ten dolphins were regularly surfacing a few meters away from the sampling sites in the main current. Altogether up to 37 dolphins inhabit the River Ganga stretch around Patna (Sinha *et al.,* 2010).

**Materials and Methods**

The macro-invertebrate fauna of the Ganga River was investigated frequently along the right bank in the city of Patna. Benthic samples were collected qualitatively using a hand net. Annelid specimens were preserved in 70% ethanol; leeches were usually relaxed in 15% ethanol, and then transferred into 70% ethanol for preservation. Molluscs and decapods were washed from the sediment samples at the spot and if necessary preserved in 4% formaldehyde. Usually only empty shells of large bivalves have been collected and living specimens were released.

***Study area:*** The main study area is the right (erosion-) bank of a 4km stretch of River Ganga along the city of Patna from Mahendrughat in the west (25° 37' 19" N, 85° 09' 18" E) downstream to Bhadraghat in the East (25° 36' 40" N, 85° 12' 35" E). The faunal collection were done from Mahendrughat, seeping springs, Mahendrughat downstream, Adalatghat, Periphyton, Krishnaghat upstream, Gandhighat, Old Palace, Lithal, artificial stone substrate, Old Palace, Phytal: *Potamogeton crispus*.

The research was conducted from 31st January 2000 to 31st January 2011 including frequent field observations. Altogether eight sites have been visited frequently and their exact results are shown in table 1-3. In addition the left (sedimentation-) bank opposite city of Patna was visited between October and March for collecting faunal samples from different habitats (Boulders, sand, silt and mud substrate).

**Results**

The benthic macro-invertebrate fauna of the main channel comprises 95 identified taxa with high diversity of 26 species of annelids (Table 1), 35 species of mollusks (Table 2) and 29 families, genera or species of arthropods (Table 3), The higher crustacean (Malacostraca) fauna includes 8 taxa of crabs, prawns, shrimps, mysid shrimps and one isopod. Aquatic insects are mainly represented with 21 identified taxa out of which nymphs of Dragonflies and Damselflies, larvae of Two-winged flies and adults of Water-Bugs are the most striking groups. Additionally the presence of Roundworms (Nematoda) and Ribbon worms (Nemertina) was generally noticed with small abundances.

***Functional Feeding Groups of Macro-invertebrates in the River Ganga:*** The habitat was classified according to longitudinal and lateral terminology described and defined by Illies (1961), Illies & Botosaneanu (1963) and Amoros & Roux (1988). The River Ganga at Patna is a heterotrophic Meta-Potamon system. Organic load is brought from upstream through river-continuum or it is introduced from surroundings along the banks and during flood. According to the commonly used classification of higher invertebrate taxa and field observations, their particular role in processing food can be roughly outlined at least at family level. Each taxon is assigned to a specific functional feeding group based on the definitions of Vannote *et al.* (1980), Williams & Feltmate (1992), Merritt & Cummins (1996). Functional feeding groups at family level (Tables 1-3) are summarized and figured for 51 taxa found in River Ganga at Patna, based on the qualitative composition of benthic fauna (Fig. 1).

The detritivores include in part shredders (Polychaeta) and scrapers or grazers (Gastropoda) with all sediment- and filter feeders. Altogether 54 % of the families can be assigned to this group (Fig. 2). The true carnivores represent 34 % of the qualitative faunal composition, indicating high diversification and prey specialization (Fig. 3). Herbivores (minimum of 2 % or more) are the minor group in the turbid River Ganga, and this may well reflect the rare occurrence of vascular

aquatic plants along the banks. Some scrapers among the gastropods, especially Lymnaeidae, and miners among the insects e.g. Pyralidae nymphs of moths feed mainly on living algae and macrophytes.

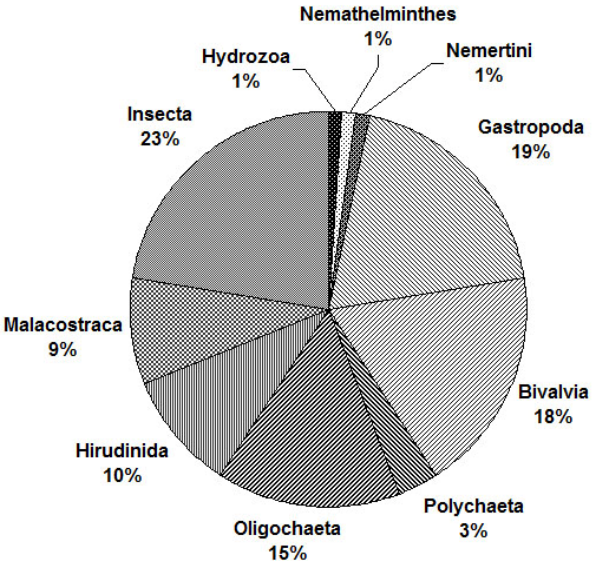


**Figure 1:** Qualitative composition of Benthic Macro-Invertebrates of the River Ganga at Patna with 95 identified taxa.

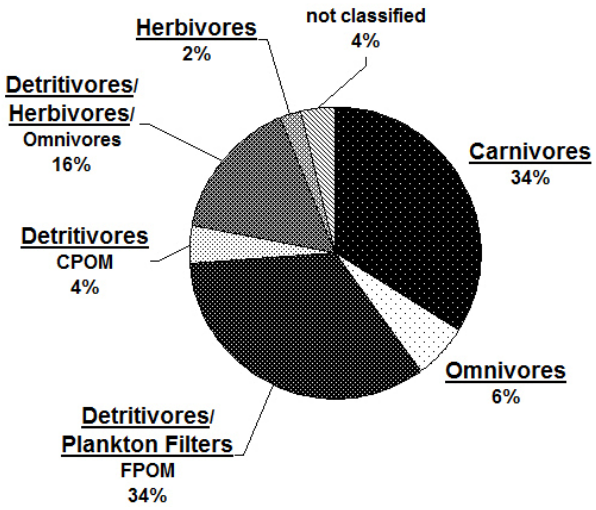


**Figure 2:** General Feeding Guilds of Benthic Macro-Invertebrates in River Ganga with 51 classified families of the present study: Dominance of Detritivores (54 %), Herbivores and others (12 %) over Carnivores (34 %).

***The "Marine Element" (Annandale 1922):*** Besides the Gangetic River dolphin *Platanista gangetica gangetica,* some unique freshwater species of predominantly or nearly exclusively marine invertebrate families have drawn early attention of scientists. Annandale (1922) has already distinguished two groups of marine origin characterizing these as "The Euryhaline Fauna of the Delta" and "The Relict Fauna of the River". He listed three bivalves *Novaculina gangetica*, *Scaphula celox* and *Scaphula deltae* as relict fauna. Their occurrence in River Ganga nowadays extends upstream to 1500 km away from coastal waters and the Gangetic delta region. According to Annandale (1922) they are possible marine relics of the former tertiary sea.

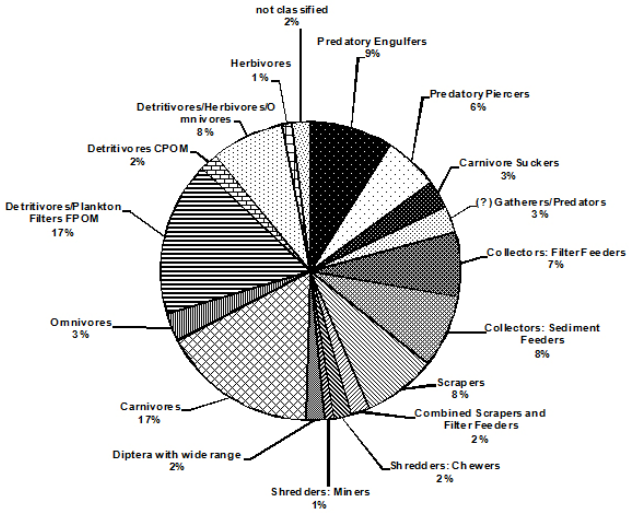


**Figure 3:** Functional Feeding Groups of Benthic Macro-invertebrates in River Ganga with 51 classified families of the present study.

Presently a total of twelve species of the macro-invertebrates occur at Patna belonging to marine-originated or primary brackish water families. These are Nereididae: *Namalycastis indica*, Nephthydae: *Nephthys oligobranchia*, Ozobranchidae: *Ozobranchus shipleyi*, Stenothyridae: *Stenothyra ornata*, *Gangetia miliacea*, Arcidae: *Scaphula celox*, *S. deltae*, Psammobiidae: *Novaculina gangetica*, Mysidae: *Gangemysis assimilis*, Corallanidae: *Tachaea spongillicola*, and Hymenosomatidae: *Hymenicoides carteri*, *Neorhynchoplax* spp.

Recent observations of invertebrate invasion along large rivers used as waterways allow two alternative hypotheses:

**1.** The occurrence of the above-mentioned species in freshwater upstream from the upper tidal limit are true marine "Relict fauna of the River Ganges" according to Annandale (1922).

**2.** The occurrence of the above mentioned species in freshwater upstream from the upper tidal limit is based on both recent introduction by shipping and ongoing upstream range extension by active dispersal as a response to the increasing human impact with environmental changes of habitat.

Since the species are restricted to the Ganges River, their presence may be due to the use of the waterway during the last one hundred years. On other hand, some species of "marine origin" are widespread throughout the Gangetic plain. Here the artificial introduction by shipping is most unlikely. All species are native to the Indian subcontinent, eleven of them being originally described from the delta region of River Ganges with type localities somewhere in Hugli River floodplain or connected channels. Two examples will be described here in detail with data of their first collections (Nesemann *et al.,* 2007) and additional records (Nesemann 2009):

***Tachaea spongillicola* (Stebbing 1907)**

Material examined: Nepal, Rupandehi District, Ghagara Khola, February 1994, leg. S. Sharma & H. Nesemann; Nepal, Rautahat District, Lamaha Khola at Shivpur, February 1994, leg. S. Sharma & H. Nesemann, October 2005, leg. Sharma, Tachamo, Shah, Nesemann; Nepal, Rautahat District, Jhajh Nadi confluence into Bagmati River, October 2005, May 2006, leg. Timalsina, Tachamo, Shah, Nesemann; Nepal, Kailali District, Jagadishpur reservoir, January 2008, leg. Tachamo, Shah, Nesemann; Nepal, Sunsari District, Khantaha River at Kushaha and Haripur, December 1996, leg. S. Sharma, S. Khanal & H. Nesemann; India, Bihar, Ganga River right bank at Patna, Old Palace, March 2003, leg. H. Nesemann; India, Bihar, Pupun River at Fatuha, November 2002, leg. G. Sharma & H. Nesemann; India, Bihar, Ganga River right bank upstream from Buxar, April 2004, leg. D. Kedia, G. Sharma & H. Nesemann.

This isopod has been originally described by Stebbing (1907) from a freshwater tank at Kolkata as a commensal of the freshwater sponge *Spongilla carteri*. The first record of *T. spongillicola* being collected as ectoparasites of freshwater prawns *Macrobrachium* spp. in southern India was published by Mariappan, Balasundaram & Trilles (2003). During the present survey *T. spongillicola* was regularly collected from benthic samples of lowland streams and small rivers of the Lower Gangetic Plain in Nepal and India as well as from River Ganges itself. The wide distribution range exceeds northwards to the Himalayan foothill streams in the Terai region. This may indicate the natural pattern of dispersal.

***Gangemysis assimilis* (Tattersall, 1908)**

Material examined: Nepal, Rautahat District, Barahwa Nadi north of Gaur, December 2005, May 2006, leg. Sharma, Timalsina, Tachamo, Shah, Nesemann; Nepal, Rautahat District, Jhajh Nadi confluence into Bagmati River, December 2005, May 2006, leg. Sharma, Timalsina, Tachamo, Shah, Nesemann; Nepal, Rautahat District, Jhajh Nadi confluence into Bagmati River, December 2005, May 2006, leg. Timalsina, Tachamo, Shah, Nesemann; India, Bihar, Ganga River right bank at Patna, Old Palace, March 2003, leg. H. Nesemann; India, Bihar, Ganga River at Patna, Adalatghat, March 2008, leg. G. Sharma & H. Nesemann.

This mysid shrimp has been originally described by Tattersall (1908) from a brackish water pond at Port Canning. The first records of *G. assimilis* were collected in small rivers and oxbow lakes of southern Nepal from December 2005 onwards (Nesemann *et al.,* 2007). During the present survey *G. assimilis* was collected from periphyton-samples from River Ganges itself in March 2008. The wide distribution range northwards to the Himalayan foothill streams in the Terai region resembles the distribution pattern of the isopod *T. spongillicola*. It supports the natural pattern of dispersal of this species.

**Discussion**

***How to identify invasive species (Neozoa) among benthic Macro-invertebrates in the River Ganga?***

Neozoa are numerously reported among the aquatic invertebrates of many large rivers all over the northern hemisphere. The neozoa are benefited from regulated rivers and ships often initially distribute them. The total amount of non-indigenous macro-invertebrates in rivers can be used to understand and describe the degree of anthropogenic changes of the potamocoenosis environment. Many neozoa tolerate higher salinity as well and originate from costal brackish waters. Therefore several neozoa (e.g. the Danubian *Limnomysis benedeni* Czerniavsky, 1882 of the ponto-caspian basin) have been erroneously regarded as marine relicts. This question is of great interest for the River Ganga fauna. It makes it necessary to review thoroughly the following four aspects for each species:

1. How long back does the knowledge of any particular species dates?
2. From which country and watershed the species has been described?
3. Is there any certain observation of the invasive character of the species?
4. Does the analysis of the present-day distribution pattern allow any conclusions about the probable impact of transportation by waterways?

Many taxa of River Ganga that could be identified to species level are most likely a part of the indigenous fauna; based on the knowledge from their first observations. They could have been originally described from either northern Indian subcontinent or from Gangetic delta and certain literature records are known from nineteenth or early twentieth century. For some popular gastropods, the River Ganga is representing the "terra typica" without any precise location e.g. *Brotia costula*. Early observations of numerous aquatic molluscs have been already mentioned from Gangetic plains by Preston (1915) and Annandale (1922) and additional records were summarized by Subba Rao (1989). Several malacostracans (Mysida, Decapoda) have been originally described from Gangetic delta in Bengal. Similarly some of the wide spread oriental leeches have been already reported from at least few localities of Gangetic Plains by Harding & Moore (1927). Thus the presumed theory of recent faunal changes in River Ganga by invasion or introduction of euryhaline and pollution-tolerant neozoa is not supported with any certain observations. In contrast it has to be highlighted that all members of marine-originated families are autochthonous species of the river since their scientific discovery and description.

Among all invertebrates found in the study area at Patna only two species can be certainly identified as non-native invaders, so-called neozoa (Fig. 1). The gastropod *Haitia mexicana* is of nearctic origin with rapid spreading during last fifteen years. This North American Physidae *Haitia mexicana* was invading the river system since the early nineties, starting from few introductions in 1994 in capitals like New Delhi and Kathmandu and in 1998 in Allahabad. Its rapid spreading was initiated by commercial distribution of aquaria material and aquatic plants. Shortly after colonization of River Ganga in Patna after 1998, *H. mexicana* was found in high abundance. Since that time the individual density is declining. Mass occurrence is nowadays restricted to few highly polluted places, where *H. mexicana* lives without competition with other gastropods (Sinha *et al.*, 2003).

The earthworm *Perionyx excavatus* originates from the Eastern Himalayan foothills (Gates, 1972). This species is helpful in agriculture, with successful early introductions to subtropical countries all over the world. Many pan-tropical localities have been already reported by Gates (1972) from the first half of twentieth century. In Gangetic Plain *P. excavatus* appears to be well established since long. Thus the occurrence in semi-aquatic zone of River Ganga at Patna might be the result of natural invasion from agricultural terrestrial habitats.

***Comparison of River Ganga fauna (Oriental region) with large rivers of temperate Central Europe (Palearctic region):*** Although numerous faunal lists and inventories have been published for floodplains of large rivers (Obrdlik, Falkner & Castella 1995), detailed studies on the benthic invertebrates of main channels are very rare. Important reason is the different quality of taxa-lists caused by incomparable intensity of research and different levels of identification. Thus only a few studies of large rivers can be compared with the present results of River Ganga. The current identification level for microdrile tube worms (Oligochaeta: Tubificina) and aquatic insects, especially dipterans, varies largely in different studies and it needs a detailed comparison for each individual river.

The Gangetic fauna of Patna is compared with some of the largest European rivers Rhine, Main and Oder flowing into the North and Baltic Seas for discussion of differences in Potamocoenosis of Eurasian subtropical and temperate zones. Comparable faunal lists of representative river sections in low altitudes and plains have been rarely published for all macro-zoo benthic organisms. The results investigated by Kinzelbach (1983, 1985), Sopp (1983), Ziese (1985, 1987), Schmid (1999) and Schleuter & Haybach (2003) provide benthic faunal particulars of the main river channels (Table 4). The available physico-chemical parameters show similar condition in the lowland rivers except of the temperature range.

In biodiversity all large rivers have three main components of benthic macro-invertebrates: Mollusca (Class: Bivalvia, Gastropda), Arthropoda (Class: Malacostraca, Insecta) and Annelida. Molluscs are more diversified and most dominating in River Ganga with 38 % of identified taxa. The temperate aquatic malacofauna ranges from 21 – 28 %. Arthropods are leading groups in Rhein (Rhine), Main and Oder Rivers with 33 – 51%, but identification level cannot be compared directly due to different species-, genus- and family-level. In contrast the Gangetic insects (23 %) are insufficiently known from the preliminary list at family level. In Annelids all three major groups (Polychaeta, Oligochaeta, Hirudinida) cover 28 % of the identified taxa in River Ganga and the fauna has been carefully investigated and described. The

European rivers display similar amount of annelid taxa with 30 % for Order, largely based on the very rich Tubificidae diversity, up to 19 % for Rhine and 17 % for Main River. It is noteworthy that the true freshwater Polychaeta were originally absent in the river systems of North and Baltic Sea.

***Neozoa in River Ganga compared with the European Rivers*** (Fig. 4)***:*** In regulated large rivers of temperate zone the indigenous or native benthic invertebrates are becoming accompanied by aquatic invaders or invasive species. They are partially replacing the reduced original fauna or even occupy free ecological niches. Neozoa play an important role in benthic fauna of navigable rivers. Their increasing number of species is sufficiently documented in some European rivers and especially studied for River Rhine (Fig. 4). The relative amount of non-indigenous invasive species changes from estimated 2 - 6 % to approximately 12 - 18 % of the total number of identified taxa within the last hundred years (Kinzelbach 1983, Nehring 2003). Similar tendency in Rivers Main (21 Neozoa) and Oder (14 Neozoa) is showing the same range.

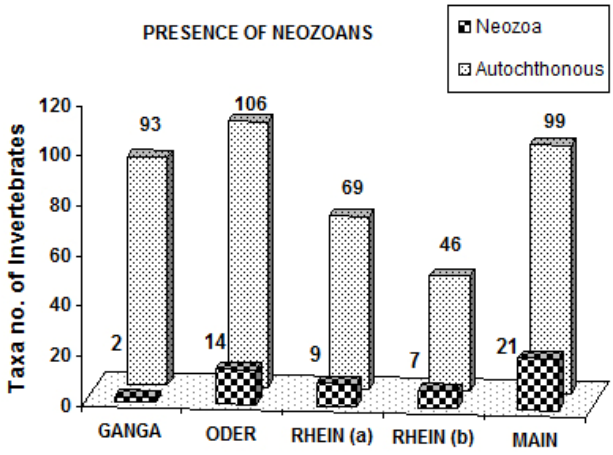


**Figure 4:** Presence of Neozoa in River Ganga main channel in comparison with lowland-reaches of large river systems (main channels) in Central Europe, Germany.

***Discussion of possible reasons for faunal changes in River Ganga:*** Natural changes are well documented and redrawn from satellite photographs. The river bed permanently undergoes a high natural dynamic process. During the last decade the lateral erosion has shifted the main channel of River Ganga bed northwards. The river became diverted upstream Patna city and the location of the confluence of the Gandak River has changed to a northern direction. The most important visible change of environmental condition is the fact that the former main channel of River Ganga along Patna has now become a southern branch with residual flow during low water season. Consequently deposition of silt from Ganges and deposition of sand from Gandak have reduced the maximum depth and water current along the right bank of the river.

Anthropogenic changes took place along the Patna section during the same time.

1. The organic load has been reduced by sewage treatment plants as a measurable result of the Ganga Action Plan.
2. The bank fixation originally constructed by standardized bricks was renewed and enlarged with large amount of natural boulders (> 30 cm) along the water's edge for low water level.

Thus substrate compositions of the right bank are gradually changed. Loam and silt have been reduced or covered and replaced by hard substrate. The quality of hard substrate in form of large natural boulders is providing stable surface habitat for lithophilic species, especially leeches (Hirudinida) and snails (Gastropoda) largely supported by the interspaces and subsurface. These artificially created micro-habitats are stable against flood-disturbance during monsoon period.

Lotic/rheophilic species are declining (*Novaculina gangetica*, *Namalycastis indica*, Hymenosomatidae), whereas lentic fauna is more supported by the residual flow with side-arm condition during low water period. Especially the increasing density and extension of large freshwater mussels is co related with the environmental changes. Dense mussel-beds were observed in May 2010 at Gandhighat, where ten years ago in January 2000 mostly *Thiara scabra* and *Thiara lineata* have been the dominating molluscs. Polychaetes and spider crabs disappeared at the same place.

## Conclusion

***Faunal change of benthic macro-invertebrates in River Ganga:*** Compared with initial studies (Sharan and Sinha 1988, Sinha 1988), the number of taxa is continually growing throughout the last years. In the following decades more detailed studies have been conducted and thorough sampling has brought to light the discovery of many species. On the other hand, the continuous field-observations have clearly documented some faunal change for several groups:

1. Appearance of invasive non-indigenous species, which have not been recorded before 1998: Physidae: *Haitia mexicana*.
2. Appearance of indigenous species, which have been overlooked or miss-identified during previous studies: Examples are the Hymenosomatidae: *Hymenicoides carteri*, *Neorhynchoplax* sp., *Tachaea spongillicola*, *Gangemysis assimilis*.
3. Decline of indigenous species, which have been recorded with high abundance during previous studies: Psammobiidae: *Novaculina gangetica*.
4. Increase of indigenous species, which have been recorded with low abundance during previous studies: Leeches Hirudinida e.g. *Alboglossiphonia* sp., *Salifa* sp. and others.
5. Enlargement and downstream-shifting of the dense mussel-bed within the present study: Unionidae and Amblemidae: *Lamellidens* spp. and *Radiatula* spp.

The present scientific knowledge of macro-invertebrates from River Ganga before the twentieth century is very poor. It is limited mainly to collections of molluscs (Preston 1915, Annandale 1922). Many invertebrate species of marine and brackish origin were described in the early twentieth century and no exact observations prior to their scientific descriptions are available. Thus "The Relict Fauna of the River" (Annandale 1922: 146) "that flourish in the Middle Reaches of Ganges" cannot be certainly assigned to invasive, non-indigenous species. Considering the high number and native character of the marine-originated families, they can be regarded as original members of the eco-region of Lower Gangetic Plains. There is neither proof for their rapid invasion within the last decades, nor for their absence. The few studies on benthic fauna do not allow comparison of the present-day situation with former conditions one hundred years ago. While comparing River Ganga with regulated European rivers the presumed analogous faunal change is not supported. In contrast Ganges fauna has preserved comparatively semi-natural conditions with original species inventory of most invertebrates. The benthic neozoa are actually represented with 2 % of total identified taxa, similar to large European rivers at the end of nineteenth century (Fig. 4). Thus the River Ganga around Patna displays a rich aquatic biodiversity, but the ecological status needs sustainable conservation and improvement of the ecosystem.

**Table 1:** Taxa-list for Annelida in River Ganga at Patna.

| **Phylum Annelida** Taxon: | **Records and Abundance (2000-2010)** |
|---|---|
| **Class Polychaeta** | |
| **Family Nereididae** | |
| *Namalycastis indica* (Southern, 1921) | Common, frequent in winter |
| **Family Nephthydae** | |
| *Nephthys oligobranchia* Southern, 1921 | Badarghat, March 2002 |
| *Nephthys polybranchia* Southern, 1921 | Earlier records: Sharan & Sinha (1988) |
| **Class Oligochaeta** | |
| **Family Naididae** | |
| *Chaetogaster limnaei bengalensis* Annandale, 1905 | Badarghat, October 2002 |
| *Branchiodrilus semperi* (Bourne, 1890) | common |
| *Allonais paraguayensis* (Michaelsen, 1905) | Mahendrughat, October, November 2002 |
| *Pristina acuminata* Liang, 1958 | Mahendrughat, November 2002 |
| *Pristina* cf. *biserrata* Chen, 1940 | Badarghat, March 2002 |
| *Dero pectinata* Aiyer, 1930 | Badarghat, March, April 2002 |
| *Aulophorus indicus* Naidu, 1963 | Badarghat, March 2002 |
| *Nais bretscheri* Michaelsen, 1899 | Badarghat, February 2003 |
| *Nais* spec. | Mahendrughat, Adalatghat, March 2008 |
| **Family Tubificidae** | |
| *Limnodrilus hoffmeisteri* Claparède, 1862 | Locally very common |
| *Aulodrilus pigueti* Kowalewski, 1914 | common |
| *Branchiura sowerbyi* Beddard, 1892 | Gandhighat, March 2008 |
| **Family Microchaetidae** | |
| *Glyphidrilus gangeticus* Gates, 1958 | Locally very common |
| **Family Megascolecidae** | |
| *Perionyx excavatus* Perrier, 1872 | Mahendrughat, locally common |
| **Order Hirudinida** | |

| | |
|---|---|
| **Family Glossiphoniidae** | |
| *Alboglossiphonia weberi* (Blanchard, 1896)<br>*Alboglossiphonia pahariensis* Nesemann & Sharma, 2007<br>*Placobdelloides fulvus* (Harding, 1921) | common<br>Gandhighat, May 2010<br>Widespread but not abundant |
| **Family Ozobranchidae** | |
| *Ozobranchus shipleyi* Harding, 1909 | Gandak confluence, March 2001 |
| **Family Hirudinidae** | |
| *Asiaticobdella birmanica* (Blanchard, 1894) | Mahendrughat, January, November 2002 |
| **Family Salifidae** | |
| *Barbronia weberi* (Blanchard, 1894)<br>*Salifa lateroculata* (Kaburaki, 1921)<br>*Salifa biharensis* Nesemann, Sharma & Sinha, 2004<br>*Odontobdella krishna* Nesemann & Sharma, 2011 | Mahendrughat, locally common<br>Widespread but not abundant<br>Mahendrughat, Gandhighat<br>Gandhighat, May 2010 |
| Total number of identified taxa: 26 | |

**Table 2:** Taxa-list for Mollusca in River Ganga at Patna.

| **Phylum Mollusca** Taxon: | **Records and Abundance (2000-2010)** |
|---|---|
| **Class Gastropoda**<br>**Family Bithyniidae** | |
| *Digoniostoma pulchella* (Benson, 1836) | Old Palace, March 2008 |
| **Family Stenothyridae** | |
| *Stenothyra ornata* Prashad, 1921<br>*Gangetia miliacea* (Nevill, 1880) | Gandak confluence 2001, PM Ghat 2004<br>Old Palace, March 2003 |
| **Family Thiaridae** | |
| *Thiara (Tarebia) lineata* Gray, 1828<br>*Thiara (Thiara) scabra* (O. F. Müller, 1774)<br>*Thiara (Tarebia) granifera* (Lamarck, 1822)<br>*Melanoides tuberculatus* (O. F. Müller, 1774) | Very common<br>Very common<br>Rare<br>Common |
| **Family Pleuroceridae** | |
| *Brotia costula costula* (Rafinesque, 1833) | Common |
| **Family Viviparidae** | |
| *Bellamya (Filopaludina) bengalensis* (Lamarck, 1822)<br>*Mekongia crassa* (Benson, 1836) (=*Bellamya crassa*) | Common<br>Very common |
| **Family Lymnaeidae** | |
| *Lymnaea acuminata* (Lamarck, 1822) | Krishnaghat, 2003, Gandhighat, May 2010 |
| *Radix persica* (Issel, 1865) | Common |
| **Family Planorbidae** | |
| *Ferrissia verruca* (Benson, 1855)<br>*Ferrissia baconi* (Bourguignat, 1853)<br>*Indoplanorbis exustus* (Deshayes, 1834)<br>*Gyraulus convexiusculus* (Hutton, 1849) | Rare<br>Krishnaghat, 2002<br>Rare<br>Rare |
| **Family Physidae** | |
| *Haitia mexicana* (Phillipi, 1889) | Common |
| **Family Succineidae** | |
| *Quickia bensoni* (Pfeiffer) | Common: Mahendrughat |
| **Class Bivalvia** (=Pelecypoda)<br>**Family Arcidae** | |

| | |
|---|---|
| *Scaphula celox* Benson, 1836 | Locally abundant on hard sustrate |
| *Scaphula deltae* Blanford, 1867 | Rare: Mahendrughat, Old Palace |
| **Family Psammobiidae** | |
| *Novaculina gangetica* Benson, 1830 | Silt, loam substrate (? declining population) |
| **Family Corbiculidae** | |
| *Corbicula striatella* Deshayes, 185 | Common |
| *Corbicula bensoni* Deshayes, 1854 | Rare, common only at Badarghat |
| *Corbicula assamensis* Prashad, 1828 | Rare: Mahendrughat, Badarghat |
| *Corbicula aurea* Nesemann & Sharma, 2007 | Rare: Mahendrughat, Badarghat |
| **Family Sphaeriidae** | |
| *Pisidium (Afropisidium) clarkeanum* G. & H. Nevill, 1871 | Rare: Gandhighat, common: Badarghat |
| *Pisidium (Afropisidium) nevillianum* Theobald, 1876 | Rare: Badarghat |
| **Family Unionidae** | |
| *Lamellidens corrianus* (Lea, 1834) | Very common |
| *Lamellidens consobrinus* (Lea, 1859) | Fairly common |
| **Family Amblemidae** | |
| *Radiatula caerulea* (Lea, 1831) | Very common |
| *Radiatula occata* (Lea, 1860) | Common |
| *Radiatula lima* (Simpson, 1900) | Rare |
| *"Radiatula" olivaria* (Lea, 1831) | Common, left bank opposite Patna + upstream |
| *Parreysia favidens chrysis* (Benson, 1862) | Common |
| *Parreysia corrugata laevirostris* (Benson, 1862) | Fairly common |
| Total number of identified taxa: 35 | |

**Table 3:** Taxa-list for Arthropoda (Malacostraca, Insecta) in River Ganga at Patna

| **Phylum Crustacea** Taxon: | **Records and Abundance (2000-2010)** |
|---|---|
| **Class Malacostraca: Order Mysida**<br>**Family Mysidae** | |
| *Gangemysis* cf. *assimilis* (W.M. Tattersall, 1908) | Adalat Ghat, March 2008 |
| **Order Isopoda: Family Corallanidae** | |
| *Tachaea spongillicola* Stebbing, 1907 | Old Palace, March 2003 |
| **Order Decapoda: Family Palaemonidae** | |
| *Macrobrachium* spec. | Old Palace, frequently observed |
| **Family Atyidae** | |
| *"Caridina"* spec. | Common |
| **Family Hymenosomatidae** | |
| *Hymenicoides carteri* Kemp, 1917 | Common, winter saison 2000-2003, 2011 |
| *Neorhynchoplax* spec. | Widespread but not abundant, winter saison |
| **Family Parathelphusidae** | |
| *Barythelphusa lugubris* (Wood-Mason, 1871) | Locally common |
| *Parathelphusa martensi* (Wood-Mason, 1871) | Krishnaghat, March 2010 (Exuviae's) |
| **Class Insecta: Order Odonata**<br>**Family Gomphidae:** | |
| *Asiagomphus* spec. | Common, adults March-May |
| *Macrogomphus* spec. | Ghajghat, January 2011 |
| **Family Libellulidae** Gen spp. | Gandhighat, May 2010 |
| **Family Protoneuridae** Gen spp. | Old Palace, aquatic plants, March 2008 |

| | |
|---|---|
| **Family Coenagrionidae** Gen spp. | Left bank opposite Patna, Macrophytes |
| **Order Trichoptera** | |
| **Family Hydropsychidae** Gen spp. | Very common, adults April-June |
| **Order Lepidoptera** | |
| **Family Pyralidae** Gen spp. | Old Palace, aquatic plants, March 2008 |
| **Order Diptera** | |
| **Family Chironomidae** Gen spp. | Common |
| **Family Ceratopogonidae** Gen spp. | Gandak confluence, sand substrate |
| **Family Psychodidae** Gen spp. | Rare: Mahendrughat, March 2008 |
| **Family Culicidae** Gen spp. | Very common |
| **Family Muscidae** Gen spp. | Old Palace, hard substrate |
| **Order Heteroptera: Family Belostomatidae** | |
| *Diplonychus annulatus* ( Fabricius, 1781) | Old Palace, aquatic plants, March 2008 |
| **Family Nepidae**: Nepinae: *Laccotrephes* spec.<br>Ranatrinae: *Ranatra* spec. | Old Palace, March 2008, Gandhighat, May 2010<br>Adalat Ghat, Old Palace, March 2008 |
| **Family Pleidae**: *Paraplea* spec. | Old Palace, aquatic plants, March 2008 |
| **Family Micronectidae**: *Micronecta* spec. | Very common |
| **Family Corixidae**: *Sigara (Tropocorixa)* spec. | Adalat Ghat, Old Palace, March 2008 |
| **Family Mesoveliidae**: *Mesovelia* spec. | Old Palace, aquatic plants, March 2008 |
| **Order Coleoptera** | |
| **Family Gyrinidae** Gen spp. | Widespread and locally abundant |
| **Family Dytiscidae** Gen spp. | Fairly common |
| **Family Hydrophilidae** Gen spp. | Fairly common |
| Total number of identified taxa: 30 | |

**Table 4:** Benthic Macro-Invertebrates of River Ganga main channel in comparison with lowland-reaches of large river systems (main channels) in Central Europe:

| **Phylum / Class** | **Subtropical River of Oriental Region (India)** | **Temperate Rivers of Palearctic Region (Germany)** | | | |
|---|---|---|---|---|---|
| | **Ganga** | **Oder** | **Rhein (a)** | **Rhein (b)** | **Main** |
| Porifera | - | - | 2 | 2 | 3 |
| Bryozoa | 1 | 5 | 5 | 6 | - |
| Hydrozoa | 1 | 2 | 2 | 2 | 1 |
| Nemathelminthes | 1 | - | 4 | - | 1 |
| Nemertini | 1 | - | 1 | - | - |
| Turbellaria | - | 3 | 3 | 3 | 4 |
| Gastropoda | 18 | 14 | 14 | 7 | 14 |
| Bivalvia | 17 | 15 | 8 | 4 | 15 |
| Polychaeta | 3 | - | - | - | 1 |
| Oligochaeta | 14 | 28 | 6 | 4 | 5 |
| Hirudinida | 9 | 9 | 7 | 6 | 14 |
| Malacostraca | 8 | 7 | 7 | 7 | 10 |
| Insecta | 22 | 37 | 19 | 12 | 52 |
| Total number of identified taxa | 95 | 120 | 78 | 53 | 120 |

River Ganga, Lower Gangetic Plain, Patna (India), altitude ≈ 53-55 m a.s.l.; Oder River (Schmid 1999), Lower Oder Valley (Germany), altitude ≈ 28-33 m a.s.l.; Rhein/Rhine (a) River (Ziese 1985, 1987), (a) Mainz – Wiesbaden (Germany), altitude ≈ 83m a.s.l.; Rhein/Rhine (b) River (Sopp 1983), (b) Loreley – St. Goarshausen (Germany), altitude ≈ 75m a.s.l.; Main River (Schleuter and Haybach 2003), Lower Main Plain (Germany), altitude ≈ 85-115m a.s.l..

**Table 5:** Physico-chemical parameters of River Ganga (India) compared with Oder, Rhine and Main Rivers (Germany)

| Parameters | Rivers | | | |
|---|---|---|---|---|
| | **Ganga** | **Oder** | **Rhein (a)** | **Main** |
| Water Temperature (°C) | 14.0-31.2 | 0.0-26.7 | -22.0 | -27.0 |
| Conductivity (µS/cm) | 229-313 | - | 475-850 | 414-872 |
| pH | 8.3-8.7 | 7.1-9.3 | 7.3-9.0 | - |
| Dissolved Oxygen (mg/l) | 6.7-9.4 | 3.3-15.7 | 5.0-10.0 | 5.45-13.35 |

Data sources: Ziese (1987), Sharma (1998), Trzebiatowski (1999), Bernerth *et al.* (2005), Brahmer & Teichmann, (2008).

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