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Food overlap of benthic fishes in the Danube Delta, with special respect to two invasive gobiids (Teleostei: Gobiidae, Percidae, Cyprinidae)

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With 2 figures and 3 tables

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On a shallow, sandy shore of River Danube, Danube delta, food overlap of *Neogobius fluviatilis, Benthophilus stellatus* (Gobiidae), *Blicca bjoerkna* (Cyprinidae) and *Gymnocephalus schraetser* (Percidae) was analysed comparing the food niche of gobiids, known to be invasive to Central Europe, with other co-occurring common fish species. The food overlap between gobiids and coexisting species was found to be low due to different food preferences and due to different spatial distribution within the habitat examined.

1 Introduction

Several Ponto-Caspian gobiids are expanding their native range to Central Europe, coming along the lower River Danube (Ahnelt et al. 1998) and, through the Pypyet-Bug canal, from River Dniepr (Danilkiewicz 1996, Danilkiewicz 1998). Whereas the invasion of large artificial water reservoirs by estuarine gobiids was recorded since the 1940s in Ukraine rivers (Smirnov 1986), the upriver range expansion in the River Danube seem to have started in the late 1960th. (Banarescu 1964, P. Banarescu pers. comm.). In the 1970s *Neogobius fluviatilis* appeared in lake Balaton where it might have been introduced (Biro 1971). The increasing numbers of records of *Proterorhinus marmoratus* in the middle and upper Danube basin might be partly due to insufficient faunistic knowledge and partly due to range expansion. This species reached the Rhine basin in 1999 (Reinartz & Hilbrich 2000). Recently *Neogobius melanostomus* invaded the Baltic Sea most properly from upper Volga basin and is already present in the lower River Vistula. *Neogobius kessleri*, *N. gymnotrachelus* and *N. melanostomus* invaded the upper Danube (Ahnelt & al. 1998, Seifert & Hartmann 2000) and *N. fluviatilis* and *N. gymnotrachelus* invaded the Vistula basin. *Benthophilus stellatus* represent an additional species, passing the Iron Gate II in Danube in the middle 1999th, being already abundant in the River Dniepr up to

Kiev and in middle River Don. The effects of these invaders on the local ecosystem and the local fish fauna are unknown, and can only be examined shortly after the invasion event. In order to get some ideas about the effects of invasive species on Central European fish faunas, the relationship between invasive species and non-invasive species can be examined in their natural habitat, where they occur sympatric. This investigation is a small step in this direction, comparing the food niche of two gobiids, known to be invasive, with other co-occurring common fish species.

2 Material and Methods

Fish were collected on 20th and 21st August 2001 in the Sf. Gheorghe branch of the Danube Delta, Romania, at km 96 (45°07'47 N 29°00'16E). The Sf. Gheorghe branch leads about 25 % of the Danubian water to the Black Sea, the mean discharge (1858–1988) is 1580 m^3/s (Gastescu 1993). A beach-seine (10 m x 1.9 m; mesh size 2.5 mm x 2.0 mm) was applied to collect fish from the bank. Fish were collected during day between 08.45 and 19.00 h and during night between 22.00 and 01.00 h and preserved in 4 % formaldehyde, after two weeks transferred to 70 % ethanol for examination and storage.

Due to the low presence of benthic fishes in the day samples, only fish from night samples were examined. The five most abundant species/size classes of benthic species were selected for food analyze: *N. fluviatilis, Blicca bjoerkna* (Cyprinidae), *Gymnocephalus schraetser* (Percidae), and *B. stellatus.*

No food overlap was expected between the benthic gobiids and the pelagic and surface foraging *Alburnus alburnus* and *Chondrostoma nasus* (both Cyprinidae) feeding on periphyton and detritus (Banarescu 1964). Therefore food overlap was examined between *B. bjoerkna*, *G. schraetser*, and two gobiids *B. stellatus* and *N. fluviatilis* known to be invasive in the middle and upper Danube. Samples of *Neogobius fluviatilis* were subdivided in two groups according to their length frequency distribution. The standard length (SL) of 67 fishes, showed two clear peaks, one from 22 mm to 50 mm, and the other one from 55 mm to 84 mm standard length. It was expected, that these two stages may feed on different pray items.

Stomachs and guts were dissected under a binocular microscope. In species without stomach, the anterior third of intestine was dissected. Specimen without content in stomach or the anterior third of gut were considered as empty. The guts or stomach contents were embedded in Gelvatol, (Polyvenylalcohol containing 50 g Polyvenylalcohol, 100 ml Glycerin, 6g Phenol, and 500ml aqua dest.). Food items were identified, and their relative part of surface cover was estimated for each individual fish. Owing to the difficulty of identifying the ingested food, prey items were assigned to broad taxonomic units or groups (Bischoff & Freyhof 1999). The following 12 categories were considered: Amphipoda, Mysidacea, *Corbicula* sp., *Lithoglyphus naticoides*, Chironomidae larvae, Chironomidae pupae, Corixidae, fish scales, pieces of plants, detritus, and mineral material including sand. Unidentifiable material was considered as "rest". The term detritus was used to describe fine organic material in different stages of decomposition.

Data analysis

The mean percentage of each food category was calculated for each species/size class. Dietary overlap between different species/size classes was compared using the index proposed by Schoener (1970):

$$O = 1 - \frac{0{,}5 \sum |p_a - p_b|}{100}$$

Where p_a = percentage of food item in species/size class a, and p_b = percentage of food item in species/size class b. The index produces values from 0 (no overlap) to 1 (complete overlap).

The relative importance of food items was evaluated using the index of food importance (I) (Delariva & Agostinho 2001):

$$I = 100OV(\Sigma OV)^{-1}$$

Where O= the occurrence, of this food category in the species/size class, and V (%)= proportional amount of this food category in the ratio of each fish in the species/size class.

3 Results

The following 18 fish species were recorded from the sampling location: *Atherina boyeri* (Atherinidae), *Cobitis elongatoides* (Cobitidae), *Alburnus alburnus*, *Aspius aspius*, *Barbus barbus*, *Blicca bjoerkna*, *Chondrostoma nasus*, *Leuciscus idus*, *Rheogobio vladykovi*, *Rutilus rutilus* (Cyprinidae), *Esox lucius* (Esocidae), *Benthophilus stellatus*, *Knipowitschia caucasica*, *Neogobius fluviatilis*, *Neogobius kessleri*, *Neogobius melanostomus* (Gobiidae), *Sander lucioperca*, *Gymnocephalus schraetser* (Percidae). Abundance of these species in day and night samples are shown in figure 1. A strong shift of fishes inhabiting this sand shore during day and night was observed.

Altogether, 46 intestine parts (anterior 1/3) of juvenile *B. bjoerkna* have been dissected and 107 stomachs of the other species (tab. 1). Only 105 of them contained food items. The relative presence of different food categories of the five analysed fish species/size classes is summarized in figure 2. The calculated overlap index is based on the relative food consumption, of the five species. The average dietary overlap (Schoener-Index) between species/size classes was 0.49, i.e. nearly one half of the possible total overlap. It ranges from 0.35 between small *N. fluviatilis* and *B. stellatus* to 0.79 between juvenile *B. bjoerkna* and small *N. fluviatilis* (tab. 3).

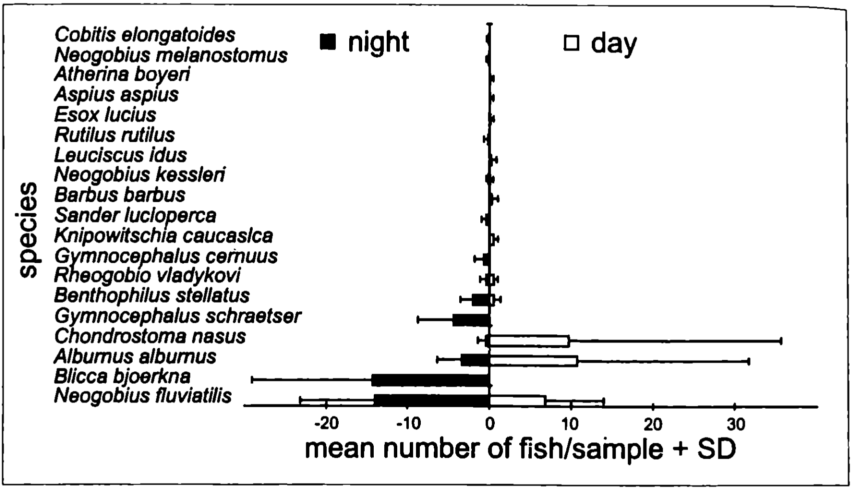

Fig. 1: Catch composition in day and night samples at stream km 96 Sf. Gheorghe branch, Danube Delta. Mean number of specimens per sample plus SD

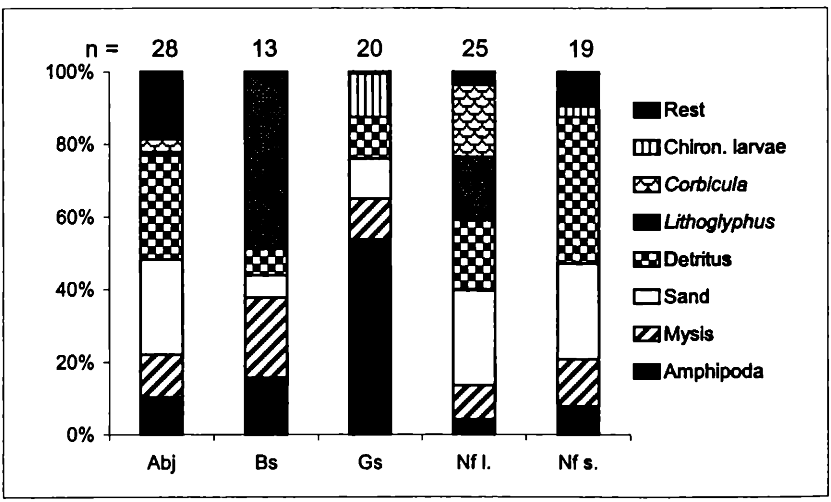

Fig. 2: Relative food consumption of the five most abundant species/size classes. For abbreviations see table 1

Tab. 1: Species/size classes selected for food analysis

Species	SL mm	Abbreviation	dissected	empty
Blicca bjoerkna	38-105	Bbj	46	18
Benthophilus stellatus	19-36	Bs	19	6
Gymnocephalus schraetser	55-82	Gs	21	1
Neogobius fluviatilis	56-84	Nf l.	28	3
Neogobius fluviatilis	22-50	Nf s.	39	20

In respect to food contents, three different foraging strategies can be distinguished. The first one was represented by *G. schraetser* which preferred Amphipods (I = 64.06), only small amounts of sand and detritus were found in its diet. The second was represented by *B. stellatus* which referred *Lithoglyphus* (I = 64.49), and Mysidacea (I = 16.94) (tab. 2). The fishes with the third strategy had mainly consumed sand and detritus. This group was represented by the juvenile *B. bjoerkna*, and the two size groups of *N. fluviatilis*. They consumed in different amounts detritus and sand, with an "Importance Index" between 90.8 % for small *N. fluviatilis*, and 70.4 % for larger *N. fluviatilis*. For larger *N. fluviatilis* molluscs were of some importance as food items. In the diet of these three species Amphipoda and Mysidacea were present, but of minor importance (tab. 2). Between these three species, the dietary overlap was above average, and reached his maximum between the small *N. fluviatilis* and juvenile *B. bjoerkna;* and it was below the average to the other species (tab. 3).

4 Discussion

4.1 Diet and food importance

In rivers *B. bjoerkna* is supposed to feed mostly on chironomids, other insect larvae, gastropods and benthic crustaceans (Heuschmann 1957; Banarescu 1964, Marszal & al. 1996), but also on detritus and parts of vascular plants (Banarescu 1964). It was suggested that *B. bjoerkna* feed ubiquistic on a broad variety of food items. In this study the juvenile *B. bjoerkna* have mainly feed on detritus, crustaceans and fish scales. Scales and sand could accidentally been taken, while the fishes were feeding on detritus. For the diet of *B. stellatus* there were only few previous investigations available. Banarescu (1964) mentioned, that they feed on small invertebrates as crustaceans, molluscs, insect larvae and even fish. The dissected *B. stellatus* contained mainly *Lithoglyphus* snails, followed by crustaceans especially Mysidacea, and few Amphipods. The presence of the detritus and sand in the diet could also be explained by the fact, that *Lithoglyphus* were covered by detritus.

Tab. 2: Result of gut content analyses of five species/size classes studied. O = occurrence, V = % volume, I = index of food importance

	Bbj			Bs			Gs		
Food items	V	O	I	V	O	I	V	O	I
Corbicula	0.89	1.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
Lithoglyphus	0.00	0.00	0.00	47.69	7.00	64.49	0.00	0.00	0.00
Mysidacea	11.79	4.00	3.11	21.92	4.00	16.94	11.25	3.00	2.87
Amphipoda	10.36	7.00	4.78	15.77	3.00	9.14	53.75	14.00	64.06
Chironomidae larvae	0.00	0.00	0.00	1.15	2.00	0.45	12.00	8.00	8.17
Chironomidae pupae	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.00	0.02
Corixidae	3.57	1.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Sand	26.07	23.00	39.52	6.15	4.00	4.75	11.00	14.00	13.11
Detritus	28.75	23.00	43.58	7.31	3.00	4.23	11.50	12.00	11.75
Scales	10.18	10.00	6.71	0.00	0.00	0.00	0.25	1.00	0.02
Plants	5.54	5.00	1.82	0.00	0.00	0.00	0.00	0.00	0.00
Rest	2.86	1.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00

	Nf s			Nf l		
Food items	V	O	I	V	O	I
Corbicula	0.00	0.00	0.00	19.80	7.00	10.16
Lithoglyphus	0.00	0.00	0.00	17.60	11.00	14.19
Mysidacea	12.89	4.00	4.32	9.40	4.00	2.76
Amphipoda	7.89	3.00	1.98	4.20	6.00	1.85
Chironomidae larvae	2.89	5.00	1.21	1.80	2.00	0.26
Chironomidae pupae	3.68	4.00	1.23	1.80	3.00	0.40
Corixidae	4.74	1.00	0.40	0.00	0.00	0.00
Sand	26.32	15.00	33.06	26.00	22.00	41.94
Detritus	40.53	17.00	57.70	19.40	20.00	28.45
Scales	0.00	0.00	0.00	0.00	0.00	0.00
Plants	0.00	0.00	0.00	0.00	0.00	0.00
Rest	1.05	1.00	0.09	0.00	0.00	0.00

Tab. 3: Dietary overlap between five species/size classes represented by Schoener-Index, reaching from 0 = no overlap to 1 = total overlap

	Benthophilus stellatus	Gymnocephalus schraetser	Neogobius fluviatilis large	Neigobius fluviatilis small
Blicca bjoerkna	0.36	0.44	0.60	0.79
Benthophilus stellatus		0.42	0.46	0.35
Gymnocephalus schraetser			0.38	0.45
Neogobius fluviatilis, large				0.63

Gymnocephalus schraetser was mentioned to feed mainly on benthic invertebrates, and occasionally on fish eggs and fry (Gaschott 1928; Banarescu 1964; Zauner 1996). In this study, *G. schraetser* consumed mainly amphipods and small amounts of chironomids. Sand and detritus might be ingested occasionally by foraging on crustaceans and chironomids.

For *N. fluviatilis* is known to feed on Amphipods, *Cladocera, Limnomysis benedeni*, and chironomids in freshwaters (Biro 1995, Troitsky & Tsunikova 1983). Only less then 1 % of their diet were molluscs in Lake Balaton (Biro 1995). There was also a shift observed in the diet between small and larger *N. fluviatilis*, especially in regard to the size of food items. Biro (1995) considered specimens smaller 55 mm standard length as age group 1+, larger than 55 mm standard length as 2+, and older. These findings correspond well with the length class used in this study: <50 mm standard length-small group, and >55 mm standard length-large group. In this study, larger *N. fluviatilis* had incorporated a high amount of molluscs. These food items were not found in the small gobies. Small gobies fed mainly on detritus. In the Danube there was also a shift observed in the foraging strategy between the small, 1+ group and the larger, older specimen. The shift in this case was from the energetically poor detritus, to the energetically richer molluscs (Heerkloss 1996). The shift was probably size dependent, because the small specimen could not handle the to voluminous *Corbicula* due to the smaller mouth. They also seemed unable to bite off parts of the feet of *Lithoglyphus* like larger specimen do.

4.2 Dietary overlap

In order to predict the effects of potential invasion of the two Ponto–Caspian gobiid, their niche and their niche overlap in relation to the other benthic species was examined. Because the resource overlap (especially in food and foraging places) is one of the first steps in understanding a community (Krebs 1989), the food overlap of these four species has been examined.

Benthophilus stellatus and also *G. schraetser*, had their own foraging strategy which did not correspond to the other species/size class investigated. Each of them had an overlap index to the other species/size classes below average. *Gymnocephalus schraetser* showed a clear feeding activity during the night at the bank, 95 % of the specimens had food in the stomach.

Where and when *B. stellatus* feed remain unclear, however there were weak indications for indifferent feeding time. They were present during day and night on the bank, and only 68 % of the specimen caught during night had food items in their stomach, but most of them had full hindguts.

A higher similarity in foraging strategy was detected between juvenile *B. bjoerkna*, and *N. fluviatilis*. They showed a high overlap with a maximum index value between juvenile *B. bjoerkna* and small *N. fluviatilis*. Juvenile *B. bjoerkna* and small *N. fluviatilis* seemed to feed during daylight however they might be spatially separated. The small *N. fluviatilis* occur during daylight at the bank (during the day 88% of the *N. fluviatilis* were from the small group), while juvenile *B. bjoerkna* were absent in the day catch at the bank (see fig. 2). The group of larger *N. fluviatilis* has a high food similarity to juvenile *B. bjoerkna*. Larger *N. fluviatilis* might foraging mainly during the night on the bank, when the juvenile *B. bjoerkna* are present but do not feed. Nearly all specimen of larger *N. fluviatilis* from the night catch had food items in the stomach (table 1). The frequency of larger *N. fluviatilis* during the night was with 29 % of all *N. fluviatilis* more then twice as high as during the daylight (12 %). The larger *N. fluviatilis* might come to the bank to feed or to avoid predation during night. There might be a spatial differentiation in foraging strategy between juvenile *B. bjoerkna* foraging in the middle of the river channel and small *N. fluviatilis* foraging on the bank, and a temporal differentiation between juvenile *B. bjoerkna*, small *N. fluviatilis* and larger *N. fluviatilis* by day time, respectively nocturnal feeding activity. No indicates for cannibalism pressure which might evoke these spatial and temporal differentiation's in foraging strategy were found, like they are reported by Hopper & Crowley (1996) for dragonfly larvae, or Perrson & al. (2000) for perch. The pressure from terrestrial and aquatic predators, which could lead to a different distribution in the deeper water and on the bank (Crowder & al. 1997), was not examined, but could also be a reason for these temporal and spatial differentiation's beneath food competition. Naturally this study only gives a small clips to the ecological situation in the lowermost Danube.

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