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Opportunistic feeding strategy as a factor promoting the expansion of racer goby (*Neogobius gymnotrachelus* Kessler, 1857) in the Vistula basin

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With 1 figure and 1 table

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The main goal of this preliminary study was to analyse the diet spectrum of racer goby (*N. gymnotrachelus*), the most abundant gobiid invader in the Polish inland waters. That aspect of the species biology has never been investigated in Central Europe, outside its natural range. The research was conducted in the Wloclawski Dam Reservoir located on the lower section of the Vistula River, Poland. The main component of the goby diet were Mollusca, followed by Insecta and Crustacea. Mollusca comprised the most abundant fraction in the reservoir benthic fauna and are usually avoided by other fishes. That suggests racer goby is an opportunistic feeder, and this strategy may promote its invasion. Comparing our results with literature data from large Ponto-Caspian rivers where the species had different diet supports that conclusion. Also, some casual observations of the goby spawning behaviour suggest its expansion success may be related to the multispawning reproductive strategy and male guarding behaviour.

1 Introduction

The rapid development of civilisation has seriously accelerated natural processes of organism dispersion from one side, but from the other it has made possible an exchange of species from the previously isolated regions even on intercontinental scale. Since the beginning of the 20th century even more intensified translocations of species could be observed (Drake & al. 1989, Williamson 1996). In case of aquatic fauna that phenomenon is due not only to intentional acclimatisations or accidental introductions (Di Castri 1989) but also to the construction of artificial waterways joining formerly isolated river systems (Jazdzewski 1980). The following examples may illustrate the scale of the above processes. First, it was estimated that an average of 3000-4000 species are worldwide transported each day in ship ballast water tanks (Carlton & Geller 1993; Gollasch 1996), and second – only in Germany approximately 1770 km of inland waterways have already been constructed (Tittizer 1996). In case of European fresh and brackish waters, the analysis of newly established

species shows the very important source of invaders is the Ponto-Caspian region (Bij de Vaate & al. 2002).

In the past, the Ponto-Caspian region was one of the most important European glacial refugia, serving as a source of species or even entire communities for the newly born network of inland waters in Central Europe. The area was almost completely covered with an ice sheet until the end of the Würm glaciation – the catchment areas of two major Baltic rivers, Vistula and Oder, were formed during the last 18 000 years (Lindberg 1955, Lebiediev 1960) when the ice cover retreated. However, a connection between the refugium and the Baltic basin was present only during a short postglacial period when the melting ice masses formed large ephemeral lakes. Along with the development of the new inland water systems, the connection closed until the recent times. The new opportunity for the expansion of Ponto-Caspian fauna was the construction of an artificial canal network joining the isolated basins of the Black Sea, Caspian Sea, Baltic Sea and North Sea. Bij de Vaate & al. (2002) identified three main invasion corridors resulted from the canal connections:

1) Northern corridor: Covers the route Volga River → Lake Beloye → Lake Onega → Lake Ladoga → Neva River → Baltic Sea

2) Central corridor: Covers the route Dnieper River → Vistula River → Notec River → Warta River → Oder River → Elbe River → Rhine River → North Sea.

3) Southern corridor: Covers the route Danube River → Rhine River → North Sea

The above authors estimated that more than 20 Ponto-Caspian aquatic macroinvertebrate species have successfully invaded Western European waters by this way.

One of the very first, and at the same time most spectacular invasion events through these corridors was the case of zebra mussel (*Dreissena polymorpha*). The species spread across Central and Western Europe already in the 19th century (Kinzelbach 1992), and has just started its massive invasion in North America (MacIsaac 1996).

Concerning the territory of Poland, almost entirely belonging to the Baltic Sea drainage system, the northern and central corridors play the main role as invasion routes for the Ponto-Caspian species. The routes e.g. have possibly been used by the five Amphipoda species that have almost completely replaced the native species the Vistula and the Oder rivers and now are spreading towards West European waters (Jazdzewski & al. 2002).

Apart of invertebrates, the corridors have enabled westward dispersal of several gobiid fishes. In Poland, three species of *Neogobius* were recorded so far:

round goby (*N. melanostomus*), racer (goad) goby (*N. gymnotrachelus*), and monkey goby (*N. fluviatilis*). The current distribution of the species in Polish waters is illustrated in figure 1. The natural range of these Gobiidae includes the brackish lagoons of the Black Sea and the Caspian Sea and lower courses of their rivers: Danube and its larger tributaries, the Dnjester drainage, Boh, Dnjeper and Don (Berg 1949).

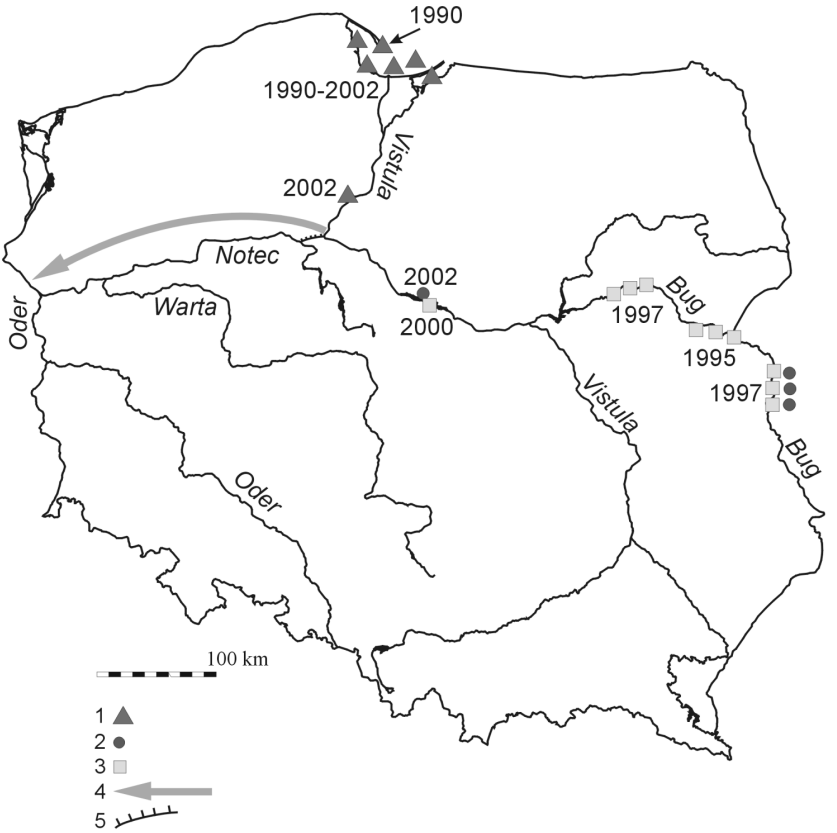

Fig. 1. Expansion of Ponto-Caspian gobiids in the Vistula basin. 1 = *Neogobius melanostomus*, 2 = *N. fluviatilis*, 3 = *N. gymnotrachelus*, 4 = possible route of further expansion, 5 = Bydgoski Canal

The first species recorded in Polish waters was round goby (*N. melanostomus*), found near the Hel port in 1990 (Skora & Stolarski 1993). Since that time, the species has colonised the entire Bay of Gdansk and the Vistula Lagoon (Kuczynski 1995, Skora 1996, Sapota & Skora 2000). In spring 2002 we found it

for the first time in the freshwater section of the Vistula River near Swiecie, 130 km upstream from the river mouth.

In 1995 the next species, racer goby (*N. gymnotrachelus*), was found in the middle section of the Bug River between Terespol and Drohiczyn (Danilkiewicz 1996). It spread rapidly downstream the Bug River (Danilkiewicz 1998) and in 2000 we recorded it in the Wloclawski Dam Reservoir, built on the lower Vistula River (Kostrzewa & Grabowski 2001). According to our unpublished data a large and vividly reproducing population of the species inhabits the reservoir.

In 1997 monkey goby (*N. fluviatilis*) was found in the middle section of the Bug River between Terespol and Mezenin (Danilkiewicz 1998). Since that time there were no further recordings of that species in Polish waters, until we have found it in the already mentioned Wloclawski Dam Reservoir (Kostrzewa & Grabowski 2002).

The rapid expansion of Ponto-Caspian Gobiidae takes place also in the other European countries, located along the Danube drainage system (Ahnelt & al. 1998). Primarily limited to lower course of the Danube (from its mouth to the Iron Gate) they have been now recorded in Hungary (*N. fluviatilis*, *N. kessleri*), in Austria near Vienna (*N. kessleri*) and in Germany (*Proterorhinus marmoratus*).

Two of the species – *P. marmoratus* and *N. melanostomus* have been already translocated to the Great Lakes in North America, where they spread rapidly causing severe disturbance in the local biotic communities (Charlebois & al. 1997).

The phenomenon of this recent expansion of the Ponto-Caspian Gobiidae and other aquatic organisms is hard to explain ultimately. An important circumstance is that the regional fauna is predominantly euryoecious – a result of a specific and complex geological history of the area. Its leading events were recurrent transgressions and regressions of the sea level caused first by tectonic movements and later by changes in the extent of glacier in the Central Europe. As a result, the local sea basins were characterised by rapidly changing salinity conditions (Mojski 1993). For that reason the Ponto-Caspian fauna comprises a set of euryoecious organisms tolerant towards a wide spectrum of environmental conditions. Also, the invasions may be promoted by special features of species biology, among which feeding and reproductive strategies seem to be utterly important (Ehrlich 1989).

The main goal of our preliminary study was to analyse the diet spectrum of racer goby (*N. gymnotrachelus*), the most abundant gobiid invader in the Polish inland waters. That aspect of its biology is especially interesting as it has never been investigated in Central Europe, outside its natural range. The possible diet

overlap with some native fish species is discussed. Also, some casual observations of the species spawning behaviour are provided.

2 Study area, materials and methods

N. gymnotrachelus were collected in Wloclawski Dam Reservoir located in the lower section of the Vistula River in Nowy Duninow Village (19° 28' E, 52° 35'N), Poland. The sampling site was situated in the littoral zone of the reservoir on muddy bottom covered by empty shells of molluscs, mainly *Viviparidae*, *Unionidae, Sphaeriidae* and *Dreissena polymorpha*.

The sample for diet analysis was taken in October 2001 at 11.00 h. Fish were caught with electro-shocker IUP-12, (350 V, 20-100 Hz), anaesthetised in benzocaine solution and preserved in 4 % formaldehyde solution. Each individual was weighted with accuracy to 0,01 g, and its total length was measured with accuracy to 1 mm. The fish were dissected to determine sex, and alimentary canal was removed for further analysis of stomach content. Food categories were identified using a stereomicroscope; prey abundance was defined as the number of specimens belonging to each prey category found in all stomaches. The biomass estimation of each prey category was made by comparing the size of eaten animals with the size and the weight of conspecific organisms taken from benthic samples.

Ten benthic samples were taken every 5 meters with a bottom dredge along 10-m-transects perpendicular to the shoreline. The macrobenthic fauna was identified, and individuals representing species found in stomachs were measured and weighted.

This site was penetrated also next year in the spring (March and April) to follow spawning and reproduction of the gobiids and some casual preliminary observations are presented in this paper.

3 Results

104 specimens of the racer goby caught in October 2001 ranged from 50 to 104 mm in total length (average 75.17 mm; SD 13.76) and weighted from 1.32 to 14.33g (average 5.63g; SD 3.14). The sex ratio was 1:1. In March 2002, the total length of 60 sampled specimens ranged from 46 to 106 mm (average 77.32 mm; SD 14.94), and weight ranged from 1.93 to 13.12 g (average 6.00 g; SD 2.94). Males were more numerous than females, and the sex ratio was 1: 2.53. In April we managed to capture only a few adults but we found single individuals of new-hatched gobiid larvae, and their eggs deposited on submerged old willow branch, plastic waste and inside empty *Anodonta* shells guarded by males. All males sampled in the spring were nearly black in colour and had longer

than usual dorsal and pectoral fins. In the following months (May-August) almost no adults occurred in the littoral zone but fish fry of various size was very abundant.

Accompanying species were mainly: three-spined stickleback *Gasterosteus aculeatus*, bitterling *Rhodeus sericeus*, spined loach *Cobitis taenia*, roach *Rutilus rutilus*, perch *Perca fluviatilis*, as well as single individuals of chub *Leuciscus cephalus*, pike *Esox lucius*, zander *Stizostedion lucioperca*, ide *Leuciscus idus, Percottus glenii* and gudgeon *Gobio gobio*.

Among 104 specimens used for diet analysis, the stomachs of 10 individuals were empty. The main component of the racer goby diet in Wloclawski Dam Reservoir were molluscs composing 60 % of prey abundance, and 77 % of total food biomass (Tab. 1). The most numerous in this food category were gastropods (60 % of stomach content biomass): *Valvata piscinalis*, *V. naticina*, *Bithynia tentaculata*, *Physa acuta*, *P.fontinalis*, *Potamopyrgus antipodarum*. Gastropods were also present in almost 70 % of dissected stomachs. Second important prey were bivalves represented by *Sphaeridae* (17 % of biomass; 13 % of abundance; 38 % frequency of occurrence in stomachs). Supplementary food categories were insects (Chironomidae and others, not identified), Amphipoda (invasive Pontogammaridae), and animal detritus. Ostracoda found in the diet, however numerous (22 % of abundance), were too small to be treated as an important prey because they composed only 0,1 % of the food biomass. It is possible that they were picked up accidentally with larger prey. Similarly, Copepoda and Cladocera occurred only in two stomachs.

Tab. 1: Percentage of food items in diet of the racer goby in Wloclawski Dam Reservoir. N = percentage of total prey abundance; B = percentage of total stomach content biomass; F = frequency of prey occurrence in diet

Food item	B	N	F
Gastropoda	60.27	47.95	66.67
Bivalvia	16.74	12.87	35.71
Ostracoda	0.09	21.64	26.19
Amphipoda	11.75	3.51	9.52
Copepoda/Cladocera	0.004	6.43	2.38
Insecta	1.44	7.60	23.81
Detritus	9.65	not estimated	38.10

In the macrobenthos of the studied site, Gastropoda made a dominant fraction (44 %) of the total abundance. They were mainly *Valvata* spp. (23 %), *Viviparus sp*. (6 %), *Bithynia tentaculata* (5 %) and *Physa* spp. (4 %). Oligochaeta were also very numerous (39%). The other components of benthos were Bivalvia,

predominantly Sphaeridae compounding 10 % of abundance, and Chironomidae larvae (6 %).

4 Discussion

As the potential impact of invaders on local biota is considered, the food competition with the native species is supposed to be an important element (Holcik 1991). However, numerous studies revealed that the success of invading organism is often a consequence of free available ecological niches (Brown 1989, Williamson 1996). Our analysis of the racer goby stomach contents shows that the most preferred food items are molluscs. This type of prey does not occur in the diet of the native fish inhabiting Wloclawski Dam Reservoir, with exception for the generally herbivorous roach that supplements its diet with Sphaeridae (Kakareko 2002). It would suggest that the Gobiidae avoid energetically expensive competition by using an empty food niche (Ross 1986, Schoener 1986). However, Mollusca are the most abundant organisms in the bottom fauna of our study site and also in the whole reservoir (Zbikowski 2000) and as such cannot be a subject of the competition. The analysis of the species diet in its natural range indicated that in the upper Dnjester estuary the main diet component were Crustacea (64%), followed by Polychaeta (14 %). Mollusca comprised only up to 10 % and fish up to 9 % of its diet. In other reservoirs (e.g. Lake Razelm) the species fed mostly on Chironomidae larvae, Crustacea and small fish (Pincuk & al. in print). In the Danube River gobiids consumed predominantly Crustacea, larval Chironomidae and Tichoptera, *Theodoxus* (Gastropoda) and small fish as well as fish eggs (Pincuk & al. in print, Smirnov 1986). Also in other rivers like Boh, the dominant food items were Chironomidae larvae (Smirnov 1986). In the middle section of Dnjeper River up to 50 % of the diet composed of Mollusca (*Dreissena*) and Amphipoda supplemented with other Crustacea, Oligochaeta and small fish. Our data suggest other than above feeding preferences of racer goby in the Wloclawski Reservoir. Although we have no data on the benthic fauna composition in the mentioned Ponto-Caspian rivers, it is known that Chironomidae larvae are generally the most abundant component of zoobenthos in large European rivers (Grzybkowska & al. 1990). It may suggest that *N. gymnotrachelus* is an opportunistic feeder and chooses prey that is the most numerous and therefore easily available in a particular locality. Such feeding strategy seems to be optimal for an invasive species colonising new territories where food base may differ from that in its natural range.

The other crucial aspect of an invasion is settlement in new habitats, meaning successful reproduction (Ehrlich 1989). All gobiids, as other small fish, are multispawners. It allows to extend reproduction effort even for several months,

and partly solves the trade-off between size of eggs and their number shed by a female (Wootton 1992). Such strategy seems to be favourable for an invader. Fry of distinctly different sizes found in the reservoir may suggest it is a result of multispawning, although this question is still under our study. Males of racer goby are known to guard eggs deposited in shelters, e. g. under stones or in empty shells of mussels (Georgiiev 1966, Smirnov 1986). We observed the same activity in the Wloclawski Dam Reservoir. That feature of spawning behaviour is common also to other *Gobiidae* and increase the probability of leaving numerous offspring.

Our results show that racer goby is a very successful invader in the Vistula River. By avoiding competition with local species, supported by a possible multispawning reproductive strategy and guarding behaviour the goby may effectively colonise new sections of the river and its tributaries. We already observed some individuals of the species in the lower sections of Bzura and Skrwa Prawa rivers in the summer 2002. Thus, we can assume that moving downstream the Vistula River, racer goby will reach the Bydgoski Canal joining the Vistula and the Oder drainages. As a consequence the species may spread further to the West, namely Germany, continuing its way along the central migration corridor as defined by Bij de Vaate & al. (2002). That way is also possible for monkey goby and for round goby; the latter has been already known to colonise the Vistula River, 130 km upstream from its mouth (Kostrzewa & Grabowski 2002).

This study is just a small attempt to elucidate the expansion phenomenon of Ponto-Caspian gobiids. However it indicates clearly that such investigations should be undertaken in the future as they may reveal yet unknown features of the species promoting their invasion, as well as their interaction with local biota.

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