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Trophic preferences of three allochthonous fishes in Bormida River (Alessandria, NW Italy)

Preferencias tróficas de tres especies alóctonas de peces en el río Bormida (Alejandría, Italia, NO)

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ABSTRACT

The introduction of alien species is currently one of the greatest threats to biodiversity conservation. This is particularly true in river systems, where in recent years the growth of allochtonous or non-native species has increased dramatically. Numerous studies have investigated the presence and the distribution of invasive species, but few focused on the trophic habits of fish species introduced into new lotic environments. This paper provides information on the diet of three alien species in the Bormida River, a lotic system previously altered by chemical pollution. *Barbus barbus* shows a wide trophic spectrum, feeding mostly on benthic invertebrates but also consuming terrestrial arthropods, coarse particulate organic matter, filamentous algae and, more rarely, fish. Feeding activity of *Pseudorasbora parva* was mostly based on aquatic invertebrates but also algae and fine particulate organic matter was frequently ingested. Regarding diet analysis of *Rhodeus amarus*, fine detritus and algae were the most important components in the examined guts. There are significant potential overlaps with the trophic spectrum of native species.

Key words: Exotic species, freshwater fish, NW Italy, trophic preferences.

RESUMEN

La introducción de especies exóticas es actualmente una de las mayores amenazas para la conservación de la biodiversidad. Esto es particularmente cierto en los sistemas fluviales, donde el crecimiento de especies alóctonas o no nativas, ha aumentado espectacularmente en los últimos años. Numerosos estudios han investigado la presencia y la distribución de las especies exóticas, pero pocos se han centrado en los hábitos tróficos de las especies de peces introducidas en nuevos ambientes lóticos. Este artículo ofrece información acerca de la dieta de tres especies exóticas en el Río Bormida (NO de Italia), un sistema lótico previamente alterado por la contaminación química. *Barbus barbus* mostró un espectro trófico amplio, alimentándose principalmente de invertebrados bentónicos, pero también consumiendo artrópodos terrestres, partículas gruesas de materia orgánica,algas filamentosas y, más raramente, peces. La actividad alimenticia de *Pseudorasbora parva* se basó principalmente en invertebrados acuáticos, pero también ingirió con frecuencia algas y materia orgánica particulada fina. En *Rhodeus amarus*, los detritos finos y las algas fueron los componentes más importantes en los contenidos estomacales examinados. Posiblemente existen importantes traslapes en el espectro trófico de estas especies exóticas con varias otras especies nativas.

Palabras clave: Especies exóticas, NO de Italia, peces de agua dulce, preferencias tróficas.

INTRODUCTION

Human activities have had a profound, and usually negative, influences on freshwater biota, from the smallest creeks to the largest rivers. Some negative effects are due to various contaminants, while others are associated with changes in watershed hydrology (Wellman *et al.*, 2000; Fenoglio *et al.*, 2007), habitat modifications (Bo *et al.*, 2007), alteration of energy sources upon which the aquatic biota depends, and introduction of alien species (Closs *et al.*, 2004). In fact, after habitat degradation, the introduction of invasive species is the second leading cause of biodiversity loss, particularly in freshwater ecosystems (Moyle *et al.*, 1986; Mack *et al.*, 2000; Clavero & García-Berthou, 2005; Fenoglio *et al.*, 2010). The invasion of exotic species in the lotic systems is a global phenomenon, and a subject of elevate interest. When exotic taxa invade communities of species that have co-evolved over long periods, the equilibrium between native species may become seriously disrupted. This can take place through competition, predation, hybridization, or through the transfer of parasites and diseases (Giller & Malmqvist, 1998). There are many examples of successful invasions in freshwaters, mostly because in these environments: i) many human activities, such as sport and commercial fishing, aquaculture practices, pet trade, and fur farming, have lead to allochtonous species import; ii) eradication of exotic taxa can be very difficult or quite impossible; iii) there is high connectivity among streams and lakes, because of drift and water flow. Among vertebrates, the fish fauna of lotic systems are probably the most vulnerable to this threat. Kottelat & Freyhof (2007) report a total of 28 non native fish species established in European fresh waters. These species often compete, pass on diseases and parasites (Dezfuli *et al.*, 2011), predate upon or even hybridize with native species, and cause local native species extirpation (Baltz & Moyle, 1993; Gido & Brown, 1999; Kottelat & Freyhof, 2007). Many species are intentionally introduced for sport fishing, orage species, food or aesthetic reasons, some have escaped from aquaculture or released by aquarists, but many others are invasive, expanding their range through canals connecting historically separated river basins (e.g. Copp *et al.*, 1993; Hickley & Chare, 2002; Copp *et al.*, 2006). Actually, Italy is characterised by the presence of more than 20 exotic fish species, mostly arrived trough direct import, such as the pumpkinseed (*Lepomis gibbosus* - Linnaeus, 1758) firstly introduced in the Varano Lake in 1900, and the Wels Catfish (*Silurus glanis* - Linnaeus, 1758), which appeared in the 1957 and that, in these last years, experienced an impressive increase of distribution (Zerunian, 2002).

As stated Monakov (2003): "there is no discipline in hydrobiology that does not require a study of the feeding and nutrition of aquatic animals", and this statement is particularly proper regarding biological invasion studies. In fact, fishes represent a considerable proportion of the total freshwater biomass and their feeding interactions exercise a strong influence on all the biotic communities (Hynes, 1970), and provide an important links within aquatic, and between aquatic and terrestrial food webs (Gelwick & Matthews, 1996; Sakano & Iguchi, 2009). The aim of our study was to analyze the diet of three exotic fish species at present widespread in the hydrographic network of most Northern Italy, and especially in the Alessandria district (Provincia di Alessandria 2003, 2005) and to provide first data about their feeding composition. We investigate diet preferences of three cyprinids: European Barbel (*Barbus barbus* Linnaeus, 1758), a species that in Europe is locally threatened by water pollution and river regulation, but introduced and very abundant in freshwater systems of Northern Italy; Pseudorasbora (*Pseudorasbora parva* Temminck & Schlegels, 1825), a species native from Amur to Zhujiang drainages (Siberia, Korea, China), introduced in Romania in 1961 (Kottelat & Freyhof, 2007) and actually widespread in central and southern Europe; and Bitteling (*Rhodeus amarus* Bloch, 1782), a little cyprinid linked to mussels (*Unio* and *Anodonta*) for reproduction, and invasive in France, Great Britain and Italy.

MATERIALS AND METHODS

The study area was a reach of the Bormida River near Alessandria (NW-Italy, 44°52'20''N, 8°36'12''E, elevation of 95 m., Fig. 1). This river is desolately note because for many decade has been severely polluted by industrial chemical wastes, and it was a "dead river" (Hellmann, 2005). However, since 1990, water quality has rapidly improved, because of the limitation and then the closure of the polluting chemical factories of Cengio, so that macroinvertebrate and fish fauna returned in this lotic system. At present, fish assemblages is characterized by a massive presence of allochtonous species: apart the three studied species, the following exotic species are present in Bormida River: European catfish (*Silurus glanis*), Asp (*Aspius aspius* Linnaeus, 1758), pumpkinseed (*Lepomis gibbosus*), Crucian carp (*Carassius carassius* Linnaeus, 1758), Black Bullhead (*Ameiurus melas* Rafinesque, 1820; Badino *et al.*, 2007). In the sampling station, Bormida River is characterized by dense riparian vegetation, good morphological diversity, but poor

Figure 1. Study area and location of the sampling station.

and altered physical-chemical quality (see Table 1). In a single sampling date (31 October 2008), 182 specimens of allochtonous fishes were collected (68 *B. barbus*, 57 *P. parva* and 57 *R. amarus*; all specimens were in the adult stage). Fishes were caught by using a Scubla IG200/2 electro-fishing device, and stored in ethanol 90%. In laboratory, each fish was measured with an accuracy of 0.1 mm (total length). Digestive tracts were removed and the contents were analyzed with a Nikon SMZ 1500 light microscope (60-100 x) coupled with a Sony HD videocamera and a Samsung LCD Video. Identification of prey was based on sclerotized body parts, particularly head capsules, mouth parts and leg fragments. Organisms in guts were classified generally to genus or family level. Stewart and Stark (2002) stated that the count of sclerotized fragments (i.e. head capsules or legs) can give a reasonably accurate count of prey consumed. The other components of the fish diet are classified into five food items or categories: Algae, CPOM (Coarse particulate organic matter), FPOM (Fine particulate organic matter), undeterminable animal matter and sand. Gut contents were also compared with the natural composition and abundance of macroinvertebrate communities. In fact, using a Surber net (20 x 20 cm; mesh 250 µm), 156 samples (with more than 20000 invertebrates) were collected in the same period (October 2008) in the study site to assess the availability of prey invertebrate taxa in the benthic environment. Samples were preserved in 90% ethanol. In the laboratory, all organisms were counted and identified to genus or species level, except for: Oligochaeta and larvae of some Trichoptera and Diptera, which were identified to family or sub-family level. To investigate the existence of feeding preferences, we compared gut contents with natural composition and abundance of macroinvertebrate community in the riverbed using the trophic electivity index of Ivlev (1961):

Table 1. Main chemical and ecotoxicological parameters of the water of Bormida River near Alessandria, Italy (single sampling date).

Parameters	31 October 2008
Conductivity (µS/cm)	391
pH	7.9
$B.O.D._{.5}$ (mg/l)	3.15
C.O.D. (mg/l)	7.71
Total Phosphorous (mg/l)	1.72
Ammonia nitrogen (mg/l)	<0.05
Na^+ (mg/l)	13.04
Mg^{2+} (mg/l)	14.69
Ca^{2+} (mg/l)	47.29
Cl^- (mg/l)	17.67
Total hardness (°F)*	17.86
Escherichia coli (UFC/100 ml)	120

* °F = Grados franceses.

$$E = (ri-pi) / (ri+pi)$$

where

ri = relative abundance of a particular taxon in the diet and

pi = relative abundance of the same taxon in the benthic community.

The formula considers the number of taxa (i) found in the diet. The index ranges from –1 to 1. A value of –1 means total avoidance, 1 indicates preference and 0 indicates indifference.

RESULTS

In total we collected 182 specimens, but we analyzed data from gut contents of 171 specimens, because respectively two individuals of Barbel, six of Pseudorasbora and three of Bitteling had empty guts. The mean length of body was 16.03 mm ± 7.61 (SD) for Barbel, 5.07 mm ± 0.91 for Pseudorasbora and 5.35 mm ± 0.59 for Bitteling.

Regarding the diet composition, the aquatic macroinvertebrates constituted an important food for *B. barbus* and *P. parva* (in fact, the invertebrates were present in 89.7 % and 66.7 % of the analyzed guts, respectively), while *R. amarus* seems to prefer algae and detritus, the only invertebrates found in their guts were larvae of Chironomidae and Ephemeroptera (Table 2).

In Bormida River, *B. barbus* showed a wide trophic spectrum, feeding not only on aquatic insects, but also on terrestrial arthropods (e.g. coleopterans, hemipterans, hymenopterans and arachnids as spiders) and, more rarely, on some fish (e.g. *Lepomis gibbosus* and *Alburnus alburnus* (Linnaeus 1758), find in 8.82% of guts). Also coarse detritus (CPOM) and filamentous algae were ingested by analyzed specimens (Fig. 2). Feeding activity of *P. parva* was mostly based on aquatic invertebrates (Chironomidae and Ostracoda), which constituted respectively 55.4% and 12.1% of all ingested prey items. Furthermore, both algae and fine detritus (FPOM) were frequently ingested.

In the diet composition of *R. amarus*, both fine detritus and algae were the most important food items in the examined guts: these trophic resources were found of respective manner in 91.2% and 66.6% of the total analyzed specimens. Also, coarse particulate organic matter (CPOM) and seeds constituted important trophic resources.

Sand was found frequently in the guts of the three examined alien fishes, probably ingested during the predation on benthic prey.

We performed a trophic electivity analysis using some selected benthic taxa,that exemplify the different niches and habits of local macrobenthic fauna. *B. barbus* select positively bottom-living invertebrates, such as *Physa* sp. (Ivlev index = 0.97),

Table 2. List of prey and relative importance (% of total items) in the guts of the three exotic fish species to collected in Bormida River in Alessandria, Italy.

Aquatic preys	*B. barbus*	*P. parva*	*R. amarus*
Ephemeroptera			
Baetis sp.	0.04	1.35	0.00
Ephemera sp.	0.04	0.00	0.00
undet.	0.04	4.05	4.35
Coleoptera			
Dryopidae	0.04	0.00	0.00
Dytiscidae	0.04	0.00	0.00
undet.	0.08	0.00	0.00
Odonata			
Gomphidae	0.04	0.00	0.00
Calopterygidae	0.04	0.00	0.00
Zygoptera undet.	0.16	0.00	0.00
Diptera			
Chironomidae larvae	65.74	55.41	32.61
Chironomidae pupae	0.70	0.68	2.17
Simuliidae	0.12	0.00	0.00
Limoniidae	0.04	0.00	0.00
Tipulidae	0.25	0.00	0.00
Tabanidae	0.04	0.00	0.00
Athericidae	0.04	0.00	0.00
Psychodidae	0.08	0.00	0.00
undet. larvae	0.20	5.41	0.00
Trichoptera			
undet. larvae	0.04	0.68	0.00
Hydropsychidae	14.00	0.00	0.00
Undet. Aquatic insects	0.00	15.54	56.52
Gastropoda			
undet.	7.08	0,68	0.00
Planorbidae	0.04	0.00	0.00
Physidae	1.39	0.00	0.00
Lymnaeidae	1.68	0.00	0.00
Crustacea			
Ostracoda	5.53	12.16	0.00
Gammaridae	0.04	1.35	0.00
Hirudinea			
Erpobdellidae	0.08	0.00	0.00
Hydracarina	0.20	1.35	0.00
Nematoda	0.00	0.68	0.00
Vertebrata (Pisces)			
Fishes undet.	0.29	0.00	0.00
Alburnus alburnus (Linnaeus, 1758)	0.04	0.00	0.00
Lepomis gibbosus (Linnaeus, 1758)	0.04	0.00	0.00
Terrestrial preys	***B. barbus***	***P. parva***	***R. amarus***
undet. Arthropods	1.19	0.68	2.17
Hemiptera	0.04	0.00	2.17
Homoptera	0.04	0.00	0.00
Lepidoptera larvae	0.04	0.00	0.00
Arachnida	0.08	0.00	0.00
Coleoptera	0.08	0.00	0.00
Formicidae	0.04	0.00	0.00

Table 2. Continuación.

Hydropsyche sp. (Ivlev index = 0.85), *Ephemera* sp. (Ivlev index = 0.42). Chironomidae were positively selected both by *B. barbus* (Ivlev index = 0.19) and *P. parva* (Ivlev index = 0.11). Simuliidae, despite their relative importance in the benthic community were not positively selected, also if they enter in the diet of the Barbel. *R. amarus* did not show any preference for some particular macrobenthic taxa.

DISCUSSION

Freshwater and estuarine biota is changing rapidly worldwide (Moyle & Leidy, 1992; Allan & Flecker, 1993; Fenoglio *et al.*, 2010). Human-mediated invasions of aquatic organisms are associated with these changes, which commonly include extirpation of native organisms. In fact, invasive species have caused enormous disruption to ecosystems around the world (Lodge & Shrader-Frechette, 2003), and actually alien fish species have received considerable attention, given that the integrity of aquatic ecosystems is being increasingly challenged worldwide by species invasions (Moyle & Light, 1996). Despite this, the effects of the vast majority of introductions have not been studied and their impacts on the native biota are poorly assessed therefore, studies on feeding behaviour and diet represent essential and fundamental elements to improve our knowledge about the effects of alien species on aquatic ecosystem. Recently many studies have focused their attention on particular invasive species such as the *Silurs glanis* (e.g. Czarnecki *et al.*, 2003; Riva *et al.*, 2004; Syväranta *et al.*, 2009), or the worldwide distributed rainbow trout *Onchorhyncus mykiss* (Walbaum, 1972) (e.g. Angradi & Griffith, 1990; Dedual & Collier, 1995; Bernini *et al.*, 2006; Candiotto *et al.*, 2011).

This study is the first attempt to describe the diet of some invasive freshwater fish in a previously highly polluted river in Italy. The three species analyzed differ greatly in size, habitat preferences and thus to the diet. In the Bormida River, *B. barbus* is

markedly carnivorous, although with a tendency to feed on plant material (CPOM, seeds): Diptera, Trichoptera and Gastropods constitute the vast majority of prey, testifying that this species usually feeds on the river bottom. *P. parva* feeds mainly on small invertebrates (Chironomidae but also Ostracoda) and late organic detritus. *R. amarus* is a microphagous that feeds primarily on fine detritus and algae.

Trophic spectrum of these three allocthonous species potentially overlap with some native taxa that are present in the study site: for example, the diet of the European Barbel can partly cover the trophic niche of *B. plebejus* Bonaparte, 1839, a northern Adriatic endemic species; the niche of *P. parva* can overlap those of some native Cyprinidae and *R. amarus* can compete with *A. alburnus*.

Many authors (e.g. Hobbs, 2000; Lozon & MacIsaac, 1997) have pointed out that successful invasion by introduced organisms is widely regarded as being more probable in anthropogenically disturbed habitats. In particular introduced freshwater fish have commonly been documented to thrive in degraded aquatic habitats in many areas of the world (Brown, 2000; Meador *et al.*, 2003). An interesting element is that the fish fauna of the river Bormida mostly consists of alien species; we could suppose that the long history of pollution of this river has cleared the local fishing community, probably favoring the implantation of allocthonous taxa. Another problem related to alien fish species is that the removal of invasive taxa in the river systems of medium order is very hard and the effective eradication is virtually impossible.

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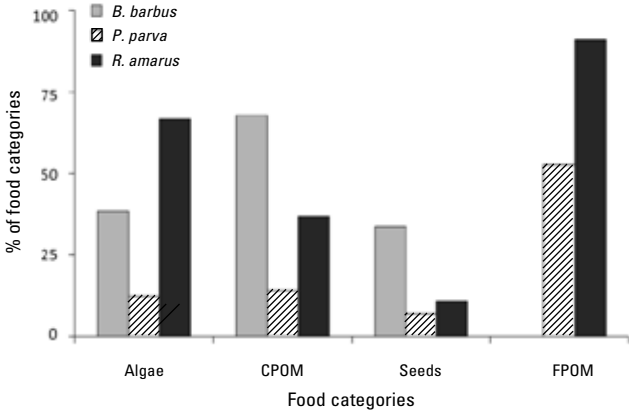

Figure 2: Presence of food categories in the studied alien fish guts. CPOM = Coarse particulate organic matter. FPOM = Fine particulate organic matter.

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