Ecology of Freshwater Fish 2008: 17: 165–173
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ECOLOGY OF
FRESHWATER FISH

Fish fauna in a Protected Greek lake: biodiversity, introduced fish species over a 80-year period and their impacts on the ecosystem

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Leonardos ID, Kagalou I, Tsoumani M, Economidis PS. Fish fauna in a Protected Greek lake: biodiversity, introduced fish species over a 80-year period and their impacts on the ecosystem.
Ecology of Freshwater Fish 2008: 17: 165–173. © 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard

Abstract – Lake Pamvotis is a tertiary natural shallow lake located in the NW of Greece. For biogeographical reasons, it historically contained only four fish species: two endemics (*Phoxinellus epiroticus*, *Squalius pamvoticus*), one native to the West Greece (*Barbus albanicus*) and the ubiquitous *Anguilla anguilla*. These species were almost exclusively present in the lake before 1920, forming remarkable commercially exploited populations. From the 1930s through the 1990s, 20 species were introduced into the lake for purposes of eutrophication control or to enhance the fishery. These introductions, some of them accidental have led to the apparent decline, even loss, of the native species. During the last three decades the fish fauna of the lake has shifted from the native, clear-water species to a predominance of introduced species, mainly those adapted for turbid eutrophic water (*Rutilus panosi*, *Cyprinus carpio* and *Carassius gibelio*, and several Asian cyprinids). The current fish assemblage in the lake is dominated by introduced species particularly the Mosquitofish (*Gambusia affinis*) and the Lourogobios (*Economidichthys pygmaeus*) in the littoral zone, the benthopelagic allogynogenetic Prussian carp (*C. gibelio)*, and the opportunistic Trichonis roach (*R. panosi*), in the pelagic zone.

Key words: invasive species; Pamvotis Lake; shallow lake; fish introduction

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Accepted for publication August 25, 2007

Introduction

The introduction of allochthonus fishes into drainages outside of their natural range has occurred for centuries. In Europe for instance, the introduction of the Common Carp *Cyprinus carpio* (L.) from the Danube to Italy and western and southern Greece is believed to date from Roman times (Balon 1995). Introduction of alien species is a worldwide ecological problem, especially in freshwater systems (Moyle 1997; Garcia-Berthou & Moreno-Amich 2000). There is an impressive record of inland fish invasions that have contributed to the loss of many native species throughout the world (Taylor et al. 1984; Lever 1996) and had negative influences on environmental quality (Zambrano et al. 2001). Among the most vulnerable to introductions are the endemic fish species (Allan & Flecker 1993; Leidy & Moyle 1998; Saunders et al. 2002). As a result of such actions, several species have disappeared or have seen major reductions in their population density or reductions of their distribution to the extent that are now threatened in various levels (Arthington 1991; Witte et al. 1992). Alien species have frequently been blamed for the extinction or decline of endemic fish species, but the evidence is largely anecdotal (Elvira 1990). A large number of introduced exotic or translocated species also occur in Greece (Economidis et al. 2000) and in southern Europe (Crivelli 1995).

Lake Pamvotis has recently been recognised as globally significant for its biodiversity (Krystefek & Reed 2004) and, because of its great nature conservation value, is now listed in Natura Special Conservation areas according to the Habitats Directive EC, 92/43 on the conservation of natural habitats and of wild fauna and flora. This inclusion is due to the presence of the following fish species: Trichonis roach *Rutilus panosi* (Bogutskaya & Iliadou 2006), Epirus barbell or Maritsi *Barbus albanicus* (Steindachner 1870), Epirus minnow *Phoxinellus epiroticus* (Steindachner 1895) and habitat types of *Magnopotamion* or *Hydroharition* vegetation.

As in many Greek lakes, the introduction of alien fishes into Lake Pamvotis over the last century was used as a major tool in shaping freshwater fisheries. Three distinct periods are apparent in the change of fish fauna of the lake. During the first period, in the 1930s the benthopelagic Tench *Tinca tinca* (L.) and the Common Carp (*C. carpio*) were introduced by stocking from Italy (Stephanidis 1939). During the 1950s, the pelagic planktivorous, but rather opportunistic, Trichonis Roach (*R. panosi*) and the benthic piscivorous Aristotle's Catfish *Silurus aristotelis* (Agassiz 1857) were introduced following stocking from Lake Trichonis, along with the Mosquitofish *Gambusia affinis* (Baird & Girard 1853) for the malaria control. In the same period or a bit later, Prussian Carp *Carassius gibelio* (Bloch 1782) was introduced probably from Lake Kerkini (River Strymon drainage, Central Macedonia, Greece) and from Italy. During the 1980s, the Grass Carp *Ctenopharyngodon idella* (Valenciennes 1844), the Silver Carp *Hypophthalmichhtys molitrix* (Valenciennes 1844), the Bighead Carp *Aristichthys nobilis* (Richardson 1845) and more fry of the allogynogenetic Prussian Carp (*C. gibelio*), were introduced with stocks from Hungarian hatcheries (Economidis et al. 2000). In addition to these intentionally stocked species, several small size species were likely introduced accidentally. These include the Hellenic Loach *Cobitis hellenica* (Economidis 1991) probably from the nearby River Louros, the Lourogobios *Economidichthys pygmaeus* (Holly 1929) from Rivers Louros and/or Kalamas (Thyamis) or elsewhere, and the Caucasian goby *Knipowitschia caucasica* (Berg 1916) from Lake Trichonis. During the middle 1990s, the European Catfish *Silurus glanis* (L.), the Goldfish *Carassius auratus* (L.), the Siberian Sturgeon *Asipenser baeri* (Brandt 1869), the Russian Sturgeon *Asipenser gueldenstaedtii* (Brandt & Ratzeburg 1833) and the Mississippi Paddlefish *Polyodon spathula* (Walbaum 1792) were added to the rather artificial fish fauna of the lake. During this last period, specimens of some euryhaline species such as the Thinlip Mullet *Liza ramada* (Risso 1810) and the Grey Mullet *Mugil cephalus* (L.) were also occasionally introduced. Finally, an attempt to introduce the Sea Bass *Dicentrarchus labrax* (L.) was unsuccessful (Nathanailides et al. 2005). The aforementioned introductions and the recent fish species composition of the lake is presented in Table 1.

The primary focus of this paper is to examine changes in the fish fauna of Lake Pamvotis and to study the effects of the various introductions on the native freshwater fish and their ecosystems in this region.

Materials and methods

Lake Pamvotis is located in the NW part of Greece, (39°40′N, 20°53′E) and is about 470 m above the sea level within the Ioannina Basin of the Epirus region. It is a relatively small (having total area of about 22 km^2) and shallow lake (mean depth of 4.5 m and maximum of 7.5 m). The present Lake Pamvotis is the last remaining part (about 8 × 5 km) of a larger lake (30 km long × 15 km wide) covering the flat part of the basin which included two lakes separated by a peaty march: the Lake Pamvotis and the ex-lake Lapsista which was drained at the end of the 1950s and yielded to agricultural use (Fels 1957). The lake is one of the older lakes in the Balkan Peninsula and was formed during the late Miocene to Pliocene period (Frogley et al. 2001). Lakeside shore vegetation consists mainly of reeds (mostly *Phragmites communis*) and other macrophytes (Sarika-Hatzinikolaou 1994; Stephanidis 2005). However, cultivation, logging and over-grazing have degraded the natural vegetation communities of the surrounding lake basin substantially, causing soil desilisation and erosion. Lake Pamvotis itself is a typical Mediterranean lake, fresh (salinity <0.35 p.s.u.), slightly alkaline (pH = 7.6–8.2), $Ca^{2+}$and HCO_3^- dominated. The thermocline is not pronounced (Anagnostidis & Economou-Amili 1980; Kagalou et al. 2003b). Because of the anthropogenic pollution, the lake is increasingly eutrophic showing frequent algal blooms, depletion of dissolved oxygen and a rapid sediment accumulation caused by high productivity, which decreases the depth and extension of the macrophyte zone (Sarika-Hatzinikolaou 1994). In the course of the last decades, the ecosystem of Pamvotis supported many activities such as irrigation, discharge of domestic sewages and sediment deposit, which caused serious problems in its trophic state (Stalikas et al. 1994). Urban pollution originates from the city of Ioannina (population 100,000), laying along the south-western shoreline. Moreover, agricultural effluents of several smaller settlements and light industrial waste from the surrounding area inflow the lake (Stalikas et al. 1994).

To see the historical changes of the lake's fish assemblages, data were collected from historical fish catches record (Steindachner 1896; Panagiotopoulos 1916; Athanassopoulos 1917; Stephanidis 1939; Economidis & Miller 1990; Economidis 1991; Economou et al. 1999; Economidis et al. 2000; Economidis &

Table 1. Fish species records in Lake Pamvotis. Species are ordered by family and by first record date. The first three Cyprinidae and the European Eel are native to the lake.

Family	Scientific name	Origin	Status or acclimatisation	Reasons for introduction	Record date and reference
Cyprinidae	*Squalius pamvoticus* (Stephanidis 1939)	Endemic	Rare or extinct		1896[a], 1916[b], 1917[c], 1939[d]
	Barbus albanicus (Steindachner 1870)	Endemic	Rare		1896[a,] 1999[f],2003[k]
	Phoxinellus epiroticus (Steindachner 1896)	Endemic	Rare or extinct		1896[a], 1999[f], 2005[l]
	Pseudophoxinus stymphalicus (Valenciennes 1844)	Translocated†	Rare	Accidentally	1999[f]
	Cyprinus carpio (Linnaeus 1758)	Introduced	Dependent on stocking	Improve fisheries	1928[d], 2000[h], 1999[f]
	Tinca tinca (Linnaeus 1758)	Introduced	Rare	Improve fisheries	1928[d], 1991[j], 1999[f], 2006[n]
	Rutilus panosi (Bogutskaya & Iliadou 2006)	Translocated‡	Abundant	Improve fisheries	1950[j], 1991[j], 1999[f], 2006[n]
	Hypophthalmichthys molitrix (Valenciennes 1844)	Introduced	Dependent on stocking	Improve fisheries, plankton control	1999[e], 2000[h]
	Aristichthys nobilis (Richardson 1845)	Introduced	Dependent on stocking	Improve fisheries, plankton control	1999[e], 2000[h]
	Ctenopharigodon idella (Valenciennes 1844)	Introduced	Dependent on stocking	Improve fisheries, vegetation control	1999[e], 2000[h]
	Carassius gibelio (Bloch 1782)	Introduced	Abundant	Uncontrolled	1999[f], 1991[j], 2006[n]
	Carassius auratus (Linnaeus 1758)	Introduced	Abundant	Accidentally	1999[f], 1991[j], 2006[n]
Gobiidae	*Economidichthys pygmaeus* (Holly 1929)	Translocated†	Abundant	Accidentally	1999[f]
Cobitidae	*Cobitis hellenica* (Economidis & Nalbant 1997)	Translocated†	Rare	Accidentally	1999[f], 2006[n]
	Knipowitschia caucasica (Berg 1916)	Translocated	Abundant	Accidentally	1990[g, h]
Poecilidae	*Gambusia affinis* (Baird & Girard 1853)	Introduced	Abundant	Mosquitoes control	1944
Anguillidae	*Anguilla anguilla* (Linnaeus 1758)	Native	Rare as native stocked	Improve fisheries	1916[b], 1917[c], 1939[d]
Siluridae	*Silurus aristotelis* (Garman 1890)	Translocated‡	Abundant	Improve fisheries	1950[j], 2006[m]
	Silurus glanis (Linnaeus 1758)	Introduced	Rare or doubtful	Improve fisheries	1999[e]
Mugillidae	*Mugil cephalus* (Linnaeus 1758)	Introduced	Dependent on stocking	Improve fisheries	1999[e], 2000[h]
	Liza ramada (Risso 1826)	Introduced	Dependent on stocking	Improve fisheries	1999[e]
Acipenseridae	*Acipenser baeri* (Brandt 1869)	Introduced	Doubtful presence in the lake	Improve fisheries	1999[e]
	Acipenser gueldenstaedtii (Brandt & Ratzeburg 1833)	Introduced	Doubtful presence in the lake	Improve fisheries	1999[e]
	Polyodon spathula (Walbaum 1792)	Introduced	Doubtful presence in the lake	Improve fisheries, plankton control	1999[e]

References are given as superscripts (a: Steindachner 1896; b: Panagiotopoulos 1916; c: Athanassopoulos 1917; d: Stephanidis 1939; e: Romero & Imberger 1999; f: Economou et al. 1999; g: Economidis & Miller 1990; h: Economidis et al. 2000; j: Economidis 1991; k: Economidis & Herzig-Straschil 2003; l: Leonardos et al. 2005a,b; m: Leonardos et al. 2007; n: personal observations and present study). †Translocated from neighbouring Rivers Louros or Kalamas. ‡Translocated from Lake Trichonis (West Greece).

Herzig-Straschil 2003; Leonardos et al. 2005a,b, 2007), from the Fisheries Management Agency (Romero & Imberger 1999) and from the field surveys carried out during the present study. The data were summarised using the Jaccard index of similarity referring to the unaltered assemblages, i.e. before 1920. The Jaccard index (Cj) for a certain period was calculated as: $Cj = a/(a + b + c)$, where a = number of fish species in both periods, b = the number of fish species present in the second period but not in the reference period, c = the number of fish present in the reference period, but not in the second period (Ludwig & Reynolds 1988). This index ranges from one for identical samples (i.e. the unaltered assemblage) to zero for completely different samples (i.e. if all the native species had disappeared).

Fish from Lake Pamvotis were sampled quarterly from December 2004 to October 2005. Seven sites at the littoral zone were chosen, which differed in bottom cover, substratum, macrophyte cover and inflows. Sampling was carried out by electrofishing. Gillnets, trammel nets and fish traps were used in six sampling sites in the pelagic zone of the lake, which differed in depth, ranging from 1.5 to 7.5 m. The sampling sites differed according to this depth range. Four types of gillnets with mesh size of 6, 12, 14 and 20 mm, and length 50, 60 and 150 m respectively were used. Four types of trammel nets with 28 mm; 160 mm, 32 mm; 200 mm, 60 mm; 240 mm and 80 mm; 300 mm inner outer mesh sizes and 100, 250, 200 and 400 m length respectively were used. Moreover, traps having mesh size of 6, 12 and 16 mm were employed. The fishing tools used was the same used by local professional fishermen. The fishing tools were placed from dusk until dawn guided by a local fisherman. All captured fish were transferred to the laboratory and were: (i) counted in relation to the sampling net, (ii) sexed, (iii) measured to the nearest 0.1 mm and (iv) weighted to the nearest 0.1 g.

Correspondence analysis (CA) was used on the number of fish captured by species, sampling date and sampling net to describe the main sources of variation. CA is an ordination method that reduces a species × sampling date and species × sampling net matrixes to a few dimensions explaining most of the variation. CA is the suitable ordination method for community ecological data (Digby & Kempton 1987). All statistical analysis was performed using SPSS v. 14 (SPSS 2006. User's guide, Chicago, Illinois, U.S.A).

Results

The fish assemblages before 1920 consisted only of four species (*Phoxinelus epiroticus*, *B. albanicus*, *Squalius pamvoticus* and *Anguilla anguilla*). Up until now, 20 introduced or exotic or translocated fish species, representing eight families, have been recorded in Lake Pamvotis (Table 1). The origin of these species is as follows: (i) European, 40%; (ii) North American, 10%; (iii) Asian, 25% and translocated from other Greek fresh or brackish water, 25%. About 71% of them have been introduced during the last 25 years. The reasons for these introductions were: (i) improving the commercial fisheries, 62%; (ii) accidental, 29% (escapes from fish farms, aquarium fish released carelessly, hazardous transporting of fertilised eggs in wet bags or aquatic plants, alive fry among other alive transporting target species, etc); (iii) vegetation and plankton management, 5% and (iv) control of mosquitoes, 5% (Table 1). In several cases, fish species were introduced for more than one reason.

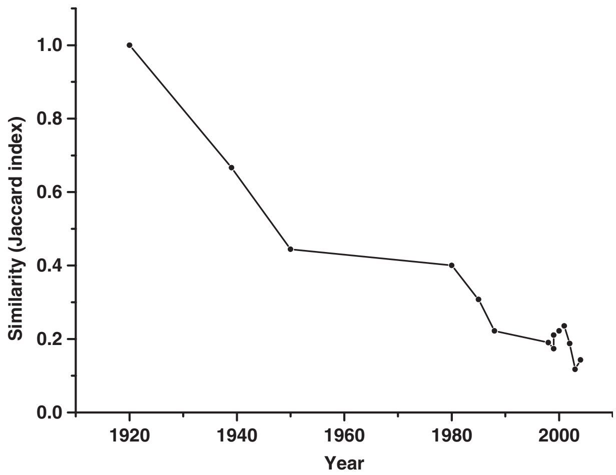

Fig. 1. Changes in similarity (Jaccard index) of the fish fauna of Lake Pamvotis during the period 1920–2005.

The Jaccard index (Fig. 1) summarises the changes in the fish assemblages. There are two steep decreases in similarity located in the middle 1950s and middle 1980s when most introductions were carried out. The first steep decrease coincides with the introduction of the Trichonis Roach (*R. panosi*), the Aristotle's Catfish (*S. aristotelis*) and the Mosquitofish (*G. affinis*). The second decrease is occurred after the 1980s when 18 or more other alien species were introduced. The final calculated value indicates a 14% similarity between the 1920s original assemblage and that of the present day.

The lake is now dominated by nonnative species. The most widespread fish species at the littoral zone are the Mosquitofish (*G. affinis*) and the Lourogobios (*E. pygmaeus*); the Trichonis Roach (*R. panosi*) dominates the pelagic zone. The 5181 specimens collected in the pelagic zone, were found to belong in nine different species, 99.6% of which were allochthonous, mostly the pelagic planktivorous Trichonis Roach (90%). The next more abundant species were the benthic piscivorous Aristotle's Catfish (*S. aristotelis*) and the benthopelagic omnivorous Prussian Carp (*C. gibelio*) representing the 4.5% and the 3.5% of the total catches respectively.

Trichonis roach (*Rutillus panosi*) was captured mainly with gillnets, while the larger specimens were captured in the upper parts of trammel nets. Moreover, during the winter, small-sized specimens were collected in fish traps. The latter is attributed to the trend of the Trichonis Roach to move to deeper parts of the lake under the influence of the low water temperature. Aristotle's catfish (*S. aristotelis*) was captured exclusively during the night (because it is a night feeder) in fish traps and in the lower part of trammel nets. Prussian carp (*C. gibelio*) and Common carp (*C. carpio*) were captured mainly with trammel nets and with trap nets during the day. The benthic

European Eel (*A. anguilla*) and Epirus barbel (*B. albanicus*) and the benthopelagic, Tench (*T. tinca*) were captured mainly with fish traps. The analysis of the size composition of the captured fish from littoral and pelagic zone showed, as expected, that small specimens from all species dominate (Fig. 2).

The first two dimensions in the CA cumulatively explain the 78% of the variation. The first dimension distinguishes the only pelagic planktivorous species of the Lake Trichonis Roach (*R. panosi*) from the others, while the second dimension is related to sample depth and separates the benthic species (*S. aristotelis*, *T. tinca*, *A. anguilla* and *B. albanicus*) in the lower part, from the benthopelagic (*C. gibelio* and *C. carpio*) which exploit the middle and upper layers of the water column (Fig. 3).

Discussion

The native fish fauna of Lake Pamvotis consists of only four species [*P. epiroticus*, *B. albanicus*, *S. pamvoticus* and *A. anguilla* (Steindachner 1896; Panagiotopoulos 1916; Athanassopoulos 1917; Stephanidis 1939)]. The first three species are rather rheophilic and clean water dwellers. The European Eel (*A. anguilla*), being an anadromous species with a life cycle closely related to the rivers, is present in Pamvotis, a fact that could be attributed to the communication of the lake with River Kalamas (Thyamis). The other native species require flow or spring water conditions for spawning and for early life stages (Leonardos et al. 2005a), and these were found mainly in the eastern part of the lake where the majority of springs exist. Accordingly, part of the fauna of the Pamvotis Lake are several, ecologically

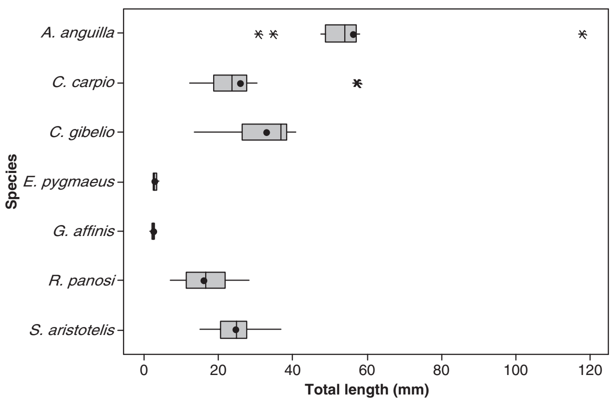

Fig. 2. Size structure of the fish assemblages from littoral and pelagic zone of Lake Pamvotis in 2004–2005. Box plot of total length are shown for each fish species. This corresponds to 25th and 75th percentiles, the line inside the box represents the median length (50%), the dots are the means, asterisks are the remaining data (outliers). The rarest fish (three specimens of *Barbus albanicus* and four of *Tinca tinca*) are not included.

close related, Crustacea Decapoda (rheophilic species that prefer aquatic vegetation) such as the noble crayfish (*Astacus astacus*) and the freshwater shrimps *Palaemonetes antennarius* and *Atyaephyra desmaresti* (Anastasiadou et al. 2005).

In particular, the Epirus Minnow (*P. epiroticus*) which is exclusively endemic in Lake Pamvotis (Stephanidis 1939; Economidis 1991; Leonardos et al. 2005a), was traditionally the only small pelagic fish in the lake forming large fishable populations and being the most popular in the market of the city of Ioannina. During the period 1967–1980, the mean annual yield amounted to 8 tones. However, a tendency of decline was still observed during the 1980s thus the species was proposed and included in the Annex II of the European Council Directive 92/43. In the year 2000, the annual yield dropped to about 2 tones and during the last 3 years, only seven specimens were collected (Leonardos et al. 2005a).

The likely loss of the population of the second endemic fish, the Pamvotis Chub (*S. pamvoticus*), is unfortunate because it was probably one of the most important lacustrine freshwater populations in West Greece as it was the only one being exclusively lacustrine. The third native species, the Epirus Barbel (*B. albanicus*), has as type locality the Lake Pamvotis (Steindachner 1896), but its distribution is wider covering almost all western Greece (Economidis & Herzig-Straschil 2003). The species is considered extinct or critically endangered in the lake.

The decline of the natural population of European Eel, the unique ubiquitous native species, is attributed, on the one hand to the decline of the species population all over Europe and on the other hand to the high level of pollution, the anoxic conditions and mass mortalities that occur often during the summer, the construction of dams in the River Kalamas (Thyamis), which prevent natural migration probably through subterrain waters, and the draining up of the Lapsista marsh. The recent Eel population of Lake Pamvotis consists of specimens that derived from stocking since 2000, through annual introductions of elvers.

Among the alien species, introduced and/or translocated, the pelagic *R. panosi*, the benthic *S. aristotelis*, the allogynogenetic *C. gibelio*, and the littoral *E. pygmaeus* and *G. affinis* have become established with viable and dense populations. But some of the other introduced species, such as *Acipenser baeri*, *Acipenser gueldenstaedtii*, *P. spathula* and *S. glanis*, could not be acclimated in the wild (poor water quality and food, unsuccessful reproduction, etc.) and they evidently vanished soon after their introduction. Especially *S. glanis* compete with *S. aristotelis*, a species which has been adapted long ago to the lake's environment (Leonardos et al. 2007). Moreover,

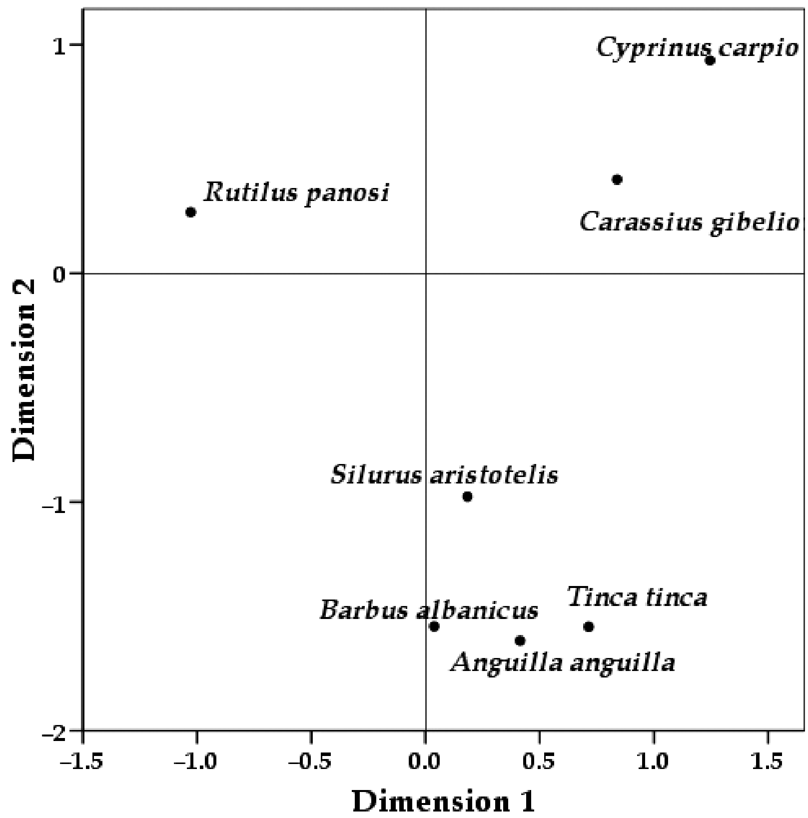

Fig. 3. Correspondence analysis of the number of fish captured by species and sampling net in Lake Pamvotis during 2004–2005. The scores for the first two dimensions are shown.

several other species, such as *A. nobilis*, *C. idella* and *Hypophthalmichthys molitrix*, did not adapt to the lake's environment.

For management purposes, lake planners and/or decision makers have attempted to support the above alien species populations with periodical stocking since 1986. The population of *C. carpio* is enriched annually even though it can freely reproduce in the lake, because its population is permanently overfished.

Rutilus panosi is considered as a 'threatened' and a protected species by EU Habitat Directive 92/43 in its native range (River Acheloos – Lake Trichonis drainage in western Greece). This alien species of Lake Pamvotis has created an abundant population that colonises the pelagic ecosystem of the lake. This is because it is an ecologically tolerant species, well adapted even as planktivorous pelagic resistive in eutrophication and pollution cyprinid fish (Leonardos et al. 2005b). The species mean percentage weight composition to the total catches during the period 1967–1976 was 62% while during the period 1999–2004 dropped to 52% but still remained high.

The size of captured commercial fish in Lake Pamvotis, is smaller than that in the Lakes Trichonis and Lysimachia and other lakes, especially for *C. carpio* and *R. panosi* (Fig. 2). The mean total length of *R. panosi* is smaller in Pamvotis than in Lysimachia and Trichonis (15.9 cm vs. to 19.9 and 18.0 cm respectively) (Leonardos et al. 2005b). The mean length of the Common Carp (*C. carpio*) was small because the specimens that were collected during the first year survey were young of the year with an exception of only one specimen that was 3+ years. This result is consistent with the high fishing pressure or the feeding competition that is practiced in Lake Pamvotis (Leonardos et al. 2005a). According to that, the decline of the large-sized zooplankton (e.g. Cladocerans), being the main food item for the cyprinids, was observed to be greater during late spring/early summer coinciding with the high abundance of cyprinids larvae and fry (Kagalou et al. 2003a). Thus, the absence of an effective piscivore may often lead in an increased predation pressure on the zooplankton community.

Furthermore, the role of the benthivorous species in the quality of the water is very important. For instance, Common Carp directly consume macrophytes and indirectly uproot or break macrophytes by mechanically damaging plants while foraging (Crivelli 1983; Zambrano & Hinojosa 1999; Miller & Crowl 2006). Therefore, a decrease of aquatic plants abundance would be the result of the switch from benthic food to aquatic plants resulting in excessive sediment erosion (Stephanidis 2005). Common Carp is also implicated in the resuspension of the sediment and the organic enrichment causing increase of turbidity and resulting in the reduction of light penetration and photosynthesis (Zambrano et al. 2001) which in turn affects the growth of submerged vegetation. In addition, inadequate light caused by increased turbidity and continuous physical disturbance through Common Carp activity decreases macrophyte re-establishment (Hootsman 1999). The introduction of the Prussian Carp (*C. gibelio*) in the Lake Mikri Prespa (north-western Greece) had the same effect on the benthos community (Crivelli 1995). As turbidity and submerged vegetation are key factors in the functioning of shallow lakes, understanding the effect of benthivorous cyprinid fish on turbidity is crucial for the estimation of the impact of these animals on lake ecosystems. The fact that benthivorous cyprinid fish play a key role in shallow lakes has been illustrated long ago by carp removal experiments and by various biomanipulation experiments, resulting in vegetation recovery and enhanced transparency of the water (Rose & Moen 1952; Hosper & Meijer 1993; Hosper 1994; Roberts et al. 1995). A potential influence on the water quality is the increase in turbidity as a result of a switch in feeding behaviour from planktonic food to benthos beyond a certain critical size. Finally, another alternative influence could be that beyond certain critical damage of the sediment surface caused by fish, the sediment becomes vulnerable to resuspension by wind-induced waves. The presence mainly of common carp but also that of other benthopelagic species, can potentially cause changes in richness and diversity of invertebrates (Zambrano et al. 2001) through changes in their habitat and refuge areas (Parkos et al. 2003; Miller & Crowl 2006). So, the macro-invertebrate assemblage shift to Chironomids and Oligochetae species, which almost entirely inhabitat the soft sediment. This move has been attributed to the uprooted macrophytes by carps (Bremigan et al. 1997).

Lake Pamvotis has experienced a serious decline in macro-invertebrate community during the last decades presenting a shift to the Chironomids and Oligochaetae taxa (Kagalou et al. 2006). This seems to be a result of Common Carp intensive stocking. Additionally, the alien Asian cyprinids and especially the Grass Carp (*C. idella*) had apparently two clear effects on the lake during the last decades: a steady decline of submerged macrophytes and a significant contribution in the near disappearance of endemic (*P. epiroticus* and *S. pamvoticus*) and native cyprinids, *B. albanicus*, merely through competition, egg predation and the loss of habitat (plant beds) (Leonardos et al. 2005a). The decline in the diversity of macrophytes, as a result of cyprinids introduction, and consequently damage and/or loss of habitats, has already been well documented (Garcia-Berthou & Moreno-Amich 2000; Miller & Crowl 2006). In addition, Grass Carp (*C. idella*), considered as one of the most herbivorous fish, was used as a tool to control aquatic vegetation and it has been introduced, unjustified, in Lake Pamvotis aiming especially to limit the reed-beds (*Phragmites australis*) and to improve the fisheries by contributing with its own fish production. One of the most characteristic influences of the introduction of this species in the lake, was the significant reduction of the submerged vegetation (Stephanidis 2005). Hence, by grazing selectively on tender species enhanced the development of tougher plants, a fact that provoked greater problems. Aquatic plants (including native forms) might become overly decimated as a result of Grass Carp grazing which in turn can cause loss of ecological space (niches) for other species (limiting nursery areas for juvenile fishes, causing bank erosion, accelerating eutrophication through release of nutrients previously stored in the plants, etc.). Finally, Grass Carp has significantly altered the food chains and trophic structure of aquatic systems by inducing changes in plant, invertebrate and fish communities.

The above native species are all nearly extinct because of the cumulative impacts of alien invaders, water quality, habitat alteration (deterioration, degradation and fragmentation) provoked mainly by urbanism, urban pollution and ecologically unsustainable agricultural development. The above threats in combination with the intensive fishing pressure, practiced by local fishermen, have significantly decreased the endemic species populations (Leonardos et al. 2005a).

Conservation proposals

The effects of introduced freshwater fish are a serious problem worldwide. In Lake Pamvotis and in Greece in general, new alien species continue to be introduced without any concern on the part of general public, government agencies and planners or fisherman. In many cases, some unauthorised local people and official authorities still use fish introductions, as a management tool in contrast with the national and/or international guidance. As the removal of introduced populations is practically impossible, their manipulation is limited to preventing further introductions, controlling their populations and promoting and preserving the native species.

In particular, provisions should be made to protect the native species, mainly the endemics, and their habitat to ensure their survival. The long-term key remains the effective habitat conservation and the rehabilitation, including prevention of the further spread of invasive alien fishes, the education of fishermen and any other related people. A detailed study of current distribution, population status and the biology and ecology of species is required. Finally, artificial propagation of the native fish species should be promoted to increase the size of the native fish population in concern.

Acknowledgements

This research was partially funded by the programme 'Pythagoras I' of the Operational Program for Education and Initial Vocational Training of the Hellenic Ministry of Education under the 3rd Community Support Framework and the European Social Fund. We appreciate concern shown by A. Charatsaris during the samplings, and P. Moutsaki for the linguistic improvement of the text. Moreover, the authors would like to thank the editor Dr Javier Lobon-Cervia, and the anonymous referees for their constructive comments on the manuscript.

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