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Variations in the fish community in lake Piediluco (Italy) caused by changes in the lake's trophic status and the introduction of alien species

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Summary

The composition of fish populations in lake Piediluco has undergone significant changes in recent years, mainly as a result of environmental deterioration due to the eutrophication of its waters and the introduction of some alien species. Lake Piediluco is a natural, regulated lake, which has been used for the production of hydroelectric power since 1908. Over the years, the trophic status of the lake has been profoundly modified: until 1980 it was mesotrophic; by 1989 it had become eutrophic, and now it is deemed to be hyper-eutrophic. The aim of this research was to analyze variations in the composition of fish populations in relation to the trophic evolution of the lake and the introduction of alien species. The data on fish populations were gathered during four monitoring campaigns carried out in 1988, 1996, 1999 and 2004. To estimate the abundance of the various species, catches were standardized in terms of catch per unit effort (CPUE). The results of the research reveal that the increase of the trophic status of the lake has been accompanied by a qualitative and quantitative change in the composition and structure of the fish community, which is being increasingly dominated by omnivorous cyprinids, such as *Scardinius erythrophthalmus* and the alien *Rutilus aula*. This is taking place at the expense of species that are ecologically less resilient and commercially more interesting, supported by provincial management policies as annual repopulation programs and deployment of artificial spawning substrates. Moreover, in more recent years the presence of some new alien species has been recorded, such as *Rutilus rutilus* and *Gymnocephalus cernuus*. These species, which were not previously found, pose a further threat to commercial fishing in the lake.

Introduction

Eutrophication is a process rather than a state (Rast and Thornton, 1996). Under natural conditions, it represents the aging process of a lake and takes place over a geological timescale. However, when human activities influence the biogeochemical cycling of nutrient, such as nitrogen and phosphorus, the enrichment process can greatly accelerate; this latter phenomenon is termed cultural eutrophication.

Lake Piediluco is a natural, regulated lake, which has been used for the production of hydroelectric power since 1908. Over the years, regulation of the lake's waters has caused progressive environmental deterioration, which began when the catchment basin was artificially extended, allowing larger amounts of nutrients to flow into the lake. As a result, the trophic status of the lake has been profoundly altered. Indeed, data regarding concentrations of total phosphorus reveal that the lake was mesotrophic (40 μg L^{-1}) until 1980; by 1989 it had become eutrophic (80 μg L^{-1}), and is now deemed to be hyper-eutrophic (110 μg L^{-1}) (Mearelli, 1988; Cioffi and Gallerano, 2000). In recent years, the composition of fish populations has undergone significant changes, mainly as a result of the eutrophication of the lake's waters and the introduction of some alien species. On the basis of the data on catches recorded by the local fishermen's cooperative, the annual yield in lake Piediluco in 1988 was estimated to be 143 kg ha^{-1}, whereas in 1993, decreased to only 51 kg ha^{-1} (F. Bisonni, unpubl. data) (Table 1). No commercial perch catches have been taken from lake Piediluco since 2002, when the local fishermen's cooperative suspended its operations; moreover, since 1979 a program to support the reproduction of this species has been in force. Nevertheless, the perch population does not seem to be able to recover its former abundance (Viali et al., 1999).

The present study aimed to analyze the variations in the composition of fish populations in relation to the trophic evolution of the lake and the introduction of alien species. In particular, the dynamics of the individual species, and also of groups of species (cyprinids and percids), were analyzed.

Study area

Lake Piediluco is situated in the centre of the Italian peninsula (Fig. 1). It extends roughly east-west and has spike-shaped arms to the north and south. The deepest part lies in front of the community of Piediluco, whereas the waters of the lateral arms are shallow (Enel-DCO, 1989). For further morphometric and abiotic characteristics, see Table 2.

Lake Piediluco is used as a daily water-storage basin for the Galleto hydroelectric plant. This hydroelectric use determines a particular hydraulic regime, which is regulated by the water flow rates of the Medio-Nera channel and Velino river. During the daily power-generation cycle, water from the Velino river and Medio-Nera channel is stored in the lake, the level of which rises by about 58 cm in 9 h. For the other 15 h, the water flowing out from the lake and that of the Velino river are conveyed to the hydroelectric plant by a system of gates.

Material and methods

The analysis utilized the set of data collected during the ENEL-DCO research campaign conducted in 1988 ⁄ 89 (Enel-DCO, 1989), the campaigns promoted by the Province of Terni in 1996 and 1999 and the monitoring campaign carried out in

Table 1
Relative frequencies expressed as a percentage of data catches recorded by Piediluco professional fishermen's cooperative

Species	1988	1993
Anguilla anguilla	33	19
Coregonus lavaretus	8	1
Esox lucius	8	6
Perca fluviatilis	43	10
Tinca tinca	4	11
Other	4	14
Alburnus alburnus alborella		13
Rutilus aula		20
Scardinius erythrophthalmus		6
Total	100	100

2004. Seasonal sampling campaigns were conducted by means of bottom gill-nets, floating gill-nets, fyke-nets and trotlines, in order to investigate the overall composition of the fish community living in lake Piediluco.

Gill-nets were made up of three panels (25×1.5 m) of 20, 28, and 45 mm bar mesh size, weighted with lead lines, for a total net area of about 112.5 m^2. The panels were arranged in series, according to increasing mesh size, and were set at six sampling stations near the shore of the lake, at a depth of about 3.5 m, for a night fishing session of about 12 h. Floating gill-nets were composed of three panels (35×6 m) of 35 mm mesh size, for a total net area of about 630 m^2, and set at three sampling stations for 12 h. Fyke-nets were constructed with a mesh bar length of 16 mm, with a mouth width of 1.5 m and wings 4 m height and 8 m long. Each fishing session was conducted at two sampling stations with a single net for a dwell-time of approximately 36 h. Trotlines with 40 hooks were baited with worms and deployed at three sites for 12 h of fishing time.

Catches were separated according to the sampling station and the equipment used. All fish captured were identified by species, and the total length ($\pm$ 0.1 cm) and total weight ($\pm$ 0.1 g) of each specimen were recorded.

Table 2
Characteristics of lake Piediluco (Regione dell'Umbria, 1997)

Parameter	Value
Perimeter (km)	14.84
Area (km^2)	1.67
Volume (millions m^3)	18.56
Maximum depth (m)	21
Mean depth (m)	10.9
Length (km)	2.8
Mean width (km)	0.39
Sinuosity index (Tonolli, 1964)	3.28
Mean annual temperature (°C)	15.33
pH	7.92
Oxygen dissolved (%)	131.65
Clorophyll α (mg m^{-3})	12.12
Trasparency (m)	1.68
External phosphorus loads (kg $year^{-1}$)	74390

To assess the abundance of the various species in terms of number and biomass, catches per unit effort (CPUE) (Ricker, 1975) were analyzed. The CPUEs were calculated separately for each type of fishing gear and, in the case of gill-nets, for each mesh size. In addition, with regard to gill-nets and floating gill-nets, both the dwell-time of the nets and the surface area of the panels were considered in order to express catches in relation to these two parameters. CPUEs were calculated by the following formulas:

$$\mathrm{CPUEn} = n/t \cdot s$$

$$\mathrm{CPUEb} = b/t \cdot s$$

Where:
n = number of fish caught;
b = biomass of fish caught, expressed in grams;
t = dwell-time of the nets, expressed in hours;
s = surface area of the nets in m^2.

In order to synthetically describe the evolution of the structure and composition of the fish community, the following

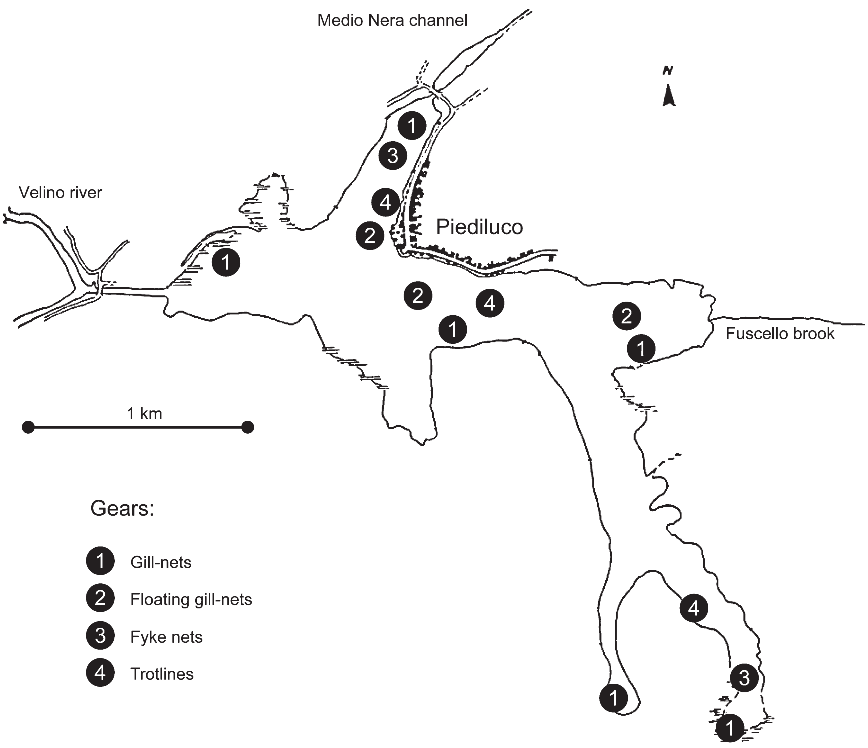

Fig. 1. Lake Piediluco and locations of fishing gear

indexes were used: Shannon-Weaver diversity (H'), evenness (J), dominance (D), species richness (S) and qualitative integrity (IIQual) (Bianco, 1990), calculated on a seasonal basis.

The fish species in lake Piediluco were grouped into four main trophic categories: omnivores, invertivores, invertivores / carnivores and carnivores. Omnivores are fish which consume a wide range of plants, detritus and material, with at least 25% plants and 25% animals (Karr et al., 1986); invertivores are fish that eat insects and other invertebrates including crustaceans, mollusks, and worms; invertivores / carnivores are fish that have a diet based on fish and invertebrates; carnivores are fish that eat primarily other fish.

Comparisons among annual CPUE data and temporal variations in community indexes were conducted by using one-way ANOVA with a significance level of 0.05 (Sokal and Rohlf, 1995).

Results

In 2004, sampling revealed the presence of 15 species belonging to six different families, 60% of which alien species (Table 3). The most common family was that of cyprinids, with seven species, followed by salmonids (three species) and percids (two species). Comparison with the data yielded by previous monitoring campaigns revealed that the overall number of species had not undergone marked variations. However, few recently alien species were recorded. In fact, roach and carp were first detected in 2004, though the latter were probably already present but had not been captured owing to their low population density. As different types of fishing gear were used, each with its own particular characteristics and deployed in different areas of the lake, the CPUE values were examined independently.

Gill-nets proved to be the most effective fishing devices, with a mean CPUEn of 0.019 ind h^{-1} m^{-2}. Comparison of the mean CPUEs in the various years (Table 4) revealed significant variations in terms of biomass ($F = 5.186$, $P < 0.01$), but not in terms of abundance ($F = 2.169$, $P > 0.05$). Indeed, from 1988 to 2004 the values of CPUEb were more than doubled, while those of CPUEn remained almost unchanged. On breaking down the data according to individual species, a considerable increase was observed in catches of ruffe (from 4×10^{-5} in 1996 to 0.023 spec m^{-2} h in 2004) and, to a lesser degree, of rudd (from 0.014 in 1996 to 0.015 spec m^{-2} h in 2004) and northern italian roach (from 0.005 in 1996 to 0.014 spec m^{-2} h in 2004), while tench catches were seen to have declined markedly (from 0.001 in 1988 to 0.0002 spec m^{-2} h in 2004 (Fig. 2). The species that displayed the greatest increase in CPUEb was the rudd (from 1.281 in 1988 to 4.394 g m^{-2} h in 2004), followed by pike (from 0.127 in 1988 to 1.233 g m^{-2} h in 2004), whitefish (from 0.114 in 1996 to 0.939 g m^{-2} h in 2004) and ruffe (from 0.002 in 1996 to 0.948 g m^{-2} h in 2004).

On examining the catches made by floating gill-nets, it should be borne in mind that this type of gear is highly selective. Indeed, in the 2004 campaign, the target species *Coregonus lavaretus* accounted for more than 90% of the catch, and some rudd (approx. 3%) were always found (Fig. 3). The data on catches (Table 4) confirm a rising trend in CPUE values over time with regard to both abundance and biomass, with statistically significant differences being recorded (CPUEn: $F = 6.818$, $P < 0.05$; CPUEb: $F = 8.385$, $P < 0.05$).

Like the gill-nets, the fyke-nets also displayed significant variations in CPUE values only with regard to the overall biomass ($F = 4.164$, $P < 0.05$), which was seen to have increased noticeably from 1988 to 2004 (Table 4), while from a numerical standpoint the values remained substantially

Table 4
Annual mean variations of CPUEs (Catches Per Unit Effort) in terms of abundance (n) and biomass (b) calculated from four seasonal sampling data

	1988	1996	1999	2004
CPUE n				
Gill-nets	0.02	0.016	0.015	0.022
Floating gill-nets	0.0001	0.001	0.001	0.003
Fyke-nets	0.104	0.152	0.181	0.222
Trotlines	–	–	0.21	0.27
CPUE b				
Gill-nets	1.582	1.983	2.648	3.232
Floating gill-nets	0.076	0.317	0.392	0.812
Fyke-nets	12.943	19.423	39.022	57.62
Trotlines	–	–	61.147	39.735

Table 3
List of fish species caught in lake Piediluco

Family	Species	Origin	Trophic guild	1988	1996	1999	2004
Anguillidae	*Anguilla anguilla* (Linnaeus, 1758)	Native	Invertivore / carnivore	x	x	x	x
Cyprinidae	*Alburnus alburnus alborella* (De Filippi, 1844)	Alien	Invertivore	x	x	x	x
	Carassius auratus (Linnaeus, 1758)	Alien	Omnivorous			x	
	Cyprinius carpio (Linnaeus, 1758)	Alien	Omnivorous				x
	Leuciscus cephalus (Linnaeus, 1758)	Native	Invertivore	x	x	x	x
	Rutilus aula (Bonaparte, 1841)	Alien	Omnivorous	x	x	x	x
	Rutilus rubilio (Bonaparte, 1837)	Native	Omnivorous		x		
	Rutilus rutilus (Linnaeus, 1758)	Alien	Omnivorous				x
	Scardinius erythrophthalmus (Linnaeus, 1758)	Alien	Omnivorous	x	x	x	x
	Tinca tinca (Linnaeus, 1758)	Native	Invertivore	x	x	x	x
Esocidae	*Esox lucius* (Linnaeus, 1758)	Native	Carnivore	x	x	x	x
Percidae	*Perca fluviatilis* (Linnaeus, 1758)	Native	Invertivore / carnivore	x	x	x	x
	Gymnocephalus cernuus (Linnaeus, 1758)	Alien	Invertivore		x	x	x
Centrarchidae	*Lepomis gibbosus* (Linnaeus, 1758)	Alien	Invertivore	x	x	x	x
Salmonidae	*Salmo trutta* (Linnaeus, 1758)	Native	Invertivore / carnivore	x	x	x	x
	Coregonus lavaretus (Linnaeus, 1758)	Alien	Invertivore	x	x	x	x
	Oncorhynchus mykiss (Walbaum, 1792)	Alien	Invertivore / carnivore	x		x	x
	Thymallus thymallus (Linnaeus, 1758)	Alien	Invertivore			x	

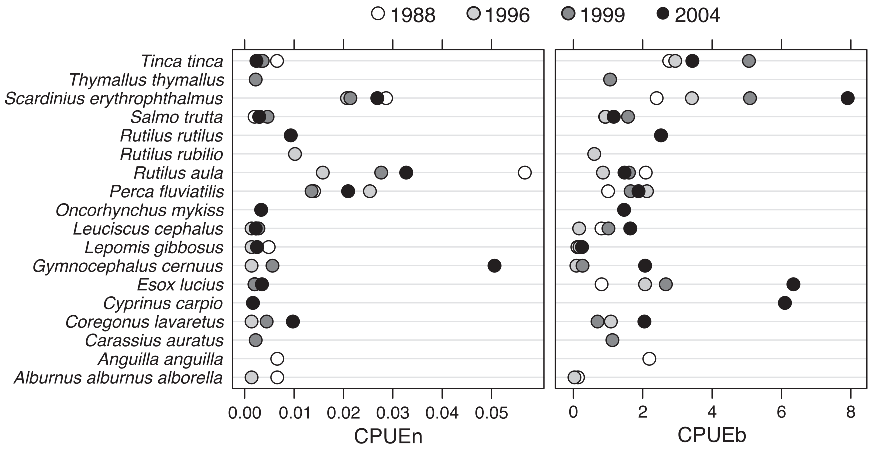

Fig. 2. Annual mean of gill-nets CPUEs (Catches Per Unit Effort) calculated from four seasonal sampling data. CPUEn is referred to the number (n) of fish caught (1988 n = 870; 1996 n = 1161; 1999 n = 1082; 2004 n = 2311); CPUEb is referred to the biomass of fish caught (1988 kg = 86.1; 1996 kg = 145.6; 1999 kg = 206.9; 2004 kg = 369.8)

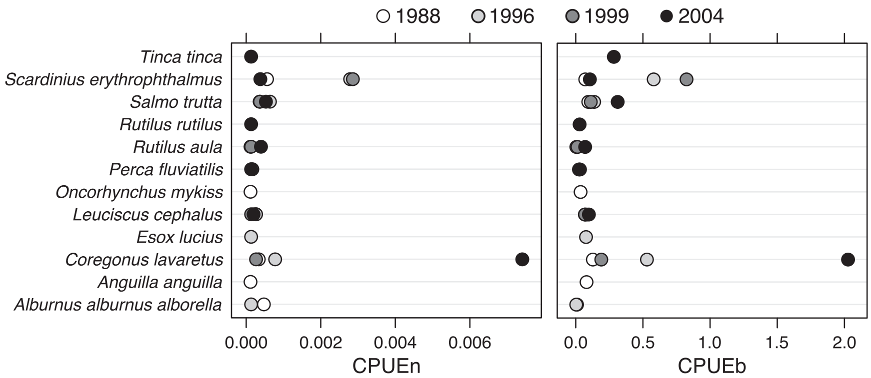

Fig. 3. Annual mean of floating gill-nets CPUEs (Catches Per Unit Effort) calculated from 4 seasonal sampling data. CPUEn is referred to the number (n) of fish caught (1988 n = 201; 1996 n = 370; 1999 n = 276; 2004 n = 730); CPUEb is referred to the biomass of fish caught (1988 kg = 39.3; 1996 kg = 100.7; 1999 kg = 83.1; 2004 kg = 208.7)

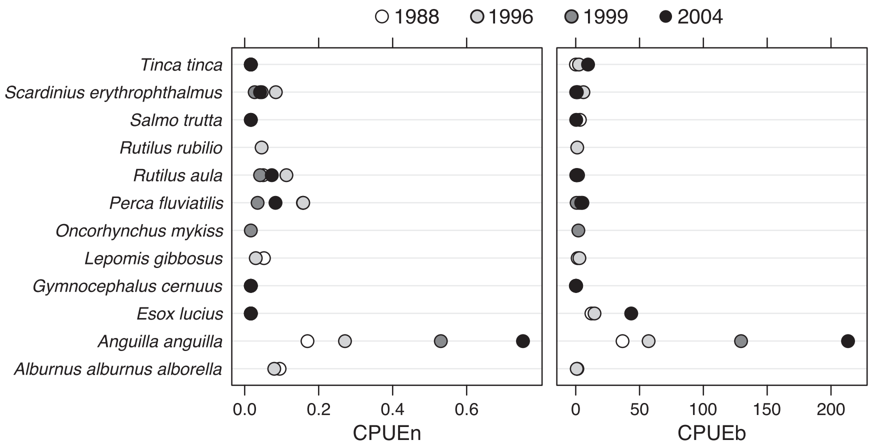

Fig. 4. Annual mean of fyke-nets CPUEs (Catches Per Unit Effort) calculated from four seasonal sampling data. CPUEn is referred to the number of fish caught (1988 n = 1156; 1996 n = 1165; 1999 n = 401; 2004 n = 386); CPUEb is referred to the biomass of fish caught (1988 kg = 143.7; 1996 kg = 149.2; 1999 kg = 86.6; 2-004 kg = 100.3)

constant over the years ($F = 1.972$, $P > 0.05$). These nets were able to capture a good number of species, though eel account for most of the catch (Fig. 4).

Data on catches made by trotlines were available only for 1999 and 2004. No statistically significant differences in catches ($P > 0.05$) were seen with regard to either biomass or abundance. However, examination of the proportion of the catch accounted for by each species revealed a marked increase in ruffe and a reduction in European perch over time, while the number of eel remained substantially stable (Fig. 5).

The Shannon index (H') showed a significant upward trend over the years (Table 5). From a minimum value of 1.03 in 1988, the index rose to 1.51 in 2004, the overall differences being highly significant ($F = 3.063$, $P < 0.001$). The evenness index (J) displayed a substantially similar trend, though the differences among the mean values did not prove statistically significant ($F = 2.282$, $P > 0.05$). Comparison of these data with the variation in the dominance index (D) clearly revealed a trend towards a more balanced distribution of species within the fish community, which was formerly dominated by a few species that monopolized the available resources. Comparison of the values of the dominance index did not, however, reveal any statistically significant differences ($F = 2.394$, $P > 0.05$). Nevertheless, it is noteworthy that in 1999 only three species – rudd, ell and northern Italian roach – accounted for 80% of catches, while in 2004 the four most numerous species (ruffe, whitefish, northern Italian roach and rudd) accounted for only 71.9% of the total in terms of abundance. The species richness

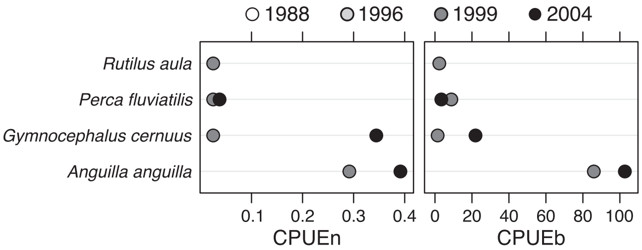

Fig. 5. Annual mean of trotlines CPUEs (Catches Per Unit Effort) calculated from four seasonal sampling data. CPUEn is referred to the number of fish caught (1999 n = 109; 2004 n = 227); CPUEb is referred to the biomass of fish caught (1999 kg = 31.8; 2004 kg = 33.4)

Table 5
Annual mean variations in community indexes

Year	Diversity (H')	Evenness (J)	Dominance (D)	Species richness (S)	IIQual
1988	1.03	0.49	0.49	7.91	0.47
1996	1.23	0.63	0.4	7.11	0.57
1999	1.21	0.62	0.41	7.17	0.55
2004	1.51	0.68	0.29	9.42	0.46

index (S) also displayed a significant increase over time ($F = 3.592$, $P < 0.05$); however, the IIQual index revealed that this increase corresponds to a significant worsening of the conditions of the integrity of the community as a result of the introduction of new alien species ($F = 3.171$, $P < 0.05$).

In 2004, omnivores and invertivores were the most abundant feeding categories, accounting for 36.61 and 40.42% of specimens caught and 34.39 and 41.31% of the biomass, respectively (Fig. 6). In comparison with 1999, when omnivores accounted for over 50% of both specimens and biomass and predators made up only 2%, the structure of the community showed a gradual improvement. Analysis of variance did not reveal statistically significant differences among the values recorded in the various years with regard to carnivores ($F = 1.868$, $P > 0.05$). Nor were any significant differences observed in the fluctuations of the levels of invertivores/carnivores ($F = 2.339$; $P > 0.05$); nevertheless, a progressive downward trend in the presence of this feeding category could be discerned. By contrast, marked quantitative variations could be seen with regard to invertivores; by 2004, this category shrank to its 1988 level after heavy depletion in the 1990s. Finally, the variations seen in the category of omnivores bordered on significance in the long period ($F = 2.813$; $P = 0.051$), a steadily rising trend up to 1999 being offset by a phase of retrenchment in 2004.

The ratio between carnivores and other feeding categories displayed a prevalence of prey categories. Indeed, even on combining the values recorded for pike, brown trout, rainbow trout, European perch and eel in 2004, predators accounted for only 31% of specimens caught and 23.4% of the biomass.

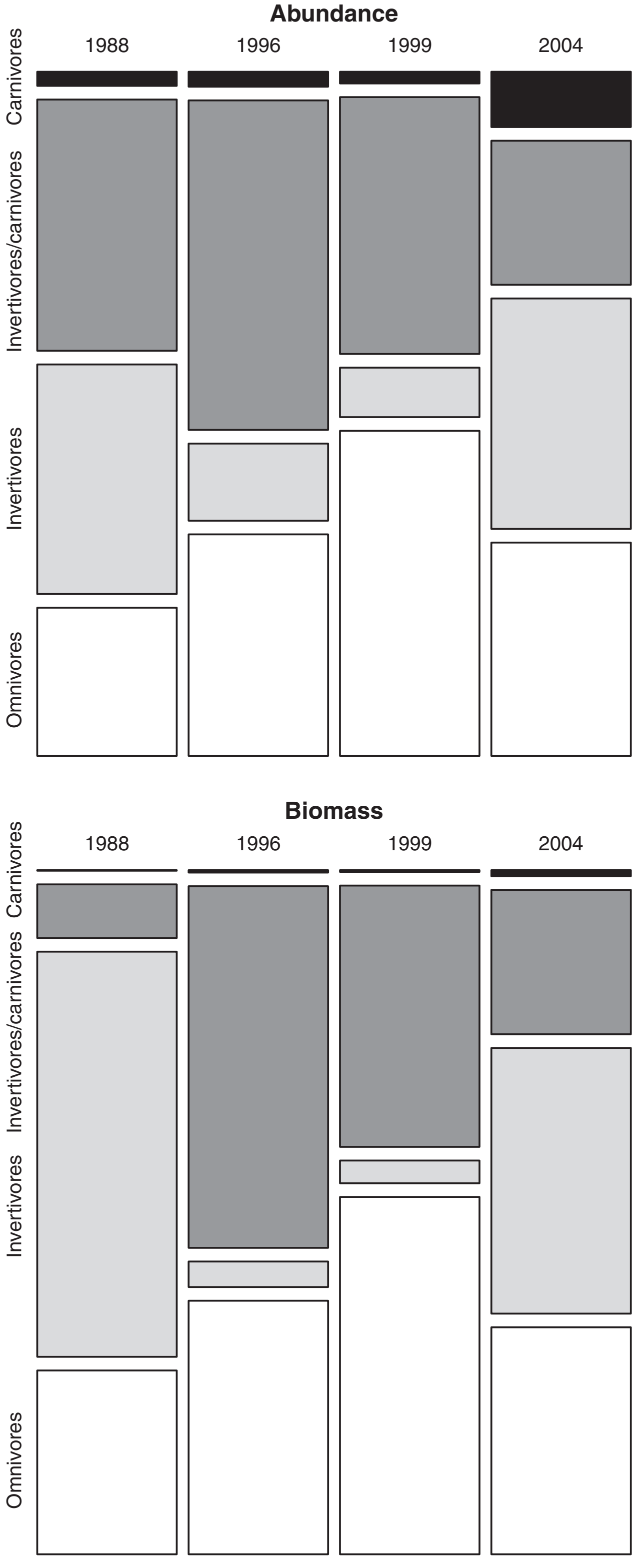

Fig. 6. Changes over time of proportion of the main trophic categories: omnivores that eat at least 25% plants and 25% animals; invertivores that eat insects and other invertebrates; invertivores/carnivores that eat fish and invertebrates; carnivores that eat primarily other fish. Frequencies expressed in percentage terms

Discussion

The eutrophication of lakes induces changes in abiotic and biotic environmental factors, which are reflected in the structure of the fish community. In temperate lakes in Europe, the characteristic shift along a productivity gradient is from the dominance of salmoniformes in oligotrophic lakes to the dominance of percids in moderately productive lakes and to the dominance of cyprinids in highly productive lakes (Leach et al., 1977; Persson et al., 1991). Moreover, the eutrophication process is responsible for marked changes in the plankton community, on which the food chain and fish biocenosis depend (Olin et al., 2002).

The results of the monitoring campaigns conducted in lake Piediluco reveal a fish community dominated by cyprinids, in accordance with the evolution of the trophic state of the lake, and a significant increase in the number of invasive alien species. The success of cyprinids in eutrophic environments is determined by their great efficiency in zooplankton predation, their omnivory and their ability to adapt to turbid waters in which visibility is poor (Persson et al., 1991). By contrast, visual predators, such as pike, are heavily penalized. In lake Piediluco, the species that have shown the greatest increase in abundance over time are the aliens: roach, northern Italian roach and ruffe. Though the first of these appeared only in 2004, the data on catches indicate that its population has become firmly established; the second is now well acclimatized in lake Piediluco and its population seems to be stable and well structured; the third appears to be proliferating more rapidly, since catches increased 10-fold from 1996 to 2004. To these three species we should add the rudd, the native species that has benefited most from the changes that have taken place in the lake. The CPUE data reveal a marked increase in catches of this species in terms of biomass and a lesser increase in terms of abundance, thus indicating a structural evolution of the population in favor of the older age-classes. Precisely the opposite trend is displayed by the Italian bleak, disappeared in recent sampling campaigns, which seems to be one of the species most heavily penalized by the environmental changes that have occurred in recent years. In fact, in '60 after its introduction, became particularly abundant (Lorenzoni et al., 2007). Pike are now seen to have increased in abundance. The results of previous monitoring campaigns provided evidence of the steady decline of this species; however, this trend seems to have been reversed thanks to the intervention undertaken by the annual repopulation program of the provincial administration, that in the spring season release young pike of approximately 8 cm in length in the lake's water. Likewise, the variations in catches of whitefish and eel cannot be ascribed to the natural evolution of these populations, as their stocks are regulated through replenishment programs. The situation of the European perch seems to be more complex. The data on catches indicate a partial recovery of the population, though current abundance remains far below the maximum levels recorded in 1996. The present structure of the fish community and the trophic conditions of the lake's water are unfavorable for young perch, which are highly intolerant of eutrophication and weak competitors for zooplankton resources compared with cyprinids (Persson, 1983; Volta and Jepsen, 2008). As small perch compete with roach high competition for zooplankton may force perch to switch to bentic invertebrates (Persson and Greenberg, 1990). Moreover, wherever ruffe have become established as an alien species, changes in the fish community structure have been observed (Mills et al., 1994; Adams and Maitland, 1998). Most studies agree that juvenile perch and ruffe are potential competitors for benthic macroinvertebrates, because with increasing density of ruffe, European perch consumed less benthic macroinvertebrates and more zooplankton (Bergman and Greenberg, 1994). Recent data reveal that in lake Piediluco dietary overlapping between the ruffe and the European perch is high, thus confirming concerns over the interaction between the two species (Lorenzoni et al., 2007).

In lake Piediluco, too many components of the fish community seem to be currently exerting predatory pressure on zooplankton. Indeed, the young stages of numerous ciprinids present in the lake (rudd, northern Italian roach, roach) and of the ruffe are particularly efficient feeders on zooplankton in the conditions that arise in eutrophic lakes. In this regard, the marked increase in the abundance of ruffe and the introduction of the roach have exacerbated previous worries. The increased abundance of the whitefish, which is in some ways surely positive, may also impact negatively on the trophic equilibrium of the lake, since this species is a plankton-feeder par excellence. The introduction of this species should therefore be commensurate with the need to maintain this equilibrium and, especially, should be counterbalanced by the selective culling of other plankton-feeding species.

The trophic structure of the community is regarded as an indicator of environmental quality. Indeed, it is well known that changes in the quality of the water and habitat conditions can impact negatively on food resources and may even lead to their total disappearance (Araujo, 1998). Moreover, it is generally accepted that fish strongly influence trophic dynamics in lakes, occasionally exerting a great impact on phytoplankton, the quality of the water and the ecological state (Carpenter and Kitchell, 1993; Rudstam et al., 1993; Jeppesen et al., 1997, 2000). The analysis of the ratio between predators and species occupying lower levels of the food chain can be considered a further indicator of the state of the fish community, since it has been observed that the proportion of predators declines as the quality of the water worsens (Persson et al.,1988; Araujo, 1998). The trophic structure of the fish community in lake Piediluco revealed an imbalance among the various categories. In fact, the proportion of predators proved to be lower than expected. Studies conducted on other lakes have suggested that piscivores should account for 30–40% of the total population in order to ensure the stability of the fish community (Benndorf, 1990). Templeton (1984) claims that the optimum ratio between the biomass of the pike and that of its prey is 1 : 7–1 : 8; according to Lelek (1991), the ratio (P ⁄ Fp) between piscivorous predators (P) and prey fish (Fp) should be between 1 : 3 and 1 : 6.

The data collected in this study provide a further contribution in the exploration of the ecology of Piediluco's fish community and its dynamics. The introduction of alien fish species and their great increase in abundance over time constitute a negative element that can be added to changes in the trophic state and the general environmental worsening, but some recent trends in the quality of the water and composition of the fish community are strong signs to intensify administration efforts to combat eutrophication, assess the impact of invasive alien species and promote the conservation of natural resources.

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References

Adams, C. E.; Maitland, P. S., 1998: Resumen The ruffe population of Loch Lomond, Scotland: its introduction, population expansion, and interaction with native species. J. Great Lakes Res. **24,** 249–262.

Araujo, F. G., 1998: Adaptaçao do Indice de integridade biotica usando a comunidade de piixes para o rio Paraiba do Sul. Rev. Bras. Biol. **58,** 547–558.

Benndorf, J., 1990: Conditions for effective biomanipulation; conclusions derived from whole-lake experiments in Europe. Hydrobiologia **200–201,** 187–203.

Bergman, E.; Greenberg, L. A., 1994: Competion between a planktivore, a benthivore and a species with ontogenetic diet shifts. Ecology **75,** 1233–1245.

Bianco, P. G., 1990: Proposta per l'impiego di indici e coefficienti per la valutazione dello stato di degrado dell'ittiofauna autoctona delle acque dolci. Rivista di Idrobiologia **29,** 130–149.

Carpenter, S. R.; Kitchell, J. F., 1993: The trophic cascade in lakes. Cambridge University Press, Cambridge, pp. 385.

Cioffi, F.; Gallerano, F., 2000: Response of lake Piediluco to the change of hydrodynamic conditions and nutrient load reductions. Ecol. Modell. **135,** 199–229.

Enel-DCO, 1989: Indagine per la valorizzazione ambientale del lago di Piediluco. Rapporto finale. Enel-DCO, Laboratorio di Piacenza, Piacenza, 56.

Jeppesen, E.; Jensen, J. P.; Søndergaard, M.; Lauridsen, T. L.; Pedersen, L. J.; Jensen, L., 1997: Top-down control in freshwater lakes: the role of nutrient state, submerged macrophytes and water depth. Hydrobiologia **342,** 151–164.

Jeppesen, E.; Lauridsen, T. L.; Mitchell, S. F.; Christoffersen, K.; Burns, C. W., 2000: Trophic structure in the pelagial of 25 shallow New Zealand lakes: changes along nutrient and fish gradients. J. Plankton Res. **22,** 951–968.

Karr, J. R.; Faush, K. D.; Angermeier, P. I.; Yant, P. R.; Schlosser, I. J., 1986: Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey, Special Publication, 5, Champaign, Illinois.

Leach, J. H.; Johnson, M. G.; Kelso, J. R. M.; Hartmann, J.; Nimann, W.; Entz, B., 1977: Responses of percid fishes and their habitats to eutrophication. J. Fish. Res. Bd. Can. **34,** 1964–1971.

Lelek, A., 1991: The predator-prey relationship in the fish community of the Rhine River. Verh. Internat. Verein. Limnol. **24,** 2455–2460.

Lorenzoni, M.; Carosi, A.; Pedicillo, G.; Trusso, A., 2007: A comparative study of the feeding competition of the european perch *Perca fluviatilis* L. and the ruffe *Gymnocephalus cernuus* (L.) in lake Piediluco (Umbria, Italy). Bull. Fr. de la Pêche et de la Pisciculture **387,** 35–57.

Mearelli, M., 1988: Eutrofizzazione. Rivista di Idrobiologia **27,** 651–661.

Mills, E. L.; Leach, J. H.; Carlton, J. T.; Secor, C. L., 1994: Exotic species and the integrity of the Great Lakes. Bioscience **44,** 666–676.

Olin, M.; Rask, M.; Ruuhijarvi, J.; Kurkilahti, M.; Ala-Opas, P.; Ylonen, O., 2002: Fish community structure in mesotrophic and eutrophic lakes of southern Finland: the relative abundances of percids and cyprinids along a trophic gradient. J. Fish Biol. **60,** 593–612.

Persson, L., 1983: Effects of intra and interspecific competition on dynamic and size structure of a perch *Perca fluviatilis* and a roach *Rutilus rutilus*. Oikos **41,** 126–132.

Persson, L.; Greenberg, L. A., 1990: Interspecific and intraspecific size class competition affecting resource use and growth of perch, *Perca fluviatilis*. Oikos **59,** 97–106.

Persson, L.; Andersson, G.; Hamrin, S. F.; Johansson, L., 1988: Predator regulation and primary production along the productivity gradient of temperate lake ecosystem. In: Complex interactions in freshwater ecosystem. Carpenter, S. R. (Eds). Elsevier Science, Amsterdam, pp. 43–65.

Persson, L.; Diehl, S.; Johansson, L.; Andersson, G.; Hamrin, S. F., 1991: Shifts in fish communities along productivity gradient of temperate lakes-patterns and importance of size-structured interactions. J. Fish Biol. **38,** 281–293.

Rast, W.; Thornton, J .A., 1996: Trends in eutrophication research and control. Hydrol. Process. **10,** 295–313.

Regione dell'Umbria, 1997: Relazione sullo stato dell'ambiente in Umbria. Stampa grafica Salvi, Perugia, pp. 343.

Ricker, W. E., 1975: Computation and interpretation of biological statistics of fish population. Bull. Fish. Res. Bd. Can. **191,** 382.

Rudstam, L. G.; Lathrop, R. C.; Carpenter, S. R., 1993: The rise and fall of a dominant planktivore: direct and indirect effects on zooplankton. Ecology **74,** 303–319.

Sokal, R.; Rohlf, J., 1995: Biometry: the principles and practice of statistics in biological research, 3rd edn. W. H. Freeman and Co, New York, pp. 887.

Templeton, R. G., 1984: Freshwater fisheries management. Fishing News Book Ltd, England, pp. 241.

Tonolli, V., 1964: Introduzione allo studio della limnologia. Istituto Italiano di Idrobiologia, Verbania Pallanza, pp. 280.

Viali, P.; Bisonni, F.; Carosi, A.; Petesse, M. L.; Lorenzoni, M., 1999: Prime esperienze di sostegno alla riproduzione del persico reale in un lago naturale regolato: il lago di Piediluco (Umbria-Provincia di Terni). Quaderni ETP. **28,** 221–226.

Volta, P.; Jepsen, N., 2008: The recent invasion of *Rutilus rutilus* (L.) (Pisces: Cyprinidae) in a large South-Alpine lake: Lago Maggiore. J. Limnol. **67,** 163–170.

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