NATIVE AND EXOTIC FISH SPECIES IN THE TIBER RIVER WATERSHED (UMBRIA – ITALY) AND THEIR RELATIONSHIP TO THE LONGITUDINAL GRADIENT

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ABSTRACT

In this study we examine the spatial variations in the fish communities in the Tiber River watershed, including both native and exotic species. Its main objectives were to assess the quality of fish communities of this area and to verify if factors of fish community disturbance are constant over the basin or if they change along the river gradient. The level of degradation was evaluated according to the ratio between the number of native fish species and total number of species (ZIC = Zoogeographic Integrity Coefficient). A total of 37 fish species was found, 13 native and 24 exotic (64.86%). Cyprinid is the prevailing family with 15 species (7 native, 8 exotic). The species most frequently introduced are cyprinids, followed by salmonids (4 species) and gobids (3 species). Of the 24 exotic species only 11 (45.83%) can be considered intentionally introduced by man: the proportion of intentionally introduced transplanted species (66.67%) is considerably higher than the translocated species (33.33%). There is a correlation between the longitudinal gradient of the river, the morphological evolution of the riverbed and decline in water quality. High ZIC values were related to higher elevation, greater slope and better water quality. As the size of the river increases the fish communities appear to be ever-more dominated by species of exotic origin, whose number progressively increases with the worsening of the water quality and downstream movement. The number of native species is the greatest in the middle reaches of the rivers, and decreases both upstream and downstream. Compared to the introduced species, the native species tend to stay upstream and are often the only species found in the headwaters. The number of introduced species increases downstream. We have also found differences among translocated and transplanted species: the first ones tend to favor the middle reaches of the rivers, while transplanted species seem to prefer the downstream sectors. In almost all cases, the sampling station immediately below an impoundment has the lowest ZIC values in comparison to the river stretches above the dam. Our preliminary results suggest that characteristics of fish community alterations depend on the type of river sector involved; the small rivers of the basin are a refuge zone for the native community and are currently of fundamental importance for maintaining biodiversity.

Key-words: introduction, exotic species, fish community, Tiber River, longitudinal gradient, Zoogeography Integrity Coefficient.

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ESPÈCES PISCICOLES INDIGÈNES ET EXOTIQUES DU BASSIN VERSANT DU TIBRE (OMBRIE ITALIE)

RÉSUMÉ

Cette étude examine la variation spatiale des communautés piscicoles du bassin versant du Tibre en prenant en considération les espèces indigènes et exotiques. L'objectif principal est d'examiner la qualité des peuplements piscicoles du bassin et de vérifier si les facteurs de détérioration des peuplements piscicoles sont constants ou variables le long du gradient longitudinal. Le niveau de détérioration de la communauté a été évalué par le rapport entre le nombre d'espèces indigènes et le nombre total d'espèces piscicoles (CIZ = Coefficient d'Intégrité zoogéographique) Le nombre total d'espèces rencontrées est de 37 ; 13 indigènes et 24 exotiques (64,86 %). Les Cyprinidés sont la famille la plus représentée avec 15 espèces (7 indigènes, 8 exotiques). Les espèces introduites les plus fréquentes sont des Cyprinidés, suivies par des Salmonidés (4 espèces) et des Gobidés (3 espèces). Des 24 espèces exotiques seulement 11 (45,83 %) peuvent être considérées comme introduites intentionnellement par l'homme : la proportion d'espèces introduites volontairement est plus élevée pour les espèces transplantées (66,67 %) par rapport aux espèces issues de translocation (33,33 %). On observe une corrélation entre le gradient longitudinal des cours d'eau, l'évolution morphologique du lit et le déclin de la qualité de l'eau. Les hautes valeurs du CIZ sont en relation avec les fortes altitudes, les pentes du lit plus prononcées et une meilleure qualité de l'eau. Quand la taille des cours d'eau augmente, les communautés piscicoles apparaissent dominées en priorité par les espèces d'origine exotique : leur nombre augmente avec la dégradation de la qualité de l'eau et en se déplaçant en aval. Le nombre d'espèces indigènes est plus élevé dans les portions fluviales intermédiaires et diminue soit en amont, soit en aval. Confrontées avec les espèces introduites, les espèces indigènes se déplacent plus en amont et sont souvent les seules espèces présentes dans les portions à proximité de la source. Le nombre d'espèces introduites augmente vers l'aval. Il existe aussi des différences entre les espèces issues de translocation et les espèces transplantées : les premières tendent à préférer les portions intermédiaires des cours d'eau, tandis que les transplantées privilégient les portions en aval. Dans la plupart des cas, les portions fluviales immédiatement en aval d'un barrage ont des valeurs du CIZ plus basses par rapport aux portions situées en amont. Ces résultats suggèrent que les caractéristiques des altérations présentes dans les communautés piscicoles dépendent du type de portion fluviale considéré. Les petits cours d'eau du bassin constituent des zones refuge pour les communautés piscicoles indigènes et sont d'une importance fondamentale pour maintenir la biodiversité du bassin du fleuve Tibre.

Mots-clés : introduction, espèces exotiques, peuplement piscicole, fleuve Tibre, gradient longitudinal, coefficient d'intégrité zoogéographique.

INTRODUCTION

The native fish fauna in the Italian lakes and rivers have become progressively more impoverished over the years as a result of an overall degradation of the aquatic ecosystems due to human activities (SOMMANI, 1967). Water pollution and eutrophication, variations in river morphology and hydrologic regimes and the construction of dams that impede fish circulation are the main factors that disturb the fish fauna. Another problem is the introduction of exotic species, which is considered as one of the most important but least studied factors that disrupt aquatic ecosystems (MILLS *et al*., 1993; LEACH, 1995; LODGE *et al*., 2000; MACK *et al*., 2000; BYERS *et al*., 2002). With the introduction of exotic species, biodiversity usually decreases as the exotic species replace the native ones, followed by a widespread diffusion of only a few species (McKINNEY and LOCKWOOD, 1999). Literature regarding the impact of exotic species reports numerous examples of the extinction of native species (COWX, 1997; LODGE *et al.*, 2000; MACK *et al*., 2000). Nevertheless, the cause-effect relationship frequently remains hypothetical, given the limited information that is available about the status of native species prior to the introduction. In addition, habitat destruction often concurs with the introductions which complicates the unequivocal interpretation of all the changes that occur in natural populations (ROSECCHI *et al*., 1997; McKINNEY and LOCKWOOD, 1999).The degree of changes brought about by the introduction and acclimatization of a new species in an aquatic ecosystem depends on the particular circumstances (KEITH and ALLARDI, 1997). The pre-existing fish community may be changed greatly as a result of competition for food or other resources (LEVEQUE, 1997), predation (JACKSON and WILLIAMS, 1980; LEVEQUE, 1997), parasitism or the introduction of pathogenic agents (BLANC, 1997; DOVE and ERNST, 1996; LODGE *et al*., 2000); hybridisation and modification of the environment should also be included as possible harmful effects resulting from the introduction of exotic species. The management of non-indigenous species is therefore crucial for maintaining native biodiversity and natural ecosystem functions (BYERS *et al*., 2002).

In Italy a rapid evolution of freshwater fish communities is in progress; the streams in the Tiber River watershed are being seriously degraded due to the stocking programs that are modifying their native fish fauna. During the last 30 years there has been a progressive loss of zoogeographic identity in the Italian fish assemblages, with the transplantation of native species from northern to central Italy, followed by the introduction of Danubian species throughout Italy (BIANCO and KEITMAIER, 2001). The number of fish species in the Tiber River has increased from 20 original species to the current 40 or more (BIANCO, 1990a, 1993). Earlier studies conducted on the fish fauna in the upper tract of the Tiber River (MEARELLI *et al.*, 1994) provided valuable information about species abundance and distribution. In this study we examine the spatial variation in the fish communities, including both native and exotic species. The main objectives were to assess the quality of fish communities of this area and to verify if factors of fish community disturbance are constant throughout the basin or if they change along the river gradient. Changes in the fish community have been evaluated in an attempt to determine the factors that influence the trends.

MATERIALS AND METHODS

The Tiber River is the third-longest river in Italy and has the second-largest watershed. Its source is located on Mount Fumaiolo (about 1,270 m a.s.l.). It is 405 km long and is the backbone of the hydrological network in the region of Umbria. The total Tiber River watershed (12,692 km^2) also extends into the Italian regions of Emilia Romagna, Tuscany, Lazio, the Marches and the Abruzzo. The study, conducted between April, 1989 and November, 1993 examined the upper and middle portions of the Tiber River, from its source to its confluence with the Nera River. The study area was located in the regions of Umbria, Tuscany and Emilia Romagna (Fig. 1) and corresponds to a surface of 9,413 km^2, equal to 55% of the total drainage area of the Tiber River (MEARELLI *et al*., 1994). The study area included numerous tributaries, the most important ones being the Nestore River (watershed = 1,033 km^2), the Paglia River (1,338 km^2), the Chiascio River (5,963 km^2) and the Nera River (4,280 km^2) (MEARELLI *et al*., 1994). The study area was divided into five hydrographic units made up of the main sub-watersheds: the Chiascio, the Nera, the Nestore, the Paglia and the remainder of the Tiber River which included the main channel and other minor tributaries. A total of 132 streams and rivers were included in the study with 265 sampling stations.

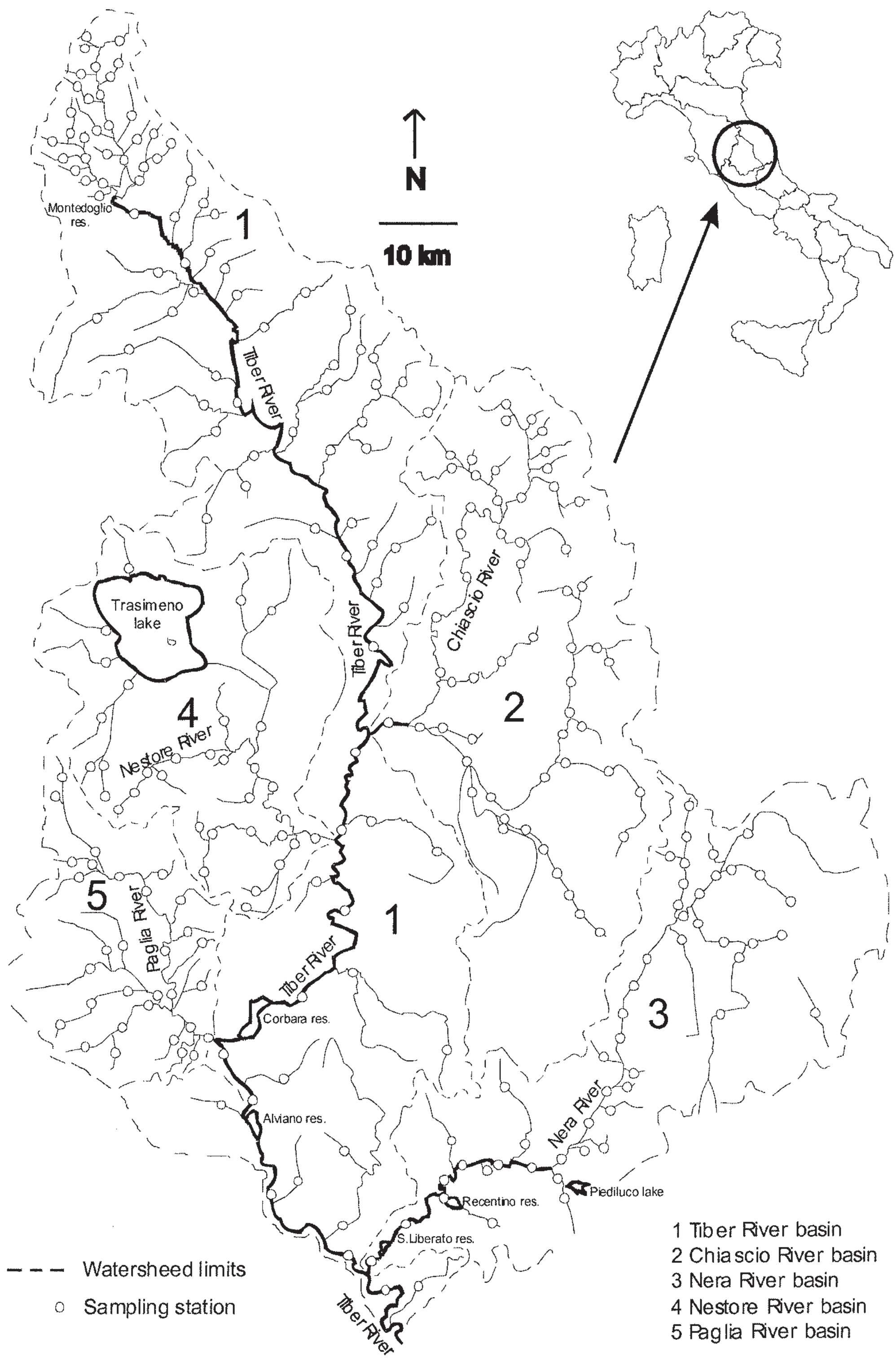

Figure 1
Study area and location of the sampling sites.

Figure 1
Localisation du secteur fluvial étudié et des stations de pêche.

Two natural lakes are found in the Tiber River basin, Lake Trasimeno and Lake Piediluco, as well as numerous reservoirs. Trasimeno Lake (Fig. 1) is a lake of tectonic origin without a natural effluent stream, situated in the Nestore River sub-basin (43°9”11”N. Lat. and 12°15’E. Long.). It is the fourth-largest lake in Italy (124.3 km^2) and is the most extensive of the Italian peninsula. Its shallowness (average depth = 4.72 m; max. depth = 6.3 m) characterizes Lake Trasimeno as the largest laminar lake in Italy. The catchment basin covers an area of 357.98 km^2. Piediluco Lake, located in the Nera River sub-basin, is the second largest natural lake (1.7 km^2) of the study area. The catchment basin has a surface of around 74 km^2 and a middle altitude of 765 m a.s.l. The reservoirs are Montedoglio (area 15.70 km^2, altitude 396 m a.s.l.), Corbara (area 15.00 km^2, altitude 138 m a.s.l.), Alviano (area 3.49 km^2, altitude 77.5 m a.s.l.), Recentino (area 0.76 km^2, altitude 110 m a.s.l.) and S. Liberato (area 0.42 km^2, altitude 65 m a.s.l.). The first three were created by dams along the watercourse of the Tiber River (33.5 km, 185 km and 199 km, respectively, from the source) while the other two are located in the Nera River sub-basin (Aja Stream and Nera River).

A census of the fish fauna was carried out at each sampling station. The fish were captured at low flow period using a continuous or pulsed current electric shocker with power varying between 1,500 and 4,000 W. All captured fish were identified and counted. For all reaches, tract length was defined as 10 times the wetted channel, with a minimum and maximum length of 50 to 400 m. In wadeable rivers sampling was conducted once in upstream, usually in a zigzag direction during daylight, with only one pass without use of stop nets. Some reaches had a depth and width of the river bed that did not allow an efficient estimate of abundance of fish populations. In these cases sampling protocol was modified to guarantee a suitable evaluation of the species’ richness. In larger, non-wadeable rivers samples were collected using an electro-fishing unit mounted on a boat (MAY and BROWN, 2000). Where the depth allowed it, the sampling was carried out in a similar way to that in wadeable rivers, while in the deeper reaches it was done only along the shores, but in these cases gill nets and trammel with different sized meshes were also used. Use of a boat was necessary in 11 sampling stations (5 in the Tiber River, 4 in the Nera River, 2 in the Velino River); in 3 sites nets were also used. During the study, samples were also taken at the Montedoglio Reservoir, located along the upper tract of the Tiber River, about 30 km from its source (LORENZONI *et al*., 1994), as well as at the Recentino and San Liberato Reservoirs located in the Nera River watershed. Gill nets and trammel with different sized meshes were used in addition to the electric shocker. Data on the fish fauna in the other Umbrian lakes were obtained from the existing literature (MORETTI and GIANOTTI, 1966; MEARELLI *et al*., 1990; LORENZONI *et al*., 1997).

Habitat controls the longitudinal distribution of fish, and changes in habitat characteristics are often associated with changes in the composition of the fish assemblage (HUET, 1949, 1954, 1962; VANNOTE *et al*., 1980; MINSHALL *et al*., 1985; MORIN and NAIMAN, 1990; CHANGEUX, 1995; BELLIARD *et al*., 1999; ARUNACHALAM, 2000; BUNN and DAVIES, 2000). Some environmental parameters were used to characterize the river sectors and these are reported in Table I. The Extended Biotic Index (EBI) (GHETTI, 1986) is a biotic index used to evaluate the overall water quality based on the composition of the macrobenthic fauna. This index is based on the sensitivity of key groups to pollution and on the number of component groups in a sample: clean streams are given an index of 15 and this value decreases as pollution increases (BAUDO, 2001). The parameters were usually assessed on the same day or within several days of the fish collections. Hydrologic variables were measured at transects within each sampling reach; depth was measured at three or more points within each transect and velocity in three positions along the vertical of the same point of depth measurement. Watershed area, distance from the source, average slope and altitude were determined from IGM topographic maps. Field measurements of specific conductivity, pH, water temperature and dissolved oxygen were made with electronic meters. The other chemical parameters of the water were determined

Table I
Environmental features of the 265 sampling sites separated into sub-basins.

Tableau I
Caractéristiques environnementales des 265 sites d'échantillonnage désagrégés par sous-bassin.

	Sub-basin	**Tevere**	**Chiascio**	**Nera**	**Nestore**	**Paglia**	**All**
	N	**97**	**57**	**48**	**32**	**31**	**265**
Altitude (m a.s.l.)	average	348.177	310.870	354.438	262.531	205.065	314.111
	std	187.553	115.564	206.110	62.278	77.611	163.976
Distance from the source (km)	average	31.177	15.208	35.277	10.981	16.284	24.899
	std	55.454	19.368	34.050	9.769	17.312	40.117
Watershed area (km^2)	average	185.041	69.750	322.343	48.614	116.754	166.249
	std	396.693	77.358	473.376	57.866	200.503	343.490
Average slope (%)	average	2.484	4.044	1.631	0.982	2.417	2.344
	std	2.872	2.189	2.045	0.895	2.182	2.517
Flow rate (m^3 sec^{-1})	average	0.182	0.854	1.705	0.160	1.191	0.687
	std	0.300	1.169	3.877	0.347	2.075	1.988
Wetted river section (m^2)	average	1.579	2.038	4.591	0.594	2.638	2.212
	std	2.751	2.810	13.160	0.792	3.981	6.415
Average current speed (m sec^{-1})	average	0.181	0.383	0.437	0.205	0.295	0.280
	std	0.184	0.157	0.513	0.131	0.184	0.292
Water temperature (°C)	average	15.269	13.976	13.074	17.714	5.694	13.642
	std	3.888	2.202	2.748	3.214	2.257	4.625
pH	average	8.257	8.213	7.968	8.175	7.977	8.145
	std	0.239	0.176	0.398	0.131	0.227	0.287
Conductivity (S sec^{-1} a 25 °C)	average	546.878	528.132	464.255	737.857	684.194	568.282
	std	167.513	98.799	196.566	194.458	266.142	203.136
Dissolved oxygen (O_2 mg l^{-1})	average	9.681	10.079	9.087	9.096	10.616	9.680
	std	1.318	1.601	1.307	1.919	2.027	1.618
NH_3 (mg l-^{1})	average	0.157	0.322	0.291	0.779	0.669	0.352
	std	0.300	0.588	0.328	1.436	1.942	0.939
PO_4 (mg l^{-1})	average	0.031	0.074	0.043	0.158	0.058	0.059
	std	0.040	0.090	0.060	0.240	0.029	0.104
SO_4 (mg l^{-1})	average	46.281	51.589	36.300	51.714	117.935	55.281
	std	28.588	36.947	32.009	23.936	131.554	60.464
Cl (mg l^{-1})	average	19.278	13.224	12.155	45.679	29.684	21.402
	std	25.409	5.565	27.808	37.173	26.706	27.677
Extended Biotic Index	average	7.899	7.308	6.957	5.271	7.000	7.196
	std	1.822	2.041	1.944	2.575	1.713	2.095

according to APHA, AWWA and WPCF (1989) specifications. All raw data (fish and environmental data per sampling station) and the map of station locations are available at http://www.bio.unipg.it/ecologia/ Download/BFPP.html.

Fish names follow GANDOLFI *et al*., 1991. The spined loach (*Cobitis taenia* L., 1758) is included in the list of introduced species, while pike (*Esox lucius* L., 1758) and tench (*Tinca tinca* L., 1758) are considered indigenous, even though some authors do not agree (MORETTI and GIANOTTI, 1966; SOMMANI, 1967; BIANCO, 1993). The systematic position of the barbel populations in south-central Italy is still uncertain, and it is difficult to distinguish morphologically native species (BIANCO, 1995). Therefore, all captured specimens were considered to be *Barbus plebejus* (Bonaparte, 1839).

Some of the terms and definitions used are: **introduced** or **exotic**: any species voluntarily or accidentally released into an environment outside of its original range (HOLCIK, 1991; COWX, 1997); introduced species are **transplanted** when they come from another country. Introduced species are **translocated** when they come from other Italian watersheds (DELMASTRO, 1986). An introduced species is **acclimatized** when it breeds and naturally maintains itself without any human interference (SHAFLAND and LEWIS, 1984; KEITH and ALLARDI, 1997). The level of degradation in the fish fauna was evaluated using the Zoogeographic Integrity Coefficient (ZIC) (BIANCO, 1990a; ELVIRA, 1995) expressed as the ratio between the number of native fish species and the total number of species found. This index varies from one (no exotics present) to zero (maximum level of alteration).

An analysis to verify the relationships among the environmental conditions of the investigated area was conducted using principal component analysis (PCA): the matrix used included 16 variables (altitude, distance from the source, watershed area, average slope, flow rate, wetted river section, average speed of current, water temperature, specific conductivity, pH, dissolved oxygen, ammonium, phosphates, sulphates, chlorides and EBI) and 265 observations (sampling stations). All the variables (N), were transformed ($\log10(N + 1)$) to normalize the distribution (BROWN and AUSTEN, 1996) and standardized to a mean of 0 and standard deviation of 1. The existing relationship between the first axis of PCA with ZIC and the number of species was subsequently investigated by regression analysis. The ZIC values were converted using the arcsine transformation, while the number of species was converted using log transformation.

The longitudinal distribution of the various fish species was evaluated using Canonical Correspondence analysis (CCA) (ter BRAAK, 1986). CCA is a multivariate direct gradient analysis method specifically developed to analyze the relationships among multivariate ecological data matrices. The results of CCA generate a diagram that displays approximate values of the weighted averages of fish assemblage parameters (points) with respect to the supplied environmental variables. In the diagram, the environmental variables are represented by arrows that roughly point in the direction of maximum factor variation (ter BRAAK, 1986). The length of the arrow is proportional to the rate of change; therefore, a long arrow indicates a large change and indicates that change is strongly correlated with the ordination axes. The position of the points in relationship to the arrows indicates the relationship between each point and the variable represented by the arrow. Those that are farthest along towards the head of the arrow are those with the largest values for that variable. To assess the statistical significance of the ordination axis we ran Monte Carlo tests for 1,000 permutations; an axis was considered statistically significant if the eigenvalue from the randomly permuted set exceeded the original in 50 or fewer cases $\alpha = 0.05$). The environmental matrix used included 16 variables (the same as for PCA) and 265 observations (sampling stations). The fish assemblage matrix used included 30 variables (fish species) and 265 observations (sampling stations). In this analysis, we only considered the fish species living in the watercourses and directly captured by electro-fishing with the exception of the marble trout (*Salmo marmoratus* Cuvier, 1817), that was found in only one sampling station and is not an acclimatized species in the study area. The abundance of a fish species was encoded using a scale that varies from 0 to 3 based on the number of captured specimens, as proposed by PENCZACK *et al*. (2000) (0 = absent; 1 = rare, from 1 to 5 specimen; 2 = sub-dominant, from 6 to 20 specimens; 3 = dominant, more than 20 specimens).

RESULTS

Environmental Parameters

The streams and rivers in the Tiber River watershed are, for the most part, short and of limited size (Table I). The basins of the sampling stations are generally small (average 131.49 km^2) and are mostly mountainous and hilly (average elevation 315.24 m a.s.l.). There are very pronounced differences in water quality among the various sampling stations, with some clear cases of degradation as shown by the EBI and physical-chemical parameter values. The EBI values varied from one to ten with an average of 7.27. There were noticeable geo-morphological differences in the particular sub-basins (MEARELLI *et al*., 1994). The Nera is predominantly mountainous and permeable; the Nestore and Paglia begin in the plains and are impermeable with mostly hilly relief. The upper tract of the Tiber River is mountainous and impermeable, while the middle and lower tracts are in the plains. The characteristics of the Chiascio River are intermediate. The differences in the hydrogeological characteristics of the single sub-basins strongly affect the water quality. The waterways that run through predominantly impermeable lands show very marked flow rate oscillations. In general, the Nestore River shows the greatest variations in conductivity and EBI with the latter fluctuating between the III and IV quality classes, indicating a very high pollution level. In contrast, the Nera River has lower EBI values, indicating the best water quality among all the watersheds considered (MEARELLI *et al*., 1994).

Fish Fauna

A list of the species found in the sub-watersheds is reported along with information about their origin and distribution (Table II). Thirty-seven fish species were present belonging to 13 families and 31 genera in the study area; 13 species are native and 24 exotic. Cyprinids dominate the fauna (15 species, 7 of which are indigenous). With respect to the particular sub-basins, 22 species were present in the Chiascio and Nera Rivers, 20 in the Nestore and Paglia Rivers and 25 in the Tiber River. The number of fish captured by electro-fishing was 11,803 specimens, for a weight exceeding 483 kg. Only a few species were captured at each sampling station (average 4.3, range 1-14). The average number of native species is low, 3.35 (range 0-8) and even lower for the exotic species, 0.95 (range 0-7).

Average values of the fish assemblage for each sub-basin are reported in Table III. The average ZIC value for the Nestore (0.71) is the lowest of all the sub-basins, while the Nera has the highest average value (0.94). An ANOVA showed that the differences in ZIC among sub-basins are significant ($F = 4.296$; $P < 0.01$). The ZIC values for the lakes (mean $\pm$ std = 0.36 $\pm$ 0.07) are lower than those for the rivers (mean $\pm$ std = 0 .85 $\pm$ 0.23) and the differences were significant at t-test ($t = 32.69$, $p = 0.0001$). The ZIC values for the lakes vary from a maximum of 0.50 for the Montedoglio reservoir to a minimum of 0.28 for Lake Trasimeno (Table IV) which has the highest number of exotic species (n = 13) while S. Liberato reservoir has the lowest number of indigenous species (n = 4). Except for the Recentino reservoir, each sampling station immediately below an impoundment has the lowest ZIC values in comparison to the river stretches above the dam.

Table II
List of fish species of the River Tiber Watershed and their distribution (T = Tiber River basin, C = Chiascio River basin, N = Nera River basin, Ns = Nestore River basin, P = Paglia River basin, Tr = Trasimeno Lake, Pi = Lake of Piediluco, M = Montedoglio Reservoir, C = Corbara Reservoir, A = Alviano Reservoir, R = Recentino Reservoir, L = S. Liberato Reservoir).

Tableau II
Liste des espèces piscicoles du bassin versant du fleuve Tibre et leur distribution (T = bassin du fleuve Tibre, C = bassin de la rivière Chiascio, N = bassin de la rivière Nera, Ns = bassin de la rivière Nestore, P = bassin de la rivière Paglia, Tr = lac Trasimeno, Pi = lac de Piediluco, M = retenue artificielle de Montedoglio, C = retenue artificielle de Corbara, A = retenue artificielle de Alviano, R = retenue artificielle de Recentino, L = retenue artificielle de S. Liberato).

Family	Species	Common Name	Origin	Distribution
Anguillidae	*Anguilla anguilla* (Linnaeus, 1758)	Eel	Native	T, C, N, Ns, P, Tr, Pi, M, C, A, R, L
Cyprinidae	*Rutilus rubilio* (Bonaparte, 1837)	Italian roach	Native	T, C, N, Ns, P, C
	Rutilus erythrophthalmus Zerunian, 1982	North italian roach	Translocated	N, P, M, A, R, L
	Leuciscus cephalus (Linnaeus, 1758)	Chub	Native	T, C, N, Ns, P, Tr, Pi, M, C, A, R, L
	Leuciscus lucumonis Bianco, 1982	Etruscan chub	Native	T, C, Ns, P,
	Telestes souffia Risso, 1826	Vairone	Native	T, C, N, Ns, P, P,
	Tinca tinca (Linnaeus, 1758)	Tench	Native	T, C, N, Ns, P, Tr,Pi, M, C, A, R, L
	Scardinius erythrophthalmus (Linnaeus, 1758)	Rudd	Native	T, N, Ns, Tr, Pi, M, C, A, R, L
	Alburnus alburnus alborella (De Filippi, 1844)	Bleak	Translocated	T, C, N, Ns, P, Tr, Pi, M, C, A, R, L
	Chondrostoma soetta Bonaparte, 1840	Italian sneep	Translocated	N, M
	Chondrostoma genei (Bonaparte, 1839)	Italian nase	Translocated	T, C, N, Ns, P, M, A, R
	Barbus plebejus (Bonaparte, 1839)	Barbel	Native	T, C, N, Ns, P, M, C, A
	Carassius auratus (Linnaeus, 1758)	Goldfish	Transplanted	T, C, N, Ns, P, Tr, M, C, A, R, L
	Cyprinus carpio Linnaeus, 1758	Carp	Transplanted	T, C, N, Ns, P, Tr, Pi, M, C, A, R, L
	Ctenopharyngodon idellus (Valenciennes, 1844)	Grass Carp	Transplanted	Tr, Pi
	Pseudorasbora parva (Schlegel, 1842)	Top mouth gudgeon	Transplanted	T, Ns, P
Cobitidae	*Cobitis taenia* Linnaeus, 1758	Spined loach	Translocated	T, C, Ns, P, Tr,
Ictaluridae	*Ictalurus melas* (Rafinesque, 1820)	Black bullhead	Transplanted	T, C, N, Ns, P, Tr, M, C, A, R, L
Esocidae	*Esox lucius* Linnaeus, 1758	Pike	Native	T, C, N, Tr, Pi, M, R

Family	Species	Common Name	Origin	Distribution
Salmonidae	*Salmo trutta* Linnaeus, 1758	Brown trout	Native	T, C, N, Ns, P, Pi, M
	Salmo marmoratus Cuvier, 1817	Marble trout	Translocated	N
	Oncorhynchus mykiss (Walbuam, 1792)	Rainbow trout	Transplanted	T, C, N, P, Pi,
	Coregonus lavaretus (Linnaeus, 1758)	Common whitefish	Transplanted	Pi
	Thymallus thymallus (Linnaeus, 1758)	Grayling	Translocated	N
Poecilidae	*Gambusia holbrooki* Giraud, 1859	Eastern mosquitofish	Transplanted	T, C, Tr, Pi, C, A, R, L
Atherinidae	*Atherina boyeri* Risso, 1810	Sandsmelt	Translocated	Tr
Gasterosteidae	*Gasterosteus aculeatus* Linnaeus, 1758	Three-spined stickleback	Native	C, N
Cottidae	*Cottus gobio* Linnaeus, 1758	Bullhead	Native	C, N
Centrarchidae	*Micropterus salmoides* Lacépède, 1802	Largemouth bass	Transplanted	T, C, P, Tr, M, C, A
	Lepomis gibbosus (Linnaeus, 1758)	Pumpkinseed	Transplanted	T, C, N, Ns, P, Tr, Pi, M, C, A, R, L
Percidae	*Perca fluviatilis* Linnaeus, 1758	Perch	Translocated	T, N, Ns, Tr, Pi, M, C, A, R, L
	Gymnocephalus cernuus Linnaeus, 1758	Ruffle	Transplanted	Pi, C
	Stizostedion lucioperca Linnaeus, 1758	Pikeperch	Transplanted	T, C, A, L
Gobidae	*Knipowitschia panizzae* (Verga, 1841)	Lagoon goby	Translocated	Ns, Tr
	Pomatoschistus canestrini (Ninni, 1883)	Little goby	Translocated	Tr
	Padogobius martensii Gunther, 1861	Po goby	Translocated	T
	Padogobius nigricans (Canestrini, 1867)	Arno goby	Native	T, C, Ns, P

The results of the principal component analysis are reported in Fig. 2. The first component of the analysis explains 33.17% of the overall variability and shows a positive correlation between altitude, average slope and EBI, while the relationship is inverse with distance from the source, watershed area, flow rate, wetted river section, conductivity, sulphates and chlorides. This axis is representative of a gradient of increasing river size and the corresponding increase in sediment load and dissolved matter with the decreasing of elevation and slope. A progressive decline in water quality (shown by negative correlation of EBI) seems to be associated with an increase in river size. The second component is less informative (15.79% of the overall variability) and reflects negative correlations between average current speed and flow rate with conductivity and chlorides: this axis seems to explain the increase of the diluting power of the river to rise of flow.

The regression analysis mainly shows a clear relationship between the longitudinal evolution of the rivers in the Tiber River basin and the quality of the fish communities (Fig. 3). The relationship between the first PCA axis and the ZIC could be described by a linear equation (Table V): arcsine ZIC = 1.224 ± 0.136x (R^2 = 40.10%) (F = 130.56,

Table III
Descriptive statistics of the fish parameters separated into sub-basins.

Tableau III
Description statistique des paramètres piscicoles désagrégés par sous-bassin.

River basin		No. of species	No. of introduced species	No. of indigenous species	Zoogeographic Integrity Coefficient
CHIASCIO n = 57	Average	4.06	0.47	3.59	0.91
	Std deviation	2.11	0.82	1.81	0.16
	Min	1.00	0.00	1.00	0.33
	Max	9.00	3.00	7.00	1.00
NERA n = 48	Average	2.54	0.61	1.93	0.94
	Std deviation	2.99	1.73	1.46	0.17
	Min	1.00	0.00	1.00	0.33
	Max	14.00	7.00	7.00	1.00
	Average	5.35	1.65	3.70	0.71
NESTORE n = 32	Std deviation	2.15	1.35	1.71	0.26
	Min	2.00	0.00	0.00	0.00
	Max	8.00	5.00	7.00	1.00
	Average	4.76	1.48	3.28	0.76
PAGLIA n = 31	Std deviation	2.50	1.83	1.31	0.22
	Min	2.00	0.00	1.00	0.13
	Max	13.00	7.00	6.00	1.00
	Average	4.98	1.07	3.82	0.86
TEVERE n = 97	Std deviation	2.76	1.79	1.79	0.22
	Min	1.00	0.00	1.00	0.14
	Max	12.00	7.00	8.00	1.00

p = 0.000). The quality of the fish communities is strongly conditioned by the longitudinal gradient of the rivers and water quality. High ZIC values are related to higher elevations, greater slopes and the best water quality. As the river size increases the fish communities appear to be more dominated by species of exotic origin. The number of exotic species increases moving downstream as the water quality declines. The relationships between the first PCA axis and the number of fish species are reported in Table V; for native species the relationship is: log Nspecies = 0.648-0.027x-0.009x^2 (R^2 = 15.47%) (F = 534.66, p = 0.000), while for introduced species it is: log Nspecies = 0.201-0.100x + 0.006x^2 (R^2 = 41.70%) (F = 79.06, p = 0.000) (Fig. 4). The number of native species is highest in the middle reaches of the river and decreases both upstream and downstream. Native species are often the only ones found near the source. Moving downstream, the number of introduced species increases. Within the introduced species, there are some small differences between the translocated and transplanted species (Fig. 5). The relationship between the first axis and the number of translocated species is: log Nspecies = 0.147-0.084x + 0.002x^3 (R^2 = 39.74%) (F = 87.76, p = 0.000), while for the transplanted species it is: log Nspecies = 0.082-0.039x + 0.006x^2 (R^2 = 26.92%) (F = 49.69, p = 0.000). The transplanted species show a preference for the lower tracts of the rivers, while the translocated species seem to be mostly rheophilic forms which, in comparison to the former, prefer intermediate stream reaches.

Table IV
Fish parameters in the lakes and reservoirs.

Tableau IV
Paramètres piscicoles des lacs naturels et artificiels.

Lake	No. of species	No. of introduced species	No. of indigenous species	ZIC	No. of transplanted species	No. of translocated species
Trasimeno Lake	18.00	13.00	5.00	0.28	7.00	6.00
Piediluco Lake	17.00	11.00	6.00	0.35	8.00	3.00
Montedoglio Reservoir	16.00	8.00	8.00	0.50	5.00	3.00
Corbara Reservoir	16.00	10.00	6.00	0.38	8.00	2.00
Alviano Reservoir	16.00	11.00	5.00	0.31	7.00	4.00
Recentino Reservoir	14.00	9.00	5.00	0.36	5.00	4.00
S. Liberato Reservoir	13.00	9.00	4.00	0.31	6.00	3.00
Velino River above Piediluco Lake	9.00	3.00	6.00	0.67	0.00	3.00
Velino River below Piediluco Lake	9.00	4.00	5.00	0.56	2.00	2.00
Tiber River above Montedoglio Reservoir	5.00	0.00	5.00	1.00	0.00	0.00
Tiber River below Montedoglio Reservoir	7.00	4.00	3.00	0.43	2.00	2.00
Tiber River above Corbara Reservoir	7.00	6.00	1.00	0.14	2.00	4.00
Tiber River below Corbara Reservoir	8.00	7.00	1.00	0.12	2.00	5.00
Tiber River above Alviano Reservoir	3.00	2.00	1.00	0.33	1.00	1.00
Tiber River below Alviano Reservoir	8.00	7.00	1.00	0.13	2.00	5.00
AjA Stream above Recentino Reservoir	9.00	6.00	3.00	0.33	2.00	4.00
AjA Stream below Recentino Reservoir	9.00	5.00	4.00	0.44	2.00	3.00
Nera River above S.Liberato Reservoir	14.00	7.00	7.00	0.50	5.00	2.00
Nera River below S.Liberato Reservoir	13.00	9.00	40.31	0.31	5.00	4.00

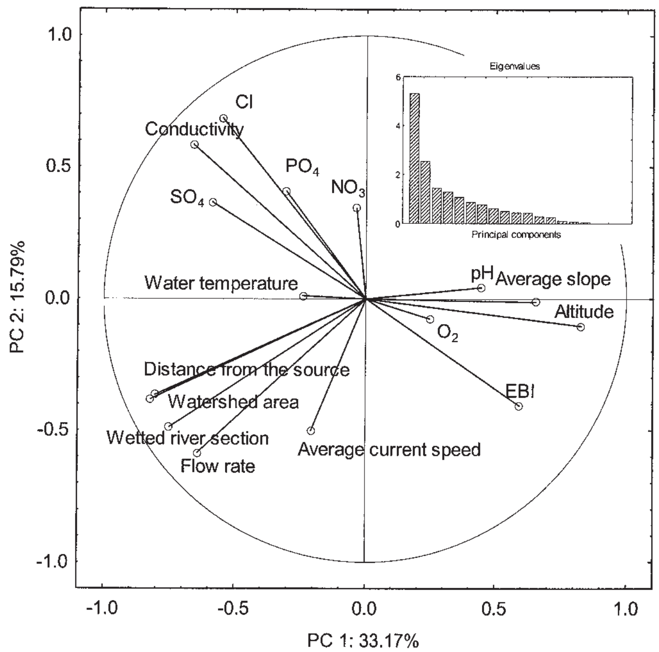

Figure 2

Principal Component Analysis: projection of the variables on the factorial plane PC1 × PC2.

Figure 2

Résultats de l'Analyse en Composantes Principales : cercle de corrélation des variables dans le plan factoriel PC1 × PC2.

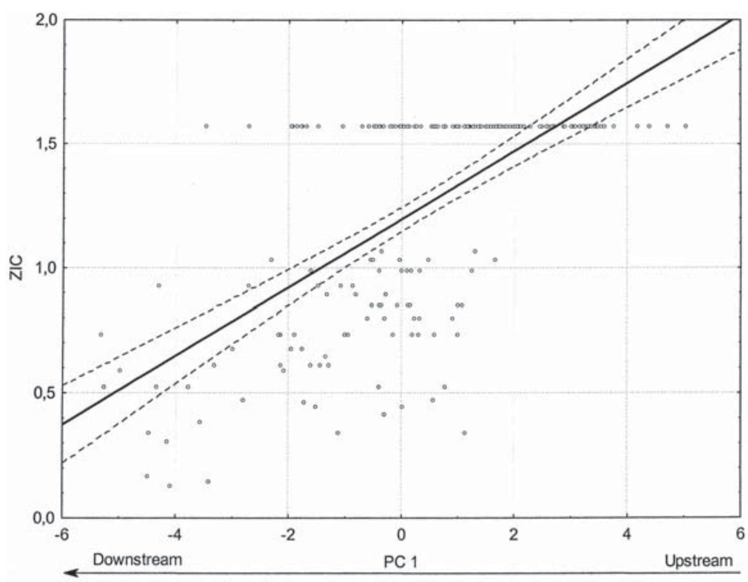

Figure 3

Fit between ZIC and the first Axis of PCA (PC1) (solid line), dashed lines representing the 95% confident level.

Figure 3

Ajustement entre l'axe 1 de la ACP (PC1) et le CIZ (trait plein), les traits pointillés représentant les intervalles de confiance à 95 %.

Table V
Regression analysis between the first axis of PCA (PC1) with ZIC and the number of species.

Tableau V
Analyse par régression entre le premier axe de PCA (PC1) avec ZIC et le nombre des espèces.

	Coefficient	Standard error	t	p
ZIC				
a	1.224	0.030	40.343	0.000
b	0.136	0.012	11.454	0.000
c	– 0.006	0.004	1.490	0.138
N. of native species				
a	0.648	0.016	39.395	0.000
b	– 0.027	0.012	2.207	0.028
c	– 0.009	0.002	4.097	0.000
d	– 0.000	0.001	0.237	0.813
N. of introduced species				
a	0.201	0.018	10.844	0.000
b	– 0.100	0.014	7.274	0.000
c	0.006	0.003	2.138	0.034
d	– 0.001	0.001	1.469	0.143
N. of translocated species				
a	0.147	0.014	10.212	0.000
b	– 0.084	0.011	7.868	0.000
c	0.003	1.610	4.097	0.109
d	0.002	0.001	2.586	0.011
N. of transplanted species				
a	0.082	0.015	5.515	0.000
b	– 0.039	0.011	3.526	0.001
c	0.006	0.002	2.882	0.004
d	– 0.000	0.001	0.507	0.612

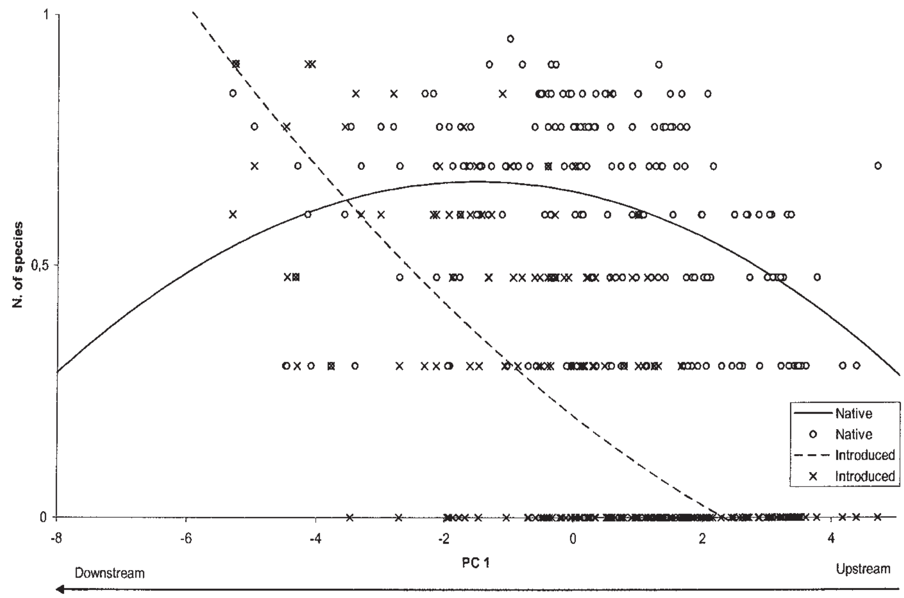

Figure 4
Polynomial fit Axis 1 PCA/exotic species and Axis 1 PCA/native species.

Figure 4
Ajustement polynomial entre l'axe 1 de la ACP et les espèces exotiques et l'axe 1 de l'ACP et les espèces indigènes.

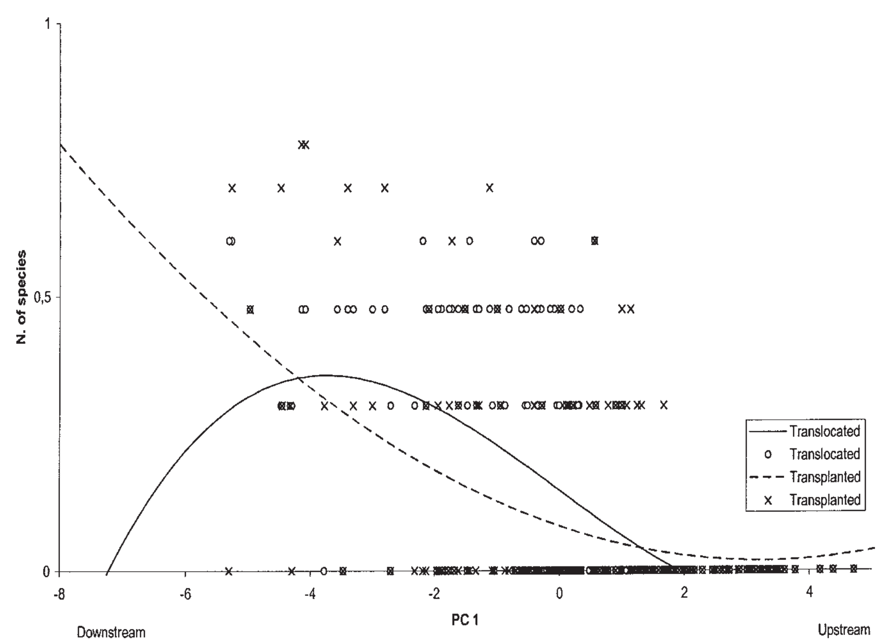

Figure 5
Polynomial fit Axis 1 PCA/translocated species and Axis 1 PCA/transplanted species.

Figure 5
Ajustement polynomial entre l'axe 1 de la ACP et les espèces transplantées et l'axe 1 de l'ACP et les espèces ayant subi une translocation.

Table VI and Fig. 6 show the results of the CCA analysis: the first axis explains 11.50% of the overall variability (total inertia = 3.32). The results confirm what is already underlined by the PCA analysis: in the study area, a progressive decline in water quality (EBI, ammonium, phosphates, sulphates, chlorides) seems to be associated with an increase in river size (distance from the source, watershed area, wetted river section) and with a decrease in elevation, slope and average current speed (Fig. 6a). The second axis is much less informative (3.30% of the overall variability) and reflects correlations between river size (distance from the source, watershed area, river section, average current speed) with water temperature and pH. Both the eigenvalue of the first canonical axis and traces (the sum of all eigenvalues) of all canonical axes are significant with the Monte Carlo test ($p < 0.001$) and this emphasizes the strong association among environmental variables and fish assemblage composition (ter BRAAK, 1986). The preferred position of the single fish species along the longitudinal gradient is illustrated by the CCA fish species plot (Fig. 6b), which confirms the existence of a clear relationship between the longitudinal evolution of the rivers and the quality of the fish communities. As the river size increases the fish communities appear to be more dominated by species of exotic origin, whose presence increases downstream as the water quality declines. The results are in accord with the hypothesis of a succession of fish species along the run of a mountain river towards valley. Along the longitudinal axis, in fact, it is possible to verify the substitution of the more specialized reophilic fish species with species progressively more limnophilic (cyprinids and predators) (HUET, 1949; 1954; 1962). The brown trout (*Salmo trutta* L., 1758) and the bullhead (*Cottus gobio* L., 1758) are two native fish species that live in the upper torrent stretches of the Tiber River watershed (trout zone). The barbel zone, characteristic of the intermediary sectors, consists of a native association of vairone (*Telestes souffia* Risso, 1826), barbel, chubs (*Leuciscus lucumonis* Bianco, 1982 and *Leuciscus cephalus* L., 1758), north Italian roach (*Rutilus rubilio* Bonaparte, 1837) and Arno goby (*Padogobius nigricans* Canestrini, 1867). Pike, tench and rudd (*Scardinius erythrophthalmus* L., 1758) are the most limnophilous native fish species. Originally this species, together with the fish of the barbel zone, constituted the community of the downstream reaches (bream zone). Currently this community appears to be excluded from the lower sectors of the Tiber River watershed. With the exception of the rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792) and the eastern mosquito fish (*Gambusia holbrooki* Giraud, 1859) most of the transplanted species colonize the downstream reaches. All the translocated species prefer the intermediary river sectors and spined loach, Po goby (*Padogobius martensii* Gunther, 1861), north Italian roach (*Rutilus erythrophthalmus* Zerunian, 1982) and Italian nase (*Chondrostoma genei* Bonaparte, 1839) live together with the native assemblage of the barbel zone. Differences among the average values on the first dimension axis of CCA for the native (No = 13; mean±std = 0.049 ± 0.778), translocated (No = 8; mean±std = -0.781 ± 0.622) and transplanted species (No = 9; mean±std = -0.899 ± 1.037) appear to be statistically significant when analyzed by Anova ($F = 4.311$; $p = 0.024$).

DISCUSSION

The fish fauna in the Tiber River has been directly altered by humans from ancient times. The Tiber was probably one of the first Italian rivers to have hosted carp (*Cyprinus carpio* L., 1758) which were introduced during the Roman epoch (BIANCO, 1990b). The introduction of exotic species has become a widespread phenomenon, particularly in recent times due to an increase in aquaculture and stocking programs (COWX, 1997). Most of the 40 fish species found in the Tiber River are non-native (BIANCO, 1990a, 1993). Zoogeographical pollution has meant the loss of genetic identity in the local populations, a high level of hybridaztion and extinction or reduction of the native species (BIANCO, 1990a). The middle and upper parts of the Tiber River basin, considered in this study, confirm this worry about the state of the native communities: of the 37 species recorded, 24 (64.86%) are exotic (12 transplanted and 12 translocated). As in other parts of Europe (HOLCIK, 1991), cyprinids are introduced most frequently (8 species), followed by salmonids

Table VI

Summary statistics for Canonical Correspondence Analysis (CCA) (in bold value for $p < 0.05$).
A. Canonical and correlation coefficients of environmental variables with axis 1 and 2.
B. Eigenvalues of axis 1 and 2 expressed as % of total variance.

Tableau VI

Statistiques sommaires pour Analyse Canonique des Correspondances (ACC) (en gras valeur pour $p < 0.05$).
A. Coefficients canoniques et coefficients de corrélation des variables environnementales avec les axes factoriel 1 et 2.
B. Valeurs propres des axes factoriel 1 et 2, exprimées en % de l'inertie totale.

A	Canonical coefficients		Correlations with axis			
	Axis 1	Axis 2	Axis 1	p	Axis 2	p
Altitude	0.115	0.177	0.459	0.000	0.122	0.068
Distance from the source	– 0.278	0.205	– 0.278	0.000	0.209	0.002
Slope	0.251	0.043	0.369	0.000	0.120	0.073
Watershed area	0.090	0.262	– 0.204	0.002	0.243	0.000
Wetted river section	– 0.372	0.269	– 0.152	0.023	0.164	0.014
Current speed	0.063	– 0.001	0.209	0.002	0.239	0.000
Flow rate	0.259	– 0.110	– 0.053	0.428	0.125	0.062
Water temperature	– 0.308	– 0.769	0.020	0.761	0.146	0.029
Conductivity	0.574	– 0.295	– 0.030	0.652	0.099	0.139
pH	1.300	2.748	0.075	0.261	0.142	0.034
O_2	– 0.185	– 1.176	0.057	0.393	0.123	0.067
NH_3	– 0.023	0.131	– 0.231	0.000	0.038	0.575
PO_4	0.058	– 0.047	– 0.215	0.001	– 0.020	0.767
SO_4	– 0.300	– 0.656	– 0.280	0.000	– 0.080	0.231
Cl	– 1.395	– 0.029	– 0.356	0.000	– 0.080	0.233
E.B.I.	– 0.003	– 0.472	0.287	0.000	0.065	0.329

B	Axis 1	Axis 2
Eigenvalues	0.381	0.111
Percentage	11.50	3.30
Cum. Percentage	11.50	14.80
Cum constr. percentage	52.40	67.60

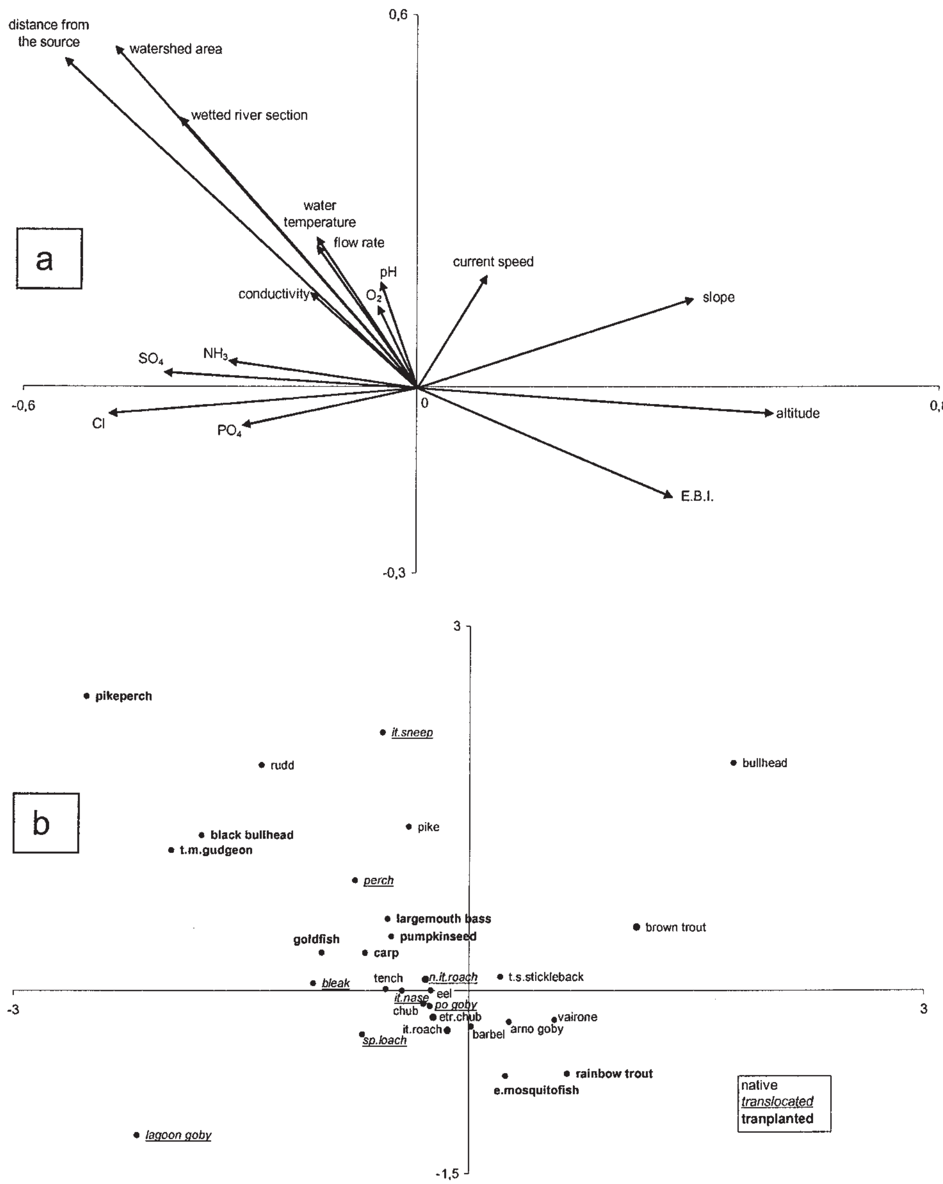

Figure 6

Canonical Correspondance Analysis (CCA): biplot of enviromental variables (a) and fish species (b). Enviromental variables are represented by arrows; circles give positions of the fish species. The length of the arrow is proportional to the rate of change: a long arrow indicates that change is strongly correlated with the ordination axes. The position of the points in relation to the arrows indicates the relationship between each point and the variable represented by the arrow.

Figure 6

Analyse Canonique des Correspondances (ACC) : biplot des variables environnementales (a) et des espèces de poissons (b). Les variables environnementales sont représentées par des flèches ; les positions des espèces de poissons sont figurées par les points noirs. La longueur de la flèche est proportionnelle au taux de changement : une longue flèche indique que le changement est corrélé fortement avec les axes de l'ordination. La place des points par rapport aux flèches indique le rapport entre chaque point et la variable a représentée par la flèche.

(4 species) and gobids (3 species). All the exotic species with the exception of the marble trout, grayling (*Thymallus thymallus* L., 1758) and grass carp (*Ctenopharyingodon idellus* Valenciennes, 1844) have become acclimatized. Some fish species have been intentionally introduced into the Tiber for their commercial (i.e., perch *Perca fluviatilis* L., 1758; whitefish *Coregonus lavaretus* L., 1758; carp) or sport value (i.e., largemouth bass *Micropterus salmoides* Lacépède, 1802; grayling). Others, such as Eastern mosquito fish and grass carp, have been introduced as biological control agents (SOMMANI, 1967). The proportion of accidentally introduced species is very high; of the 24 exotic species only 11 (45.83%) can be considered as intentionally introduced by man. In the transplanted species, the proportion of intentional introductions (8 species = 66.67%) is notably superior in comparison to the translocated species (3 species = 33.33%). One of the principal causes for unintentionally introducing exotic species is the restocking programs, which often use a mixture of different unidentified species, mostly native to northern Italy (BIANCO, 1990b).

Fish assemblage composition varied along the Tiber River according to environmental variables, a common feature of stream fish communities (HUET, 1949, 1954, 1962; VANNOTE *et al*., 1980; MINSHALL *et al*., 1985; CHANGEUX, 1995). The flow rate and size of the rivers increase with the distance from the source, while slope and altitude decrease; this upstream-downstream gradient in habitat generated by water flow organizes the communities in its longitudinal dimension. The degree of degradation in the fish community of the Tiber watershed also appears to be related to the longitudinal gradient. Although studies on the environmental organization of freshwater fish communities in Italy are still limited, some of the trends revealed by our analysis have been described for other geographic areas (AADLAND, 1991; BELKESSAM *et al*., 1997; LOBB and ORTH, 1991; SCOPPETTONE, 1993; COLLARES-PEREIRA *et al*., 1995; GODINHO *et al*., 1997; GODINHO and FERREIRA, 2000). The upper part of the Tiber River basin consists of cold lotic environments, usually characterized by steep gradients. The native brown trout is the dominating fish species and, in many cases, the only one. Sometimes bullheads are also present. The only other introduced salmonids are the rainbow trout, the marble trout and grayling, but these species are very rare in the Tiber River basin and only the rainbow trout has occasionally become acclimatized in the upper reaches of several watercourses. Consequently, the maximum ZIC values were recorded for the mountainous sectors of the basin. The ZIC is particularly low for the sectors in the lowland river catchment. This situation appears to be due to the particular relationship that ties the number of native species to the longitudinal gradient of the rivers in the Tiber River watershed. In fact, in temperate rivers the species richness progressively increases from mountain to valley (SHELDON, 1968; SCHLOSSER, 1982; BALON *et al*., 1986; MORIN and NAIMAN, 1990; PONT *et al*., 1995; BELKESSAM *et al*., 1997; CHANGEUX, 1995; PETERSON and RABENI, 2001) and this pattern surely characterized the autochthonous populations in the Tiber River in the past (BIANCO, 1990a; BIANCO and KEITMAIER, 2001). Currently, most of the native fish species appear to be confined to the intermediate reaches of the river and their number is particularly low in the downstream sectors, where fish communities are dominated by the transplanted species. These results seem to support the hypothesis that exotic species have a greater impact when environmental degradation is high and water quality declines (McKINNEY and LOCKWOOD, 1999; GODINHO and FERREIRA, 2000; LODGE *et al*., 2000). A link between the disturbance of fish communities and global human pressures in catchment areas has been observed for numerous river systems (LEONARD and ORTH, 1986; STEEDMAN, 1988; BELLIARD *et al.*, 1999). However, it is impossible to clearly separate all the negative influences of habitat degradation and introduced species upon the native species. These studies have also shown that transplanted species prefer slow-moving waters and the lower reaches of a river and that they adapt well and can live in degraded environments (MAY and BROWN, 2000). Those characteristics that permit a fish species to be raised in captivity and be transported successfully are often the same characteristics that allow the species to adapt to polluted environments (ROSECCHI *et al*., 1997; McKINNEY and LOCKWOOD, 1999).

Fish communities in the rivers in western Europe are usually not saturated with species, so transplanted species can occupy empty niches (BELKESSAM *et al.*, 1997). This is particularly true in south-central Italy where the number of species is especially low (BIANCO, 1996). The native fish fauna of the Tuscany-Lazio zoogeographical district includes few limnophilic species. In addition, the lowland rivers were also originally dominated by rheophilic forms (BIANCO, 1993) that are more sensitive to the consequences of pollution and are probably excluded in the slow-moving river reaches and in the lakes by inter-specific competition with the introduced limnophilic species. However, we must acknowledge that marked changes in fish assemblage composition can also be the result of biological processes other than competition, including predation (BUNN and DAVIES, 2000). The introduction of fish-eating species like pikeperch (*Stizostedion lucioperca* L., 1758), largemouth bass and black bullhead (*Ictalurus melas* Rafinesque, 1820) in the lower parts of the Tiber River could be another cause for the decline of indigenous species in this area (LINFIELD, 1984; GODINHO *et al*., 1998; GODINHO and FERREIRA, 2000).

Pollution and eutrophication, physical alterations in river morphology, variation in hydrologic regimes and the construction of dams are other main factors that disturb the native fish fauna. The ZIC values for the lakes in the Tiber River basin are very low. A dam is not only a barrier for migratory fish, but the reservoir lake represents a point from which limnophilic-introduced species can spread to the adjacent streams (GODINHO *et al*., 1998), particularly in the downstream direction (LORENZONI *et al*., 1994; GODINHO and FERREIRA, 2000; PENCZACK and GOMES, 2000). In the U.S.A. WITTHIER *et al*. (2002) found that impoundments had the greatest proportions of non-native species and of fish species that are tolerant to human disturbance.

Translocated species in the Tiber usually come from environments similar to those of the rivers into which they are released. These are often rheophilic forms that can also colonize the middle reaches of the river, as well as the smallest streams. For example, a few specimens of Italian nase and the bleak (*Alburnus alburnus alborella* De Filippi, 1844) were both accidentally introduced into the Tiber basin in the ‘60s. Since then, they have spread throughout the entire Tiber River watershed reaching high densities (LORENZONI *et al.*, 1997). In the piedmont streams of the Tiber basins, the ZIC is not as low as in the lower tracts but the fish communities appear to be threatened by the translocated species rather than by the transplanted ones. These sectors are characterized by small- to medium- sized streams in which the environmental degradation is generally limited or nonexistent. The native fish community is prevalently made up of Arno goby and rheophilic cyprinids: barbel, vairone, chub, Etruscan chub and Italian roach. The translocated species have recently been introduced into these sectors and include several vicariant forms of the native ones. Hence, the probability of competition seems high and this could also subsequently endanger the state of the native populations in those river sectors where the integrity of the fish communities is currently good. Competitive exclusion has been hypothesized between north-Italian roach and Italian roach (BIANCO, 1990b; BIANCO and KEITMAIER, 2001), between Italian nase and Etruscan chub (BIANCO and KEITMAIER, 2001) and between Po goby and Arno goby (LORENZONI *et al*., 1997; ZERUNIAN and TADDEI, 1998; BIANCO and KEITMAIER, 2001). If competitive exclusion between the transplanted and native species is confirmed, the integrity of the rheophilic community in the Tiber River basin will be strongly threatened and efforts to conserve some of the most valuable endemic forms of the Italian fish fauna may also be impeded.

Examination of earlier lists of fish species (SILVESTRI, 1892; ANONYMOUS, 1929; D’ANCONA, 1929) shows that the only fish species that have become extinct in the entire

Tiber watershed are anadromous ones. Today these species are denied access to their reproductive grounds (SOMMANI, 1967) by the dams constructed along the river, so the sturgeon (*Acipenser sturio* L., 1758), the twaite shad (*Alosa fallax* Lacépède, 1803) and the river lamprey (*Lampetra fluviatilis* L., 1758) have definitely disappeared from the waterways of the Tiber basin. At the local level, numerous populations of indigenous species have declined drastically, in some cases to the point of extinction. The Italian roach recently disappeared from Lake Trasimeno (BIANCO 1990b; MEARELLI *et al*., 1990) and from Lake Piediluco (BIANCO, 1990b). In the latter case, its extinction was coincident with the appearance of the north Italian roach. Similar local extinctions are less probable in the rivers and are more difficult to individualize; lotic environments are much more variable and less isolated than lentic ones and, therefore, extinctions are probably avoided or are followed by the recolonization of the nearest upstream sites (HUGUENY and PAUGY, 1995; BELKESSAM *et al*., 1997).

Some of the results of our study seem to be of particular interest as regards the application of the EC Water Framework Directive (2000/60/EC) to Italian bodies of water. This Directive establishes a new, integrated approach to the protection, improvement and sustainable use of rivers, lakes, estuaries, coastal waters and groundwater in the member states of the European Community. With this Directive, EC members must prevent the further deterioration of bodies of water by improving and restoring the status of associated aquatic and terrestrial ecosystems. As a final objective, the WFD aims to achieve the good status of all bodies of water by the year 2015. For the surface waters, good ecological status is defined in Annex V of the Water Framework Proposal, in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics. As no absolute standards for biological quality can be set which apply across the Community, because of ecological variability, the controls are specified so as to allow only a slight departure from the biological community which would be expected in conditions of minimal anthropogenic impact. Further, in this context, the data gathered during this study represent a useful reference point to make comparisons and to verify the future evolution of the situation.

CONCLUSION

The present study provides useful information for improving fish community management and the results show that it is no longer possible to delay initiatives aimed at protecting the most threatened species and restoring the aquatic ecosystems. To succeed, however, any strategy for maintaining native biodiversity requires a sound base of information about the spread, ecological effects and control of non-indigenous species (BYERS *et al*., 2002). Our preliminary results suggest that the characteristics of fish community alterations depend on the type of river sector involved. In the lower part of the Tiber River basin, fish community management must include controlling exotic species as well as improving water quality and habitat restoration. The small rivers of the basin are a refuge zone for the native community and currently play a fundamental role in maintaining biodiversity. In these sectors, rehabilitation should focus mainly on the control of translocated species with greater attention being given to the restocking programs, because these are considered one of the principal sources for the introduction of exotic species. Our results also suggest that caution must be taken when new impoundments are proposed.

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