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Are fish introductions a threat to endemic freshwater fishes in the Northern Mediterranean region?

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ABSTRACT

Seventy species of exotic or transplanted fish species have been introduced into this region, 60% of them in the last 40 years. The effects of these introductions on endemic species have rarely been described. The few exceptions are: hybridization of Salmo marmoratus with Salmo trutta; the extinction of three endemic species of Phoxinellus in a Turkish lake owing to the introduction of Stizostedion lucioperca; and the spatial displacement of Aphanius in sites where Gambusia affinis occurs. A further phenomenon possibly attributable to the introduction of exotic fish is the increased turbidity in Lake Mikri Prespa following the introduction of Carassius auratus. Because of the paucity of information, the effects of introductions on endemic species remain controversial. It is therefore essential to initiate conservation action plans, for each catchment in wetland areas rich in endemic fish. An awareness campaign directed at land managers and decision-makers on the role and importance of fish in the functioning of aquatic ecosystems must also be undertaken very soon.

Keywords: endemic, fish, conservation, introductions

INTRODUCTION

Thirty years ago Elton (1958) wrote the first review of the ecological consequences of introduced species. Since then, introductions of plants and animals, including fish, have increased steadily (Simberloff, 1981; Mooney & Drake, 1987; Drake *et al.,* 1989; di Castri *et al.,* 1990; Soulé, 1990). It is unlikely that such introductions will cease in the future, since practically all of them are due, either intentionally or accidentally, to human activities and legal measures taken to halt such introductions have generally proved to have little effect (ICES, 1988; Courtenay & Robins, 1989; Winfield, 1992). Among vertebrates, introductions of freshwater fish species (exotic introductions or local translocations) have been among the most numerous. Their impact on native fish faunas and their ecosystems are, however, among the least well documented. The consequences of such introductions are still highly controversial and have been the subject of fierce debate between fisheries managers and conservationists (Ben Tuvia, 1981; Gophen *et al.,* 1983; Courtenay & Stauffer, 1984; Arthington & Mitchell, 1986; Bruton, 1986; Maitland, 1987; Welcomme, 1988; Courtenay & Robins, 1989; de Silva, 1989; Miller *et al,* 1989; Coblentz, 1990; Ferguson, 1990; Pollard, 1990; Temple, 1990; Arthington, 1991; Holcik, 1991; Minckely & Deacon, 1991; Stewart, 1991; Crivelli 1992; Wheeler, 1992; Allan & Flecker, 1993; Frissel, 1993; Rowe, 1993). The reason that it is so difficult to arrive at a consensus on this problem is that there are divergent interests among the various users of water bodies and because, with few exceptions, it is not easy to analyse the effects of these introduced species on the native fauna and their ecosystems. There are three main reasons for this state of affairs: (a) baseline data on fish communities and their ecosystems before the introductions take place are almost always lacking; (b) usually, there have been habitat alterations due to human activities, either before or at the same time as the introductions, which can facilitate the establishment of introduced species (Moyle, 1976; Arthington *et al,* 1990; Townsend & Crowl, 1991; Kaufman, 1992); and (c) the introduction of species, even when it is done intentionally, is rareiy followed by a monitoring programme to determine the impacts on the host fish community and its ecosystem.

Among the most vulnerable to introductions throughout the world are endemic fish species. As a result of introductions, several have disappeared or have seen major reductions in their numbers to the extent that they are now threatened with extinction (Schoenherr, 1981; Courtenay & Meffe, 1989; Lloyd, 1990; Arthington, 1991; Townsend & Crowl, 1991; Minckley & Douglas, 1991; Witte *et al,* 1992). A very large number of freshwater endemic fish species occur in the northern Mediterranean region (Bianco, 1990; Miller, 1990; this issue). Similarly, a large number of introduced exotic or translocated species also occur in this region. They have frequently been blamed for the extinction or decline of endemic fish species, but the evidence is largely anecdotal (Sarihan, 1970; Delmastro, 1986; Elvira, 1990; Povz & Ocvirk, 1990; Moreno-Amich *et al.,* 1991). The purpose of this brief paper is to review and synthesize current knowledge on the status of endemic fish species and of introduced species in the northern Mediterranean region, and the effects of introductions on endemic freshwater fish and their ecosystems in this region.

The endemic species

In the northern Mediterranean region, from the Iberian peninsula to the Mediterranean part of Turkey, 229 taxa of endemic freshwater fish have been recorded, representing 13 families. Cyprinidae are the most numerous, accounting for 66% of recorded species, followed by Cobitidae (11·3%) and Salmonidae (8·3). The great majority are lowland river fishes, the rest occur in lakes and a few occur in springs. Many of the endemic species in the northern Mediterranean region live in communities that lack predatory fish species (de Sostoa & Lobon-Cervia, 1989; Celikkale, 1990; Crivelli, 1990; Elvira, 1990).

The introduced species

Up until now 70 introduced, exotic or translocated species and subspecies, representing 17 families, have been recorded in the northern Mediterranean region (Appendix 1). The origin of these introduced or transplanted species is as follows: (a) European origin, 68·5%; (b) North American origin, 15·7%; (c) Asian origin, 12·9%; and (d) tropical South American or African origin, 2·9%.

About 60% of these species have been introduced in the last 40 years (Fig. 1). The reasons for these introductions are in decreasing order of importance; (1) to improve angling catches; (2) to improve commercial fisheries yield; (3) accidental (escapes from fish farms, live bait, aquarium fish); (4) for wetland management; and (5) to control mosquitoes.

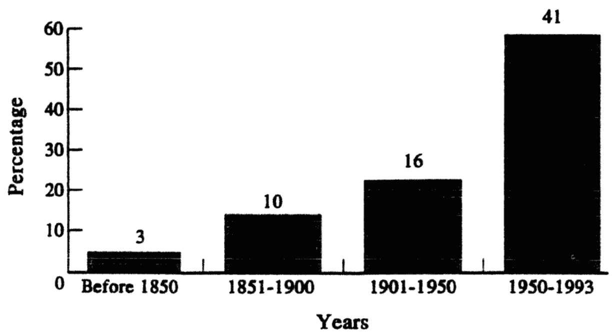

Fig. 1. Proportion of exotic species introduced into the northern Mediterranean region from before 1850 to the present day. The total number of species is indicated above each bar.

At the present time, I estimate that more than 80% of the endemic freshwater fish coexist with one or more exotic or transplanted species. In any one water body harbouring endemic freshwater fish, up to 14 introduced species can be encountered, e.g. Lake Skadar, Montenegro; Maric, this issue) and in many lakes, rivers and reservoirs more than half of the species present are introduced.

Of the 70 introduced species or subspecies, 58 have been able to establish self-sustaining populations; the others require continual restocking from hatcheries in order to maintain themselves. Most of the latter species, although they survive perfectly well in the habitat into which they have been introduced, are incapable of breeding for climatic reasons (usually temperatures that are too low in spring) or because they do not find the necessary habitat conditions for successful reproduction.

THE EFFECTS ON INTRODUCED SPECIES

Hybridization

Hybridization among closely related species can be one of the most immediate consequences of introductions, particularly among Salmonidae and Cyprinidae. It reduces the diversity of fish communities and the fitness of the native species (Nelson & Soulé, 1987; Dowling & Childs, 1992; Meffe, 1992). The best known example in the northern Mediterranean region is between the marbled trout *Salmo marmoratus* and the brown trout *Salmo trutta,* introduced almost throughout the range of the marbled trout, which is endemic to the rivers of the Adriatic basin of Italy, Slovenia, Croatia, Bosnia-Herzegovina, Montenegro and Albania (Povz, 1989).

In the Adriatic catchment of Slovenia, the brown trout was introduced for the first time into the River Soca in 1906 (Ocvirk, 1989; Povz & Ocvirk, 1990; Povz, this issue). It not only displaced the marbled trout from its original habitat but also hybridized with it, producing fertile hybrids. Apparently the situation was not too serious until the 1950s, because Ocvirk (1989) found only marbled trout in the River Soca at Krsivek in 1957. Since then, however, the situation has deteriorated, coinciding with the economic development of the region which has improved access to water courses and possibly increased the number of releases of brown trout. In 1965, Ocvirk (1989) found only 13% of the trout at Krsivek were marbled, 69% were hybrids and 18% were brown, at a density of 1059 trout/ha. In 1970 there were only 359 trout/ha, of which only 2·5% were marbled. In 1983-85 there was only one water course in Slovenia in which a pure marbled trout population survived, the Zadlascica, a rather inaccessible river with natural barriers preventing invasion. In all the other rivers, the marbled trout had either disappeared, or had greatly declined and coexisted with a percentage of hybrids ranging from 0·8 to 51·0% and/or a percentage of brown trout ranging from 5·5 to 99·2%.

In northern Italy, in the Torino province, Forneris *et al.* (1990) showed that the number of stations in the River Po and its tributaries in which only marbled trout occur has steadily declined. In the stations furthest upstream, only hybrids are now found, whereas the lowermost stations contain a mixture of hybrids and marbled trout. In the River Pellice, also in the Torino province, Alessio *et al.* (1990) found that 70% of the trout were hybrids.

Apart from the marbled trout, only two other cases of hybridization, between an endemic cyprinid and an introduced species, are known in the northern Mediterranean region: (a) *Alburnus albidus* with *Leuciscus cephalus cabeda,* a translocated cyprinid, in the rivers of southern Italy (Bianco, 1982, this issue); (b) *Chondrostoma toxostoma arrigonis* with *Chondrostoma polylepis polylepis,* a translocated cyprinid, in the rivers of Mediterranean Spain (Elvira, this issue).

Predation

One of the commonest effects of introductions is that of predation on native species by an introduced predator. Often such predation results either in the extinction of one or more of the native endemic species (Barlow *et al,* 1987; Witte *et al.,* 1992) or in the displacement of native species to different habitats (Schlosser, 1987; Brown & Moyle, 1991). Many fish communities in northern Mediterranean water bodies lack predatory fish species, and such communities are especially vulnerable to the introduction of predators (Townsend & Crowl, 1991). It is not surprising, therefore, that the best known cases of predation by introduced species involve such communities, in Turkey and in Spain.

Nine species of fish used to occur in Lake Egridir in south-west Anatolia: Cyprinus carpio, Cobitis tenia, Vimba vimba and six endemic species: Capoeta pestai, Aphanius chantrei, Noemacheilus lendli, Phoxinellus zeregii, Phoxinellus handlirschi and Phoxinellus egridiri (Nümann, 1958; Sarihan, 1970). The last two species have only been recorded from Lake Egridir. In 1955, about 10,000 pikeperch Stizostedion lucioperca were introduced and from 1961 onwards it was an important species in the commercial fisheries (Table 1). The consequences of this introduction were rapid and irreversible (Sarihan, 1970; Kuhn & Rahe, 1978; Celikkale; 1990; Balik, this issue): (1) the three species of Phoxinellus disappeared and the two species endemic to this lake can be considered as extinct; (2) N. lendli and C. taenia have also probably disappeared; (3) A. chantrei has found refuge from pikeperch in the lake's inflows; (4) C. pestai, C. carpio and V. vimba have survived but their numbers have greatly declined; and (5) there has been a tremendous increase in captures of a freshwater crayfish native to Turkey, Astacus leptodactylus, to the extent that Lake Egridir now accounts for 50% of the catch of this species for the whole of Turkey (Celikkale, 1990). According to Nümann (1958), this crayfish was introduced into Lake Egridir, but the date of this introduction is unknown. Sarihan (1970) thought that crayfish were already present in the lake when the pikeperch were introduced, but that they were rare because of the predation exerted on their eggs and larvae by the cyprinids and cobitids.

Table 1. Fishery statistics for each species in Lake Egridir from 1958 to 1981 (tonnes/year)

Species	Year									
	1958–60	1961–64	1965–67	1968–69	1976	1977	1978	1979	1980	1981
Cyprinus carpio	500	500	550	500	100	90	120	117	120	128
Capoeta pestai + *Vimba vimba*	175	65	9	10	12	20	15	23	15	10
Phoxinellus handlirschi	175	0	0	0	0	0	0	0	0	0
Stizostedion lucioperca	0	100	220	300	315	204	380	482	450	310
Astacus leptodactylus	0	0	20	?	1712	2852	2116	1781	2174	1573
Total (fish)	850	665	799	810	427	314	515	622	585	448

The situation in Lake Egridir demonstrates how the introduction of a single piscivorous fish species can cause major changes to an ecosystem. While the changes were disastrous for the endemic fish fauna, they appear to have had considerable economic benefits. Both the pikeperch and crayfish are high-value species in the local fisheries. Crayfish from the lake are exported in large quantities to Europe, providing badly needed foreign exchange for the Turkish economy. Before the introduction of the pikeperch, the fisheries were of low value and only provided fish for local markets. However, the benefits of the introduction, especially the explosion of the crayfish populations, were fortuitous and largely unpredictable. Introductions of predatory fish can just as easily lead to the collapse of fisheries or to the reduction in availability of fish protein to resident people when high-value fish are exported rather than being consumed locally. Even the improved fisheries in Lake Egridir may be temporary because there is a high likelihood that crayfish plague (introduced from North America) will eventually reach the lake and eliminate the crayfish populations (Celikkale, 1990).

Similar effects can also occur when predators are introduced into river systems. Rincon *et al.* (1990) studied the fish communities in seven tributaries of the River Esla, in Spain, following the introduction of pike *Esox lucius.* Depending on stations, up to seven species of endemic fish and four introduced species were recorded. From the upper to the lower reaches, the population changed from one of native species to a population dominated by two introduced species, the gudgeon *Gobio gobio* and pike. The native endemic species reacted in different ways to the presence of pike: the genera *Rutilus* and *Leuciscus* were more sensitive than the genera *Chondrostoma* and *Barbus* (Rincon *et al.,* 1990). These differences were only partially confirmed by the study of Pena *et al.* (1987), who analysed more than 500 pike stomachs from the basin of the River Esla. This study showed that the diet of pike (>200 mm long) consisted of 38-45% fish with a preference for the genera *Chondrostoma, Barbus* and *Rutilus.* The gudgeon sympatric with the pike in its original distribution range did not seem to be affected by the presence of pike. Because of the absence of data before the introduction of pike, this example is not entirely convincing, as Rincon *et al.* (1990) concede.

De Sostoa and Lobon-Cervia (1989) studied the impact of the introduction of pike on the community of fish present in the lower reaches of the River Matarrana in the Ebro catchment, also in Spain. In this case 75% of the pike's diet consisted of endemic cyprinids *(Barbus, Chondrostoma),* 15% of *Leuciscus cephalus* and the remainder of *Gobio gobio* and invertebrates. In the upper reaches of the Matarrana, these authors showed that introduction of rainbow trout *Oncorhynchus mykiss* had a negligible effect on native species present since this trout only consumed 6% of fish compared with 94% invertebrates. De Sostoa and Lobon-Cervia (1989) showed that these two predators introduced into the river Matarrana consumed various prey species in direct relation to their respective abundance and that there was no prey selection. No endemic or non-endemic native species disappeared and no serious decline in abundance related to the introduction of these two predators could be demonstrated. This tends to confirm that in Mediterranean rivers it is not predator-prey relations which control the structure of the fish populations, but rather the major and frequent seasonal or annual fluctuations in environmental variables which maintain the densities of fish at low levels, well below the carrying capacity of the habitat (Grossman *et* *al,* 1987*a,b*). Caution is called for, however, since controversy exists over whether density-dependent or density-independent factors control the dynamics and structure of fish populations in rivers subjected to unpredictable climates (Ross, 1991; Strange *et al,* 1992; Baltz & Moyle, 1993).

Competition

In undisturbed fish populations, competition is rarely observed since it is avoided by character displacements or niche shifts by the species present. When a species is introduced into one of these undisturbed fish populations, the situation is different because the species present have not co-evolved with the newcomer and they have not been able to evolve mechanisms that avoid competition between themselves and the introduced species. In such cases, competition can take place for resources and by means of behavioural interactions (e.g. aggression). It is, however, always difficult to demonstrate effectively that competition exists between species.

A few cases of competition between an endemic and an introduced species have been identified in the Mediterranean region. The most frequently cited case is the possible competition between introduced *Gambusia affinis* and the various endemic species of Cyprinodontidae such as *Aphanius fasciatus, A. iberus, Valencia hispanica* and *V. letourneuxi* (Fernandez-Delgado, 1989; Garcia-Marin *et al,* 1990; Economidis, this issue; Elvira, this issue; Bianco & Ahnelt, in press). In addition, Fernandez-Delgado (1989) and Elvira (1990) mention that the introduction of *Fundulus heteroclitus* could have negative effects on *Aphanius iberus.* The only convincing evidence for competition between these species is the observation that *Aphanius* spp. are always displaced towards more saline habitats in areas in which *G. affinis* has been introduced.

Elsewhere in the world, *G. affinis* or *G. holbrooki* have also been accused of seriously harming small-sized native species (Bruton, 1986; Courtenay & Meffe, 1989; Lloyd, 1990; Arthington, 1991; Krupp, 1992). However, only Schoenherr (1981) has clearly shown that if the native species occur together with *G. affinis* and do not have the opportunity of finding refuge, then they are eliminated by the latter by predation and/or by reduced survival of the females, apparently caused by physiological stress.

Effects on the ecosystem

I have been unable to find any publication showing that a fish species introduced into the northern Mediterranean region has brought about habitat alteration. This is hardly surprising if account is taken of the extreme difficulty of identifying and quantifying the effects of fish introductions on ecosystems (Werner, 1980). Nevertheless, as part of a long-term programme of monitoring the fish population in Lake Mikri Prespa, north-western Greece (Crivelli, 1990; Rosecchi *et al.,* 1993; Crivelli & Catsadorakis, unpublished data), we have suggested that the introduction of the goldfish *Carassius auratus gibelio* has affected the ecosystem of this shallow lake by causing greatly increased turbidity.

The goldfish was introduced at the end of the 1970s to improve the fishery. In 1984, its numbers in the lake became sufficiently high for it to figure for the first time in the commercial catch statistics, accounting for 31% of the total catch. Since then, this percentage increased steadily to reach 32·6% in 1990. The great increase in numbers of fish in Lake Mikri Prespa is confirmed by the results of our experimental sampling, which show a significant increase in catch per unit effort (CPUE) between 1984 and 1993 ($r = 0{\cdot}50$, $n = 81$, $p < 0{\cdot}001$, Fig. 2). An increase in turbidity was also recorded, coinciding with the increase in the numbers of goldfish; Secchi disc measurements for the month of April decreased significantly from 1984 to 1993 ($r = -0{\cdot}64$, $n = 14$, $p < 001$). If data from before 1984 are included (Koussouris & Diapoulis, 1983), an even higher correlation is found for the month of April from 1977 to 1993 ($r = -0{\cdot}74$, $n = 17$, $p < 0{\cdot}001$).

Usually, the underlying cause for such an increase in the turbidity of lake waters is eutrophication. This is not the case for Lake Mikri Prespa: Stevenson and Flower (1991) have clearly shown, by means of an analysis of diatoms in the sediments laid down over a period of 70 years, that the lake has been little affected by any increase in nutrient loading. This conclusion is confirmed by the water analyses which show low phosphorus concentrations. Richardson and Whoriskey (1992) have shown that goldfish significantly increase the water turbidity in experimental ponds into which they have been introduced. It is the numbers, rather than the biomass, that are important and they cause this increase in turbidity by sucking up sediment when feeding. Another possibility is that increased turbidity can also be caused by increased predation on zooplankton by goldfish, reducing grazing on phytoplankton, resulting in an increase in phytoplankton blooms. We therefore conclude that the main cause of the increase in turbidity in the shallow Lake Mikri Prespa is the explosion in the population of goldfish. This increased turbidity could have harmful effects on some of the species in the fish community of this lake, which is rich in endemic species (Rosecchi *et al.,* 1993), and could also affect the use of the lake by fish-eating birds that are very numerous in this region (Crivelli & Catsadorakis, unpublished data).

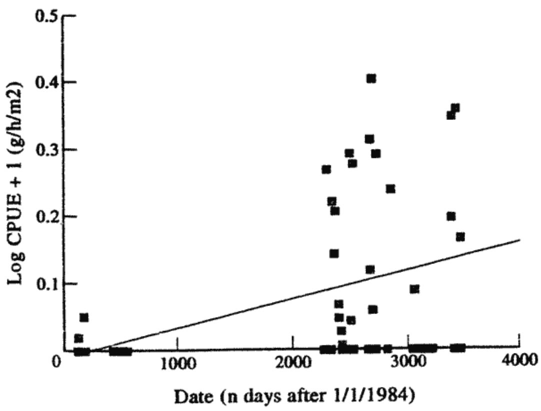

Fig. 2. Catch per unit effort (g/h/m^2) of *Carassius auratus* in spring of 1984, 1985, 1990, 1991, 1992 and 1993 in Lake Mikri Prespa, north-western Greece.

Elsewhere in the Mediterranean region, the introduction of the grass carp *Ctenopharyngodon idella* into Lake Oubeira in Algeria has led to the complete disappearance of beds of submerged vegetation and reedbeds. This habitat alteration has had a harmful impact on the fish population and on the numbers of wintering ducks using the lake (Crivelli, 1992).

CONCLUSIONS

Although it has become customary to blame introductions of non-native species for the decrease or even extinction of endemic fish in the northern Mediterranean region, it has been difficult, with few exceptions, to find examples that clearly support such an assertion. This does not mean that the impacts of such introductions are negligible, but instead reflects strikingly both the paucity of information on fish populations in northern Mediterranean water bodies (this issue) and also the almost complete absence of studies of the possible effects of introductions of exotic and/or transplanted fish.

The northern Mediterranean region is typified by fish populations of low diversity but a high degree of endemism. These fish communities thus contribute to the overall biodiversity of the aquatic systems of this region. For a variety of reasons, one of which is probably the introduction of exotic or transplanted species, many of these endemic species are currently threatened with extinction.

In order to ensure improved conservation of these fish, conservation action plans must be developed for each basin, for those water bodies which are not yet too degraded and which are particularly rich in endemic species. The entire catchment of the water bodies in question must be taken into account in these action plans (Stroud, 1992). The emphasis should be put on measures for rehabilitating the habitat and the management of the entire catchment (Arthington *et al.,* 1990). Procedures for assessing the impact of any new introductions should be included in these plans (ICES, 1988; Townsend & Winterbourn, 1992). Water transfers between basins should be banned to restrict the introduction of new species (Davies *et al.,* 1992). The role and the effects of hatcheries need to be redefined in concert with hatchery managers, decision-makers, angling associations and wildlife conservationists, in order to limit the impact of stocking with alien species (Meffe, 1992). Finally, long-term studies on the impact and fate of introduced species need to be promoted and campaigns launched to make land managers and decision-makers aware of the role and importance of fish, endemic or otherwise, in the functioning of aquatic ecosystems (Andersson *et al.,* 1978; Carpenter *et al.,* 1985; Benndorf, 1988), so that more account is taken of the fish fauna, especially in sites of high endemism.

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APPENDIX 1

Exotic and translocated (boxed) fish taxa known from the waters of the northern Mediterranean region. Reproductive status: + = established; – = not established; ? = unknown. Countries: AL = Albania; HR = Croatia; FR = France; GR = Greece; IT = Italy; MO = Montenegro; PO = Portugal; SL = Slovenia; SP = Spain; TU = Turkey.

Species	Countries	Reproductive status
CLUPEIDAE		
Alosa fallax nilotica	IT	+
COREGONIDAE		
Coregonus lavaretus	GR HR	+
Coregonus forma hybrida	IT	+
Coregonus oxyrhynchus	IT	+
Coregonus peled	HR	?
SALMONIDAE		
Salmo marmoratus	IT	?
Oncorhynchus mykiss	IT SP FR SL Al MO PO GR	+ –
Oncorhynchus kisutch	IT GR	–
Hucho hucho	SP	–
Salmo trutta	IT MO SL HR SP	+
Salvelinus fontinalis	MO GR FR IT SP	+ –
Salvelinus alpinus	IT	+
Salmo carpio	IT	+
THYMALLIDAE		
Thymallus thymallus	IT HR SL	?
CYPRINIDAE		
Rutilus rutilus	SP IT	+
Rutilus rubilio	IT	+
Rutilus aula	IT	+
Rutilus ylikiensis	GR	+
Leuciscus cephalus squalus	IT	+
Leuciscus polylepis	SP	+
Leuciscus souffia	IT	+
Chondrostoma nasus	IT FR SL	+
Chondrostoma soetta	IT	+
Chondrostoma genei	IT	+
Scardinius erythrophthalmus	SP IT	+
Carassius carassius	FR GR HR	+
Carassius auratus	MO AL GR SP HR IT PO FR	+
Cyprinus carpio	All countries	+
Barbus plebejus	IT	+
Barbus meridionalis	IT	+
Barbus eques	IT	+
Phoxinus phoxinus	IT	+
Gobio gobio	SP PO	+
Gobio benacensis	IT	+
Alburnus alburnus alborella	IT	+
Alburnus albidus	IT	+
Pachylon pictum	IT	+
Abramis brama	IT	+
Tinca tinca	PO GR IT	+
Rhodeus sericeus amarus	HR IT GR	+
Megalobrama terminalis	MO AL	–
Parabramis pekinensis	GR AL	–
Mylopharyngodon piceus	MO AL	–
Pseudorasbora parva	MO AL GR FR IT	+
Hypophthalmichthys molitrix	MO AL GR IT	–
Hypoptthalmichthys nobilis	MO AL GR IT	–
Ctenopharyngodon idella	MO AL GR IT SL	–
ICTALURIDAE		
Ictalurus melas	FR MO IT SP AL	+
Ictalurus nebulosus	HR SK	+
SILURIDAE		
Silurus glanis	HR IT SP FR SL	+
Siurus aristotelis	GR	

APPENDIX 1—*contd*

Species	Countries	Reproductive status
PERCIDAE		
Stizostedion lucioperca	HR IT SP FR TU SL [GR]	+
Perca fluviatilis	SP [GR] IT	+
Acerina cernua	[SL]	+
CENTRARCHIDAE		
Lepomis gibbosus	IT SL SP GR FR PO	+
Micropterus salmoides	IT SP FR PO	+
ESOCIDAE		
Esox lucius	SP PO [IT] [GR]	+
GASTEROSTEIDAE		
Gasterosteus aculeatus	[IT]	+
CYPRINODONTIDAE		
Fundulus heteroclitus	SP PO	+
POECILIIDAE		
Gambusia affinis	MO AL IT FR GR TU PO [HR]	+
Gambusia holbrooki	SP	+
Poecilia reticulata	AL	+
CICHLIDAE		
Cichlasoma facetum	PO	+
ATHERINIDAE		
Odontesthes bonariensis	IT	+
Atherina boyeri	[IT]	+
COBITIDAE		
Misgurnus fossilis	HR	+
Cobitis taenia bilineata	[IT]	+
Sabanejewia larvata	[IT]	+
GOBITIDAE		
Knipowitschia panizzai	[IT]	+
Padogobius martensii	[IT]	+