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Identification of non-native freshwater fishes established in Europe and assessment of their potential threats to the biological diversity

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*3*NDEX

Introduction 3

1. **Trends in introductions of freshwater fishes in Europe** 3

2. **Biological characteristics of aliens** 4

3. **Reasons for introductions** 4
   3.1. Ornament 4
   3.2. Sport 5
   3.3. Improvement of wild stocks 5
   3.4. Aquaculture 5
   3.5. Biological control 5
   3.6. Accident 6

4. **Ecological impacts of naturalized fishes** 6
   4.1. Habitat alterations 7
   4.2. Trophic alterations 7
   4.3. Introduction of parasites, pathogens and diseases 8
   4.4. Genetic deterioration through hybridization 8
   4.5. Environmental effects 9
   4.6. Socio-economic effects 9
   4.7. Loss of biodiversity 9

5. **Management of invasive and nuisance introduced fishes** 9
   5.1. Prevention and public awareness 9
   5.2. Eradication versus control 10
   5.3. Control programmes 10
   5.4. Integrated control strategies 11

Acknowledgements 11

References 11

Appendix 1. Terminology relating to the fish introductions 14
Appendix 2. Exotic freshwater fishes introduced in European waters 15
Appendix 3. Selected references of freshwater fish introductions in European countries 16
Appendix 4. Allochthonous fish species introduced in European countries 21

"An introduction is an introduction, whether the source is intranational, intracontinental or foreign. Impacts, ranging from negligible to major, are to be expected."

Courtenay & Taylor (1984)

Introduction

Since early times, man has attempted to adapt and shape the world in which he lives to suit his own perceived requirements. One of the ways in which man has sought to modify the natural environment is by the introduction of animals and plants throughout the world. Although major introductions of exotic fishes into countries outside their natural range are a relatively recent phenomenon, in Europe introductions of some species are believed to date from Roman times, when carp *Cyprinus carpio* from the river Danube were reared in ponds in Italy and western and southern Greece (Balon 1995). During the Middle Ages, the monks transferred fish between different communities to ensure food supply during the long periods of abstinence.

From around the middle of the 19th century, international transfers of fish species, especially for sporting purposes and the provision of an additional food supply increased apace. After the end of the Second World War the number of introductions of alien fish species increased still further, helped by the development of advanced artificial spawning techniques.

1. Trends in introductions of freshwater fishes in Europe

Welcomme (1992) found that transfers of European cyprinids, poeciliids, centrarchids and salmonids, took place at a relatively early stage, and have since been succeeded by those of cichlids and Asian cyprinids. Introductions of aliens species peaked towards the end of the 19th century and again, after a lull, in the 1960s and 1970s.

The fact that European countries are important recipients of alien fish is ascribed by Welcomme (1992) to the fact that they have generally impoverished fish faunas and that introductions have been made, with a variety of motives, to increase their ichthyological biodiversity. The naturalization of some of the alien fish species that are able to reproduce successfully in the wild has had catastrophic consequences.

There are a number of pressures that currently increase the potential for unwanted impacts from introduced fishes. One of these is the increase in numbers of fish hobbyists, and the habit of selling or exchanging specimens or releasing them in public waters. Likewise, there is an ongoing interest by anglers for new species, hatchery support of existing populations, and in angling opportunities where none existed previously. Baitfishes are still commonly used, and ongoing transfer of them from one area to another occurs. Another problem is the escape of species transferred or imported for aquaculture.

2. Biological characteristics of aliens

The qualities of a successful introduced species are generally in accordance with what we refer to as opportunistic species and which it was fashionable to regard as *r*-selected. First, the introduced species must be able to either find or adapt to a habitat in its new range that is conductive to its survival. The introduced species must be able to reproduce successfully in its new range and all stages of the life cycle can be completed, again successfully. The subsequent spread of the species to the fullest capacity of its new range can take place usually by neighbourhood diffusion.

The following qualities of a successful introduced species are most applicable to fishes: a short life span, rapid growth, rapid sexual maturity, high fecundity, euryoecious (ability to colonize a wide range of habitat types), eurytopic (wide range of physiological tolerances), gregarious behaviour, wide genetic variability and phylogenetic plasticity.

Species associated with high impact tend to have a broad diet and abundant populations in native and disturbed habitats. Vulnerable hosts systems tend to have low species diversity, simple community structure, and few competitors and predators of the introduced species. Introduced fish having low impact are characterized by a specialized diet, limited dispersal ability, few common parasites and diseases, and little ability to directly reduce and hybridize with native fish. Likewise, host aquatic environments resistant to impact tend to be heavily managed or disturbed, productive, and inhabited by complex communities.

Moyle & Light (1996) presented empirical rules for biotic invasions into freshwaters, as follows:

1. Most invaders fail to become established.
2. Most successful invaders are integrated without major negative effects (extirpations or extinctions) on the communities being invaded.
3. All aquatic systems are invasible and invasibility is not related to diversity of the resident organisms.
4. Major community effects of invasions are most often observed where the number of species is low.
5. In systems that have been minimally altered by human activity, fishes most likely to be successful invaders are top predators and omnivore/detritivores.
6. Piscivorous invaders are most likely to alter the fish assemblages they invade while omnivore and detritivores are least likely to do so.
7. In aquatic systems with intermediate levels of human disturbance, any species with the right physiological and morphological characteristics can become established.
8. In the long term, or in relatively undisturbed aquatic systems, success of an invader will depend on a close match between its physiological and life history requirements and the characteristics of the system being invaded.
9. Invaders into natural aquatic systems are most likely to become established when native assemblages of organisms have been temporarily disrupted or depleted.
10. Long-term success (integration) of an invading species is much more likely in an aquatic system permanently altered by human activity than in a lightly disturbed system.
11. The invasibility of a natural aquatic system is related to the interactions among environmental variability, predictability, and severity.
12. Invaders are most likely to extirpate native species in aquatic systems with extremely low variability or severity.

Evidence that intrinsic characteristics of fish species can predispose them to be successful invaders comes from instances of some species repeatedly being successful invaders while close relatives repeatedly are less successful. One characteristic of fishes that are good invaders is an ability to tolerate a wide range of physical conditions. Classic examples are the mosquitofishes *Gambusia affinis* and *Gambusia holbrooki*, which because of their use as a biological control agent now may be two of the most widely distributed species of freshwater fish. *Gambusia* can survive in water as cold as 6ºC and as hot as 35ºC, extremely low oxygen concentrations, and salinities as high as twice that of seawater. These fishes also have reproductive strategies that appear to help make them successful colonizers. They are livebearers that produce a few well-guarded young and prey on the young of competitors.

3. Reasons for introductions

Alien fishes have been introduced with a variety of motives in Europe: ornament, sport, improvement of wild stocks, aquaculture, biological control and accident. In many cases fish introductions have been carried out for more than one motive.

Welcomme (1988, 1991, 1992) has analysed the relative importance of the above categories. He found that introductions made for aquacultural purposes have always comprised significant proportion of the total, and have steadily increased in importance. Since the early 1970s such importations have accounted for well in excess of 50% of all introductions made.

3.1. Ornament

The primary purpose of importing ornamental fish species in Europe is to enable members of the public to keep these species as a hobby in closed aquaria and ponds. FAO statistics shows that Europe is the major importer of ornamental fish, before North America and Asia. Data for 1993 show that total value of European Union ornamental fish imports was ECU67.6 million (Davenport 1996). In the U.K., ornamental fish species are the third most popular pets after cats and dogs. It is estimated that 3.5 million households (13% of the total) in the U.K. own ornamental fish.

Fishes introduced for ornamental reasons fall into two main categories. In the first are species such as the goldfish *Carassius auratus* that have been widely distributed for breeding in ornamental fishponds, from which it has frequently escaped to become established in natural waters. In the second category are the

numerous species of small, mostly tropical, species that have been widely dispersed in Europe by the flourishing aquarium fish trade.

Most of the introductions of fish species for ornament have been made by private individuals or have resulted from escapes into the wild. On this account, the date at which the introduction occurred is frequently unknown.

3.2. Sport

Introductions of fishes for sport fishing comprise those species (principally salmonids) valued for their fighting qualities and for their flesh. The most widely disseminated of these are the rainbow trout *Oncorhynchus mykiss* and, among centrarchids, the largemouth bass *Micropterus salmoides*. Several other species of lesser importance have also been introduced to provide diversity for the recreational angler.

Often the introduction of one species produces the need to introduce further species. Following introduction of major predators into fish communities which are not adapted to heavy predation the decline in native species is such that it has often been assumed to be necessary to introduce a forage species more closely adapted to survive along the predator.

3.3. Improvement of wild stocks

A range of motives are cited for introducing fish species for the improvement of wild stocks: to establish new food fisheries, to fill a "vacant niche", stocking natural waters, forage for predators, restoration of fisheries, establish a wild stock or control stunted species. The major motivation, however, is to introduce some element that is perceived as lacking to the fauna of a water body. This is usually termed to fill a "vacant niche" or some variant to it. Although not strictly in line with the niche concept, which sees the niche as a property of the organism, the idea of a vacant niche is used to describe the perception that there are resources within a water body which are not being used efficiently for lack of a suitable species. It usually applies in Europe in new habitats such as reservoirs or regulated rivers, where the native fauna lacks elements competent to establish themselves in the new water body.

The principal objective for the introduction of exotic fishes under this heading is the foundation of a new commercial or subsistence fishery. Introductions have also been made into newly created artificial habitats, man-made impoundments such as reservoirs, in which autochthonous species were unable to establish themselves.

3.4. Aquaculture

Alien species have played an important part in the development of aquaculture in Europe. The rearing of carp *Cyprinus carpio* in monastic fish-stews for fast-day food in early times paved the way for present day intensive commercial aquaculture of rainbow trout *Oncorhynchus mykiss* in Europe. Species originally introduced for aquaculture eventually escape from the confinement of their ponds often but not always to colonize natural waters. Therefore any introduction made for aquaculture must be thought of as a potential addition to the wild fauna in the receiving country.

The performance and possible impact of cultured fish in nature vary with both the life stage and the season of escape. In general, the earlier the fish escape, the better they perform as adults. Possible measures for reducing the impact of cultured fish include localization of the points of rearing, better containment, and development of cultured fish that do not reproduce in the wild. Domestication of cultured fish until they are unable to breed or survive in the wild may be an effective means of eliminating gene flow into wild populations.

3.5. Biological control

Fishes in this category were released for control of pest aquatic plants or insects. Unfortunately, many introductions were conducted without prior testing or further monitoring. If a fish introduced as a biological control reproduces in great number, it becomes a biological control "out of control".

For many years exotic fish have been used for the biological control of unwanted (pest) aquatic organisms, for which they have numerous advantages compared with the alternative of chemical control with its contaminant environmental dangers.

Early attempts in the 1920s concentrated on the control of mosquito larvae, for which the aptly named mosquitofishes *Gambusia affinis* and *Gambusia holbrooki* were the species most frequently used. Although in some places the results of introduction have been beneficial, the swarming habits have in many places disrupted the balance of the native fish fauna.

In the 1960s and 1970s, exotic herbivorous fishes began to be used to control aquatic vegetation. Several species, of which the grass carp *Ctenopharyngodon idella* is the prime example, have been introduced in Europe to control excessive growths of aquatic weeds. This species normally has the advantage that it does not breed in the waters to which is introduced thus permitting periodic adjustments in the number and sizes of fish present. The silver carp *Hypophthalmichthys molitrix* has been widely introduced specifically to control excessive growths of phytoplankton in natural waters.

3.6. Accident

Many of introductions into natural waters were unplanned and resulted from some form of accident or private initiative. The relatively large percentage of unintentional introductions illustrates the difficulty of containing an exotic species within limited environments such as ponds or aquaria. Other sources of new species can be the introduction of fry of non-target species along with those of a species whose introduction was intended, and the escape or release of baitfish. The high mobility of species once they have been introduced illustrates the need for international agreement to limit the spread of undesirable species and to reduce risks of introduction of ones that are judged to be useful.

The numerous cases of escapes or releases of species from captivity that have resulted in the establishment of naturalized populations have almost invariably proved ecologically and/or economically detrimental. After escapes or releases from captivity, natural diffusion via freshwater waterways is probably the most common means whereby alien species have spread to new countries. Thus, for example, the Eastern mudminnow *Umbra pygmaea* and North American catfishes (ictalurids) spread by diffusion in the lowland waters of northern Europe, while numerous small cyprinids introduced to waters in the Danube basin have spread throughout that river system.

Another fairly common accidental means by which aliens fishes are introduced outside their natural range is when species, most frequently cyprinids, are inadvertently transported with the juveniles of carp *Cyprinus carpio* or grass carp *Ctenopharyngodon idella*. In this way the stone moroko *Pseudorasbora parva* appeared in the River Danube, or the bleak *Alburnus alburnus* and silver bream *Abramis bjoerkna* in Cyprus.

4. Ecological impacts of naturalized fishes

Experiences throughout the world have shown that a number of problems may arise following the introduction of a new species. Elton (1958) seems to be the first who wrote a review of the ecological consequences of introduced species. Among vertebrates, introductions of freshwater fish species have been among the most numerous. Moyle *et al.* (1987) have labelled the impact of introduced fishes on native indigenous species as the “Frankenstein effect” because the effects of introductions tend to be negative in unpredictable ways.

The presence of an introduced species in an open environment necessarily involves an impact of some kind. Non-indigenous species may affect indigenous species by competing for resources, preying on native fauna, transferring pathogens, or significantly altering habitat. The introduction of a non-indigenous species may work synergistically with other factors, such as water diversions or pollution, to alter the population and distribution of indigenous species. The factors are often cumulative and/or complementary. For example, habitat degradation may make a species more vulnerable to the introduction of non-indigenous species.

The impact of most introductions of fishes in Europe is still unknown. Particularly with naturalized fishes, it is often difficult, or in some cases well nigh impossible, accurately to assign individual causes to specific impacts, because frequently more than on is involved. Although the effects of introductions are, in general, hard to predict, exotic fishes are most likely to become naturalized: a) in a mild climate, b) in disturbed or man-made habitats such as reservoirs and canals, and c) in communities with a low species diversity.

Unfortunately, a robust theory of invasion biology is not yet available (Townsend 1991). A theory which incorporates an understanding of likely ecological impacts would permit rational decisions about which species are safe to import and which accidental introductions should take priority in eradication efforts. A basic problem is that there are generally far too few data to demonstrate how introduced species affect native species.

4.1. Habitat alterations

Alterations in habitat composition by naturalized fishes involve principally the displacement of aquatic vegetation and the degradation of water quality. The former can be brought about by the consumption of plant material by herbivorous species, by the uprooting of macrophytes through digging for food or nesting sites, and by roiling and organic enrichment which increase turbidity and thus reduce light penetration and photosynthesis. Modification of aquatic plant communities can significantly affect native fishes and other animals.

Grass carp *Ctenopharyngodon idella* has been introduced in Europe to control aquatic vegetation, but by feeding selectively on tender species may enhance the development of tougher plants, which can prove an even greater problem. Although grass carp have proven to be an excellent biological control for aquatic vegetation, a risk exists that aquatic plants (including native forms) might become overly decimated as a result of grass carp predation which in turn would limit nursery areas for juvenile fishes, cause bank erosion, and accelerate eutrophication through release of nutrients previously stored in the plants. The introduction of the goldfish *Carassius auratus* has affected the ecosystem of the Lake Mikri Prespa, north-western Greece, by causing greatly increased turbidity (Crivelli 1995).

Concern about the destructive impact that naturalized fishes can have on water quality is confirmed by numerous records in the literature that document a correlation between habitat degradation and a reduction in the numbers and diversity of species in native freshwater fish faunas.

4.2. Trophic alterations

Naturalized fishes can alter trophic relationships in aquatic communities in at least three different ways, all of which may cause changes in the populations of native species. First, their presence may significantly increase the amount of prey available to native predators. Second, the feeding habits of naturalized fishes can reduce the amount of forage available to native species through a dietary overlap. Finally, naturalized predatory fishes can profoundly affect the population dynamics of indigenous prey species. Documentation of predation by introduced species on native species serves as the most definitive example of impacts on communities.

The reduction in the population of an autochthonous species can sometimes be difficult to attribute with certainty to predation or competition from an exotic, and on occasion both influences may act in concert. Salmonids have one of the worst records for damaging native species of fish. For example, rainbow trout *Oncorhynchus mykiss* has been at least partly responsible for the reduction of indigenous salmonids in Lake Ohrid, in the former Yugoslavia. Grass carp *Ctenopharyngodon idella* have significantly altered the food chains and trophic structure of aquatic systems by inducing changes in plant, invertebrate and fish communities.

The quality of fish stocks can also deteriorate by “stunting”, described by Welcomme (1988) as “a process whereby the population of a species expands rapidly, producing large numbers of individuals which mature and breed at a much reduced size”. This phenomenon occurs both in the wild and in captivity, and severely diminishes the sporting or commercial value of the species concerned. Species known to be subject to “stunting” include the bleak *Alburnus alburnus*, European perch *Perca fluviatilis* and silver bream *Abramis bjoerkna* in Cyprus; redbreast sunfish *Lepomis auritus*, pumpkinseed *Lepomis gibbosus* and catfishes (ictalurids) in France, Netherlands and Italy, and the stone moroko *Pseudorasbora parva* in the Danube basin and parts of the former USSR (Welcomme 1984).

4.3. Introduction of parasites, pathogens and diseases

Diseases caused by bacteria, viruses, and parasites are all too often conveyed along with introduced aquatic species. This aspect represents one of the most severe threats that an introduced species may pose to a native community.

The transfer of parasites from exotic to native fishes can have severe consequences for the native fishes because the native host and the exotic parasite have not had the evolutionary time to evolve an equilibrium relationship.

In contrast to other ecological effects, the importation of parasites, pathogens and diseases can be made via exotic fish never intended for release into the wild. Thus, nematode parasites of the genus *Anguillicola*, which is endemic to Australian and Asiatic *Anguilla* spp., have been introduced into Europe with oriental eels intended for human consumption and not for stocking purposes.

Many diseases of salmonids that infect hatchery-reared fish and also occur in wild populations have been imported. Rainbow trout *Oncorhynchus mykiss* from western North America have carried furunculosis to Europe. More recently, the North American fathead minnow *Pimephales promelas* has been proved to introduce *Yersinia ruckeri*, which is the causative agent of redmouth disease to parts of northern Europe. This disease can cause significant mortality in many species of fish.

One of the most notable disease problems in Europe in recent years has been the outbreak in Norway of the parasitic fluke *Gyrodactylus salaris* that has been spread by introductions from farmed salmonids to wild populations. It has been suggested that Norwegian wild stocks were unadapted to it and therefore had no resistance, but it is also suggested that the resistance of the wild stocks in Norway has been lowered genetically by the introduction of alien stocks from fish farms over the years.

The importation of pathogens that are not group specific is the greater risk associated with the introduction of exotic species. Pathogens are frequently more serious in atypical hosts, and thus occur when such hosts come in contact with typical hosts.

4.4. Genetic deterioration through hybridization

Fishes have, in general, a great potential for successful hybridization without sterility, and may produce long-lasting hybrids in the wild. Naturalized species may thus interbreed with either native congeners or with other introduced exotics. Under the pressures exerted through introduction, normal behaviour patterns may be abandoned and hybrids arise from species or genera that do not normally interbreed.

Hybridization between released and resident fishes involves genetic risks, which vary with the genetic characteristics of each population, the proportion of stocked to resident individuals and the potential for introgression following hybridization. The impacts can be significant and include loss of pure forms (biodiversity), reduced mating efficiency, less fit stocks through the loss of adapted gene complexes, disruption of migration (spawning and feeding) patterns, altered behaviour, changes in life-cycle timing, lower reproductive output and other effects.

Welcomme (1988) refers to the concern that has been evidenced in Europe about the translocation of hatchery reared brown trout *Salmo trutta* that are genetically inferior to wild-bred stock with which, if they escaped into the wild, they might interbreed. Machordom *et al.* (1999, 2000) found a current high level of introgression in brown trout populations in Spain after many years of stocking with allochthonous individuals.

When closely related species, whose specific integrity is maintained by geographic barriers, are involved, there is always a danger of hybridization. Thus in many of the glacial lakes of Europe the identity of local stocks has been confused by the naturalization of various *Coregonus* species.

A well known example of salmonid hybridization in Europe is between the marbled trout *Salmo marmoratus*, endemic to some rivers of the Adriatic basin, and the introduced brown trout *Salmo trutta*. Near a century after the first stocking of brown trout in 1906, the native marble trout has either disappeared, or has greatly declined and coexists with a high percentage of hybrids, and/or a high percentage of brown trout.

Fleming *et al.* (2000) found that invasions of farm Atlantic salmon *Salmo salar* in Norway have the potential for impacting on native population productivity, disrupting local adaptations and reducing the genetic diversity of wild salmon populations.

Genetic impacts of introductions and stocking can also occur without hybridization. Changes in the genetic structure of a population can occur due to a reduction in its size, reductions in numbers of its subpopulations or reductions in certain vulnerable phenotypes, due to competition, habitat alterations or predation following and introduction or transfer. There is, therefore, a close relationship between genetic and ecological impacts of any movement.

4.5. Environmental effects

It is axiomatic that the more diverse the autochthonous fish community and the more complex the limnological ecosystem into which an alien species is introduced, the less will be its immediate significance. The most successful naturalized fishes are usually established where indigenous fish communities are either comparatively fragile or are composed of relatively few species, or which are already under the influence of overfishing or environmental disturbance.

The effects of introductions of aquatic organisms on the environment are frequently surprising especially as the new species may adopt a niche that differs completely from the occupied in its native range.

Apart from disease related effects which may be independent, serious impacts on the environment can be anticipated from two main classes of species: those whose reproductive pattern enables them to form stunted populations, and major predators, especially where these are introduced into communities which lack ichthyophages.

Proper fishery management must be based on the best available knowledge of aquatic ecology, fishery biology and ichthyology, and not on the “introduce anything” psychology that has developed over more than a century.

4.6. Socio-economic effects

In addition to the ecological impact of naturalized fishes outlined above, some species have also on occasion been of socio-economic significance. This is specially so when a naturalized species not favoured for human consumption replaces a popular food species. This phenomenon commonly occurs in not developed countries and is still rare in Europe.

4.7. Loss of biodiversity

Courtenay & Moyle (1992) called fish introductions “crimes against biodiversity”. Fish assemblages receiving an introduction may be altered through competition between the new and the existing faunistic elements, by direct predation on the native species, or by other aggressive effects.

Some introductions have proved so effective that the new species has been able to out compete existing fishes resulting in a considerable reduction in their populations or even in their complete disappearance. For instance, redbreast sunfish *Lepomis auritus* has supplanted the native bleak *Alburnus alburnus* in some Italian oligotrophic lakes.

One of the recurrent themes in reports on the impact of introductions is the elimination by predation of local species. These are sometimes localized in distribution and sufficiently rare as to cause concern for possible extinctions. One predator that has been blamed for the disappearance of local species is the largemouth bass *Micropterus salmoides*. The effects of predation by this species have possibly been avoided in some water bodies by the contemporaneous introduction of forage fish such as *Lepomis* species. The mosquito fish *Gambusia* has been called the “fish destroyer”, and is said to replace native species aggressively.

5. Management of invasive and nuisance introduced fishes

Any attempts to control or eliminate a problematic non-indigenous species are futile or require tremendous expense if actions are delayed until after a species is already firmly established. Prevention and public awareness is a first objective, always better than measures of control or eradication.

5.1. Prevention and public awareness

Potential risks related to intentional introductions of non-indigenous species are reduced by careful consideration of an introduction before it occurs. As a means of evaluating proposed introductions, a number of protocols have been developed. Examples of protocols that may serve as guidelines for

satisfactorily addressing environmental concerns include the ICES Code of Practice (ICES 1984), the American Fisheries Society protocol (Kohler & Courtenay 1986), and others.

There is broad consensus that while non-indigenous species issues were extremely important, in general they were poorly recognized and not well understood. Consequently, "education and extension" and "research" are by far the most widely supported concepts.

Environmental agencies should support the development of education and extension programs that promote or enhance: 1) general awareness of non-indigenous species issues, 2) understanding of the risks associated with introductions and how to minimize them, 3) understanding and enforcement of existing authorities, and 4) the preferred use of indigenous species.

Education may be the most effective means of reducing the risk associated with specific introduction pathways, e.g., aquarium and baitfish releases. This education is not solely the responsibility of Public Administrations, either financially or otherwise. Industries should make an effort to inform end users of the consequences of inappropriate use or disposal of their products. The case of baitfish introductions illustrates how education has the potential to reduce the risk of introductions. To deal with such a problem, the most appropriate measure may be to seek an improvement in angler ethics through an educational programme to help anglers understand why the release of live baitfish can be costly and environmentally unsound. End users be reached by providing educational materials through pet stores for aquarium organisms and with fishing licenses in the case of baitfish.

People in all walks of life must be made more aware of the extent to which introductions have been carried out, of the need for study and careful documentation of any authorized in future, and of the potential for irreversible environmental impact of even a single unwise exotic fish species.

Information and education are critical components of any effort to prevent the spread of the introduced fish species. There is great value in co-ordinating information/education efforts within and among European countries, and in using the diversity of creativity, expertise, and brainpower within a region or country to develop effective information and education products and recommendations. To prevent introduction and spread of fish nuisance species, pathways of introduction and dispersal must be interrupted. A very important tool to do this is education to change common behaviours, ensuring that all aquaculture operators, bait dealers, commercial fishing operators, aquarium hobbyists, and anglers take preventative actions. An additional relevant objective is to inform and to educate user groups and decision-makers on the environmental negative impacts of introduced species, and to involve policy makers on the need for significant increased funding to mitigate these impacts.

5.2. Eradication versus control

To protect native biodiversity, management of freshwater exotic species should be targeted on lakes or drainages that are both vulnerable to colonization by an exotic, and that harbour endemic species. Management should focus on preventing introduction because eradication after establishment is usually not possible.

The application of a piscicide is the only method other than complete dewatering that will extirpate entire populations of fishes. Complete elimination of fish is often needed to accomplish the critical fish management activities of removing nuisance exotic species, in order to restore threatened and endangered species. Fisheries managers for more than 50 years have used rotenone in North America as a management tool. Eradication of exotic fish is one of the most common uses of rotenone by North American fish and wildlife agencies (McClay 2000). Despite the importance of rotenone in fisheries management, its continued availability and use are uncertain. Most rotenone treatments have occurred without incident; however, putting any chemical into water, especially one that kills fish, can create controversy.

Although gill netting is likely to be more expensive and time consuming than rotenone application, it is also a viable alternative under some conditions and should be the method of choice when sensitive native species are present.

5.3. Control programmes

The control of a pest species, in the sense of holding its density at a reduced level, is essentially a sustained-yield operation where the yield is not used. Control of aliens may be defined as a management action designed to restore an altered system to its previous state by reducing numbers of introduced nuisance species. The action ought to be temporary. Control is not itself an objective, it is

simply a management action. Control operations must have clear objectives framed in terms of damage mitigation. Their success must be measured by how closely those objectives are met, not by the number of fishes killed.

Control methods can be divided into those aimed at directly increasing mortality; those aimed at directly reducing fertility, and those that act indirectly to manipulate mortality, fertility, or both. The success of an operation is not gauged by the reduction in the density of the target species but by the reduction in the deleterious effects of the target species. In all cases the prime responsibility is to determine whether the control adequately reduces deleterious effects of alien.

5.4. Integrated control strategies

To mitigate the negative impacts of introduced fish species will require continued co-operation within governments, academia, and the private sector. As funding becomes tighter, it will have to make tougher decisions about what to support and what not to support. As a result, the three C´s (Communication, Collaboration, and Co-operation) will be necessary and will be rewarded as never before. Everybody must work even harder to help the public decision-makers understand the magnitude of the current and future impacts and changes caused by introduced species.

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Appendix 1. Terminology relating to the fish introductions

Acclimatization. Living in the wild in an alien environment or climate with the support of and dependent on man.
Adventive. An introduced species which is not as yet established in the wild.
Alien. See Exotic.
Allochthonous. See Exotic.
Autochthonous. See Native.
Colonization. See Naturalization.
Established species. A species with existing naturally reproductive populations.
Establishment. See Naturalization.
Exotic. A species native to an area outside of, or foreign to, the geographic area under discussion. An introduced species.
Feral. A species that has reverted to the wild from domestication. The term "feral" should never be used to describe the naturalization of a wild species.
Hybridization. The process of interbreeding between two different species, either in the wild or under artificial conditions.
Indigenous. See Native.
Introduced species. See Exotic.
Introduction. The deliberate or accidental release of a species into a region in which it is not known to have occurred within historic times. The movement by man, whether deliberate or accidental, of living organisms to a new location outside their recent geographic range.
Introgression. The entry or introduction of a gene from one gene complex (pool) into another.
Invasive. An introduced species, not necessarily one that has had a negative ecological impact.
Maintained species. A species that must be maintained artificially (no natural reproduction) in the environment into which it was introduced or transferred.
Native. A species that is a member of the natural biotic community.
Naturalization. The introduction of species to regions where they were not indigenous, but in which they may flourish under the same conditions as those that are native. More particularly, the establishment of self-maintaining and self-perpetuating populations unsupported by and independent of man of an introduced species in a free-living state in the wild.
Non-indigenous species. See Exotic.
Reintroduction. The deliberate release by man of a species into a geographic area in which it was indigenous in historic times but where it subsequently became extinct.
Restocking. The deliberate release by man of a species into an area where it already occurs, with the intention of augmenting the existing population of that species.
Stocking. The repeated injection of individuals of a species into an ecosystem from one external to it. Stocked species may either be already native to the recipient water body or may be exotic to it.
Transfer. The deliberate or accidental movement by man of individuals of a species within its geographic range.
Transferred species. A species deliberately or accidentally transported and released within its geographic range.
Translocation. The deliberate or accidental movement by man of a species from an area where it is established, as either native or alien, to another area within the same national geographic range.
Transplantation. See Translocation.

Appendix 2. Exotic freshwater fishes introduced in European waters

Acipenseridae	*Acipenser baerii*	Siberian sturgeon
Polyodontidae	*Polyodon spathula*	Mississippi paddlefish
Cyprinidae	*Carassius auratus*	Goldfish
	Ctenopharyngodon idella	Grass carp
	Hypophthalmichthys molitrix	Silver carp
	Hypophthalmichthys nobilis	Bighead carp
	Mylopharyngodon piceus	Black carp
	Parabramis pekinensis	White amur bream
	Pimephales promelas	Fathead minnow
	Pseudorasbora parva	Stone moroko
Catostomidae	*Ictiobus bubalus*	Smallmouth buffalo
	Ictiobus cyprinellus	Bigmouth buffalo
	Ictiobus niger	Black buffalo
Cobitidae	*Misgurnus anguillicaudatus*	Oriental weatherfish
Ictaluridae	*Ameiurus melas*	Black bullhead
	Ameiurus natalis	Yellow bullhead
	Ameiurus nebulosus	Brown bullhead
	Ictalurus punctatus	Channel catfish
Salmonidae	*Oncorhynchus kisutch*	Coho salmon
	Oncorhynchus mykiss	Rainbow trout
	Salvelinus fontinalis	Brook trout
Umbridae	*Umbra pygmaea*	Eastern mudminnow
Atherinidae	*Odontesthes bonariensis*	Pejerrey
Adrianichthyidae	*Oryzias latipes*	Japanese rice fish
Fundulidae	*Fundulus heteroclitus*	Mummichog
Poeciliidae	*Gambusia affinis*	Mosquitofish
	Gambusia holbrooki	Eastern mosquitofish
	Poecilia reticulata	Guppy
	Poecilia sphenops	Molly
Gasterosteidae	*Culaea inconstans*	Brook stickleback
Centrarchidae	*Ambloplites rupestris*	Rock bass
	Lepomis auritus	Redbreast sunfish
	Lepomis cyanellus	Green sunfish
	Lepomis gibbosus	Pumpkinseed
	Micropterus dolomieui	Smallmouth bass
	Micropterus salmoides	Largemouth bass
Cichlidae	*Cichlasoma facetum*	Chameleon cichlid
Odontobutidae	*Perccottus glenni*	Amur sleeper
Gobiidae	*Neogobius fluviatilis*	Monkey goby
	Neogobius melanostomus	Round goby

Appendix 3. Selected references of freshwater fish introductions in European countries

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Appendix 4. Allochthonous fish species introduced in European countries

Albania

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Probably yes
Carassius auratus	Goldfish	Peshk i kuq	Yes
Ctenopharyngodon idella	Grass carp		Probably no
Cyprinus carpio	Carp	Krapi	Yes
Gambusia affinis	Mosquitofish	Barkaleci	Yes
Hypophthalmichthys molitrix	Silver carp		Probably no
Hypophthalmichthys nobilis	Bighead carp	Ballgjeri laraman	Probably yes
Oncorhynchus mykiss	Rainbow trout	Trofta ylberi	Probably yes
Parabramis pekinensis	White Amur bream		Probably no
Poecilia reticulata	Guppy	Lareza tripikaloshe	Probably yes
Pseudorasbora parva	Stone moroko		Yes

Austria

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish		Yes
Ctenopharyngodon idella	Grass carp		Probably no
Gasterosteus aculeatus	Three-spined stickleback	Stichling	Yes
Lepomis gibbosus	Pumpkinseed	Sonnenbarsch	Yes
Micropterus dolomieui	Smallmouth bass		Probably no
Micropterus salmoides	Largemouth bass	Forellenbarsch	Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Pseudorasbora parva	Stone moroko		Yes
Pungitius pungitius	Ninespine stickleback		Probably no
Salvelinus fontinalis	Brook trout		Yes

Azerbaijan

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Pseudorasbora parva	Stone moroko		Yes

Belarus

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish	Zolotaja rybka	Yes
Ctenopharyngodon idella	Grass carp		?
Cyprinus carpio	Carp	Sazan	Yes
Lepomis gibbosus	Pumpkinseed	Soletschnaja pyba	Yes
Micropterus salmoides	Largemouth bass	Bolsherotnyi amerikanskii tscherny okun	Yes

Belgium

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Yes
Carassius auratus	Goldfish	Poisson rouge	Yes
Coregonus lavaretus	Common whitefish		Yes
Coregonus nasus	Broad whitefish		Yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Yes
Cyprinus carpio	Carp	Carpe	Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Lepomis gibbosus	Pumpkinseed	Perche-soleil	Yes
Leucaspius delineatus	Belica	Able de Heckel	Yes
Micropterus dolomieui	Smallmouth bass	Black-bass à petite bouche	Yes
Micropterus salmoides	Largemouth bass	Forellenbaars	Yes
Oncorhynchus kisutch	Coho salmon		Probably yes
Oncorhynchus mykiss	Rainbow trout		Probably yes
Oreochromis niloticus	Nile tilapia		Probably no
Pimephales promelas	Fathead minnow		Yes
Salvelinus fontinalis	Brook trout	Bronforel	Probably yes
Silurus glanis	Wels catfish		Probably no
Umbra pygmaea	Eastern mudminnow		Yes

Bulgaria

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish	Zlatnakarracuda	Yes
Ctenopharyngodon idella	Grass carp		Probably no
Hypophthalmichthys nobilis	Bighead carp		Probably yes
Lepomis gibbosus	Pumpkinseed		Yes
Oncorhynchus mykiss	Rainbow trout		Probably yes
Pseudorasbora parva	Stone moroko		Yes
Salvelinus fontinalis	Brook trout	Siven	Probably yes

Croatia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius carassius	Crucian carp		Yes
Ctenopharyngodon idella	Grass carp		Probably yes
Cyprinus carpio	Carp	Krapi	Yes
Misgurnus fossilis	Weatherfish		Probably yes
Rhodeus sericeus	Bitterling		Probably yes
Sander lucioperca	Zander		Probably yes
Silurus glanis	Wels catfish		Probably yes

Cyprus

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Abramis bjoerkna	White bream		Yes
Alburnus alburnus	Bleak		Yes
Aspius aspius	Asp		Probably yes
Carassius auratus	Goldfish		Yes
Carassius carassius	Crucian carp		Yes
Cyprinus carpio	Carp		Yes
Gambusia affinis	Mosquitofish		?
Hypophthalmichthys molitrix	Silver carp		Yes
Ictalurus punctatus	Channel catfish		Probably yes
Micropterus salmoides	Largemouth bass		Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Oreochromis aureus	Blue tilapia		Pobably yes
Oreochromis niloticus	Nile tilapia		Pobably no
Perca fluviatilis	European perch		Yes
Rutilus rutilus	Roach		Yes
Salmo trutta	Trout		Probably yes
Salvelinus alpinus	Charr		Probably yes
Sander lucioperca	Zander		?
Silurus glanis	Wels catfish		Probably no
Tinca tinca	Tench		?

Czech Republic

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish		Yes
Channa warpachowskii	Amur snakehead		Probably no
Clarias gariepinus	North African catfish		Probably no
Coregonus albula	Vendace		Probably no
Coregonus lavaretus	Common whitefish		Yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Probably yes
Cyprinus haematopterus	Amur carp		Probably no
Gasterosteus aculeatus	Three-spined stickleback		Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Hypophthalmichthys nobilis	Bighead carp		Probably yes
Ictalurus punctatus	Channel catfish		Probably yes
Ictiobus cyprinellus	Bigmouth buffalo		Probably no
Lepomis gibbosus	Pumpkinseed		Yes
Micropterus dolomieui	Smallmouth bass		Probably no
Micropterus salmoides	Largemouth bass		Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Oreochromis mossambicus	Mozambique tilapia		Probably no
Oreochromis niloticus	Nile tilapia		Probably no
Oreochromis hornorum	Wami tilapia		Probably no
Poecilia reticulata	Guppy		Probably no
Poecilia sphenops	Molly		Probably no
Pseudorasbora parva	Stone moroko		Yes
Sander lucioperca	Zander		Yes
Thymallus arcticus	Arctic grayling		?
Xiphophorus hellerii	Green swordtail		Probably no

Denmark

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead	Dværgmalle	Yes
Carassius auratus	Goldfish	Guldfisk, Sølvkaruds	Yes
Carassius gibelio	Prussian carp		Yes
Coregonus peled	Peled	Stor Svævhelt	Probably no
Cyprinus carpio	Carp	Karpe	Yes
Hypophthalmichthys molitris	Silver carp		Probably no
Hypophthalmichthys nobilis	Bighead carp		Yes
Micropterus dolomieui	Smallmouth bass	Småmundet black bass	Probably no
Micropterus salmoides	Largemouth bass	Stormundet black bass	Probably no
Oncorhynchus mykiss	Rainbow trout	Ørred, Regnbueørred	Yes
Salvelinus alpinus	Charr		Probably no
Salvelinus fontinalis	Brook trout	Kildeørred	Yes
Salvelinus namaycush	Lake trout	Amerikansk søørred	Probably no
Sander lucioperca	Zander	Sandart	Yes
Silurus glanis	Wels catfish		Probably yes
Umbra pygmaea	Eastern mudminnow	Lille hundefisk	Yes

Estonia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish		Yes
Coregonus peled	Peled		Probably no
Ctenopharyngodon idella	Grass carp		?
Cyprinus carpio	Carp		Probably yes
Lepomis gibbosus	Pumpkinseed		?
Micropterus salmoides	Largemouth bass		?
Oncorhynchus mykiss	Rainbow trout		Probably yes

Finland

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Acipenser ruthenus	Sterlet		Probably no
Ameiurus nebulosus	Brown bullhead		Yes
Catostomus catostomus	Longnose sucker	Imukarppi	Probably no
Coregonus peled	Peled	Peledsiika	Yes
Ctenopharyngodon idella	Grass carp	Ruohokarppi	Yes
Culaea inconstans	Brook stickleback	Viisipiikki	Yes
Leucaspius delineatus	Belica	Allikkosalakka	Yes
Oncorhynchus gorbuscha	Pink salmon	Kyttyrälohi	Probably yes
Oncorhynchus mykiss	Rainbow trout	Kirjolohi	Probably no
Salvelinus fontinalis	Brook trout	Puronieriä	Probably yes
Salvelinus namaycush	Lake trout	Harmaanieriä	Probably no

France

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ambloplites rupestris	Rock bass	Crapet de roche	Yes
Ameiurus melas	Black bullhead	Poisson-chat	Yes
Ameiurus nebulosus	Brown bullhead	Poisson-chat	Yes
Aspius aspius	Asp		Probably yes
Carassius auratus	Goldfish	Carassin doré	Yes
Carassius carassius	Crucian carp	Carassin	Yes
Coregonus albula	Vendace	Corégone blanc	Yes
Coregonus peled	Peled		Probably no
Cyprinus carpio	Carp	Carpe commune	Yes
Gambusia affinis	Mosquitofish	Gambusie	Yes
Gambusia holbrooki	Eastern mosquitofish	Gambusie	Yes
Hucho hucho	Huchen	Huchon	Probably no
Hypophthalmichthys molitrix	Silver carp	Carpe argentée	Probably yes
Lepomis gibbosus	Pumpkinseed	Perche soleil	Yes
Leuciscus idus	Ide	Ide mélanote	Yes
Micropterus salmoides	Largemouth bass	Black-bass à grande bouche	Yes
Oncorhynchus kisutch	Coho salmon	Saumon argenté	Yes
Oncorhynchus mykiss	Rainbow trout	Truite arc-en-ciel	Yes
Pimephales promelas	Fathead minnow		Yes
Pseudorasbora parva	Stone moroko	Pseudorasbora	Yes
Salvelinus fontinalis	Brook trout		Yes
Salvelinus namaycush	Lake trout	Cristivomer	Probably no
Umbra pygmaea	Eastern mudminnow		Yes
Vimba vimba	Baltic vimba		Yes

Germany

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead	Schwarzer Zwergwels	Probably yes
Ameiurus nebulosus	Brown bullhead	Zwergwels	Yes
Carassius auratus	Goldfish	Goldfisch	Yes
Carassius gibelio	Prusian carp	Giebel	Probably no
Coregonus lavaretus	Common whitefish	Blaufelchen	Yes
Coregonus peled	Peled	Peledmaräne	Yes
Cyprinus carpio	Carp	Karpfen	Yes
Hypophthalmichthys molitrix	Silver carp	Silberkarpfen	Probably yes
Lepomis auritus	Redbreast sunfish		Yes
Lepomis cyanellus	Green sunfish		Yes
Lepomis gibbosus	Pumpkinseed	Sonnenbarsch	Yes
Micropterus dolomieui	Smallmouth bass		Probably yes
Micropterus salmoides	Largemouth bass		Probably yes
Mylopharyngodon piceus	Black carp		Probably no
Oncorhynchus mykiss	Rainbow trout	Regenbogenforelle	Yes
Pimephales promelas	Fathead minnow		Yes
Pseudorasbora parva	Stone moroko	Blaubandbärbling	Yes
Salvelinus fontinalis	Brook trout	Bachsaibling	Yes
Salvelinus namaycush	Lake trout		Yes
Sander lucioperca	Zander	Zander	Yes
Umbra pygmaea	Eastern mudminnow	Amerikanischer Hundsfisch	Yes

Greece

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish	Cheisopsaro	Probably yes
Carassius carassius	Crucian carp		Probably yes
Coregonus lavaretus	Common whitefish		Probably yes
Cyprinus carpio	Carp	Cyprinos	Yes
Gambusia affinis	Mosquitofish		Yes
Hypophthalmichthys molitrix	Silver carp		Probably yes
Hypophthalmichthys nobilis	Bighead carp		Probably no
Lepomis gibbosus	Pumpkinseed		Yes
Oncorhynchus mykiss	Rainbow trout	Pestropha	Probably yes
Parabramis pekinensis	White Amur bream		Probably no
Pseudorasbora parva	Stone moroko		Yes

Hungary

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Yes
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish	Aranyhal	Yes
Colossoma macropomum	Tambaqui		?
Coregonus lavaretus	Common whitefish		Probably no
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Yes
Gambusia affinis	Mosquitofish		Yes
Gasterosteus aculeatus	Three-spined stickleback	Tükes pikó	Yes
Hypophthalmichthys molitrix	Silver carp	Fehér busa	Yes
Hypophthalmichthys nobilis	Bighead carp		Yes
Ictiobus bubalus	Smallmouth buffalo		Probably no
Lepomis gibbosus	Pumpkinseed	Naphal	Yes
Micropterus salmoides	Largemouth bass	Fekete sügér	Yes
Neogobius fluviatilis	Monkey goby	Folyami géb	Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Poecilia reticulata	Guppy		Probably yes
Poecilia sphenops	Molly		Yes
Pseudorasbora parva	Stone moroko	Kinai razbóra	Yes
Salvelinus fontinalis	Brook trout	Pataki szajbling	Probably yes
Xiphophorus hellerii	Green swordtail		Probably yes

Iceland

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Oncorhynchus gorbuscha	Pink salmon	Bleiklax, Hnúolax	Probably yes

Ireland

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Probably yes
Ameiurus nebulosus	Brown bullhead		Yes
Barbatula barbatula	Stone loach	Cailleach Rua	Yes
Cyprinus carpio	Carp	Carban	Yes
Esox lucius	Northern pike	Lius	Yes
Gobio gobio	Gudgeon	Bronnòg	Yes
Leuciscus leuciscus	Common dace	Deas	Yes
Oncorhynchus gorbuscha	Pink salmon		Probably yes
Oncorhynchus mykiss	Rainbow trout		Probably yes
Rutilus rutilus	Roach	Roiste	Yes
Tinca tinca	Tench	Curaman	Yes

Italy

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Abramis bjoerkna	White bream		Probably yes
Abramis brama	Carp bream	Abramide	Probably yes
Acipenser transmontanus	White sturgeon	Storione bianco	Probably yes
Ameiurus melas	Black bullhead	Pesce gatto	Yes
Ameiurus natalis	Yellow bullhead	Pesce gatto	Yes
Ameiurus nebulosus	Brown bullhead	Pesce gatto	Probably yes
Barbus barbus	Barbel		Probably yes
Barbus cyclolepis			Probably yes
Carassius auratus	Goldfish	Carassio dorato	Yes
Carassius carassius	Crucian carp		Probably no
Chondrostoma nasus	Sneep		Probably yes
Coregonus lavaretus	Common whitefish		Yes
Cyprinus carpio	Carp	Carpa	Yes
Gambusia affinis	Mosquitofish	Gambusia	Yes
Gambusia holbrooki	Eastern mosquitofish	Gambusia	Yes
Gasterosteus aculeatus	Three-spined stickleback	Spinarello	Yes
Gymnocephalus cernuus	Ruffe	Acerina	Probably yes
Hypophthalmichthys molitrix	Silver carp	Carpa argentata	Yes
Hypophthalmichthys nobilis	Bighead carp	Carpa dalla testa grande	Yes
Ictalurus punctatus	Channel catfish	Pesce gatto punteggiato	Probably no
Lepomis auritus	Redbreast sunfish		Yes
Lepomis gibbosus	Pumpkinseed	Persico sole	Yes
Micropterus salmoides	Largemouth bass	Persico trota	Yes
Oncorhynchus mykiss	Rainbow trout	Trota iridea	Probably no
Odontesthes bonariensis	Pejerrey	Pesce re	Yes
Pachychilon pictum			Yes
Poecilia reticulata	Guppy		Probably no
Pseudorasbora parva	Stone moroko	Pseudorasbora	Yes
Rhodeus sericeus	Bitterling		Yes
Rutilus rutilus	Roach	Rutilo	Probably yes
Salvelinus fontinalis	Brook trout	Salmerino di fonte	Yes
Salvelinus namaycush	Lake trout		Probably no
Sander lucioperca	Zander	Lucioperca	Yes
Silurus glanis	Wels catfish		Yes

Kazakhstan (European territory)

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ctenopharyngodon idella	Grass carp		Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Knipowitschia caucasica			Yes
Mylopharyngodon piceus	Black carp		Yes
Neogobius fluviatilis	Monkey goby		Yes
Neogobius melanostomus	Round goby		Yes
Pseudorasbora parva	Stone moroko		Yes

Latvia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Acipenser gueldenstaedtii	Russian sturgeon		Probably no
Carassius auratus	Goldfish	Zolotaja rybka	Yes
Coregonus muksun	Muksun		Probably no
Coregonus peled	Peled		Yes
Cyprinus carpio	Carp	Sazan	Probably yes
Hypophthalmichthys molitrix	Silver carp		Probably no
Lepomis gibbosus	Pumpkinseed	Soletschnaja pyba	Yes
Micropterus salmoides	Largemouth bass	Bolsherotnyi amerikanskii tscherny okun	Yes
Oncorhynchus gorbuscha	Pink salmon		Probably no
Oncorhynchus keta	Chum salmon		Probably no
Oncorhynchus kisutch	Coho salmon		Probably no

Liechtenstein

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Cyprinus carpio	Carp		Yes
Oncorhynchus mykiss	Rainbow trout		Probably no

Lithuania

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Acipenser ruthenus	Sterlet		Probably no
Carassius auratus	Goldfish		Yes
Cyprinus carpio	Carp		Yes
Lepomis gibbosus	Pumpkinseed		Yes
Micropterus salmoides	Largemouth bass		Yes
Oncorhynchus mykiss	Rainbow trout		Probably yes
Salvelinus fontinalis	Brook trout		?

Luxembourg

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Cyprinus carpio	Carp		Yes
Oncorhynchus mykiss	Rainbow trout		Probably yes

Malta

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Cyprinus carpio	Carp		Yes
Oreochromis mossambicus	Mozambique tilapia		Probably no

Moldova

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish		Yes
Ctenopharyngodon idella	Grass carp		Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Lepomis gibbosus	Pumpkinseed		Yes
Mylopharyngodon piceus	Black carp		Yes
Pseudorasbora parva	Stone moroko		Yes

Netherlands

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead	Zwarte amerikaanse dwergmeerval	Yes
Ameiurus nebulosus	Brown bullhead	Bruine amerikaanse dwergmeerval	Yes
Carassius auratus	Goldfish	Goudvis	Yes
Clarias gariepinus	North African catfish		Probably no
Cyprinus carpio	Carp	Karper	Yes
Hypophthalmichthys molitrix	Silver carp	Zilverkarper	Probably no
Hypophthalmichthys nobilis	Bighead carp	Grootkopkarper	Probably yes
Lepomis gibbosus	Pumpkinseed	Zonnebaars	Yes
Leuciscus idus	Ide	Winde	Probably yes
Micropterus salmoides	Largemouth bass	Forelbaars, Zwarte baars	Probably yes
Oncorhynchus kisutch	Coho salmon	Cohozalm	Probably yes
Oncorhynchus mykiss	Rainbow trout	Regenboogforel	Yes
Poecilia reticulata	Guppy	Gup	Yes
Sander lucioperca	Zander	Snoekbaars	Yes
Silurus glanis	Wels catfish	Meerval	Yes
Umbra pygmaea	Eastern mudminnow	Amerikaanse hondsvis	Yes
Vimba vimba	Baltic vimba	Blauwneus	Probably yes

Norway

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead	Dvergmalle	Probably yes
Carassius auratus	Goldfish	Gullfisk, Karuss	Probably yes
Cyprinus carpio	Carp	Karpe	Yes
Gobio gobio	Gudgeon		Yes
Leucaspius delineatus	Belica	Regnlaue	Yes
Oncorhynchus gorbuscha	Pink salmon	Pukkellaks	Probably yes
Oncorhynchus keta	Chum salmon	Ketalaks	Probably yes
Oncorhynchus mykiss	Rainbow trout	Regnbueørret	Yes
Salvelinus fontinalis	Brook trout	Bekkeror	Yes
Salvelinus namaycush	Lake trout	Canadaröye	Yes
Tinca tinca	Tench	Sudre, Suter	Yes

Poland

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Acipenser baerii	Siberian sturgeon	Jesiotr syberyjski	Yes
Acipenser ruthenus	Sterlet		Probably yes
Ameiurus melas	Black bullhead		Yes
Ameiurus nebulosus	Brown bullhead	Sumik karlowaty	Yes
Carassius auratus	Goldfish	Karas zlocisty	Yes
Coregonus peled	Peled	Peluga	Yes
Ctenopharyngodon idella	Grass carp	Amur bialy	Yes
Cyprinus carpio	Carp	Karp	Yes
Hucho hucho	Huchen		Probably no
Hypophthalmichthys molitrix	Silver carp	Tolpyga biala	Yes
Hypophthalmichthys nobilis	Bighead carp	Tolpyga pstra	Probably yes
Ictiobus niger	Black buffalo		Probably yes
Lepomis gibbosus	Pumpkinseed	Bass sloneczny	Yes
Micropterus salmoides	Largemouth bass	Bass wielkgebowy	Probably yes
Oncorhynchus gorbuscha	Pink salmon	Gorbusza	Probably yes
Oncorhynchus mykiss	Rainbow trout	Pstrag teczowy	Yes
Pseudorasbora parva	Stone moroko	Kielb amurski	Yes
Salvelinus fontinalis	Brook trout	Pstrag zrodlany	Yes
Umbra pygmaea	Eastern mudminnow	Mulawka a. umbra	Probably yes

Portugal

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish	Peixe dourado	Yes
Cichlasoma facetum	Chameleon cichlid	Chanchito	Yes
Cyprinus carpio	Carp	Carpa	Yes
Esox lucius	Northern pike	Lúcio	Yes
Fundulus heteroclitus	Mummichog		Yes
Gambusia holbrooki	Eastern mosquitofish	Gambúsia	Yes
Gobio gobio	Gudgeon	Góbio	Yes
Lepomis gibbosus	Pumpkinseed	Perca-sol	Yes
Micropterus salmoides	Largemouth bass	Achiga	Yes
Oncorhynchus mykiss	Rainbow trout	Truta-arco-iris	Yes
Tinca tinca	Tench	Tenca	Yes

Romania

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish	Caras-auriu	Yes
Coregonus albula	Vendace	Coregon-mic	Probably yes
Coregonus lavaretus	Common whitefish	Coregon	Yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Yes
Gambusia affinis	Mosquitofish		Yes
Hypophthalmichthys molitrix	Silver carp	Crap-chinezesc-argintiu	Yes
Hypophthalmichthys nobilis	Bighead carp		Yes
Ictalurus punctatus	Channel catfish		Probably no
Ictiobus bubalus	Smallmouth buffalo		Probably yes
Ictiobus cyprinellus	Bigmouth buffalo		Probably yes
Ictiobus niger	Black buffalo		Probably yes
Lepomis gibbosus	Pumpkinseed	Biban-soare	Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Pseudorasbora parva	Stone moroko	Murgoi-baltat	Yes
Salvelinus fontinalis	Brook trout	Fintinel	Yes

Russia (European territory)

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Yes
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish	Chernyi teleskop	Yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Yes
Gambusia affinis	Mosquitofish		Yes
Hypophthalmichthys molitrix	Silver carp	Belyi tolstolob	Yes
Hypophthalmichthys nobilis	Bighead carp	Pestryi tolstolob	Yes
Ictiobus bubalus	Smallmouth buffalo		Yes
Ictiobus cyprinellus	Bigmouth buffalo		Yes
Ictiobus niger	Black buffalo		Yes
Lepomis gibbosus	Pumpkinseed	Vysokotelyi solnechnyi okun'	Yes
Micropterus salmoides	Largemouth bass	Bol'sherotyi chernyi okun'	Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Oreochromis aureus	Blue tilapia		Probably no
Oreochromis mossambicus	Mozambique tilapia		Probably no
Oreochromis ornorum	Wami tilapia		Probably no
Oryzias latipes	Japanese rice fish		Yes
Perccottus glenni	Amur sleeper		Yes
Polyodon spathula	Mississippi paddlefish	Veslonos	Probably yes
Pseudorasbora parva	Stone moroko		Yes
Sarotherodon melanotheron	Blackchin tilapia		Probably no
Tilapia guineensis			Probably no
Tilapia mariae	Spotted tilapia		Probably no
Tilapia zillii	Redbelly tilapia		Probably no

Slovakia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish		Yes
Channa warpachowskii	Amur snakehead		Probably no
Clarias gariepinus	North African catfish		Probably no
Coregonus albula	Vendace		Probably no
Coregonus lavaretus	Common whitefish		Yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Probably yes
Cyprinus haematopterus	Amur carp		Probably no
Gasterosteus aculeatus	Three-spined stickleback		Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Hypophthalmichthys nobilis	Bighead carp		Probably yes
Ictalurus punctatus	Channel catfish		Probably yes
Ictiobus cyprinellus	Bigmouth buffalo		Probably no
Lepomis gibbosus	Pumpkinseed		Yes
Micropterus dolomieui	Smallmouth bass		Probably no
Micropterus salmoides	Largemouth bass		Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Oreochromis mossambicus	Mozambique tilapia		Probably no
Oreochromis niloticus	Nile tilapia		Probably no

Oreochromis hornorum	Wami tilapia	Probably no
Poecilia reticulata	Guppy	Probably no
Poecilia sphenops	Molly	Probably no
Pseudorasbora parva	Stone moroko	Yes
Salvelinus fontinalis	Brook trout	Yes
Thymallus arcticus	Arctic grayling	?
Xiphophorus hellerii	Green swordtail	Probably no

Slovenia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead	Somic	Yes
Carassius auratus	Goldfish	Srebrni koreselj	Yes
Ctenopharyngodon idella	Grass carp	Beli amur	Yes
Gambusia affinis	Mosquitofish	Gambuzija	Yes
Hypophthalmichthys molitrix	Silver carp	Srebrni ali beli tolstolobik	Yes
Hypophthalmichthys nobilis	Bigheadcarp	Sivi ali pisani tolstolobik	Yes
Mylopharyngodon piceus	Black carp	Crni amur	Yes
Lepomis gibbosus	Pumpkinseed	Soncni ostriz	Yes
Oncorhynchus kisuth	Coho salmon	Srebrni losos	Yes
Oncorhynchus mykiss	Rainbow trout	Sarenka	Yes
Pseudorasbora parva	Stone moroko	Pseudorazbora	Yes
Salvelinus fontinalis	Brook trout	Potocna zlatovcica	Yes

Spain

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Abramis bjoerkna	White bream	Brema blanca	Yes
Alburnus alburnus	Bleak	Alburno	Yes
Ameiurus melas	Black bullhead	Pez gato negro	Yes
Aphanius fasciatus		Fartet oriental	Probably yes
Carassius auratus	Goldfish	Pez rojo	Yes
Cichlasoma facetum	Chameleon cichlid	Chanchito	Yes
Cyprinus carpio	Carp	Carpa	Yes
Esox lucius	Northern pike	Lucio	Yes
Fundulus heteroclitus	Mummichog	Fúndulo	Yes
Gambusia holbrooki	Eastern mosquitofish	Gambusia	Yes
Gobio gobio	Gudgeon	Gobio	Yes
Hucho hucho	Huchen	Huchón	Yes
Ictalurus punctatus	Channel catfish	Pez gato moteado	Probably no
Lepomis gibbosus	Pumpkinseed	Pez sol	Yes
Micropterus salmoides	Largemouth bass	Blacbás	Yes
Oncorhynchus kisutch	Coho salmon	Salmón plateado	Probably yes
Oncorhynchus mykiss	Rainbow trout	Trucha arco iris	Probably yes
Perca fluviatilis	European perch	Perca	Yes
Poecilia reticulata	Guppy	Gupi	Probably yes
Rutilus rutilus	Roach	Gardí	Yes
Salvelinus fontinalis	Brook trout	Salvelino	Yes
Sander lucioperca	Zander	Lucioperca	Yes
Scardinius erythrophthalmus	Rudd	Escardinio	Yes
Silurus glanis	Wels catfish	Siluro	Yes

Sweden

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Acipenser baerii	Siberian sturgeon	Sibirisk stör	Probably no
Acipenser gueldenstaedtii	Russian sturgeon	Rysk stör, Osetr	Probably no
Acipenser ruthenus	Sterlet	Sterlett	Probably no
Ameiurus nebulosus	Brown bullhead		Yes
Ctenopharyngodon idella	Grass carp	Gräskarp	Yes
Cyprinus carpio	Carp	Karp	Yes
Hypophthalmichthys molitrix	Silver carp	Silverkarp	Probably no
Hypophthalmichthys nobilis	Bighead carp		Probably no
Micropterus dolomieui	Smallmouth bass	Svartabborre	Probably yes
Micropterus salmoides	Largemouth bass	Öringsaborre	Probably yes
Oncorhynchus clarki	Cutthroat trout	Strupsnittsöring	Probably no
Oncorhynchus gorbuscha	Pink salmon	Puckellax	Probably no
Oncorhynchus mykiss	Rainbow trout	Regnbågslax	Probably yes
Oncorhynchus nerka	Sockeye salmon	Rödlax	Probably no
Salvelinus fontinalis	Brook trout	Bäckröding	Yes
Salvelinus namaycush	Lake trout	Kanadaröding	Probably no

Switzerland

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Yes
Cyprinus carpio	Carp	Carpe, Carpa, Karpfen	Yes
Lepomis gibbosus	Pumpkinseed	Perche soleil, Persico sole, Sonnenbarsch	Yes
Micropterus salmoides	Largemouth bass	Forellenbarsch, Persico trota	Yes
Oncorhynchus mykiss	Rainbow trout	Truite arc-en-ciel	Yes
Pseudorasbora parva	Stone moroko	Pseudorasbora	Probably yes
Salvelinus fontinalis	Brook trout	Bachsaibling, Salmerino di fontaine	Yes
Salvelinus namaycush	Lake trout	Amerikanische Seeforelle	Yes

Turkey

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Carassius auratus	Goldfish		Probably yes
Gambusia affinis	Mosquitofish		Probably yes
Gambusia holbrooki	Eastern mosquitofish		Yes
Nothobranchius guentheri	Redtail notho		?
Oncorhynchus mykiss	Rainbow trout	Alabalik türü	Yes
Sander lucioperca	Zander	Sudak baligi	Yes

U.K.

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ambloplites rupestris	Rock bass	Rock bass	Yes
Ameiurus melas	Black bullhead	Black bullhead	Yes
Ameiurus nebulosus	Brown bullhead	Brown bullhead	Yes
Carassius auratus	Goldfish	Goldfish	Yes
Carassius carassius	Crucian carp	Crucian carp	Yes
Catostomus commersoni	White sucker	White sucker	Probably no
Clarias batrachus	Walking catfish	Walking catfish	Probably no
Ctenopharyngodon idella	Grass carp	Grass carp	Probably yes
Cyprinus carpio	Carp	Carp	Yes
Hypophthalmichthys molitrix	Silver carp	Silver carp	Probably no
Ictalurus punctatus	Channel fish	Channel fish	Yes
Lepomis gibbosus	Pumpkinseed	Pumpkinseed	Yes
Leuciscus idus	Ide	Ide	Yes
Micropterus salmoides	Largemouth bass	Largemouth bass	Yes
Oncorhynchus gorbuscha	Pink salmon	Pink salmon	Probably no
Oncorhynchus mykiss	Rainbow trout	Rainbow trout	Yes
Oreochromis mossambicus	Mozambique tilapia	Mozambique tilapia	Probably no
Oreochromis niloticus	Nile tilapia	Nile tilapia	Probably no
Poecilia reticulata	Guppy	Guppy	Probably no
Pseudorasbora parva	Stone moroko	Stone moroko	Probably yes
Rhodeus sericeus	Bitterling	Bitterling	Yes
Salvelinus fontinalis	Brook trout	Brook trout	Yes
Sander lucioperca	Zander	Zander	Yes
Silurus glanis	Wels catfish	Wels catfish	Yes
Tilapia zillii	Redbelly tilapia	Redbelly tilapia	Probably yes

Ukraine

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus nebulosus	Brown bullhead	Kanalnyi somik	Yes
Carassius auratus	Goldfish	Karas, Zolotaja rybka	Yes
Coregonus albula	Vendace	Evropeiskaja riapushka	Yes
Coregonus nasus	Broad whitefish	Chir	?
Coregonus peled	Peled		?
Ctenopharyngodon idella	Grass carp	Belyi amur	Yes
Gambusia affinis	Mosquitofish	Gambuzija	Yes
Hypophthalmichthys molitrix	Silver carp	Belyi tolstolobik	Yes
Hypophthalmichthys nobilis	Bighead carp	Piestryi tolstolobik	Yes
Lepomis gibbosus	Pumpkinseed	Soletschnaja pyba	Yes
Micropterus salmoides	Largemouth bass	Bolsherotnyi amerikanskii tscherny okun	Yes
Mylopharyngodon piceus	Black carp	Chernyi Amur	Yes
Oncorhynchus mykiss	Rainbow trout		Yes
Pseudorasbora parva	Stone moroko	Tschebatschek	Yes

Yugoslavia

SPECIES	*COMMON NAME*	*LOCAL NAME*	*ESTABLISHED*
Ameiurus melas	Black bullhead		Yes
Ameiurus nebulosus	Brown bullhead		Yes
Carassius auratus	Goldfish		Yes
Coregonus lavaretus	Common whitefish		Probably yes
Coregonus peled	Peled		Yes
Ctenopharyngodon idella	Grass carp		Yes
Gambusia affinis	Mosquitofish		Yes
Hypophthalmichthys molitrix	Silver carp		Yes
Lepomis gibbosus	Pumpkinseed	Soncni ostriz	Yes
Micropterus salmoides	Largemouth bass		Yes
Oncorhynchus mykiss	Rainbow trout	Pastrva	Yes
Pseudorasbora parva	Stone moroko		Yes
Salvelinus alpinus	Charr	Barjaktarica	Yes
Salvelinus fontinalis	Brook trout	Kanadska pastrva	Probably yes