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AND NATURAL HABITATS

Action plans for *Margaritifera auricularia* and *Margaritifera margaritifera* in Europe

Authors
Dr. Rafael ARAUJO and Dr. Mª Ángeles RAMOS
Museo Nacional de Ciencias Naturales (CSIC)
José Gutiérrez Abascal, 2. 28006-Madrid, Spain
Tel 34-914111328, Fax 34 915645078
e-mail rafael@mncn.csic.es, m.ramos@mncn.csic.es

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GENERAL CONTENTS

Action plan for *Margaritifera auricularia* in Europe

CONTENTS

SUMMARY

Margaritifera auricularia is one of the most threatened invertebrates in Europe. Although some records of isolated specimens collected in recent years exist in the non-scientific literature, the species was thought probably to be extinct throughout most of its range (Council of Europe, 1996; Woodward, 1996). The most recent voucher specimens in museum collections are from Spain and Morocco.

The “discovery” of a population of around 2,000 specimens in the Canal Imperial de Aragón and of some specimens in the medium and lower Ebro river, all in Spain, as well as a few live specimens in the Loire basin in France, make it possible to design an action plan for species recovery.

This document deals with the initial part on *M. auricularia* description and identification, the second part concerns planned objectives to protect it, and the final part covers proposed conservation measures.

The causes of decline in the species are not completely known, but habitat alteration and fragmentation are probably the origin. The species needs a fish to host the metamorphosis of its larval stage, called glochidium. Thus, alterations to the habitat of the host fishes also work against the mussel.

As a freshwater animal, *M. auricularia*, is in constant conflict with people, mainly due to the large-scale engineering works for water exploitation (canalisation, dredging, regulation, impoundment, power plants, etc.). As a result of the severe conflicts that have arisen between conservationists and the water authorities a legislative framework must be developed in Spain to protect *M. auricularia* habitat that is the target of future macro-hydraulic works planned for the Ebro basin.

Maintaining the Canal Imperial de Aragón and protecting selected areas of the River Ebro are the main goals to protect the species, as they, especially the former, host the largest populations in its distribution area. In this report, the protection of these habitats is included as part of a comprehensive project for rational water use and sustainable development in the area, including the creation of natural parks, tourism, recreation (bathing, rafting, etc.), interpretation centres, experimental and educational irrigated fields, nacre workshops, etc.

Extremely interesting results for the satisfactory development of the action plan are being obtained thanks to a research project already in progress. With captive and assisted reproduction of adult mussels using suitable host fishes in addition to juvenile propagation and reintroduction, the proposed plan will attempt to spread new specimens of the species in selected habitat that it occupied in the past. Indeed, juvenile and adult mussels will be maintained in raceways and aquaria as the ultimate source of specimens. Reintroduction of stocks of the host fish species together with *M. auricularia* populations will lead to successful reproduction of the mussel in natural habitats, probably the best result that can be expected from an action plan.

1. INTRODUCTION

There is general agreement that the ecosystem-oriented and habitat conservation approaches are more far reaching and cost-effective for maintaining biodiversity than a species-by-species conservation approach. Nevertheless, in the case of many animal species, protection and habitat preservation may be insufficient to halt population decline and save threatened species from extinction (Cade & Temple, 1995 in Machado, 1997). The need to promote action plans for the recovery of threatened species is acknowledged in the framework of the United Nations Convention on Biodiversity (1992), the Bern Convention (1979 and subsequent recommendations), the "Habitats Directive" (Directive 92/43 EEC), the Pan-European Biological and Landscape Diversity Strategy (1995), etc. The moral obligation in recovery efforts is greater for regions or countries where particular species are restricted as a matter of international solidarity and public affairs (Machado, 1997). Such is the case of *Margaritifera auricu - laria* (Spengler, 1793), the giant European freshwater pearl mussel, one of the two *Margaritifera* species currently living in Europe, and which is considered to be one of the most threatened animal species in the world.

In the background information on invertebrates of the Habitats Directive and the Bern Convention, the status of *M. auricularia* is reported as "at least vulnerable, probably extinct throughout most of its range". The species is listed on Appendix IV of the EEC Habitats Directive, which includes animal and plant species of European interest requiring strict protection, and on Appendix II of the Bern Convention, which includes strictly protected animal species and their habitats. Indeed, in the Recommendation number 51 the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats (December, 6th, 1996) considered *M. auricularia* as a first priority species requiring an Action Plan (Council of Europe, 1999).

Available information on this species is scarce compared with data available on the congeneric species *Margaritifera margaritifera*, other threatened naiad living in Europe but with worldwide distribution. Thanks to the papers of the German malacologist Fritz Haas, who found a population of *M. auricula - ria* in Spain in 1916, we know that the species was very abundant in the River Ebro on a 70-120 metre-wide section of the river among stones and boulders with a predilection for deep bottoms (5-7 m), as well as in one of its channels, the Canal Imperial de Aragón, and that the nacre of the empty valves was collected to manufacture knife hilts (Haas, 1916, 1917). Due to the fact that the populations of the species in the main course of the River Ebro have been declining for many years, the specimens currently living in the Canal Imperial (Araujo & Ramos, 1996a, b, c, 1998a, b; Ramos, 1998a), in the medium (pers. obs.) and lower river (Altaba, 1997) and in the Loire basin (Cochet, 1996; Nienhuis, pers. com.; Bacchi and Gilbert, pers. com.) are the last representatives of a species that may disappear even before its biology is fully known.

Freshwater mussels can live in large numbers and their filter feeding ability makes them a very important part of the secondary trophic level as consumers of primary production (McMahon, 1991). They all share a complex life cycle because they require a vertebrate host, usually a fish, during their larval stage. This microscopic thin-shelled larva (glochidium), which the mussels brood and release by the millions, normally has hooks and/or teeth to attach itself to the fish's body where it encapsulates and spends several weeks completing its development until its recruitment as a metamorphosed benthic juvenile. This is the mussel's dispersal method. For this reason, maintaining natural populations of native fishes is essential for the conservation of the naiads. Although there are no conclusive data as yet on the fish hosts of *M. auricularia*, the species has been successfully bred in captivity with two species of fishes, *Acipenser baeri* (Araujo & Ramos, 1998a, b, 2000a, b) and *Salaria fluviatilis* (Araujo *et al*., 2001).

The present action plan almost constitutes a recovery plan (Machado, 1997) as, due to its very restricted distribution, *M. auricularia* is a critically endangered species belonging to one genus with only five or six species in the world (the taxonomic status of some populations is still uncertain). The case of the Canal Imperial de Aragón, the habitat of the main known population of the species is also special. Therefore we have tried not to obviate the "human factor" and to work with two kinds of approaches in accordance with Council of Europe's recommendations (1997; Machado, 1997) involving integrated ecosystem management and control of processes that negatively affect biodiversity.

Through this dossier, we have tried to meet the required objectives included in the design of an action plan to recover *M. auricularia*:

1. To update the data on distribution and biology.
2. To establish the threats to the species.
3. To establish useful and realistic conservation measures.
4. To recover the populations.

Unfortunately, data for France are nowadays mainly based on the few existing published reports and personal communications, and are, therefore, still partial and incomplete.

2. BACKGROUND INFORMATION

2.1. Systematics

Phylum: Mollusca
Class: Bivalvia
Order: Unionoida
Family: Margaritiferidae

Common name: Spengler's freshwater mussel, Almeja perlífera gigante de río, Perla de río, Margaritona, Náyade auriculada, Petxina de riu.

The genus *Margaritifera* was described by Schumacher in 1816, with *Mya margaritifera* Linnaeus (= *Margaritifera margaritifera*) as the type species. Although it is a declining genus, with all its species endangered, living species of *Margaritifera* have been recorded from North America and Europe, with only two species from Europe, *M. auricularia* and *M. margaritifera*.

Margaritifera auricularia was described by Spengler in 1793, citing the erroneous locality of East India, as *Unio auricularius.* Lamarck later redescribed the same species with 'European'specimens (French rivers) as *Unio sinuata.* The subgenus *Pseudunio* was introduced by Haas in 1910 to isolate this species. The populations from Moroccan rivers probably constitute a subspecies named *M. auricularia marocana* (Pallary, 1918).

Margaritifera, together with the North American genus *Cumberlandia* and the uncertain Asiatic genus *Margaritanopsis*, constitute the family *Margaritiferidae*, including the oldest species of the Unionacea. It includes species with characteristic conchological and anatomical features (i.e. absence of diaphragm, incubation in the four gills, marsupium without water tubes, hookless glochidium) different from other naiads (Unionidae, Mutelidae and Etheridae families) (Davis & Fuller, 1981; Smith & Wall, 1984). These differences have recently been supported using molecular data (Davis & Fuller, 1981; Lydeard, Mulvey & Davis, 1996; own unpublished data).

2.2. Species description

Margaritifera auricularia is a very big naiad, maximum length 20 cm, with a black periostracum and flattened umbones (Figure 1). The two valves are equal, shortened in the anterior part and elongated posteriorly. Growth lines are marked in the shell (and the periostracum) although near the shell edge many lines are together, making it impossible to make a realistic estimation of age based on these external marks.

Figure 1. Spanish specimen of *M. auricularia*

The ventral border is normally excavated, giving an auriculated shape to the shell.

Internally, the valves are nacred white, with very obvious aductor mussel scars, especially in the anterior part. The left valve presents two cardinal pyramidal teeth under the umbo and two long laterals behind them. The right one presents one cardinal, smaller than the ones in the opposite valve, and one lateral, which fits between the two in the left valve. This tooth widens just under the umbo, looking like another cardinal. The pallial line is well marked in both valves, especially at the front.

The shell is much thicker in the anterior part, the posterior part being thin and fragile.

The only anatomical description of the species is by Haas (1924) although a detailed study is currently in progress. The foot is white and very big, capable of becoming as large as the whole shell when it protrudes. There are no real syphons, as only a transversal thickening on the inner side of the posterior mantle (the diaphragm) maintains the exhalant and inhalant apertures separate in live specimens. The edge of the mantle in this area is thickened by rows of papillae. Anteriorly, the labial palps, two on each side, move the water currents in order to select food, which is ingested through the mouth between the palps once it has been sorted by the gills. There are two inner and two external gills under the mantle, all without water tubes, which is an important difference with other Unionacea families.

In the dorsal part of the foot, embedded in the visceral mass, is the gonad, which is sometimes hermaphroditic (Grande *et al.*, 2001).

2.3. Distribution and population numbers

Although there is recent information on the collection of two live specimens of *M. auricularia* in the Loire basin (Nienhuis, pers. com.; Bacchi and Gilbert, pers. com.), at present the only data on living European populations of the species are from Spain, in the basin of the River Ebro. More research is needed to assess the real distribution of the species in France, where it was very abundant in the past. Fresh empty shells have been recently collected in the Dordogne, Charent and Aveyron (Guilbot *et al.*, 1998; Cochet, 1999). It might be more difficult to find it in other European countries, from where it disappeared many years ago. Recent specimens, collected live in Moroccan rivers in 1991, are deposited in the Zoological Museum of Amsterdam (Araujo & Ramos, 2000c). The fossil, historical and current distributions of the species are shown in Figure 2.

Until more data are available from future sampling expeditions to Morocco and France, this report will concentrate mainly on the scientific publications reporting the species in north western Spain.

Based on standard mark-release-recapture methods, the known population in the Canal Imperial has been estimated at about 2,000 specimens (Araujo & Ramos, 2000a, b) although a complete survey of the channel is pending. Recent information has been published on the presence of *M. auricularia* in the middle section of the River Ebro (Álvarez, 1998a, b), where the authors of this report have found one living specimen in July 2000. Nevertheless, there is not enough information to ascertain if there are isolated specimens or viable populations in this river section until more deep sampling has been carried out.

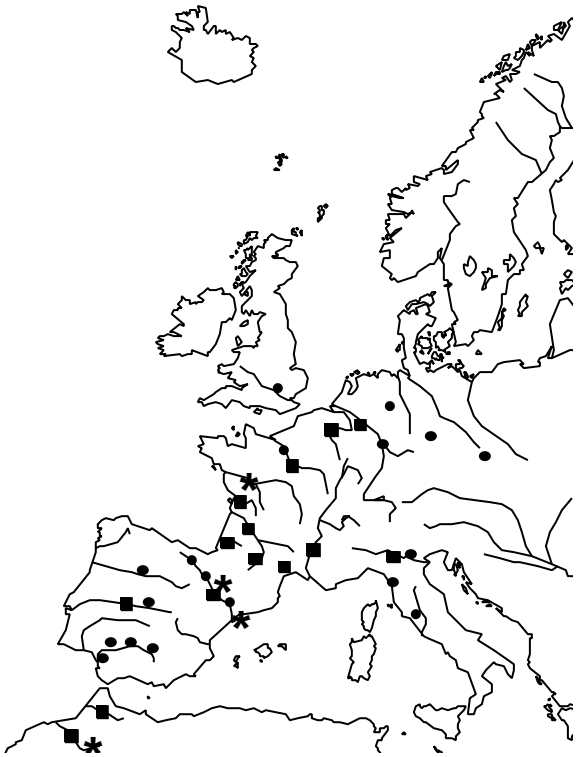

Figure 2. Fossil (dots), historical (squares) and current (asterisks) distributions of *M. auricularia*.

The case of the lower section of the Ebro is similar. The conflicting data on the size of this supposed population vary between several thousand (Altaba, 1997) and "small groups separate one from another" (Altaba, 1999). Sampling problems in wide rivers (depth, current, turbidity) together with the lack of expertise in specimen identification make caution advisable when evaluating data. Dead specimens were recorded in the area (Altaba, 1990), and the species has been historically cited from there (Haas, 1929) so the lower Ebro may be important enough to be taken into consideration.

The population structure in the Canal Imperial de Aragón based on length measurements of 438 specimens (Figure 3) is highly skewed to large specimens (Araujo & Ramos, 2000a, b).

Margarififera auricularia populations present patchy distribution, as is common among naiads, an example of how these species survive in groups of small interconnected subpopulations in a spatially structured habitat mosaic. Interconnection is provided by its peculiar life cycle (sperm dispersal through water and juvenile dispersal by fishes). This population structure is important as regards conservation because the extinction of some patches could lead to species extinction in the long term, and so it is important to conserve the whole series of suitable habitats.

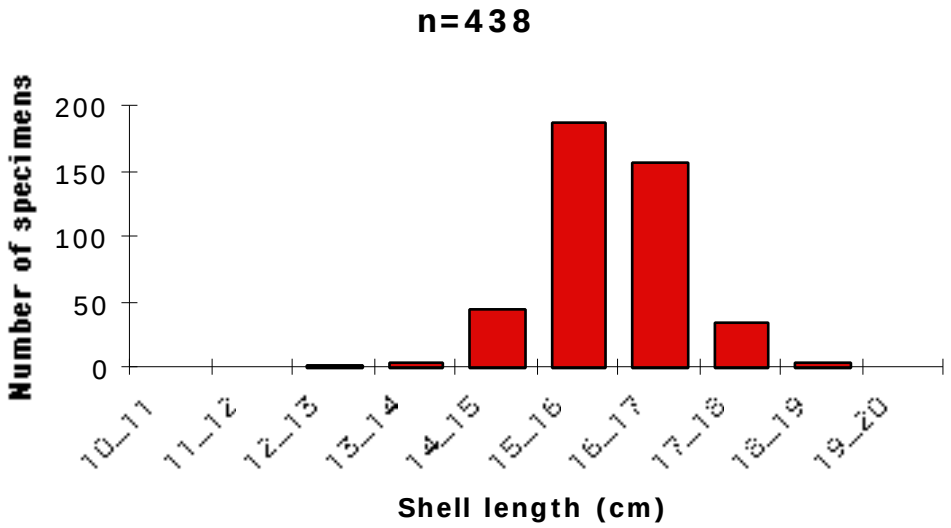

Figure 3. Size structure of the *M. auricularia* population in the Canal Imperial

2.4. Life history

2.4.1. Life cycle

All freshwater mussels share a complex life cycle, requiring a vertebrate host, usually a fish, during their parasitic larval stage. These microscopic thin-shelled larvae (glochidium), which are brooded in the mussel gills and released by the millions, were presumed in the nineteenth century to be a parasitic species of fish (*Glochidium parasiticum*). The glochidium usually has hooks to attach itself to the fish's body (fins or gills), where it becomes encapsulated for several weeks before changing into a free-living juvenile.

Margaritifera auricularia is a short-term brooder (tachytictic) (Grande *et al*., 2001), as are all known species of the genus *Margaritifera*, and it incubates the embryos during one-three months. It appears

to be a hermaphrodite species, gametogenesis occurring from December to March. Gonadal tissue occurs at visceral mass without a specific location, male and female gonads being mixed (Grande *et al*., 2001). Sperm is shed into the water and inhaled by other mussels downstream as a consequence of normal filtering action. Following fertilisation, the eggs are incubated in a brood chamber (marsupium) formed from a modification of the four mussel gills where they develop into glochidia.

Haas (1917a) demonstrated that the species does not incubate between mid-July and early September. Recent results show that *M. auricularia* releases glochidia in March and April (Araujo *et al*., 2000). The glochidium of *M. auricularia* was recently described by Araujo & Ramos (1998a) as the biggest of the family Margaritiferidae (length: 127-144 µm; height: 120-142; width: 54-71). It is of the hookless type, but presents very minute teeth at the ventral border, which means it can only attach to fish gills.

Knowledge of host fishes and of the relationship between mussel and host fish is essential in any attempt to preserve endangered freshwater mussels. Altaba (1990) hypothesised about the possible specificity between the glochidium of *M. auricularia* and the European sturgeon *Acipenser sturio* (Linnaeus 1758), a relict fish in European rivers and practically extinct in Spain (Elvira *et al*. 1991; Blanco & González 1992). Both species occur together in Pleistocene deposits(Preece 1988) and both have been declining since the first half of this century.

Successful infestations have recently been carried out in aquarium experiments using *M. auricularia* glochidia and specimens of *Acipenser baeri*, an exotic sturgeon (Araujo & Ramos, 1998a, b, 2000a, b). Metamorphosed juveniles have also been obtained with artificial infestations of *Salaria fluviatilis* (the blenny river fish), a native fish from the Ebro basin, also endangered and protected by law (Araujo *et al*., 2001).

Juveniles were born after one month of encystment at 20°C on sturgeon gills, or after 43 days at 16-17°C on both sturgeon and blenny river fish. No data exists about the growth ratio of the juveniles nor the time taken to become adults.

Our genetic unpublished data (Machordom *et al*., in prep.) indicate the clear singularity of *M. auricularia* respect to *M. margaritifera.* The genetic variability found in *M. auricularia* was in the usual ranges for Unionoids, suggesting the real possibility of species recovery.

2.4.2. Habitat requirements

Adult specimens of *M. auricularia* were detected in several transects of the Canal Imperial, but were absent from all the areas with artificially covered beds. The species coexists with a very rich community of other freshwater mussels such as *Potomida littoralis*, *Unio elongatulus* (another protected and endangered species) and *Anodonta cygnea*.

Margaritifera auricularia is a specific hard water species, calcium levels in the River Ebro being around 150 mg/l. Several physico-chemical analyses of the water have been taken where the Canal Imperial population lives (Table 1). Range values of these factors during a complete year indicate that the habitat of *M. auricularia* is basic, well oxygenated, subsaline (Hammer 1986), beta-alpha mesosaprobic (Sládecek 1990) and oligo-hyperthophic (Unesco 1989) water. Temperature in the Imperial Canal ranges between 7.4 (March) and 22.9 °C (August) (Araujo & Ramos, 2000a).

Freshwater mussels feed by filtering organic material from the water. Their filtering capacity is so high that they not only play an important role at the secondary trophic level as consumers of primary production (McMahon, 1991), but it has been speculated that where the mussels occur in large numbers, they may be partly responsible for maintaining water quality.

Margaritifera auricularia is a very sedentary species (Araujo & Ramos, 2000a). The main fraction of the sediment where it lives consists of pebbles, followed by gravel and sand. The finest fraction is very small. The only place were the behaviour of the species has been studied is the Canal Imperial de Aragón, where it lives partially buried in clay-sand and gravel beds, sometimes (specially in the breeding season) nearly vertical with the posterior end exposed and sometimes horizontal, showing only the dorsal margin. However, adults are capable of active mobility and may burrow into the sediment for a few metres, leaving very obvious traces (about 8 cm wide) when the water level is low.

water quality metric	low water	high water
pH	8.3	8.1
Temperature °C	12.2	12.8
Conductivity at 20°C	1547	1077
Suspended material mg	45	51
Organic material mg/l	12.7	12.1
Dissolved oxygen mg/l	10.6	10.3
DBO_5 mg/litre O_2	2.2	6.2
Total ammonium mg/lit	0.13	0.10
Ca mg/litre	163	114
Mg mg/litre	49.9	23.8
Na mg/litre	64.5	98.5
K mg/litre	4.4	3.3
Cl mg/litre	103	135
SO_4 mg/litre	373	196
NO_3 mg/litre	15.1	25.2
NO_2 mg/litre	—	0.057
Alkalinity mg/litre CO_3	253	187
PO_4 mg/litre	0.28	0.11
Zn mg/litre	0.01	0.02
Cu mg/litre	0.00	0.00
Cd mg/litre	0.00	0.00
Hg mg/litre	0.00	0.00

Table 1. Physico-chemical analyses of the water in the Canal Imperial

Old data from Haas (1916, 1917) situated the species in quiet river pools at depths of up to 6 m**.** Recent unscientific records of the species, mainly from fishermen and craftsmen living in the riverside villages (especially Sástago, Zaragoza), mention flourishing populations in the meandrous areas of the middle course of the Ebro, generally immediately downstream of small waterfalls, where hundreds of specimens were easily collected at low water several years ago.

From the literature and our own experience, we know that substratum stability is an essential feature for naiad survival, and, of course, the presence of the host fish (or fishes) in the habitat is also essen-

tial for naiads to thrive. They particularly dislike siltation, eutrophication and water impoundment. A clean and well oxygenated sediment is very important for juveniles for if the substratum becomes clogged with silt, they can no longer obtain oxygen and die. Nevertheless, data on autoecological requirements in the early years of the mussel's life are still lacking.

2.5. Threats and limiting factors

The dramatic decline of *M. auricularia* in Europe has run parallel to that of other naiads in the world. Bogan (1993) described the reasons for naiad extinction as habitat alteration or destruction, decline or extinction of host fishes, commercial exploitation, and introduced species. *M. auricularia'*s recorded habitat, big rivers of Western Europe and North Africa, is clearly disappearing. The maintenance of such pseudo-natural habitat as the Canal Imperial is proverbial for the species until more thorough surveys can be done on the main river. The "modernisation" planned for the Canal Imperial is, therefore, the main threat currently facing the species. It is important to note that the Canal Imperial can be considered a "natural laboratory" because of the experimental facilities provided by easy water regulation.

River regulation, dredging, water pollution and pesticides (there are very large irrigated fields along the banks of the Ebro) and water availability are among the most important reasons for *M. auricularia'*s decline. Irrational water use in the area is behind all these problems and represents the main threat to the species.

The only known European populations of the species are currently threatened by Spanish water management plans, which include, on the one hand, the proposed "modernisation" of the Canal Imperial, and on the other, water transfers, canalisations and construction of several hydroelectrical plants on the medium and lower Ebro, all, paradoxically, overseen by the Spanish Environment Ministry.

2.5.1. Habitat loss

- Spain

The existing plan for the "modernisation" of the Canal Imperial, consisting in covering the natural bottom with concrete slabs, will kill the whole population of *M. auricularia*. Indeed, the "small" works regularly carried out to solve specific problems of bank leakages are directly responsible for the disappearance of dozens of *M. auricularia* specimens.

River regulation, dredging for gravel and sand, canalisation, impoundment, pollution and all kinds of alterations to the natural water flow in the Ebro basin are responsible for the decline in naiads through siltation, eutrophication, changes in flow and other important non-natural changes in water quality. Changes that affect the natural migrations (millraces, dams) and breeding (canalisations, dredging) of host fishes are extremely important factors in naiad rarefaction. We think that *M. auricularia* might be unable to breed successfully in its present habitat, probably due to the absence of the host fish and the absence of a clean and well oxygenated river substratum. At present, in the Canal Imperial, there are no records of one of the two likely host fishes identified to date, the sturgeon, but specimens of the blenny river fish have been historical and recently collected. The latter species is also a very sedentary species. Although some populations still live in specific parts of the Ebro, their main populations are probably not sympatric with *M. auricularia* populations. The sturgeon is virtually extinct in the Ebro.

Historical changes in the Ebro have been widely reported (Ollero, 1996), and typical ecosystems, such as the "galachos" (leaved meanders) and meander areas, the latter typically inhabited by *M. auricularia*, have undergone dramatic changes. Factories on the river banks are also responsible for severe biological changes in the Ebro. The new Spanish National Hydrological Plan to transfer water from the Ebro to other river systems could also have unpredictable consequences on the species habitat (Prat & Ibáñez, 1995).

Nevertheless, *M. auricularia* distribution was much wider at least 5,000 years ago (Preece *et al*., 1983; Araujo & Moreno, 1999), and climatic factors may also be involved in its decline.

- France

The existence of living specimens of *M. auricularia* in the Loire, Dordogne, Charente and Aveyron must be urgently confirmed in order to protect these habitats.

2.5.2. Human activities

The aforementioned threats are, of course, due to human activities, but this section deals with more direct human activities limiting species survival. Although recent references to exploitation of *M. auricularia* (Álvarez, 1998b) exist, this activity appeared to have finished, at least in Spain, once the decline of the naiad populations became evident (Álvarez, 1998b).

The species's nacre was used to manufacture knife hilts, especially in the riverside village of Sástago near the Ebro river, where there were abundant *M. auricularia* populations. Traces exist indicating that this activity probably began two centuries ago. Álvarez (1998a, b) summarised all the available data on this activity.

As regards pearls, it seems that *M. auricularia* is not a real pearl mussel, as no reference to pearls is available, at least, none comparable with the pearl production reported in *M. margaritifera* (Hessling, 1859).

Another threat arising directly from people is the possible capture of specimens by poachers, once the risk to the species is known. Collectors may be interested in having specimens of *M. auricularia* for their value as pretty objects (nacre) and because it is a rare species.

As *M. auricularia* is a highly protected species, its presence in rivers and/or channels may be an important factor to bear in mind as regards the possible development of future hydraulic works. The water supply problem is becoming a difficult one, especially in Aragón, a region with historical "water wars". Vandalism and destruction of naiad populations are not incredible events as the aforementioned works move enormous amounts of money. Only public awareness can boost efforts to maintain this species as a valuable asset to our historical and natural heritage.

2.6. Conservation status and current legal protection

2.6.1. International agreements

— The IUCN (International Conservation Union) Red Data List (Wells *et al.*, 1983) included the species as "Indeterminate". In 1990, the same organisation (IUCN, 1990) considered the species to be

"Vulnerable" and on the 1994 list (Groombridge, 1994) it appears as "Endangered". Finally, after the application of the new IUCN/WCMC criteria, the species was included on the 1996 Red Data List (IUCN, 1996) as "Critically Endangered".

— Habitat and Species Directive (European Union Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna, Directive 92/43/EEC). The species is listed on Annex IV, which includes "animal and plant species of European interest requiring strict protection". The species was not listed on Annex II because of the possibility of it being extinct due to the fact that the last scientific records were from 1933 (Azpeitia, 1933) even if the collection date for those specimens is unknown.

— Bern Convention (Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats, 1979). The species was included in 1987 on Appendix II**,** "Strictly Protected Fauna Species". Since then, and after the corresponding country reports (Ramos, 1994; Ramos & Rosas, 1994, Ramos, 1996, Ramos, 1998b, Guilbot *et al.* 1998), several recommendations of the Standing Committee have been addressed to countries presumed to hold live populations. They are encouraged to carry out surveys of the geographical distribution and status of the species (Council of Europe, 1990, Recommendation No. 35) to take the appropriate measures to protect the remaining populations of *M. auricularia* in the Ebro basin (Council of Europe, 1992) and urgently investigate the status of *M. auricularia* in the Ebro, carrying out a recovery plan for the species (Council of Europe, 1994, Recommendation No. 50).

After a Spanish report of a live population in the Canal Imperial de Aragón (Ebro River basin) (Araujo & Ramos, 1996b), the Standing Committee (Council of Europe, 1996, Recommendation No. 51) recommended Spain to considere the implementation of Action Plans for the species including: 1) establish, as a matter of urgency, a recovery plan for the species as foreseen in the Spanish conservation law for species which are critically endangered, 2) give appropriate protection and management to the sites where the species survives, 3) carry out a full survey of the Canal Imperial and appropriate sites on the River Ebro and its tributaries, 4) promote research on relevant aspects of the biology and conservation of the species, giving special attention to the identification of host fishes and 5) consider carrying out a captive breeding and re-introduction programme. In addition, the Council of Europe recommended the member states of the European Union to "consider listing *M. auricularia* in Annex II of the Habitats Directive, taking into account the fact that when the Directive was adopted, no living population of the species was known". A recommendation to France and Italy to carry out surveys to search for the species was also included. After the presentation of the first draft of the present Action Plan for the species (Araujo & Ramos, 2000d) and under the scope of Recommendation No. 59 (Council of Europe, 1997), the Standing Comitee recommends to set up a joint bilateral project with France to implement national Action Plans and ensure exchange of experiences and scientific information on the species as well as to ensure that the species receives appropiate conservation attention by international instruments and funding schemes.

2.6.2. Listing of individual countries

2.6.2.1.Countryside Acts

- Spain

Margaritifera auricularia is protected under the following legislation:

— Transcription of the Bern Convention to Spanish legislation following the General Disposition of the Foreign Affairs Ministry of 26 May 1988 (BOE No. 136, of 07/06/1988, p. 17554), updated by

Disposition General of the *Jefatura del Estado* of 13 May 1986 (BOE Nº 235 of 01/10/1986): "Strictly protected wildlife species".

— Transcription of Directive 92/43/EEC to Spanish legislation by Royal Decree 1997/1995 of December 7 (Ministry of Agriculture, Fisheries and Food (BOE No. 310, of December 29, p. 37330). Annex IV: "Animal and plant species of Community interest requiring strict protection".

— National Endangered Species List (Order of 29 August 1996 of the Ministry of the Environment, BOE, Nº. 217 (1) of 7 September 1996, p. 27246), under Act 4/1989 of 27 March (BOE Nº. 74, of 28/03/1989) of the *Jefatura del Estado*, on Conservation of Natural Areas and Wild Flora and Fauna, and regulated by the Royal Decree 439/1990 of March 30 (BOE Nº. 82, of 05/04/1990) of the Ministry of Agriculture, Fisheries and Food: Included in Annex I "Endangered".

• France

Décret no. 99-615 du 7 juillet 1999. Annexe II: Strictly Protected Fauna Species.

2.6.2.2.Regional Acts

• Spain

— Included on Annex b) "Invertebrates" of the Order of 16 November 1994 of the *Conselleria d'Agricultura, Ramaderia i Pesca* (Regional Ministry of Agriculture, Livestock and Fisheries) (DOGC Nº. 1980 of 02/12/1994, p. 7806), under Act 3/1988 of March 4 (DOGC Nº. 967 of 18/03/1988) of the Cataluña Regional Government concerning animal protection: "Governs photographic, scientific and sporting activities that may affect wild animal species".

— Included on Appendix IV of the Red Data List of Threatened Species of Aragón by Decree 49/1995 of March 28 of the Aragón Regional Government (BOA Nº. 42, de 07/04/1995, p.1275): "Wildlife species of special interest".

• France

No data at present

2.7. Current Action

• Spain

* Research

Surveys have been conducted following the recommendations of the Bern Convention Standing Committee. They have been carried out through two different conventions between the General Directorate for Nature Conservation (ex-ICONA) and the Natural History Museum (CSIC):

— The first one compiled existing information on all the invertebrates in Spain that are protected by international agreements (Rosas *et al.,* 1992).

— The second one included fieldwork to assess the distribution and status of those species listed in the Habitats Directive and in the Bern Convention recommendations to Spain (Ramos, 1998a; Araujo & Ramos, in press). In the course of that study, a live population of *M. auricularia* was found (Araujo & Ramos, 1996a, b, c), leading to the inclusion of this species as the first invertebrate on the National Red Data List and to the initiation of surveys focusing more on the species's unknown biology (see Section 2.4 of this document).

— A new two-year convention was recently signed to survey the real distribution and numbers of the species in the River Ebro as well as to continue research on habitat requirements, population structure, fish hosts, genetic variability, etc. in order to design a recovery plan for the species.

— A research convention between the Museo Nacional de Ciencias Naturales and the Environment Department of the Aragón Regional Government, on the biology and protection of the species in Aragón, is currently under preparation.

* Other actions

— A working group inside the Fauna and Flora Committee has been promoted by the General Directorate for Nature Conservation (Ministry of the Environment), including the regional governments involved (Diputación General de Aragón and Generalitat de Catalunya), protected natural areas where the species is found and scientists in order to assess current knowledge on the species and plan future actions.

— Another technical working group promoted by the Canal Imperial water authorities (Confederación Hidrográfica del Ebro) joined with some organizations from the previous working group and all the other social and economic sectors involved, including different user communities, NGOs and engineers, etc. to analyse the specific problems related with the conservation of the Canal Imperial and the main *M. auricularia* population known at present.

Although very promising, so far none of these groups has been very active.

* Organisations involved in these actions

— Ministerio de Medio Ambiente (Dirección General de Conservación de la Naturaleza, Dirección General de Obras Hidráulicas y Calidad de las Aguas y Dirección General de Calidad y Evaluación Ambiental). *Ministry of the Environment* (*Directorate-General for Nature Conservation, General Directorate for Water Works and Water Quality and General-Directorate for Environmental Quality and Assessment*).

— Diputación General de Aragón (*Aragón Regional Government*)

— Generalitat de Catalunya (*Catalunya Regional Government*)

— Confederación Hidrográfica del Ebro -CHE- (Ministerio de Medio Ambiente) (*Ebro Water Authority -Ministry of the Environment*)

— Canal Imperial de Aragón (administratively dependent on the CHE)

— Centro de Experimentación de Obras Públicas -CEDEX- (Ministerio de Fomento) *(Water Works Experimental Centre - Development Ministry*)

— Consejo Superior de Investigaciones Científicas (Museo Nacional de Ciencias Naturales e Instituto Mediterráneo de Estudios Avanzados de Baleares). (*Higher Council for Scientific Research. National History Museum and Mediterranean Institute for Advanced Studies in the Balearic Islands).*

— Servicio de Protección de la Naturaleza de la Guardia Civil -SEPRONA- (*Civil Guard Nature Protection Service*)

— Sociedad Española de Malacología -SEM- (*Spanish Malacology Society*)

— Other non-governmental organisations

— User communities

• France

The Group of Experts on Invertebrates (Council of Europe, 2000) has recommended to set up a joint bilateral (Spain and France) project to implement national action plans and ensure exchange of experiences and scientific information on the species.

Contacts have been established with the LIFE ESTURGEON project at the Garonne basin to study the possibility of a common programme for both species (Cochet, *in litt.*).

3. GOALS AND OBJECTIVES

The main goal is, of course, the effective conservation of *M. auricularia* populations, their habitat, future viability and long-term survival. Below is a list of tools that may be used and items that must be complied with to meet the proposed goals. Legislation, rational water use, research, management (including species re-introduction), monitoring and education/advisory work will be of prime importance.

3.1 Policy and legislation

Due to the fact that *M. auricularia* lives in fresh water, conflicts between people and the species are very important. Success is impossible if the corresponding administrations do not put all their co-ordinated efforts into the joint task. We are aware that the presence of a species name on a red data list is not the final step towards its conservation, but only a necessary tool with which to work. Once this tool is functioning, the relevant laws must be scrupulously executed. In the following items, we summarise the proposed direct actions that should be implemented in order to preserve *M. auricularia* populations.

Positive dialogue and co-operation between the environmental and hydraulic administrations at national and regional levels is the first objective, and conservation of fresh waters inhabited by this threatened species is one of the starting points. Scrupulous adherence to the legislation protecting *M. auricularia* (see Point 2.6. of this report), would mean that none of the current engineering hydraulic works on the River Ebro and Canal Imperial should be carried out without a prior impact assessment study by accredited experts.

New legislation regulating new water uses is needed and could be the pioneering basis to tackle similar problems in other areas or countries. This should include a) legislation to ensure that the species's water quality requirements (when identified) form the basis for setting statutory water quality objectives, b) legislation to ensure that planning permission be sought for engineering work in rivers and channels where the species lives, and that such developments must be regulated, c) ensure that relevant management plans (e.g. agricultural, forestry, sailing) take account of the species's interests and contribute to its conservation, d) ensure that local authorities are informed of *M. auricularia* populations in their areas as well of the implications of the relevant legislation and provided with contact points where advice may be sought.

3.2. Species and habitat protection

All countries should designate specially protected areas and habitats for the species.

- Spain

The following main goals must be achieved under national legislation. The planned "modernisation works" of the Imperial Channel must be stopped as the first step to protect the species's main population once it is known that such works are not needed (expert commission pers. com.).

— Maintenance of the natural appearance of the Canal Imperial, which means maintaining the organic substrate and similar hydrological features, is essential to survivorship of *M. auricularia.* Indeed, due to its accessibility, the Canal Imperial is the only known habitat in which it is possible to carry out experimental work with live specimens and populations. Nevertheless, as minor works must be carried out yearly in specific areas of the channel in order to improve and/or maintain the general state of the banks, the following recommendations may be useful:

— Extensive hard engineering works in the Canal Imperial of Aragón would be fatal for the species's survivorship. This imponderable is reinforced by the criteria of the advisory group (architects, engineers and hydrogeologists), who do not appreciate the real need for such a drastic action as that planned for the Canal Imperial. The recommendations are to treat the zones that present major potential danger using soft solutions in order to solve the problems, which are always very specific, in the required areas. Special stress should be laid on the need to solve the problems by working from outside the bed of the water course, especially where the potential danger is due to the Canal being raised on embankments. Except for rare cases in which important filtrations in the channel bed might call for proofing, restoration of the Canal must be done from outside the Canal bed.

— Notify the Directorate-General for Nature Conservation, regional governments and the Natural History Museum (CSIC) prior to any proposed work on the Canal Imperial in order to evaluate the problem and translocate the affected specimens, if necessary.

— If any work is needed, it must be done with the maximum care, avoiding movement of natural substrate, water flow containing dissolved concrete, dangerous substances and siltation in the Canal. Heavy machinery in the channel bed must be avoided. If it is necessary to remove the substratum in a specific area or if there are problems caused by filtrations or chasms, affected specimens must be translocated to safe areas.

— The creation of a commission to document and protect the cultural, historic and aesthetic heritage and symbolic values of the Canal Imperial is highly recommended.

— Regarding the medium and lower Ebro, an assessment of the advisability of the proposed energy plants and canalisation must be carried out and, if considered necessary, an impact assessment should be done and "soft" works designed. Nevertheless, more realistic data about the presence of the species are needed beforehand.

— Protection of the Canal Imperial, and the areas of the Ebro River harboring populations of the species under the Natura 2000 Network on as UNESCO Biosphere Reserves.

• France

First of all, an evaluation of the presence of the species must be carried out. There is no news about the results of a scuba diving campaign scheduled for 1998 (Guilbot *et al*., 1998). The existence of living specimens of *M. auricularia* in the Loire, Dordogne, Charente and Aveyron must be urgently confirmed in order to protect these habitats.

3.2.1. Develop and implement a management plan to prevent further decline

A plan for rational water use in the areas where the species lives must be designed and implemented under a major sustainable development project for the latter areas, the Canal Imperial and special areas of the River Ebro, achieving a balance between water demands for irrigation**,** urban and industrial uses, and new leisure and recreational uses of those areas by the surrounding human populations that are more compatible with protection of the ecosystem. New cultural/recreational development of the villages along the River Ebro could easily underpin a wider perspective, creating natural parks, interpretation centres, jetties, bathing areas, rehabilitation of historic buildings and bridges, etc., an idea that might be widely accepted by interested groups and largely demanded by local NGOs.

It is a fact that irrigation farming around the world is undergoing review. New social demands have given rise to generalised reflection in order to achieve sustainable ways to improve the quality and diversity of agricultural produce, while attempting to conserve natural resources, which, in this case, is an endangered species and an endangered part of the natural, historic and cultural patrimony.

The Canal Imperial and the mid- and lower sections of the River Ebro are areas demanding a special outcome that could be emblematic if combined with the use of production methods that permit the requisite development of the populations using its water without jeopardising the assets of future generations. We cannot maintain, nor, of course, increase existing levels of production and development without improving levels of productivity, but this should not be achieved by overstretching a hydraulic structure built 200 years ago (the Canal Imperial) nor by overexploiting the River Ebro. This idea does not mean producing less, but rather handling the means of production in a controlled way, with minimal costs and without damaging the environment.

This kind of action along the Canal Imperial and the meanders area of the River Ebro, both in Aragón and in the lower Ebro in Cataluña, will be a useful tool to prevent the future decline of the species and will bring new development opportunities to the people most directly concerned. Under this general philosophy, specific commissions involving all political, scientific and socio-economic stakeholders involved should be created to analyse the best conservation actions to be implemented in each case.

3.2.2. Conduct population surveys

- Spain

Surveys of the whole length of the Canal Imperial need to be carried out jointly with the Canal authorities to ensure that sampling can be done in sections never before sampled.

Population assessment in the main course of the River Ebro must be done during low water seasons (July, August, September) along the entire length of the river from Cantabria to Tortosa. Subaqua work will be the prominent survey method because it is the most respectful of benthic conditions. Once the species's real distribution is known and the appropriate population estimates made, subsequent monitoring (e.g. 3-year intervals) will be necessary to assess population trends.

- France and Italy

Population surveys must be carried out in France (Loire, Dordogne, Charente and Aveyron basins) and Italy (Po basin).

3.3. Conflicts with people

Only direct conflicts are going to be dealt with in this section due to the fact that major problems (water use, hydroelectric works, river regulation etc.) have been already mentioned in this report.

Margaritifera auricularia nacre has been used to manufacture knife hilts for many years by people of the Ebro riverside villages. Although these knives were world-famous, capture of the species to make them was probably not directly responsible for its rarefaction. Although, fortunately, mussels are no longer caught for nacre-work (Álvarez, 1998b), vandalism, poaching and ignorance may be among the main threats. Close surveillance by personnel of the Spanish Civil Guard's Nature Protection Service will be required, especially when the Canal Imperial is almost empty. It will also be needed along the banks of the Ebro.

The problem with collectors can be prevented through surveillance and information.

Material needed for craftsmen could be regulated and provided from empty shells through the Regional Environmental Service, if convenient. Organisation of a workshop on old (200 years) craftsmanship in nacre must be added to the proposed sustainable development projects for the area.

In France, there are no data on artesanal exploitation of *M. auricularia* nacre. Nevertheless, the protection measures proposed for Spain could be applied to combat collectors**.**

3.4. Public awareness

This is an important task that must be undertaken through joint action by scientists, local and national conservation authorities and other experts. Advisory publications, videos, conferences and other educational material dealing with the ecological importance of the species, legislative protection and the interest of its conservation for local people can be produced and disseminated under an awareness campaign co-ordinated by the environmental authorities and NGOs.

The items to be "sold" could be: water cleanliness, beauty, uniqueness, natural interest, historic interest (nacre industry), all under comprehensive habitat rehabilitation that could run parallel with social and economic advantages for local communities which would increase their quality of life.

Establishing contact points in relevant areas should be encouraged not only to disseminate information, but also to target people who could submit new *M. auricularia* records.

Special attention should be given to the civil servants responsible for surveillance of the relevant areas. They should receive suitable training on species identification and threat factors.

3.5. Population conservation

In fact, an overall conservation programme for the species together with specific actions for the protection of each of the known *M. auricularia* populations will probably be the keys to the survival of the species.

Maintenance of all the different populations may be essential as a source of genetic variability. This makes the survey to identify new populations not yet discovered in the River Ebro and in other French or Italian rivers very important.

Ways of conserving populations are dealt with in Section 4 of this report.

3.6. Captive breeding

The first step is to develop a programme to maintain breeding specimens of *M. auricularia* in direct contact with selected fish species (native or not) in both controlled raceways and aquaria during the mussel breeding season. It would be necessary to build a basic laboratory with aquaria and several raceways near the Canal or river in order to use this water to ensure that artificial infestation of fishes occurs under the most natural conditions for the survival of new-born juveniles.

3.7. Artificial propagation and reintroduction

In this way, the possibility exists of working with millions of recently released *M. auricularia* juveniles. Only the construction of the aforementioned raceways is needed to hatch the small juveniles until they grow several centimetres. These small mussels can be reintroduced into selected areas of already known habitats in order to obtain breeding mussels. Maintaining recently released juveniles in the laboratory may be a good option. However, it will require the study of different feeding methods and a suitable substratum. The advice of other specialists in aquaculture (marine clams and mussels) may be of prime interest in this regard. Important advances may be made in the biology of the species by checking the performance of different substrates in the different raceways, both for adults and juveniles.

3.8. Natural recovery

Probably the best recovery method for the species is the reintroduction of natural fish hosts into the former habitat. In the case of *Acipenser sturio*, this possibility might not be feasible since the sturgeons will not be able to live their usual anadromous life and successive reintroductions might be needed.

Recent results with the native fish species *Salaria fluviatilis* may point to unexpected help. The release of juveniles from an infested blenny river fish may recommend the reintroduction of this species, which was common many years ago, into areas with numerous fertile specimens of *M. auricularia*.

Electro-fishing might be a good way of monitoring further infestation in the fishes' gills. Selected areas of the Canal Imperial and the River Ebro could be used to investigate the viability of recruitment success.

3.9. Monitoring and research

Further studies are needed to fill the gaps in the known distribution of the species, particularly in the River Ebro and in French rivers. As basic information on the species life cycle and life history is, as yet, incomplete, research to investigate other possible fish hosts, life history in different places, genetic variation of the populations, substratum and water quality requirements, juveniles' habitat requirements or survival of reintroduced juveniles in natural ecosystems should be promoted.

Once "natural" fish hosts (if any) have been identified, the relationship between mussel breeding success and fish population levels should be investigated in order to carry out a management plan for fish reintroduction, if necessary.

Successful laboratory experiments (see Sections 3.6 and 3.7) are the starting point for the following outdoor experiments. A very close follow-up of fish infestation, juvenile growth and acclimatisation to pseudo-natural habitat (selected areas of the Canal and River) will be necessary (for at least five years) to evaluate the success of the recovery.

In the case of artificial propagation, averages of juvenile mortality should be investigated in relation to suitable habitats.

A programme of regular monitoring of known populations also needs to identify further threats to the species.

4. CONSERVATION ACTIONS

Although some actions to be urgently implemented were dealt with in the section on threats and limiting factors determining whether *M. auricularia* thrives or not, a comprehensive list of conservation actions to be carried out in Spain and other countries with the species is outlined below.

As the case of *M. auricularia* is special because of its restricted distribution and risk of extinction, the recommended conservation actions are directly related to ecosystem management and habitat protection, together with some actions specifically concerning the species.

4.1. International actions

Taking into account the species's restricted distribution, its uniqueness in taxonomic terms and the imminent threats to its habitats, the listing of *M. auricularia* in Annex II of the Habitats Directive as soon as possible following the recommendations of the Council of Europe to Member States of the European Union (Recommendation number 50 of the Standing Committee -December, 6th, 1996-) is highly encouraged.

It is also encouraged the starting of joint bilateral projects between Spain and France to ensure exchange of experiences and scientific information on the species (Council of Europe, 2000).

4.2. Spanish actions

— Maintain the organic status of the Canal Imperial to protect the habitat of the main known population of *M. auricularia*. Stop the "modernisation" works and include the presence of the species as an added value in this historic habitat. Develop a sustainable alternative future for local people (tourism, recreation, education, etc.).

— Use new crops that are better adapted to the sustainable agriculture model and require less water would complete a model that could be adopted in areas with similar problems. Rationalisation of water use in Aragón.

— Survey the main course of the River Ebro.

— Monitor the engineering works in the medium and lower Ebro.

— Prevent vandalism and poaching.

— Artificially breed and reintroduce the species.

— Reintroduce the host fish species (*Acipenser sturio* or *Salaria fluviatilis*) in areas of the Canal Imperial and the River Ebro with live populations of *M. auricularia*.

— To propose those areas inhabited by *M. auricularia* as Natura 2000 sites and/or UNESCO Biosphere Reserves.

4.3. Other countries with necessary actions

The main action is to design a macro-survey in countries thought to harbour populations of the species, mainly France (Loire, Charente, Dordogne and Aveyron basins) and Italy (Po basin). A public survey of fishermen and naturalists in these countries may be of interest. The natural historic channels of large French rivers where the species used to live should also be surveyed.

5. REFERENCES

Altaba, C. R. 1990. The last known population of the freshwater mussel *Margaritifera auricularia* (Bivalvia, Unionoida): A conservation priority. *Biological Conservation* 52: 271-286.

Altaba, C. R. 1997. Al límit de l'extinció: *Margaritifera auricularia* (Bivalvia: Unionoida). *Butlletí de la Institució Catalana d'Historia Natural* 65: 137-148.

Altaba, C. R., 1999. La náyade *Margaritifera auricularia*. *Biológica* 36 (Sept. 1999): 62-63.

Álvarez, R. M. 1998a. Salvar la almeja de río: *Margaritifera auricularia*, una especie en peligro de extinción. *Trébede, Mensual Aragonés de Análisis, Opinión y Cultura* 21: 7-14.

Álvarez, R. M. 1998b. La industria del nácar de *Margaritifera auricularia* en Aragón y la gestión ambiental. *Temas de Antropología Aragonesa* 8: 113-212**.**

Araujo, R., Bragado, D. & Ramos, M. A. 2000. Occurrence of glochidia of the endangered *Margaritifera auricularia* (Spengler, 1793) and other mussel species (Bivalvia: Unionoida) in drift and on fishes in an ancient channel of the Ebro River, Spain. *Archiv für Hydrobiologie* 148(1): 147-160.

Araujo, R., Bragado, D. & Ramos, M. A. 2001. Identification of the river blenny, *Salaria fluviatilis*, as a host to the glochidia of *Margaritifera auricularia*. *Journal of Molluscan Studies*, 67: 128-129.

Araujo, R. & Moreno, R. 1999. Former Iberian distribution of *Margaritifera auricularia* (Spengler) (Bivalvia: Margaritiferidae). *Iberus* 17(1): 127-136.

Araujo, R., and M. A. Ramos. 1996a. La última población viva de *Margaritifera auricularia* (Spengler, 1793). *Libro de resúmenes XI Congreso Nacional de Malacología,* Almería, 17-20 September, 1996 pp 18-19.

Araujo, R., and M. A. Ramos. 1996b. *Margaritifera auricularia* re-discovered in Spain: observations on a relict population. *Convention on the Conservation of European Wildlife and Natural Habitats. Conservation, Management & Restoration of habitats for invertebrates: enhancing biological diversity*. Killarney (Ireland) 27-28 May.

Araujo, R., and M. A. Ramos. 1996c. The last living population of *Margaritifera auricularia* (Spengler, 1793). Molluscan Conservation. *A strategy for the 21st Century. National Museum & Gallery,* Cardiff (Wales, Great Britain) 20-22 November 1996 pp 1-2.

Araujo, R., and M. A. Ramos. 1998a. Description of the glochidium of *Margaritifera auricularia* (Spengler, 1793) (Bivalvia, Unionoidea). *Philosophical Transactions of The Royal Society of London B* 353: 1553-1559.

Araujo, R., and M. A. Ramos. 1998b. *Margaritifera auricularia* (Unionoidea, Margaritiferidae), the giant freshwater pearl mussel rediscovered in Spain. *Graellsia* 54: 129-130.

Araujo, R. & Ramos, M. A. 2000a. Status and conservation of the relict giant European freshwater pearl mussel *Margaritifera auricularia* (Spengler, 1793). *Biological Conservation* 96(2): 233-239-.

Araujo, R. & Ramos, M. A. 2000b. Life History data on the virtually unknown *Margaritifera auricularia*. In: *Ecological Studies "Ecology and Evolutionary Biology of the Freshwater Mussels Unionoidea"* ed. by G. Bauer and K. Wächtler. Springer-Verlag. Heidelberg, pp. 143-152.

Araujo, R. & Ramos, M. A. 2000c. A critic revision of the historical distribution of *Margaritifera auricularia* (Spengler, 1793) (Mollusca: Margaritiferidae) based on museum specimens. *Journal of Conchology* 37(1): 49-59.

Araujo, R. & Ramos, M. A. 2000d. Action Plan for *Margaritifera auricularia. Council of Europe.* T-PVS (2000) 9. Strasbourg, 25 pp.

Araujo, R. & Ramos, M. A. In press. *Margaritifera auricularia*. In: *"Invertebrados no Insectos de la Directiva Hábitats en España"*. Serie Técnica del Ministerio de Medio Ambiente. En prensa.

Azpeitia, F. 1933. *Conchas bivalvas de agua dulce de España y Portugal*. Memorias del Instituto Geológico y Minero de España. Madrid: 402 pp.

Blanco, J. C., and J. L. González. (eds.). 1992. *Libro Rojo de los Vertebrados de España.* ICONA Colección Técnica, Madrid: 113-114.

Bogan, A. E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): A search for causes. *American Zoologist* 33: 599-609.

Cochet, G. 1996 (1999). Le statut des Margaritiferidae de France (Mollusca: Bivalvia: Unionacea: Margaritiferidae). *Vertigo* 6: 27-31.

Cade, T. J. & Temple, S. A. 1995. Management of threatened bird species: evaluation of the hands-on-approach. *Ibis* 132 (Supplement 1): 161-172.

Council of Europe. 1990. Convention on the conservation of European wildlife and natural habitats. *Secretariat Memorandum.* Appendix 7. T-PVS (90) 13E: 20.

Council of Europe. 1992. Convention on the conservation of European wildlife and natural habitats. *Secretariat Memorandum*. Appendix 11. T-PVS (92) 24: 76.

Council of Europe. 1994. Convention on the conservation of European wildlife and natural habitats. *Secretariat Memorandum*. Appendix 3. (T-PVS96-3).

Council of Europe. 1996. Draft recommendations on the conservation of *Margaritifera auricularia*. In: Convention on the conservation of European wildlife and natural habitats. *Group of Experts on Conservation of Invertebrates. Secretariat Memorandum* Appendix 4. T-PVS (96) 33: 66-67.

Council of Europe. 1997. Recommendation No. 59 (adopted on 5 December 1997) on the Drafting and Implementation of Action Plans of Wild Fauna Species. In: *Convention on the conservation of European wild - life and natural habitats*. T-PVS (97) 63: 70-73.

Council of Europe. 1999. Recommandation No. 51 (adoptée le 6 décembre 1996) sur les plans d'action concernant les espèces d'invertébrés dans les Annexes de la Convention. T-PVS (99) 30 addendum: 4-7.

Council of Europe. 2000. Convention on the conservation of European wildlife and natural habitats. Group of experts on conservation of Invertebrates. Neuchatel, 13 May, 2000. T-PVS (2000) 26: 84-85.

Davis, G. M. & S. L. H. Fuller. 1981. Genetic relationships among recent Unionacea (Bivalvia) of North America. *Malacologia* 20(2): 217-253.

Elvira, B., A. Almodóvar. & J. Lobón-Cerviá. 1991. Recorded distribution of sturgeon (*Acipenser sturio* L., 1758) on the Iberian Peninsula and actual status in Spanish waters. *Archiv für Hydrobiologie* 121(2): 253-258.

Grande, C., Araujo, R. y Ramos, M. A. 2001. Histological description of the gonad of *Margaritifera auricularia* (Spengler, 1793) and *Margaritifera margaritifera* (L, 1758) (Bivalvia: Unionoidea). *Journal of Molluscan Studies*, 67: 27-35.

Groombridge, B. 1994. *The IUCN Red List of Threatened Animals*. WCMC, Chapman & Hall, Cambridge.

Guilbot, R., Bellan-Santini, D., Deschamps-Cottin, M., Cochet, G., Descimon, H. & Dommanget, J. L. 1998. Examen des actions menées en France depuis 1996 pour la conservation des invertébrés inscrits à l'Annexe 2 de la Convention de Berne. In: Convention on the conservation of European wildlife and natural habitats. *Group of Experts on Conservation of Invertebrates. Council of Europe.* T-PVS (98) 18: 20-31.

Haas, F. 1916. Sobre una concha fluvial interesante (*Margaritana auricularia*,, Spglr.) y su existencia en España. *Boletín de la Sociedad Aragonesa de Ciencias Naturales* XV(2): 33-45.

Haas, F. 1917. Estudios sobre las Náyades del Ebro. *Boletín de la Sociedad Aragonesa de Ciencias Naturales* XVI: 71-82.

Haas, F. 1924. Anatomische Untersuchungen an europäischen Najaden. I. *Archiv für Molluskenkunde* 56: 66-82.

Haas, F. 1929. Fauna malacológica terrestre y de agua dulce de Cataluña. *Treballs del Museu de Ciencias Naturales de Barcelona* 13: 491 pp.

Hammer, U. T. 1986. *Saline lake ecosystems of the world*. Junk Publ. 616 pp.

Hessling, T. von, 1859. *Die Perlnmuscheln und thre Perlen (Naturwissen-schaftlich und geschichtlich mit Beruecksichtigung der Perlgewaesser Baerns)*. Leipzig. 372 pp.

IUCN., 1996. *1996 IUCN Red List of Threatened Animals*. IUCN, Gland, Switzerland and Cambridge, UK, 228 pp.

Lydeard, Ch., M. Mulvey., and G. M. Davis. 1996. Molecular systematics and evolution of reproductive traits of North American freshwater unionacean mussels (Mollusca: Bivalvia) as inferred from 16S rRNA gene sequences. *Philosophical Transactions of the Royal Society of London Series B* 351: 1593-1603.

Machado, A. 1997. *Guidelines for action plans for animal species: planning recovery. Convention on the con - servation of European wildlife and natural habitats (Bern Convention)*. Nature and Environment, No. 92. Council of Europe Publishing. 76 pp.

Machordom, A., R. Araujo, D. Erpenbeck & M. A. Ramos. Conservation genetics of endangered Margaritiferidae (Bivalvia: Unionoidea). In prep.

McMahon, R. 1991. Mollusca: Bivalvia. Pages 341-399 in: J.H. Throp & A.P. Covich. *Ecology and classification of North American freshwater invertebrates*. Academic Press, INC. San Diego, California.

Ollero, A. *El curso medio del Ebro*. Publicaciones del Consejo de protección de la Naturaleza de Aragón. Serie: Investigación. Zaragoza, 311 pp.

Prat, N. & Ibañez, C. 1995. Effects of water transfers projected in the Spanish National Hydrological Plan on the ecology of the lower River Ebro (N. E. Spain) and its delta. *Water Science and Technology* 31(8): 79-86.

Preece, R. C. 1988. A second British interglaciar record of *Margaritifera auricularia*. *Journal of Conchology* 33(1): 50-51.

Preece, R. C., R. Burleigh., M. P. Kerney., and E. A. Jarzembowski. 1983. Radiocarbon age determination of fossil *Margaritifera auricularia* (Spengler) from the River Thames in West London. *Journal of Archaeological Science* 10: 249-257.

Ramos, M.A. 1994. Progress in invertebrate conservation in Spain in 1992-1994. In: Convention on the conservation of European wildlife and natural habitats. Group of Experts on Conservation of Invertebrates. Council of Europe T-PVS-INV (94) 6: 2.

Ramos, M.A. 1996. Report from Spain. In: Convention on the conservation of European wildlife and natural habitats. *Group of Experts on Conservation of Invertebrates. Council of Europe*, T-PVS (96) 33: 42-43.

Ramos, M.A. 1998a. Implementing the Habitats Directive for molluscs species in Spain. *Journal of Conchology, special publication*, 2: 125-132.

Ramos, M.A. 1998b. Main progress towards the conservation of Bern Convention Invertebrates in Spain since 1996. In: Convention on the conservation of European wildlife and natural habitats. *Group of Experts on Conservation of Invertebrates. Council of Europe*, T-PVS (98) 18: 59-69.

Ramos, M. A. (Ed.) In Press. *Invertebrados no insectos de la Directiva Hábitats en España*. Serie Técnica del Ministerio de Medio Ambiente.

Ramos, M.A. & Rosas, G. 1994. Bern Convention invertebrates requiring special habitat conservation measures in Spain. In: Convention on the conservation of European wildlife and natural habitats. *Group of Experts on Conservation of Invertebrates. Council of Europe* T-PVS-INV (94) 6: 3-28.

Sládecek, V. 1990. Water quality in Czechoslovak water-supply impoundments. *Archiv für Hydrobiologie* 33: 819-825.

Smith, D. G. & W. P. Wall. 1984. The Margariferidae reinstated: a replay to Davis and Fuller (1981), "Genetic relationships among recent Unionacea (Bivalvia) of North America". *Occasional Papers on Mollusks, Museum of Comparative Zoology (Harvard University)* 4(64): 321-330.

Unesco, 1992. Clasificación de masas de agua en relación con sus pretendidos usos. En: *"El control de la eutro - fización en lagos y pantanos"*. Ed. Pirámide. Madrid. pp. 315-335.

Wells, S. M., Pyle, M. & N. M. Collins. 1983. *The IUCN Invertebrate Red Data Book*. IUCN Gland., pp. 147-156.

Woodward, F. R. 1996. *Margaritifera auricularia* (Spengler, 1793). In: *Background information on invertebrates of the Habitats Directive and the Bern Convention*. Part III- *Mollusca and Echinodermata*. Nature and Environment, No. 81. Eds: van Helsdingen, P. J., Willemse, L. & Speight, M. C. D. Council of Europe Publishing. pp. 495-500.

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Action plan for *Margaritifera margaritifera* in Europe

CONTENTS

SUMMARY

The freshwater pearl mussel *Margaritifera margaritifera* (L.) was probably the most abundant bivalve in ancient rivers all around the world. Although it is very threatened, populations still exist in many European countries. The species is protected under the Habitats Directive (Appendix II and Appendix V) and the Bern Convention (Appendix III). In the IUCN 1996 Red Data Book it is listed as Endangered.

The species needs a fish of the family Salmonidae to host the metamorphosis of its larval stage, called glochidium. Thus, alterations to the habitat of the host fish also work against the mussel. The river bed substratum is of great importance to the mussels, and determines the river areas where they can survive. Clean gravel and sand are essential for a healthy population, being very important for juveniles because if the substratum becomes clogged with silt, oxygen can no longer reach them and they die. For them to thrive, there needs to be enough brown trout or salmon with viable natural reproduction. Anomalies in feeding conditions within mussel habitats and in their environments are the clues to the rarification of this species.

The causes of the species decline are not completely known, but habitat alteration and fragmentation are probably the origin. Taking into account the data provided by each country's National Nature Conservation Agencies, the main reasons for the decline in *M. margaritifera* are anthropogenic influences on aquatic systems: eutrophication, impoundment, river regulation, drainage, sewage disposal, dredging, farms, new agricultural land use, loss of forests and natural river banks, water pollution, acidification, pesticides, and introduced exotic fish species. Factors influencing the abundance of fish hosts are also responsible. Data suggest that around 90% of the European specimens of *M. margariti - fera* disappeared in the twentieth century. Overfishing for pearls was one of the main factors, particularly in some countries.

Legislation, rational water use, research, management (including species reintroduction), monitoring and education/consultation will be of foremost importance for species conservation. As a freshwater animal, *M. margaritifera* comes into constant conflict with people, mainly due to the large-scale engineering works for water exploitation (canalisation, dredging, regulation, impoundment, power plants, etc.). Due to this fact, the first thing is to establish the priorities in the respective countries. There is no sense in demanding freshwater species conservation at the same time as main roads, dams and macrochanges in the landscape make the freshwater ecosystem unsuitable for those species. As fertility is maintained even in sparse populations and in pollute rivers, the populations should recover if the causes of decline are removed.

Further studies are needed to fill the gaps in the known distribution of the species in Europe.

Protection of European freshwater systems harbouring populations of *M. margaritifera* under the Natura 2000 Network or as UNESCO Biosphere Reserves may be essential for species survival.

1. INTRODUCTION

The freshwater pearl mussel *Margaritifera margaritifera* (L.) was probably the most abundant bivalve in ancient oligotrophic rivers all over the Northern Hemisphere (Holarctic Region). Although dense populations have been described from Northern Europe, *M. margaritifera* lived on both sides of the Atlantic. The identity of similar species living on the North American West coast (*M. falcata*) and in the Far East (*M. laevis*) has not yet been clarified. The best preserved populations are at present in Western Russia in rivers on the Kola Peninsula.

Although in decline, populations still exist in many European countries. The species is protected under the Habitats Directive (Appendix II and Appendix V) and the Bern Convention (Appendix III). It is listed as Endangered in the IUCN 1996 Red Data Book. Some European countries harbouring populations of the species have developed action plans to protect it (see below); however, this document is the first attempt at a Pan-European Action Plan for the species.

Until 1985, the main bibliography about the species was summarised by Jungbluth, Coomans & Grohs (1985), but a lot of new information is currently flourishing (see references).

All freshwater mussels share a complex life cycle because they require a vertebrate host, usually a fish during their larval stage. This microscopic thin-shelled larva (glochidium) that the mussels brood and release by the millions normally has hooks and/or teeth to attach itself to the fish body where it encapsulates and spends several weeks completing its development until its recruitment as a metamorphosed benthic juvenile. This is the mussel's dispersal method. For this reason, maintaining natural populations of native fish is essential for the conservation of the naiads. Many data exist about the specificity between the glochidium of *M. margaritifera* and fish of the Salmonidae family, especially *Salmo salar* and *Salmo trutta fario*. Thus, alterations to the habitat of the fish hosts also work against the mussel.

Margaritifera margaritifera, as a freshwater animal, is in constant conflict with people, mainly as a result of big engineering works for water exploitation (canalisation, dredging, regulation, impoundment, power plants, etc.). When preparing this action plan, we tried not to obviate the "human factor" and to work with two kinds of approaches in accordance with Council of Europe recommendations (Council of Europe, 1996; Machado, 1997) on integrated ecosystem management and control of processes that negatively affect biodiversity.

In this dossier we have attempted to compile information from the countries with living populations in order to fulfil the necessary objectives required in drafting an action plan for *M. margaritifera.* These objectives are as follows:

1. To update the distribution and biological data.
2. To establish the threats hanging over the species.
3. To establish useful and realistic conservation measures.
4. To recover populations.

The information included in this report has been compiled from the bibliography, personal data and data provided by the different governmental agencies in countries where the species is thought to live. The answers to our questionnaire were very heterogeneous, as can be seen from this report, probably according to the level of knowledge in each country. Being aware of the risk of this heterogeneity, we

preferred to assume it, including detailed information from countries where it was available. The report contributors are listed in Appendix 1. We are very grateful to all of them for their help.

2. BACKGROUND INFORMATION

2.1. Systematics

Phylum Mollusca
Class Bivalvia
Order Unionoida
Family Margaritiferidae

Common name: Freshwater pearl mussel, Ostra de río, Almeja perlífera, Madreperla de río, Ameixa de río, Mulette perlière, Moule perlière, Flussperlmuschel, Elvemuslingen, Flodpärl musslan, Ziemelu upesperlene, Upes perlgliemene, Presnovodnaja zhemchuznitsa.

The genus *Margaritifera* was described by Schumacher in 1816, with *Mya margaritifera* Linnaeus, 1758 (= *Margaritifera margaritifera*) as the type species. However, its taxonomy is still unclear and, therefore, also the number of living species it contains. Although it is a declining genus, with all its species endangered, living species of *Margaritifera* have been recorded from North America, Europe and Asia, with only two species in Europe, *M. margaritifera* and *M. auricularia*.

Margaritifera, with the North American genus *Cumberlandia* and the uncertain Asiatic genus *Margaritanopsis*, constitute the family *Margaritiferidae*, including the oldest species of the Unionacea. It includes species with characteristic conchological and anatomical features (i.e. absence of diaphragm, incubation in the four gills, marsupium without water tubes, hookless glochidium) different to other naiads (families Unionidae, Mutelidae, Etheridae) (Davis & Fuller, 1981; Smith & Wall, 1984). These differences have recently been supported using molecular data (Davis & Fuller, 1981; Lydeard, Mulvey & Davis, 1996).

The taxonomic status of the Irish hardwater *M. durrovensis* is scientifically discussed in relation to *M. margaritifera* (Phillips 1928; Chesney, Oliver & Davis, 1993; Moorkens & Costello 1994). At present, only *M. margaritifera* and *M. auricularia* appear on the list of wildlife species under the Council of Europe's Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 1979). However, the European Union Directive on the Conservation of Natural and Semi-Natural Habitats and of Wild Fauna and Flora (Directive 92/43/EEC, Habitats Directive), recently listed *M. durrovensis* as *M. durrovensis* (*M. margaritifera*) in Annex II and Annex V (Directive 97/62/CE). In the International Union for the Conservation of Nature and Natural Resources Red Data List (IUCN 1996) *M. durrovensis* is listed as Critically Endangered.

2.2. Description of the species

Adults present a large, dark, fragile and elongated shell up to 15 cm long. The umbones do not rise above the shell and are generally very eroded. The longer region of the shell contains the posterior part of the body, including the water interchange inhalant and exhalant apertures; the foot aperture is located in the anterior region.

The inner side of the shell is pearl white, sometimes with iridescent colours. The pallial line is less obvious than in *M. auricularia* and the inner muscle scars are obvious, mainly the anterior one. The

hinge has vestigial posterior lateral teeth, practically inexistent, and pseudocardinal teeth less developed than in *M. auricularia*, one in the right valve and two in the left, the posterior one being less developed.

The foot is white and very big, capable of becoming as large as the whole shell when protruding. There are no real siphons, as only a transversal thickening on the inner side of the posterior mantle (the diaphragm) maintain the exhalant and inhalant apertures separate in live specimens. The edge of the mantle in this area is thickened by rows of papillae. Anteriorly, the labial palps, two on each side, move the water currents in order to select the food which will be ingested through the mouth, between the palps, once it has been sorted by the gills. The latter are under the mantle, two inner and two external, all without water tubes, an important difference with other families of Unionacea. In the dorsal part of the foot and embedded in the visceral mass is the gonad, which is sometimes hermaphroditic.

The glochidia are very small (60 x 70 µm). They were recently described as having neither spines nor teeth (Nezlin *et al*., 1994; Pekkarinen and Valovirta, 1996) although Harms (1907, 1909) described very minute teeth at the ventral border in the first description of this larva.

2.3. Distribution and population numbers

2.3.1. World distribution

Margaritifera margaritifera lives on both sides of the Atlantic in clean streams and rivers with healthy populations of salmonids throughout much of the Holarctic region. It is known from north-west Russia, Northern Europe, eastern North America and Canada. In Europe, it occurs in rivers of the Arctic and Atlantic oceans. Its range is bounded by the Alps to the South and by the basin of the Severnaya Dvina River to the East (Ziuganov *et al*., 1994). In North America, it occurs on the Atlantic coast from Newfoundland, Canada down to Delaware and Pennsylvania. To the West, the range is bounded by the Appalachians.

Population numbers are declining in all countries. The species is nearly extinct in many areas and only undisturbed river basins, such as those on the Kola Peninsula, maintain flourishing populations with important juvenile recruitment.

2.3.2. European distribution by countries

- Austria

The species is endangered and has been reduced by about 97-98% since the late 19th century. Of the 231 river sections sampled, 27 populations were located (Moog *et al*., 1998). Most of the remaining populations are either senescent or declining (Moog *et al*., 1998). There is an estimated total of 50,000 individuals covering approximately 2,520 km^2. The largest population so far discovered contains about 20,000 individuals, and 19 populations have less than 1,000 (Moog *et al*., 1998).

- Belgium

The past distribution of the species included only south-eastern rivers all of them flowing in the Ardenne region: Amblève, Ourthe, Lomme, Lesse rivers (Adam, 1960). It was also known from the

Schwalm (Jungbluth, 1993) and the River Our, mainly in the Luxembourg section (Trois Frontières, Frein, Moulin de Kalborn, Tintesmühle, Grossenaul) (Birringer & Truffner, 1990). At present its distribution is poorly known, and although the data are contradictory it seems that only a few agged specimens have been located in small streams of the Rhine catchment (including the river Our) and from rivers belonging to the basin of some important tributaries of the Meuse (Vrignaud, 2000; Roland Libois, pers. obs.).

- Czech Republic

There are about 130,000 specimens in 15 localities of different rivers and brooks. The main population is in the River Blanice, with 115,000 individuals (Hruska, 1999).

- Denmark

The species is only found along a relatively short stretch of the River Varder in the north-west of Jütland, the last records being from 1974. There is no current data on the species in the river, and there is a need to investigate if the species still occurs in the locality and if possible specimens can still breed (Stoltze & Pihl, 1998).

- Estonia

According to data from 1998, there is only one locality with an old population of around 40,000 specimens.

- Finland

At the beginning of this century there were approximately 200 rivers with freshwater pearl mussel populations. Today, only 25% of these rivers still contain populations. In southern Finland, the populations have declined radically, only in one of the eight rivers is there a breeding population (Valovirta & Yrjänä, 1996). The species never occurred in the lake district of Central Finland. The last estimation (1999) yielded about 3 million individuals, 90% of them in eastern Lapland (65°N-69°N). Together with its tributaries, the River Lutto harbours the most numerous populations. The current total is estimated at least 1.5 million.

- France

Historically the species was present in water courses of the oldest mountains such as the Armorican Massif, the Vosges, the Ardennes, the Central Massif and the western Pyrenees. The cites of the Alps and the Jura are probably erroneous (Vrignaud, 2000). The population has decreased by about 90% in the last century, the estimated number of individuals being about 100,000. The main decrease occurred in Brittany, Normandy, Vosges and the Massif Central (Cochet, 1999).

Data derived from surveys since 1993 report the species from at least 74 rivers in 26 *départements* as follows (Guilbot *et al*., 1998): 14 Armorican Massif, 57 Central Massif and Morvan, 1 Vosges and 2 Pyrenees. News of breeding populations only comes from rivers in Morvan, the Central Massif and the Pyrenees.

• Germany

The information on *M. margaritifera* detailed by regions is as follows:

— Schleswig-Holstein: No viable populations have ever existed.

— Niedersachsen: A population of 2,000-2,500 specimens exists in the Lachte-Lutter stream system.

— Nordrhein-Westfalen: The species is extinct. The last small populations of the Eiffel mountain system were translocated four years ago to Belgium.

— Rheinland-Pfalz: Although formerly occurring in several rivers of this state the species is now regarded as extinct, except for the population in the river Our, shared with the country of Luxemburg.

— Hessen: No data on presence of the species are available. There exists one relic population of about a dozen of aged specimens in the Vogelsberg mountain (Kremer, pers. comm.).

— Baden-Württemberg: Listed as threatened with extinction in the Red List of Endangered Snails and Mussels in Baden-Württemberg (1995), but regarded as extinct nowadays. The species does not occur in this state. Mussels were artificially introduced in the 18th century into the Steinach river system (Odenwald mountains), being the only successful introduction in this state, but the population is currently (1978) extinct.

— Bayern: In the nineteenth century, the population was estimated at 20 million individuals. There are now approximately 200,000 in 60 populations in freshwater systems of the Bayerischer Wald, Oberpfälzer Wald and Fichtelgebirge mountains. In the last decade, only 10 populations contained juveniles, but the reproductive rate is not enough to ensure their future survival.

— Thüringen: The species in this state only lived in small freshwater systems, but went extinct in the last or first half of the twentieth century. Two no-chance specimens exist in the Wettera River near Schleiz.

— Sachsen: In the Wolfsbach, the population in the watershed system of the Saale stream numbers 1,700; in the Triebelbach and Raunerbach in the watershed system of the Weisse Elster stream, there are approximately 100 specimens.

• Ireland

According to recent reports (Moorkens, 1999), the species is still widespread, with at least well-dispersed remnant populations around the country away from the central limestone plain in soft waters lying mainly on granite or sandstone bedrock, except for the *M. durrovensis* population in the lime-rich River Nore. Of 32 living populations, only eight have young mussels. In some of these populations, the last successful recruitment of young dates back to the 1960s or early 1970s (Moorkens, 1999). However, populations are numerous and apparently successfully reproducing in a small number of rivers. Recent survey (1999) demonstrates that two of these each contain in excess of 2,500,000 living, adult mussels (Speight, pers. comm.).

- Latvia

There are five populations in five different streams with total length of 25 km in the eastern part of the country. Population number (about 11,800 specimens) and size have decreased by more than 80% since the beginning of the 20th century. There are no specimens younger than 35-40 years (63 mm).

- Lithuania

The last record of the species is from 1990 in the east of the country.

- Luxembourg

Until the first half of the twentieth century the species was widely distributed in the Ardennes region, being common in Ösling streams (Ferrant, 1892, 1902). Altitude is between 180m (low section of the River Our) and 400m (east of the Ardennes). A few shells of recently dead mussels were found 30 years ago in the Rivers Troine, Clerve, Wiltz, Sure and Our (Groh, 1999).

West of the Rhine, the populations of the Vosges, the Eifel and the Hunsrück are extinct and in regression in the Ardenne. In this region, some rivers, either in Belgium (Amblève, Ourthe, Lomme, Lesse) or in Luxembourg (Troine, Cleve, Wiltz) where thriving populations were mentioned in the past, require further research to assess if live populations still exist there. Fortunately, the River Our and some small rivers of southern Belgium are still populated, sometimes by a reasonable number of mussels (>1000 ind) (Libois, pers. comm.). Therefore, these streams and the River Our seem to be the most important for the conservation of the species in the north-western continental Europe. However, the populations seem to be at risk because it seem that they contain only aged non-breeding specimens. In the River Our, the population was estimated at about 3,000 adults in 1989, while in 1999 only 1,500 specimens were estimated along a 20 km section of the river (Groh, 1999).

- Netherlands

The species does not occur in this country. There was one unsuccessful recolonization attempt in 1991.

- Norway

The populations of the species have shown a steady decrease over a long period. In many localities they have become extinct or recruitment has ceased, resulting in populations top-heavy with old individuals (Larsen, 1997). The species occurs in 340-350 watercourses in all the counties of Norway, but is most numerous along the coast. The greatest decline has been recorded in the counties of Vest-Agder, Aust-Agder and Rogaland. Little information is available for the rest of the country.

- Poland

The species has been extinct in Poland for fifty years. It was fairly abundant in Lower Silesia until the end of the Middle Ages. It was also known to be a common species in a few Sudetic streams in the early 1900s. Its occurrence in Poland has not been confirmed since the 1930s.

• Portugal

There are only old published reports of the species in Portugal (Nobre, 1941) and specimens stored at the Museu de Historia Natural (Faculdade de Ciencias do Porto), which were collected in the Douro, Sousa and Vouga rivers. A very recent record of the species is reported in the Rabasal River (Rolán, pers. comm.).

• Slovakia

The species did not originally occur in this country.

• Spain

Results point to the decline of Spain's salmon rivers during the twentieth century although new records of the mussel have been added to those reported by Bauer (1986), extending the species's distribution area to other river basins in Asturias and Zamora (Araujo & Ramos, in press; Ramos, 1998). The species is present in 14 rivers of the following provinces: Pontevedra, A Coruña, Lugo, Asturias and Zamora. The best populations occur in the Narcea River (Asturias), where densities are between 14.5±15.9 ind/m^2 and 76±5.72 ind/m^2 and the existence of juvenile recruitment has been demonstrated (INDUROT, 1999; Álvarez-Claudio *et al*., 2000). New surveys are needed to ascertain the real distribution and densities of the species.

• Sweden

The freshwater pearl mussel was the subject of inventories in the field in the period 1980-1997 in 18 of the 21 counties, being absent in the other three. It was present in 370 of the 1100 watercourses surveyed. About three million individuals were estimated at 53 carefully studied sites, although following recent data from the WWF, the current number of specimens is about eight million (Henrikson, pers. com.). Compared with data from the first half of the twentieth century, the species has disappeared from more than 35% of its former sites, and recruitment fails at approximately 75% of sites.Nowadays, recruitment occurs at only one third of the inhabited sites. The healthiest populations are found in the northern and extreme south-eastern parts of Sweden. A common pattern is that populations in the main streams have disappeared, while isolated fragments or more widespread populations exist in the tributaries.

• United Kingdom.

— Scotland: Scotland is the UK stronghold for the freshwater pearl mussel . Historical records indicate that the freshwater pearl mussel was originally present throughout mainland Scotland (except in the River Tweed catchment and in the sandstone area of Caithness) and on some of the larger Western Isles, occupying over 150 rivers in total. All data suggest that in Scotland populations of the species are undergoing a catastrophic decline. In a recent survey, only 48 of the 148 sites that were known to be occupied 100 years ago retain functional populations; of these only 15 populations show evidence of recruitment, ten of them having more than 500 mussels per 50 m transect. The rate of extinction has doubled since 1970, with an average rate of loss of two populations per year since then (Cooksley, 1999).

— England: Few populations of the species remain in England. There are historical records from Devon, north Cornwall, the rivers Wye and Severn, the North Yorkshire Moors, the North Tyne and

Cumbria. A survey of seven of these rivers and one small stream found generally sparse populations, with only four having evidence of recruitment. Of these four rivers there is only one potentially viable population, numbering several hundred thousand adults, however, mortality greatly exceeds recruitment in this population. (Cooksley, 1999).

— Wales: In Wales the species is very scarce. There is historical evidence of large populations in the Rivers Conway and Wye, but which are now virtually extinct. There are records from streams in Pembroke, Carmarthenshire, Cardiganshire, Glamorganshire, Denbighshire, Snowdonia and some tributaries of the River Severn. The south-west and most of the Snowdonian populations now consist of only a few hundred senescent individuals. Only one Snowdonian population, which numbers approximately 3000 adults, shows evidence of some recent recruitment (Cooksley, 1999).

— Northern Ireland: Historically, populations of M. margaritifera were found in the Foyle, Bush and Erne catchments, and the central Loaugh Neagh feeder streams. Recent surveys have found live mussels at only 20 sites (3 rivers) out of 250 surveyed. Juveniles are virtually absent in these populations and recruitment rates are well below those needed to sustain them (Cooksley, 1999).

2.4. Life history

2.4.1. Life cycle

All freshwater mussels share a complex life cycle, requiring a vertebrate host, usually a fish, during their parasitic larval stage. These microscopic thin-shelled larvae (glochidium), which are brooded and released by the millions, were presumed in the nineteenth century to be a parasitic species of fish (*Glochidium parasiticum*). The glochidium usually has hooks to attach itself to the fish body (fins or gills), where it becomes encapsulated for several weeks before changing into a free-living juvenile. The glochidium of *M. margaritifera* is of the hookless type, but presents very minute teeth at the ventral border (Harms, 1907, 1909) although this larva was recently described as having neither spines nor teeth (Nezlin *et al*., 1994; Pekkarinen and Valovirta, 1996).

Information on the relationship between mussel and fish hosts is essential in any attempt to preserve endangered freshwater mussels. A lot of published information exists on the specificity between the *M. margaritifera* glochidium and salmonid fish, especially *Salmo salar* and *Salmo trutta fario*.

Once encysted in the fish gill filaments, the glochidium metamorphoses during a period of time which lasts depending on temperature. Two kinds of strategies have been described in the case of *M. margaritifera,* from 20-60 days to seven-nine months, although both strategies have been observed in the same population (Ziuganov *et al*., 1994). Very little is known about juvenile habitat once they have emerged from the fish gill. Studies on this subject are currently underway in several European countries.

Sexual maturation occurs between seven and 15 years of age (Meyers & Milleman, 1977; Young & Williams, 1984) and the fertile period may be prolonged into old age. It is supposed to be a dioecious species although several cases of hermaphroditism have been reported (Bauer, 1987; Hanstén, Pekkarinen & Valovirta, 1997; Grande, Araujo & Ramos, 2001). According to Bauer (1987), the species can change it sex towards hermaphroditism under conditions of population stress. In all known European populations, females are gravid for two-three months from June, and glochidia are present in the fish gills from August.

The larvae are incubated in the four gills as in all other species of the family. An average of 9.8 million glochidia were found to be produced per female (Ross, 1992).

According to Bauer (1992), the species lifespan is between 30 and 132 years and the maximum shell length between 80 to 145 mm depending on the population (latitude and altitude). When there is enough available food, juveniles grow rapidly, but population lifespan is shorter. The largest known specimen is from the River Keret (Karelia, Russia) with 162 mm and the absolute theoretical maximum age is 167 years old (Ziuganov *et al*., 1994).

Recent molecular data dealing with populations from Spain to Kola (Machordom *et al*., in prep.) indicates that they can be considered as a metapopulation due the slight genetic differentition among the specimens studied.

2.4.2. Habitat requirements

It was a common species in upper and middle river sections, mainly in rapid, clean and oligotrophic waters. *M. margaritifera* lives in granitic areas with low calcium rates. It lives partially burrowed in gravels and stones, sometimes behind stones or rocks, taking advantage of the available currents. Juvenile specimens (under 50 mm) can live completely burrowed (up to 20 cm) in the substratum. There is one hardwater population in Ireland known as *Margaritifera durrovensis* whose taxonomic status is under discussion (Chesney, Oliver & Chesney, 1993; Moorkens, 1996).

The river bed substratum is very important to mussels and determines the river areas where they can survive. Clean gravel and sand are essential to a healthy population (Moorkens, 1999) and it is very important for juveniles because if the substratum becomes clogged with silt, they can no longer obtain oxygen and so they die.

Margaritifera margaritifera lives in typical salmon rivers at depths of between 0.5 and 2 m (Ziuganov et al., 1994), but it may also be common at greater depths. It can tolerate temperatures of up to 28°C for a short time (10-20 min) and is able to survive out of water for 30 days at 15°C. It avoids turbid waters and waters with low oxygen levels. Except for people, it has no natural enemies although it may be predated by the muskrat (*Ondatra zibethicus*). For it to thrive, there needs to be sufficient brown trout or salmon with viable natural reproduction.

The fact that old mussels can breed and that high mortality is not common suggests that juvenile interstitial phase may be the most sensitive period of the life cycle. Knowledge of auto-ecological requirements during the first 4-5 years of the mussel's life is still lacking (Moog *et al*., 1998). Nevertheless, we discovered very recently that anomalies in nutritional conditions within mussel habitats as well as in their environments are clues to the species rarification (Hruska, 1999). According to this author, plant detritus entering the water from their surroundings serves as food source, and young mussels depend on this supply of detritus, which consists of small particles that penetrate the waters via underground transport processes.

2.5. Threats and limiting factors

The dramatic decline of *M. margaritifera* in Europe has run parallel to that of other naiads throughout the world. Bogan (1993) described the reasons for naiad rarification and extinction as habitat alteration or destruction, decline or extinction of fish hosts, commercial exploitation, and introduced species. Suitable habitat, i.e. Europe's clean salmonid rivers, is clearly disappearing.

The main reasons for the decline of *M. margaritifera* are anthropogenic influences on aquatic systems: eutrophication, impoundment, river regulation, drainage, sewage disposal, dredging, farms, new agricultural land use, loss of forests and natural river banks, water pollution, acidification and pesticides and introduced exotic fish species. Factors influencing fish host numbers are also responsible. However, data suggest that around 90% of European specimens disappeared in the twentieth century, overfishing for pearls being one of the main factors, particularly in Germany (Hessling, 1859; Boettger, 1954).

As we know that there is a very direct relationship between survivorship and availability of nutritive material from the environment, it seems that substances from areas subjected to intensive agriculture or forestry reach the water and could be directly related with the disappearance of the species (normally through the death of juveniles and consequent ageing of the populations).

The minimum population sub-unit is considered to be 500 reproductive individuals within 0.5 km of river (Irish data from Moorkens, 1999). This author summarises the threats to the species in her country as follows: 1- Nutrient enrichment. 2- Pollution incidents. 3- River bank erosion. 4- Forest plantation. 5- Road building. 6- Bog drainage and arterial drainage schemes. 7- Salmonid stocks. 8- Pearl fishing. 9- River modification. 10- Overgrazing. 11- Water abstraction. 12- Introduction of exotic species.

The spread of invasive species, such as the zebra mussel (*Dreissena polymorpha*), will be one of the main threats to native freshwater mussels, especially naiads.

2.5.1. Habitat loss and habitat alteration

The natural habitat of *M. margaritifera* was probably similar to those existing in the undisturbed rivers in the south of the Kola Peninsula. Although there are still some undisturbed rivers with *M. margariti - fera* populations in a few countries of Northern Europe, this habitat is virtually being destroyed in most of the European countries where the species used to be common.

The main unwanted changes in freshwater or stream systems are mainly caused by the human activities listed below, either by direct physical destruction or due to sedimentation or eutrophication. For instance, a recruitment population of *M. margaritifera* numbering 5,000 individuals (the largest known population in Wales) was destroyed by dredging work on the Afon Ddu (Killeen, Oliver & Fowles, 1998).

Human activities responsible for freshwater pearl mussel decline through habitat alteration:

— Expansion and change in water bodies (river modifications, developments of drainage/abstraction schemes, flow regulation, hydro-electric schemes, fishery improvements) have been widely cited as unfavourable for freshwater mussels to thrive. One typical example is the construction of dams along freshwater mussel rivers that interrupt migratory trips of anadromous or catadromous fishes likely to harbour glochidia. Regarding river canalisation, there is a strong negative correlation between rivers that have been canalised and the presence of pearl mussels (Moorkens, 1996).

— Substrate mobilisation and dredging are directly responsible for freshwater mussel extraction (adults and juveniles) and secondary alterations to fish breeding areas.

— Deforestation causes a dramatic increase in river sedimentation. The disappearance of river shore trees leads to soil and nutrient losses through runoff and subsequent eutrophication and siltation.

— Eutrophication and decreasing water quality are also important factors working against freshwater mussel populations and river fish diversity. Although adult specimens can survive in eutrophicated waters, reproduction of those relict specimens in such conditions always presents a dangerous dependency. The juvenile stage is very susceptible to pollutants and a drop in water quality. Increasing organic material fills interstitial spaces in the substrate, which is the habitat of released juveniles.

— Bad agricultural land use causes alterations to river water quality (fertilisers, chemical pollutants, algal growth, eutrophication) and sedimentation systems. Cattle going into the river to drink cause river bank erosion and river bed siltation (Moorkens, 1999).

— Acid rains reduce salmonid populations and, therefore, freshwater pearl mussels, but it is not known to what extent acidification directly affects species (Cooksley, 1999).

2.5.2. Human activities

The abovementioned threats are of course due to human activities, but in this section we will deal with more direct human activities limiting species survivorship.

Fishing for the pearls of freshwater mussels has been known since the time of the Romans. More recently, data from Hessling (1859) give us an idea of the dangers derived from overfishing: between 1814 and 1857, 158,000 pearls were collected in the Bavaria region alone. This is a horrifying number bearing in mind that in order to find one pearl, nearly 3,000 mussels have to be opened (Hessling, 1859). In Ireland, Moorkens (1999) reports that at least five of the eight rivers containing breeding mussel populations were fished in the recent past.

Another threat directly associated with humans is the possible capture of specimens by poachers, once the risk to the species is already known. Collectors may be interested in having specimens of *M. margaritifera* due their value as pretty objects (pearls) and rare species.

Although not common now, log floating used to be a widespread technique on European rivers. In order to permit log floating, many rivers were altered by modifying the cross-section of their channels and, thus, the habitat of benthic fauna. This problem has been reported at least in Finnish rivers (Valovirta & Yrjänä, 1996).

The introduction of exotic fish species (i.e. rainbow trout *Oncorrynchus mykiss*) restricts the number of native fish as hosts of *M. margaritifera* glochidia.

The spread of invasive bivalve species favoured by Man (i.e. passive transport on the bottom of boats or in ballast water) reduces *M. margaritifera*'s ability to thrive. This has occurred in all countries invaded by the zebra mussel *Dreissena polymorpha.*

2.6. Conservation status and current legal protection

2.6.1. International agreements

— IUCN (International Union for Conservation of Nature and Natural Resources) 1996 Red Data List included the species as "Endangered" (IUCN, 1996).

— Habitats and Species Directive (European Union Directive on the Conservation of Natural Habitats and of Wild Flora and Fauna, -Directive 92/43/EEC). The species is listed in Annex II, which includes “animal and plant species of Community interest requiring the design of special conservation areas” and Annex V including “animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures”. More recently, the EU adopted a new Directive (Directive 97/62/EEC) modifying the previous list. On this new list *M. durrovensis* has been listed as *Margaritifera durrovensis* (*Margaritifera margaritifera*), as well in Annexes II and V.

— Bern Convention (Council of Europe’s Convention on the Conservation of European Wildlife and Natural Habitats, 1979). The species was included in 1987 in Appendix III**,** “Protected fauna species”. However, until more scientific information on the taxonomic status of *M. durrovensis* is published, the Council of Europe does not plan to amend the list to include this taxon. The last meeting of the Group of Experts on Conservation of Invertebrates (Neuchatel, 2000) reviewed a draft version of this Action Plan (Araujo & Ramos, 2000) raising its quality and asked the Secretariat to prepare a reviewed version insisting in the need of international collaboration and a common protocol to standardize surveys of the species.

2.6.2. Listing of individual countries

• Austria

Although the species is endangered and threatened by extinction in most parts of its Austrian distribution (Moog *et al*., 1998), it is not listed under nature protection laws. Nevertheless, it is protected by the fishery laws of Upper and Lower Austria. There are currently two projects aimed at protecting it, one in Upper Austria and the other in Lower Austria.

• Belgium

In addition to the abovementioned international agreements, the Bern Convention (Annexes III) and Habitats Directive (Annexes II and V), *M. margaritifera* is also included in the Regional Walloon Order of 3 June 1999 concerning the protection of several species of molluscs (M.B. 17/07/99).

• Czech Republic

On the River Blanice, where the main population lives, a species recovery project is currently in progress (Hruska, 1999). Nevertheless, problems from mechanical pollution due to the sand and other sediments during irregular flows and the absence of the necessary ecological agriculture in the river basin are threatening this population. Similar problems are affecting the other populations.

Margaritifera margaritifera appears on the Red Data List of Endangered and Rare Species of Plants and Animals of the CSFR 3-Invertebrates and among the critically endangered species on the Red List of Water Molluscs of the Czech Republic.

It is protected on a nationwide scale by Act No. 114/1992 Gazette on Protection of Nature and Landscape Conservation as a specially protected species in the “critically endangered” category. The River Blanice is a biogenetic reserve of the Council of Europe and River Teplá Vltava is part of a UNESCO biosphere reserve.

The conservation project is co-ordinated by the Nature Conservation and Landscape Protection Agency of the Czech Republic.

- Denmark

It was protected by Ministerial Order No. 67 of 4/2 1999 with later amendments, now under revision. The River Varde has been nominated as a protected site under the EC Habitats Directive because of the presence of *M. margaritifera*. The decline in the species is probably caused by past discharges of mercury into a lake belonging to the river system. At present, there are no plans to recover the species.

- Estonia

The species is protected on the Red Data List in Category 1 as an endangered species. According to the Act on Protected Natural Objects the species comes within Protection Category I. The site is also protected as habitat. The main threats affecting habitat are dredging, canalization and irregular water level.

- Finland

Finland's Red Data Book (1992) classifies *M. margaritifera* as a threatened species (threatened, vulnerable). The third edition of this Red Data Book (in preparation) will follow the new classifications of threatened species compiled by the IUCN. The species was protected by decree in Finland in 1955. More recently, the Habitats Directive and, in particular, the Natura 2000-network have been the key protection tools. In 1995 the Ministry of the Environment set a confiscation value of 3,500 FIM (585 EUROs) for a single *M. margaritifera.*

The World Wide Fund for Nature in Finland (WWF-SF), acting together with the Finnish Museum of Natural History, established (1978) a "*Margaritifera* working group" to inventory and study the distribution, ecology, morphology and protection of this species. Sub-aqua work is very prominent in the research of this group. During the last 22 years, the working group has checked freshwater pearl mussel populations in more than 70 rivers in different parts of Finland, and in some rivers in Russian Karelia and Estonia. All together, *Margaritifera* populations have been inventorised in more than 2000 km of one metre wide, underwater research transect.

In 1988, thirteen *M. margaritifera* sites were proposed as Natura 2000 sites (SCI). The on-going LIFE-Nature project (1997-2000) "Restoration of Fluvial Ecosystems Containing Pearl Mussels" includes the restoration of three riverine sites which have been proposed as SCI's for the Natura 2000 Network, as well as increasing public awareness. Seven organisations are taking part in this project**,** being the University of Helsinki the co-ordinator. The European Union granted 360,000 ECUs to start this LIFE Nature project. Recent progress in conserving *M. margaritifera* is summarised in the report of the conference "The freshwater pearl mussel in Europe: population status and conservation strategies" at Hof, Germany (Valovirta, pers. com.).

There are six main components in the project:

1) Inventory and history of *Margaritifera* populations. In the Korvuanjoki river (old pearl fishing river) only 500 specimens were found. The main reason was a thick layer of loose sand. Both of the southern rivers have been inventorised (SCUBA diving) very carefully by 5x5 m squares. In the river Pinsiö-Matalusjoki about 19,000 mussels were recorded and in the river Ruonanjoki 26,000 mussels.

The confiscation value (nature value) of these two populations is all together 150 millions FIM, which is about 2.5 million EUROs. This inventory has been comprehensive and the most accurate in Europe. It gave lot of new information about the optimum environment for *Margaritifera*. Moreover, the importance of the right water flow and the natural continuity of different river habitats, was quite a new result for the restoration of small rivers for freshwater pearl mussel, and for salmon (brown trout) too. It gave answers also to the question of why restoration work for salmon rivers has so often failed.

2) Restoration of river bed. For effective conservation of the freshwater pearl mussel two aspects of river quality must be addressed: The physical effects that contribute to river bed deterioration, and the parameters which define the quality of the water required by mussels in the river and drainage basin. During the last decade extensive projects have been started to restore the original habitat structure of canalised rivers in Finland. By 2000, more than 200 restoration projects had been completed, covering about 2000 separate rapid-flow sections of river channels. The right water flow and the natural continuity of different river habitats have proved very important in successful restoration of rivers for *Margaritifera* and for salmon, too. The Finnish “soft restoration technique” has been developed for *Margaritifera* rivers in the Natura-2000 areas. The core element of this technique is to restore rapid to rapid, stream to stream and still water to still water, using different construction methods, which re-establish the natural water dynamic specific to every river habitat. In restoring a seminatural river for *Margaritifera* we recognise the different types of river habitat and provide them with levels of natural water energy typical for every habitat type, as determined by channel slope and friction characteristics. It necessitates restoring what were originally rapids to rapids, streams to streams, still water to still water. In particular, restructuring a rapid into a series of short rapids and pools by deepening some sections and introducing bottom dams to others, will have a domino effect on other habitats both upstream and downstream, causing breakdown in their natural progression and consequent reduction in the sustainability of their conservation value.

3) Quality and flow of water. An extensive network of sampling stations for water analysis has been established on the watercourses since 1997, especially along the small southern rivers. The water quality parameters identified as active were to a significant extent established by comparisons made between sites with breeding mussel populations and sites with non-breeding populations or without any mussel population. The effects of water quality proved to be different for adult specimens and glochidial larvae. Continuous measurements of water flow, especially the overflow in spring and autumn, are suitable for recording in extreme habitat. Water volume, especially the volume of cool ground water, is important in southern Finland for the breeding of both *Margaritifera* and its brown trout host. For mussels, it is of paramount importance that, whatever restoration procedures are used, those procedures minimise the load of fine material entering the river water as a result of the restoration works, and leave the actual living area of the mussel untouched. The average suspended solids content we have recorded during the “soft” restoration process proved 6-15 times greater in the restoration areas than in control areas, but maximum quantities recorded hardly ever exceeded levels critical to the mussel populations. By contrast, where the ”hard” restoration process was used the average suspended solids content was about 60 times greater than in the control areas, so that average quantities were way beyond the capacity of mussels to tolerate.

4) Artificial breeding of *Margaritifera* and transport of specimens. We have used artificial breeding in our project to help the glochidium of *Margaritifera* to find the gills of host fish in a laboratory and also under field conditions. The most critical epoch is one to two weeks in late summer or early autumn, when the mother mussel releases the larvae into the water of the river, and in the spring when the young mussels drop down into the river bottom. During these periods, good water quality is extre-

mely important for the lifecycle of *Margaritifera.* As a last conservation method we have used the translocation of freshwater pearl mussels from restoration areas. To do this we have adapted a method used for transporting salmon fry.

5) Host fish populations. We have used genetic tests to identify the original trout populations of the *Margaritifera* rivers. One product has been recognition that there are differences between brown trout populations from different rivers, in the degree of success with which they may be used to transplant mussel glochidia. Moreover, we now have information on which brown trout populations (from other rivers or fish-breeding farms), and which age classes, are the most suitable as a host fish for particular *Margaritifera* populations.

6) Publicity and nature conservation. Every year we are several times on TV and radio, we write numerous articles in newspapers and contribute lectures to national or international conferences. The project has a publication series of it´s own (Raakkuraportti = *Margaritifera* report). In 1999 the project had a display in the Wild Life Exhibition in Kuopio (>30000 visitors). We have used video films for documentation of the restored river sections. The Commission of the EU has selected this project as a "Success story" for the year 2000.

• France

Décret no. 99-615 du 7 juillet 1999. Annexe III: Protected Fauna Species. The species has received particular attention under the LIFE programme for the Allier and Loire basins.

An management plan has been approved in two regional parks (Morvan and Livradois-Forez) to avoid destruction of habitats suitable for the species.

• Germany

The species is listed as "threatened with extinction" on the "German Red List of Endangered Animals" (Jungbluth & Knorre 1998). It is strictly protected according to the German Federal Nature Conservation Law, off-take or changes in its habitat are generally prohibited. By region the situation is as follows:

— Niedersachsen: It is regarded as threatened with extinction. The main threat in this state is the expansion and change in water bodies. A large-scale conservation programme for the species (restoration of the natural river bank, removal of spruce forest, building of sandcatchers and extension of agricultural use) have led to juvenile recruitment. The programme costs 32,400,000 DM for the years 1989-2001 plus an additional 20,000 DM annually for direct species conservation measures (excluding salaries).

— Rheinland-Pfalz: It is listed as threatened with extinction on the Red List of Endangered Snails and Mussels in Rheinland-Pfalz (1994), but regarded as extinct in 1999. There is an intensive ongoing conservation project on the River Our in Luxembourg concerning as well the state of Rheinland-Pfalz due to the 'Condominum" status of this river.

— Hessen: It is listed as threatened with extinction on the Red List of Endangered Snails and Mussels of Hessen (1995).

— Bayern: It is listed as threatened with extinction on the last Red List of the Threatened Molluscs of Bavaria (1996) and strictly protected by the Fishery State Law (offtake is generally prohibited). A monitoring programme for the species in 17 selected streams was introduced by the Bavarian State Agency for Environmental Conservation including annual surveys of population status, water quality study, release of previously infested brown trout (since 1990) and breeding programmes under semi-natural conditions. A large-scale conservation programme to improve the habitat of the Zinnbach stream, near the Czech border, and other plans for freshwater and landscapes have been in progress since the mid-eighties. In 1995 a population of 5,000 individuals was translocated from an area threatened by road construction to an upstream area with an existing natural population. Monitoring in this case has not yet indicated the success or failure of the project. The project carried out in the Zinnbach (1985-1988), including construction of a separate waste-water collection channel and the establishment of protected areas on the direct stream bank, cost 1,165,000 DM.

— Thüringen: Listed as threatened with extinction on the last Red List of Endangered Mollusc Species of Thüringen (1993) and listed in the Fishery State Law of Thüringen, which includes the obligation to care and protect the species. There are no specific conservation measures with regard to *M. margaritifera*; however, there are general measures in operation in order to recover some parts of the Wettera stream. Nevertheless, every five years a population survey for large mussels is carried out in this state on behalf of the state Environment Agency in Thüringen.

— Sachsen: Listed as threatened with extinction on the last Red List of Endangered Terrestrial and Freshwater Molluscs of Sachsen (1996) and strictly protected by the Nature Conservation Act as well as the State Fishery Act (offtake or changes in habitat are generally prohibited). There are other state laws calling for the conservation of natural freshwater systems and ecological restoration following waste-water operations. The Wolfsbach is already protected because it is situated in the nature reserve NSG “Dreiländereck”. Moreover, the Wolfsbach population and the one of the Raunerbach are proposed for being protected under the (FFH) Habitats Directive. In general, the aim to save the pearl mussel habitats in Sachsen was only partly achieved. Recent habitat changes have led to a dramatic decrease in populations.

• Ireland

In Northern Ireland legislation prohibits the sale of mussels (and pearls as their derivatives) (Schedule 7 of the Wildlife (NI) Order 1985). This but does not give the species protection from killing, injury or disturbance. Under Irish law, it is illegal to interfere with *M. margaritifera* (Statutory Instrument No. 112, 1990); thus pearl fishing is currently outlawed in the country (Moorkens, 1999). The hard-water form of pearl mussel *Margaritifera durrovensis* (Phillips, 1928) is restricted to one population in the River Nore, and enjoys the same level of legal protection under Irish and European law (Moorkens, 1999). A pamphl*et al*erting people to the conservation status of *M. margaritifera* has been produced as well as a recommendation to recognise the species *M. m. durrovensis* in the Bern Convention (Council of Europe, 1996). *M. m. durrovensis* is now listed separately as an Annex to *M. margaritifera* in the EU habitats Directive (van Helsdingen *et al*., 1996). According to Costello *et al*., (1996) the conservation of this species requires habitat restoration that will benefit the host fish and other species, *M. m. durrovensis* being a flagship species. Ongoing control of effluent discharges, river bank stabilisation and reduced phosphorous inputs from farmland have been proposed. In this report, the authors also proposed fencing using sponsors to finance stretches of the river. The co-ordination of all the tasks involved must be the responsibility of the nature conservation authorities (Costello *et al*., 1996).

Recent estimations suggest that in one river of SW Ireland the population consists of over 2,000,000 reproductively mature individuals (Speight, 1998). This river's catchment is greatly affected by recent speculative forestry initiatives. Acquisition of large areas for conservation purposes have been suggested. The recent report that the zebra mussel (*Dreissena polymorpha*) has arrived in Ireland from Britain on pleasure boats is really alarming.

- Latvia

The species is included in Category 1 (endangered) of the Latvian Red Data Book (1985), new Latvian Red Data Book (1998) and Red Data Book of the Baltic Region. It is also included on the State List of Protected Animals (Latvian SSR Supreme Council Ruling 1957 and 1987) and List of Specially Protected Animals (Regulation of the Cabinet of Ministers in planning stage).

Forest zones along streams are protected through the prevention of felling. Part of one population is situated in Gauja National Park.

A project entitled "Inventories of Species and Habitats, Development of Management Plans and Capacity Building in Relation to Approximation of EU Birds and Habitats Directives" financed by Denmark's Nature Agency is currently in progress.

River regulation and general eutrophication over the last 50 years are reported to be the limiting factors. The threats are the expansion of successfully reintroduced beaver, dams, illegal wood cutting and overfishing of trout.

There is information on overfishing and export of pearl mussels to Sweden and Russia in the seventeenth and eighteenth centuries.

- Lithuania

Currently listed in the Red Data Book of Lithuania and protected by the Protected Animal, Plant, Fungi Species and Communities Act.

It is forbidden to destroy or damage protected species and their localities (breeding sites). The perpetrator has to compensate all damage and, if possible, restore the object to its former state (Augustasukas, 1998).

There are currently no plans or projects for the species.

- Luxembourg

Apart from the protection provided by the Bern Convention and the Habitats Directive, the species is included on the provisional Red List of Mollusc Species of Luxembourg promoted by the Lanius Office of Studies (Groh, 1997) in the category ***.

Margaritifera margaritifera is strictly protected by the "règlement grand-ducal" of 8th April 1986 concerning protection of certain species of wild fauna and as such under the legal status of a condominum.

As the Our is a frontier river, the protection provided by German legislation is also valid for the population in Luxembourg and *vice versa*. Legislation on pearl fishing (Perlrecht), species protection and nature protection laws (at Bund and at Länder) are also applicable.

The German area by the Our-basin containing an important population of *M. margaritifera* is already a protected area. Luxembourg's Nature Conservation Service is now pursuing the declaration of the equivalent area as protected. If this occurs, the pearl mussel could benefit from the synergy of the protection, management and development plans of both protected areas, which could be decisive for conservation of its habitat.

In order to protect fish hosts, the international commission on fishing has published special regulations for trout fishing in the River Our upstream of Vianden. Kayaking and river rafting boats have been forbidden between Trois Frontières and Dasbourg-Pont to protect the mussels from mechanical threats.

Since 1989 the "Direction des Eaux et Forets de Luxembourg" has being carrying on a research programme on the physical, chemical and biological water conditions as well as on the threats. These data will be completed with parallel data from the German and Belgian governments.

Experiences with artificial trout infestations in captivity and subsequent release of these fish started in 1991 on the River Our following the Wellmann (1943) method. In 1998 and 1999 (seven to eight years after propagation) Jungbluth & Groh (in Groh, 1999) found juveniles of six to seven years old in the river.

Water quality has also been improved in most rivers in Luxembourg.

Monitoring of the population of *M. margaritifera* and its host fish in the River Our is ongoing since 1989.

A project on the Cartography of Molluscs has been underway since 1996 and involves drafting measures to protect the species.

Ideas for artificial raising of *M. margaritifera* under controlled conditions are under study as a joint project between german, luxembourg and probably belgian authorities.

- Norway

The species was given national protection on January 1st 1993 by the Act Governing Salmonids and Freshwater Fish (No. 47 of May 1992). This only protects the species against exploitation; however, the County Governor, as the local management authority, may issue permits if the proposed exploitation plan fulfils certain criteria. As far as is known, such exemptions have not yet been given. A number of nature protection areas (nature reserves) where the species occur have been established.

The national strategy to protect populations of the species involves mapping localities at national, regional (county) and local community levels. The information is fed into databases and marked on local maps to be used by area planners whenever exploitation plans are raised.

A recommendation for a ban on collecting and protection of the remaining habitats was recently concluded (Aagaard, 1998).

• Poland

Although the species is currently extinct, during the last few decades it was under strict legal protection, and now is still strictly protected by law.

• Portugal

No data available.

• Spain

Margaritifera margaritifera is protected under the following legislation:

— Transposition of the Bern Convention to Spanish legislation according to the General Provision of the Foreign Affairs Ministry of 26 May 1988 (BOE No. 136, of 07/06/1988, p. 17554), updated by the General Provision of the *Jefatura del Estado* of 13 May 1986 (BOE Nº 235 of 01/10/1986): "Protected Wildlife Species".

— Transposition of Directive 92/43/EEC to Spanish legislation by Royal Decree 1997/1995 of 7 December (Ministry of Agriculture, Fisheries and Food) (BOE No. 310, of 28 December, p. 37330). Annex II: "Animal and plant species of Community interest that require strict protection" and Annex V: "Animal and plant species of Community interest the collection of which in the wild and use may be the subject of management measures". The modification of the Habitats Directive (Directive 97/62/EEC) was recently transposed to Spanish legislation by Royal Decree (1193/1998) of 12 June.

— National Endangered Species List. A project to include *M. margaritifera* on the National Red List as a 'vulnerable" species has already been approved by the National Fauna and Flora Committee. The species has not yet been included on any of the regional lists.

Two recent conventions between the Spanish Ministry for the Environment and the National Natural History Museum (Consejo Superior de Investigaciones Científicas -CSIC-) have been developing an updated bibliographical and distribution database (with field sampling) of the European threatened invertebrate species living in Spain, including *M. margaritifera.*

• Sweden

The species is included on the National Red List and has been classified as "vulnerable". It is protected in the whole of Sweden by virtue of the fishery legislation.

At the Swedish Environmental Protection Agency, preparations are currently underway to produce a national action plan for *M. margaritifera*.

• United Kingdom

Freshwater pearl mussle is fully protected in Great Britain under Schedule 5 of the Wildlife and Countryside Act (1981 as ammended 1998). In Northern Ireland legislation prohibits the sale of mus-

sels (and pearls as their derivatives) (Schedule 7 of the Wildlife (NI) Order 1985). This does not, however give the species protection from killing, injury or disturbance.

The species has been identified by the UK Government in its Biodiversity Action Plan (BAP) as a priority for conservation action (Biodiversity Steering Group 1995). Recently, the species has been the object of a national action plan drafted by Cooksley (1999) in consultation with the freshwater pearl mussel species action plan steering group (March 1999). Many organisations are involved in promoting and implementing the UK BAP. Scottish Natural Heritage (SNH) acts as the contact point and, in partnership with the Environment Agency act as lead partners.

37 Natura 2000 sites have been put forward, either specifically for *M. margaritifera* or have *M. margaritifera* present.

The objectives and targets of the national action plan are (Ball, 1996; Cooksley, 1999): 1- Establish the current status in UK and its ecological requirements at all stages of the life cycle. 2- Maintain and increase the size of existing populations. 3- Encourage re-colonisation. 4- Establish educational and monitoring programmes. 5- Determine effects of controlled exploitation in fished rivers and enforce legislation on pearl fishery practices.

Since 1994 intensive surveys for populations of the species have been carried out all over the country. Research into the ecological requirements of the species has been undertaken (postgraduate studies at Aberdeen University, the National Museum of Wales and Queen's University Belfast). A project entitled 'Culturing freshwater pearl mussel *Margaritifera margaritifera* in Northern Ireland. A first step towards the reintroduction of a threatened species' is currently underway. Specific freshwater mussel actions developed in the UK are summarised in Cooksley (1999).

3. GOALS AND OBJECTIVES

The main goal is, of course, effective conservation of *M. margaritifera* in each European country where populations exist, their habitat, future viability and long-term survival. Below is a list of tools to use and some points to be complied with in order to meet the proposed goals. Legislation, rational water use, research, management (including species re-introduction), monitoring and education/advisory work will be of the utmost importance. It is important to know that fertility of specimens is maintained in sparse populations and polluted rivers, indicating that they should recover if the causes of decline are removed (Bauer, 1988).

3.1 Policy and legislation

Due to the fact that *M. margaritifera* lives in fresh waters, conflict with people is of prime importance. Success is impossible if the corresponding administrations do not put all their co-ordinated efforts into the joint task. We know that the presence of a species name on a red list is not the final step towards its conservation, but only a necessary tool to work with. Once this tool is operating, the corresponding laws must be scrupulously adhered to. The items below summarise the proposed direct actions to be implemented to preserve the existing *M. margaritifera* populations.

To give the maximum level of protection to the species in all countries.

A positive dialogue and co-operation between Environmental, Hydraulic and Land-use administrations at national and regional levels is the primary objective and conservation of fresh waters inhabited by this threatened species one of the starting points.

New legislation regulating new water and land uses are needed. This should include: a) legislation to ensure water quality requirements for the species (when identified) form the basis for setting statutory water quality objectives, b) legislation to ensure that planning permission be sought for engineering work in rivers and channels where the species lives, and that such developments must be regulated, c) a guarantee that relevant management plans (e.g. agricultural, forestry, navigation) take account of the species interests and contribute to its conservation, d) ensure that local authorities are informed of *M. margaritifera* populations in their areas, the implications of the relevant legislation and contact points where advice may be sought.

National legislation to ensure that pearl fishing ceases in those countries with old traditions in this activity (e.g. Ireland, Germany) is also needed.

3.2. Species and habitat protection

All countries should designate areas and habitats of special protection for the species. Detailed conservation actions for each country are summarised below (Point 4 of this report). The protection of European freshwater systems harbouring populations of the species under the Natura 2000 Network and UNESCO biosphere reserves must be considered. Wider countryside measures need to be developed and implemented to protect the species, and its habitat, outside protected areas.

3.2.1. Develop and implement management plans to prevent further decline

A plan for rational use of water and land in the areas where the species lives must be designed. This can be carried out under major sustainable development projects in these areas.

It is a fact that irrigation farming around the world is under review. New social demands have given rise to generalised reflections to achieve sustainable ways of improving the quality and diversity of agricultural produce while attempting to conserve natural resources, which in this case are an endangered species and endangered freshwater habitats.

We cannot maintain, nor, of course, increase, existing levels of production and development without improving levels of productivity. This idea does not mean producing less, but rather handling the means of production in a controlled way, with minimal costs and without damaging the environment.

Under this general philosophy, specific commissions involving all political, scientific and socio-economic partners should be created to analyse the best conservation actions to be implemented in each case when new engineering or agricultural plans appear.

3.2.2. Conduct population surveys

Surveys of the rivers and water bodies harbouring the species or suspected to harbour it are still necessary in all countries. The results of these studies will be of great interest in the selection of the populations to be recovered in each European country. Although we already have current and realistic estimations of the populations in countries such as the Czech Republic, U. K. and Germany, there are other countries in which information is very scarce as for instance in Austria, Estonia, Lithuania, France, Spain or absent as in Portugal.

Rivers must be sampled using excavation and sieving techniques; relaying solely on diver searches may lead to inaccurate assesment of population size structure. For assesing successful recruitment, total substratum removal of selected areas with subsequent sieving seems to be the best method (Miller & Payne, 1988; Richardson & Yokley, 1996).

3.3. Conflicts with humans

Only direct conflicts are going to be dealt with in this section due to the fact that major problems (water and land use, hydroelectric works, river regulation, etc.) have already been mentioned in this report.

Pearl fishing has historically been the most important activity acting against survivorship of the species and is still a real threat in some countries. Effective vigilance and a penalty policy can act in favour of the species.

The problem of collectors may be avoided with surveillance and information.

3.4. Public awareness

This is an important task that must be undertaken through joint action among scientists, local and national conservation authorities and other experts. Advisory publications, videos, conferences and other educational material dealing with the ecological importance of the species, legislative protection and the interest of its conservation for local people can be produced and distributed under an awareness campaign co-ordinated by Environmental Authorities and NGOs.

The items to be “sold” can be: water cleaning, beauty, uniqueness, natural interest, historical interest (pearl industry). In some cases, these items can be run under the heading of comprehensive rehabilitation of the habitats with social and economic advantages to local communities increasing their life quality.

The setting up of contact points in relevant areas should be encouraged not only to disseminate information, but also to target people who might be able to submit new *M. margaritifera* records.

Special attention should be given to civil servants responsible for surveillance in the relevant areas. They should receive suitable training on species identification and threat factors.

3.5. Population conservation

Indeed, a global conservation programme for the species, together with specific actions for the protection of each of the known populations of *M. margaritifera*, will probably be the key to the survival of the species.

Maintenance of all the different populations may be an essential source of genetic variability. This makes the survey to identify new populations very important. Special effort can be focused on aged populations because of the imminent risk of extinction.

Ways of conserving the populations will be dealt with in Section 4 of this report.

3.6. Artificial reproduction

The first step is to develop a programme to maintain breeding specimens of *M. margaritifera* in direct contact with salmon or trout in both monitored river sections and aquaria during the mussel's breeding season. Basic laboratories with aquaria and several raceways need to be available near the selected rivers in order to ensure that artificial infestation of fish occurs under the most natural conditions for the survival of newborn juveniles.

Successful results in artificial reproduction of *M. margaritifera* have recently been reported in the Czech Republic (Hruska, 1999).

3.7. Artificial propagation and reintroduction

Protected areas must be developed to house new generations of artificially bred mussels.

In this way, we have the opportunity to work with millions of recently released juveniles of *M. margaritifera* in the selected rivers of all countries. The juveniles can be hatched and kept in the selected river sections until they have grown several centimetres. These small mussels can be re-introduced in selected areas of the already known habitats in order to obtain reproductive mussels.

On the other hand, maintenance of recently released juveniles in the laboratory may be a good option. It will, however, require the study of different feeding methods and a suitable substratum. The advise of aquaculture specialists (marine clams and mussels) may be of prime interest in this regard.

3.8. Natural recovery

Probably the best method to recover the species is the re-introduction and maintenance of stocks of natural fish hosts in its former habitat. This possibility can only work in rivers where the fish can live and reproduce without problems.

Electro-fishing might be a good way of monitoring further infestation in the fish gills. Selected areas of the selected rivers could be used to investigate the success of mussel recruitment.

3.9. Monitoring and research

Further studies are needed to fill the gaps in knowledge of the known distribution of the species in Europe.

Research to investigate life history in different countries, genetic variation of the populations (for reintroduction and/or restocking experiences), substratum and water quality requirements, habitat requirements of juveniles or survival of re-introduced juveniles in natural ecosystems should be promoted.

The relation of mussel reproductive success to fish population levels has to be investigated in order to carry out a management plan of fish restocking, if necessary.

A very close follow-up of the infestation of fish, juvenile growth and their acclimatisation to selected habitats will be necessary (for at least five years) to evaluate the success of the recovery.

In the case of artificial propagation, averages of juvenile mortality have to be investigated in relation to suitable habitats.

A programme of regular monitoring of known populations also needs to be set up to identify further threats to the species.

4. CONSERVATION ACTIONS

It is difficult to provide a general list of measures to improve species conservation due to the individuality of each river or brook. General preservation measures must be developed after analysing each situation in detail (Moog *et al*., 1998). Nevertheless, an evaluation of the data provided by the different countries with living populations of the species or from which it has recently been lost points to the same problem: anthropogenic influences on aquatic ecosystems. Given this fact, the priorities in the respective countries need to be established first. There is no sense in demanding a freshwater species be conserved at the same time as main roads, dams and macro-changes in the landscape make the freshwater ecosystem unsuitable for that species.

4.1. International actions

At present, the only known international initiative promoting the conservation of *M. margaritifera* is the current Council of Europe Action Plan.

Given that *M. margaritifera* only produces pearls in a minimum percentage of cases (one in every 3,000) and given the bad state of the European populations, as can be seen from the current report, it does not seem reasonable to maintain the species in Annex V of the Habitats Directive (animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures). Listing *M. margaritifera* in Annex IV of the Habitats Directive (animal and plant species of Community interest that require strict protection) instead of in Annex V is highly encouraged.

It would be desirable for European freshwater ecosystems inhabited by *M. margaritifera* to be protected as Natura 2000 sites and/or UNESCO Biosphere Reserves.

A positive dialogue with the Russian authorities should be encouraged in order to gain mutual benefits on the basis of the huge populations currently thriving on the Kola Peninsula.

4.2. Listing of countries with necessary actions

- Austria

Reintroduction experiments using glochidia-infested fishes could take place in former pearl mussel habitats. Additionally, it is necessary to support the increase of remaining populations through fish hosts artificially infested with glochidia. Suitable measures to improve water quality in biological and chemical terms are an absolute necessity (Moog *et al*., 1998).

• Belgium

Conservation measures have been proposed in a recent report on the pearl mussel situation in the River Our (Kinet & Libois, 1999) that could be the basis for a species action plan for all the rivers in the Walloon region. They include:

— The need for studies to obtain more information on the species distribution, population numbers and conservation status.

— To improve water quality by reducing the input of nitrates via a reduction of waste water mainly from communal areas and agriculture. It is necessary to identify the main sources of pollution, as well as solutions to avoid them within the framework of a general policy for water cleansing and to legislate or promote public awareness in order to avoid the use of fertilisers containing nitrates and phosphates in a 50-metres area along river banks. Complementary measures such as conservation of the already existing vegetation along river banks, bearing in mind that planting new trees and shrub-like vegetation can help to reduce the input of sediments. Economic compensation for owners of the surrounding private land should also be considered.

— Habitat restoration or protection. Besides other measures, it is considered to be very important to remove coniferous trees and replace them with shady riparian vegetation, particularly in stream sections with *M. margaritifera* and upstream of the watershed system. It is also important to reduce the input of suspended solids and fertilisers by stabilising river bank vegetation. Protection of areas that are important to the survival of the species could mean buying land in order to extend some of the existing protected areas.

— Maintain a healthy trout population.

— Undertake further assessment of known populations and initiate programmes of regular monitoring of the mussel population and of water quality.

— If water quality improves once the previous proposed measures have been adopted, a programme of infestation in captivity of young trout and subsequent release in areas containing rich populations of senescent mussels should be encouraged.

— In the Luxembourg section of the River Our, experiments in species restoration are currently in progress with infestation of captive trout and their subsequent release into the natural river ecosystems.

• Czech Republic

Establishing ecological agriculture in the Blanice river basin and maintaining the current quality of the water in the River Teplà Vltava are important measures to be continued**.** Other rivers containing freshwater pearl mussel populations must be optimised (agriculture and forest management) and cross-border co-operation improved in cases of borders with other countries (Austria and Germany).

Three kinds of species protection measures are proposed: a) short-term, consisting in the breeding of juvenile specimens from separate localities and subsequent monitoring, b) medium-term, saving the separate localities and stabilisation or decrease in the negative impact on habitats (acidification, chemical and mechanical pollution of rivers and brooks, use of chemical pollution in the economic exploitation of areas), c). long-term, reaching the required water quality and optimisation of the ecological

improvement of the economy in selected river basins. They will be the most important steps to achieve availability of the food spectrum needed for successful recruitment in mussel populations.

Given that the best populations are in protected areas far from human impact, the social and cultural influence of the proposed measures will be minimal. Nevertheless, the limiting factors in this task may be the absence of financial support.

• Estonia

There is a real need for an action plan for the species, but the question of financial resources has not been resolved. The proposed conservation measures involve the prevention of overheating of the water by planting trees along the river banks, keeping numbers of the mussel's temporary host glochidia high enough and working against river siltation.

• Finland

Short- and medium-term proposals to conserve the species and its habitats involve protection of the remaining populations, implementation of the Natura 2000 network, especially at sites where the pearl mussel is found, and continuation of the LIFE-project for the species.

The following could be considered as long-term proposals:

— establish freshwater pearl mussel reserves

— improve public awareness of pearl mussels

— carry out assessments on the effects of pollution on pearl mussels, in particular of suspended solid contents in water

— reduce the amount of suspended solid contents in water due to forest and peatland drainage, especially at the Natura 2000 sites

— carry out impact assessments prior to release of North American rainbow trout (*Oncorhynchus mykiss*)

— assess the need to establish breeding and reintroduction programmes

— promote co-ordination at national and international levels

The most significant socio-economic impact of the Natura 2000 network has been the uncertainty created by its effects on land use, water use and on local people's rights. The costs of implementing the network to areas including *M. margaritifera* are quite low due to the fact that the sites are either within existing nature conservation areas or protected by existing legislation (e.g. the Water Act). The required restoration measures may, in some cases, increase the implementation cost.

In order to help reproduce the species, infestations of brown trout with glochidia have been carried out in the laboratory. Indeed, salmon densities have been improved in areas with low numbers. Restocking mussels in different parts of the same river has had a success rate of over 90% after 16 years; this rate

falls to 50% when transfer of mussels from one river to another is involved. Information aimed at preventing further damage has been disseminated via the press, radio and TV.

• France

Surveys to know the actual species distribution and population numbers are urgent. Restricting river regulation and protecting freshwater systems containing populations of the species are the main actions needed in this country.

Species protection measures: protect the water systems inhabited by the species under the Natura 2000 Network. Considere the inclusion of the 10 better sites in the Ramsar Convention. To undertake agri-environmental measures at the Central Massif. Pedagogical information on the species and its ecological interest. Upbringing of the Conseil Superieur de la Peche guards to follow up the existing populations.

• Germany

— Niedersachsen: the ongoing decrease needs to be halted and the subsequent recovery of the population in the Lutter and Lachte streams promoted. Consequently, implementation of the sustainable development of landscape is indispensable in a large-scale conservation programme. Unless the input of sediments mobilised by human activities is halted, it will be impossible to ensure the survival of the pearl mussel.

Financial support will be needed in other stream systems in order to buy land.

Two research projects are currently being carried on in order to monitor the efficiency of the ongoing conservation measures in the Lutter watershed system: (i) Effects of disposal facilities for farmland drainage ditches which flow into the main streams of the Lutter watershed system. (ii) Sand freight monitoring in the Lutter watershed system and control of sand freight reduction due to the measures of the Lutter large-scale conservation project.

— Bayern: the ongoing conservation measures outlined in Section 2.6.2. will be continued in the forthcoming years. Both the monitoring programme and the conservation measures will be continued by the state authorities responsible for nature conservation and landscape planning.

The costs of the large-scale conservation project carried out in the Zinnbach area between 1985-1988, which included the construction of a separate wastewater collection channel and the “establishment of protected areas on the direct stream bank” amounted to a total of 1,165,000 DM.

— Sachsen: this state is currently preparing a broad species conservation programme involving co-ordination of different activities and measures within the management of agriculture, forestry, fisheries, water resources and traffic. It will also include crossborder co-ordination of conservation measures in Saxonia, Bavaria and the Czech Republic. Specific measures will be as follows:

* Habitat conservation by protecting certain parts of the watershed system from the input of undesirable substances (nutrients and harmful substances through special treatment of waste waters from communal areas) and by reducing the input of these substances from

agricultural areas. To guarantee the water quality required for pearl mussel conservation. Both the stream areas of the watershed system upstream of the mussel population and large parts of the valley area will have to be included. To realise this aim, extensive areas will have to be purchased.

* Promotion of nature conservation concurring with agricultural management (extensification) in order to minimise substance inflow from streams in adjacent areas. Large parts of the valley and adjacent farmland as well as large areas upstream of the mussel populations have to be changed to extensive agricultural use (including changing arable fields to pasture land); the use of fertilisers and pesticides also has to be prohibited.

* Restriction on land use in areas with mussel populations. As mussels are very sensitive to the effects of different land uses in the catchment area of the watershed system, these uses have to be restricted or carried out in a way that avoids accidents. The different uses involve hydraulic engineering, large building projects, traffic and recreation.

* Measures to promote population development directly. These measures include concentrating extremely scattered mussel occurrences in appropriate stream sections by means of translocation for a certain time.

* Stabilisation of water quality and restoration of the conditions needed for the juvenile mussel development.

* Boosting mussel reproduction in streams by induced infestation of brown trout with glochidia and by halting the release of other fish species, especially rainbow trout.

* Direct relief action in the case of a meander breaking through or grass sod breaking off.

* Protection measures for bank vegetation.

* Measures to restructure and recover natural conditions in the stream area of the mussels as well as upstream areas of the watershed system.

* Develop an emergency action plan in the case of a disaster.

* Research activities in various aspects needed for successful conservation of the pearl mussel in the specific local area of Saxonia.

* Public relation activities. To achieve acceptance of the species conservation programme as a cross-department nature conservation programme and of the conservation measures, especially by local communities and land users, and to convey the message that the pearl mussel in Saxonia is part of the region’s identity.

* Create the time-restricted post of co-ordinator for all the different conservation and promotional activities.

* Implement and finance the species conservation programme from various sources.

• Ireland

— Establish reliable *M. margaritifera* survey methods (scuba and glass-bottomed bucket).

— Salmonid host survey.

— Check suitability of *M. margaritifera* habitat in target rivers.

— Improve forestry management

— Reduce siltation caused during forestry operations in conifer plantations. Install silt traps in conifer plantation drainage systems emptying into target rivers by agreement with forestry management.

— Reduce influence of conifer plantation drainage waters. Block surface drains originating in conifer plantations, where these drains cross land with protected area status and empty into target rivers. Bottom-line 100m lengths of selected, additional conifer plantation surface-drains emptying into target rivers, using limestone chips or the equivalent.

— Reduce influence of conifer plantations within the riparian zone.

— Re-establish *M. margaritifera* populations (via transfer of glochidially-infested host fishes).

— Improve river beds.

— Contribute to the English-language dossier on *M. margaritifera* for installation on the Internet.

• Latvia

Establish protected areas - freshwater pearl mussel reserves. In this areas carry out: 1- Strict control of beavers, preventing the establishment of beaver dams. 2- Assess the hydrological and hydrobiological conditions at each pearl mussel location to determine the limiting factors. 3- Control the population of salmonid fishes. 4- Control of human impact (wood cutting, use of fertilizers, pollution, flow regulation, fishing).

Develop a monitoring programme on condition of oligotrophic waters and eutrophycation. Apply methods of trout infestation with glochidia in salmonid breeding centre (nursery) Karli. Develop international protection for pearl mussel rivers crossing the borders of state. Continue survey of potential habitats for the freshwater pearl mussel in the Gauja, Salaca, Ogre, Aiviekste, Mçmele and Durbe River watersheds.

Two new recent problems have arisen: 1- financial resources for continuation of the Action Plan 2000 are not yet received and 2- the existence of a critically endangered population of pearl mussels in a private land (wood cutting, flow regulation, intensive pisciculture).

• Lithuania

Searching for new populations and protecting the respective habitats are essential measures.

- Luxembourg

It is important to continue research on the species's reproductive biology, demography, population structure, conservation status, situation of the host fish population and adult and juvenile habitats in the River Our.

In this area, measures to avoid negative environmental influences on the species should be taken by drawing up a plan to restore the areas that are susceptible to flooding, to restore the riverside vegetation, reduce the input of harmful substances, consolidate the river banks and restore optimal migration conditions for fishes by suppressing or transforming small river dams.

All catchments with potential populations of *M. margaritifera* should be identified in order to establish the real distribution of the species. In the case of new live populations being found, studies should be conducted on their size and age structure and on the situation of the host fish populations. If necessary, pilot reintroduction projects should be undertaken, which should include long-term monitoring programmes.

Fostering public awareness of the importance of the species and publicising that it is protected by law would help to conserve the species habitat.

Strict control of observance of the legislation.

Finally, a monitoring programme on the pearl mussel population needs to be established, including the results of the artificial propagation experiments and water quality monitoring.

- Norway

To increase knowledge about its biology and design a management strategy. Reduce erosion and secure areas with erosion. Prevention of clear-cutting, removal of riparian vegetation and other man-made alterations. Reduce the use of organic compounds, phosphorous and nitrogen. Introduction of adult mussels or infested fish, hatching and release of juveniles in suitable localities. In acidified areas, liming is important to secure remaining populations or create an environment for mussel reintroduction.

- Portugal

A survey of the rivers of the northernmost part of Portugal is needed, namely in the Montesinho and Peneda-Geres National Parks (Libois, pers. comm.).

- Spain

In a recent forum on the species, proposals were put forward for the urgent inclusion of *M. margariti - fera* on the National Endangered Species List in order to have a legal tool to avoid new public works damaging the mussel populations. The proposed category is entitled `sensitive to habitat alteration´ or, provisionally, ´vulnerable´ species.

Protect the populations in Galicia, Asturias and Castilla-León regions. To increase knowledge of the species biology and its ecological requirements throughout its life cycle. Inclusion of the species on the

Regional Endangered Species Lists and drafting of regional action plans. Avoid channelling and impoundment works in the main courses of the rivers and channels harbouring the species. To support the development of riparian forest and restoration of populations of autochtonous salmonids.

The rivers of the north-west corner of the Iberian Peninsula need to be surveyed for new populations.

- Sweden

Conservation measures will be formulated as part of the action plan currently being prepared. At present, liming is the most important single conservation measure being carried out. Future activities are likely to include: 1- protection of sites or river sections, where priority will be given to sites at which recruitment is functioning. 2- Improved site monitoring. 3- Information and advisory services to landowners, forest companies, fishermen. 4- Continued liming of waters, which is of benefit to the general environment.

- United Kingdom

Legislation was introduced in 1998 which gave *M. margaririfera* complete protection in England, Scotland and Wales. Action is needed to raise awareness of this legislation and to enforce prohibition of pearl fishing. Maintenance/improvement of water quality and protection from river engineering work must be addressed wherever populations occur. Every effort should be made to support measures that address the collapse of salmonid stocks and, where appropriate, to include freshwater pearl mussel interests in these measures.

A detailed programme of actions promoted by the national action plan to which lead agencies have agreed to contribute is summarised in Cooksley (1999).

A rivers project under EC LIFE funding is in progress. The project includes specific work for the pearl mussel, including investigations into water quality requirements.

5. REFERENCES

Aagaard, K. 1998. Protection and management of invertebrates in Norway. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 57.

Adam, W. 1960. *Faune de Belgique. Mollusques*. Tome 1. *Mollusques terrestres et dulcicoles*. Institut Royal des Sciences Naturelles de Belgique. 402 pp. + 4 planches.

Álvarez-Claudio, C., García-Rovés, P., Ocharan, R., Cabal, J. A., Ocharan, F. J. & Álvarez, M. A. A new record of the freshwater pearl mussel *Margaritifera margaritifera* L. (Bivalvia, Unionoida) from the River Narcea (Asturias, north-western Spain). *Aquatic Conservation: Marine and Freshwater Ecosystems* 10: 93-102.

Araujo, R. & Ramos, M. A. 2000. Action Plan for *Margaritifera margaritifera* in Europe. *Council of Europe*, T-PVS (2000) 10. 38 pp.

Araujo, R. & Ramos, M. A. In press. *Margaritifera margaritifera* (L.). In: *Invertebrados no insectos de la Directiva Hábitats en España*. Ramos, M. A. (Ed.). Serie Técnica del Ministerio de Medio Ambiente.

Augustauskas, J. 1998. Report on the progress towards the conservation of Bern Convention Invertebrates in Lithuania, 1996-1998. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 47.

Ball, S. G. 1996. United Kingdom. In: *Convention on the conservation of European wildlife and natural habitats.* Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (96) 33: 49-64.

Bauer, G., 1986. The status of the Freshwater Pearl Mussel *Margaritifera margaritifera* L. in the South of its European Range. *Biological Conservation* 38: 1-9.

Bauer, G. 1987. Reproductive strategy of the freshwater pearl mussel *Margaritifera margaritifera*. *Journal of Animal Ecology* 56: 691-704.

Bauer, G. 1988. Threats of the freshwater pearl mussel in Central Europe. *Biological Conservation* 45: 239-253.

Bauer, G., 1992. Variation in life span and size of the freshwater pearl mussel. *Journal of Animal Ecology* 61: 425-436.

Biodiversity Steering Group. 1995. *Biodiversity: The UK Steering Group Report*. Vol. 2: *Action Plans*. HMSO, London.

Birringer, D. & Truffner, U. 1990. *Studie der Ourbeckens zwischen Ouren und Dasburg im Hinblick auf die Schaffung eines Naturschutzgebietes*. Mém. Dipl. europ. Sc. Environ. F.U.L., Arlon. 189 pp + ann.

Boettger, C. R. 1954. Flussperlmuschel und Perlenfischerei in der Lüneburger Heide. *Abhandlungen der Braunschweigischen Wissenschaftlichen Gesellschaft* 6: 1-40.

Bogan, A. E. 1993. Freshwater bivalve extinctions (Mollusca: Unionoida): A search for causes. *American Zoologist* 33: 599-609.

Cochet, G. 1999. Le statut des Margaritiferidae de France (Mollusca: Bivalvia: Unionacea: Margaritiferidae). *Vertigo* 6. 1996 (1999): 27-31.

Cooksley, S. 1999. Work programme for the freshwater pearl mussel *Margaritifera margaritifera* UK species action plan 1999-2002. Draft.

Costello, M. J., Moorkens, E., Larkin, M. & Kurz, I. 1996. The River Nore and its almost extinct pearl mussel: a priority for management and river restoration. In: *Convention on the conservation of European wildlife and natural habitats. Colloquium on Conservation, Management and Restoration of Habitats for Invertebrates: Enhancing Biological Diversity*. Killarney, Irlande, 26-29 May 1996. Council of Europe. T-PVS (96) 51: 31-37.

Council of Europe. 1996. The present state of Bern Convention Invertebrates in Ireland. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. T-PVS (96) 33: 36.

Chesney, H. C. G., Oliver, P. G. & Davis, G. M. 1993. *Margaritifera durrovensis* Phillips, 1928: Taxonomic status, ecology and conservation. *Journal of Conchology* 34(5): 267-299.

Davis, G. & Fuller, S. 1981. Genetic relationships among recent Unionacea (Bivalvia) of North America. *Malacologia* 20: 217-253.

Ferrant, V. 1892. *Beiträge zur Molluskenfauna des Grossherzogthumus Luxemburg*. - Separat-Abdruck aus den: Mitteilungen der Fauna, Verein Luxemburger Naturfreunde, Jahrg. 1891-1892 (mit eigener Paginierung: 3-49); Luxemburg (P. Worré-Mortens).

Ferrant, V. 1902. Faune des Molluskes terrestres et fluviatiles du Grand-Duché de Luxembourg. *Publications de l'Institut grand-ducal de Luxembourg, section des sciences naturelles et mathématiques*, 27(A): 1-232, 144 Abb. Luxembourg (M. Huss).

Grande, C., Araujo, R. & Ramos, M. A., 2001. The gonads of *Margaritifera auricularia* (Spengler, 1793) and *Margaritifera margaritifera* (L, 1758) (Bivalvia: Unionoidea). *Journal of Molluscan Studies*, 67: 27-35.

Groh, K. 1997. Liste der in Luxemburg vorkommenden und in den Nachbarländern auf der Roten Liste stehenden Weichtierarten mit einer Gefährdungs-Einschätzung für das Land Luxemburg. -2 S. Liste im Auftrag des Naturschutzbüros Lanius, Buschdorf (L) für das Naturschutzförderprogramm Luxemburg (unpublished); Hackenheim.

Groh, K. 1999. Cahier espèce *Margaritifera margaritifera* (L. 1758). Grand-Duché de Luxembourg. Ministère de l'Environnement. 11 pp. Unpublished.

Guilbot, R., Bellan-Santini, D., Deschamps-Cottin, M., Cochet, G., Descimon, H. & Dommanget, J. L. 1998. Examen des actions menées en France depuis 1996 pour la conservation des invertébrés inscrits à l'Annexe 2 de la Convention de Berne. In: *Convention on the conservation of European wildlife and natural habitats.* Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 20-31.

Hanstén, C, Pekkarinen, M. & Valovirta, I. 1997. Effect of transplantation on the gonad development of the freshwater pearl mussel, *Margaritifera margaritifera* (L.). *Boreal Environment research* 2: 247-256.

Harms, W., 1907. Zur Biologie und Entwicklungsgeschichte der Flussperlmuschel (*Margaritana margaritifera* Dupuy). *Zoologischer Anzeiger* 31: 814-824.

Harms, W., 1909. Postembryonale Entwicklungsgeschichte der Unioniden. *Zoologische Jahrbücher. Abteilung für Anatomie und Ontogenie der Tiere* 28: 325-386.

Hessling, T. von, 1859. *Die Perlnmuscheln und thre Perlen (Naturwissen-schaftlich und geschichtlich mit Beruecksichtigung der Perlgewaesser Baerns)*. Leipzig. 372 pp.

Hruska, J. 1999. Nahrungsansprüche der Flussperlmuschel und deren halbnatürliche Aufzucht in der Tschechischen Republik. *Heldia* 4(6): 69-79 + Tafel 2-5.

INDUROT, 1999. *Informe preliminar sobre la situación de la madreperla de río* (Margaritifera margaritifera) *en España.* Universidad de Oviedo e Instituto de Recursos Naturales y Ordenación del Territorio, Ministerio de Medio Ambiente. Unpublished report. 12 pp.

IUCN, 1996. *The 1996 IUCN Red lists of Threatened Animals*. IUCN. Gland, Switzerland and Cambridge, UK.

Jungbluth, J. H. 1993. Analyses concernant la détérioration des eaux courantes dans les bassins hydrologiques de la Rur et du système Schwalm/Perlenbach. Annexe au point 3b de la rèunion du 7 octobre 1993. 5 pp. Unpublished.

Jungbluth, J. H., Coomans, H. E. & Grohs, H. 1985. Bibliographie der flussperlmuschel *Margaritifera margari - tifera* (Linnaeus, 1758) (Mollusca: pelecypoda). *Instituut voor Taxonomische Zoologie (Zoologish Museum). Universiteit van Amsterdam*, 41: 1-220.

Jungbluth, J. H. & Knorre, D. V. 1998. Rote Liste der Binnenmollusken (Schnecken (Gastropoda) und Muscheln (Bivalvia)). In: Binot, M., Bless, R., Boye, P., Gruttke, H. & Pretscher, P. (Eds.). *Rote Liste gefährdeter Tiere Deutschlands. Schriftenreihe für Landschaftspflege und Naturschutz*, 55: 283-289.

Killeen, I. J., Oliver, P. G. & Fowles, A. P. 1998. The loss of a freshwater pearl mussel (*Margaritifera margari - tifera*) population in NW Wales. *Journal of Conchology* Special Publication 2: 245-250.

Kinet, S. & Libois, R. 1999. Propositions pour la conservation des Unionides (Mollusques Bivalves) dans le bassin de l'Our (Parc Naturel Hautes-Fagnes Eifel). Université de Liège. Institut de Zoologie. Rapport Ministère Règion Wallone, DGRNE, Service Conservation de la Nature, Namur, Octobre 1999. Unpublished.

Larsen, B. M. 1997. Pearl mussel (*Margaritifera margaritifera* L.). A review of national and international knowledge. *NINA Fagrapport* 28: 1-51.

Lydeard, Ch., M. Mulvey., and G. M. Davis. 1996. Molecular systematics and evolution of reproductive traits of North American freshwater unionacean mussels (Mollusca: Bivalvia) as inferred from 16S rRNA gene sequences. *Philosophical Transactions of the Royal Society of London Series B* 351:1593-1603.

Machado, A. 1997. *Guidelines for action plans for animal species: planning recovery. Convention on the con - servation of European wildlife and natural habitats (Bern Convention)*. Nature and Environment, No. 92. Council of Europe Publishing. 76 pp.

Machordom, A., R. Araujo, D. Erpenbeck & M. A. Ramos. Conservation genetics of endangered Margaritiferidae (Bivalvia: Unionoidea). In prep.

Meyers, T. R. & Milleman, R. E. 1977. Glochidiosis of salmonid fishes. I. Comparative susceptibility to experimental infection with *Margaritifera margaritifera* (L.). *Journal of Parasitology* 63: 728-733.

Miller, A. C. & Payne, B. S. 1988. The need for quantitative sampling to characterize size demography and density of freshwater mussel communities. *American Malacological Bulletin* 6(1): 49-54.

Moog, O., Ofenböck, T., Neseman, H. & Stundner, C. 1998. The freshwater pearl mussel *M. margaritifera* (L.) in Austria: Fundamental conservation measures for an endangered species. *Verhandlungen - Internationale Vereinigung für Angewandte Limnologie* 26: 2438-2443.

Moorkens, E. A. 1996. *Studies on the biology and ecology of* Margaritifera *in Ireland*. Inpublished Ph. D Thesis, University of Dublin, Trinity College.

Moorkens, E. A. 1999. *Conservation management of the freshwater pearl mussel* Margaritifera margaritifera. *Part 1: Biology of the species and its present situation in Ireland.* Irish Wildlife Manuals, No. 8. Dúchas, The Heritage Service, Dublin. 34 pp.

Moorkens, E. A., and M. J. Costello. 1994. Imminent extenuation of the Nore freshwater pearl mussel *Margaritifera durrovensis* Phillips: a species unique to Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems* 4: 363-365.

Nezlin, L. P., Cunjak, R. A., Zotin, A. A. y Ziuganov, V. V., 1994. Glochidium morphology of the freshwater pearl mussel (*Margaritifera margaritifera*) and glochidiosis of Atlantic salmon (*Salmo salar*): a study by scanning electron microscopy. *Canadian Journal of Zoology* 72: 15-21.

Nobre, A. 1941. Fauna malacológica de Portugal II. Moluscos terrestres e fluviais. *Memorias e Estudos do Museu de Zoologia da Universidade de Coimbra* 124: 1-278.

Pekkarinen, M. y Valovirta, I., 1996. Anatomy of the glochidia of the freshwater pearl mussel, *Margaritifera mar - garitifera* (L.). *Archiv für Hydrobiologie* 137(3): 411-423.

Phillips, R. A. 1928. On *Margaritifera durrovensis*, a new species of pearl mussel from Ireland. *Proceedings of the Malacological Society of London* 18:69-73.

Ramos, M. A. 1998. Main progress towards the conservation of Bern Convention Invertebrates in Spain since 1996. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 59-69.

Richardson, T. D. & Yokley, P. 1996. A note on sampling technique and evidence of recruitment in freshwater mussels (Unionidae). *Archiv für Hydrobiologie* 137(1): 135-140.

Ross, H. (1992). The reproductive biology of the freshwater pearl mussel *Margaritifera margaritifera* in Co Donegal. *Irish Naturalists' Journal* 24 (2): 44-50.

Smith, D. G. & W. P. Wall. 1984. The Margariferidae reinstated: a replay to Davis and Fuller (1981), "Genetic relationships among recent Unionacea (Bivalvia) of North America". *Occasional Papers on Mollusks, Museum of Comparative Zoology (Harvard University)* 4(64):321-330.

Speight, M. C. D. 1998. Progress report in Ireland, 1996-1998. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 40-41.

Stoltze, M. & Pihl, S. (eds.). 1998. *Roedliste 1997 over planter og dyr I Danmark*. Miljoe-og Energiministeriet, Danmarks Miljoeundersoegelser og Skov-og Naturstyrelsen.

Van Helsdingen, P. J., Willemse, L. & Speight, M. C. D. 1996. *Background information on invertebrates of the Habitats Directive and the Bern Convention.* Part III. *Mollusca and Echinodermata*. Nature and environment, No. 81. Council of Europe: 399-529.

Valovirta, I. 1996. Finland. Main progress in invertebrate conservation in Finland since 1994. In: Convention on the conservation of European wildlife and natural habitats. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (96) 33: 22.

Valovirta, I. 1998. Finland. Progress in invertebrate conservation in Finland in 1996-1997. In: *Convention on the conservation of European wildlife and natural habitats*. Group of Experts on Conservation of Invertebrates. Council of Europe. T-PVS (98) 18: 18.

Valovirta, I. & Yrjänä, T. 1996. Effects of restoration of salmon rivers on the mussel *Margaritifera. margaritife - ra* (L.) in Finland. In: *Convention on the conservation of European wildlife and natural habitats.* Colloquium on Conservation, Management and Restoration of Habitats for Invertebrates: Enhancing Biological Diversity. Killarney, Irlande, 26-29 May 1996. Council of Europe. T-PVS (96) 51: 38-48.

Vrignaud, S. 2000. *Raréfaction de la Moule perlière* (Margaritifera margaritifera) *dans l'Ardenne belge: bilan et perspectives (stage du 10/01 au 14/04/2000)*. Institut Supérieur Européen des Métiers de l'Environnement. TS + Conseiller Technique en Protection de l'espace Rural. Session 1999/2000. 41 pp + 10 Annexes.

Wellmann, G. 1943. Fischinfektionen mit Glochidien der *Margaritana margaritifera. Zeitschrift für Fischerei* 41: 385-390, 5 Abb.

Young, M. R. & Williams, J. C. 1984. The reproductive biology of the freshwater pearl mussel *Margaritifera mar - garitifera* (Linn.) in Scotland. II. Laboratory studies. *Archiv für Hydrobiologie* 100: 29-43.

Ziuganov, V., A. Zotin., L. Nezlin., and V. Tretiakov. 1994. *The freshwater pearl mussels and their relationships with salmonid fish*. VNIRO Publishing House, Moscow, 104 pp.

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7. APPENDIX 1: Summary on protection and management measures on *M. margaritifera*.

1. Water quality requirements of pearl mussel water bodies

Habitat requirements for the species are reported in point 2.4.2. of this document. Nevertheless here are summarized aspects of river quality for effective conservation based on Irish data (Moorkens, Valovirta & Speight, 2000):

- The water must be clean enough not to cause any direct stress on adult or juvenile mussels.
- Water quality must be high enough to ensure that eutrophication does not occur.

That means:

- Interstitial water chemistry must resemble free running water nutrient levels.
- Dissolved oxygen > 9 mg/l
- PH< 8 > 6.3
- B. O. D. < 3
- Total ammonia < 0.10 mg/l
- Condutivity < 200 µS/cm
- Nitrate < 1.7 mg/l
- Phosphates 8ortho-P) < 0.06 mg/l
- Other parametres to ensure effective conservation and reproduction of the species are not yet evaluated.

2. Land and water use practices adjacent to pearl mussel habitats

It is known that chemical derivates from agriculture uses and engineering works (dams, water derivations etc...) are among the main problems affecting successful thrieving of *M. margaritifera* populations. Recommendations to avoid these problems can be:

- Ecological maintenance of water sources and small brooks of the rivers with populations of the species.
- Maintenance of natural forests and shore vegetation.
- Create buffer zones of 5-10 metres (minimmum) width along rivers.
- To forbid gravel extraction, dam construction and water derivation in rivers to avoid siltation.
- To forbid all kind of farms along rivers to avoid eutrophication.
- To regulate agricultural fields along these rivers improving the soil quality (ecological maintenance of meadows by organic fertilization) in order to recuperate the healthy of the organic detritus in the water (base of the mussel food).

3. Methodological recommendations on artificial breeding and raising of young mussels.

- To develop protected areas with fertile populations of *M. margaritifera* to obtain gravid adults as source of glochidia.
- Installation of facilities (aquaria and raceways) to ensure controlled infestation of fish.
- To hatch the juveniles borned until several centimetres in both, indoor facilities and cages in the river in natural substrate of clean aerated gravel.
- Re-introduction of these juveniles in selected areas of the river.
- Re-introduction of infestated host fish in selected areas of the river.

4. Methodological recommendations on the monitoring of known populations.

- Regular survey (one or two times yearly) of adult specimens by trained people (diving, snorkeling, viewing glass, etc...).
- Regular survey of suitable salmonid fishes (electro fishing) during glochidial release period.
- Regular survey of juvenile recruitment using excavation and sieving techniques in selected areas. (total substratum removal with subsequent sieving) .
- Regular monitoring of water quality (sources of pollution, flood changes, etc...).

8. APPENDIX 2: LIST OF REPORT CONTRIBUTORS

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Figure 1. European countries with living population of *M. margaritifera.* Asterisk indicates the flourishing populations of the Kola Peninsula rivers.