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CONVENTION ON THE CONSERVATION OF EUROPEAN WILDLIFE  
AND NATURAL HABITATS

## **Action plan for *Margaritifera auricularia* in Europe**

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## 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 auricularia* (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. auricularia* 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 nacreous white, with very obvious adductor 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 siphons, 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.

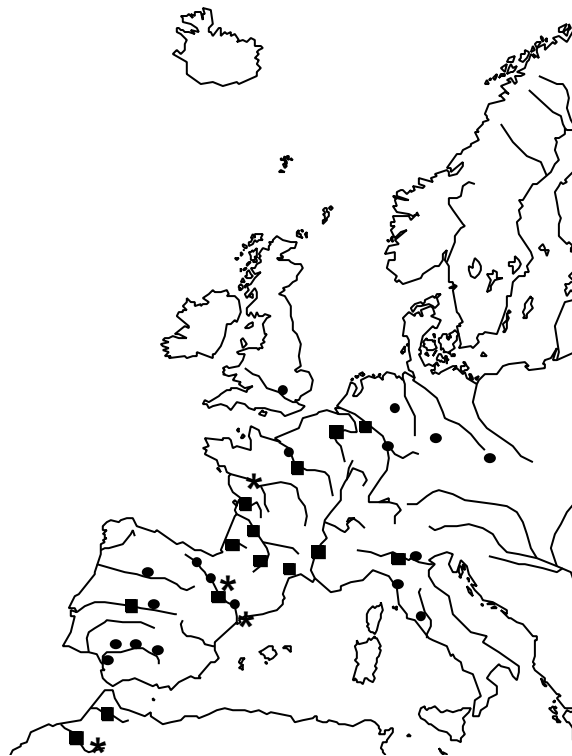


Figure 2. Fossil (dots), historical (squares) and current (asterisks) distributions of *M. auricularia*.

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).

*Margaritifera 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.

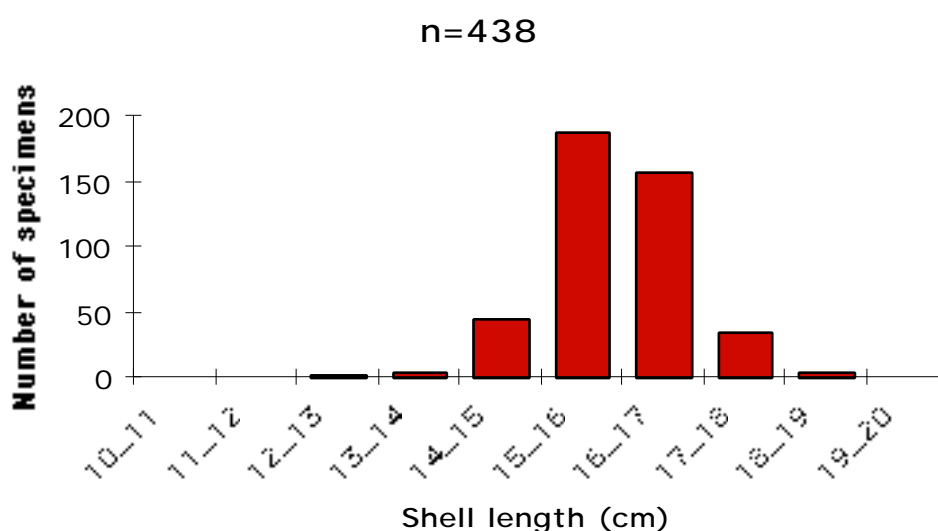


Figure 3. Size structure of the *M. auricularia* population in the Canal Imperial

## 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 *Salarias 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 (Sládeček 1990) and oligo-hyperthrophic (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 where 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 (especially 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 <sub>5</sub> mg/litre O <sub>2</sub>	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 <sub>4</sub> mg/litre	373	196
NO <sub>3</sub> mg/litre	15.1	25.2
NO <sub>2</sub> mg/litre	—	0.057
Alkalinity mg/litre CO <sub>3</sub>	253	187
PO <sub>4</sub> 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 consider 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 Committee 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 appropriate 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 N° 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, N°. 217 (1) of 7 September 1996, p. 27246), under Act 4/1989 of 27 March (BOE N°. 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 N°. 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 N°. 1980 of 02/12/1994, p. 7806), under Act 3/1988 of March 4 (DOGC N°. 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 N°. 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 overstressing 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 artisanal 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.

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