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Opinion paper

Current conservation strategies for European crayfish

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ABSTRACT

Key-words: *ark site,* Astacus *spp.,* Austropotamobius *spp., conservation management, restocking*

A round table discussion involving 25 researchers from 11 European countries was organized during the congress "European Crayfish: food, flagships and ecosystem services" (held in Poitiers, France, 26–29th October 2010) to consider current activities dealing with management of indigenous crayfish species (ICS) with special regards to their culture, restocking and conservation strategy. In the following opinion paper, we attempt to summarize best practice of current conservation strategy as well as advantages and disadvantages of applied tools and approaches for listed species or species complexes. The development of conceptual models for the protection of ICS in Europe seems to be necessary; however, currently recommended approaches of conservation strategy of ICS differ according to countries and species. The different approaches to conservation of *Astacus astacus* and species in the genus *Austropotamobius*, such as genetic diversity, captive breeding, origin and characteristics of stocking material and establishment, as well as long-term objectives of sanctuary or "ark" sites, were highlighted during the round table discussion.

RÉSUMÉ

Stratégies actuelles de conservation des écrevisses européennes

Mots-clés : *« site sanctuaire »,* Astacus *spp.,* Austropotamobius *spp., gestion de conservation, réintroduction*

Une table ronde regroupant 25 chercheurs de 11 pays européens a été organisée lors du congrès « European Crayfish: food, flagships and ecosystem services » (qui s'est tenu à Poitiers, France, du 26 au 29 octobre 2010) pour examiner les activités actuelles concernant la gestion des espèces indigènes d'écrevisses (ICS) avec une attention particulière sur leur élevage, les réintroductions et les stratégies de conservation. Dans cet article d'opinion, nous tentons de résumer les meilleures pratiques de stratégie de conservation actuelle autant que les avantages/désavantages des outils et des démarches pour ces espèces ou complexes d'espèces. Le développement de modèles conceptuels pour la protection des ICS en Europe semble être nécessaire ; toutefois, les démarches recommandées aujourd'hui pour les stratégies de conservation des ICS diffèrent suivant les pays ou les espèces.

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Des questions différentes pour la conservation d'*Astacus astacus* et des espèces du genre *Austropotamobius*, telles que la diversité génétique, les stocks captifs, l'origine et les caractéristiques du matériel introduit et son implantation comme les objectifs à long terme des sanctuaires ou sites « arches » ont été abordées pendant les discussions de cette table ronde.

INTRODUCTION

The rapid spreading of non-indigenous crayfish species (NICS) throughout Europe has resulted in the alteration or destruction of invaded habitats and biota (Gherardi, 2006; Scalici *et al.*, 2010). These changes influence both directly and indirectly the occurrence of indigenous crayfish species (ICS) populations, whose extinction is often related to outbreaks of crayfish plague (Diéguez-Uribeondo, 2009; Kozubíková *et al.*, 2009). Regarding this, the future of ICS occurring in Central and Western Europe – the noble crayfish *Astacus astacus*, the stone crayfish *Austropotamobius torrentium* and the white-clawed crayfish species complex *Austropotamobius pallipes* (Souty-Grosset *et al.*, 2006) – remains uncertain. Although these crayfish species are protected by a series of both European and national laws (Holdich *et al.*, 2009), their status in the IUCN red list is different. *Astacus astacus* is classified as vulnerable (Edsman *et al.*, 2010). At present, in Sweden wide-scale re-stocking of this species occurs into lakes from which it was formerly known. Restocking in Sweden is taking place but has met with little success (L. Edsman pers. comm., 2010). Given the continuing population decline, several species protection programmes have been initiated (including re-stocking and re-introduction activities) in various parts of Austria (Füreder, 2009). *Austropotamobius pallipes* is today classified as endangered (Füreder *et al*., 2010b) whereas it was only classed as vulnerable in 1996 (Baillie and Groombridge, 1996); it was concluded from this assessment that population monitoring is needed within countries for which trend information is lacking. Further research within these countries on the main drivers of decline is also required. This classification as endangered may now help in promoting reintroduction programmes. However, the assessment for *A. torrentium* is data deficient (Füreder *et al.*, 2010a). While this species is relatively widespread across Europe it is undergoing significant declines throughout much of its range. However, rates of decline have not been quantified and are needed through long-term population monitoring.

Although reintroductions of ICS to favourable areas have been suggested as a crucial part of management and conservation strategies in Europe (Schulz *et al.*, 2002; Souty-Grosset and Reynolds, 2009), they are not allowed in several EU countries, *e.g.* Czech and Slovak Republics (Kozák *et al*., 2009). Thus, development of a conceptual model for the protection of ICS in Europe seems to be necessary. Several proposed approaches to conservation have led to the development of clear rules for the implementation of ICS conservation management, such as selection of "ark" sites for restocking (Peay, 2009), or a post-release monitoring protocol (Souty-Grosset and Reynolds, 2009). However, there are still several related issues dealing with these actions which require more in-depth discussions for conceptual recommendations.

In the light of these facts, some 25 researchers from 11 European countries took part in a round table discussion organized during the congress "European Crayfish: food, flagships and ecosystem services" (held in Poitiers, France, 26–29th October 2010), to consider current activities dealing with management of ICS with special regards to their culture, restocking and conservation strategy.

ROUND TABLE DISCUSSIONS

Within the topic "Developing a catchment-based conservation strategy for European crayfish" the following are the main questions that arose during the discussion among European

scientists from Austria, Croatia, Czech Republic, England, Estonia, Finland, France, Germany, Italy, Spain and Sweden.

- Is restocking (reintroduction) or perhaps also the so-called "assisted migration" a useful tool in conservation strategy?
- How important is genetics of donor population?
- Which origin of source stocking material is the best for restocking?
- Could artificial breeding of crayfish help in protection of ICS?
- Are juveniles or adults better for restocking?
- How effective are "ark sites" in conservation management?

Participants' responses to these questions differed, based not only on their experiences with particular approaches to conservation strategy for ICS in each country, but especially between species. In the following text, we try to summarize best practice of current conservation strategy as well as advantages and disadvantages of applied tools and approaches in the viewpoint of listed species or species complexes. For this purpose we divided crayfish into three types according to different conservation strategies. The first is *Astacus astacus* as a representative of the most abundant indigenous species with high commercial value. In the second group are members of genus *Austropotamobius* – seriously endangered crayfish species with unique ecological and cultural heritage values. The last one is *Astacus leptodactylus* as a representative of NICS in Central and Western Europe. *Astacus leptodactylus* was introduced into Western Europe mainly from Eastern Europe to supplement stocks of declining ICS populations. In the majority of West European countries, *A. leptodactylus* would not be considered as ICS according to the IUCN ruling (present before 1500 AD). However, in some countries in which it had been introduced, it has been adopted as an indigenous species according to the national laws (Holdich *et al.*, 2009). As a majority of round table participants came from Central and West European countries, the conservation strategy for this species was not discussed in depth; however several basic rules could be applied to this species in areas of its original distribution.

- Is restocking (reintroduction) or perhaps also the so-called "assisted migration" a useful tool in conservation strategy?

The majority of participants emphasized reintroduction or restocking as a very useful management strategy for the conservation of ICS, which could help either in their protection in the case of highly endangered species, or in sustainability of their potential commercial exploitation, *e.g.* in the case of *A. astacus*. According to the round table discussion and questionnaire completed by participants, there are only a few countries where restocking is not provided as a powerful tool in the conservation strategy (Table I) (Kozák *et al.*, 2009). Establishing new populations, *e.g.* in closed flooded quarries, pits and other former aggregates and minerals workings or in extensive fish ponds, is a good strategy not only for safe-keeping of genetic sources away from the distribution areas of NICS. Such activities may also involve stakeholders who can start with crayfish production for further restocking and/or (at least in the case of *A. astacus* and *A. leptodactylus*) recreational crayfishing tourism, with public educations as a key part of these integrated actions. In addition, new knowledge mainly in population genetics should be integrated into new principles of conservation strategies for reintroduction.

- How important is genetics of donor population? Which origin of source stocking material is the best for restocking?

Genetic variability and origin are among the most debated questions in conservation actions over the last decade. Which is more important: to save the highly diverse populations established by differing origins of brood stocks, or to save less diverse local populations related to different water bodies? In an ideal case, an abundant donor population with presumably high genetic variability is used as a source of stocking material for as close as possible suitable target localities. However, such a source is rarely available. The criteria for choosing both donor populations and target habitats are listed by Souty-Grosset and Reynolds (2009).

Table I
*Restocking, breeding and exploitation of indigenous crayfish species (*A. astacus*,* A. leptodactylus *and* Austropotamobius *sp.) in some European countries, according to the questionnaire completed by participants of the workshop in France.*

Tableau I
Réintroduction, élevage et exploitation des espèces d'écrevisses indigènes (*A. astacus*, *A. leptodactylus* et *Austropotamobius* sp.) dans quelques pays européens, selon les questionnaires remplis par les participants au groupe de travail en France.

	Yes	No
Restocking	Austria, Italy, England, Estonia, Ireland, France, Portugal	Czech Rep., Croatia,
Breeding	Austria, England, Italy, Estonia, France	Czech Rep., Croatia, Ireland, Portugal
Exploitation	Estonia, France	Czech Rep., England, Italy, Croatia, Ireland, Portugal

The different approaches to conservation of *A. astacus* and species belonging to the genus *Austropotamobius* were also highlighted during the round table discussion.
A combination of prehistoric recolonisation patterns with more recent large-scale translocations of *A. astacus* across Europe for consumption and trade, has led many scientists to argue that the original phylogeographical patterns have been substantially changed. These changes were further developed by restocking or reintroduction of animals either from the wild or from aquaculture over the last few decades (*e.g.* a large part of Germany has been stocked by crayfish originating from the Augsburg hatchery, as explained by Max Keller). Consequently, most of the central European populations of *A. astacus* are genetically very similar (Schrimpf *et al.*, submitted) and it is difficult to determine the original genetic strain of a specific river catchment. It is of course accepted that local and diverse populations should preferably be used for reintroduction to new localities to preserve genetic diversity and locally adapted gene pools. However, apart from the evaluation of genetic diversity, there is no consensus what exactly "local" means and perception of this term may vary widely from a few to hundreds of water bodies in each country. Hence, a common concensus is that strict preservation of almost any local population of *A. astacus* is meaningless. Unfortunately, no general rule solving this problem exists and decision makers are usually dependent on their own perception and knowledge of specific conditions. Nevertheless, new approaches to conservation strategy of ICS should be continuously verified and applied according to the current state of art.
In the case of *A. torrentium* and especially the species complex *A. pallipes*, a majority of scientists support a more careful approach for local population-based protection because of their unique intraspecific genetic diversity. Current status of these species is at least in part related to their less suitable size for human consumption. Although some exceptions exist, their lower attractiveness has without doubt saved them from man-mediated translocations. However, most current populations are small and isolated. The smaller the population, the more profound is the loss of genetic diversity as well as the higher is the risk of extinction. Bearing in mind that a certain degree of genetic variability must be maintained within the population, governing its adaptation potential (the population must be capable of responding to new environmental conditions), small, isolated and genetically uniform populations are seriously endangered and their existence on a long-term basis is unsure. In these cases, conservation actions should be considered.

- Could artificial breeding of crayfish help in protection of ICS?

Artificial breeding of crayfish is now a sophisticated and well-handled technology. Captive breeding is not only a useful tool for commercial production but a very effective approach in conservation strategy. Successful captive breeding on a local (genetic) basis is better than stocking crayfish from unknown or feeble wild donor populations (Souty-Grosset and Reynolds, 2009). Artificial breeding gives a big opportunity to establish regional farms using

Table II
The advantages and disadvantages of different kinds of stocking material for restocking of crayfish.

Tableau II
Les avantages et désavantages des différents stades et origines pour la réintroduction d'écrevisses.

Stocking material	Advantages	Disadvantages
Cultured crayfish	- Provide high number of crayfish. - Could use local stocks – regional farms. - May provide disease-free stocks.	Long-term stocking of cultured juveniles in a continually declining population may lead to decrease of fitness of this established population.
Indigenous	- Less demanding of human labour, equipment and culture facilities – relatively cheaper. - Could use local stocks.	- Pillaging donor populations in cases of feeble stocks. - Troubles with identifying right donor populations. - Possible transfer of diseases including crayfish plague.
Juveniles	- Better adaptation to a new environment. - Stationary behaviour for better establishment of population in particular area. - Higher number could be introduced. - Could be easily produced by breeding.	- Easily predated by fish. - Longer time to establish reproducing population.
Adults	- Good dispersal activity for rapid colonization. - Lower mortality.	- Higher post-stocking movements. - Male aggressiveness.

local stocks. They can provide high numbers of juveniles or selected age classes of specific stocks every year. Aquaculture seems to be the best supply for restocking in the future, as the number of suitable donor populations will be lower and pressures for controlling diseases more meaningful. Indeed, modern aquaculture practice can effectively reduce vertical transfer of diseases (including crayfish plague) from donor population broodstock to cultured animals in hatchery using methods of artificial egg incubation, when combined with chemical egg disinfection (Makkonen *et al.*, 2010). Moreover, if only a part of females' egg complement is detached and incubated in the hatchery, the rest remain maternally incubated and consequently can contribute to the respective cohort of the donor population. Such an approach can save this population with less interference than the transfer of captured adults or of all available eggs.

- Are juveniles or adults better for restocking?

There are some advantages to the use of juveniles for restocking to new localities (Table II). Firstly, they have better adaptation capabilities than do adults to a new environment. Secondly, juveniles have a non-dispersing behaviour which allows better establishment of a population in the particular area. It is also significant that high numbers of juveniles can be produced for restocking by aquaculture. On the other hand, juveniles are easily predated by fish and it takes a longer time to establish a developing population. Stocked adult crayfish have lower mortality due to predation, which could lead to rapid colonization of the new locality. On the other hand, they have higher dispersal activity which could be disadvantageous if it is intended to colonize a particular section of a river catchment. Stocking of adults or juveniles should therefore be judged case by case, not only in relation to accessibility of stocking material but also taking into account the characteristics of the new locality; however, size-stratified stocks including juveniles, pre-adults, mature males and females, and even berried females are also often used.

- How effective are “ark sites” in conservation management?

Considering the known facts of almost unstoppable spreading of NICS (Holdich *et al.*, 2009), the concept of safe isolated sanctuaries or “ark sites” is now widely accepted by the scientific community as a future necessity for ICS. This approach basically follows and improves the rules for previously realized repatriations of indigenous crayfish. The criteria for selecting these new refuges are comprehensively described by Peay (2009) and the invertebrate conservation trust Buglife (www.buglife.org.uk) provides step by step guidance on using former aggregate sites (Kindemba and Whitehouse, 2009). Although the mentioned criteria seem to be written in a somewhat complicated way for ordinary stakeholders and decision makers, such levels of detail will maximise the chances of success in the long term. Several populations have already been established following this protocol (Sibley *et al.*, 2007; Horton, 2009) and further potential localities for stocking are being under consideration (Gladman *et al.*, 2009; Nightingale, 2009).

Although there is agreement about the usefulness and overall support of these activities, one related question remains unanswered. What is the goal of these activities? Are we aiming at conservation of selected strains in a few safe localities or would we like to stock all suitable ark sites? Although everything depends on future circumstances, the prospects of ICS are substantially unsure. For example, the first approach is appropriate when we consider that five currently established ark sites hold more than one fifth of the remaining populations of *A. pallipes* in the whole of South-West England (Holdich *et al.*, 2009). This example accepts that the spread of NICS will be no less devastating across Europe in the long term, and thus as many ark sites as possible should be conceptually created and saved. Furthermore, when we are talking about education of the public, we have to avoid a situation where only a few ark sites are set up to hold ICS. The public and especially children need to be in as close as possible contact with ICS for education and thus, ark sites must be close to them. If it is to the contrary, insufficient ICS distribution is the best pathway to their “extinction in peoples’ minds” and consequently also to their real extinction in nature. Anyway, only an educated public will ensure long term viability of the ark sites-based concept.

CONCLUSION

- The development of a conceptual model for protection of ICS in Europe seems to be essential. However, currently recommended approaches of conservation strategy of ICS vary between countries and species. The different approaches to conservation of *A. astacus* and species belonging to the genus *Austropotamobius* were highlighted as crucial during the round table discussion.
- Concerning *A. astacus,* a majority of scientists argue that original phylogeographical patterns have been substantially changed due to large translocations especially during the last two centuries across Europe, promoted by restocking or reintroduction of animals either from the wild or from aquaculture in the last few decades.
- In the cases of *A. torrentium* and species complex of *A. pallipes* and *A. italicus*, the majority of scientists support a more careful approach to local population-based protection related to unique intraspecific genetic diversity.
- Captive breeding is not only a useful tool for commercial production but a very effective approach in conservation strategy. Artificial breeding gives a big chance to establish regional farms using locally adapted stocks.
- Stocking of adults or juveniles should be judged case by case, not only related to accessibility of stocking material but taking into account the characteristics of the new locality. There are some advantages in using juveniles for restocking new localities such as better adaptation, stationary behaviour and the possibility of production of high numbers of juveniles from aquaculture.
- Concerning the known facts of almost unstoppable spreading of NICS, the concept of safe isolated “ark sites” is now widely accepted by the scientific community as a future necessity for ICS.

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