A PLAN OF RESTORATION IN NAVARRA FOR THE NATIVE FRESHWATER CRAYFISH SPECIES OF SPAIN, *AUSTROPOTAMOBIUS PALLIPES.*

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ABSTRACT

This paper describes the attempts to protect and re-establish threatened populations of the native freshwater crayfish, *Austropotamobius pallipes*, of Navarra, Spain. Three species of crayfish are presently thriving in Navarra, the native species *A. pallipes* and the introduced North American species *Pacifastacus leniusculus* and *Procambarus clarkii*. Both species are known to carry the fungus *Aphanomyces astaci* in their cuticles and to transmite it to the native species. The management strategies implemented by the authorities in order to restore native populations of crayfish are discussed.

Key-words : Plan of restoration, *Austropotamobius pallipes*, *Pacifastacus leniusculus*, *Procambarus clarkii*, *Aphanomyces*, endangered species.

PLAN DE RESTAURATION EN NAVARRE DE L'ÉCREVISSE AUTOCHTONE D'ESPAGNE, *AUSTROPOTAMOBIUS PALLIPES.*

RÉSUMÉ

Cet article décrit les essais entrepris pour protéger ou rétablir en Navarre, Espagne, des populations menacées de l'écrevisse autochtone, *Austropotamobius pallipes*. Trois espèces prospèrent actuellement en Navarre, l'espèce autochtone, *A. pallipes*, et les espèces américaines introduites, *Pacifastacus leniusculus* et *Procambarus clarkii*. Ces deux dernières espèces sont connues comme porteuses du champignon *Aphanomyces astaci* dans leurs cuticules et comme vecteurs transmettant ce parasite aux espèces autochtones. Les stratégies de gestion arrêtées par les Autorités pour restaurer les populations d'écrevisses autochtones sont discutées.

Mots-clés : Plan de restauration, *Austropotamobius pallipes*, *Pacifastacus leniusculus*, *Procambarus clarkii*, *Aphanomyces*, espèce en voie d'extinction.

INTRODUCTION

The populations of native freshwater crayfish species in Europe have been greatly reduced during the last century due to a combination of factors such as diseases, introduction of alien crayfish species, habitat alterations, human disturbance, overfishing, *etc.* (UNESTAM, 1973 ; HOLDICH, 1988 ; TAUGBØL and SKURDAL, 1993). Thus, the European native species of freshwater crayfish are listed in the Red Data Book of the International Union for the Conservation of Nature and Natural Resources (IUCN) as endangered species (WELLS *et al.*, 1983 ; GROOMBRIDGE, 1994). The white-clawed crayfish, *Austropotamobius pallipes* (Lereboullet) is not an exception and it is listed as a vulnerable or rare species.

This species is the only native freshwater crayfish species of the Iberian Peninsula. The white-clawed crayfish was wide-spread and very abundant until the end of the 1970's, when its populations were dramatically reduced (CUELLAR and COLL, 1983). The main reason for this decline was an epizooty caused by the crayfish plague fungus, *Aphanomyces astaci* (Schikora) (CUELLAR and COLL, 1983). This fungus has devastated many of the native populations of freshwater crayfish in Europe (UNESTAM, 1973 ; ALDERMAN *et al.*, 1984 ; SMITH and SÖDERHÄLL, 1986 ; TAUGBØL *et al.*, 1993).

In Spain, the first outbreaks diagnosed as crayfish plague occurred in 1978, and five years later, most populations of native crayfish were affected by this epizooty (CUELLAR and COLL, 1983). This disease was certainly introduced into Spain in 1973 when two North American species, *i.e.*, the signal crayfish, *Pacifastacus leniusculus* (Dana), and the swamp crayfish, *Procambarus clarkii* (Girard), were imported for restocking and aquaculture purposes (DIÉGUEZ-URIBEONDO *et al.*, 1997 a). These crayfish are known to carry this fungus as a chronic infection (PERSSON and SÖDERHÄLL, 1983 and PERSSON *et al.*, 1987 ; DIÉGUEZ-URIBEONDO and SÖDERHÄLL, 1993 and DIÉGUEZ-URIBEONDO *et al.*, 1995, respectively). To make things worst, *P. clarkii* has multiplied and extended its territory to most parts of the central and southern rivers of Spain. Furthermore, recent restocking plans with *P. leniusculus* by some Local Governments have also allowed this species to extend throughout many areas of Spain.

As a result, the distribution of *A. pallipes* has been significantly reduced in Spain. Today, this species is mainly occupying habitats which are well preserved, far from the threat of human activities and/or the crayfish plague, *i.e.*, head-waters, closed water bodies, *etc.*

The threat to future survival of the native species has led the Navarra Government to establish a new legislation which includes a Plan of restoration for the native crayfish species *A. pallipes*. In order to develop this plan, this Department is funding a research program which included several research activities such as distribution studies, health controls and cage experiments. The results of these researches and the management strategies implemented are presented here.

CRAYFISH DISTRIBUTION IN NAVARRA

Navarra is a region of the north-western Spanish Pyrenees. There are two river versants. Most rivers are tributaries of the Ebro river which drains into the Mediterranean sea. The Atlantic versant comprises north-western rivers of Navarra which drain into the Cantabric sea (Figure 1).

Figure 1

Plan of restoration for the Native Crayfish Species of Navarra, *Austropotamobius pallipes*. The Plan has established two areas in order to implement an appropriate management strategy ; (1) « Native Crayfish Area », (2) « Alien Crayfish Area ».

Figure 1

Plan de restauration de l'écrevisse autochtone de Navarre, *Austropotamobius pallipes*. Le Plan a établi deux zones par rapport à une stratégie d'aménagement appropriée ; (1) « zone à écrevisses autochtones », (2) « zone à écrevisses exotiques ».

Navarra is a calcareus area and therefore native crayfish used to dwell in most of the watersheds. Nowadays, three species of crayfish are thriving in Navarra, the native species *A. pallipes* and the introduced North American species *P. leniusculus* and *Pr. clarkii* (AYERRA *et al.*, 1985, unpublished ; ALDABE *et al.*, 1991, unpublished ; DIÉGUEZ-URIBEONDO and RUEDA, 1994, 1997, unpublished) (Figures 2, 3 and 4).

In 1985, after the big hit of the plague during the period 1975-1980, at least 63 populations of native crayfish still remained in Navarra. However, only 19 of them were recorded in 1991 (Figure 2). New populations of *A. pallipes* have been found during the period 1991-1997 and thus, the number of populations recorded until data is, about 55. The native species populations are basically distributed in, small rivers, brooks and ponds of the central and northern parts of Navarra (Figure 2). This species occurs in areas where its habitat is well preserved and probably protected from the action of the plague by barriers such as weirs, waterfalls, dried parts of watercourses, underground waters, or stretches of empty crayfish which make it impossible for the crayfish to spread the plague by upstream migration.

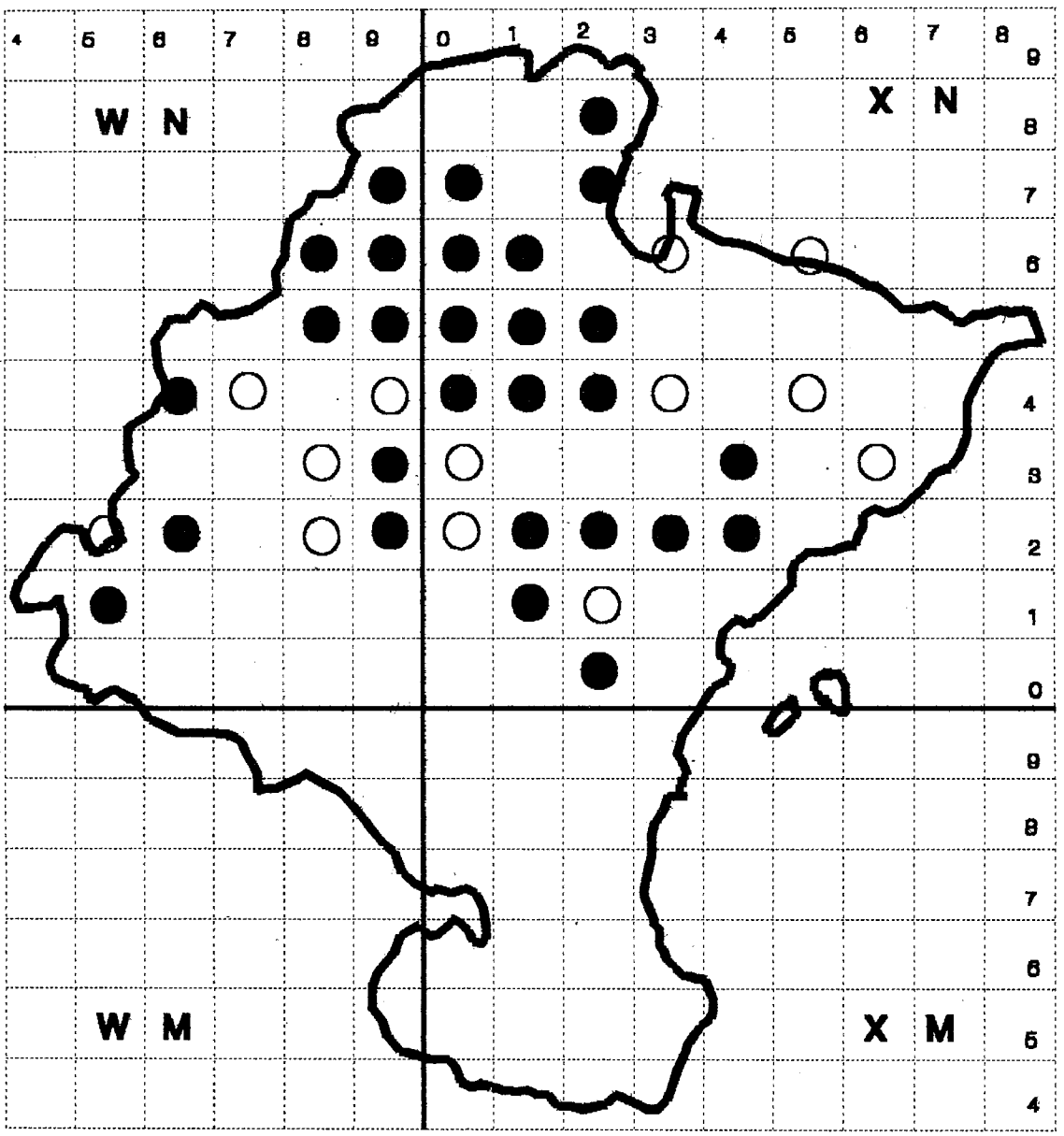

Figure 2

Distribution of the native species, *Austropotamobius pallipes*, in 1985 (O, ●) and 1991 (●) in Navarra. Each circle represents an area where populations of *A. pallipes* were detected.

Figure 2

Distribution de l'écrevisse autochtone, *Austropotamobius pallipes*, en 1985 (O, ●) et 1991 (●) en Navarre. Chaque cercle représente un endroit où les populations d'*A. pallipes* ont été détectées.

In addition, two alien species were introduced into Navarra during the 1980's, *Pr. clarkii* and *P. leniusculus*. The swamp crayfish was introduced in Navarra in the early 1980's due to the commerce of live crayfish and the illegal restocking. Nowadays, this species is basically distributed throught the central and southern parts of the main watersheds of Navarra, especially in irrigation systems (Figure 4). Its densities are sometimes so high that this crayfish has been considered as plague. Furthermore, a few populations of *Pr. clarkii* can also be found in some areas of North Navarra (Figure 4) although their densities are very low, which is probably due to the low temperatures and the limited oligotrophic characteristics of these waters. The presence of this species is a threat for the survival of the native populations situated nearby.

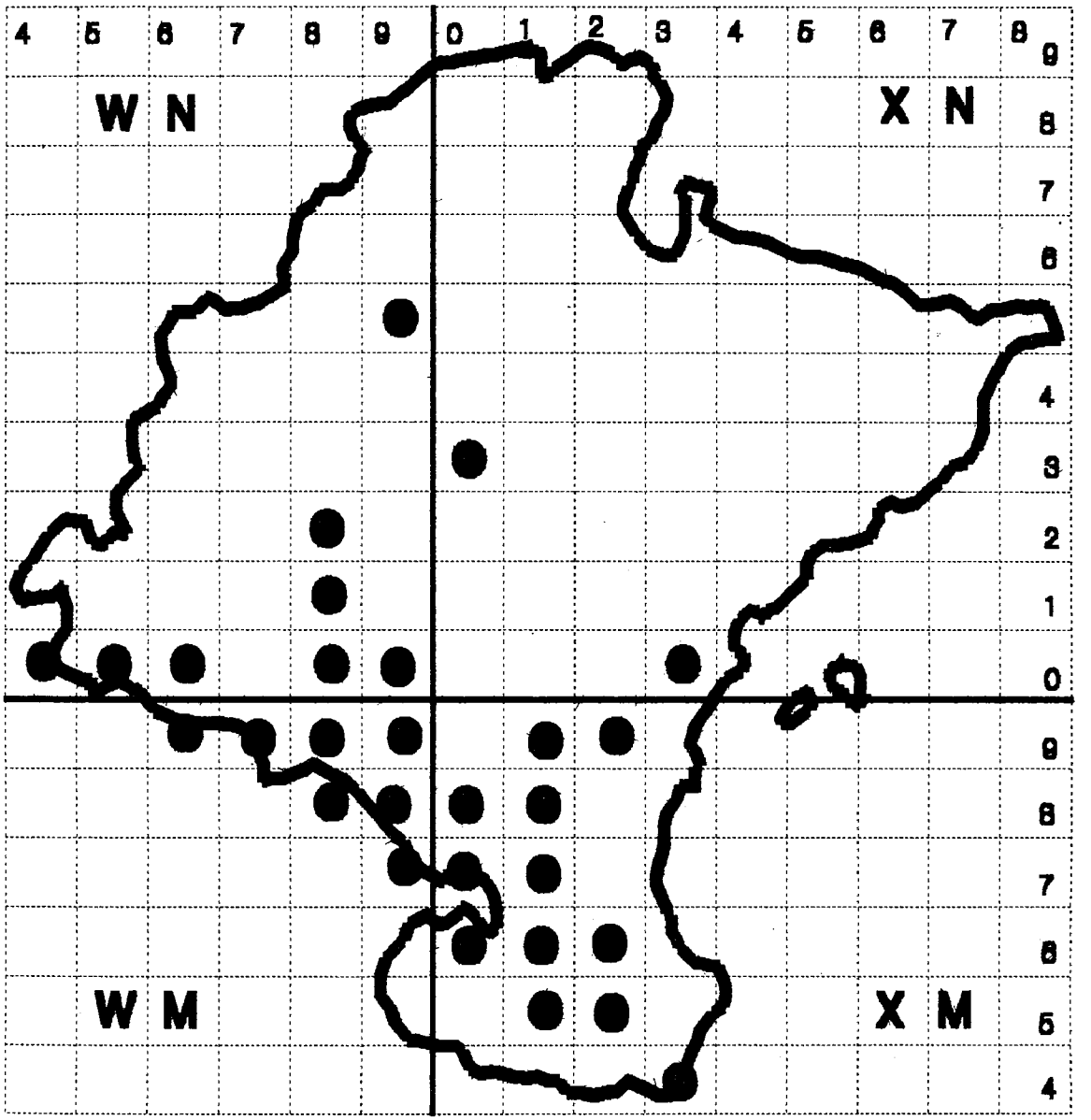

Figure 3

Distribution of the swamp crayfish, *Procambarus clarkii*, in 1991 (●) in Navarra. Each circle represents an area where populations of *Pr. clarkii* were detected.

Figure 3

Distribution de l'écrevisse américaine, *Procambarus clarkii*, en 1991 (●) en Navarre. Chaque cercle représente un endroit où les populations de *Pr. clarkii* ont été détectées.

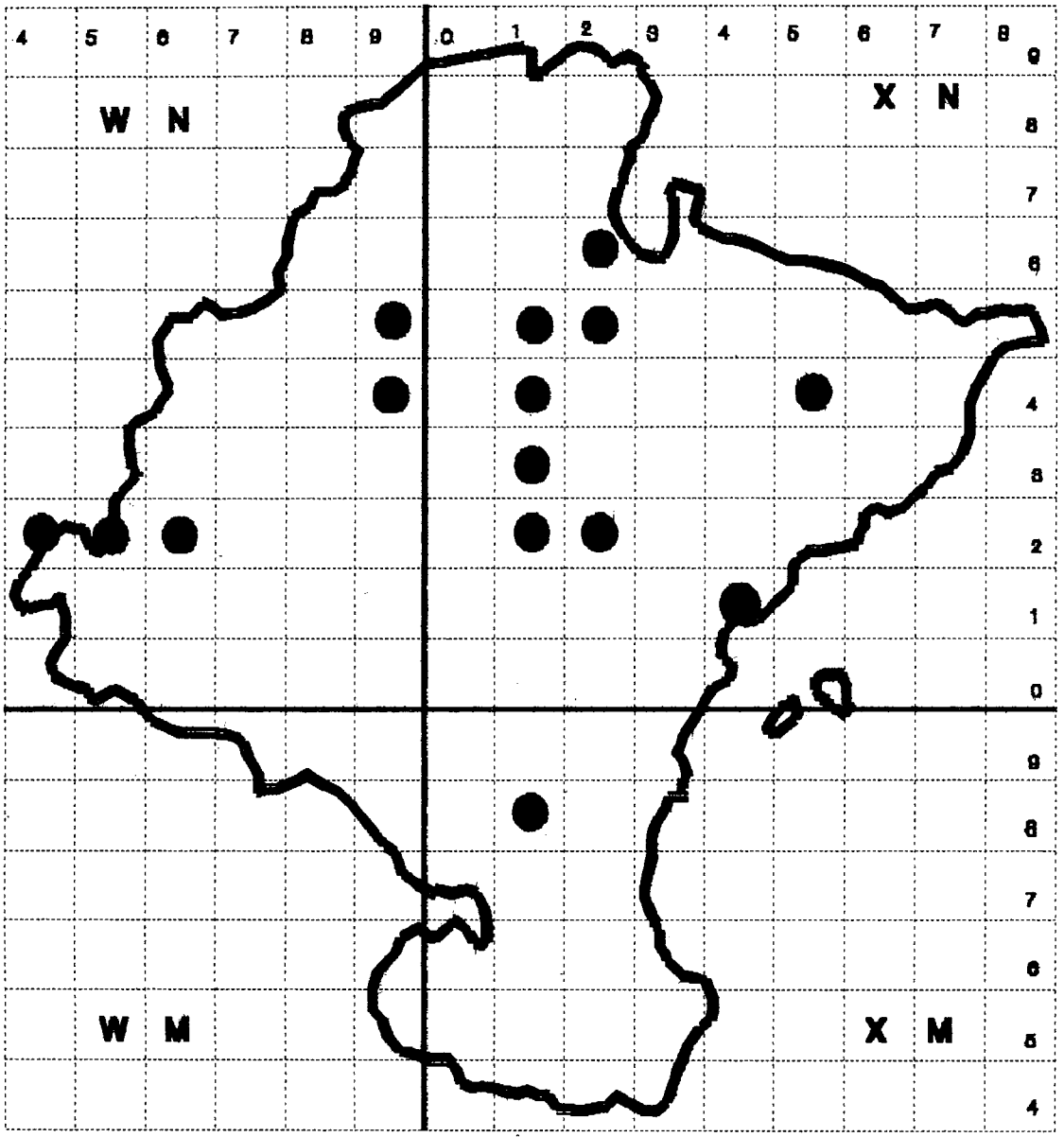

Figure 4

Distribution of the signal crayfish, *Pacifastacus leniusculus*, in 1991 (●) in Navarra. Each circle represents an area where populations of *P. leniusculus* were detected.

Figure 4

Distribution de l'écrevisse signal, *Pacifastacus leniusculus*, en 1991 (●) en Navarre. Chaque cercle représente un endroit où les populations de *P. leniusculus* ont été détectées.

Finally, the signal crayfish was introduced in 1987 by the Local Government in order to study its interaction with *Pr. clarkii*. But again illegal catching and restocking have played an important role in spreading this species and today, it is found in some areas of the central and northern parts of Navarra and it is also a threat to the native species (Figure 4).

Other species of alien crayfish have not been found in Navarra. However, there are reports about the presence of *Orconectes limosus* (Rafinesque) in the neighbour areas of French Basque Country (VIGNEUX *et al.*, 1995) and the Australian species *Cherax destructor* (Clark) in Aragón (DIÉGUEZ-URIBEONDO and RUEDA, unpublished).

HEALTH CONTROLS OF CRAYFISH POPULATIONS

Recent investigations have shown that crayfish may act as a vector for a broad spectrum of different pathogens (SÖDERHÄLL *et al.*, 1991 ; CERENIUS and SÖDERHÄLL, 1992 ; HENTTONEN *et al.*, 1994). Restocking programs involve transport and movements of crayfish which might be a way of spreading parasites and pathogens for crayfish and also for the rest of the flora and fauna. Therefore, knowledge of the health status of the existing crayfish populations is needed in order to establish a suitable management strategy for the native crayfish populations.

A health control program for crayfish populations is being carried out in Navarra since 1992 in collaboration with the Department of Animal Pathology of the University of Zaragoza, Spain and the Department of Physiological Botany of the University of Uppsala, Sweden. This program basically consists of examining the health status of the three crayfish species thriving in Navarra and the crayfish plague situation.

The presence of potential pathogenic saprolegniaceous fungi in the crayfish was examined. Fungi such as *Aph. astaci* (UNESTAM, 1972 and UNESTAM and WEISS, 1970), *Saprolegnia* spp (WILLOUGHBY, 1978 ; SÖDERHÄLL *et al.*, 1991, and DIÉGUEZ-URIBEONDO *et al.*, 1994), *Leptolegnia* spp (SEYMOUR, 1984), *etc.*, and other described crayfish pathogens such as *Psorospermium haeckeli* (Hilgendorf) (CERENIUS and SÖDERHÄLL, 1992, and THÖRNQVIST and SÖDERHÄLL, 1993), *Thelohania contejeani* (Henneguy) (CERENIUS and SÖDERHÄLL, 1992), *Trichosporon beigelii* (SÖDERHÄLL, *et al.*, 1993), *Cothurnia* spp (ALDERMAN and POLGLASE, 1988), *Branchiobdella* spp (ALDERMAN and POLGLASE, 1988).

From each population, samples of 50 animals were collected (only 10 crayfish for *A. pallipes*), at intermoult stage and analyses were done on living crayfish when possible. If not, samples were preserved in ethanol 70 %. When crayfish were found dead, they were fixed in 70 % ethanol and examined in laboratory as described in CERENIUS *et al.* (1987).

So far the most representative populations of the main watersheds have been studied and the results are summarized in Table I. Basically, the results show that native crayfish populations of Navarra seem to be free of most crayfish pathogens. For example, *Ps. haeckeli* and *T. contejeani* were not found in any of the specimens analyzed. However, these two parasites have been observed in the neighbour areas of Alava (DIÉGUEZ-URIBEONDO *et al.*, 1993 ; 1997 b, respectively). *Saprolegnia* spp were frequently found in all species studied but no mortalities due to them could be demonstrated. In addition, *Cothurnia* spp and *Branchiobdella* spp were found in North American species.

On the other hand, one of the main purposes of the health control was to know whether crayfish plague was still striking the native populations. Since 1993 it has not been recorded any crayfish plague attack to *A. pallipes* populations of Navarra. However, several cases of crayfish plague have been detected in the neighbour provinces of Alava, Burgos, Soria and Zaragoza (DIÉGUEZ-URIBEONDO *et al.*, 1997 a). Recent crayfish plague outbreaks in Europe have been shown to be due to introductions of *P. leniusculus*, *i.e.*, into Sweden (HUANG *et al.*, 1994), British Islands, Finland and Germany (K. SÖDERHÄLL, personal communication). The crayfish plague fungus was identified in all populations studied of signal crayfish of Navarra. Moreover, the crayfish plague fungus was also observed in *Pr. clarkii* (DIÉGUEZ-URIBEONDO and SÖDERHÄLL, 1993), isolated and characterized (DIÉGUEZ-URIBEONDO *et al.*, 1995). Interestingly the isolated strain from *Pr. clarkii* was adapted to warm temperatures in contrast with the rest of *A. astaci* so far isolated (DIÉGUEZ-URIBEONDO *et al.*, 1995).

Table I

Results from Health Control Program of Navarra.

Tableau I

Résultats du programme de la surveillance sanitaire en Navarre.

CRAYFISH SPECIES	PATHOGENS AND PARASITES
Austropotamobius pallipes	*Cothurnia sp.*
	Saprolegnia sp.
	Achlya sp.
Pacifastacus leniusculus	*Aphanomyces astaci*
	Saprolegnia sp.
	Branchiobdella sp.
	Cothurnia sp.
Procambarus clarkii	*Aphanomyces astaci*
	Saprolegnia sp.
	Achlya sp.
	Branchiobdella sp.
	Cothurnia sp.

In order to know whether the plague carried by these alien crayfish could hit some watercourses, preliminary tests were carried out in watercourses where crayfish have disappeared during the last 20 years. These watercourses were selected because of their good habitat conditions, absence of alien crayfish populations in their vicinity and presence of possible barriers preventing crayfish plague spread. The tests consisted of placing cages with live crayfish at different sites. Cages were placed at different sites of the selected streams and ponds ; at least 3 cages were used in each site. None of the sites were struck by the plague.

LEGISLATION

In Spain, the separate Autonomic Regions or « Comunidades Autónomas » are responsible for their own Nature Conservation and Research related to species preservation. Thus, the Autonomic Region of Navarra has its own Wild Life Legislation and Policy (GOBIERNO DE NAVARRA, 1993).

In the light of the results showed above, the Departamento de Medio Ambiente del Gobierno de Navarra has decided to list the native crayfish species of Navarra, *A. pallipes*, in the Catalogue of Endangered Species as a species on risk of extinction (DECRETO FORAL 142/1996). The Act 225/1993 of the Navarra Legislation for Protection and Management of the Wild Life and its Habitats establishes that a Plan of restoration has to be implemented if a species is listed as an endangered one (GOBIERNO DE NAVARRA, 1993). As a consequence of that, the local authorities have established a Plan of restoration for the native freshwater crayfish species (DECRETO FORAL 143/1996) and a Plan of control and management of alien crayfish (DECRETO FORAL 144/1996).

PLAN OF RESTORATION FOR THE NATIVE CRAYFISH, *A. PALLIPES*

This plan delimits two areas named « Native Crayfish Area » and « Alien Crayfish Area » (Figure 1). The « Native Crayfish Area » comprises all watercourses where *A. pallipes* occurs, and also a no-go area which extends to an area named « Alien Crayfish Area » where most introduced crayfish species dwell and the restoration of the native species appears impossible.

The plan intends to :

(1) preserve and re-establish the populations of *A. pallipes* within its habitat range, and for this purpose a program for detection of suitable watercourses for stocking the native crayfish will be implemented. Moreover, a restocking program will also be carried out in these areas, and the Local Government will also take all necessary regulations in order to preserve the natural habitat of the native crayfish according to the European Community Habitat Directive 92/43 ;

(2) stop the spreading of the alien crayfish into the area of native crayfish. In order to prevent the invasion of the « Native Crayfish Area » by alien crayfish species, the following regulations have been adopted :

1- the transport or commerce of live crayfish are not allowed ;

2- catching of swamp crayfish is only allowed within the « Area of Alien Crayfish » and only at those sites listed by the Authorities according to the annual fisheries regulations ;

3- catching of signal crayfish is only allowed within the « Area of Alien Crayfish » or exceptionally within the « native crayfish area » if a special policy is implemented. There are presently two catching-areas and the number is regulated by the annual fisheries regulations ;

4- in all cases crayfish should be killed after catching.

Moreover, a yearly program has been implemented in order to monitor the spread of alien crayfish populations and thus evaluate the efficiency of these regulations. In addition, the plan also includes several activities for health control of crayfish populations and distribution studies of crayfish populations, and also a program to study the dynamics of the restored areas.

Finally, to increase the public knowledge and awareness several information activities will be taken, *i.e.*, brochures, information in newspapers, on TV, *etc.*

DISCUSSION

Several European countries have accomplished a number of action plans for conservation and restoration of their native freshwater crayfish, *i.e.*, Norway (TAUGBØL *et al.*, 1993), Great Britain (ROGERS and HOLDICH, 1995), France (LAURENT *et al.*, 1993), *etc.* The attempt made so far in this direction has proven successful (HOLDICH *et al.*, 1995). In Navarra, it appears that restoration of native crayfish is also possible at least in some areas as judged by the results obtained, *i.e.*, there still are dense populations of native crayfish and also suitable areas for restoring the white-clawed crayfish. Consequently, the Local Government of Navarra has implemented a Plan of restoration for the native crayfish comprising a number of regulations, management strategies and research programs. This Plan of restoration is the first official plan accomplished by any Local Government of Spain in order to protect and restore the threatened populations of native crayfish, *A. pallipes*. The

implemented regulations intend to stop the factors responsible for the decline of the native crayfish populations, *i.e*, the crayfish plague, introduction of alien species, habitat alterations and poaching. Consequently, two types of regulation have been adopted : **(1)** regulations concerning management, catching, commerce, and transport of alien species, and **(2)** regulations related to the native crayfish habitat range according to the European Community Habitat Directive 92/43.

This is important because after the outburst of the plague in Spain there were not sufficient actions taken in order to control and prevent the presence of alien crayfish and crayfish habitat alterations. For example, the measures proposed by the first official regulation against the crayfish plague, dated from 9th March 1981 (RESOLUCIÓN 18-3-81), were certainly unefficient because the commerce of live crayfish, especially *Pr. clarkii*, was not prohibited and also because the introduction of alien species, *i.e.*, signal crayfish, was allowed by some Local Governments. This combination was certainly an efficient method of spreading the crayfish plague fungus throughout Spain.

Thus, actions preventing introduction of alien crayfish ought to be implemented in order to prevent the spreading of the crayfish plague. In addition, actions need to be focused on stopping the ways by which the spread of these alien species take place. These are the sale and transport of living crayfish, the open catching season in no controlled areas and the illegal restocking. A clear example of the relevance of these actions, is the province of Burgos, Comunidad Autonoma de Castilla-León. The bans of the commerce of living crayfish and its catching implemented in the province of Burgos, Spain, have resulted out in a slower spread of *Pr. clarkii* if compared with the neighbour provinces where the bands of the commerce and catching have not been strictly followed.

Furthermore, another important aspect for preventing alien species spread is illegal restocking. In order to prevent that, it is important to inform and co-operate with local people/local authorities. Numerous examples, especially from Sweden (TAUGBØL, personal communication) show that it is very difficult to protect the native crayfish and prevent the spread of alien ones if people want otherwise. Therefore, it is very important that also the local people look at the native crayfish as a resource that is important to protect. Nowadays, *A. pallipes* is listed as a risk of extinction but it is possible that in the near future native crayfish population could recover and good native stocks could be allowed to exploit. So, information in newspapers, on TV and in brochures is distributed by the Local Government of Navarra.

As above-mentioned, Navarra has implemented these kinds of measures. However, there are already in Navarra alien species populations within the habitat range of the « Native Crayfish ». In these areas investigations are carried out in order to monitor and eliminate if possible these chronically infected crayfish into new areas. In addition, in some areas the populations of alien crayfish are so abundant that their eradication appears to be difficult if not impossible. In order to solve this situation, the plan has delimited an area of the « Alien Crayfish Species ». In this area the crayfish are no longer categorized as unwanted and actions are orientated in order to do a proper management strategy and catching.

Concerning crayfish habitat alterations, it should be said that in many cases the importance of the crayfish plague fungus has shadowed the effects of other reasons such as habitat alterations by different means. The distribution studies in Navarra carried out in 1985 and 1991 have shown that around 70 % of *A. pallipes* populations have disappeared during the last 12 years (Figure 2) and similar results have been obtained by other authors (TEMIÑO *et al.*, 1997, unpublished). Many of these populations seem to have disappeared because of habitat alterations, climatic drought or poaching. This may be easily explained because these populations are mainly thriving in small watercourses like brooks where any alteration can dramatically affect a native crayfish population. The Plan of restoration of the

native crayfish species guaranties that all actions will be implemented in order to conserve the habitat of the native crayfish species. These actions established in this way will be implemented according to the European Community Habitats Directive.

This plan implemented in Navarra will be revised every 5 years and regulations will be modified according to the results obtained from the research programs.

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REFERENCES

ALDABE J., ESQUISABEL J.I., FERNÁNDEZ M.I., IRURZUN J.C., MENDIA F., RUEDA A., YOLDI B. 1991. Estudio de distribución y abundancia de las especies de cangrejos presentes en los ríos navarros. Servicio de Medio Ambiente del Gobierno de Navarra, Negociado de Gestión Cinegética y Piscícola, 1, 1-20. (unpublished)

ALDERMAN D.J., POLGLASE J.L., 1988. Pathogens, Parasites and Commensals. *In* HOLDICH D.M. and LOWERY R.S. (eds.), Freshwater Crayfish : Biology, Management and Exploitation, 167-212, Croom Helm, London.

ALDERMAN D.J., POLGLASE J.L., FRYLING M., HOGGER J., 1984. Crayfish plague in Britain. *Journal of Fish Diseases, 7*, 401-405.

AYERRA J., CIRIZA F., ESQUISABEL C., ESQUISABEL J.I., IBARRA J., INSAUSTI J.A., 1985. Estudio de la distribución actual del cangrejo de río *(A. pallipes)* en Navarra. Sevicio de Medio Ambiente del Gobierno de Navarra, 1, 1-17. (unpublished)

CERENIUS L., SÖDERHÄLL K., 1992. Crayfish diseases and crayfish as a vector for important diseases. *Finnish Fisheries Research, 14*, 125-133.

CERENIUS L., SÖDERHÄLL K., PERSSON M., AJAXON A., 1987. The crayfish plague fungus *Aphanomyces astaci* - diagnosis, isolation and pathobiology. *Freshwater Crayfish, 7*, 131-144.

CUELLAR L., COLL M., 1983. Epizootiology of the crayfish plague *(Aphanomyces astaci)* in Spain. *Freshwater Crayfish, 5*, 545-548.

DECRETO FORAL 142, 1996. Inclusión del cangrejo de río autóctono en el Catálogo de Especies Amenazadas de Navarra, con la categoría de especie « en peligro de extinción ». Boletin Oficial de Navarra, 38, 1750 p. (In Spanish and Basque)

DECRETO FORAL 143, 1996. Plan de Recuperación del Cangrejo de Río Autóctono. Boletin Oficial de Navarra, 38, 1750-1752. (In Spanish and Basque)

DECRETO FORAL 144, 1996. Plan de Ordenación de los cangrejos alóctonos en Navarra. Boletin Oficial de Navarra, 38, 1752-1753. (In Spanish and Basque)

DIÉGUEZ-URIBEONDO J., RUEDA A., 1994. Estudio sobre el estado sanitario de las poblaciones de cangrejo en Navarra y ensayos de supervivencia de *Austropotamobius pallipes*. Sección de Caza y Pesca, Departamento de Ordenación del Territorio y Medio Ambiente, Gobierno de Navarra. (unpublished)

DIÉGUEZ-URIBEONDO J., SÖDERHÄLL K., 1993. *Procambarus clarkii* as a vector for the crayfish plague fungus *Aphanomyces astaci* Schikora. *Aquaculture and Fisheries Management, 24*, 761-765.

DIÉGUEZ-URIBEONDO J., PINEDO RUIZ J., CERENIUS L., SÖDERHÄLL K., 1993. Presence of *Psorospermium haeckeli* in a *Pacifastacus leniusculus* population of Spain. *Freshwater Crayfish, 9*, 286-288.

DIÉGUEZ-URIBEONDO J., CERENIUS L., SÖDERHÄLL K., 1994. *Saprolegnia parasitica* and its virulence on three different species of crayfish. *Aquaculture, 120*, 219-228.

DIÉGUEZ-URIBEONDO J., HUANG T.S., CERENIUS L., SÖDERHÄLL K., 1995. Physiological adaptation of an *Aphanomyces astaci* strain isolated from the freshwater crayfish *Procambarus clarkii. Mycological Research, 99*, 574-578.

DIÉGUEZ-URIBEONDO J., PINEDO RUIZ J., MUZQUIZ J.L., 1997 b. *Thelohania contejeani* in the province of Alava, Spain. *Bulletin Français de la Pêche et de la Pisciculture, 347.*

DIÉGUEZ-URIBEONDO J., TEMIÑO K., MUZQUIZ J.L., 1997 a. The crayfish plague in Spain. *Bulletin Français de la Pêche et de la Pisciculture, 347.*

GOBIERNO DE NAVARRA, 1993. *In* Legislación Sobre Fauna Silvestre y Consejo Navarro de Medio Ambiente. Colección Textos Legales, Volume 13. Departamento de O.T. y Medio Ambiente. Fondo de Publicaciones del Gobierno de Navarra, Pamplona, Spain, 120 p. (in Spanish)

GROOMBRIDGE B. (ed.), 1994. *In* Red list of threatened animals. I.U.C.N, 286 p, Gland Switzerland and Crambridge, U.K.

HENTTONEN P., HUNER V.J., LINDQVIST O.V., 1994. *In* Possible movement of epibionts, parasites and diseases with crayfish introductions. Book of Abstracts from the World Aquaculture Society, 244, New Orleans Marriot, New Orleans, Louisiana, USA.

HOLDICH D.M., 1988. The danger of introducing alien animals with particular reference to crayfish. *Freshwater Crayfish, 7*, 25-30.

HOLDICH D.M., READER J.P., ROGERS W.D., 1995. *In* Crayfish Conservation Final Project Record for the National Rivers Authorities, 378/10/N, 278 p.

HUANG T.S., CERENIUS L., SÖDERHÄLL K., 1994. Analysis of the genetic diversity in crayfish plague fungus, *Aphanomyces astaci*, by random amplification of polymorphic DNA assay. *Aquaculture, 26*, 1-10.

LAURENT P.J., NICOLAS J., PARIS L., 1993. Five years of action in Lorraine and Morvan (France) to restore the noble crayfish, *Astacus astacus. Freshwater Crayfish, 9*, 380-389.

PERSSON M., SÖDERHÄLL K., 1983. *Pacifastacus leniusculus* Dana and its resistance to the parasitic fungus *Aphanomyces astaci* Schikora. *Freshwater Crayfish, 5*, 292-298.

PERSSON M., CERENIUS L., SÖDERHÄLL K., 1987. The influence of the haemocyte number on the resistance of the freshwater crayfish, *Pacifastacus leniusculus* Dana, to the parasitic fungus *Aphanomyces astaci. Journal of Fish Diseases, 10*, 471-477.

RESOLUCIÓN 18-3-1981. Instituto Nacional para la Conservación de la Naturaleza. Boletin Oficial del Estado 18-3-81, 17-18. (in Spanish)

ROGERS W.D., HOLDICH D.M., 1995 Conservation and management of crayfish in Britain. *Freshwater Crayfish, 10*, 583-595.

SEYMOUR R.L., 1984. *Leptolegnia chapmanii*, an oomycete pathogen of mosquito larvae. *Mycologia, 76*, 670-674.

SMITH V.J., SÖDERHÄLL K., 1986. Crayfish Pathobiology : an overview. *Freshwater Crayfish, 6*, 199-211.

SÖDERHÄLL K., DICK M.W., CLARK G., FÜRST M., CONSTANTINESCU O., 1991. Isolation of *Saprolegnia parasitica* from the crayfish *Astacus leptodactylus. Aquaculture, 92*, 122-125.

SÖDERHÄLL K., RANTAMÄKI J., CONSTANTINESCU O., 1993. Isolation of *Trichosporon beigelii* from the freshwater crayfish *Astacus astacus. Aquaculture, 116*, 25-31.

TAUGBØL T., SKURDAL J., 1993. Noble Crayfish in Norway : legislation and yield. *Freshwater Crayfish, 9*, 134-143.

TAUGBØL T., SKURDAL J., HASTEIN T., 1993. Crayfish plague and management strategies in Norway. *Biological Conservation, 63*, 75-82.

THÖRNQVIST P.O., SÖDERHÄLL K., 1993. *Psorospermium haeckeli* and its interaction with the crayfish immune system. *Aquaculture, 117*, 205-213.

UNESTAM T., 1972. On the host range and origin of the crayfish plague fungus. Reports from the Institute of Freshwater Research. *Drottningholm, 52*, 192-198.

UNESTAM T., 1973. Fungal disease of crustacea. *Review of Medical and Veterinary Biology, 8*, 1-20.

UNESTAM T., WEISS D.W., 1970. The host-parasite interaction relationship between freshwater crayfish and the crayfish disease fungus *Aphanomyces astaci :* responses to infection by susceptible and resistant species. *Journal of General Microbiology, 60*, 77-90.

VIGNEUX E., KEITH P., NOEL P., 1995. *In* Atlas Préliminaire des Crustacés Décapodes d'Eau Douce de France. Coll. Patrimoines Naturels, vol. 14, S.F.F., B.I.M.M-M.N.H.N., C.S.P, Min. Env., Paris, 55 p. (in French)

WELLS S.M., PYLE R.M., COLLINS R.M., 1983. The IUCN invertebrate Data Book. IUCN, Gland, Switzerland, 632 p.

WILLOUGHBY L.G., 1978. Saprolegnias of salmonids fish in Windermere, a critical analysis. *Journal of Fish Diseases, 1*, 51-67.