Int Aquat Res (2010) 2: 1-14
ISSN 2008-4935
Available online at www.intelaquares.com

International Aquatic Research

Review

Crayfish in Italy: distribution, threats and management

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Received: 28 February 2010; Accepted: 25 March 2010

Abstract

Many populations of indigenous crayfish species (ICS) are at serious risk of extinction in Italy due to the growing number of threats to their integrity. These mostly derive from various forms of anthropogenic pressure, dramatically increased in the last 50 years. The distribution of the most widespread ICS in Italy, *Austropotamobius pallipes*, is noticeably smaller than in the last century and the number of *A. torrentium* and *Astacus astacus* populations is today small. On the contrary, Italy has been invaded by several non-indigenous crayfish species (NICS), particularly the North American *Procambarus clarkii*, *Orconectes limosus*, and *Pacifastacus leniusculus.* The distribution of a fourth NICS, the Ponto-Caspian *Astacus leptodactylus*, is still limited, probably due to its susceptibility to the oomycete *Aphanomyces astaci*, whereas the marbled crayfish, *Procambarus* sp., and the Australian *Cherax destructor* have already appeared in the wild. Any intervention aimed at the conservation of ICS should rely on a broad-spectrum actions; in any case, a crucial step will be to restore and maintain the integrity of the natural habitats that will be accomplished also by reducing environmental stresses, including those induced by NICS. The management of crayfish populations require guidelines firmly based on the growing body of scientific knowledge on the biology and ecology of the target species. Finally, special attention should be paid to informing, educating, and raising awareness among non-specialists, whose support and participation are essential prerequisites for the success of any intervention.

Keywords: Indigenous crayfish species, Non-indigenous crayfish species, Distribution, Management

Introduction

At the end of the 19th century the status of the indigenous crayfish species (ICS) populations in Italy was already seriously jeopardized. As reported by Prof. Decio Vinciguerra to the Fishing Advisory Commission in 1899, the distribution of *Austropotamobius pallipes* and *A. torrentium*, called by him "stone crayfish" (i.e. "gambero sassaiolo"), had drastically shrunk, particularly in Northern Italy, as compared to the previous 30 years. Today we assign such shrinkage to outbreaks of the crayfish plague (Ninni 1865), a disease transmitted by the infectious North-American oomycete *Aphanomyces astaci*. In the last century, crayfish were important market commodities in Italy: they were abundantly consumed in some Italian provinces (Belluno, Sondrio, Como, L'Aquila, Perugia, and Salerno) and large quantities (over 100 kg of crayfish were fished daily from each single stream) were exported from the regions of Abruzzo and Umbria to the fish markets in Naples, Rome, and Florence and in France as well.

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To solve the problem of crayfish disappearance, Vinciguerra pinpointed the need to regulate their exploitation by extending fishing ban to the entire breeding period and by posing a minimum size limit of catches. Finally, in order to counteract the reduction in natural populations, Vinciguerra recommended both to favour crayfish farming and to introduce other species, such as the noble crayfish (*Astacus astacus).* Vinciguerra concluded his report by advising against the introduction of the Ponto-Caspian crayfish *(Astacus leptodactylus*) and conversely by indicating the North American *Cambarus cambarus* (the today's *Procambarus clarkii*) as a possible substitute for the stone crayfish. In fact, as Vinciguerra puts it, this is a species with the "valuable quality" of being "resistant to the epidemics".

More than a century later, ICS populations have declined even more drastically all over Italy due to the multiplication of the threats to their integrity, including the introduction of NICS (Holdich et al. 2009). As in the rest of Europe, over the past 50 years the main risks come from the increasing human pressures. In the 1960s and 1970s, many watercourses in the most industrialized areas, which had previously hosted highly dense populations of crayfish, were subject to severe deterioration and impoverishment, often culminating in the local extinction. Along with overfishing and the frequent epizootics due to *A. astaci*, other causes responsible for the current plight of Italian crayfish include: changes of land use; drainage and canalization works; closing of watercourses (dams, locks etc.); overdrawing and waste of water for industrial, agricultural and public use; hot water discharge associated with the production of electricity; industrial waste emissions and urban sewage; water acidification; and the deliberate or accidental introduction of alien species with their parasitic load.

Current distribution of indigenous species

The white-clawed crayfish, *Austropotamobius pallipes*, is the most widespread ICS in Italy. In recent years, through allozyme analyses (Santucci et al. 1997) and molecular biology techniques (Fratini et al. 2005), its systematic appears to be more complex than previously described. The taxon *A. pallipes* in Italy seems now to be composed of two genetically distinct evolutionary lineages: *A. pallipes* in the north-west and *A. italicus* in the rest of the peninsula. As shown by genetic analysis, the two species live in sympatry in the Apennine Ligure and in the Province of Alessandria (Zaccara et al. 2004). A preliminary analysis was not able to discriminate the two taxa for their morphology (Ghia et al. 2006). More recently, the analysis of a wider range of morphometric traits by the use of a geometric approach revealed significant differences between the two lineages, particularly in the morphology of the reproductive organs (Bertocchi et al. 2008a). Such a diversity was even more evident when the genetic analysis was extended to populations from different Italian regions, showing four subspecies in *A. italicus*: *A. i. italicus* in the Tuscan-Emilian Apennines*; A. i. carinthiacus* in central and north-western Italy*; A. i. carsicus* in north-eastern Italy, and *A. i. meridionalis* in the regions Latium, the Marches, and Abruzzo and in southern Italy (Zaccara et al. 2004, 2005; Paolucci et al. 2004; Baric et al. 2005; Fratini et al. 2005; Cataudella et al. 2006; Bertocchi et al. 2008b).

As seems clear from the upsurge of scientific interest in recent years (Manganelli et al. 2006), the systematic identity of *A. pallipes*/*A. italicus* is still in a state of flux. Consequently, pending official recognition of *A. italicus* as a distinct specific entity, in this chapter we shall use the conservative diction *A. pallipes* (Holdich et al. 2006). As shown in Figure 1, *A. pallipes* occupies three different climate areas across Italy, islands excluded, at heights between 90 and 1050 metres above sea level, from coastal areas on the Mediterranean Sea to the Alps and the Apennines (Holdich 2002). Its current distribution in Italy seems to result from two distinct phenomena. Firstly, it was caused by competition with the river crab, *Potamon fluviatile* (Barbaresi and Gherardi 1997), which apparently started in the Pleistocene when the two species met each other after having migrated from eastern Europe (Pretzmann 1987). According to Barbaresi and Gherardi (1997), crayfish lost competition with crabs: the latter forced them to migrate to less favorable areas at higher altitudes and lower temperatures. Indeed, on the southern mountainside of the Tuscan-Emilian Apennines, where the two species co-exist, crayfish populations are to be found at higher altitudes; on the contrary, a few hundred kilometres away on the northern slopes of the Apennine where they are not subject to competition from crabs, crayfish live at lower altitudes and in more favorable temperature regimes (Barbaresi and Gherardi 1997). Similarly, the presence of *P. fluviatile* makes the crayfish rare in the Province of La Spezia, while in the rest of the Region Liguria large populations of *A. pallipes* occur (Salvidio et al. 2002).

The second factor that affects the today's distribution of *A. pallipes* is the frequent release into the wild of crayfish with a different genetic structure. In fact, genetic analyses have shown that some populations from the south occur in northern Italy, e.g. populations of *A. i. meridionalis* in the Province of Prato where instead populations of *A. i. italicus* typically live (Fratini et al. 2005).

Fig. 1. Distribution in Italy of the indigenous crayfish *Austropotamobius pallipes*

The other two ICS in Italy are the noble crayfish, Astacus astacus, and the stone crayfish, *Austropotamobius torrentium*. Compared to *A. pallipes*, only few and small populations of these species occur today in the peninsula and all these are under serious threat (Figures 2 and 3). Up to now, populations of *A. astacus* have been recorded in the provinces of Bolzano (Füreder 2007), Belluno and Udine, and *A. torrentium* in the Province of Udine (De Luise 2006). However, at least one of the three populations of *A. torrentium* found in the Province of Udine is close to extinction if not already extinct (Machino and Füreder 2005).

Main threats to indigenous species

Biological properties

ICS show characteristics proper to K-selected species. In particular, *A. pallipes* has a slow growth rate and a relatively long average life span (8.2 years for males and 7.8 for females) (Brusconi et al. 2008). Sexual maturity is reached relatively late (after 2-3 years) and fertility is low (50-200 eggs per lay). Mating takes place in autumn and is followed by a long period, until June of the subsequent year, during which females hide in a shelter to take care first of the eggs and then of the juveniles. The above listed biological properties make this and other ICS particularly vulnerable to the numerous human-induced changes of their habitat. Obviously, to be effective, crayfish management requires the identification of all the threats and the removal, or at least the reduction, of their negative impact.

Fig. 2. Distribution in Italy of the indigenous crayfish *Astacus astacus*

Fig. 3. Distribution in Italy of the indigenous crayfish *Austropotamobius torrentium*

Habitat alteration

Global warming over the later decades has contributed to reducing the habitats suitable for ICS. During the last summers (e.g. summer 2003), many watercourses have been subject to drought for months, possibly leading to the local extinction of *A. pallipes*, as recorded in some watercourses in Tuscany (Renai et al. 2006). Together with climate change, water abstraction for irrigation, domestic purposes, and watering livestock has had the effect of decreasing water availability seriously. This has led to the fragmentation of watercourses into small to medium sized pools characterized by very different micro-environments with respect to the original conditions, thus increasing the risk of chemical pollution especially when these pools are located near drains and farms. Finally, the fragmentation of watercourses has caused reproductive isolation into sub-populations with the consequent reduction in genetic diversity.

After having analyzed 409 sites on 361 watercourses in the Province of Alessandria for 3 consecutive summers (2002-2004), Nardi et al. (2005) showed that water abstraction for intensive agriculture is the main cause of the decline in the number of indigenous populations. In fact, over 40% of the streams where *A. pallipes* populations were extinct had dried up during the summer, while in 7% of the streams surface water was fragmented into temporary pools. Almost 80% of the crayfish populations still extant were distributed in areas with a human density below 100 individuals per km², and 36% in areas with no urbanisation. In Alto Adige, an intense soil use, due to the elevated production of orchards and vineyards, seemed to have caused a reduction in the number of *A. pallipes* populations: only 6 out of 50 sites appear today to host populations; these populations show also a low genetic diversity (Füreder et al. 2002; Baric et al. 2005; Füreder 2007).

Local extinctions of *A. pallipes* can be ascribed to sporadic events of chemical pollution, as revealed in the Fosso di Gambrano near Lucca (Tuscany) following the discharge of sewage from a pig farm (Renai et al. 2006). Indeed, this species is highly susceptible to chemical alterations, to the extent that it is typically considered to be a good indicator of water quality (Scalici and Gibertini 2005; Brusconi et al. 2008).

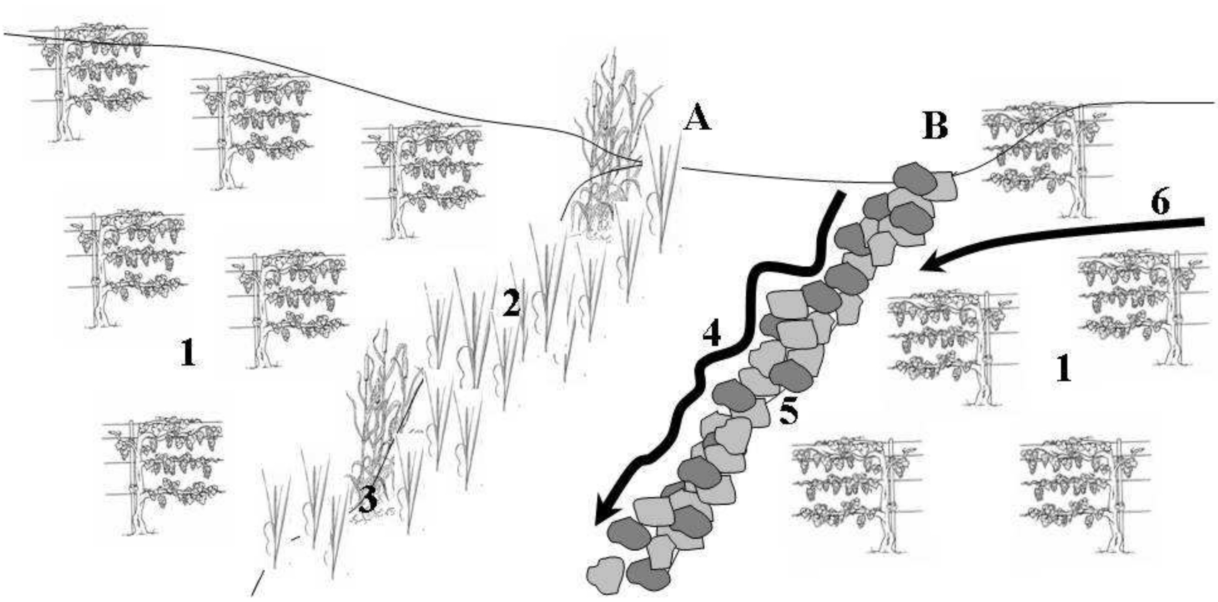

Fig. 4. Potential benefits linked with the presence of riparian vegetation. The watercourse, running through an intensively cultivated area (1), has two different types of river bank: (A) with riparian vegetation and (B) without riparian vegetation. In (A), riparian vegetation works as filter for agricultural sewages (2) and increases the habitat complexity and food availability for crayfish (3); in (B), the absence of riparian vegetation causes increasing water torbidity and bank erosion (4), movement of sediments (5) and unfiltered agricultural sewages (6) (Modified from Füreder et al. 2002).

Local extinction can also be ascribed to physical alterations of the waterbodies, mostly caused by channelling the riverbed: partial or total concreting of the banks reduces or destroys the riparian vegetation (Figure 4). The importance of riparian vegetation for the survival of *A. pallipes* has recently been demonstrated by Brusconi et al. (2008) in Tuscany. Monitoring carried out on 19 streams in the Magra, Serchio, Sieve and Arno basins (9 where *A. pallipes* populations are today extant and 10 where they are today extinct but extant in the recent past) showed that the presence/absence of crayfish does not depend on the physico-chemical and biological characteristics of the water, such as pH, concentration of ions and dissolved oxygen, temperature, water speed and depth, Extended Biotic Index (the Italian IBE), or the Fluvial Functionality Index (the Italian IFF). The difference found between the two categories of watercourse was due to the abundance of the vegetal component of the streams; in particular, the presence of crayfish was associated with the abundance of both plant debris on the stream bed and periphyton along the banks. Other studies had shown that plant debris and periphyton provide important food sources for crayfish (Gherardi et al. 2004), as well as shelter from predators (Benvenuto et al. 2008). Riparian vegetation also plays an important role as a source of debris, provides shade, thus maintaining water temperature at an optimal value for crayfish, and offers protection from predators (Benvenuto et al. 2008).

Genetic pollution

As already discussed, the genetic status of *A. pallipes* in Italy is complex. The current distribution of the taxon appears to be conditioned by the frequent, often deliberate, introduction of crayfish with a different genetic structure from the populations to be repopulated. In addition to the risk of introducing subjects unsuited to local conditions, which would make the intervention useless, there are threats to the indigenous populations posed by the “pollution” or even the extinction of the local genotype. However, the introduction of “populations genetically distinct or with inheritable adaptive characteristics that are significantly different from the population subject to intervention” is today illegal in Italy, as prescribed by the “Guidelines for reintroducing and repopulating animal and plant species of interest to the community” (2006).

Overfishing

At least in Tuscany, fishing is one of the main causes of local extinctions of *A. pallipes* (Renai et al. 2006). Fishing leads to a drastic decrease in population size; if a population is already at low density because of other human induced threats (Scalici and Gibertini 2005), its exploitation might reduce the genetic diversity (Bertocchi et al. 2008b) thus increasing the vulnerability to both environmental stresses and random events. There are today regulations in Italy that restrict crayfish fishing, but in certain areas poaching continues as part of cultural traditions. In various towns in the regions Friuli, Venezia Giulia, Umbria and Marches festivals are held devoted to *A. pallipes*, e.g. in the town of Remanzacco and Amaro (crayfish is the symbol of this town) in the province of Udine crayfish are cooked following traditional recipes (De Luise 2002).

Introduction of NICS

One of the main threats to freshwater biodiversity in general and to crayfish diversity in particular is the introduction of non-indigenous species (NICS). Pending the future expansion of *Pacifastacus leniusculus*, NICS that pose the greatest threat to ICS are today *Procambarus clarkii* and *Orconectes limosus* (Gherardi 2006).

As in the rest of Europe, in Italy NICS are more numerous than ICS: five NICS occur in the wild with reproductive populations (*Astacus leptodactylus*, *O. limosus*, *P. leniusculus*, *P. clarkii*, and *Cherax destructor*), one is still confined to farms (*C. quadricarinatus*), and one occurs in domestic aquaria (the marbled crayfish, *Procambarus* sp.), although a specimen has been already found in the wild (Nonnis Marzano et al 2009). The success of NICS is the result of their properties typical of *r*-selected species (rapid growth, early maturity, and high fertility; Scalici and Gherardi 2007). Besides, they show a high tolerance towards extreme environmental conditions (including chemical pollution, high temperatures, and drought) and resistance to parasites and diseases.

The most successful NICS in Italy is the red swamp crayfish, *P. clarkii*. As shown in Figure 5, this species occurs with extremely abundant populations in northern Italy, particularly in the Po River Valley where it has colonized various environments, including the rice paddies of Vercelli and Pavia and the Land Reclaim Consortia channels. The species appeared for the first time in the wild in 1989, in the River Banna, a tributary of the River Po, after the escape of a few specimens from an experimental farm (Delmastro 1992). It spread widely in Lombardy (Fea et al. 2006) and in Veneto (P. Turin, pers. comm.); it occurs in the Lake of Garda (I. Confortini, pers. comm.) and is widespread in the regions Marches, Abruzzo, Latium (Chiesa et al. 2006), and Umbria (Dörr et al. 2006). Recently, it was found in two brackish biotopes: “Padule di Torre Flavia” (Latium, Scalici et al. 2009c) and the

Regional Park "Migliarino, San Rossore, Massaciuccoli" (Tuscany, 2008). In southern Italy and in the islands, the species is present in the wild in the Region Basilicata (M. Visceglia, pers. comm.) and in the Province of Trapani in Sicily (Dörr et al. 2006).

In Tuscany (Gherardi et al. 1999a), *P. clarkii* is especially abundant in the Lake of Massaciuccoli and in the surrounding area: in 1993, a stock of crayfish cultivated in a farm poured into the lake after a flood or was released into it when the farm went bankrupt (Gherardi et al. 1999b). In any case, most populations of *P. clarkii* finding in the wild in Tuscany during the following years appear to have been originated from human translocations from the Lake of Massaciuccoli (Gherardi et al. 1999b). An exception is a population inhabiting in a neighbourhood of Florence, as revealed from genetic analyses (Barbaresi et al. 2007): a hypothesis is that this population has been introduced from China following the immigration of a Chinese community to Florence.

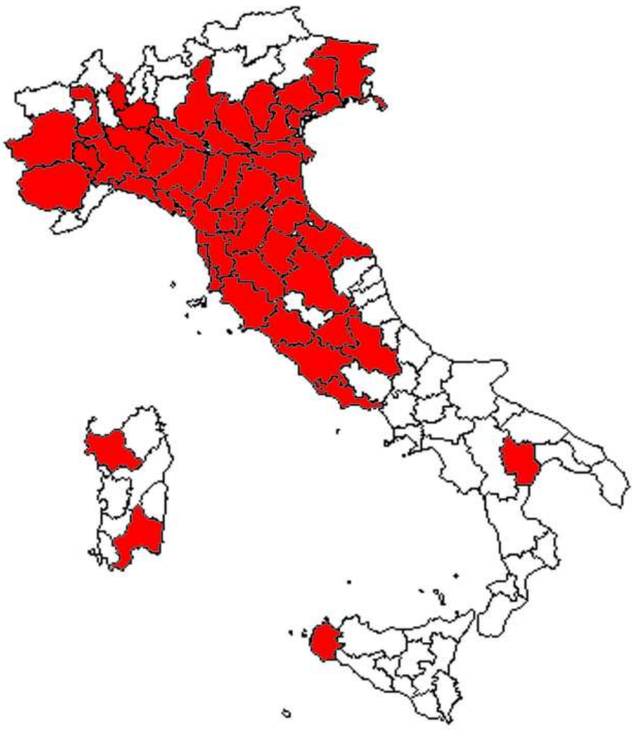

Fig. 5. Distribution in Italy of the non-indigenous crayfish *Procambarus clarkii*

P. clarkii's resistance to the crayfish plague was the main reason of its introduction into Europe in 1973 and then into Italy (Gherardi 2006). Cultivation of this species is facilitated by its generalistic and opportunistic feeding habits (Gherardi and Barbaresi 2007), its high plasticity, elevated reproductive capacity (Paglianti and Gherardi 2004) and tolerance to extreme environmental conditions (Gherardi 2006). The same characteristics, however, make it a highly invasive species because of its elevated ability to disperse (Barbaresi et al. 2004a). It is also able to survive for long periods in still and deoxygenated waters or even out of water (Gherardi et al. 2000) and in brackish water (Scalici et al. 2009c). In addition, its intense burrowing inflicts structural damages to the banks of rivers and lakes (Barbaresi et al. 2004b) and causes water bioturbation leading to a reduction in primary productivity (Gherardi 2007). Due to its voracious feeding habit and high density, *P. clarkii* is today recognized to be a cause of biodiversity loss in the invaded waterbodies. It causes the local extinction of various species of molluscs, fish, amphibians, and hydrophytes (Gherardi et al. 2001; Renai and Gherardi 2004; Gherardi and Acquistapace 2007). Since it bioaccumulates heavy metals (Gherardi et al. 2002a) and toxins from microalgae (Tricarico et al. 2008), it can be dangerous for the human consumer. *P. clarkii* outcompetes ICS, and in particular *A. pallipes,* being dominant in aggressive interactions (Gherardi and Cioni 2004) and transmitting to it *A. astaci* (Diéguez-Uribeondo and Söderhäl 1993). The Spiny-cheek crayfish *Orconectes limosus* was first recorded in the wild in 1991, in Iseo Lake (Delmastro 1992; Gherardi et al. 1999b), and is now widespread in northern Italy, particularly in the Po River

Valley. In 1994, it was reported for the first time in the Veronese plain in Veneto (Confortini and Natali 1995) and has since then spread into the southern part of the Lake of Garda (I. Confortini, pers. comm.). It is now to be found across the Veneto Region, except for the Province of Belluno (P. Turin, pers. comm.), and in Lombardy (Fea et al. 2006). It is spreading through the Province of Trento and is now present in the Levico and Madrano lakes in the Valsugana valley where it threatens *A. pallipes* populations (B. Maiolini, pers. com.). In central Italy *O. limosus* is present with a few populations in Latium, particularly in some lakes of the Province of Rieti (Figure 6): Salto (Chiesa et al. 2006), Lungo and Ripasottile (Scalici et al. 2009a). In these lakes, it cohabits with *A. leptodactylus*, another NICS. *O. limosus* seems to have been introduced into Italy accidentally, probably in association with batches of fish imported from Poland where the species was first introduced in 1890.

The Turkish crayfish, *A. leptodactylus*, originating from the Ponto-Caspian region, has been found in the wild in three lakes in the Province of Rieti (Salto lake, Chiesa et al. 2006; Lungo and Ripasottile lakes, Scalici et al. 2009a), in the Province of Milan, in a sport fishing lake in the Province of Bologna, and in the Province of La Spezia (in the Vara River basin) (Gherardi et al. 1999b) (Figure 7). Its diffusion seems to have been limited by its high degree of susceptibility to *A. astaci* and to other parasites (the oomycete *Saprolegnia* sp. and the protozoa *Psorospermium haeckeli* and *Thelohania contejeani*).

The signal crayfish, *P. leniusculus*, seems to have been introduced from Austria in 1981 into the Province of Bolzano where it was first reported in a stream near Brunico (Machino 1997) (Figure 8). In 2002, a population was reported in the Lake of Brugneto in the Province of Genoa (Liguria), where it was probably introduced by fishermen (Capurro et al. 2007). This species has been monitored since 2005: if nothing is done to eradicate it, *P. leniusculus* is expected to reach the River Po (115 km away) in 7 years (Capurro et al. 2007).

Finally, *C. destructor* and *C. quadricarinatus* seem to be still confined to experimental farms in central and northern Italy, while the marbled crayfish *Procambarus* sp., a parthenogenetic species and consequently potentially highly evasive, can easily be purchased in Italy from aquarists even through the commerce through internet. However, a reproductive population of *C. destructor* has been recently recorded in the Natural Reserve of “Laghi di Ninfa” in the Province of Latina (Scalici et al. 2009b) and at least a specimen of the marbled crayfish has been signalled in Tuscany (Foiano della Chiana, Province of Arezzo) within an abundant population of *P. clarkii* (Nonnis Marzano et al. 2009).

Fig. 6. Distribution in Italy of the non-indigenous crayfish *Orconectes limosus*

Parasites

A. pallipes is subject to attacks from numerous parasites, such as bacteria (*Citrobacter freundii*, *Pseudomonas fluorescens*, *P. putida*), protozoans (*Psorospermium haeckeli*, *Thelohania contejeani*), oomycetes (*Aphanomyces astaci*, *Saprolegnia* spp.), mycetes (*Fusarium* sp.), and annelids (*Branchiobdella* spp.) (Quaglio et al. 2006). Apart from *A. astaci*, other parasites can damage their host in many ways: they often reduce immune defences and reproductive potential, and alter organ functionality.

A. astaci, the etiological agent for the "crayfish plague", appeared in Italy in 1859, probably introduced by infected crayfish accidentally present in fish batches imported from North America. The plague exterminated the *A. pallipes* populations in Lombardy (Alderman 1996) and rapidly spread throughout Europe, causing the extinction of countless populations of ICS. *A. astaci* causes 100% mortality in the affected populations (Diéguez-Uribeondo 2006) and is able to survive for 1-2 weeks at 14 °C and up to 2 months at 2 °C, even after the death of its host. In addition, the spores of this species can be transferred from one watercourse to another on fishing equipments, or by birds and fishes. As a consequence, the infection can affect ICS populations that are not in direct contact with the source of the spores (Diéguez-Uribeondo 2005). This highlights the danger posed by North American species in Italy, notwithstanding that they do not typically live in syntopy with ICS populations. No *A. astaci* infected populations are currently reported in Italy, although recent epizootics of some *A. pallipes* populations in Lombardy (in 2004, P.A. Nardi, pers. comm.) and in the Province of Isernia (in 2009, L. Sammarone, pers. comm.) may be due to the plague. A recent episode of mortality recorded in Molise (Trigno River near the village of Carovilli) was assigned to *A. astaci* infection as shown by PCR and DNA sequencing (Cammà et al. 2010).

Branchiobdellidae (Anellida), whose effects on the host are still under discussion, often occur in the branchial chambers and on the exoskeleton of ICS, as found in several populations in northern (Gelder et al. 1999; Oberkofler et al. 2002) and central Italy (Gherardi et al. 2002b). They may belong to several species: *A. pallipes* hosts *Branchiobdella italica*, *A. astacus* hosts *B. italica* and *B. hexodonta*, and *P. leniusculus* hosts the North American species *Xironogiton victoriensis* (Oberkofler et al. 2002).

Fig. 7. Distribution in Italy of the non-indigenous crayfish *Astacus leptodactylus*

Fig. 8. Distribution in Italy of the non-indigenous crayfish *Pacifastacus leniusculus*

Management measures

The two main and complementary objectives of crayfish management are (1) the conservation of ICS populations and their genetic diversity and (2) control or eradication of invasive populations of NICS. Over the past few years, various attempts have been made in Italy to protect ICS or to re-establish extinct populations. These actions, however, have been carried out for short periods (maximum 4 years), so that it is difficult to gauge their success. Despite this, a common procedure has been developed, which includes: (a) environment monitoring to identify suitable watercourses into which ICS can be repopulated or reintroduced; (b) setting up hatcheries able to produce juveniles to re-stock ICS; (c) selection of reproductive individuals by the use of genetic analysis; and (d) education and raising awareness among the public.

Some projects aimed at managing ICS have been cofunded by the European Union through the programme LIFE ("L'Instrument Financier pour l'Environement"). Most recent projects include:

1- "Conservation of *Austropotamobius pallipes* in two SICs in Lombardy" (LIFE00 NAT/IT/007159) coordinated by the Regional Park of Valle del Lambro between 2001 and 2004;

2- "*Austropotamobius pallipes*: conservation and management in the SCIs in central Italy" (LIFE03 NAT/IT/000137) coordinated by the Province of Chieti from 2003 to 2006;

3- "Requalifying biocoenosis in Valvestino and Corno della Marogna" (LIFE03 NAT/IT/000147) coordinated by ERSAF (Regional Body for Agricultural and Forestry Services) in Lombardy from 2004 to 2007.

However, the interest that the EU has shown towards the conservation of ICS in Italy is still limited if we compare the number of the LIFE projects with *A. pallipes* as target that have been funded since 1992 (only 6) with all the LIFE projects carried out in Italy (145, about 4%). In addition, interventions aimed at protecting *A. pallipes* have been carried out in 35 Sites of Community Interest (SCIs) only out of a total of 2503 Natura 2000 sites designated in Italy between 1992 and 2005 (about 1.4%) (Picchi et al. 2006).

For what concerns the actions aimed at the control/eradication of NICS, several interventions have been proposed but, mainly due to limited money allocated and thus to the short duration of each single project, up to now there have been only some results coming from experimental studies, mostly conducted in the laboratory. The methods that have been until now investigated include trapping (P. Acquistapace, pers. comm.), the use of biocides (Morolli et al. 2006), the use of sexual pheromones (Aquiloni and Gherardi 2010), and the use of indigenous predators (Aquiloni et al. 2010), but, so far, prospects of success remain limited. A recently investigated method which has produced promising results is the "Sterile Male Release Technique" (SMRT). This technique, widely used by applied entomology, is based on the release into the wild of sterile or partially fertile males which are, however, still able to compete with wild males for the access of a mate, thus interfering with the reproductive success of the latter. Recently, we have explored the possibility of obtaining sterile males through exposure to ionizing radiations (Aquiloni et al. 2009). The results show a reduction in fertility of, on average, 43%, which do not affect male competitiveness and sexual attraction (Aquiloni et al. 2009).

Conclusions

ICS conservation in Italy requires the development of actions focused on the management of the river basin as a whole to ensure the maintenance or the restoration of the pristine habitats and the mitigation of environmental stresses, including those produced by NICS. The reintroduction of crayfish can only start from a detailed knowledge first of the ecology of the areas where the intervention will take place and second of the biology of the populations that are the object of intervention. In particular, in view of the complex genetic structure of *A. pallipes* in Italy, any intervention must be preceded by the analysis of the evolutionary lineages present in the area of intervention. The release of individuals belonging to other evolutionary lineages, in fact, could lead, in the medium-long term, to the loss of the genetic identity of the population and, in the short term, to the failure of the intervention and, as a consequence, to the waste of public money.

Management must be carried out following guidelines based on the extensive knowledge of the crayfish biology and ecology acquired by the numerous research groups active today in Italy: only through a constant and constructive exchange between management and scientific research will we be able to detect problems and find solutions. Finally, particular attention should be paid to informing, educating, and raising awareness among non-specialists, since the success of any action may be ensured only by the continuous support and participation of the public at large.

Acknowledgements

We thank Silvia Bertocchi, Sara Brusconi, Giuseppe Mazza, and Massimo Morpurgo for having provided us information and suggestions.

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