Chapter six

Non-indigenous animal species naturalized in Iberian inland waters

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INTRODUCTION

Invasions by human-introduced non-indigenous species (NIS) are one of the main threats to biodiversity and a driving force of global change (Vitousek *et al*. 1997, Mack *et al*. 2000, Clavero and García-Berthou 2005). The Iberian Peninsula (IP) is a hotspot of biodiversity (Médail and Quézel 1999) and a knowledge of the invasive species inhabiting it is essential for conservation and environmental management. Naturalized vertebrates and plants in the IP have received considerable attention (see e.g. Vilà *et al*. 2001, Pleguezuelos 2002, Sobrino *et al*. 2002, Lloret *et al*. 2004, Alcaraz *et al*. 2005), but its invasive invertebrates are very poorly known. Although there are many records of some invertebrate invasive species, particularly crustaceans, there are very few available reviews of selected taxa of invertebrate invaders in the IP (e.g. Espadaler and Collingwood 2001). The aim of this chapter is to review the animal species naturalized in Iberian inland waters, including vertebrates and free-living and parasitic invertebrates. As usual, the taxonomy and biogeography of vertebrate species are much better known than for invertebrates, so our data for invertebrates should be regarded as a preliminary check-list. Similarly, the parasites of non-commercial aquatic species are poorly studied and the data in the IP mostly come from studies of the eel, *Anguilla anguilla* (Linnaeus), thus certainly underestimating the range of introduced parasites (Blanc 1997, 2001). We feel, however, that it is important to provide such a

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first check-list because many of the invertebrates involved are nowadays common in the IP and for many of them it is largely unknown even by biologists that they are not indigenous to the IP. Increasing the awareness on the introduced status and current distribution of these species is essential to reduce their spread and impact.

We compiled animal species cited (by March 2006) as currently naturalized in Iberian inland waters from the scientific literature and unpublished Spanish Ph.D. theses (http://teseo.mec.es/teseo/). We included species from estuaries and saline coastal lagoons but excluded purely marine taxa and terrestrial animal species not strictly linked to aquatic ecosystems. We list invertebrate and vertebrate species introduced by humans and currently naturalized, i.e. species that reproduce and sustain populations in the wild without human intervention (see e.g. Richardson *et al.* 2000, Pyšek *et al.* 2004). A few uncertain cases are listed in a separate table. The introduced origin of parasite invertebrates is particularly uncertain but we followed Blanc (1997, 2001), who has recently provided a comprehensive list of aquatic parasites introduced to Europe, together with their native distribution.

NATURALIZED ANIMALS IN IBERIAN INLAND WATERS

The invertebrate and vertebrate species naturalized in Iberian inland waters are listed in Tables 1 and 2, respectively. A few cases, for which it is not clear whether the species is indigenous to the IP or whether they have established, are listed in Table 3. We found 45 invertebrate and 28 vertebrate species certainly naturalized at present in Iberian inland waters.

Among the 45 invertebrates, 12 were parasites (mostly Platyhelminthes flatworms), mainly of freshwater fish and introduced to Europe from Asia with common carp (*Cyprinus carpio*), goldfish (*Carassius auratus*), or Japanese eel (*Anguilla japonica* Temminck and Schlegel) (see Blanc 1997, 2001); several of the parasites have now been recorded on fish species indigenous or endemic to the IP (see references in Table 1). The remaining 33 invertebrates were free-living species, mostly crustaceans (18 species) or molluscs (6 species). Most of the 28 vertebrates were fish (23 species), and there was no aquatic bird naturalized and only one amphibian and one reptilian species.

The continent of origin was significantly different between vertebrates and invertebrates (independence test; $\chi^2 = 37.1$, df $= 7$, $P < 0.0005$) because most naturalized vertebrates were native to the rest of Europe (43% of the 28 species) or North America (29%), origins that in turn were rare among invertebrates (0 and 12%, respectively), which predominantly came from Asia (38%). There was no significant variation in origin between free-living and parasitic invertebrates ($\chi^2 = 6.5$, df $= 5$, $P = 0.26$) or between crustaceans and molluscs ($\chi^2 = 3.8$, df $= 5$, $P = 0.59$).

Table 1 Non-indigenous invertebrate species naturalized in inland waters of the Iberian Peninsula (IP). When a species is probably an old introduction, but the introduction date is largely unknown, a question mark is given as the first record date. The habitats for non-parasite species are coded as: 1, streams and rivers (excluding estuaries); 2, lakes and reservoirs; 3, ponds and pools; 4, rice fields; and 5, estuarine or saline waters.

GROUP Species	Indigenous distribution	First record in the IP	Habitat/ Parasite	References for the IP	Other references
CNIDARIA					
Cordylophora caspia (Pallas)	Ponto–Caspian	2001	1,2,5	Escot *et al.* 2003, Solà 2004	Schuchert 2004
Craspedacusta sowerbyi Lankester	Asia	1968	1,2	Margalef 1974, Ferreira 1985	
Haliplanella lineata (Verrill)	Pacific coast	1996	5	Cuesta *et al.* 1996	Gollasch and Riemann-Zürneck 1996
PLATYHELMINTHES TURBELLARIA					
Dugesia tigrina (Girard)	North America	?	1,2	Baguñà *et al.* 1980	Young and Reynoldson 1999
PLATYHELMINTHES MONOGENEA					
Dactylogyrus anchoratus (Dujardin)	Asia	?	parasite	Sánchez Suárez 2002	Blanc 1997, 2001
Gyrodactylus cyprini Diarova	Asia	?	parasite	Lacasa Millán 1992	Blanc 1997, 2001
Gyrodactylus katharineri Malmberg	Asia	?	parasite	Gutiérrez Galindo and Lacasa Millán 1999	Blanc 1997, 2001
Gyrodactylus salaris Malmberg	Baltic	?	parasite	Bakke *et al.* 2002	Blanc 1997, 2001
Pseudodactylogyrus anguillae (Yin and Sproston)	Asia and Australia	?	parasite	San Martín Outeiral 2004, Gómez-Juaristi and Salvador 2006	Blanc 1997, 2001
Pseudodactylogyrus bini (Kikuchi)	Asia and Australia	?	parasite	Orts Muñoz 1993, Gómez-Juaristi and Salvador 2006	Blanc 1997, 2001

Table 1 Continued.

GROUP Species	Indigenous distribution	First record in the IP	Habitat/ Parasite	References for the IP	Other references
PLATYHELMINTHES TREMATODA					
Phyllodistomum folium (Olfers, 1816)	Ponto–Caspian?	2004	parasite	Peribáñez *et al.* 2006	
PLATYHELMINTHES CESTODA					
Bothriocephalus acheilognathi Yamaguti [= *Bothriocephalus opsarichthydis* (Yeh)]	Asia	?	parasite	Lacasa Millán 1992	Blanc 1997, 2001
NEMATODA					
Anguillicola crassus Kuwahara, Niimi and Itagaki	Asia	?	parasite	Gallastegi *et al.* 2002, Maillo *et al.* 2005	Blanc 1997, 2001
MOLLUSCA GASTROPODA					
Gyraulus chinensis (Dunker)	Asia	1979	2,4	Brown *et al.* 1998	Anderson 2005
Physella acuta (Draparnaud)	North America	1845	1,2,4	Vidal-Abarca and Suárez 1985	Anderson 2003
Potamopyrgus antipodarum (Gray) [= *P. jenkinsi* (Smith)]	New Zealand	1951	1,5	Vidal-Abarca and Suárez 1985	Paavola *et al.* 2005
MOLLUSCA BIVALVIA					
Corbicula fluminea (Müller)	Asia, Africa, and Australia	1981	1,3,5	Vidal-Abarca and Suárez 1985, Escot *et al.* 2003	McMahon 2000
Dreissena polymorpha (Pallas)	Ponto–Caspian	1880	1,2	Vidal-Abarca and Suárez 1985, Altaba *et al.* 2001	
Mytilopsis leucophaeta (Conrad)	Gulf of Mexico	1993	1,2,5	Escot *et al.* 2003	Laine *et al.* 2006
ANNELIDA					
Branchiura sowerbyi Beddard	Asia	1970s	1,2,5	Prat 1980	Brinkhurst and Jamieson 1971
Xironogiton victoriensis Gelder and Hall	North America	1996	parasite	Gelder 1999	Ohtaka *et al.* 2005

Ficopomatus enigmaticus (Fauvel) (= *Mercierella enigmatica* Fauvel)	Indian Ocean	1924	5	Rioja 1924, Fischer-Piette 1951	
CRUSTACEA BRANCHIOPODA					
Artemia franciscana (Kellog)	North, Central, and South America	1980s	5	Amat *et al*. 2005	
Wlassicsia pannonica Daday	Eurasia	1990s	4	Martinoy *et al*. 2006	Leoni *et al*. 1999
CRUSTACEA OSTRACODA					
Dolerocypris sinensis Sars	Asia	1986	3,4	Forés *et al*. 1986, Baltanás *et al*. 1996	Rossi *et al*. 2003
Ilyodromus viridulus (Brady)	Australia and New Zealand	1996	4	Baltanás *et al*. 1996	Rossi *et al*. 2003
Cypris sp. (= *Cypris subglobosa* Sowerby)	America, Africa, and Asia?	1986	2,4	Forés *et al*. 1986, Baltanás *et al*. 1996	Whatley *et al*. 2003
Isocypris beauchampi (Paris)	Africa	1976	2,4	Armengol 1976, Baltanás *et al*. 1996	Rossi *et al*. 2003
Stenocypris major (Baird)	Asia	1986	3,4	Forés *et al*. 1986, Baltanás *et al*. 1996	Rossi *et al*. 2003
Strandesia vavrai (Müller)	Africa	1983	4	Paulo and Moutinho 1983, Baltanás *et al*. 1996	
Strandesia vinciguerrae (Masi)	Africa	1986	4	Forés *et al*. 1986, Baltanás *et al*. 1996	
Tanycypris sp.	Asia	1988	3,4	Forés 1988, Baltanás *et al*. 1996	Rossi *et al*. 2003
CRUSTACEA COPEPODA					
Acartia tonsa Dana	North and South America	1990s	5	Sobral 1985, Frisch *et al*. 2005	
Lernaea cyprinacea Linnaeus	Asia		parasite	Moreno *et al*. 1986, Gutiérrez-Galindo and Lacasa-Millán 2005	Blanc 1997, 2001

Table 1 Continued.

GROUP Species	Indigenous distribution	First record in the IP	Habitat/ Parasite	References for the IP	Other references
CRUSTACEA BRANCHIURA					
Argulus japonicus Thiele	Asia	1921	parasite	http://www.fauna-iberica.mncn.csic.es/	Blanc 1997, 2001
CRUSTACEA MYSIDACEA					
Synidotea laticauda Benedict	North Pacific and South Atlantic coasts	1996	5	Cuesta *et al*. 1996	
CRUSTACEA DECAPODA					
Cherax destructor Clark	Australia	1983	5	Gutiérrez-Yurrita *et al*. 1999	
Eriocheir sinensis (Milne Edwards)	Asia	?	5	Cuesta *et al*. 2006	
Pacifastacus leniusculus (Dana)	North America	1974	1	Habsburgo-Lorena 1978	
Palaemon macrodactylus Rathbun	Asia	1999	5	Cuesta *et al*. 2004	
Procambarus clarkii (Girard)	North America	1974	1,2,4,5	Habsburgo-Lorena 1978	
Rhithropanopeus harrisii (Gould)	North-west Atlantic	1991	5	Cuesta *et al*. 1991	
INSECTA					
Aedes albopictus (Skuse)	Asia	2004	3	Aranda *et al*. 2006	Eritja *et al*. 2005
Stenopelmus rufinasus Gyllenhal	Asia	2003	1,2,4,5	Dana and Viva 2006	
Trichocorixa verticalis (Fieber)	Atlantic coast of America	1997	3,5	Günther 2004, Sala and Boix 2005	Hutchinson 1931

Table 2 Non-indigenous vertebrate species naturalized in inland waters of the Iberian Peninsula (IP). The habitats are coded as: 1, rivers (excluding estuaries); 2, lakes and reservoirs; 3, rice fields; and 4, estuarine or saline waters.

GROUP Species	Indigenous distribution	First record in the IP	Habitat	References for the IP
PISCES				
Abramis bjoerkna (Linnaeus)	Europe	1995	1,2	Doadrio 2002
Abramis brama (Linnaeus)	Europe	2004	2	Benejam *et al.* 2005
Alburnus alburnus (Linnaeus)	Europe	1992	1,2	Doadrio 2002
Ameiurus melas (Rafinesque)	North America	1910	1,2	Doadrio 2002
Carassius auratus Linnaeus	Asia	17th century	1,2,3	Doadrio 2002
Cobitis bilineata Canestrini	Europe	2002	1	Doadrio 2002
Cyprinus carpio Linnaeus	Eurasia	17th century	1,2	Doadrio 2002
Esox lucius Linnaeus	Europe	1949	1,2	Doadrio 2002
Fundulus heteroclitus (Linnaeus)	North America	1970	4	Doadrio 2002
Gambusia holbrooki (Girard)	North America	1920	1,2,3,4	Doadrio 2002
Herichthys facetum (Jenyns)	South America	1985	1,2	Doadrio 2002
Hucho hucho (Linnaeus)	Europe	1970	1	Doadrio 2002
Lepomis gibbosus (Linnaeus)	North America	1910	1,2	Doadrio 2002
Micropterus salmoides (Lacepède)	North America	1955	1,2	Doadrio 2002
Oncorhynchus mykiss (Walbaum)	North America	19th century	1,2	Doadrio 2002
Perca fluviatilis Linnaeus	Europe	1975	1,2	Doadrio 2002
Poecilia reticulata Peters	South America	2000	1,4	Doadrio 2002
Pseudorasbora parva (Temminck and Schlegel)	Asia	2001	1	Caiola and Sostoa 2002
Rutilus rutilus (Linnaeus)	Europe	1910	1,2	Doadrio 2002
Salvelinus fontinalis (Mitchill)	North America	19th century	1,2	Doadrio 2002
Sander lucioperca (Linnaeus)	Europe	1975	1,2	Doadrio 2002
Scardinius erythrophthalmus (Linnaeus)	Europe	1910	1,2	Doadrio 2002
Silurus glanis L.	Europe	1974	1,2	Doadrio 2002
AMPHIBIA ANURA				
Discoglossus pictus Otth	Africa	1900	1	Pleguezuelos 2002
REPTILIA CHELONIA				
Trachemys scripta (Schoepf)	America	1985	1,2,3,4	Pleguezuelos 2002
MAMMALIA				
Mustela vison Schreber	North America	1978	1,2,3,4	Ruiz-Olmo *et al.* 1997, Palomo and Gisbert 2002
Myocastor coypus Molina	South America	1970	1	Palomo and Gisbert 2002
Ondatra zibethicus (Linnaeus)	North America	2002	1	Elosegi 2004

Table 3 Animal species possibly introduced to inland waters of the Iberian Peninsula (IP), but with uncertain status. Some species are cryptogenic (Carlton 1996), i.e. it is very difficult to know whether they are indigenous or introduced; the other species have been reported in the wild but it is uncertain whether they have established permanent populations (naturalized).

GROUP Species	Possibly indigenous to the IP	Uncertain establishment	References
MOLLUSCA GASTROPODA			
Ferrissia wautieri (Mirolli) [= *F. clessiniana* (Jickeli)]	yes	no	Anderson 2005
CRUSTACEA DECAPODA			
Austropotamobius italicus (Faxon) / *Austropotamobius pallipes* (Lereboullet)	yes	no	Grandjean *et al.* 2001
PISCES			
Acipenser baeri Brandt	no	yes	Elvira and Almodóvar 2001
Aphanius fasciatus (Valenciennes)	no	yes	Doadrio 2002
Ctenopharyngodon idella (Valenciennes)	no	yes	J. M. Queral 2005, personal communication
Ictalurus punctatus (Rafinesque)	no	yes	Doadrio 2002
Oncorhynchus kisutch (Walbaum)	no	yes	Doadrio 2002
Tinca tinca (Linnaeus)	yes	no	Doadrio 2002
AMPHIBIA			
Bufo mauritanicus Schlegel	no	yes	Pleguezuelos 2002
Rana catesbeiana Shaw	no	yes	Pleguezuelos 2002
Rana ridibunda, Rana kl. *esculenta, Rana lessonae*	no	yes	Arano *et al.* 1995, García-París *et al.* 2004
REPTILIA CHELONIA			
Pelodiscus sinensis (Wiegmann)	no	yes	Pleguezuelos 2002
AVES			
Aix galericulata (Linnaeus)	no	yes	GAE 2006
Anser erythropus (Linnaeus)	no	yes	GAE 2006
Branta canadensis (Linnaeus)	no	yes	GAE 2006
Oxyura jamaicensis (Gmelin)	no	yes	GAE 2006
MAMMALIA			
Castor fiber Linnaeus	yes	yes	Ceña *et al.* 2004

The main habitat also differed between vertebrates and invertebrates (independence test; $\chi^2 = 22.8$, df $= 4$, $P < 0.0005$), because the former were mostly present in streams and rivers (26 of the 28 species were present in streams and rivers) or lakes and reservoirs, whereas several invertebrates were only present in estuaries/saline waters (e.g. several decapod crustaceans introduced into the Guadalquivir River through ballast water) or in rice fields (namely ostracods).

The mechanism of introduction is obviously also different for invertebrates and vertebrates, because most of the former are accidental introductions (e.g. Asian ostracods in rice fields, ballast water, etc.), whereas most fish species have been introduced intentionally (nowadays illegally). Therefore, naturalized vertebrates and invertebrates showed opposite patterns, with the former (mostly fish) intentionally introduced from the rest of Europe or North America to Iberian streams and reservoirs and most invertebrates originating from Asia and accidentally introduced to estuaries or rice fields.

UNCERTAIN CASES

We found four species for which it is uncertain whether the species is indigenous to the IP and 13 species that they may not have established (Table 3). An interesting case illustrating both the lack of knowledge on invasive species and the power of modern genetic techniques is the crayfish of the *Austropotamobius pallipes* species complex. Until the 1980s the populations in the IP were generally regarded as an endemic species or subspecies in strong decline due to the introduction of the oomycete *Aphanomyces astaci* Schikora with North American crayfish (Martínez *et al*. 2003). Grandjean *et al*. (2000) showed that two species (*A. pallipes* and *Austropotamobius italicus*) could be distinguished within the species complex and that Spanish populations were very close to some Italian populations, so they might be of anthropogenic origin, as already proposed by Albrecht (1983), and should be regarded as *A. italicus*. Grandjean *et al*. (2001) demonstrated a drastic bottleneck in Spanish populations but discussed several potential mechanisms alternative to the hypothesis of introduction by humans. With further genetic analyses, Trontelj *et al*. (2005) supported the anthropogenic origin for the Spanish populations but did not find unequivocal separation between *A. pallipes* and *A. italicus* (but see also Schulz and Grandjean 2005).

These genetic techniques might also prove useful for tench [*Tinca tinca* (Linnaeus)] in the IP. Tench is indigenous to many parts of Europe but considered introduced into Italy (Bianco 1998) and Portugal (Almaça 1995). This latter country shares its largest river basins (Duero, Tajo, and Guadiana rivers) with Spain. There are doubts about its indigenous status in Spain (Doadrio 2002). In fact, Gómez Caruana and Díaz Luna (1991) considered it introduced into the IP around the 17th century. There are records of tench stocking by monks in Spanish and Portuguese ponds several centuries ago (Almaça 1995, García-Berthou and Moreno-Amich 2000). As far as we know, no phylogeographic study on tench has been performed, in contrast to many other European cyprinids, although they could be most helpful in clarifying its native distribution.

A similar, more solved example of ''cryptogenic'' species (see Carlton 1996) is the case of the freshwater snail *Physella acuta* (Draparnaud). This species was first described from Europe (Drapanaud, 1805), namely from the River

Garonne, near Bordeaux (France). This species is widely distributed in the IP and the rest of western Europe (Vidal-Abarca and Suárez 1985) and inhabits all types of fresh waters. It has been generally regarded as indigenous to continental Europe (Haas 1929, Germain 1930, Macan and Cooper 1977, Girod *et al*. 1980, Vidal-Abarca and Suárez 1985) and its presence in North America was not reported until the 1990s (Wu *et al*. 1997). Nowadays, three types of evidence indicate, however, that *P. acuta* is indigenous to North America and not to Europe: (i) the lack of records of *Physella* shells from European sediments older than the 18th century (Lozek 1964); (ii) recent studies using internal morphology comparisons (Anderson 2003) and reproductive isolation experiments (Dillon *et al*. 2002) showing that at least one *Physella* species from North America [*Physella heterostropha* (Say)] is actually *P. acuta*; and (iii) some historical data of the cotton trade between France and the United States in the 18th century that could explain the arrival of this species to the River Garonne, where it was first observed (Anderson 2003).

The case of *P. acuta* illustrates the importance of historical data and the fossil record as tools for the identification of old introductions by man. Fossil records have been very helpful to establish the introduced nature of ostracods and suggest that dispersal by man of many other invertebrates is very old and has been generally neglected (McKenzie and Moroni 1986, Rossi *et al*. 2003).

The other group of species in Table 3 are species that have been reported in the wild but it is uncertain whether they have established. There are several other NIS that have been recorded in the wild (see e.g. Elvira and Almodóvar 2001, Pleguezuelos 2002) but have certainly not established permanent populations.

ECOLOGICAL IMPACT

The ecological impact of most of these NIS is largely unknown with a few exceptions. The red swamp crayfish, *Procambarus clarkii*, has altered the functioning and structure of many aquatic ecosystems in the IP reducing macrophytes and associated species, among other impacts (Geiger *et al*. 2005, Rodríguez *et al*. 2005, Chapter 28). The eastern mosquitofish (*Gambusia holbrooki*) has been experimentally demonstrated to affect endemic cyprinodontiform fishes [*Aphanius iberus* (Valenciennes) and *Valencia hispanica* (Valenciennes)] by resource and interference competition (Rincón *et al*. 2002). The zebra mussel (*Dreissena polymorpha*) is one of the best known invasive species and, although it is a very old introduction into Portugal, only recently has it been introduced to Spain through the Ebro River, where it is widespread nowadays and might affect the endangered giant pearl mussel, *Margaritifera auricularia* Spengler (Altaba *et al*. 2001). The zebra mussel is still not widespread in the IP, but it will probably be fostered by the illegal, poorly controlled introduction and translocations of fish that are still very frequent.

The polychaete *Ficopomatus enigmaticus* (Fauvel) is very abundant in some Spanish coastal lagoons and probably profoundly affects its ecosystem functioning because it builds large reef-like aggregates (Schwindt and Iribarne 1998). Many piscivorous fish have been introduced into the IP and some unique ecosystems such as Lake Banyoles have been profoundly altered and are nowadays completely dominated by NIS (García-Berthou and Moreno-Amich 2000).

The distribution, abundance, and impact of introduced parasites in the IP is largely unknown but some species such as *Lernaea cyprinacea* are widespread (Moreno *et al.* 1986, Gutiérrez-Galindo and Lacasa-Millán 2005) and several of them have now been recorded on endemic fish species (see references in Table 1). The swimbladder nematode *Anguillicola crassus*, which was transferred from its indigenous host (the Japanese eel, *A. japonica*) to the European eel (*A. anguilla*), can severely impair swimbladder function (and thus possibly spawning migration) and has caused mortalities in both farmed and wild populations in the presence of other stressors (Kirk 2003). Similarly to the case of crayfish plague, Gozlan *et al.* (2005) have recently shown that the topmouth gudgeon, *Pseudorasbora parva*, an Asiatic cyprinid highly invasive in Europe and recently introduced to the IP, carries a pathogen that strongly affects indigenous cyprinids.

Given the enormous impact of the few well-investigated invasive species, the considerable number of introduced species, and the presence in the IP of many endemic species of plants (Médail and Quézel 1999), freshwater fish (Doadrio 2002), and amphibians (Pleguezuelos *et al.* 2002), the overall potential impact of these naturalized species is enormous and should be urgently investigated. The room for management and educational improvement by public administrations to prevent further introductions and translocations and to reduce the spread of invasive species is even larger. We hope this paper will contribute to the improved understanding and control of invasive species in European waters.

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REFERENCES

Albrecht, H. 1983. Besiedlungsgeschichte und ursprünglich holozäne Verbreitung der europäischen Flußkrebse (Decapoda: Astacidae). Spixiana **6**, 61–77.

Alcaraz, C., A. Vila-Gispert, and E. García-Berthou. 2005. Profiling invasive fish species: the importance of phylogeny and human use. Diversity and Distributions **11**, 289–298.

Almaça, C. 1995. Fish species and varieties introduced into Portuguese inland waters. Publicações avulsas do Museu Bocage, Lisboa, Portugal.

Altaba, C. R., P. J. Jiménez, and M. A. López. 2001. El temido mejillón cebra empieza a invadir los ríos españoles desde el curso bajo del río Ebro. Quercus **118**, 50–51.

Amat, F., F. Hontoria, O. Ruiz, A. J. Green, M. I. Sánchez, J. Figuerola, and F. Hortas. 2005. The American brine shrimp as an exotic invasive species in the western Mediterranean. Biological Invasions **7**, 37–47.

Anderson, R. 2003. *Physella* (*Costatella*) *acuta* Draparnaud in Britain and Ireland – its taxonomy, origins and relationships to other introduced Physidae. Journal of Conchology **38**, 7–21.

Anderson, R. 2005. An annotated list of the non-marine mollusca of Britain and Ireland. Journal of Conchology **38**, 607–638.

Aranda, C., R. Eritja, and D. Roiz. 2006. First record and establishment of the mosquito *Aedes albopictus* in Spain. Medical and Veterinary Entomology **20**, 150–152.

Arano, B., G. A. Llorente, M. García-París, and P. Herrero. 1995. Species translocation menaces Iberian waterfrogs. Conservation Biology **9**, 196–198.

Armengol, J. 1976. Crustáceos acuáticos del Coto de Doñana. Oecologia aquatica **2**, 93–97.

Baguñà, J., E. Saló, and R. Romero. 1980. Les planàries d'aigües dolces a Catalunya i les Illes Balears. I. Clau sistemàtica i distribució geogràfica.Butlletí de la Institució Catalana d'Història Natural **45**, 15–30.

Bakke, T. A., P. D. Harris, and J. Cable. 2002. Host specificity dynamics: observations on gyrodactylid monogeneans. International Journal for Parasitology **32**, 281–308.

Baltanás, A., B. Beroiz, and A. López. 1996. Lista faunística y bibliográfica de los ostrácodos no-marinos (Crustacea, Ostracoda) de la Península Ibérica, Islas Baleares e Islas Canarias. Asociación Española de Limnología, Madrid, Spain, 71 pp.

Benejam, L., J. Carol, C. Alcaraz, and E. García-Berthou. 2005. First record of the common bream (*Abramis brama*) introduced to the Iberian Peninsula. Limnetica **24**, 273–274.

Bianco, P. G. 1998. Freshwater fish transfers in Italy: history, local modification of fish composition, and a prediction on the future of native populations. Pages 165–197 in I. J. Cowx, editor. Stocking and introductions of fishes. Fishing News Books, Blackwell, Oxford, UK.

Blanc, G. 1997. L'introduction des agents pathogènes dans les écosystèmes aquatiques: aspects théoriques et réalités. Bulletin Français de la Pêche et de la Pisciculture **344/345**, 489–513.

Blanc, G. 2001. Introduction of pathogens in European aquatic ecosystems: attempt of evaluation and realities. Pages 37–56 in A. Uriarte and B. Basurco, editors. Environmental impact assessment of Mediterranean aquaculture farms. CIHEAM-IAMZ, Zaragoza, Spain.

Brinkhurst, R. O. and B. G. M. Jamieson. 1971. Aquatic Oligochaeta of the world. Oliver and Boyd, Edinburgh, UK, 860 pp.

Brown, D. S., M. A. A. Gracio, and C. Meier-Brook C. 1998. The Asian freshwater snail *Gyraulus chinensis* (Dunker, 1848) (Planorbidae) in West Africa and Europe. Journal of African Zoology **112**, 203–213.

Caiola, N. and A. de Sostoa. 2002. First record of the Asiatic cyprinid *Pseudorasbora parva* in the Iberian Peninsula. Journal of Fish Biology **61**, 1058–1060.

Carlton, J. T. 1996. Biological invasions and cryptogenic species. Ecology **77**, 1653–1655.

Ceña, J. C., I. Alfaro, A. Ceña, U. Itoitz, G. Berasategui, and I. Bidegain. 2004. Castor europeo en Navarra y La Rioja. Galemys **16**, 91–98.

Clavero, M. and E. García-Berthou. 2005. Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution **20**, 110.

Cuesta, J. A., J. E. García-Raso, and J. I. González-Gordillo. 1991. Primera cita de *Rhithropanopeus harrisii* (Gould, 1814) (Crustacea, Decapoda, Brachyura, Xanthidae) en la Península Ibérica. Boletín del Instituto Español de Oceanografía **7**, 149–153.

Cuesta, J. A., E. González-Ortegón, P. Drake, and A. Rodríguez. 2004. First record of *Palaemon macrodactylus* Rathbun, 1902 (Decapoda, Caridea, Palaemonidae) from European waters. Crustaceana **77**, 377–380.

Cuesta, J. A., E. González-Ortegón, A. Rodríguez, F. Baldó, C. Vilas, and P. Drake. 2006. The decapod crustacean community of the Guadalquivir Estuary (SW Spain): seasonal and inter-year changes in community structure. Hydrobiologia **557**, 85–95.

Cuesta, J. A., L. Serrano, M. R. Bravo, and J. Toja. 1996. Four new crustaceans in the Guadalquivir river estuary (SW Spain), including an introduced species. Limnetica **12**, 41–45.

Dana, E. D. and S. Viva. 2006. *Stenopelmus rufinasus* Gyllenhal 1836 (Coleoptera: Erirhinidae) naturalized in Spain. The Coleopterists Bulletin **60**, 41–42.

Dillon, R. T., A. R. Wethington, J. M. Rhett, and T. P. Smith. 2002. Populations of the European freshwater pulmonate *Physa acuta* are not reproductively isolated from American *Physa heterostropha* or *Physa integra*. Invertebrate Biology **121**, 226–234.

Doadrio, I., editor. 2002. Atlas y libro rojo de los peces continentales de España. Ministerio de Medio Ambiente, Madrid, Spain, 347 pp.

Draparnaud, J. P. R. 1805. Histoire naturelle des mollusques terrestres et fluviatiles de la France. Paris, 164 pp.

Elosegi, M. M. 2004. Observación de una rata almizclera, *Ondatra zibethicus* (Linnaeus, 1766) en Ezkurra (Navarra). Galemys **16**, 63–64.

Elvira, B. and A. Almodóvar. 2001. Freshwater fish introductions in Spain: facts and figures at the beginning of the 21st century. Journal of Fish Biology **59**, 323–331.

Eritja, R., R. Escosa, J. Lucientes, E. Marquès, R. Molina, D. Roiz, and S. Ruiz. 2005. Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. Biological Invasions **7**, 87–97.

Escot, C., A. Basanta, F. Cobo, and M. A. Gonzalez. 2003. Sobre la presencia de *Mytilopsis leucophaeata* (Conrad, 1831) (Bivalvia, Dreissenacea, Dreissenidae) en el río Guadalquivir (sur de la Peninsula Ibérica). Graellsia **59**, 91–94.

Espadaler, X. and C. A. Collingwood. 2001. Transferred ants in the Iberian Peninsula (Hymenoptera, Formicidae). Nouvelle Revue d'Entomologie **17**, 257–263.

Ferreira, M. T. 1985. Occurrence of the freshwater medusa *Craspedacusta sowerbyi* Lank. 1880 (Hidrozoa: Olindiidae) in Portuguese reservoirs. Boletim da Sociedade Portuguesa de Ciências Naturais **22**, 41–46.

Fischer-Piette, E. 1951. Stations de l'annélide tubicole *Mercierella enigmatica* Fauvel sur la côte Nord d'Espagne. Bulletin du Laboratorie Maritime de Dinard **34**, 7–9.

Forés, E. 1988. Els ostràcodes dels arrossars del Delta de l'Ebre: sistemàtica, ecologia i distribució geogràfica. Butlletí de la Institució Catalana d'Història Natural **45**, 15–30.

Forés, E., M. Menéndez, and F. A. Comín. 1986. Contribución al conocimiento de Crustáceos y Rotíferos del Delta del Ebro. Miscellània Zoològica **10**, 105–111.

Frisch, D., H. Rodríguez-Pérez, and A. J. Green. 2005. Invasion of artificial ponds in Doñana Natural Park, southwest Spain, by an exotic estuarine copepod. Aquatic Conservation-Marine and Freshwater Ecosystems **15**, 483–492.

GAE (Grupo de Aves Exóticas de SEO/BirdLife). 2006. Aves invasoras en España: lista de especies en las categorías C y E. http://www.seo.org/programa_ficha.cfm?idPrograma=17.

Gallastegi, I., A. Rallo, and M. F. Mulcahy. 2002. A report of *Anguillicola crassus* from Spain. Bulletin of the European Association of Fish Pathologists **22**, 283–284.

García-Berthou, E. and R. Moreno-Amich. 2000. Introduction of exotic fish into a Mediterranean lake over a 90-year period. Archiv für Hydrobiologie **149**, 271–284.

García-París, M., A. Montori, and P. Herrero. 2004. Amphibia, Lissamphibia. Pages 640 in M. A. Ramos *et al.*, editors. Fauna Ibérica, 24. Museo Nacional de Ciencias Naturales, Madrid, Spain.

Gelder, S. R. 1999. Zoogeography of branchiobdellidans (Annelida) and temnocephalidans (Platyhelminthes) ectosymbiotic on freshwater crustaceans, and their reactions to one another in vitro. Hydrobiologia **406**, 21–31.

Geiger, W., P. Alcorlo, A. Baltanás, and C. Montes. 2005. Impact of an introduced Crustacean on the trophic webs of Mediterranean wetlands. Biological Invasions **7**, 49–73.

Germain, L. 1930. Mollusques terrestres et fluviatiles. In Faune de France **21/22**. Lechevalier, Paris, France, 897 pp.

Girod, A., I. Bianchi, and M. Mariani. 1980. Gasteropodi, 1 (Gastropoda: Pulmonata, Prosobranchia: Neritidae, Viviparidae, Bithyniidae, Valvatidae). In S. Ruffo, editor. Guide per il riconoscimento delle specie animali delle acque interne italiane, 7. Consiglio Nazionale delle Richerche, Verona, Italy, 86 pp.

Gollasch, S. and K. Riemann-Zürneck. 1996. Transoceanic dispersal of benthic macrofauna: *Haliplanella lineata* (Verrill, 1898) (Anthozoa, Actinaria) found on a ship's hull in a ship yard dock in Hamburg Harbour, Germany. Helgoländer Meeresuntersuchungen **50**, 253–258.

Gómez Caruana, F. and J. L. Díaz Luna. 1991. Guía de peces continentales de la Península Ibérica . Penthalon, Madrid, Spain.

Gómez-Juaristi, M. and A. Salvador. 2006. Anguila – *Anguilla anguilla*. In L. M. Carrascal and A. Salvador, editors. Enciclopedia virtual de los vertebrados españoles. Museo Nacional de Ciencias Naturales, Madrid, Spain. http://www.vertebradosibericos.org/

Gozlan, R. E., S. St Hilaire, S. W. Feist, P. Martin, and M. L. Kent. 2005. Disease threat to European fish. Nature (London) **435**, 1046.

Grandjean, F., D. J. Harris, C. Souty-Grosset, and K. A. Crandall. 2000. Systematics of the European endangered crayfish species, *Austropotamobius pallipes* (Decapoda: Astacidae). Journal of Crustacean Biology **20**, 522–529.

Grandjean, F., N. Gouin, C. Souty-Grosset, and J. Diéguez-Uribeondo. 2001. Drastic bottlenecks in the endangered crayfish species *Austropotamobius pallipes* in Spain and implications for its colonization history. Heredity **86**, 431–438.

Günther, H. 2004. *Trichocorixa verticalis verticalis* (Fieber), eine nearktische Ruderwanze in Europa. Mitteilungen des Internationalen Entomologischen Verereins **29**, 45–49.
Gutiérrez-Galindo, J. F. and M. I. Lacasa-Millán. 1999. Monogenea parásitos de Cyprinidae en el río Llobregat (NE de España) (*Barbus haasi* Petersen, 1925). Revista AquaTIC **7**. http://www.revistaaquatic.com/aquatic/art.asp?t=h&c=69
Gutiérrez-Galindo, J. F. and M. I. Lacasa-Millán. 2005. Population dynamics of *Lernaea cyprinacea* (Crustacea: Copepoda) on four cyprinid species. Disease of Aquatic Organisms **67**, 111–114.
Gutiérrez-Yurrita, P. J., J. M. Martinez, M. Ilheu, M. A. Bravo-Utrera, J. M. Bernardo, and C. Montes. 1999. The status of crayfish populations in Spain and Portugal. Pages 161–192 in F. Gherardi and D. Holdich, editors. Crayfish in Europe as alien species: How to make the best of a bad situation? A. A. Balkema, Rotterdam, The Netherlands.
Haas, F. 1929. Fauna malacológica terrestre y de agua dulce de Cataluña. Treballs del Museu de Ciències Naturals **13**, 1–491.
Habsburgo-Lorena, A. S. 1978. Present situation of exotic species of crayfish introduced into Spanish continental waters. Freshwater Crayfish **4**, 175–184.
Hutchinson, G. E. 1931. On the occurrence of *Trichocorixa* Kirkaldy (Corixidae, Hemiptera-Heteroptera) in salt water and its zoo-geographical significance. The American Naturalist **65**, 573–574.
Kirk, R. S. 2003. The impact of *Anguillicola crassus* on European eels. Fisheries Management and Ecology **10**, 385–394.
Lacasa Millán, M. I. 1992. Introducción a la parasitofauna de peces ciprínidos de la cuenca media del río Llobregat. Ph.D. dissertation, Universidad Autònoma de Bacelona, Barcelona, Spain.
Laine, A. O., J. Mattila, and A. Lehikoinen. 2006. First record of the brackish water dreissenid bivalve *Mytilopsis leucophaeata* in the northern Baltic Sea. Aquatic Invasions **1**, 38–41.
Leoni, B., M. Cotta-Ramusino, and F. G. Margaritora. 1999. Seasonal succession of Cladocerans in a rice field in Italy. Hydrobiologia **391**, 241–247.
Lloret, F., F. Medail, G. Brundu, and P. E. Hulme. 2004. Local and regional abundance of exotic plant species on Mediterranean islands: are species traits important? Global Ecology and Biogeography **13**, 37–45.
Lozek, V. 1964. Quartärmollusken der Tschechoslowakie. Rozpravy ústredního ústavu geologického **31**, 1–374.
Macan, T. T. and R. D. Cooper. 1977. A key to the British fresh- and brackish-water gastropods. Freshwater Biological Association, Ambleside, UK, 46 pp.
Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications **10**, 689–710.
Maillo, P. A., M. A. Vich, H. Salvado, A. Marques, and M. P. Gracia. 2005. Parasites of *Anguilla anguilla* (L.) from three coastal lagoons of the River Ebro delta (Western Mediterranean). Acta Parasitologica **50**, 156–160.
Margalef, R. 1974. Ecología. Omega, Barcelona, Spain, 951 pp.
Martinez, R., E. Rico, and E. Alonso. 2003. Characterisation of *Austropotamobius italicus* (Faxon, 1914) in a central Spain area. Bulletin Français de la Pêche et de la Pisciculture **370–371**, 43–56.

Martinoy, M., D. Boix, J. Sala, S. Gascón, J. Gifre, A. Argerich, R. Barrera, S. Brucet, A. Badosa, R. López-Flores, M. Méndez, J. M. Utgé, and X. D. Quintana. 2006. Crustacean and aquatic insect assemblages in the Mediterranean coastal ecosystems of Empordà Wetlands (NE Iberian Peninsula). Limnetica **25**, 53–70.

McKenzie, K. G. and A. Moroni. 1986. Man as an agent of crustacean passive dispersal via useful plants – exemplified by ostracoda *ospiti esteri* of the Italian ricefields ecosystem – and implications arising therefrom. Journal of Crustacean Biology **6**, 181–198.

McMahon, R. F. 2000. Invasive characteristics of the freshwater bivalve *Corbicula fluminea*. Pages 315–343 in R. Claudi and J. H. Leach, editors. Nonindidenous Freshwater Organisms: Vectors, Biology and Impacts. Lewis Publishers. Boca Raton, FL.

Médail, F. and P. Quézel. 1999. Biodiversity hotspots in the Mediterranean basin: setting global conservation priorities. Conservation Biology **13**, 1510–1513.

Moreno, O., C. Granado, and F. Garcia-Novo. 1986. Variabilidad morfológica de *Lernaea cyprinacea* (Crustacea: Copepoda) en el embalse de Arrocampo (Cuenca de Tajo: Caceres). Limnetica **2**, 275–270.

Ohtaka, A., S. R. Gelder, T. Kawai, K. Saito, K. Nakata, and M. Nishino. 2005. New records and distributions of two North American branchiobdellidan species (Annelida: Clitellata) from introduced signal crayfish, *Pacifastacus leniusculus*, in Japan. Biological Invasions **7**, 149–156.

Orts Muñoz, M. E. 1993. Parásitos y parasitismo de la anguila *Anguilla anguilla* L. Ph.D. dissertation, University of Valencia, Valencia, Spain.

Paavola, M., S. Olenin, and E. Leppäkoski. 2005. Are invasive species most successful in habitats of low native species richness across European brackish water seas? Estuarine Coastal and Shelf Science **64**, 738–750.

Palomo, L. J. and J. Gisbert. 2002. Atlas de los mamíferos terrestres de España . Ministerio de Medio Ambiente, Madrid, Spain.

Paulo, L. F. and M. Moutinho. 1983. Systématique et distribution de Ostracodes au Portugal. Publicaçoes do Instituto de Zoologia Dr Augusto Nobre **173**, 1–32.

Peribáñez, M. A., M. L. Elrío, M. J. Gracia, D. Fernández de Luco, J. A. Castillo, J. Lucientes, and I. Cia. 2006. *Phyllodistomum folium* (Trematoda: Gorgoderidae) infecting zebra mussels (*Dreissena polymorpha*) in the Ebro River, Spain. Parasitology International **55**, 143–145.

Pleguezuelos, J. M. 2002. Las especies introducidas de anfibios y reptiles. Pages 501–532 in J. M. Pleguezuelos, R. Márquez, and M. Lizana, editors. Atlas y Libro Rojo de los Anfibios y Reptiles de España. Dirección General de Conservación de la Naturaleza/Asociación Herpetológica Española, Madrid, Spain.

Pleguezuelos, J. M., R. Márquez, and M. Lizana, editors. 2002. Atlas y Libro Rojo de los Anfibios y Reptiles de España. Dirección General de Conservación de la Naturaleza/Asociación Herpetológica Española, Madrid, Spain, 587 pp.

Prat, N. 1980. Bentos de los embalses españoles. Oecologia Aquatica **4**, 3–43.

Pyšek, P., D. M. Richardson, M. Rejmbnek, G. Webster, M. Williamson, and J. Kirschner. 2004. Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon **53**, 131–143.

Richardson, D. M., P. Pyšek, M. Rejmánek, M. G. Barbour, F. D. Panetta, and C. J. West. 2000. Naturalization and invasion of alien plants: concepts and definitions. Diversity and Distributions **6**, 93–107.

Rincón, P. A., A. M. Correas, F. Morcillo, P. Risueño, and J. Lobón-Cerviá. 2002. Interaction between the introduced eastern mosquitofish and two autochthonous Spanish toothcarps. Journal of Fish Biology **61**, 1560–1585.

Rioja, E. 1924. La Mercierella enigmatica Fauvel, serpúlido de agua salobre, en España. Boletin de la Real Sociedad Espanola de Historia Natural **24**, 160–169.

Rodríguez, C. F., E. Bécares, M. Fernández-Aláez, and C. Fernández-Aláez. 2005. Loss of biodiversity and degradation of wetlands as a result of introducing exotic crayfish. Biological Invasions **7**, 75–85.

Rossi, V., G. Benassi, M. Veneri, C. Bellavere, P. Menozzi, A. Moroni, and K. G. McKenzie. 2003. Ostracoda of the Italian ricefields thirty years on: new synthesis and hypothesis. Journal of Limnology **62**, 1–8.

Ruiz-Olmo, J., S. Palazón, F. Bueno, C. Bravo, I. Munilla, and R. Romero. 1997. Distribution, status and colonization of the American mink *Mustela vison* in Spain. Journal of Wildlife Research **2**, 30–36.

Sala, J. and D. Boix. 2005. Presence of the nearctic water boatman *Trichocorixa verticalis verticalis* (Fieber, 1851) (Heteroptera, Corixidae) in the Algarve region (S Portugal). Graellsia **61**, 31–36.

San Martín Outeiral, S. 2004. Helmintos parásitos de *Anguilla anguilla* L. en las rías de Arousa y Ferrol. Ph.D. dissertation, University of Santiago de Compostela, Santiago de Compostela, Spain.

Sánchez Suárez, I. 2002. Contribución al conocimiento de la parasitofauna de la anguila europea (*Anguilla anguilla* L., 1758). Ph.D. dissertation, Universidad Complutense de Madrid, Madrid, Spain.

Schuchert, P. 2004. Revision of the European athecate hydroids and their medusae (Hydrozoa, Cnidaria): families Oceanidae and Pachycordylidae. Revue Suisse de Zoologie **111**, 315–369.

Schulz, H. K. and F. Grandjean. 2005. Roundtable session 3, Phylogeny of European crayfish; improving the taxonomy of European crayfish for a better conservation. Bulletin Français de la Pêche et de la Pisciculture **376–377**, 829–836.

Schwindt, E. and O. O. Iribarne. 1998. Reef of *Ficopomatus enigmaticus* (Polychaeta, Serpulidae) in the Mar Chiquita Coastal Lagoon, Argentina. Bolletí de la d'Història Natural de les Balears **41**, 35–40.

Sobral, P. 1985. Distribuição de *Acartia tonsa* Dana no estuário do Tejo e sua relação com *Acartia clausi* Giesbrecht. Boletim do Instituto Nacional de Investigaçao das Pescas, Lisbon **13**, 61–75.

Sobrino, E., M. Sanz-Elorza, E. D. Dana, and A. González-Moreno. 2002. Invasibility of a coastal strip in NE Spain by alien plants. Journal of Vegetation Science **13**, 585–594.

Solà, C. 2004. Impacte de l'accident miner d'Aznalcóllar sobre el riu Guadiamar. Recuperació de la comunitat de macroinvertebrats i bioacumulació de metalls pesants. Ph.D. dissertation, University of Barcelona, Barcelona, Spain, 248 pp.

Trontelj, P., Y. Machino, and B. Sket. 2005. Phylogenetic and phylogeographic relationships in the crayfish genus *Austropotamobius* inferred from mitochondrial COI gene sequences. Molecular Phylogenetics and Evolution **34**, 212–226.

Vidal-Abarca, C. and M. L. Suárez. 1985. Lista faunística y bibliográfica de los moluscos (Gasterópodos & Bivalvia) de las aguas continentales de la Península Ibérica e Islas Baleares. Asociación Española de Limnología, Madrid, Spain, 190 pp.

Vilà, M., E. García-Berthou, D. Sol, and J. Pino. 2001. Survey of the naturalised plants and vertebrates in peninsular Spain. Ecologia Mediterranea **27**, 55–67.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science **277**, 494–499.

Young, J. O. and T. B. Reynoldson. 1999. Continuing dispersal of freshwater triclads (Platyhelminthes; Turbellaria) in Britain with particular reference to lakes. Freshwater Biology **42**, 247–262.

Whatley, R. C., S. Bajpai, and J. E. Whittaker. 2003. The identity of the non-marine ostracod *Cypris subglobosa* Sowerby from the intertrappean deposits of Peninsular India. Palaeontology **46**, 1281–1296.

Wu, S. K., R. D. Oesch, and M. E. Gordon. 1997. Missouri aquatic snails. Missouri Department of Conservation, Jefferson, MO, 97 pp.