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Survey of the naturalised plants and vertebrates in peninsular Spain

Bilan des végétaux et vertébrés naturalisés dans la péninsule ibérique

Montserrat VILÀ [1*], Emili GARCÍA-BERTHOU [2], Daniel SOL [3] & Joan PINO [1]

[1]Centre de Recerca Ecològica i Aplicacions Forestals, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain.

[2]Departament de Ciències Ambientals, Universitat de Girona, E-17071 Girona, Spain.

[3]Departament de Biologia Animal-Vertebrats, Facultat de Biologia, Universitat de Barcelona, Av. Diagonal nº 645, 08028 Barcelona, Spain. Present adress: Department of Biology, McGill University. 1205 Av. Docteur Penfield, Montréal, Québec, H3A 1B1, Canada.

*Author for correspondence: Tel: 93-5811987, Fax : 93-5811312, e-mail: vila@cc.uab.es.

ABSTRACT

The introduction of naturalised species is threatening the biodiversity of "hot-spot" regions around the World. Spain is one of the European countries with the highest diversity of species. However, a synthesis of the identity of the naturalised biota has never been conducted. We present a bibliographic survey to analyse the number and biogeography of naturalised plants and vertebrates in peninsular Spain. We found 637 naturalised plants, 20 fish species, 3 amphibians, 8 reptiles, 9 birds, and 11 mammals. The largest fraction of plants are of American origin whereas the origin of vertebrates depends on their taxonomic group. Except for amphibians and mammals, most naturalised species are found in highly disturbed habitats. The invasiveness of these species and their impact on the native biota have not been quantified. However, some of these species are very invasive in other regions of the World, and thus the probable impacts on the biodiversity conservation of Spain should be urgently investigated.

Key-words: alien plants, biological invasions, Iberian Peninsula, patterns of invasion, species diversity.

RESUME

La naturalisation d'espèces étrangères constitue une menace mondiale pour la biodiversité des zones de « hotspots ». L'Espagne constitue l'un des pays européens possèdant la plus grande diversité spécifique. Cependant, il n'existe pas pour ce pays de synthèse relative aux espèces introduites et naturalisées. Ainsi, ce travail vise à dresser une synthèse bibliographique concernant le nombre et l'origine biogéographique des végétaux vasculaires et des vertébrés naturalisés présents dans la péninsule ibérique. Ce bilan a permis de dénombrer 637 végétaux vasculaires naturalisés, 20 poissons, 3 amphibiens, 8 reptiles, 9 oiseaux et 11 mammifères non indigènes. La plus grande proportion de ces végétaux xénophytes est d'origine américaine, tandis que l'origine biogéographique des vertébrés dépend du groupe taxonomique auquel ils appartiennent. Hormis les amphibiens et des mammifères, la plupart des espèces naturalisées se rencontrent dans des biotopes fortement perturbés. L'invasibilité de ces espèces et leur impact sur les communautés et écosystèmes indigènes n'ont pas été encore quantifiés. Cependant, certaines espèces présentes en Espagne s'avèrent très dynamiques et envahissantes dans d'autres régions du Monde, et leurs impacts probables sur la biodiversité espagnole méritent d'être examiné de façon urgente.

Mots-clés : végétaux exotiques, invasions biologiques, Péninsule ibérique, modalités d'invasion, diversité spécifique

INTRODUCTION

Species dispersal driven by man is currently one of the main causes of change in the biota composition around the World (Drake *et al.*, 1989). The introduction of naturalized species has increasingly attracted the attention of ecologists because of their impact on natural systems, which include loss of biodiversity (Lodge, 1993), changes in disturbance regime (D'Antonio & Vitousek, 1992), changes in the biogeochemical cycles (Vitousek, 1994) and homogenization or creation of new landscapes (Atkinson & Cameron, 1993). The interest in naturalized species also comes from the fact that they can help to elucidate the processes that shape community structure and determine its function.

Surveys of naturalized species distribution at the regional level are the starting point to establish patterns and correlates of naturalized species diversity at the global scale (Daehler, 1998; Pysek, 1998; Lonsdale, 1999), and can also help to establish hypotheses of the ecological factors that determine which species are more invasive and which communities are more easily invaded (Crawley, 1987; Mack, 1996). In the last decade a significant effort has been achieved to determine patterns of invasion by naturalized species at the regional scale (e.g. Groves & Di Castri, 1991; Rejmánek & Randall, 1994; Weber, 1997), but there is still a lack of quantitative information on the naturalized component for major regions of the world (Heywood, 1989; Lonsdale, 1999).

Spain is one of the countries with the highest biological diversity of Europe; with a high proportion of endemic plants (Gómez-Campo *et al.*, 1984; Médail & Quézel, 1997), amphibians and reptiles (Pleguezuelos & Martínez-Rica, 1997), and birds (Blondel, 1985). Plant diversity is associated with the biogeographic location of the Iberian Peninsula and the high habitat and pedological diversity (Médail & Quézel, 1997). Spanish amphibians are more diverse than reptiles due to a combination of historical and ecological factors (Vargas & Real, 1997). The percentage of European species that are native to Spain is high for mammals and birds because they have large distribution areas and a low proportion of endemics (Oosterbroek, 1994; Covas & Blondel, 1998). The aquatic fauna of Spain is globally poor compared to the rest of Europe (Banarescu, 1992). The relatively low richness of freshwater fish (Doadrio *et al.*, 1991; Elvira, 1998; Carmona *et al.*, 1999) is generally attributed to the isolation of the Iberian peninsula and the scarcity of fresh water habitats (Hernando & Soriguer, 1992).

The naturalized component of the flora and fauna has been partially analysed for several regions within Spain and in most cases for different taxonomic groups (see Methods), yet a synthesis of both the naturalized flora and vertebrate fauna has never been conducted. This paper describes the naturalized component (exotic established species) of the flora and vertebrate fauna of Spain to answer the following questions: (i) How many naturalized plant and vertebrate species are there in Spain? (ii) What is their origin? and (iii) In which communities are naturalized species located? We limited the study to plants and vertebrates because these are well known taxa and therefore reliable information was available from most of their species.

MATERIAL AND METHODS

A database was created with all plant and vertebrate naturalized species of Spain excluding the Balearic and Canary islands. The main floras and plant species lists surveyed were: Alcázar (1984), Arnold & Burton (1995), Bolós *et al.* (1993), Campos & Herrera (1997), Carretero (1989), Casasayas (1989), Castroviejo *et al.* (1986-1997), Conesa (1992), González (1988), Greuter *et al.* (1984), Masalles *et al.* (1996), Pino (1999), Recasens & Conesa (1990, 1995), Tutin *et al.* (1993) and Valdés *et al.* (1987). The data gathered for animals came from Andrada (1985), Elvira (1998), Gozálbes (1987), Hagemeijer & Blair (1997), Lever (1985), Lobón-Cerviá & Elvira (1989), Long (1981), Llorente *et al.* (1995), MacDonald & Barrett (1993), Pleguezuelos & Martínez-Rica (1997), Purroy (1997), Rivera & Arribas (1993), Rodríguez (1993), Rodríguez & Sales (1999), Ruiz-Olmo & Aguilar (1995), Schilling *et al.* (1987), and Vives-Balmaña *et al.* (1987).

We only included well established exotic species which populations are capable to grow without direct support of humans, that is "naturalized species" sensu Williamson & Fitter (1996). Exotic plant species

listed as cultivated or planted were excluded, as well as those whose naturalization status was not certain. The following information for each naturalized plant species was gathered: family, Raunkiaer life-form (Raunkiaer 1934), origin and habitat. For vertebrates, the following information was gathered: family, common name, origin, habitat and date of introduction if known. We did not list exotic species if it was not known if they maintain self-sustaining populations (see examples in Purroy, 1997). That is, we did not include populations that failed to establish, populations that were too small to be considered viable or small populations for which there are no data on reproductive success. We did not include domestic vertebrates.

RESULTS

List and characteristics of naturalized species

Spain harbors 637 naturalized plant species distributed in 102 families, which represent 13% of the total flora. Less than 25% of these families have more than 10 naturalized species, whereas the majority only have one or two species (Appendix I).

The families with the most naturalized taxa are : Asteraceae, Poaceae, Brassicaceae and Fabaceae, followed by Solanaceae, Amaranthaceae and Lamiaceae (less than 4% of the total per family). Some families are completely naturalized: Agavaceae, Basellaceae, Phytolaccaceae, Pittosporaceae, Sapindaceae and Simaroubaceae. The majority of naturalized species are therophytes (40.98%), followed by hemycriptophytes (17.83%). Hydrophytes (0.85%), epiphytes (0.42%), parasites (0.42%) and helophytes are the least represented life-forms (Table 1).

The naturalized fauna of Spain comprises at least 20 fish species, 3 amphibians, 8 reptiles, 9 birds and 11 mammals (Appendix II). Date and reason for introduction for several of the species are uncertain. Several species such as the Turkish gecko (*Hemidactylus turcicus*) and the Mediterranean chameleon (*Chamaleo chamaleon*) are cryptogenic species, i.e. species that are not demonstrably native or introduced (Carlton, 1996). A few other species (e.g., collared turtedove: *Streptopelia decaocto*) have not been included in the Appendix II because they naturally invaded the Iberian Peninsula. The rock dove (*Columba livia*) has not been included because only part of the population is actually introduced. Some other species have been introduced in Spain (e.g. Californian quail: *Callipepla californica* and black-rumped waxbill: *Estrilda troglodytes*) but have failed to establish themselves in natural areas or their populations are too small to consider that the introduction has succeeded.

The percentage of European species that are native to Spain is the lowest for freshwater fishes (20-32%) and reptiles (30.1%), larger for mammals (34.3%) and amphibians (40.8%) and is highest for birds (52.5%) (Table 2). The percentage of the fauna that is naturalized is very high for freshwater fish (39%, excluding diadromous species), intermediate for reptiles (18%), amphibians (11%), and mammals (15%), and low for birds (3%). The apparent inverse relationship between fauna richness and percentage of naturalized species is not statistically significant ($r = -0.69$, $n = 5$, $P = 0.20$).

Origin of naturalized species

Exotic plants originated mainly from the Holarctic region (33%), most common being of the European origin. There are also a significant proportion of species coming from South America. Asian and African species also are numerous (Table 3). Although most naturalized animals originated also from the Holarctic region (Table 4), the region of origin significantly depends on the taxonomic group (Table 4: $G = 25.8$, d.f. = 12, $P = 0.01$). Exotics from North America are common within reptiles (50%) and fish (35%), and less frequent among mammals and birds, with only one species each. There are no naturalized fish from Africa, whereas for all the other groups of vertebrates more than 20% of species have an African origin.

Habitats with naturalized species

Most naturalized plants are found in ruderal communities, road-sides (44.67%) and crops (23.35%). Coastal and riparian communities are also highly invaded habitats (9.5 % and 5.7 %, respectively). In contrast, only 11 and 5 species invade forests and shrublands respectively (Table 5). Most naturalized birds, amphibians and reptiles have restricted distributions, in contrast to fish and

mammals. Exotic amphibians and mammals are common in natural habitats, whereas naturalized birds, reptiles, and fish occur in urban or human-altered habitats.

Life-form	Species (% of total)	
Therophytes	40.98	
Hemicryptophytes	17.83	
Phanerophytes	11.89	
Chamephytes	11.25	
Geophytes	7.43	
Nanophanerophytes	4.67	
Macrophanerophytes		4.03
Hydrophytes	0.85	
Epiphytes	0.42	
Parasites	0.42	
Helophytes	0.21	

Table 1. Life-forms of Spanish naturalized plant species (exotics from Balearic and Canary islands are not included).

Phanerophyte (Ph): woody plant with buds located more than 40 cm above the ground; nanophanerophyte: Ph with buds located less than 2 m above the ground; macrophanerophyte: Ph with buds located more than 2 m above the ground; chamephyte: woody plant with buds located less than 40 cm above the ground; Biannual hemicryptophytes were considered perennials.

Taxonomic group	European native	Spanish native	Spanish naturalized	Reference
Plants	11557[a]	-	-	Tutin *et al.* 1993
	-	4900[a]	-	Simon (1994)
	-	-	637	this review
Freshwater fish	215[b]	-	-	Maitland & Linsell (1980)
	-	69[b], 32[c]	-	Elvira (1995)
	-	-	20	Elvira (1998), this review
Amphibians	45	21	-	Arnold & Burton (1995), Andrada (1985)
	59	24	3	Pleguezuelos & Martínez-Rica (1997) this review
Reptiles[d]	85	36	-	Arnold & Burton (1995)
	133	40	8	Pleguezuelos & Martínez-Rica (1997) this review
Birds	514[e]	270[e]	-	Hagemeijer & Blair (1997), Purroy (1997)
	-	-	9	this review
Mammals	181[f]	62[f]	-	Schilling *et al.* (1987)
	-	-	11	this review

Table 2. Number of European and Spanish species by taxonomic group according to several references. - = not considered.

a = total number of vascular plants
b = including diadromous species (i.e., migrating from/to the sea)
c = excluding diadromous species
d = excluding marine reptiles (5 turtle species)
e = excluding non-breeding species
f = excluding whales and dolphins

Origin	Species (% of total)
Southern America	21.68
Europe	20.22
Northern America	13.11
Northern Africa and Middle East	12.93
Central and Southern East Asia	10.75
Central and Southern Africa	9.65
America	4.01
Tropical	2.55
Australia and New Zealand	2.37
Other	1.64
Macaronesia	1.09

Table 3. Origin of Spanish naturalized plant species. Exotics from Balearic and Canary islands are not included.

Origin region	Fish	Amphibians	Reptiles	Birds	Mammals	Total
Eurasia	12	0	2	3	5	22 (44)
North America	7	1	4	1	1	13 (26)
South America	1	0	0	2	1	4 (8)
Africa	0	2	2	3	4	11 (22)

Table 4. Number of Spanish naturalized vertebrate species by origin and taxonomic group. The percentage of the total value is shown in parenthesis. Exotics from Balearic and Canary islands are not included.

Habitats	Species (% of total)
Crops	23.35
Ruderal	30.63
Roadsides	14.04
Littoral	8.97
Riparian woodlands	5.75
Herbaceous communities	4.06
Wetlands and moorlands	3.89
Sandy littoral habitats	3.05
Non-riparian woodlands	1.86
Salty shrublands	1.86
Shrublands	0.85
Sandy non-littoral habitats	0.68
Littoral cliffs and rocky areas	0.51
Non-littoral cliffs and rocky areas	0.34
Springs and streamlets	0.17

Table 5. Habitats invaded by Spanish naturalized plant species. Exotics from Balearic and Canary islands are not included.

Most Spanish freshwater courses are altered by pollution or regulation but naturalized fish are particularly common in reservoirs, where they are introduced by anglers.

DISCUSSION

Diversity of species in peninsular Spain and the naturalized component

Regional reviews of the number of native and naturalized species for a particular higher taxon are numerous. However, studies considering several higher taxa, particularly for large regions, are almost lacking (but see Vitousek *et al.*, 1997). This lack of integration, which was also the case for Spain, is unfortunate because only with detailed descriptions of the alien component at a regional scale can we establish patterns and correlates of naturalized species diversity at the global scale (Lonsdale, 1999). Our study unifies and updates the number of native and naturalized species currently present in Spain and can thus serve as a starting point for future hypothesis-oriented studies.

The naturalized component of the Spanish biota is quantitatively important. This probably reflects the many opportunities that humans have offered to exotics to reach the country. However, the number of naturalized species greatly varies among taxa. For example, naturalized plants are much more frequent than naturalized vertebrates, a pattern often found in the literature of biological invasions (Williamson, 1996). The families with the largest number of naturalized species belong also to the largest families worldwide because large families have more species available to invade, so more exotics are expected from large families (Pysek, 1998).

Compared to the figures given by Heywood (1989), Spain is one of the richest regions in Europe in naturalized plants, although the number of native species is also high. The proportion of naturalized plants in the Spanish flora is about 13%. According to Quézel *et al.* (1990) the mean in the Mediterranean Basin is 1% (Quézel *et al.*, 1990). However, this gap is undervaluated because taking only into account the naturalized flora of Spain it is of 2.24%. California, which is one of the most invaded temperate regions in the world, reported 20% exotic species (Hickman, 1993).

Among freshwater fish, the percentage of naturalized species is very high. This pattern is also found in some other regions (Vitousek *et al.*, 1997). On the contrary, relatively few amphibians and reptiles have become naturalised in Spain as well as around the world (di Castri, 1991; Lever, 1994). Birds are the only group that does not fit to the general pattern: the 8 species established in Spain are far from the 27 successfully introduced in Europe (Long, 1981; but see Hagemeijer & Blair 1997 for a more recent revision).

Habitat disturbance and naturalized species

Except for amphibians and mammals, Spanish naturalized vertebrates are generally more common in disturbed or man-made habitats than in pristine habitats. Higher plants also primarily concentrate in disturbed habitats; indeed, most taxa (68%) are pioneer species that colonize ruderal habitats or infest crops. The relationship between naturalized success and perturbation has already been pointed out for plants (Hobbs & Huenneke 1992), birds (Diamond & Veitch, 1981; Moulton & Pimm, 1983) and fish (Lever, 1996; Moyle & Light, 1996a,b). To some extent, this relationship may reflect a bias towards commensal species, which are more likely to be accidentally or unintentionally introduced. However, some authors hold that disrupted environments are especially vulnerable to invasions mainly due to their low richness of native species, which is thought to leave vacant niches or reduce the intensity of competition (Levine & D'Antonio, 1999; but see Moyle *et al.*, 1986; Moyle & Light, 1996a,b). The commonness of naturalized mammals in undisturbed habitats has also been attributed to the low number of native mammal species (Brown, 1989). Secular disturbance regimes and soil resource nutrients probably difficult invasion by exotic species of typical Mediterranean habitats such as woodlands and shrublands (Casasayas, 1989).

Impact of naturalized species

The impact of an invasive species is difficult to define because it depends on the ecological level

analysed and the spatial and temporal scales of the study (Parker *et al.*, 1999).

However, the need for impact assessment is urgent because even within the scientific and land-manager community the risks and costs of alien species are ignored and masked by alien species short term utilities and benefits (Daehler & Gordon, 1997). Major noxious species are weeds that cause problems in crop production and management. This is the case of several invaders from America, such as *Abutilon theophrastii*, *Sorghum halepense* and *Cuscuta campestris* (Masalles *et al.*, 1996). In natural areas some naturalized species when dominant may displace native species (e.g. *Carpobrotus edulis*, *Robinia pseudoacacia*). However, the magnitude of their impact at the community and ecosystem level needs further investigation.

The impact of naturalized vertebrates on the Spanish native biota also remains largely unknown. It is well known that most catastrophic impacts involve mammals or top predators (Taylor *et al.*, 1984; Lever, 1994; Moyle & Light, 1996a,b). Among freshwater fish, pike (*Esox lucius*) and largemouth bass (*Micropterus salmoides*) are top predators that have been suggested to be potentially more harmful (Elvira, 1998; García-Berthou & Moreno-Amich, 2000). Among herpetofauna, the bullfrog (*Rana catesbeiana*) and the three turtle species (Appendix II) seem more problematic. The bullfrog has been found to impact fishes and amphibians in the U.S. sites where it has been translocated (Lever, 1994). The ecological impact of birds should be of limited concern because they are only common in disturbed habitats. However, they may have an economic impact, such as the case of the monk parakeet which started to invade urban parks and are now invading natural habitats (Sol *et al.*, 1997). Among mammals, the mink (*Mustela vison*) is a predator that occupies natural habitats and apparently has affected the populations of the endangered Iberian desman (*Galemys pyrenaicus*) (see also Lever, 1994). The coypu (*Myocastor coypus*) has also been problematic elsewhere (Lever, 1994) but it is not yet widespread in Spain.

Further field surveys should investigate the distribution range and abundance of these species and their impact on the native biota. With regard to plants, the Database National Research Project is currently fulfilling this gap (Dana *et al.*, 1999). The present review represents a preliminary analysis of the naturalized species in Spain. From this study some general conclusions can be drawn: (i) the naturalized component of the Spanish biota is quantitatively important; (ii) Spanish naturalized species are generally more common in disturbed or man-made habitats than in pristine habitats; (iii) some naturalized species are also naturalized elsewhere and (iv) the impact of naturalized vertebrates on the Spanish native biota can be potentially important but remains largely unknown. Mechanisms to stop the introduction of naturalized species and to control or reduce nuisance species should be implemented.

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Appendix I. Spanish naturalized plant species classified by families. For each family, the number of species and their percentage in respect to the total of naturalized species are shown. Exotics from Balearic and Canary islands are not included. Species list is available from the first author upon request.

FAMILY	*Species*	*% of total*
Asteraceae	104	14.59
Poaceae	67	9.40
Brassicaceae	48	6.73
Fabaceae	36	5.05
Solanaceae	26	3.65
Amaranthaceae	25	3.51
Lamiaceae	23	3.23
Rosaceae	21	2.95
Chenopodiaceae	19	2.66
Polygonaceae	18	2.52
Caryophyllaceae	16	2.24
Liliaceae	16	2.24
Aizoaceae	15	2.10
Onagraceae	14	1.96
Boraginaceae	13	1.82
Cactaceae	13	1.82
Convolvulaceae	12	1.68
Crassulaceae	11	1.54
Pinaceae	11	1.54
Cyperaceae	10	1.40
Scrophulariaceae	10	1.40
Euphorbiaceae	9	1.26
Mimosaceae	9	1.26
Apiaceae	8	1.12
Iridaceae	8	1.12
Oxalidaceae	8	1.12
Malvaceae	7	0.98
Ranunculaceae	7	0.98
Lythraceae	6	0.84
Papaveraceae	5	0.70
Gutiferae	4	0.56
Salicaceae	4	0.56
Asclepiadaceae	3	0.42
Balsaminaceae	3	0.42
Bignoniaceae	3	0.42
Caprifoliaceae	3	0.42
Cucurbitaceae	3	0.42
Cupressaceae	3	0.42
Dipsacaceae	3	0.42
Moraceae	3	0.42
Plumbaginaceae	3	0.42
Portulacaceae	3	0.42
Rubiaceae	3	0.42
Verbenaceae	3	0.42
Azollaceae	2	0.28
Betulaceae	2	0.28
Cesalpinaceae	2	0.28
Campanulaceae	2	0.28
Elatinaceae	2	0.28
Fagaceae	2	0.28
Haloragaceae	2	0.28

FAMILY	*Species*	*% of total*
Hydrangeaceae	2	0.28
Juglandaceae	2	0.28
Juncaceae	2	0.28
Oleaceae	2	0.28
Phytolaccaceae	2	0.28
Pittosporaceae	2	0.28
Platanaceae	2	0.28
Saxifragaceae	2	0.28
Acanthaceae	1	0.14
Agavaceae	1	0.14
Alismataceae	1	0.14
Amaryllidaceae	1	0.14
Arecaceae	1	0.14
Baselaceae	1	0.14
Berberidaceae	1	0.14
Buddlejaceae	1	0.14
Capparaceae	1	0.14
Casuarinaceae	1	0.14
Ciperaceae	1	0.14
Cistaceae	1	0.14
Commelinaceae	1	0.14
Ebenaceae	1	0.14
Elaeagnaceae	1	0.14
Geraniaceae	1	0.14
Grossulariaceae	1	0.14
Hippocastanaceae	1	0.14
Hydrocaritaceae	1	0.14
Hydrophyllaceae	1	0.14
Lauraceae	1	0.14
Linaceae	1	0.14
Meliaceae	1	0.14
Molluginaceae	1	0.14
Myoporaceae	1	0.14
Najadaceae	1	0.14
Nyctaginaceae	1	0.14
Orobanchaceae	1	0.14
Passifloraceae	1	0.14
Plantaginaceae	1	0.14
Punicaceae	1	0.14
Resedaceae	1	0.14
Rutaceae	1	0.14
Sapindaceae	1	0.14
Sapotaceae	1	0.14
Selaginellaceae	1	0.14
Simaroubaceae	1	0.14
Tamaricaceae	1	0.14
Thymelaeaceae	1	0.14
Typhaceae	1	0.14
Ulmaceae	1	0.14
Urticaceae	1	0.14
Zygophyllaceae	1	0.14

Appendix II. Spanish exotic vertebrate species. A question mark before the species name indicates uncertain native/exotic status. Group: F = fish, A = amphibians, R = reptiles, B = birds, and M = mammals. Exotics from Balearic and Canary islands not included.

Group	FAMILY/ Species	Common name	Origin	Introduction date	Reference
F	CYPRINIDAE				
	Alburnus alburnus	Bleak	Europe	1990s?	1
	Blicca bjoerkna	White bream	Europe	1990s?	1
	Carassius auratus	Goldfish	Asia	17th cent.	1
	Cyprinus carpio	Common carp	Eurasia	17th cent.	1
	Gobio gobio	Gudgeon	Eurasia	19th cent.	1
	Rutilus rutilus	Roach	Eurasia	1910s?	1
	Scardinius erythrophthalmus	Rudd	Eurasia	1910s	1
	?Tinca tinca	Tench	Eurasia	Before 1735	1
F	ICTALURIDAE				
	Ameiurus (= Ictalurus) melas	Black bullhead	North America	1910s	1
F	SILURIDAE				
	Silurus glanis	Wels	Eurasia	1970s	1
F	ESOCIDAE				
	Esox lucius	Pike	Eurasia	1949	1
F	SALMONIDAE				
	Hucho hucho	Huchen	Europe	1968	1
	Oncorhynchus mykiss (=Salmo gairdneri)	Rainbow trout	North America	19th cent.	1
	Salvelinus fontinalis	Brook charr	North America	19th cent.	1
F	FUNDULIDAE				
	Fundulus heteroclitus	Mummichog	North America	1970s	1
F	POECILIIDAE				
	Gambusia holbrooki	Mosquitofish	North America	1921	1
F	PERCIDAE				
	Perca fluviatilis	Perch	Eurasia	1970s	1
	Stizostedion lucioperca	Pikeperch, Zander	Eurasia	1970s	1
F	CENTRARCHIDAE				
	Lepomis gibbosus	Pumpkinseed sunfish	North America	1910-1913	1
	Micropterus salmoides	Largemouth bass	North America	1955	1
F	CICHLIDAE				
	Cichlasoma facetum	"Chanchito"	South America	1940?	1
A	DISCOGLOSSIDAE				
	Discoglossus pictus	Painted frog	N Africa and S Mediterranean	19th cent.	2, 3, 4
A	RANIDAE				
	Rana catesbeiana	Bullfrog	E of North America	1987-1990	3

A	BUFONIDAE				
	Bufo mauritanicus	?	N Africa	1900s	3
R	EMYDIDAE				
	Pseudemys picta	Painted turtle?	North America	?	3
	Trachemys scripta	Read-eared slider?	North America	?	2, 3
R	TRIONYCHIDAE				
	Trionyx spiniferus	Eastern spiny softshell?	North America	1990s	3
R	GEKKONIDAE				
	Hemidactylus turcicus	Turkish gecko	Middle East	Neolithic	2, 5
	Tarentola mauritanica		Africa	4000 to 2400 B.C.	2
R	IGUANIDAE				
	Anolis carolinensis	Green anole	North America	?	3
R	CHAMAELEONTIDAE				
	Chamaeleo chamaeleon	Mediterranean chameleon	N Africa and Middle East	B.C.	3, 5, 6
R	LACERTIDAE				
	Podarcis sicula	Italian wall lizard	Italy, Greece, and Turkey	?	3, 4, 7
B	ANSERIFORMES	Ruddy duck	North & South America	1990s	8
	Oxyura jamaicensis				
B	PASSERIDAE				
	Estrilda melpoda	Orange-cheeked waxbill	Sub-Saharan Africa	1990	8, 9
	Estrilda astrild	Common waxbill	Sub-Saharan Africa	1960s?	8, 9
	Amandava amandava	Red avadavat	Asia	1974	8, 9
	Leiothrix lutea	Red-billed leiothrix	Southern Asia	1990	10
B	PSITTACIDAE				
	Myiopsitta monachus	Monk parakeet	South America	ca. 1975	8, 9
	Psittacula krameri	Rose-ringed parakeet	N Africa and Asia	ca. 1976	8, 9
	Aratinga mitrata	Mitret conure	South America	1992	D. Sol (per. obs.)
B	PHASIANIDAE				
	Phasianus colchicus	Ring-neeked pheasant	Eurasia	B.C.	11
M	CAPROMYDAE				
	Myocastor coypus	Coypu	South America	?	12, 13
M	MUSTELIDAE				
	Mustela vison	Mink	North America	1983	13
M	SCIURIDAE				
	Marmota marmota	Alpine marmot	Central Europe	1948	13 , 14
M	VIVERRIDAE				
	Genetta genetta	Common genet	Africa	ca. 16th cent.	13

M	CERVIDAE				
	Dama dama	Fallow deer	S Europe and Asia	B.C.	13, 15
M	BOVIDAE				
	Ovis musimon	Mouflon	Asia and Mediterranean islands	1954	13
	Ammotragus lervia	Barbary sheep	Africa	?	14
M	MURIDAE				
	Rattus norvegicus	Brown rat	SE Asia	16th cent.	14, 15, 16
	Rattus rattus	House rat	Asia	16th cent.	14, 16
M	ERINACIDAE				
	Erinaceus algirus	Algerian hedgehog	NW Africa	?	14
M	CERCOPITHECIDAE				
	Macaca sylvanus	Barbary ape	N Africa	711 B.C.?	17

References: 1 = modified from Lobón-Cerviá & Elvira (1989) and Elvira (1998), 2 = Llorente *et al.* (1995), 3 = Pleguezuelos & Martínez-Rica (1997), 4 = Vives-Balmaña *et al.* (1987), 5 = Rivera & Arribas (1993), 6 = Arnold & Burton (1995), 7 = Andrada (1985), 8 = Hagemeijer & Blair (1997), 9 = Purroy (1997), 10 = Long (1981), 11 = Rodríguez & Sales (1999), 12 = Gosàlbez (1985), 13 = Ruiz-Olmo & Aguilar (1995), 14 = Rodríguez (1993), 15 = Lever (1985), 16 = McDonald & Barrett (1993), and 17 = Schilling *et al.* (1987).