Chapter 11
Plant Invasions of Protected Areas in Europe: An Old Continent Facing New Problems

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Abstract Europe has a particularly long history of land protection measures, and is the region of the world with the largest number of protected areas, which has grown rapidly over the last decades. This was to a large extent due to the Natura 2000 programme of the European Union which focused on extending the existing network of legally protected areas with other habitats of conservation value. As a result, Europe has over 120,000 nationally designated protected sites (the most in the world) and 21 % of the continent area (1,228,576 km^2) currently enjoys some form of legal protection. Despite these impressive statistics, the effectiveness of the existing network in protecting biodiversity is constrained by habitat fragmentation and other factors. Despite the generally high awareness of the importance of biodiversity protection in Europe, invasive alien species are not perceived as the most

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pressing problem by the public. This is in contrast with the fact that many of them have serious impacts on biodiversity and ecosystem functioning in protected areas. Among these, *Ailanthus altissima*, *Fallopia* taxa, *Heracleum mantegazzianum*, *Impatiens glandulifera* and *Robinia pseudoacacia* are considered as top invaders by managers of protected areas. Surprisingly, continent-wide rigorous data on the distribution and abundance of invasive alien species are lacking and there is an urgent need for collating checklists of alien species using standardised criteria to record their status. With the exception of very few regions such information is missing, or incomplete, based on varying criteria and scattered in grey literature and unpublished reports. To put the management on a more scientific basis the collection and curation of better data is an urgent priority; this could be done by using existing instruments of the EU as a convenient platform. As found by means of a web survey reported here, managers of protected areas in Europe are well aware of the seriousness of the problem and threats imposed by invasive plant species but are constrained in their efforts by the lack of resources, both staff and financial, and that of rigorous scientific information translated into practical guidelines.

Keywords European Union • Natura 2000 • Neophytes • Propagule pressure • Species distribution

11.1 Introduction

Europe, and in particular the European Union (EU) which comprises 27 out of the total of 52 European countries, is one the regions of the world with the highest number of protected areas (PAs), and the number has grown rapidly in recent decades (Lockwood 2006; Gaston et al. 2008). Europe has more than 120,000 nationally designated sites[1], of which 105,000 are located in the 39 member as well as collaborating countries associated with the European Environment Agency (EEA). European PAs represent 69 % of the records in the World Database on Protected Areas managed by UNEP-WCMC (European Environment Agency 2012). Protected Areas in the EU cover 15.3 % of the total surface (661,692 km^2), or even 25 % (1,081,195 km^2) if sites implemented as part of the Natura 2000 scheme (Natura 2000 Networking Programme 2007; Gaston et al. 2008) are considered. In the 39 EEA member and collaborating countries the proportion of protected land is 13.7 % (801,500 km^2), or 21 % (1,228,576 km^2) if Natura 2000 sites are included. These figures are well above the world average where the total land area under any legal protection was recently reported as 12.9 %, with only 5.8 % under strict protection for biodiversity (Jenkins and Joppa 2009). Since 1995, the Natura 2000 network has grown to 26,400 sites with a total surface area of about 986,000 km^2, now accounting for nearly

[1] A given area can be designated under several designations, often with different boundaries. By ‘site’ we mean each individual record of a given area under a specific designation type.

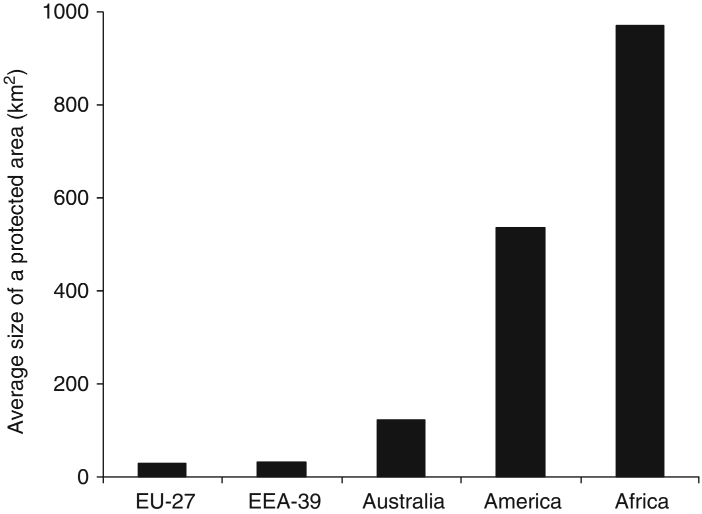

Fig. 11.1 Average size of terrestrial nationally designated protected areas in different regions of the world. EU-27 includes member states of European Union, EEA-39 includes 32 European Environment Agency member countries and seven collaborating countries (http://www.eea.europa.eu/data-and-maps/figures/political-map-of-eea-member-and-collaborating-countries. Taken from UNEP-WCMC 2011)

768,000 km^2 of land, and 218,000 km^2 of sea (European Environment Agency 2012).

In Europe, the term 'protected area' covers a wide variety of designations. Protected areas in this continent are characterised by quite different management regimes, from highly protected sites with limited access to visitors, to parks with a high numbers of visitors, and large areas with rather intense human presence, including dwellings and important economic activities within the borders of the PAs. Such intense human presence in some European PAs is reflected by the large extension of agro-ecosystems, accounting for over 28 % of PAs (European Environment Agency 2006).

The strong influence of humans on nature in Europe began as early as the Neolithic (ca. 3000–1100 BC), and over the centuries has radically altered the natural ecosystems of this region, through for example the harvesting of natural resources, the establishment of settlements, and the cultivation of land. As a consequence, Europe is characterised by a particularly high human density (the average for EU member states is 112 inhabitants per km^2), much higher than that recorded in most other regions of the world. Such density is associated with extensive urbanization, high levels of transport infrastructures and a high degree of fragmentation of the land. As a result of all these characteristics, European PAs are, on average, very small in size compared to other regions of the world (Fig. 11.1; see also Gaston et al. 2008 for more detailed data on selected countries). Most PAs in Europe (90 %) are smaller than 1,000 ha and 65 % range between 1 and

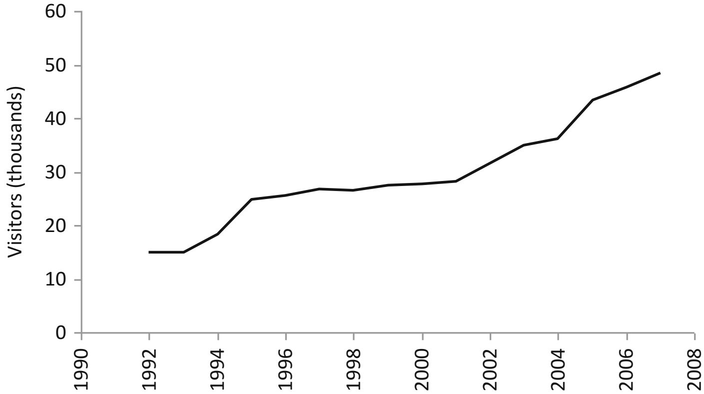

Fig. 11.2 Increase in the number of visitors to Finnish national parks between 1992 and 2007, expressed as the average number of annual visits per park (Based on data from Puhakka 2008)

100 ha; the largest PA is the Yugyd Va National Park in Russia which covers 1,891,700 ha. The high and still growing level of fragmentation of natural areas also brings about concerns about whether the existing PA systems can maintain their biodiversity values under the likely impacts of climate change (Gaston et al. 2008).

On the other hand, Europe is a continent characterised by relative political stability, low levels of poverty and slow human population growth (see e.g. Naughton-Treves et al. 2005; Foxcroft et al. 2014b). Furthermore, Europe is also characterised by a high level of attention paid by the general public to nature, as illustrated by the numbers of visitors to Natura 2000 sites (1.2–2.2 billion visitor days per annum; Gantioler et al. 2010), and by an increasing interest in PAs. For example in Finland the visitation rate to national parks more than tripled between 1992 and 2007 (Fig. 11.2). Tourism plays a key role in regional development, and many PAs have become attractive tourist destinations (Puhakka 2008). The positive trend recorded in nature-based tourism – one of the fastest growing economic sectors globally – contrasts with the declining numbers of visitors in other regions of the world such as United States or Japan (Balmford et al. 2009). On the other hand, increase in tourism also has negative connotations especially in southern and Mediterranean Europe, where extensive coastalization, landscaping of hotels and increasing urbanization, with the demand for more non-native ornamental plants, increases the threat of problem with invasive plants.

11.2 History and Legislation

The history of PAs in Europe is particularly long. It starts with monarchs, who used areas they owned for their personal benefit, for example to harvest game or wood, and prevented the rest of the society from accessing and using these areas. The first example of this kind of land protection in Europe can be dated to 1066, when William the Conqueror created the first hunting forests in Britain, declaring the first game-keeping forest in 1087. Similar legislation, aimed to protect game and forests as a symbol of royal power, was introduced repeatedly at least until the sixteenth century (Welzholz and Johann 2007). Another example of early PAs used by monarchs as hunting preserves is Coto Doñana (Spain) where Alfonso X set up a Hunting Palace in 1262. Since the seventeenth and eighteenth centuries, with the emergence of landscape gardening the interest in natural areas started to shift from the resources they contained to their natural beauty, creating the foundation of modern nature conservation. This aesthetic view was taken up by the European Romantic movement and became one important ideal of Romanticism, which placed great importance on the beauty of such untamed places (European Environment Agency 2012).

In the nineteenth century, the protection of land started to be driven also by private associations that purchased parcels of land for the intrinsic value of nature present in those sites. It was as early as in the 1820s that the first formal PAs were declared in Germany, followed by the creation of PAs in what was then the Austro-Hungarian Empire (present day Austria, Czech Republic, Hungary and Slovakia; European Environment Agency 2012).

In the twentieth century the ownership of natural areas in many cases shifted to the state, and after the Second World War European society started to value the maintenance of biodiversity in PAs. Following the establishment of national parks in North America, many European countries created similar institutions in their colonies. The first country to establish national parks that were owned by the state was Sweden in 1909, and Switzerland followed soon after, in 1914. However, most European national parks were set up after the Second World War, and only in the past 30 years has a broader vision of PAs emerged in Europe, whereby such areas are valued for multiple reasons such as their beauty, their role as repositories of biodiversity, and as potential sources of economic wealth. In this period planners and managers of PAs started to give attention to a proper management of the sites, to involving local communities, and to the need to establish networks of PAs. Protected areas in Europe are currently seen not only as reservoirs for habitats and species, but also as nodes of environmental resilience (European Environment Agency 2010). Furthermore, the economic benefits that PAs can provide are now valued much more than in the past, and Europeans now expect these sites to attract tourists, supply natural resources, and in general to provide the key ecosystem services that are crucial for their livelihood (CREDOC 2008; European Environment Agency 2010).

European legislation on PAs is extensive, complex and continuously evolving. At EU level, several directives have been particularly important for the creation of PAs. Both the EU Birds Directive and the Habitats Directive envisage the creation of PAs as a means of achieving their objectives (see e.g. Gaston et al. 2008 for evaluation of their effectiveness and state of the art). The Special Protected Areas (SPAs) classified under the Birds Directive, and the Special Areas of Conservation (SACs) designated under the Habitats Directive form the Natura 2000 network.

It must be stressed that the establishment of this network (but also its close relative, the Emerald Network[2]) was a turning point in the history of European PAs which contributed to the considerable expansion of the existing system. Through this tool Europe has created the most extensive PA system in the world, which currently (as of the end of 2012) comprises more than 26,000 sites.

In 2001, as part of its commitments to the CBD, the European Commission adopted the biodiversity strategy "Our life insurance, our natural capital: an EU biodiversity strategy to 2020", that, among other targets, commits to improve the conservation status of species and habitats by 2020 and to maintain, enhance and restore ecosystems and their services by the same date. No specific target on the coverage of PAs was included in the Europe Biodiversity Strategy, while CBD target 12 calls to conserve by 2020 "at least 17 % of terrestrial and inland water, and 10 % of coastal and marine areas (. . .) through effectively and equitably managed, ecologically representative and well-connected systems of protected areas . . ." This European decision reflects a shift from designation of new PAs toward a full implementation and enforcement of protection of species and habitats included in the Habitat Directive (in fact, Action 1 of the EU Strategy calls to a full establishment and good management of Natura 2000 sites); in this regard it must be stressed that the need to pass from legal protection to the effective management of PAs is indeed considered a crucial advancement at the global scale (Jenkins and Joppa 2009). Moreover, it must be recalled that Target 5 of the EU Biodiversity Strategy strives to identify pathways of invasions for improving prevention, and to prioritise invasive alien species (IAS) for control. As far as the legal framework on IAS is concerned, the EU has committed itself by a decision of the European Union Council of June 25th 2009, to develop a dedicated legislative instrument on the issue, also mentioned in the above mentioned EU Biodiversity Strategy. However, at this stage the scope and coverage of the instrument are not yet clear.

11.3 Big Picture: Continental Patterns

Globally, a call for developing lists of alien species in PAs was made already in the late 1990s. Usher (1988) summarised available information from 24 nature reserves all over the world, but this data set included only two PAs from Europe (Isle of Rhum, UK and Salvage Islands, Portugal). The most complete data exist for the

[2] The Emerald Network, now under development as part of the Bern Convention, is conceptually similar to the Natura 2000 network, but it incorporates more countries. As the European Union is also a signatory to the Bern Convention, the Natura 2000 network can be considered as the contribution of the EU to the Emerald Network. The Emerald Network works as an extension to non-EU countries of Natura 2000. At present, non-EU countries engaged in the constitution of the Emerald Network are Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Croatia, Georgia, Iceland, Moldova, Montenegro, Norway, the Russian Federation, Serbia, Switzerland, Turkey, Ukraine, and the former Yugoslav Republic of Macedonia (European Environment Agency 2012).

Table 11.1 Summary of available data on representation of alien species in European protected areas

Protected area	Country	Area (ha)	Total species number	Number of alien species	Inclusion criteria	% of alien	reference
Thayatal-Podyjí National Park	Austria/Czech Republic	22,700	1,287	116	neophyte	9.0	Grulich (1997)
Mt Medvednica Nature Park	Croatia	22,826	1,352	27	invasive	2.0	Vuković et al. (2010), native: Dobrovic et al. (2006)
Maksimir Park	Croatia	407	443	16	invasive	3.6	B. J. Hutinec, unpublished data
Gajna Protected Area	Croatia	1,500	235	13	invasive	5.5	Kumbarić (1999)
Labské pískovce Landscape Protected Area	Czech Republic	25,000	1,300–1,400	107	naturalised aliens	8.2–8.9	AOPK (2009)
various (n = 302)	Czech Republic	36,500	2,152 (total)	312 (total)	alien	6.1 (mean)	Pyšek et al. (2004a)
La Brede: reserve naturelle geologique de Saucats	France	75	366	15 (11)	aliens (invasive)	4.1 (3.0)	C. Gréaume, unpublished data
Etang des Landes	France	100	414	3	alien	0.7	K. Guerbaa, unpublished data
Réserve Naturelle Nationale du Bois du Parc	France	45	242	0	alien	0.0	RN Bois du Parc administration, unpublished
Réserve naturelle nationale de la Sangsurière et de l'Adriennerie	France	396	270	2	invasive	0.7	C. Binet, unpublished data
Eifel National Park	Germany	11,000	920	140 (19)	alien (invasive)	17.9 (3.3)	A. Pardey, unpublished data
Asinara National Park	Italy	74,653	n.a.	78	common aliens	n.a.	Camarda et al. (2002)
Arcipelago di La Maddalena National Park	Italy	5,134	n.a.	113	common aliens	n.a.	Camarda et al. (2002)
Selva del Lamone Natural Reserve	Italy	2,002	870	14	alien	1.6	L. Carotenuto, unpublished
Salvage Islands National Park	Portugal	400	107	15	alien	14.0	Brockie et al. (1988)
Sefton Coast, North Merseyside	UK	2,100	1,327	530	alien	40.0	Smith (2012)
Isle of Rhum National Reserve	UK	10,650	520	60	alien	11.5	Brockie et al. (1988)
Mid Yare Reserve	UK	780	572	54	alien	9.4	T. Strudwick, unpublished data

Czech Republic, the only country where a thorough analysis of plant invasions in nature reserves has been published (see Case study 1). However, even this study did not distinguish between invasive and non-invasive aliens and analysed the patterns of species richness and their determinants for all alien plants (Pyšek et al. 2002). The only other summarizing studies are the one on 10 PAs in Slovenia, which focuses on 32 selected alien species (Veenvliet and Humar 2011), and the recent account of the mapping invasive species in PAs on Mediterranean islands (Brundu 2014).

Besides the few published studies listed in Table 11.1, and unpublished reports, some continent-wide data are available from a recent web survey aimed at managers in European PAs that yielded 138 responses from 21 European countries (A. Monaco and P. Genovesi, unpublished). These data provide insights on the quality of information currently available for Europe. Of the total responses received, 95 (79 %) indicated that they have some list of alien plant species available, but the vast majority of lists included only a few invasive plant species of concern. Also, there is much variation in how invasive species are defined, with many data sets not being based on standard scientific criteria (Fabiszewski and Brej 2008; Lamprecht 2008; Schiffleithner and Essl 2010). Data resulting from the survey (Table 11.1) clearly indicates that in some PAs the focus is only on invaders that have some impact on native species and ecosystems, or are otherwise considered important. The proportions of alien/invasive species are therefore not comparable among individual regions. The data nevertheless suggest that the overall variation is within the global range of 5–30 % representation of alien species reported by Usher (1988). In general, the percentage of all aliens in European PAs is within the range of 6–18 %, while that of invasive species, where given and bearing in mind differences in definitions adopted by individual PAs, varies between 2.0 and 5.5 % (Table 11.1). A high number and proportion of aliens in the Sefton Coast PA from where 40 % alien plants are reported is caused by including also casual alien species (P. Smith, unpublished).

From the above it follows that the information on plant invasions in European PAs is surprisingly scarce and mostly scattered in unpublished reports and the grey literature (e.g. AOPK 2009; Bacchetta et al. 2009). Compared to other regions of the world, Europe does not have a comprehensive list of alien plants at least for some kinds of PAs such as national parks in USA (McKinney 2002) and South Africa (Spear et al. 2011), or a subset of PAs delimited by habitat in New Zealand (Timmins and Williams 1991). That invasions in European PAs are seriously understudied is rather surprising since in general terms, this continent is among those where plant invasions are most intensively studied (Pyšek et al. 2008). Furthermore, the majority of available reports are of little use for robust comparison or analysis of factors that determine the levels of invasion due to their incompleteness and selectivity about which species to include. This is also reflected in how often studies on impact are conducted in PAs compared to non-protected areas. In this respect, Europe also lags behind other regions of the world, with little focus on studying impacts directly in PAs (Hulme et al. 2013; Foxcroft et al. 2014a).

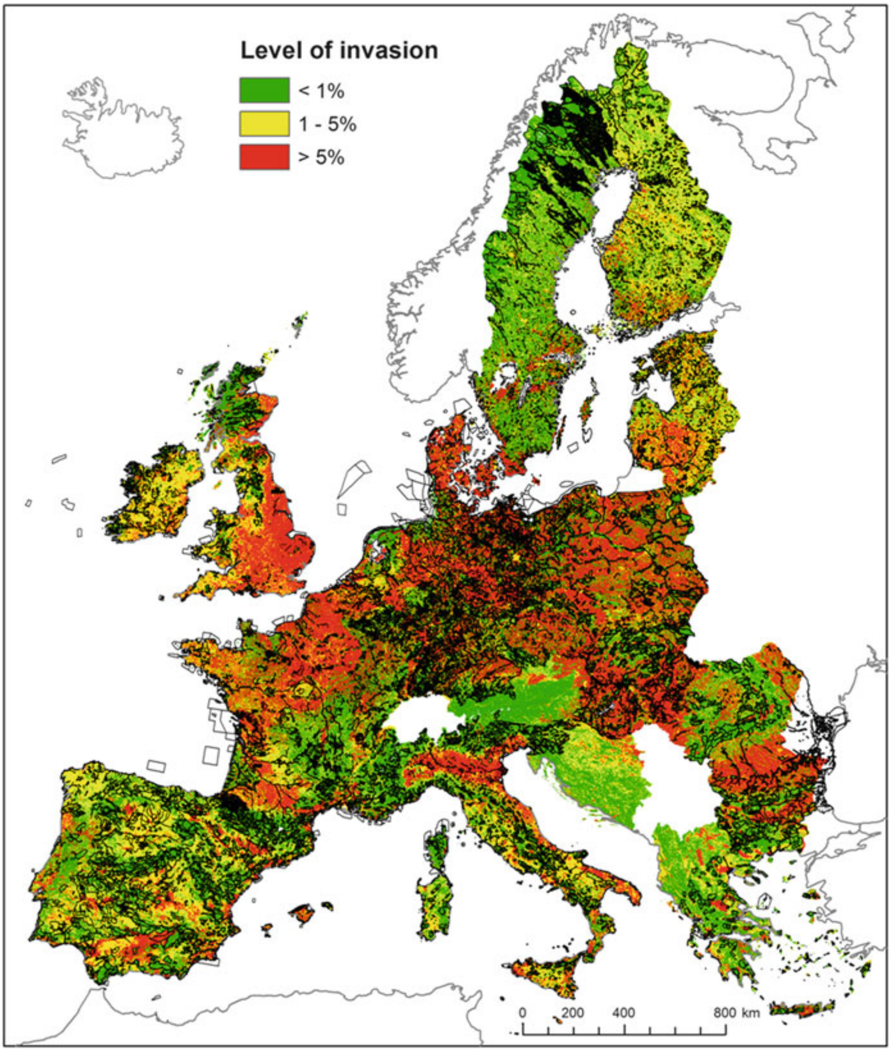

Fig. 11.3 Map of the level of invasion in Europe based on the mean percentage of neophytes (plant species introduced to Europe after ca 1500 A.D.) in vegetation plots corresponding to individual CORINE land-cover classes. Within the mapping limits, areas with non-available land-cover data or insufficient vegetation-plot data are blank. Taken from Chytrý et al. (2009); reproduced courtesy of Blackwell Scientific Publications. The position of Natura 2000 sites is shown in black (not available for some countries)

An indirect insight into the threat from plant invasions in PAs in Europe is provided by comparing the geographical distribution of Natura 2000 sites with the level of invasion in European regions derived from the map of plant invasions at the continent (Fig. 11.3). The overall picture reveals that areas of conservation interest, represented by the Natura 2000 network[3], are located in areas less threatened by invasions; this is most obvious in UK, the Mediterranean region and southern Europe. The map, however, also indicates that in many regions, namely in central and Eastern Europe, Natura sites are often located in landscapes that are heavily invaded. Overall, areas containing Natura 2000 sites are about half as invaded (containing on average 1.8 % alien species in vegetation plots; see Chytrý et al. 2009 for details on calculations) as areas without Natura 2000 sites (3.5 %).

11.3.1 Case Study 1. Regional Patterns Illustrated by Protected Areas in the Czech Republic

Surprisingly, the only comprehensive study dealing with a detailed pattern of plant invasions into European PAs seems to be the one from the Czech Republic (Pyšek et al. 2002, 2003a). These data can be used to illustrate regional patterns of invasions into natural temperate plant communities.

Based on over 300 PAs of various status and size (representing 17 % of the number of PAs in the country and 44 % in terms of protected land area), the study showed that the level of PAs invasion by neophytes (modern invaders introduced after the end of the Medieval Period; Pyšek et al. 2004b, 2012a, b) was determined by an interplay of environmental and human-related factors, the most important being climate (decreasing level of invasion with increasing altitude due to colder conditions), propagule pressure (increasing in areas with a high human population density and indirectly pointing to previously reported effects of visitation; Usher 1988; Macdonald et al. 1989; Lonsdale 1999; McKinney 2002; Mortensen et al. 2009), and habitat heterogeneity (indicated by the positive relationship with the number of native species; cf. Timmins and Williams 1991). On average only 6.1 % of plant species recorded in a PA were alien. However, there was a great variation in the level of invasion among particular sites and in some PAs the proportion of alien species was as high as 25 %. Of the two standardly distinguished categories of alien plants in Europe, based on the time of immigration, neophytes were less represented, only 2 % of the total number of species (Pyšek et al. 2002). As neophytes are the group from which the majority of important invaders are recruited in Europe (Lambdon et al. 2008), the data indicate that the overall threat from alien species in Czech nature reserves was relatively minor.

However, the overall level of invasion based on the presence of all aliens is only part of the story. Although this measure was shown to be correlated with the presence of

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[3] The degree of overlap between nationally designated PAs and Natura 2000 sites is variable; in some countries, as Malta, Estonia, Latvia, there is no overlap because there was no developed pre-existing national system of PAs (Gaston et al 2008). In other countries (e.g. Cyprus, Bulgaria, Denmark, Ireland) the overlap is more than 80 %. Other figures include, e.g.: Italy and France >40 %; Poland and Spain >60 %, Germany ~10 %, Czech Republic >20 % (source European Topic Centre on Biological Diversity – ETC/BD, 2009).

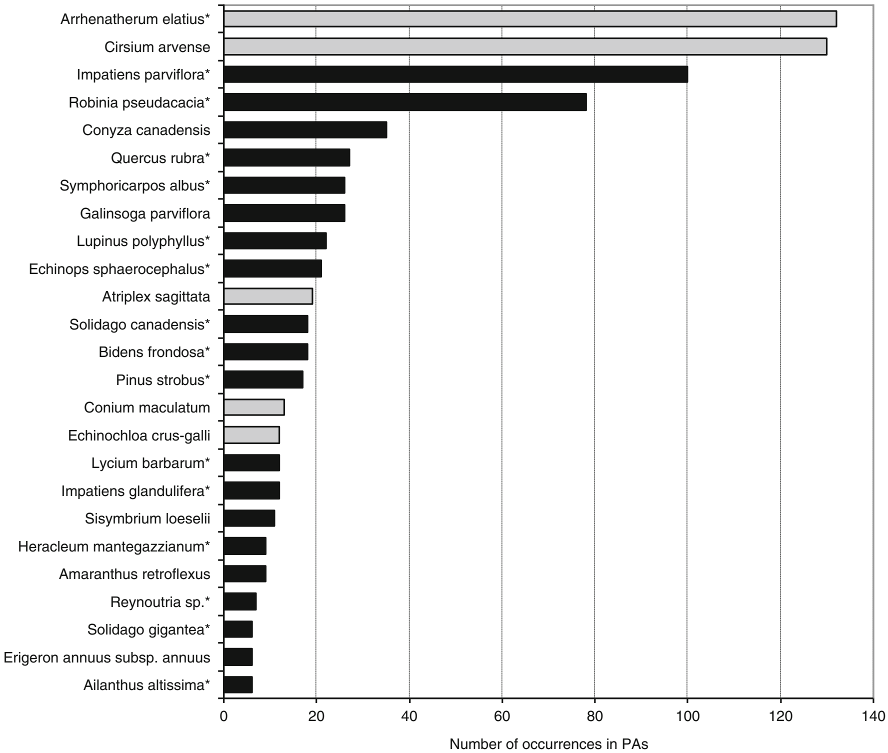

Fig. 11.4 Occurrence of invasive species in protected areas in the Czech Republic, showing the number of protected areas in which the species was recorded. Based on data in Pyšek et al. 2002, with the delimitation of an invasive species following Pyšek et al. 2012b (as invasive are considered only those that currently spread in the country). Archaeophytes (introduced to the country before 1500 A.D.) are shown as *grey bars*, neophytes (introduced after that date) in *black*. Species that are not restricted to disturbed sites and are capable of invading natural vegetation are marked with *asterisks*

major invasive plants at the continental scale of Europe (Chytrý et al. 2012), focusing on invasive species (in the sense of Richardson et al. 2000; Blackburn et al. 2011) provides deeper insights into the real threats posed by invasions. Of the total number of 50 neophytes and 11 archaeophytes currently considered as invasive in an updated national checklist (Pyšek et al. 2012a, b), 31 and 8, respectively, were recorded in the investigated sample of PAs. This corresponds to rather high percentage of the total, 62 and 72 %, respectively, a much higher figure than for all neophytes (Pyšek et al. 2002). While many invasive aliens occur only occasionally, 25 were recorded in at least five PAs and some are rather widespread – the top four species were present in at least 25 % of the PAs studied (Fig. 11.4). This group includes some neophytes invading also in semi-natural habitats, such as *Robinia pseudoacacia* (black locust), *Quercus rubra* (northern red oak), *Lupinus polyphyllus* (large-leaved lupin), *Solidago canadensis* (Canada goldenrod), *Pinus strobus* (eastern white pine), *Heracleum mantegazzianum* (giant hogweed), or *Fallopia* (knotweed) taxa. The impact of these

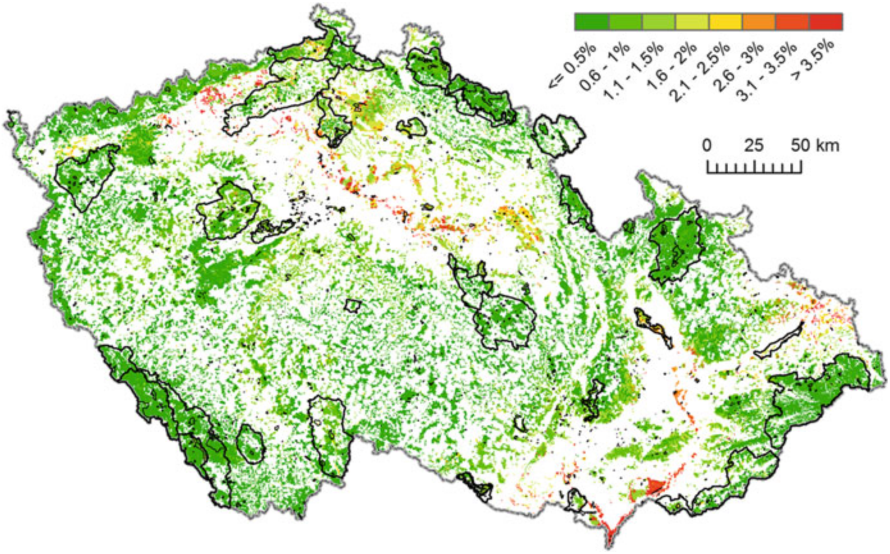

Fig. 11.5 Map of the level of invasion in seminatural habitats in the Czech Republic based on a quantitative assessment of the proportion of neophytes among the total number of species in vegetation plots located in 35 terrestrial habitat types at different altitudes (see Chytrý et al. 2009 for details on methods). The network of protected areas, as of 1994, is displayed as *black areas*; large areas are outlined. Based on the map published in Chytrý et al. (2009), reproduced courtesy of the Czech Botanical Society

species on invaded communities has been documented in the national and continental literature (DAISIE 2009; Hejda et al. 2009; Pyšek et al. 2012b, c) and the group includes a number of woody species, invasions of which are known to be especially devastating (Richardson and Rejmánek 2011). Similar results pointing to relatively high potential for future invasions emerged from a finer-scale study of 48 urban reserves in the city of Prague; these reserves harbour a comparable figure of about two-thirds of invasive neophytes recorded in the country, and many of the most invasive species are shrubs and trees (Jarošík et al. 2011). This indicates that overall levels of invasions derived from numbers of all aliens may not provide a reliable picture about the magnitude of threat from invasions, and management plans need to be designed for individual reserves based on the occurrences of major invasive species.

That the degree of threat of invasions in PAs varies at the country scale, depending on geographic conditions, climate, altitude and intensity of human influence, can be illustrated by a national map of plant invasions, based on a quantitative assessment of the proportion of neophytes among the total number of species in vegetation plots located in particular habitat types. Generally, mountain reserves are little affected but some PAs are located in heavily invaded regions such as lowland sandy areas and river corridors (Fig. 11.5).

At the global scale, nature reserves are invaded about half as much as sites outside reserves (Lonsdale 1999). This difference seems to be even more pronounced at the regional scale of the Czech Republic: the network of PAs analysed in the Czech data set captured about 80 % of the country's native flora but less than 20 % of neophytes (Pyšek et al. 2002). The mechanism underlying this phenomenon is that it is more difficult for alien species to colonise PAs than corresponding sections of non-protected landscape because natural vegetation acts as a buffer against plant invasions (see also Foxcroft et al. 2011). Among PAs in the Czech Republic those established long ago harbour significantly fewer neophytes than those established more recently, and the neophytes from a rapidly increasing pool of species in the surrounding landscapes were not captured over time in the PA network any faster than were native species from the pool available at the time of establishment of the first reserves (Pyšek et al. 2003b). This suggests that natural vegetation in nature reserves creates an effective barrier against the establishment of alien species (see also Meyerson and Pyšek 2014).

11.4 The Most Invasive Plant Species in European Protected Areas

At the species level, what information is available on the most serious plant invaders in European PAs and how does this continent stand compared to others? A summary is provided by De Poorter (2007) in her scoping report produced for the World Bank as a contribution to the Global Invasive Species Programme (GISP). This study emphasises that there is a shortage of consolidated information at global, international and/or regional level, on IAS impacts, threats and management in PAs. It also found that a wealth of information is available at site and national levels, but that it is very dispersed and not standardised, which makes it difficult to get a balanced global picture (De Poorter 2007).

De Poorter (2007) list 58 significant invasive plant and animal species for Europe, the criterion for inclusion being that they have impact and represent threat to PAs. This number, although the comparison is biased by different sizes of regions, places Europe in the middle of the range given for continents; the number of plants and animals these authors list as invasive in PAs in USA and Canada is 109 (84 of which are plant species), in Australia and New Zealand 87 (57), Africa 58 (47), Asia 43 (30), Oceania 19 (13), and South and Central America and Mexico 18 (10). Among the 58 European invaders there are 37 plants. The list includes 25 trees and shrubs, eight perennials, and four annuals. Although the results of the survey were influenced by the limited information accessible (De Poorter 2007), the species perceived as problematic in European PAs nevertheless overlap to a large degree with those known to be invasive in Europe in general, i.e. also outside PAs (DAISIE 2009).

A more detailed picture of how the major invasive plants are distributed in European PAs can be inferred from the above mentioned web survey (A. Monaco and P. Genovesi, unpublished) in which managers reported species they consider most harmful to their areas (Table 11.2). Among the 378 taxa listed at least once, the top invasive species are *Fallopia japonica* (Japanese knotweed, which most

Table 11.2 Plant species reported as most harmful in European protected areas by managers

Taxon	LH	Origin	Number of PAs	Number of European regions
Fallopia japonica et sp.	p	Asia	48	36
Impatiens glandulifera	a	Asia	29	34
Robinia pseudoacacia	t	N America	26	42
Ailanthus altissima	t	Asia	16	36
*Heracleum mantegazzianum**	p	Asia	11	25
Ambrosia artemisiifolia	a	N America	10	33
*Solidago canadensis**	p	N America	9	36
Solidago gigantea	p	N America	8	32
Amorpha fruticosa	s	N America	7	17
*Elodea canadensis**	p	N America	6	38
Acer negundo	t	N America	6	33
Acer pseudoplatanus	t	Europe	6	19
Prunus serotina	s	N America	5	24
*Baccharis halimifolia**	s	N America	4	6
*Buddleia davidii**	s	Asia	4	23
Caulerpa racemosa	al	Africa	4	15
*Echinocystis lobata**	a	N America	4	15
*Heracleum sosnowskyi**	p	Asia	4	7
*Impatiens parviflora**	a	Asia	4	31
*Opuntia ficus-indica**	p	C America	4	13
*Phytolacca americana**	p	N America	4	29
Carpobrotus edulis	p	Africa	4	22
*Asclepias syriaca**	p	N America	3	18
*Datura stramonium**	a	N America	3	42
Rhododendron ponticum	s	Europe, Asia	3	10
*Senecio inaequidens**	a	Africa	3	26
Xanthium italicum	a	N America	3	20

Based on web survey (A. Monaco and P. Genovesi, unpublished; see text for details)
Number of PAs (n = 118) in which the species ranked among the most harmful invasive plants is shown and compared with the overall distribution in Europe, expressed as the number of regions in which it occurs, based on DAISIE database (DAISIE 2009)
Species missing from the European list presented in a global survey of De Poorter (2007, see text) are marked with asterisk
LH life history, *a* annual, *p* perennial, *s* shrub, *t* tree, *al* alga

likely includes other European taxa of this genus such as *F. sachalinensis*, giant knotweed, and the hybrid *F.* ×*bohemica*; Pyšek 2009), reported to have impact in 41 % of the total number of surveyed PAs, *Impatiens glandulifera* (Himalayan balsam; 25 %), *R. pseudoacacia* (22 %), *Ailanthus altissima* (tree of heaven; 14 %), *H. mantegazzianum*[4] (9 %), and *Ambrosia artemisiifolia* (common ragweed; 9 %). Interestingly, a number of species perceived as the top invaders at the site level in European PAs are not listed for this continent in the above mentioned global survey

[4] This may include also related species *H. sosnowskyi* and *H. persicum* (Jahodová et al. 2007).

for Europe (De Poorter 2007; Table 11.2) which supports the concerns about the quality of information available. Missing from the global list are some species whose absence can be attributed to taxonomic issues (e.g. *S. canadensis*, *Opuntia ficus-indica*, prickly pear).

11.5 Magnitude of the Problem: Impact and Management

The screening conducted by De Poorter (2007) revealed that IAS are reported as having impact in 144 PAs surveyed, located in 29 European countries. Those numbers are, in absolute terms, higher than in other regions of the world, for the number of PA sites approximately twice as many as in Africa, Asia, Americas and Australia with New Zealand. Globally, the study showed a significant number of PAs where IAS have been recorded as an issue (De Poorter 2007). However, a rigorous data set recently assembled on global impacts of invasive plants on species, communities and ecosystems (Vilà et al. 2011; Pyšek et al. 2012c) indicates that in Europe, studies on ecological impacts are conducted in PAs disproportionally less frequently than on other continents. Europe contributes only 5 % to the total number of impacts tested in PAs but 31 % to those resulting from studies conducted outside PAs (P. Hulme et al. 2013).

An insight into how impacts of invasive plant species are perceived by the administration of PAs in Europe is provided by the web survey (A. Monaco and P. Genovesi, unpublished). In general, merging both plants and animals, competition with native species and changes imposed to the habitats and ecosystem functioning are considered as the most serious impacts of invasive species in European PAs (Fig. 11.6). Interestingly, a comparison with rigorous data available from the recent analysis of impacts of invasive plants reveals that the ranking of impacts perceived by managers corresponds well to the ranking of impacts resulting from published scientific studies, as reported in Pyšek et al. (2012c). The impacts that can be largely attributed to competition, i.e. those on richness, diversity and abundance of resident species, are most likely to be significant, and those affecting habitats, i.e. mainly on soil properties, come second.

Closely linked with impacts are management options that PA managers in Europe consider to be most effective (Fig. 11.7). They perceive eradication and control to be the best approaches for dealing with invasive species. The fact that European PA managers consider these two measures more important than prevention, education or public involvement, probably reflects the approach often adopted in PAs that tend to focus more on responding to invasions than working on prevention, although prevention is increasingly viewed as the best management option (Pyšek and Richardson 2010; Meyerson and Pyšek 2014). Interestingly, if available management options are compared with what is actually being implemented (Fig. 11.7), several issues emerge. The most frequently implemented action against alien species in PAs is monitoring. Both active management options, eradication and control, are in reality highly under-represented compared with how

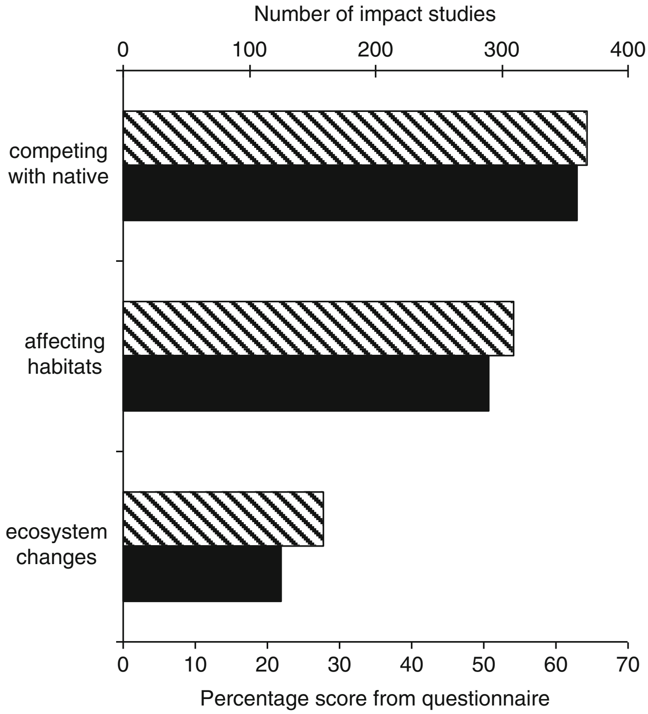

Fig. 11.6 Comparison of the most serious impacts of plant invasions as perceived by managers of protected areas in Europe (based on a web survey of A. Monaco and P. Genovesi, unpublished) with data from studies rigorously testing impact in European PAs. The former measure (hatched columns) is a percentage score calculated from the received responses. Managers were asked to rank the five most serious impacts in their PA on a semi-quantitative scale, and these were scored from 5 to 1; the full score (100 %) would therefore correspond to an impact perceived by all managers in all PAs as the most serious. The latter measure (*black columns*) are percentages of significant impacts among all tested, as addressed by studies conducted within protected areas, based on 574 individual cases (see Pyšek et al. 2012c for details on primary data, and Hulme et al. 2013, for the frequency of studies conducted in PAs). Tested impacts were grouped so as to correspond to the categories delimited by the web survey

frequently they are suggested by managers as being the best strategy. The same is true for prevention which is assumed to be most effective and cheapest measure. Well represented by real activities is part of prevention devoted to education and public involvement where communication towards public is highly used. A clear message from such comparisons is to act as early as possible when the infestations are relatively small to be effectively manageable, instead of relying on long-term monitoring (Mack and Lonsdale 2002; Simberloff 2003; Pluess et al. 2012).

Unfortunately, the ability of many European PAs to withstand biological invasions is limited by inadequate management, not only concerning biological invasions but also in general terms. As a result of this inadequacy, it has been estimated that less than 20 % of the species and habitats listed by the Habitats Directive have a

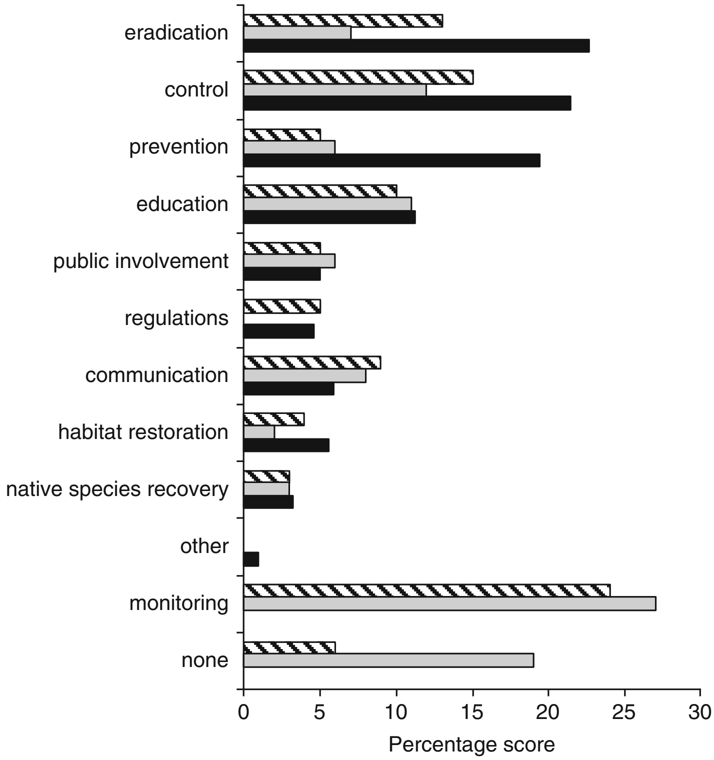

Fig. 11.7 Comparison of the management options considered by managers of protected areas as most effective (*black columns*, measured as the cumulative score from the questionnaire for both plants and animals) with the frequency of how actual measures are implemented (hatched for plants, *grey* for animals). Based on a web survey (A. Monaco and P. Genovesi, unpublished); see Fig. 11.6 for details on calculation of the percentage score

favourable conservation status in Europe (European Environment Agency 2012), similar to the situation globally (Bertzky et al. 2012). According to the adaptive management framework approach (Walters 1986; Foxcroft 2004), knowledge and expertise improve by practice, i.e. actually doing things. Therefore management actions in European PAs are often being undertaken even though the full extent of the problem is not known, especially if only a few invasive species need to be eradicated or contained rapidly. So, in a number of PAs in Europe actions were taken to control or eradicate invasive plants, for example, *Amorpha fruticosa* (desert false indigo) in Croatia (Council of Europe 2011), or management actions against invasive plants in national parks in Poland (M. Opęchowska, unpublished). These efforts were often part of LIFE projects aimed at ecological restoration within Natura 2000 sites (Scalera and Zaghi 2004; Table 11.3; see also Case study 2).

A major challenge to the management of European PAs relates to on-going global change, especially climate change. There is strong evidence in the literature that climate change is likely to result in changes in species' distributions. However,

Table 11.3 Selected LIFE projects conducted in Europe aimed to control or eradicate invasive and alien plants in Natura 2000 sites

LIFE project no.	Name	Period	Country	Major target IAS	Habitat
LIFE95 ENV/F/000782	Control of the *Caulerpa taxifolia* extension in the Mediterranean Sea	1996–1999	France	*Caulerpa taxifolia*	Posidonia beds
LIFE96 NAT/E/3180	Restoration and integrated management of the Island of Buda	1996–2000	Spain	*Phoenix* spp., *Washingtonia* spp.	Atlantic insular ecosystems
LIFE97 NAT/UK/004244	Restoration of Atlantic Oakwoods	1997–2001	UK	*Rhododendron ponticum*, non-native conifers	Atlantic forest
LIFE97 NAT/UK/004242	Securing Natura 2000 objectives in the New Forest	1997–2001	UK	*Rhododendron ponticum*, non-native conifers	Heathland
LIFE97 NAT/P/004082	Management and conservation of the Laurisilva Forest of Madeira	1998–2000	Portugal	*Hedychium gardnerianum*	Laurel forest
LIFE97 NAT/IT/4134	Restoration of alluvial woods in the Ticino Park	1997–2000	Italy	*Prunus serotina*, *Robinia pseudoacacia*, *Ailanthus altissima*, *Quercus rubra*	Wet woodlands
LIFE98 NAT/A/5418	Pannonian sand dunes	1998–2002	Austria	*Ailanthus altissima*, *Robinia pseudoacacia*	Relict dunes
LIFE99 NAT/E/6392	Restoration of the islets and cliffs of Famara (Lanzarote Island)	1999–2002	Spain	*Nicotiana glauca*	Atlantic insular ecosystems
LIFE00 NAT/UK/007074	Woodland habitat restoration: Core sites for a forest habitat network	2001–2005	UK	*Rhododendron ponticum*	Atlantic forest
LIFE00 NAT/E/007339	Dunas Albufera: Model of restoration of dunes habitats in 'L'Albufera de Valencia'	2001–2004	Spain	*Carpobrotus edulis*	Coastal dunes
LIFE00 NAT/E/7355	Conservation of areas with threatened flora on the Island of Minorca	2001–2004	Spain	*Carpobrotus edulis*	Mediterranean insular ecosystems
LIFE03 NAT/IT/000139	RETICNET 5 SCI for the conservation of wetlands and main habitats	2003–2006	Italy	Unspecified	Alpine wetland

LIFE03 NAT/FIN/000039	Lintulahdet: Management of wetlands along the gulf of Finland migratory flyway	2003–2007	Finland	*Phragmites australis*	Wetland
LIFE04 NAT/ES/000044	Recovery of the littoral sand dunes with *Juniper* spp. in Valencia	2004–2007	Spain	*Carpobrotus edulis*, *Agave americana*	Mediterranean dunes
LIFE04 NAT/CY/000013	Conservation management in Natura 2000 sites of Cyprus	2004–2008	Cyprus	*Robinia pseudoacacia*, *Eucalyptus regnans*	Mattoral
LIFE05 NAT/D/000051	Large herbivores for maintenance and conservation of coastal heaths	2005–2009	Germany	*Prunus serotina*	Heathland
LIFE05 NAT/NL/000124	Dutch coastal dunes: Restoration of dune habitats along the Dutch coast	2005–2011	The Netherland	Unspecified	Coastal dunes
LIFE05 NAT/IT/000037	DUNETOSCA: Conservation of ecosystems in northern Tuscany	2005–2009	Italy	*Yucca gloriosa*, *Amorpha fruticosa*	Mediterranean coastal ecosystems
LIFE05 NAT/IRL/000182	Restoring priority woodland habitats in Ireland	2006–2009	Ireland	*Picea abies*, *Picea sitchensis*, *Larix decidua*, *Pinus radiata*, *Fagus sylvatica*, *Acer pseudoplatanus*, *Aesculus hippocastanum*, *Laurus nobilis*, *Fallopia japonica*, *Rhododendron ponticum*	Woodland
LIFE05 TCY/CRO/000111	IBM, Central Posavina: Wading toward integrated basin management	2006–2008	Croatia	*Amorpha fruticosa*, *Xanthium* spp.	Floodplain ecosystem
LIFE08 NAT/IT/000353	Montecristo 2010	2010–2014	Italy	*Ailanthus altissima*, *Carpobrotus* spp., *Pinus halepensis*, *Acacia pycnantha*	Mediterranean insular ecosystems

the current networks of PAs may no longer be effective in conserving biodiversity under rapidly changing climatic conditions because they were designed on the basis of a paradigm of long-term stability of species' geographical distributions (Huntley et al. 2011). It is widely acknowledged that PAs will soon have to face changes due to global change. This also has important implications for the design of new PAs in that core areas need to be secured to accommodate predicted changes (Hannah 2001; Hannah et al. 2007). However, information on how these processes could influence the distribution/abundance of plant invasions in PAs is very scarce (see Kleinbauer et al. 2010; Case study 3).

11.5.1 Case Study 2. Management of **Rhododendron ponticum** *in Protected Areas in the UK*

An alien plant species that is causing major conservation problems in European PAs is *Rhododendron ponticum* (rhododendron). This densely branched evergreen shrub produces several million seeds per bush; the seeds are dispersed over long distances (up to 100 m) by wind and water under favourable open conditions, but over shorter distances in closed canopy forest, and remain viable in soil for several years. The plants are also capable of limited branch rooting in contact with soil, usually only at forest edges, and sprout vigorously after cutting (Stout 2007; Hulme 2009). It is unpalatable to vertebrates and few insects feed on the plant. The species represents an invader that is native to part of Europe but is an invasive alien outside its native range (see Lambdon et al. 2008). Formerly widely distributed throughout Europe during the Tertiary, the extant native range is disjunct with *R. ponticum* subsp. *baeticum* occurring in Iberian Peninsula, and subsp. *ponticum* occurring around the Black Sea. The species was introduced to parts of Europe where it is now invasive as an ornamental plant (Milne and Abbott 2000; Erfmeier and Bruelheide 2010) and it is still available from nurseries. It is naturalised in the British Isles and western continental Europe, and the extent of invasion is increasing. The shrubs often completely dominate the invaded area, accumulate thick litter layers allowing a few plants to survive under the canopy (Hulme 2009), and integrate into existing pollination networks (Vilà et al. 2009). The invasion success of *R. ponticum* has been attributed to the greater environmental suitability of the new regions, a wider range of favourable habitat types (Shaw 1984; Erfmeier and Bruelheide 2010), but also to genetic shift in invasive populations towards an increased investment in growth and a faster germination rate, and genotype × environment interactions play a major role during the invasion process. Both hybridization and ecological release from constraints experienced in the native range are plausible explanations for its success (Erfmeier and Bruelheide 2005).

After the initial introduction to UK in 1763, it was introduced to many private estates, parks and woodlands for game cover, mainly from Spanish populations. It was recorded as naturalised by the late nineteenth century and spread widely in the

Fig. 11.8 Invasion of *Rhododendron ponticum* in Killarney National Park, Ireland (Photo: P. Pyšek)

twentieth century (Scalera and Zaghi 2004). The species became highly invasive in semi-natural forests and woodlands, but also heaths, bogs and sand dunes on a wide range of damp acid substrates over British Isles (Fig. 11.8; Cross 1975; Foley 1990; Gritten 1995), negatively impacting numerous habitats identified for protection under the EU Habitats Directive).

In Snowdonia National Park, Wales, it was first planted as an ornamental shrub in large estates, and extensively used as rootstock for grafting ornamental varieties (Gritten 1995). Control efforts started to appear in 1980s (e.g. Shaw 1984; Gritten 1992, 1995), but by the time it has been generally accepted that control was needed, the extent of the effort required was huge, over landscapes (Scalera and Zaghi 2004). For example, the costs of control at a park-wide scale were estimated at £45 million at 1992 prices (Gritten 1995). Since 1997 the EU has co-financed five LIFE Nature projects (http://ec.europa.eu/environment/life; Table 11.3) to tackle the problem of invasion by rhododendron in England, Scotland and Wales, with focus on eradicating rhododendron populations from the core Natura 2000 areas, providing a *cordon sanitaire* around the treated sites and to work with private landowners and communities to seek support for a coordinated programme. The techniques employed involve the widespread removal of plants using mechanical methods, burning the cut plants, removing root mats to expose fresh soil, and controlling re-growth with herbicides. One of the LIFE projects was aimed at the large-scale removal of rhododendron from woodlands at Loch Sunart, western Scotland. The project mobilised private landowners by covering 95 % of the costs, and higher payment rates were offered for work within Natura 2000. In a follow-up project in Loch Sunart it appeared that until all sources of seed are tackled the threat of reinvasion persisted and not all landowners supported the continuation of eradication programme. Another project resulted in clearing of 110 ha of rhododendron-invaded heaths and woods in the New Forest National Park, followed by monitoring to ensure that any new foci were quickly targeted for management. As an additional constraint, the eradication projects faced obstacles due to rhododendron's popularity as a garden plant. Overall, despite the long-term effort and the huge investment of resources, rhododendron remains a problem in and near PAs and Natura 2000 sites. Besides a call for a general change in attitude, the replacement of cultivated stock by planting of dwarf sterile rhododendron hybrids has been suggested as a solution (Scalera and Zaghi 2004).

Rhododendron ponticum is an example of a highly invasive species whose distribution across Europe, including PAs, is rather localised (Lambdon et al. 2008; DAISIE 2009). Nonetheless, it is one of the most invasive species in European PAs, incurs great economic costs, and attempts to undertake coordinated control efforts have been ineffective. For example, in Scotland it still considered one of the most noxious plant invaders, with £1.6 million spent on its management in 2011–2012 in several districts (Forestry Commission Scotland 2012).

11.5.2 Case Study 3. Climate Warming Will Drive the Invasive Tree **Robinia pseudoacacia** *into Nature Reserves*

Robinia pseudoacacia is among the most widespread invasive plant species in Europe (Lambdon et al. 2008), in central Europe it is among those with the broadest habitat range (Chytrý et al. 2005), and it is invasive in most countries (Essl and Rabitsch 2002; Pyšek et al. 2009b, 2012a, b; Medvecká et al. 2012). This deciduous tree, native to central and eastern North America, is up to 30 m tall and grows as an early successional species in open and disturbed habitats. It has a good regeneration capacity, resprouting well from roots and stumps. It was introduced to Europe in 1601 as an ornamental species, and was later used for timber production and erosion control (Başnou 2009; Pyšek et al. 2012a). As a nitrogen fixing species, it can achieve early dominance on open sites where nitrogen is limiting to other species, and ecological impacts of this species on biodiversity and ecosystem functioning are well documented (Kowarik 2003; Rice et al. 2004).

In a study on the current and future distribution of *R. pseudoacacia* in Austria, using niche-based predictive modelling, Kleinbauer et al. (2010) investigated whether the predicted dynamics might represent invasion threat to the existing network of Natura 2000 sites. By doing this, the study addressed potential problems resulting from the static nature of the PAs network that disregards the dynamics of species ranges; this issue will be increasingly relevant under on-going environmental change, including global warming, that will potentially shift the distribution of suitable habitats for many species that are nowadays protected in areas designated based on their distribution in the past (Parmesan and Yohe 2003; Parmesan 2006). Climate change can thus not only drive potentially endangered species out of the boundaries of existing reserves but also facilitate colonization of reserves by invasive plant species (Kleinbauer et al. 2010).

The study showed that current distribution of the species was strictly controlled by temperature constraints and predicted an increase in the area invaded by *R. pseudoacacia* under warmer climate. This is a general phenomenon seen for many invasive plant species in central Europe that originate from areas climatically warmer than is this target region (Pyšek et al. 2003b). The predictions differed among the 13 forest and grassland habitats that were included in the study as potentially invasible by *R. pseudoacacia*. Therefore, the risk of invasion into legally protected areas and habitats that are vulnerable to colonization by *R. pseudoacacia* is likely to increase with climate warming, with the threat being most pronounced for endangered habitats of a high conservation value. Moreover, the study predicts not only an increase in area invaded but also that in the abundance of *R. pseudoacacia* populations, exacerbating their impact on invaded ecosystems. These results point strongly to the necessity of proactive management of PAs whereby consideration should be given to different facets of global change in a more explicit manner. They also suggest that reducing propagule pressure by avoiding the establishment of plantations close to endangered reserves and habitats is the most straightforward way to prevent further invasion under a warmer climate (Kleinbauer et al. 2010).

11.6 Challenges, Solutions and Strategy: Towards the Brighter Future of European Protected Areas?

Europe has lagged behind other regions of the world in the struggle against IAS (Genovesi and Shine 2004), largely because of the limited awareness of the European society on this issue. Despite the fact that 96 % of Europeans consider the protection of the environment to be important and 84–93 % perceive the loss of biodiversity as a serious problem, only 2–3 % of European citizens acknowledge IAS as a significant threat (Gallup Organisation 2007; Hulme et al. 2009). The limited level of understanding and concern regarding IAS is indeed a major obstacle to more effective policies on biological invasions (Brunel et al. 2013). It is therefore urgent to inform the public better on this issue. Protected areas can play a pivotal role in this regard because these institutions have a direct link with their visitors, and enjoy a high credibility in public opinion. Better information and education of the public could be ensured also by directly involving them in activities such as monitoring or

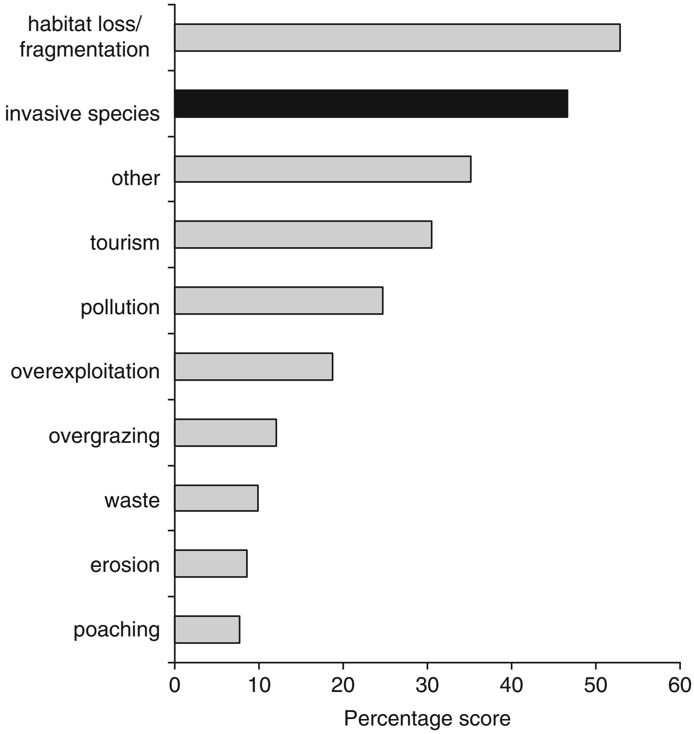

Fig. 11.9 Major threats to protected areas as perceived by managers. Based on a web survey (A. Monaco and P. Genovesi, unpublished), see Fig. 11.6 for details on calculation of the percentage score. Other threats listed with low frequency are shown together and include: human conflicts, climate change, lack of resources, ecological instability and lack of political support

management, as in the case of the "balsam blitz" at the Pembrokeshire Coast National Park (Wales), where volunteers are engaged in controlling *I. glandulifera* (NewsWales 2011). Another example is the on-going eradication of *Lysichiton americanus* (American skunk cabbage) in the Taunus Nature Park (Germany). This project involves over 100 volunteers and is planned take at least 10 years to complete it (B. Alberternst, personal communication). Such initiatives provide opportunities to launch far-reaching awareness campaigns.

Fortunately, the generally limited awareness of biological invasions by the public does not extend to the managers of PAs, who have a high concern about the threats posed by IAS (Scalera and Zaghi 2004). Based on the results of the web survey (A. Monaco and P. Genovesi, unpublished), IAs are now considered by managers and administrators of PAs the second most serious threat, after habitat loss and fragmentation – and more important than tourism (Fig. 11.9). This specific attention of European PAs on biological invasions probably reflects the direct experience of managers with the impacts caused by IAS whose numbers are constantly and rapidly growing in all European environments and regions (Hulme et al. 2009). The perception by European PA managers of these main threats

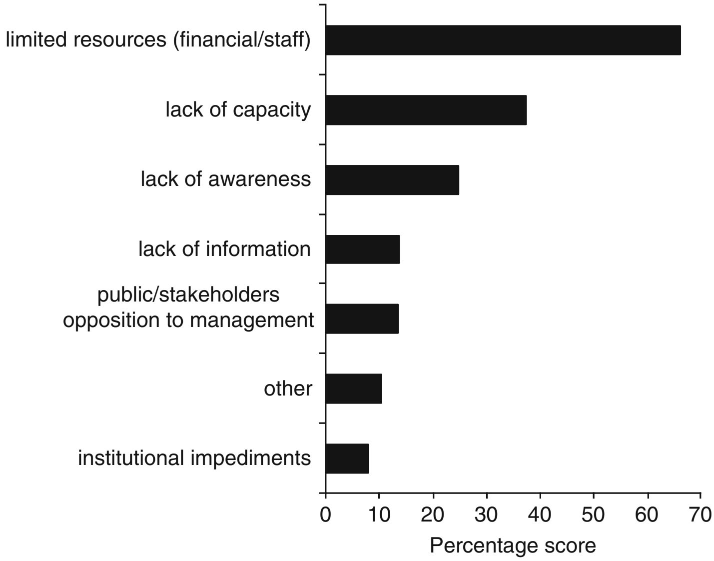

Fig. 11.10 Key impediments to dealing with the spread of invasive species in European protected areas as perceived by managers. Based on a web survey (A. Monaco and P. Genovesi, unpublished); see Fig. 11.6 for details on calculation of the percentage score

also corresponds reasonably well with general global threats as identified by e.g. Millennium Ecosystem Assessment (2005) – that underlined the need to improve the management of PAs, to mitigate the impacts of development, over harvesting, unsustainable tourism, invasive species, and climate change – or specifically for nature reserves and island ecosystems (Robertson et al. 2011).

The magnitude of impacts of invasive species in European PAs is expected to grow rapidly in the near future, with severe effects on biodiversity and ecosystem services. Besides increasing numbers of introductions to the continent, PAs are under increasing pressures from the continuous growth of tourism (Fig. 11.2) which is a major source of propagules of alien species (Usher 1988; Lonsdale 1999; Pretto et al. 2012). Furthermore, on-going climate change may aggravate the impact from invasions (e.g. Kleinbauer et al. 2010, see Case study 3 above).

However, the ability to develop more effective and science-based responses to this threat in European PAs is constrained by several factors. These include limited support from the rest of the society (including decision makers), the inadequate legal framework reflecting the European context, the lack of early warning rapid response frameworks (Brunel et al. 2013), the lack of specific financial mechanisms, including those for contingency actions, and – last but not least – the lack of data on invasive species in PAs (Fig. 11.10). Regarding the last mentioned aspect, inventories of invasive species in PAs, using standard scientific criteria, are urgently needed to support European PAs in their efforts to prevent and control invasions (e.g. Pyšek et al. 2009a). This can only be achieved through coordinated international cooperation for which the system of projects funding within EU provides a suitable framework.

To achieve this aim, and in order to improve the knowledge base of actual distribution of IAS, managers of protected areas should make more use of the ‘citizen science’ or ‘citizen as a sensor’ approach, where the public is involved in monitoring of natural resources for improving management and/or research, often allowing scientists to accomplish studies that would otherwise be unfeasible. In general the ‘citizen science’ approach can also be aimed at promoting public engagement, information and education. Properly trained volunteers could be effectively involved in inventories and monitoring programmes of IAS distribution and could play a fundamental role in the surveillance of new IAS arrivals, to support an early warning and rapid response system (Genovesi et al. 2010; Gallo and Wait 2011). The initiative of the EEA “Eye on Earth” is an interesting example of the involvement of the public for recording data on IAS (http://www.eyeonearth.org/en-us/Pages/Home.aspx, section nature), for which aim a number of open platforms can provide valuable tools, such as the applications developed for several electronic devices such as mobile phones, tablets, etc. (e.g. “Aliens Among Us app”; http://www.royalbcmuseum.bc.ca/TravellingExhibitions/default.aspx; “iAs_sess”, http://ias-ess.org).

More generally, in order to prevent further impacts by IAS, European PAs should give priority to the prevention of new introductions, by identifying the priority pathways of IAS introduction, and addressing them through a balanced and regulatory approach. European PAs, compared to other regions of the world, are characterised by widespread presence of human activities within their borders or in their immediate surroundings[5]. It is important to extend such a precautionary approach outside the borders of PAs, and to discuss with competent authorities – not only at the local or national scale, but also at the European level – ways of preventing introductions of alien plants by forestry, horticulture, or via botanical and zoological gardens. Protected areas should be involved in fostering more responsible behaviour by private individuals and industries, for example by promoting the adoption of agreed standards, best-practice guidelines, or codes of conduct that are being developed by European institutions (Heywood and Brunel 2009; Heywood 2011, 2012; Scalera et al. 2012). Furthermore, it is crucial to improve the ability of European PAs to promptly detect new invasions, and to enforce effective response measures. European institutions should consider the adoption of specific financial mechanisms to allow for prompt response to and development of contingency plans for new invasions, based on a rapid evaluation process.

[5] This is confirmed by the analysis on PAs coverage per IUCN category (EEA 2012) that highlights that the most represented IUCN category by surface (about 50 %) in European PAs is the V, that is “. . . protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, cultural and scenic value . . .” (IUCN, http\\www.iucn.org).

11.7 Conclusions

Several issues that emerge from our synthesis can be summarised as follows (see also Gaston et al. 2008):

- In Europe there is a well-developed system of PAs that was expanded by the Natura 2000 scheme, and a high level of interest of the public in nature protection. However, PAs suffer from habitat fragmentation and diverse human pressures, and are facing pressure due to climate change. Despite the extensive legal framework for conservation planning, quantitative goals and indicators of the effectiveness of biodiversity protection within PAs are still needed.
- Despite generally high levels of awareness of Europeans regarding the importance of biodiversity protection, IAS are not perceived as a key conservation issue by the public, and there is a need for more education of visitors to PAs about the threats resulting from invasions. The problem of IAS is likely to accelerate in the near future as on-going environmental change may potentially facilitate colonization of PAs by invasive species that are currently kept out due to climatic constraints. The dynamics of species ranges need to be incorporated in proactive management in a more explicit manner.
- The management of many PAs is still inadequate in general. Among other things, collecting standardised continent-wide data on the distribution and abundance of IAS is an urgent priority. The lack of such data is surprising given that Europe is one of the continents where biological invasions are most intensively studied. There is an urgent need to coordinate such systematic data collation and to integrate this element in the reporting instruments of EU, such as the reporting requested by the Habitat Directive, the Bird Directive, the Marine Strategy, and the Water Directive. It is advisable to employ citizen science in schemes aimed at improving the availability of IAS data. Also, European institutions need to support the implementation of a dedicated regional information system, as was requested by the European Union Council of June 25th, 2009.
- PA managers in Europe are aware of the seriousness of the problem and threats imposed by IAS but are constrained in their efforts to deal with them by the lack of staff and budgetary resources, the inadequate legal context, and the lack of rigorous scientific information translated into practical guidelines. European institutions should develop specific financial mechanisms to react promptly to new incursions, and PAs should establish contingency plans for invasions. It is crucial for Pan-European and national institutions to address the legal constraints to achieve more effective management of IAS.

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