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An Assessment of Stakeholder Perceptions and Management of Noxious Alien Plants in Spain

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Abstract Despite biological invasions being a worldwide phenomenon causing significant ecological, economic, and human welfare impacts, there is limited understanding regarding how environmental managers perceive the problem and subsequently manage alien species. Spanish environmental managers were surveyed using questionnaires to (1) analyze the extent to which they perceive plant invasions as a problem; (2) identify the status, occurrence, and impacts of noxious alien plant species; (3) assess current effort and expenditure targeting alien plant management; and, finally, (4) identify the criteria they use to set priorities for management. In comparison to other environmental concerns, plant invasions are perceived as only moderately problematic and mechanical control is the most valued and frequently used strategy to cope with plant invasions in Spain. Based on 70 questionnaires received, 193 species are considered noxious, 109 of which have been the subject of management activities. More than 90% of species are found in at least one protected area. According to respondents, the most frequently managed species are the most widespread across administrative regions and the ones perceived as causing the highest impacts. The perception of impact seems to be independent of their invasion status, since only half of the species identified as noxious are believed to be invasive in Spain, while 43% of species thought to only be casual aliens are causing a high impact. Records of management costs are poor and the few data indicate that the total actual expenditure amounted to 50,492,437 € in the last decade. The majority of respondents stated that management measures are insufficient to control alien plants due to limited economic resources, lack of public awareness and support, and an absence of coordination among different public administrations. Managers also expressed their concern about the fact that much scientific research is concerned with the ecology of alien plants rather than with specific cost-efficient strategies to manage alien species.

Keywords Biological invasions · Ecological impact · Environmental perception · Invasive plants · Mediterranean ecosystems · Protected areas · Spain · Weed

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Biological invasions are considered to be one of the most serious threats to global biodiversity and ecosystem integrity (Vitousek and others 1997; Parker and others 1999; Mack and others 2000). The introduction of alien species not only generates ecological impacts, but also has economic and human welfare consequences (McNeely 2001). The direct economic costs can be large due either to losses in production of natural resources, to damage to infrastructures, or to subsequent costs arising from the management of invasive species. Pimentel and others (2005) have estimated that economic damage associated with alien species impacts and their control in the United States exceeds $120 billion per year.

Economic valuation is a useful tool for policymakers to guide actions targeting biodiversity conservation priorities and raise public awareness (Costanza and others 1997; Zavaleta 2000; Brauer 2003; McConnachie and others 2003; Born and others 2005; Hulme 2006). However, the economic impacts of alien species are still poorly known for Europe (Hulme 2007) and are often limited to the costs of a single species in a specific location (Vilà and others 2008a). For plants, there are a few published papers on the costs of eradication and control for particular well-known invasive species, such as *Fallopia* spp. (Child and others 1998), *Rhododendron ponticum* (Dehnen-Schumutz and others 2004), and *Crassula helmsii* (Shaw 2003) in the United Kingdom; *Fallopia* spp. in the Czech Republic (Krivánek 2006); and *Heracleum mantegazzianum* in Denmark (Nielsen and others 2005). In the United Kingdom, Williamson (2002) has calculated the costs of 30 agricultural weeds and invasive plants based on estimated annual expenditure on herbicides. In Germany, Reinhardt and others (2003) have estimated the total costs of the management of major invasive plants in the country. However, these extrapolations are based on estimated costs of particular species in a certain area. An assessment of the actual costs of invasive plants in natural areas has not been undertaken yet in any European state.

While a quantification of costs may be useful, it must go hand-in-hand with an understanding of the limitations, impediments, and opportunities for effective management. Much of the time, managers have to deal with limited resources, which in turn require that choices must be made regarding where best to focus management efforts and which alien species to prioritize for management (Westman 1990). Therefore, there is a need to understand more fully the implications of the perceptions held by managers regarding biological invasions and how the scientific information percolates through to management decisions (Hulme 2003; Bardsley and Edwards-Jones 2007; Daehler 2008; García-Llorente and others 2008).

Questionnaire surveys have been used successfully to assess human perceptions of alien species, the risks they pose and the options for control in certain areas (Perrins and others 1992; Kowarik and Schepker 1998; Williamson 1998; Bardsley and Edwards-Jones 2006, 2007; Daehler 2008; García-Llorente and others 2008). We adopt this approach with environmental managers in Spain in order to gauge their perception regarding plant invasions and to gather information about management activities. We consider as noxious those alien plants occurring in natural areas and assumed to cause some ecological (i.e., competition with native species, hybridization, changes in ecosystem structure, etc.), economic (i.e., losses on produces, infrastructure damage, management costs, etc.), social (i.e., reduction in aesthetical values, impediments for recreation or navigation, landscape alteration), or health impacts (i.e., allergies or skin rushes). In particular, we assessed: (1) whether senior environmental managers perceive invasions as a problem; (2) the status, occurrence, and perceived impacts of noxious alien plants in natural areas; (3) the management activities undertaken in order to prevent or control noxious alien plants and their associated costs; and (4) the criteria managers use to set priorities for management. Regarding this last goal the following questions were addressed: (a) Are those alien species subject to management regarded as invasive? (b) Are managed species the most widely distributed? (c) What type and magnitude of impacts do these alien plants cause? We also discuss whether there is concordance on regional species occurrence between the information provided by environmental managers and the most updated scientific knowledge available on alien plants in Spain (Sanz-Elorza and others 2004).

Methods

Study Region

Spain is divided into 19 administrative regions: 17 autonomous communities (ACs) and 2 autonomous cities, Ceuta and Melilla, located in northern Africa. The ACs are subdivided into 50 provinces. Each AC possesses an environmental department, which is the primary environmental administrative body of the region and is responsible for the management of its natural areas. However, specific management activities are usually coordinated by the relevant provincial delegations in each AC.

The establishment and management of protected areas are under the jurisdiction of the environmental departments of each AC. There are 13 national parks, which receive the highest protection status in Spain, and 120 natural parks, the second-highest protection status. These protected areas are of great ecological, scientific, and educational value, encompassing an enormous range of ecosystem types, from arid salty flats and dunes to mountain ranges and woodlands.

The Spanish Environmental Ministry, following the recommendations of the Convention on Biological Diversity (http://www.biodivorg), launched in 1998 the "Spanish Strategy for the Conservation and Sustainable Use of the Biodiversity," in which they proposed "the elaboration and harmonization of legal and technical resources needed to control, and avoid the introduction of alien species that threaten biodiversity" (http://www.mma.es/conserv_nat/planes.htm). The Law of Natural Heritage and Biodiversity (42/2007) includes specific requirements for the prevention and control of invasive alien species. The responsibility for such requirements falls to the ACs.

Between 10% and 14% of the total Spanish flora is nonnative (Sanz-Elorza and Sobrino 2002; Dana and others 2003). According to the first national compendium of alien plants in Spain (Sanz-Elorza and others 2004), a total of 998 alien species have been identified in Spain, and following Pyšek and others (2004), 123 (12%) are considered invasive, 42% naturalized, 38% casual, and the remaining 8% correspond to alien species with unknown status.

Questionnaire Survey

Questionnaires were used to assess the perceptions, impacts, and management of plant invasions in natural areas in Spain. Respondents were senior managers of all public environmental administrations with responsibility for biodiversity conservation and management of natural areas at both national and AC levels. The environmental sectors assessed included forestry, water management, nature conservation, coastal protection, and urban green departments. The agricultural sector was not surveyed, since alien plants in arable fields are not usually managed specifically, but only as components of the total weed flora.

Environmental administrations were first contacted by telephone, in order to identify the person with responsibility for decisions regarding the management of biological invasions. Specifically we contacted the environmental departments of the 19 ACs and their respective provincial delegations in those cases where the information was not centralized. The survey also included the contact with all 13 national parks and 120 natural parks. In order to take into account all potential natural areas where plant invasions could be a problem, we also contacted 7 hydrographic confederations (responsible for catchment management) and 12 coastal protection administrations. In sum, all high-level public administrations with responsibility in conservation were contacted.

The recipients of our first telephone interview and their contact details were identified using information obtained from the Internet, from personal contacts, or by directly calling the environmental administration and asking for the senior official responsible for biodiversity conservation or natural areas management. We also used the "snowballing" method, whereby the respondent put us in touch with other secondary public bodies (i.e., county councils, municipalities) with responsibilities relevant to plant invasions (Bardsley and Edwards-Jones 2006).

Subsequently, a structured questionnaire was sent to all senior environmental managers that at least had some responsibility relating to alien plant management. All recipients of the questionnaire were informed about our aim of gauging an institutional, rather than a personal, response. The questionnaire comprised two parts: (1) a general section to assess institutional opinions and perceptions of plant invasions in relation to other environmental threats in Spain and (2) a specific section for any alien plant species they described as being noxious in their areas of responsibility (Appendix 1).

From April 2006 to February 2007 questionnaires were sent to 90 institutions, with a 78% response rate. This can be considered a high response rate compared to other studies (e.g., 58% response rate for Kowarik and Schepker 1998). Thus, our study can be regarded as representative of current perspectives and activities relating to alien plant management in Spain. We are also confident that we contacted the respondents with the highest level of knowledge regarding alien species in their departments. Each noxious alien plant mentioned by each respondent in the questionnaire's specific section was treated as a separate case. In total, we obtained information on 255 cases, and 212 of them contained information on management strategies.

Data Analysis

The relative importance of biological invasions compared to other environmental threats (natural habitat loss, habitat fragmentation, wildfire, climate change, pollution, urbanization, land use change) and the perceived effectiveness of four different management strategies against invasions (legislation reinforcement, education and outreach, entry prevention, direct population control) were compared with Kruskal-Wallis tests. We performed a multiple comparison test after Kruskal-Wallis using the package 'pgirmess' and the 'Kruskalmc' procedure under R version 2.6.2

We classified all noxious species identified by managers as being casual, naturalized, or invasive in Spain, following Sanz-Elorza and others (2004), in order to assess whether invasive species were considered more frequently as noxious. A chi-square test was used to compare differences between managed and unmanaged noxious species in relation to their invasion status as well as between invasive and casual species in relation to the magnitude of their impact (i.e., high, intermediate, low).

The number of ACs or protected areas in which a species occurred was used as a measure of how widespread the species was in Spain. Differences in the national distribution of managed and unmanaged species were compared using a Mann-Whitney test. Regression analyses were used to contrast the number of ACs where a noxious species had been recorded with its known distribution in Spain (Sanz-Elorza and others 2004). To assess whether managed species were among the most widely distributed alien plants across Spain, linear regression analysis was performed between the number of ACs or protected areas where a noxious alien plant was present and the number where it was actually managed. In order to know whether

management was directed toward species causing a particular ecological impact (ecological, economic, social, human health), differences in the proportion of unmanaged and managed species causing different ecological impacts were compared using a chi-square test.

Finally, we tested the consistency among responses to the type of impacts (i.e., ecological, social, economic, health) and management approach applied (i.e., prevention, eradication, containment, and restoration). For impacts, we selected the 10 most widely distributed noxious species across the ACs and compared the similarity of responses by respondents using the Sorensen Similarity Index between all possible paired comparisons. For example, the Sorensen Similarity between respondent A and respondent B was calculated as $S = (2 \times C)/(2C + A + B)$, where C is the number of responses common to both respondents, A is the number of responses mentioned only by respondent A, and B is the number of responses mentioned only by respondent B. A similar analysis was undertaken to compare management approaches but in this case the 10 most frequently managed species were selected as the basis for comparisons.

All analyses were carried out with the software package STATISTICA 6.0 (StatSoft 2001). Mean values ± standard errors are given.

Results

General Perceptions Regarding the Threat of Biological Invasions

Significant differences were found in the importance given by respondents to different environmental problems (Kruskal-Wallis, $H = 66.04$, df $= 7$, $P < 0.0001$). While 50% of respondents felt that biological invasions were at least a medium priority for management, and over a third stated that this threat was a high priority, on average, biological invasions were perceived as an intermediate threat to biodiversity. Managers manifested greater concern about landscape changes, such as habitat loss, urbanization, habitat fragmentation, and land use changes, than about wildfires, pollution, and climate change. Nonetheless, concern about biological invasions ranked similarly to all these environmental problems (Fig. 1).

Identity, Status, and Occurrence of Noxious Alien Species

In total, 193 alien plants were identified as noxious (e.g., listed by respondents as being of concern), yet only a little more than half of these species (109) were the subject of any management (Appendix 2). Not all noxious species were alien; 33 (17%) are native species of the Iberian

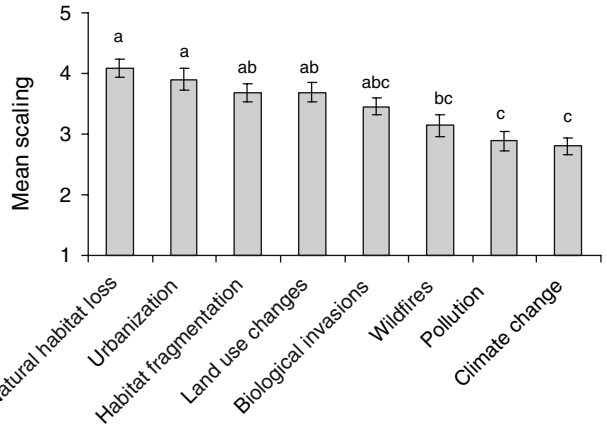

Fig. 1 Respondents' perception of the importance of the different environmental problems in Spain, on a scale from 1 (not relevant) to 5 (extremely important) points

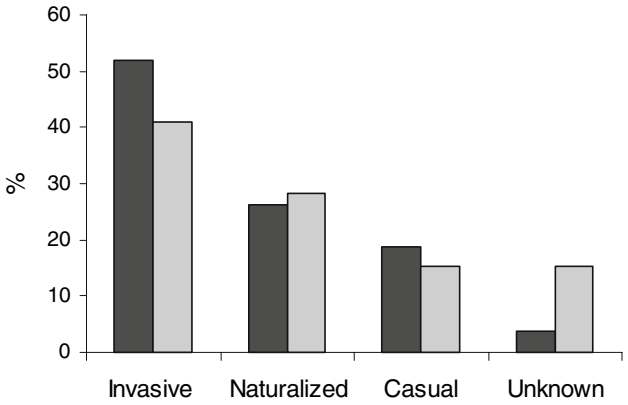

Fig. 2 Invasion status classification of managed (black) and unmanaged (gray) species that have been mentioned by respondents according to Sanz-Elorza and others (2004)

Peninsula (i.e., continental Portugal and Spain) but aliens in the Canary Islands. Only 14 of these species were managed in the Canary Islands. Most (~50%) species identified as noxious were classed as invasive (Sanz-Elorza and others 2004), but a significant proportion (~20%) was only classed as casual (Fig. 2). Overall, of the 123 alien species classified as invasive in Spain, only 60% were identified as noxious by respondents.

There was a significant difference in species status between managed and unmanaged noxious species ($\chi^2 = 39.11$, df $= 3$, $P < 0.0001$). However, differences could most probably be explained by a higher proportion of unmanaged species with unknown status (Fig. 2). In almost half the cases (49.7%) invasive species were not managed despite other naturalized or casual alien species being targeted.

The taxa most frequently identified as noxious were *Carpobrotus* spp., *Eucalyptus* spp., *Ailanthus altissima*, and *Robinia pseudoacacia* (11 ACs, of 19) followed by

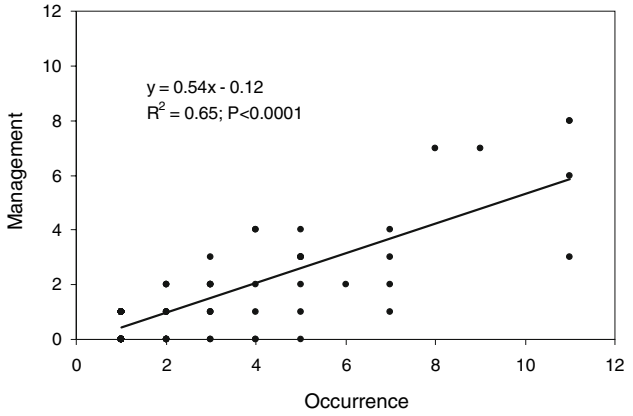

Fig. 3 Relationship between occurrence (i.e., number of autonomous communities [ACs] of Spain where a particular noxious alien plant is present) and the number of ACs where this species is managed

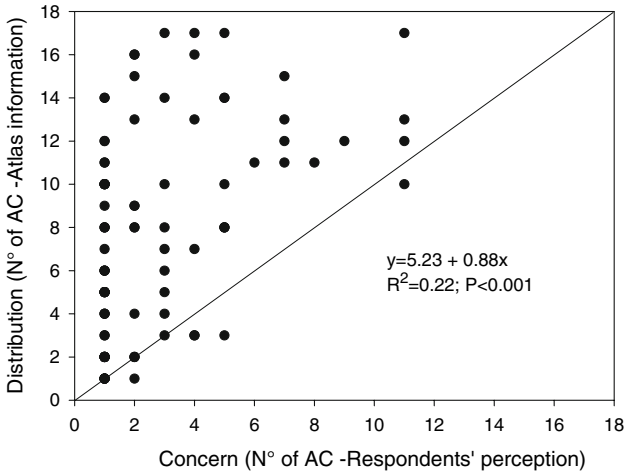

Fig. 4 Relationship between respondents' perception about the occurrence of a particular noxious alien plant in terms of the number of autonomous communities (ACs) where the species have been mentioned and the number of ACs where the species is known to occur (Sanz-Elorza and others 2004). The line of unity is indicated and represents equivalence between the two sources of information

Acacia spp. (9 ACs) and *Cortaderia selloana* (8 ACs) (Appendix 2). This group also included those species most frequently reported as managed: *Carpobrotus* spp. and *Eucalyptus* spp. (8 ACs), *Acacia* spp. (7 ACs), and *Cortaderia selloana* (6 ACs). However, most species, 130 of 193, were mentioned in only one AC. Managed species were present in more ACs across the country than unmanaged species (Mann-Whitney, $Z = 3.15$, $P = 0.001$). In general, although the most widespread species were also the most managed ($y = 0.54x - 0.12$; $R^2 = 0.65$, $P < 0.0001$), across all species, management occurred in only approximately half of the ACs (Fig. 3).

Most of the noxious alien species mentioned by respondents (92%) were neophytes (i.e., alien plants introduced after 1500, Pyšek and others 2004). Nine of them (8%) were archaeophytes (i.e., introduced before 1500, Pyšek and others 2004). *Ricinus communis, Morus* spp. and *Prunus cerasifera* were managed in some locations, and the magnitude of their impact was high. *Arundo donax* was the only archaeophyte managed in more than one case (four cases), and in all of them it was reported to have a high impact, mostly in riparian areas.

Considering protected areas, 94% of noxious species were found in at least one protected area. Management was undertaken in a significantly smaller proportion of natural (34 of 120) than national parks (8 of 13; $\chi^2 = 5.99$, df $= 1$, $P < 0.05$). In contrast to the pattern for ACs, managed species were no more widespread in protected areas than unmanaged species (Mann-Whitney, $Z = 1.52$, $P = 0.13$). Similarly to ACs, while the most widespread species were also the most managed ($y = 0.56x + 0.10$; $R^2 = 0.73$, $P < 0.0001$), no matter how widespread the species, management occurred in approximately half the recorded parks. *Carpobrotus* spp. are also the most widely distributed and most managed taxa in national and natural parks, followed by *Eucalyptus* spp.

Comparison between the occurrence records provided by respondents and the known distribution of species across all ACs in Spain (Sanz-Elorza and others 2004) reveals either that alien species are underrecorded by respondents or that species are viewed as noxious by respondents in only a few of the regions where they are found (i.e., *Amaranthus* spp., *Datura stramonium*, or *Xanthium spinosum*) (Fig. 4). However, for some species, such as *Carpobrotus* spp., *Ailanthus altissima, Pennisetum setaceum, Egeria densa*, and *Ludwigia* spp., occurrence records provided by respondents matched the known distributions of these species in Spain.

Perception of Impacts of Alien Species

Regarding the magnitude of the impacts caused by noxious alien species, 35% of the cases were perceived as having a high impact on natural areas and 28.5% a low impact. In only 36% of the cases were invasive species perceived to cause a high impact and 25% a low impact (Fig. 5), while in naturalized and casual species cases, 30% and 43% were causing a high impact, respectively (Fig. 5). No significant differences were found between invasive and casual species in their perceived magnitude of impact ($\chi^2 = 4.75$, df $= 2$, $P = 0.092$).

Most cases with a high impact (88%) were being managed, thus the magnitude of the impact could be regarded as a criterion for managers to prioritize the allocation of resources. The remaining 12% were species that, despite having a high impact on natural areas, were not being managed because control was neither feasible (because they were too widely distributed) nor affordable (due to a

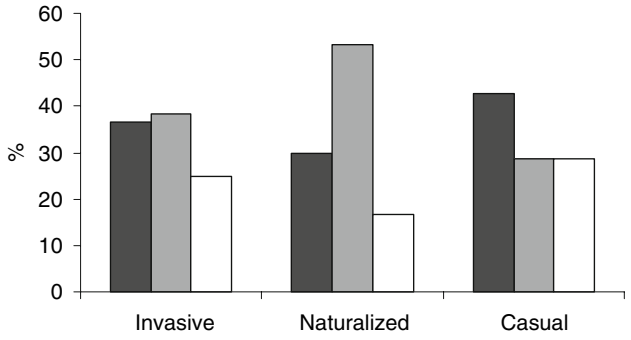

Fig. 5 Magnitude of the impact (high, black; intermediate, gray; low, white) perceived by respondents across invasive, naturalized and casual species

lack of sufficient funds). Surprisingly, 78% of species with low impacts were managed. In many cases (98%) these species were managed as part of a wider targeting of high-impacting species.

All noxious alien plants were causing some ecological impacts. Besides these impacts, respondents also mentioned social (23%), economic (9%), and human health (3%) impacts. Respondents appeared to be relatively consistent in their assessment of perceived impacts (Sorensen Similarity Index, 0.74 ± 0.04).

cThe main ecological impacts mentioned were competition with native species for space and soil resources, species loss, and changes in the integrity and stability of ecosystems. Other impacts included indirect effects on the fauna due to changes in their behavior or modification of the habitat, changes in the composition and structure of riparian forests, soil erosion and degradation, increments in biomass and flammability, and, finally, water quality deterioration and eutrophication. No significant differences were found between unmanaged and managed species in the ecological impacts they cause ($\chi^2 = 0.322$, df $= 8$, $P = 0.99$) (Fig. 6). Therefore, the type of ecological impact does not seem to be a criterion for management priorities.

Respondents were also asked to name native species that have been negatively affected by aliens. According to respondents, *Carpobrotus* spp. in Cap de Creus (Catalonia) Natural Park outcompetes with *Limonium gerondense, Armeria ruscinonensis, Astragalus massiliensis*, and *Seseli farrenyi*, causing its local displacement in some areas. In Isla Grossa (Murcia), *Carpobrotus* spp., *Acacia* spp., and *Agave americana* are thought to compete with *Lycium intricatum*, *Salsola* spp., and *Withania frutescens*. The presence of *Azolla* spp. in the Miño River leads to a loss in the cover of *Magnopotamion* and *Parvopotamion* vegetation types by occupying the same ecological niche. On Fuerteventura Island (Canary Islands) *Pennisetum setaceum* outcompetes *Launaea arborescens*, *Euphorbia balsamifera*, *Euphorbia regis jubae*, *Suaeda* sp., and *Salsola* spp., in shrublands and "cardonal-tabaidal" habitats.

Management and Costs of Alien Species

The five management activities were prioritized in the following order—direct control, prevention, education, and outreach—with legislation being perceived as the least relevant and efficient (Fig. 7). The main goal of management activities appeared to be containment (i.e., population control) (41%) or the complete eradication of the species (37%). Prevention through legislation, education, or

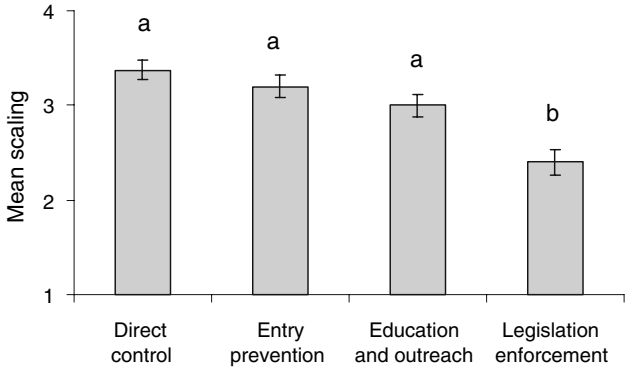

Fig. 7 Respondents' perception of the importance of different management strategies for alien plants in Spain, on a scale of 1 (not relevant) to 4 (extremely important) points

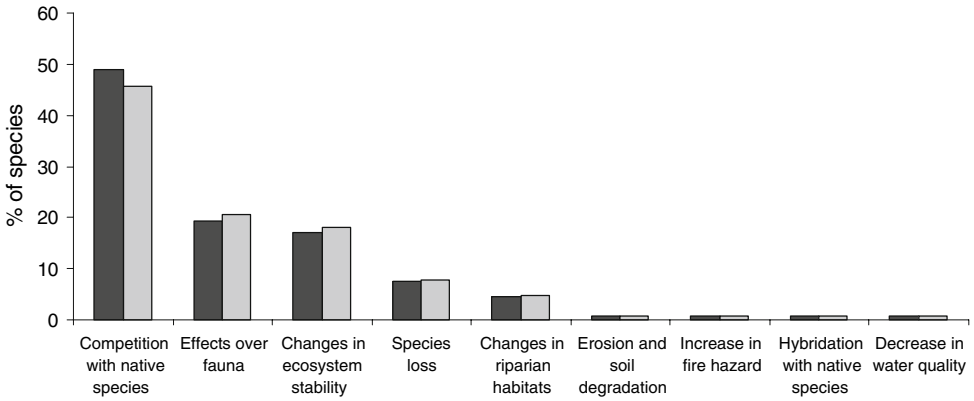

Fig. 6 Respondents' perception of the ecological impacts induced by noxious (black) and managed (gray) alien plants in Spain

communication with the general public has been used less frequently in Spain (22%). There was considerable variation among respondents in the management strategies applied to a particular species (Sorensen Similarity Index = 0.54 ± 0.03). The primary constraints to alien species management were limited economic resources (28%), insufficient coordination among administrations (22%), lack of public awareness (16%), negligible legislation (14%), paucity of research on efficient management strategies (9%), absence of long-term monitoring (6%), and few guidelines for priorization (4%).

In most cases mechanical methods (71%) have been used in management since they are considered the least harmful to the environment, but in 25% of the cases mechanical methods combined with herbicides (usually glyphosate) were used. Only 3% of the cases applied solely chemical methods. In Spain, there has been no attempt to use biological control agents for managing noxious alien plants. Less than half of all management activities (42%) were carried out annually, with 41% through external contracts and 15% via volunteers.

In the great majority of cases (85%) control measures were followed by annual monitoring in order to detect reinfestation. However, only in very few cases was the monitoring undertaken with long-term goals in mind or using standardized indicators. Restoration of habitats previously invaded has not been undertaken frequently in Spain (29%). Restoration efforts have generally followed management of *Carpobrotus* spp., *Eucalyptus* spp., *Agave* spp., *Ageratina* spp., *Ailanthus atissima*, and *Acacia* spp.

In general, management activities achieved a significant reduction in the distribution of the alien species. In almost half of the cases where management has been applied (46%), it has been effective in reducing the area of distribution, although in only 13% of the cases was the alien species totally eradicated. Rarely has control been completely ineffective (3%), but on six occasions the species have continued to increase despite the control measures applied.

In terms of monetary costs, estimates could be obtained only for direct expenditures on management activities, rather than indirect costs for ecosystem services. Only 41% of management cases provided estimates of costs, but these were largely gross costs relating to control, rather than prevention and restoration. Total expenditure on management amounted to 50,492,437 €; although annual costs could not be estimated, the total expenditure probably occurred over the last decade. Over 95% of the expenditure is targeted at five species (Table 1). Prevention costs were specified in only seven cases and amounted to <1% of the total costs (381,744 €), while expenditure on restoration accounted to about 2% (1,088,310 €) of the total management expenditure.

Table 1 Overall management costs of the alien species mentioned by the respondents

Invasive species	Management costs (€)
Eucalyptus spp.	31,528,594
Eichhornia crassipes	6,700,000
Pennisetum setaceum	6,203,300
Carpobrotus spp.	2,886,683
Azolla filiculoides	1,000,000
Acacia spp.	90,000
Rumex lunaria	86,000
Agave spp.	57,000
Ailanthus altissima	28,675
Ageratina adenophora	23,109
Senecio inaequidens	19,600
Arctotheca calendula	15,000
Cortaderia selloana	8,600
Plectranthus australis	6,251
Fallopia aubertii	6,00
Pittosporum tobira	6,000
Opuntia spp.	4,000
Hakea sericea	2,000
Ambrosia spp.	1,000
Panicum repens	1,000
Myoporum spp.	400
Lonicera japonica	200
Several species	1,819,025
Total	50,492,437

Discussion

Environmental managers in Spain are clearly aware of the risks posed by biological invasions, which ranked similarly to any other environmental problems. This awareness is encouraging given that biological invasions have not been perceived as a problem by Spanish public authorities until very recently, or included in the environmental agenda (Martín 2001; Capdevila-Argüelles and others 2006). This is not surprising, as even in regions such as Hawaii, where the threat of biological invasions is of global significance, public concern can be rather limited (Daehler 2008). However, Mediterranean ecosystems may be particularly resistant to plant invasions, even by those species regarded as major threats to biodiversity (Vilà and others 2008b). As a consequence, the institutional response in Spain was still primarily to undertake responsive actions targeting mechanical or chemical control at a local scale rather than to address broader legislative issues that might tackle prevention (Hulme 2006; Lodge and others 2006; Smith and others 2006).

Environmental managers clearly set priorities for management within their area of responsibility but such decisions

were not based on the status of the species at a national scale. Rather, decisions were made based on local perceptions of abundance, distribution, and perceived impact. Invasion status was not related to the magnitude of the impact caused by a certain species and is consistent with the finding that species capable of rapid colonization are, in general, no more likely to have impacts on biodiversity (Ricciardi and Cohen 2007). This has important implications regarding national coordination of invasive species management: a species deemed of concern at a national scale simply because it is widespread may not be a priority at the local scale of a national park and diverting resources to manage such a species may not always be sensible. One solution would be to establish national priorities based on an integrative risk index that combines information on both local and regional abundance (Hulme and others 2008).

Management did tend to target species perceived as noxious by the majority of respondents (i.e., higher occurrence). However, there are exceptions, such as *Ailanthus altissima*, *Robinia pseudoacacia*, *Arundo donax*, *Opuntia* spp., and *Oxalis pes-caprae*, that, despite being frequently identified as noxious, are rarely managed. Many of these species represent some of the most problematic species in the Mediterranean due to the difficulty and cost of control (Hulme and others 2008). Environmental managers were consistent in their perceptions of impacts of alien plants, most supporting the idea that these species outcompeted native species, though the specific type of impact did not influence management activities. There is evidence in the Mediterranean than the niches of alien and native plants do overlap (Lambdon and others 2008a), and thus competitive interactions may be important and lead to biotic homogenization (Lambdon and others 2008b).

In contrast to the perception of impacts, environmental managers differed in their views regarding how best to manage invasions, and this probably reflects a lack of guidance and limited resources that perhaps results in less effective management (Westman 1990; Bardsley and Edward-Jones 2006). Control programs often have short-term goals and few supervise the longer-term success of actions or use standardized indicators to monitor management success, e.g., native vegetation regeneration. Hulme (2003) emphasizes that the application of ecological knowledge to the management of biological invasions can lead to the most cost-effective strategies. Unfortunately, "management" is not a prevalent keyword topic in research on biological invasions (Pyšek and others 2006). Moreover, simply eliminating the alien plant from an ecosystem may not always lead to restoration of the original community and sites can often be colonized by other alien species (Simberloff 2003; Hulme and Bremner 2006). An ecosystem perspective of invasion management that addressees both the drivers of invasions and the target species control is required (Hulme 2006).

The main bottlenecks encountered when trying to obtain economic costs were as follows: (1) there was a lack of recorded expenditures, (2) the management of aliens was only one of many management tasks and thus not distinguished in budgets, and (3) where targeted management occurred, it was not specific to a single species and location. As a result, the estimate 50,492,437 € is unreliable and probably underestimates the true direct cost. This figure does not account for indirect costs to forest or pasture production, landscape changes, damage to infrastructure, or recreational opportunities. If monetary values could be assigned to losses in biodiversity, ecosystem services, and aesthetics, these costs would undoubtedly be several times higher than reported (Zavaleta 2000; Pimentel and others 2005; Binimelis and others 2007).

Conclusion

Human perception plays a strong role in addressing the issue of biological invasions (de Poorter 2001; Larson 2007; Daehler 2008). We have presented the first national assessment of these perceptions in Europe. Biological invasions are considered by Spanish environmental managers to be a medium-priority problem, and a total of 109 noxious alien species are being managed due to its impacts on natural areas. However, there remains a pressing need to raise awareness about the impacts of alien species among the general public, environmental managers, and policy-makers (Daehler 2008). Collaboration between academic research and environmental managers is required in order to achieve an efficient management of alien plants and to protect environmental integrity and native species diversity. To date, attempts to use science to advise and improve the cost-effectiveness of management strategies are few (Moody and Mack 1988; Wadsworth and others 2000; Hulme 2003; Taylor and Hastings 2004). If the putative costs identified in this study are representative of the general situation, there is substantial benefit to be gained by investing in better management strategies.

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Appendix 1: Questionnaire on Alien Plants Sent to Environmental Managers

Part 1: General Questions on Perception and Identity of Alien Species of Concern

1. Which priority would you assign to the problem of biological invasions in relation to the other environmental problems of your area of responsibility?
   i. High priority
   ii. Medium priority
   iii. Low priority
2. Could you assign a number from 1 to 5 to the following environmental problems according to their priority or importance? (1 = low importance, 2 = moderate importance, 3 = important, 4 = high importance, 5 = extremely important)?

Natural habitat loss	1	2	3	4	5
Habitat fragmentation	1	2	3	4	5
Wildfire	1	2	3	4	5
Biological invasions	1	2	3	4	5
Climate change	1	2	3	4	5
Pollution	1	2	3	4	5
Urbanization	1	2	3	4	5
Land use change	1	2	3	4	5
Other (specify which ones)	1	2	3	4	5

3. Which priority would you assign to the following management strategies against invasions? (ranking from 1 to 4: 1 = low priority and 4 = maximum priority)
   i. Legislation reinforcement
   ii. Education and outreach
   iii. Entry prevention
   iv. Direct population control
4. Which are the main limitations or difficulties for an effective management of alien species in your area of responsibility?
5. Which alien species are causing problems (i.e., noxious alien plants) in your area of responsibility?

Part 2: Questions for Each Alien Species of Concern

Species 1: Species Name

1. Which kind of impacts is it causing?
   i. Ecological
   ii. Economic
   iii. Social
   iv. Human health
2. Could you specify the impact type caused by this species?
3. Could you specify the magnitude of the impact caused by this species?
   i. High
   ii. Intermediate
   iii. Low
4. Could you mention any direct impact of this plant, which associated costs are easily quantified? (i.e., infrastructure damage)?
5. Is there any management strategy over this alien species in your area of responsibility? Yes/No
6. Which kinds of management activities do you carry out?
   i. Prevention–outreach
      1. Regional legislation
      2. Education and information activities
      3. other (specify)
   ii. Eradication
   iii. Containment (i.e., population control)
   iv. Restoration (i.e., habitat improvement, reforestation with native species)
7. How long have the management strategies been functioning?
8. Which method has been used to control or eradicate the alien species?
   i. Physical (mechanical, manual,…)
   ii. Chemical
   iii. Physical + chemical
   iv. Biological control
9. With which frequency have the treatments been carried out?
10. Are the treatments carried out by technicians or volunteers?
11. Do you monitor the success of the management measures over the time?
12. How often do you monitor the state of the invasion?
13. Have you carried out a restoration of the locations previously invaded by the alien plant?
14. Could you estimate the total economic cost of the management measures?
    i. Prevention costs (three-page leaflets, workshops, conferences…) = €.
    ii. Eradication or control costs (herbicides, salary, material, machinery, etc.) = €.

iii. Habitat restoration costs (native species plantation) = €.

15. Could you indicate which has been the result of the management measures?

i. The species has been eliminated
ii. The species has decreased considerably
iii. The species has decreased very little
iv. The species has not decreased
v. The species continues to expand

16. Do you think that the management strategies have been successful?

i. Very successful
ii. Moderately successful
iii. Not very successful
iv. No successful at all

Appendix 2

List and status of the most noxious species according to respondents and the number of autonomous communities (ACs) and protected areas where noxious and managed (status: I = invasive, N = naturalized, C = casual)

Species (family)	Status	No. of ACs where noxious	No. of ACs where managed	No. of ACs where present[a]	No. of protected areas where noxious	No. of protected areas where managed
Carpobrotus spp. (Aizoaceae)	I	11	8	10	21	13
Eucalyptus spp. (Myrtaceae)	I	11	8	13	14	13
Ailanthus altissima (Simaroubaceae)	I	11	6	12	10	4
Robinia pseudoacacia (Fabaceae)	I	11	3	17	2	1
Acacia spp. (Fabaceae)	I	9	7	12	9	8
Cortaderia selloana (Poaceae)	I	8	7	11	2	2
Agave americana (Agavaceae)	I	7	3	12	14	2
Arundo donax (Poaceae)	I	7	1	15	1	0
Opuntia spp. (Cactaceae)	I	7	4	13	9	3
Oxalis pes-caprae (Oxalidaceae)	I	7	2	11	4	2
Senecio spp. (Asteraceae)	I	6	3	11	4	2
Arctotheca calendula (Asteraceae)	I	5	3	10	2	2
Ipomoea spp. (Convolvulaceae)	I	5	3	14	1	1
Myoporum spp. (Myoporaceae)	N	5	4	3	1	1
Nicotiana glauca (Solanaceae)	I	5	2	8	5	2
Oenothera glazioviana (Onagraceae)	I	5	3	14	0	0
Paspalum spp. (Poaceae)	I	5	0	17	1	0
Ricinus communis (Euphorbiaceae)	I	5	1	8	2	2
Tradescantia fluminensis (Commelinaceae)	I	5	3	8	2	2
Aptenia cordifolia (Aizoaceae)	N	4	1	7	2	0
Aster squamatus (Asteraceae)	I	4	0	16	1	1
Baccharis halimifolia (Asteraceae)	I	4	4	3	0	0
Conyza spp. (Asteraceae)	I	4	0	17	0	0
Eichhornia crassipes (Pontederiaceae)	I	4	4	3	1	1
Xanthium strumarium (Asteraceae)	I	4	2	13	1	1
Aloe spp. (Liliaceae)	C	3	1	4	1	0
Amaranthus spp. (Amaranthaceae)	I	3	0	17	0	0
Azolla filiculoides (Azollaceae)	I	3	2	8	2	1
Buddleja davidii (Buddlejaceae)	I	3	2	7	1	1
Fallopia japonica (Polygonaceae)	I	3	2	6	0	0
Lantana spp. (Verbenaceae)	I	3	0	5	0	0
Oenothera biennis (Onagraceae)	I	3	2	14	0	0
Pennisetum setaceum (Poaceae)	I	3	1	3	2	2
Tropaeolum majus (Tropaeolaceae)	I	3	1	10	0	0
Yucca spp. (Agavaceae)	C	3	3	–	3	2

Appendix 2 continued

Species (family)	Status	No. of ACs where noxious	No. of ACs where managed	No. of ACs where present[a]	No. of protected areas where noxious	No. of protected areas where managed
Araujia sericifera (Asclepiadaceae)	I	2	0	8	0	0
Artemisia spp. (Asteraceae)	I	2	0	13	1	0
Datura stramonium (Solanaceae)	I	2	2	16	3	2
Disphyma crassifolium (Aizoaceae)	N	2	0	4	1	0
Egeria densa (Hydrocharitaceae)	N	2	1	2	1	0
Kalanchoe spp. (Crassulaceae)	C	2	1	–	0	0
Ludwigia spp. (Onagraceae)	N	2	2	2	2	0
Oenothera drummondii (Onagraceae)	N	2	1	2	1	1
Pittosporum tobira (Pittosporaceae)	C	2	1	1	0	0
Platanus hybrida (Platanaceae)	N	2	2	8	0	0
Solanum bonariense (Solanaceae)	I	2	0	9	0	0
Sorghum halepense (Poaceae)	I	2	0	15	0	0
Spartina patens (Poaceae)	I	2	0	9	0	0
Xanthium spinosum (Asteraceae)	N	2	0	16	0	0

[a] According to Sanz-Elorza and others (2004)

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