

## Eradication and control of invasive alien plants in the Mediterranean Basin: towards better coordination to enhance existing initiatives

S. Brunel<sup>1</sup>, G. Brundu<sup>2</sup> and G. Fried<sup>3</sup>

<sup>1</sup>EPPO, 21 boulevard Richard Lenoir, 75011, Paris, France; e-mail: sb@epo.int

<sup>2</sup>Department of Science for Nature and Environmental Resources, University of Sassari, Via Piandanna 4, 07100, Sassari, Italy

<sup>3</sup>Anses, Laboratoire de la santé des végétaux, Unité Entomologie et Plantes invasives, CBGP – Campus International de Baillarguet, CS 30016, 34988, Montpellier-sur-Lez Cedex, France

The European and Mediterranean Plant Protection Organization (EPPO), in the framework of its activities in the Mediterranean Basin, launched a questionnaire to gather information on eradication actions and control actions for invasive alien plants. Thirty-four (34) eradication actions were reported, 16 occurring in Spain, 7 in Italy, 7 in France, 1 in Portugal, 1 in Malta, and 2 on the southern rim of the Mediterranean, with 1 in Israel and 1 in Tunisia. Twenty-two (22) species were targeted, and the habitats where such actions were undertaken most frequently were coastal dunes, sandy shores and aquatic ecosystems. Most of the species that have been the object of an eradication action were known invasive species recorded in the EPPO lists, such as *Ailanthus altissima*, *Buddleia davidii*, *Carpobrotus* spp., *Eichhornia crassipes*, *Ludwigia peploides*, *Pennisetum setaceum*, *Pistia stratiotes*, *Solanum elaeagnifolium* and *Sicyos angulatus*. Other eradicated species have a limited distribution in the EPPO region and may represent emerging invasive plants, such as *Ambrosia confertifolia*, *Cylindropuntia rosea*, *Leersia oryzoides*, *Leptochloa fusca* subsp. *uninervia* and *Marsilea drummondii*. Control actions concerning 90 species were also reported. A large number of eradication actions, as well as management actions, are therefore happening in Mediterranean countries. At present countries appear to operate with complete autonomy, without consulting neighbouring countries or other stakeholders within the country. There is therefore a need for coordination of new eradication actions.

### Introduction

The Mediterranean Basin and its islands are particularly vulnerable to biological invasions. Climatic conditions in the Mediterranean Basin potentially allow the establishment of both subtropical and tropical plants introduced as ornamental species or for other purposes. The Mediterranean Basin could suffer severe ecological and other impacts caused by invasive alien plants, and there is thus an urgent need to gather, analyse and share lists of invasive alien plants and control options, including eradication strategies and success indicators, as well as to establish priorities for action and management of species pathways in different regions or habitats. Information exchange is a key component of effective responses to biological invasions (Browne *et al.*, 2009).<sup>1</sup> Initial attempts to fill this information gap

occurred in the framework of the organization of pan-Mediterranean conferences and workshops (see Di Castri *et al.*, 1990; Brunel, 2006; Brunel *et al.*, 2011). Currently, not all Mediterranean Basin countries have elaborated and published lists of invasive alien plants, although notable research projects have been undertaken in certain countries and by the EU-funded projects EPIDEMIE and DAISIE, and some eradication or control projects have been financially supported in the framework of the EU LIFE projects.

Coordination of preventive and management actions on invasive alien plant species is greatly needed. This is part of the European and Mediterranean Plant Protection Organization (EPPO)'s mission, as one of EPPO's tasks is to draw up and periodically revise lists of invasive (or potentially invasive) alien plants that present a risk for the whole of, or parts of, the EPPO region (composed of 50 European and Mediterranean countries). Eradication is a key management option to mitigate the impacts caused by biological invasions, and is considered to be the best option when prevention fails (guiding principles of the Convention on Biological Diversity adopted in 2002 with Decision VI/23). Eradication is defined by the International Plant Protection Convention (IPPC) as the 'application of phytosanitary measures to eliminate a pest from an area' (FAO, 2010).

<sup>1</sup>As an indication of the wider context, in October 2010 the Conference of the Parties to the Convention on Biological Diversity adopted the Strategic Plan for Biodiversity 2011–2020, which includes the Aichi Biodiversity Targets. Target 9 of the Plan is that by 2020 invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Genovesi (2011) defines eradication as ‘the complete and permanent removal of all wild populations of an alien plant or animal species from a specific area by means of a time-limited campaign’. According to these definitions, eradication is distinct from permanent control (reduction of population density, or control to a level below an impact threshold, see Panetta, 2009) or containment (which aims to limit the spread of a species by containing its presence within defined geographical boundaries). Eradication should also be distinguished from the control of a species to zero density, which aims at complete removal of the target species, but through a continued removal effort (Genovesi, 2005, 2011).

As very little information is available on eradication of invasive alien plants (versus other types of organisms), while organizing the First and Second Workshops on Invasive Alien Plants in the Mediterranean Type Regions of the World, the EPPO Secretariat launched surveys in 2005 and 2010, respectively, to collect data on the species considered invasive in Mediterranean countries. The contribution of Mediterranean experts in 2005 allowed emerging invasive alien plants for the Mediterranean Basin to be identified (Brunel *et al.*, 2010). The 2010 survey included questions on eradication actions. At the global scale, information on eradication or control projects is particularly difficult to collect, as it is scattered, and often is available only in ‘grey literature’ or local reports when it is published at all (Simberloff, 2002; Genovesi, 2005; Genovesi & Carnevali, 2011). Information provided by local experts is therefore an invaluable contribution for conducting meta-analysis.

This review presents, for the first time, general information and a list of plants that have been the object of eradication actions or control measures in the EPPO Mediterranean countries. It is hoped that the information provided will promote better sharing of knowledge on interventions between the different stakeholders involved in this topic.

## Material and methods

### Study area

The countries included in the Mediterranean Basin, for the purpose of this analysis, have been identified according to Med-checklist (Greuter *et al.*, 1984–1989), i.e. relying on political borders, as was done when interpreting the 2005 questionnaire (see Brunel *et al.*, 2010). As a consequence, part or the whole of the following countries are considered to be part of the Mediterranean area: Albania, Algeria, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Egypt, France (including Corsica), Greece (including East Aegean Islands, Crete, Karpathos), Israel, Italy (including Sardinia and Sicily), Jordan, Kosovo, Libya, Lebanon, Macedonia, Malta, Montenegro, Morocco, Portugal, Serbia, Slovenia, Spain (including Balearic Islands, Canary Islands), Syria,



**Fig. 1** Map of the Mediterranean Basin; the dark shading (green on line) indicates the areas considered for the study. Adapted from EEA Biogeographic map of Europe EEA (2011) and ETC-BD (2006), and from Groves & Di Castri (1991).

Tunisia and Turkey (see Fig. 1). Some of these countries are not yet EPPO member countries (Albania, Syria, Egypt). The Mediterranean region considered from the biogeographical point of view is illustrated in Fig. 1.

### Data collection

A questionnaire on invasive alien plants in the Mediterranean Basin was launched in 2010, for the preparation of the Second International Workshop on Invasive Alien Plants in Mediterranean Type Regions of the World, held in Trabzon (TR) (2010-08-02/08). This questionnaire was sent by email to contacts in the EPPO Mediterranean countries and was available online on the EPPO website. In addition to requesting information on lists of invasive alien plants and their status in countries, and on partnerships developed on the topic, the questionnaire asked whether eradication or control actions on invasive alien plants had been undertaken or were planned.

This questionnaire was complemented by a broad literature review, including both scientific literature and grey literature, and reports of eradication actions found on the internet or sent by experts.

### Limits of the study

As no definition of ‘eradication’ was provided in the exploratory questionnaire, in some cases respondents reported control actions under the category of eradication action. The data have therefore been interpreted by the authors of this article keeping this limitation in mind. The species, the size of the populations mentioned, and the reported measures were discriminating factors when considering whether control or eradication was the objective.

The success of these recorded eradication or control actions, which includes effective removal of the target species as well as recovery of the invaded habitat, was not investigated through the questionnaire. The aim of the survey was rather to obtain a picture of species and actions undertaken. Furthermore, the data aggregated is far from being exhaustive.

## Results

The exploratory questionnaire of the 2010 survey yielded 28 answers from the following countries: Armenia, Bulgaria, Croatia (two answers from different institutes), France (one for aquatic invasive species in France, and three for Languedoc Roussillon), Greece, Israel, Italy (two for Tuscany, one for the Bergamo area and one for the Verona area), Malta, Morocco, Portugal, Serbia, Spain (two from the Balearics, one from the Catalonia area, one from the Aragón area, one from the Valencia area, one from the Saragossa area), Tunisia (two answers) and Turkey (two answers). Most contributors were from the public sector (government, universities), and in particular from protected areas. Countries from the northern rim of the Mediterranean represented the majority of respondents. The answers were provided at different scales (e.g. at country level, at regional or at natural reserve level). All other information was found through a literature survey.

The information assembled was divided into two groups: eradication actions on invasive alien plants from a target area, and control actions for invasive alien plants in a target area. The results of the analysis of the information collected are summarized in Tables 1 and 2.

### Eradication actions on invasive alien plants in the Mediterranean Basin

The 34 cases that complied with the IPPC definition of eradication ('application of phytosanitary measures to eliminate a pest from an area') are presented in Table 1. Whether or not the eradication was successful is not recorded (e.g. see IPPC, 1998; Rout, 2009; Rout *et al.*, 2009).

Most cases of eradication actions were reported from the northern rim of the Mediterranean Basin. The only cases from the southern rim were the removal of *Ambrosia confertifolia* in Israel and of *Solanum elaeagnifolium* in Madhia, Tunisia, two species that represent a threat to agriculture rather than to the environment. The other 32 actions occurred in Spain (16 actions), Italy (7), France (7), Portugal (1) and Malta (1). Spain therefore appears to be the country attempting the highest number of eradication actions on invasive alien plants. Table 1 summarizes reported eradication actions in the Mediterranean Basin. For each alien species that has been reported as being the target of an eradication action, the listing in the EPPO framework at the time of submission of the article (A2 List, List of Invasive Alien Plants, Alert List, Observation List of Invasive Alien Plants), the country and the target area where the eradication action took place, indications on the action undertaken, the habitat(s) concerned (using the EUNIS classification – <http://eunis.eea.europa.eu/>) and references are provided.

Eradication actions took place on small islands (e.g. at Isola delle Femmine, Sicily, Italy, with a total land surface of about 0.15 km<sup>2</sup>), or in very limited areas (e.g. Pozzo del

Merro, Latium region, Italy), most often inside protected areas. The questionnaire highlighted that coastal dunes and sandy shores (EUNIS Code B1) (5 cases) followed by surface standing waters (EUNIS Code C1) and running waters (EUNIS Code C2) (4 and 3 cases, respectively) were the habitats with the highest number of eradication actions. Five cases (3 of which were in Catalonia) involving eradication actions from arable fields were also described.

The eradication actions tackled 23 invasive alien plant species. Aquatic species represented the dominant life form (5 species: *Eichhornia crassipes*, *Ludwigia peploides*, *Marsilea drummondii*, *Pistia stratiotes*, *Salvinia molesta*), followed by shrubby succulent chamaephytes (4 species: *Carpobrotus acinaciformis*, *Carpobrotus edulis*, *Cylindropuntia rosea*, *Opuntia stricta*). Grasses (3 perennials: *Cortaderia selloana*, *Pennisetum setaceum*, *Pennisetum villosum*; 2 annuals: *Leersia oryzoides*, *Leptochloa fusca* subsp. *uninervia*) were also of concern, while annual herbs were not covered except for the vine *Sicyos angulatus*. Phanerophytes, chamaephytes and hemichryptophytes were also represented.

Most of the invasive alien plant species which have been the target of an eradication action are listed by EPPO, such as *Ailanthus altissima* (EPPO List of Invasive Alien Plants), *Asparagus asparagoides* (Asparagaceae, EPPO Alert List), *Buddleia davidii* (EPPO List of IAP), *Carpobrotus* spp. (EPPO List of IAP), *E. crassipes* (EPPO A2 List), *Ludwigia peploides* (EPPO A2 List), *Pennisetum setaceum* (EPPO List of IAP), *Pistia stratiotes* (EPPO List of IAP), *Solanum elaeagnifolium* (EPPO A2 List) and *Sicyos angulatus* (EPPO List of IAP) (see Boxes 1 and 2 for the eradication actions on *E. crassipes* and *C. edulis* in Valencia region, Spain). Other species have a limited distribution in the whole EPPO region and may represent emerging invasive plants, such as *Ambrosia confertifolia*, *Cylindropuntia rosea*, *Leersia oryzoides*, *Leptochloa fusca* subsp. *uninervia* and *Marsilea drummondii* (see Box 3, eradication actions on *Leersia oryzoides* and *Leptochloa fusca* subsp. *uninervia* in Catalonia, Spain).

### Control and monitoring actions for invasive alien plants in the Mediterranean Basin

Eradication actions are difficult to undertake, as they imply a preliminary assessment of the risk that a species represents and rapid action, for which resources, as well as dialogue with the different stakeholders, are necessary. It is thus no surprise that control actions occur more frequently than eradication actions.

The questionnaire and literature review gathered control and monitoring actions for about 90 species, with an overlap for 13 species which were also the target of eradication actions. A major contribution is that of Andreu *et al.* (2009), who undertook a survey on invasive alien plants in the whole territory of Spain. These records may overlap with those gathered in other surveys or references in Spain in Table 2. Table 2 provides, for each alien species

**Table 1** Eradication actions against invasive alien plants in the Mediterranean Basin

Alien species	Country	Scale of action	EUNIS Habitat*	References
<i>Agave americana</i> (Agavaceae)	Spain	Andalucía. Action undertaken on sand dunes to aim at the recovery of plant communities.	B1	Dana <i>et al.</i> (2009)
<i>Ailanthus altissima</i> (Simaroubaceae, EPPO List of Invasive Alien Plants)	Italy	Capraia island (Tuscan Archipelago National Park). Forty infested sites were found on the island. Cutting was followed by glyphosate spraying from 1999 to 2010; action will be continued until eradication is achieved. Montecristo island (Tuscan Archipelago National Park). Cutting was followed by glyphosate spraying (local eradication is expected).	J1, F5, F6	P. Sposimo and L. Lombardi, pers. comm. (2010)
<i>Ambrosia confertifolia</i> (Asteraceae)	Spain	Isola delle Femmine (Nature reserve), Sicily. Local eradication is planned. Removal by hand and through mechanical and chemical methods in some areas of high conservation value.	J1, F5, F6 F5, F6 N/A	P. Sposimo and L. Lombardi, pers. comm. (2010) Genovesi & Camevali (2011) J. Guerrero Campo, pers. comm. (2010)
<i>Asparagus asparagoides</i> (Asparagaceae, EPPO Observation list of invasive alien plants)	Israel	Heffer valley. Eradication action started in 2006 after GIS survey in the Heffer valley, using high concentration of 2,4-D or fluoroxypr with glyphosate. The activity of these products was good but a second application was needed. The spray drift caused severe damage to cotton crop and avocado orchards. In 2007–08, the programme considered other phytosanitary products to be applied.	I1	T. Yaacoby, pers. comm. (2010)
<i>Asparagus asparagoides</i> (Asparagaceae, EPPO Observation list of invasive alien plants)	Spain	Andalucía. Manual removal in the La Barrosa peri-urban park in Chicliana de la Frontera, near Cádiz, undertaken by the Consejería de Medio Ambiente.	F5	Europa Press (2010)
<i>Buddleia davidii</i> (Scrophulariaceae, EPPO List of IAP)	Spain	Aragón. Limited distribution according to the mapping undertaken, eradication action in progress.	G1	J. Guerrero Campo, pers. comm. (2010)
<i>Carpobrotus edulis</i> (Aizoaceae, EPPO List of IAP)	Spain	Minorca Island. Funded by the EU through the LIFE 2000NAT/ES/7355 (over 250 000 EUR)	B1, B3	Pere <i>et al.</i> (2005)
<i>Carpobrotus</i> spp. (= <i>C. edulis</i> & <i>C. actinaciformis</i> ) (Aizoaceae, EPPO List of IAP)	France	Valencia region. See Box 1. Bagaud Island. <i>Carpobrotus</i> species and rats are being eradicated to protect the biological diversity of the island, and educational projects are planned including a documentary film.	B1 B3	V. Deltoro, pers. comm. (2010) Parc National de Port Cros, Institut Méditerranéen d'Ecologie et de Paléécologie (2008) MEPA (2004)
<i>Cortaderia seloana</i> (Poaceae)	Malta	The plant is reported to have been eradicated successfully from Ir-Ramla Iat-Torri (northern coast of the island of Malta) and Ir-Ramla I-Hamra (along the northern coast of the island of Gozo).	B1	Dana <i>et al.</i> (2009)
<i>Cylindropuntia rosea</i> (Cactaceae)	Spain	Andalucía. Action undertaken on sand dunes on the Mediterranean and Atlantic coasts, as well as coastal dunes and vegetated sea cliffs of the Mediterranean coast, to aim at the recovery of plant communities.	G1	J. Guerrero Campo, pers. comm. (2010)
	Spain	Aragón. Limited distribution according to the mapping undertaken, eradication in progress.	G1	J. Guerrero Campo, pers. comm. (2010)
	France	Salagou Lake, local eradication action in progress. Limited distribution, mechanical measures (excavation), annual monitoring and manual removal of regrowth.	F6	I. Mandon, pers. comm. (2012)
	Spain	Castellón, Valencia and Alicante. Three large invaded areas, multiple small or very small areas under eradication, using mechanical and chemical methods.	N/A	V. Deltoro, pers. comm. (2010)

(continued)

Table 1 (continued)

Alien species	Country	Scale of action	EUNIS Habitat*	References
<i>Eichhornia crassipes</i> (Pontederiaceae, EPPO A2 List)	Spain	Valencia region. See Box 2.	C2	V. Deltoro, pers. comm. (2010)
<i>Leersia oryzoides</i> (Poaceae)	Spain	Catalunia. Mandatory control. See Box 3.	I1	Department d'Agricultura, ramaderia i pesca (2006)
<i>Leptochloa fusca</i> subsp. <i>uninervis</i> (Poaceae)	Spain	Catalunia. Mandatory control. See Box 3.	I1	Department d'Agricultura, ramaderia i pesca (2006)
<i>Ludwigia peploides</i> (Onagraceae, EPPO A2 List)	Spain	Castellón, Valencia and Alicante. Localised invasion. Eradication action using chemical spraying.	C1, C2	V. Deltoro, pers. comm. (2010)
<i>Marsilea drummondii</i> (Marsileaceae)	France	Lac de l'Eureuil, Esterel, domanian forest. Invaded area of 100 m <sup>2</sup> , eradication action in progress with manual removal in 2010 and 2011.	C1	I. Mandon-Dalger, pers. comm. (2010), Office National des Forêts Website
<i>Nicotiana glauca</i> (Solanaceae)	France	Saint Laurent de Salanque. Mechanical and manual removal.	B1	J. Barret, pers. comm. (2012)
<i>Oenothera biennis</i> (Onagraceae)	Spain	Aragón. Limited distribution according to the mapping undertaken, eradication action in progress.	N/A	J. Guerrero Campo, pers. comm. (2010)
<i>Opuntia stricta</i> (Cactaceae)	Italy	Isola delle Femmine (Nature reserve). No details provided.	N/A	Genovesi & Carnevali (2011)
<i>Pennisetum setaceum</i> (Poaceae, EPPO List of IAP) and <i>Pennisetum villosum</i> (Poaceae)	France	Sète. Chemical control.	J4	F. Brot, pers. comm. (2010)
<i>Pistia stratiotes</i> (Araceae, EPPO List of IAP)	Spain	Andalusia. The local eradication action was undertaken within the Andalusian Program for the Control of Invasive Exotic Species ( <i>Plan Andaluz para el Control de las Especies Exóticas Invasoras</i> ).	C2	Ortega <i>et al.</i> (2005)
<i>Salvinia molesta</i> (Salviniaceae, EPPO List of IAP)	France	Corsica. No details provided.	C1	G. Paradis, pers. comm. (2013)
	Italy	Pozzo del Merro. Eradicated from a deep sinkhole located in a natural protected area managed by the Province of Rome.	C1	Giardini (2004), Butcomino <i>et al.</i> (2011)
	Portugal	Southern Portugal. The species has not been observed since the eradication action.	C1	E & H Marchante, pers. comm. (2010)
<i>Solanum elaeagnifolium</i> (Solanaceae, EPPO A2 List)	France	Etang de Berre. One single plant was eradicated mechanically.	E1	S. Brunel, pers. comm. (2005)
	Tunisia	Mahdia. As the distribution of the species in Mahdia was very limited compared with other sites in Tunisia, an action plan to eradicate the species was undertaken in 2009 by mechanical, manual and chemical means.	I1, J4	M. Mekki, pers. comm. (2010)
<i>Solanum sodomaeum</i> (Solanaceae)	Italy	Isola delle Femmine (Nature reserve).	F5, F6	Genovesi & Carnevali (2011)
<i>Sicyos angulatus</i> (Cucurbitaceae, EPPO List of IAP)	Italy	Parco del Serio (protected area). No details provided.	G1 (Riparian and gallery woodland)	ISPRA (2009)
	Spain	Catalunia. Mandatory control.	I1	Department d'Agricultura, ramaderia i pesca (2005a)

\*EUNIS Classification: B1: Coastal dunes and sandy shores – B3: Rock cliffs, ledges and shores, including the supralittoral – C1: Surface standing waters – C2: Surface running waters – E1: Dry grasslands – F5: Maquis, arborescent matorral and thermo-Mediterranean bushes – F6: Garrigue – G1: Broadleaved deciduous woodland – I1: Arable land and market gardens – J1: Buildings of cities, towns and villages – J4: Transport networks and other constructed hard-surfaced areas – N/A: Not available.

**Box 1 Eradication action against *Carpobrotus edulis* in Valencia (Spain)**

*Carpobrotus edulis* (Hottentot's fig, Aizoaceae) is a very widespread invasive alien species, listed on the EPPO List of Invasive Alien Plants. It colonizes maritime dunes along the coast of the Valencia region to a varying degree, from almost complete cover to dispersed patches, but it forms a more or less continuous population from north to south. Dense patches completely excluded native vegetation and altered natural dune dynamics. This species had been planted by the Spanish administration and by individual people to prevent sand blowing into their homes and crops. In 2003 a detailed cartography of the distribution of *C. edulis* and *Agave americana* was undertaken, and a distribution map and additional information useful for its management were produced. The invaded range of *C. edulis* along the coastline was divided into 2155 patches with an estimated total weight of 4558 tonnes of fresh phytomass.

The distribution map produced through GIS was used to establish eradication priorities among the different *C. edulis* populations. Priority was assigned to small populations of *C. edulis*, for which cost efficiency was higher. It was agreed that the Ministry of Environment, responsible for coast management, would eradicate the largest patches while the Valencia government would deal with the smallest ones. Since 2006, 1431 tonnes of the plant were manually removed. Follow-up work indicates that eradication is successful in most cases, and removal of the few plants that regrow is easy as small plants can be removed quickly. Control trials with low doses of glyphosate had been carried out successfully, with very few secondary effects. In the following years it is expected that efforts will be intensified to eliminate *C. edulis* completely from the Valencian coastline.

**Box 2 Eradication action against *Eichhornia crassipes* in Valencia (Spain)**

*Eichhornia crassipes* (water hyacinth, Pontederiaceae) is one of the most invasive alien aquatic plants worldwide, and is recommended for regulation in the EPPO region (registered on the A2 List).

In the Valencia region of Spain, *E. crassipes* was recorded in three locations: two rivers and a wetland. The pathway of entry of *E. crassipes* is not known with certainty, but is thought to be the use of the species as an ornamental plant. In the river Albaida, *E. crassipes* was occupying a stretch 1047 m long, covering 5785 m<sup>2</sup> – the largest infestation in the three sites. The occurrence of *E. crassipes* in this site was known since 2006. The removal of the plant from the river using excavators produced 207 tonnes of biomass in 168 working days. The eradication cost 114 000 EUR.

One hundred and twenty (120) tonnes of biomass were removed when eradicating the plant from the wetland. The occurrence of the plant at this site was known since 1992. The other river population ended up in the sea during flood events, where the plant died, and this population has not reappeared since then.

The eradication actions took place during 2007 to 2012. No regrowth has been observed in the largest population (Albaida river) but occasional foci have been recorded at Algar river. It is thought that this is due to the fact that small plants go unnoticed as they become entangled in the abundant vegetation covering river banks. No seed production was observed.

Collaboration between different administrative bodies (both local and regional) was necessary to eradicate the plant. The national administration was in charge of eliminating the plant from the Albaida river, as river management is under the responsibility of the Spanish Ministry of Environment.

**Box 3 Eradication actions against alien grasses in Catalonia (Spain)**

*Leersia oryzoides* and *Leptochloa fusca* subsp. *uninervia* (Poaceae) are native to North and Central America and are quite common weeds of rice fields in France and Italy. These invasive alien species reduce harvests through crop competition. In Catalonia, they were recorded in the Ebro Delta. There were very few outbreaks, with new infestations occurring at the edges of rice fields. These alien grasses are quite widespread in rice fields of Spain, but are limited in Catalonia, although they are abundant in the Baix Emporda.

The plants have been destroyed by all possible means (mechanical and chemical methods) wherever they were found, and the managed areas monitored.

In Catalonia they are officially declared as weeds and require control measures. The Catalan government established a pioneering law in Spain for the eradication and control of weeds (Department d'Agricultura, ramaderia i pesca, 2006).

**Table 2** Invasive alien species recorded to be subject to control actions in Mediterranean countries

<i>Alien taxa</i>	Country	Place and type of action	References
<i>Acacia dealbata</i> (Fabaceae, EPPO List of IAP)	Portugal	Mechanical and chemical control undertaken in some areas against this widespread species.	E & H Marchante, pers. comm. (2010)
<i>Acacia cyclops</i> (Fabaceae)	France	Various mechanical and chemical control techniques undertaken on limited areas, including Porquerolles island.	CBNMed (2013)
<i>Acacia farnesiana</i> (Fabaceae)	Spain	Castellón, Valencia and Alicante. Scattered distribution across the Valencia region, low abundance. Control by hand and chemical methods in maritime dunes.	V. Deltoro, pers. comm. (2010)
<i>Acacia longifolia</i> (Fabaceae)	Spain	Castellón, Valencia and Alicante. Scattered distribution across the Valencia region, low abundance. Control by hand and chemical methods in maritime dunes.	V. Deltoro, pers. comm. (2010)
<i>Acacia longifolia</i> (Fabaceae)	Portugal	Mechanical and chemical control undertaken in some areas against this widespread species.	E & H Marchante, pers. comm. (2010)
<i>Acacia melanoxylon</i> (Fabaceae)	Portugal	Mechanical and chemical control undertaken in some areas against this widespread species.	E & H Marchante, pers. comm. (2010)
<i>Acacia retinoides</i> (Fabaceae)	Spain	Castellón, Valencia and Alicante. Scattered distribution across the Valencia region, low abundance. Control by hand and chemical methods in maritime dunes.	V. Deltoro, pers. comm. (2010)
<i>Acacia saligna</i> (Fabaceae)	Cyprus	In Larnaka Lake, the species is locally controlled as part of a EU LIFE project. Flower stalks and young shoots are removed.	G. Brundu, pers. comm. (2013)
	Malta	Planting, propagation, sowing and sale of this species is illegal through the Trees and Woodlands Protection Regulations, 2001 (Legal Notice 12 of 2001). In Ghadira, the tree/shrub is first cut down with a chainsaw. Roots that respout are removed using a small handsaw, the tree then dies off.	D. Stevens, pers. comm. (2010)
	Portugal	Mechanical and chemical control undertaken in some areas against this widespread species.	E & H Marchante, pers. comm. (2010)
	Spain	Castellón, Valencia and Alicante. Scattered distribution across the Valencia region, low abundance. Control by hand and chemical methods in maritime dunes.	V. Deltoro, pers. comm. (2010)
<i>Acacia</i> spp. (Fabaceae)	Spain	Managed in 7 autonomous communities and protected areas for an estimated direct cost of management of 90 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Acer negundo</i> (Sapindaceae)	Spain	Aragón. Actions of mapping, monitoring and control.	J. Guerrero Campo, pers. comm. (2010)
<i>Agave americana</i> (Asparagaceae)	Malta	Widespread, the species is managed mechanically. It is illegal through the Trees and Woodlands Protection Regulations, 2001 (Legal Notice 12 of 2001).	D. Stevens, pers. comm. (2010)
	Spain	Castellón, Valencia and Alicante. The species has a scattered distribution and is removed by hand and controlled chemically in maritime dunes.	V. Deltoro, pers. comm. (2010)
	Spain	Managed in 7 autonomous communities and protected areas for an estimated direct cost of management of 57 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Agave sisalana</i> (Asparagaceae)	Malta	Localized, the species is managed mechanically.	D. Stevens, pers. comm. (2010)
<i>Ageratina adenophora</i> (Asteraceae)	Spain	Estimated direct cost of management of 23 100 EUR over the past decade.	Andreu <i>et al.</i> (2009)

(continued)

Table 2 (continued)

Alien taxa	Country	Place and type of action	References
<i>Ailanthus altissima</i> (Simaroubaceae, EPPO List of IAP)	Corsica	The species is widespread and management actions are limited in areas where mechanical control could be efficient (uprooting of young shoots, removal of bark and treating the trunk over 3–5 cm).	CBNMed (2013)
	Italy	Ente Parco Regionale Migliarino San Rossore Massaciuccoli. It has a scattered distribution, and is locally abundant in <i>Pinus</i> forests and less commonly in dune habitats. Local experimental trials of repeated treatments.	A. Perfetti, pers. comm. (2010)
	Italy	Parco del Basso Corso del Fiume Brembo. A 6-year-long experimental project on chemical treatment of low-impact techniques such as stem injection, localized treatment of cut stump and basal bark.	Mazzoleni <i>et al.</i> (2010)
	Malta	Widespread. Mechanical and chemical control.	D. Stevens, pers. comm. (2010)
	Portugal	Planting, propagation, sowing and sale of such species is illegal through the Trees and Woodlands Protection Regulations, 2001 (Legal Notice 12 of 2001).	E & H Marchante, pers. comm. (2010)
	Spain	Widespread. Mechanical control undertaken in some areas.	J. Guerrero Campo, pers. comm. (2010)
	Spain	Aragón. Containment.	Andreu <i>et al.</i> (2009)
<i>Aloe</i> spp. (Asparagaceae)	Spain	Managed in 6 autonomous communities and protected areas for an estimated direct cost of management of 26 675 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Ambrosia artemisiifolia</i> (Asteraceae, EPPO List of IAP)	Croatia	Managed in 1 autonomous community and protected area. Obligatory control.	Ministry of Agriculture, Forestry & Water of Croatia (2006) Observatoire des Ambroisies
	France	Obligatory control. For the regions concerned by this study, prefectural orders making the control of <i>A. artemisiifolia</i> obligatory have been adopted in the departments of Gard (2006), Ardèche (2000), Drôme (2001) and Vaucluse (2003).	
	Italy	Valle Cavanata (Regional protected area), hand pulling. Several other regions established obligatory control.	P. Merluzzi, pers. comm. (2013)
	Spain	An estimated direct cost of management of 1000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Amorpha fruticosa</i> (Fabaceae, EPPO List of IAP)	Italy	Valle Cavanata (Regional protected area), mechanical and chemical control (glyphosate)	P. Merluzzi, pers. comm. (2013)
	Italy	Foce dell'Isonzo (Regional Nature Reserve), local control with different techniques, i.e. cattle browsing, mechanical and chemical control (glyphosate).	P. Merluzzi, pers. comm. (2013)
	Italy	Po Delta (Regional protected area), mechanical and chemical control.	P. Virgilietti and A. Mar, pers. comm. (2013)
	Italy	Riserva naturale di Valpredina. Mechanical control.	WWF Italy, pers. comm. (2010)
	Italy	Ente Parco regionale Migliarino San Rossore Massaciuccoli. The species can be very abundant, it is managed mechanically and chemically and monitored.	A. Perfetti, pers. comm. (2010)
	France	Widespread in Camargue and along the Rhône river. Regular mechanical management actions (mechanical grinding and uprooting of young shoots) are undertaken by the Compagnie Nationale du Rhône.	G. Fried, pers. comm. (2013)
<i>Apтения cordifolia</i> (Aizoaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Arctotheca calendula</i> (Asteraceae)	Spain	Managed in 3 autonomous communities and protected areas for an estimated direct cost of management of 15 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)

(continued)

Table 2 (continued)

<i>Alien taxa</i>	Country	Place and type of action	References
<i>Arundo donax</i> (Poaceae)	Malta	Ir-Ramla. Widespread. Mechanical control and constant monitoring.	D. Stevens, pers. comm. (2010)
	Portugal	Very abundant, present in all Portuguese provinces. Mechanical control undertaken in some areas.	E & H Marchante, pers. comm. (2010)
<i>Azolla filiculoides</i> (Salviniaceae, EPPO Observation List of IAP)	Spain	Castellón, Valencia and Alicante. Very abundant and widespread across all rivers, managed mechanically and chemically.	V. Deltoro, pers. comm. (2010)
	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
	Spain	Castellón, Valencia and Alicante. The species is removed by hand in high conservation value areas.	V. Deltoro, pers. comm. (2010)
<i>Baccharis halimifolia</i> (Asteraceae, EPPO List of IAP)	Spain	Managed in 3 autonomous communities and protected areas for an estimated direct cost of management of 1 000 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
	France	Salses-Leucate and Camargue gardoise.	Life project CEN LR, pers. comm. (2010)
	France	Parc Naturel Régional de Camargue, Domaine de la Palissade They de Roustan.	G. Fried, pers. comm. (2013)
	Spain	Pais Vasco.	Life project 08NAT/E/000055
<i>Buddleia davidii</i> (Scrophulariaceae)	Spain	Managed in 4 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
	Spain	Managed in 3 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
	Malta	Widespread. Manual eradication action from sand dune systems.	D. Stevens, pers. comm. (2010)
<i>Carpobrotus edulis</i> (Aizoaceae, EPPO List of IAP)	Portugal	Widespread. Mechanical and manual control undertaken in some areas.	E & H Marchante, pers. comm. (2010)
	Spain	Castellón, Valencia and Alicante. Very abundant and widespread across all maritime dunes.	V. Deltoro, pers. comm. (2010)
<i>Carpobrotus</i> spp. (= <i>C. acinaciformis</i> and <i>C. edulis</i> ) (Aizoaceae, EPPO List of IAP)	France	Salses-Leucate & Camargue gardoise.	CEN LR, pers. comm. (2010)
	France	Port Cros National Park.	G. Fried, pers. comm. (2010)
	France	Archipel de Riou nature reserve.	G. Fried, pers. comm. (2010)
	France	Corsica. Sanguinaires islands archipelago, Lavezzi and Mezzu.	Paradis <i>et al.</i> (2008)
	Italy	Capraia Island (Toscana). Manual removal coupled with chemical treatments.	P. Sposimo and L. Lombardi, pers. comm. (2010)
<i>Cortaderia selloana</i> (Poaceae, EPPO List of IAP)	Italy	Sardinia. Various localities.	G. Brundu, pers. comm. (2013)
	Spain	Managed in 8 autonomous communities and protected areas for an estimated direct cost of management of 2 886 683 EUR over the past decade.	Andreu <i>et al.</i> (2009)
	Spain	Andalusian Plan for Control of Invasive Species. 300 ha had been treated by hand pulling. A total of 400 tonnes of plant material was transferred to composting areas.	Ortega Alegre & Ceballos (2006)
<i>Conula coronopifolia</i> (Asteraceae)	Spain	Baleares, Mallorca Island. 371 543 EUR invested in the attempted eradication of <i>Carpobrotus</i> species on the Mallorcan coastline where it was overtaking local dune systems.	The Company PPB (Proyectos Paisajísticos de los Balears) carried out this project for the Consell of Menorca.
	Spain	Castellón, Valencia and Alicante. It is becoming increasingly abundant in wetlands, mechanically managed.	V. Deltoro, pers. comm. (2010)
<i>Conula coronopifolia</i> (Asteraceae)	Spain	Managed in 8 autonomous communities and protected areas for an estimated direct cost of management of 8600 EUR over the past decade.	Andreu <i>et al.</i> (2009)
	Spain	Balearic islands. Detected in a protected area. Experimental control through manual removal.	C. Alvarez, pers. comm. (2010)

(continued)

Table 2 (continued)

Alien taxa	Country	Place and type of action	References
<i>Cylindropuntia subulata</i> (Cactaceae)	Spain	Castellón, Valencia and Alicante. The plant has a scattered distribution across de Valencia region, but is of lower concern. Manual removal.	V. Deltoro, pers. comm. (2010)
<i>Cyperus bulbosus</i> (Cyperaceae)	Tunisia	Abundant in the Cap Bon, tillage management.	A. Omezine, pers. comm. (2010)
<i>Datura stramonium</i> (Solanaceae)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Disphyma crassifolium</i> (Aizoaceae)	Spain	Castellón, Valencia and Alicante. The plant is localized in some maritime cliffs, it is removed manually.	V. Deltoro, pers. comm. (2010)
<i>Egeria densa</i> (Hydrocharitaceae, EPPO List of IAP)	Spain	Castellón, Valencia and Alicante. The species is abundant in one wetland, and the mechanical control has proven unsuccessful so far.	V. Deltoro, pers. comm. (2010)
<i>Eichhornia crassipes</i> (Pontederiaceae, EPPO A2 List)	Spain Italy Portugal	Managed in 1 autonomous community and protected area. Sardinia. Mechanical removal in Oristano area. Mechanical control undertaken in some areas. In the Municipality of Águeda, the management of the plant from December 2006 to May 2008 cost 278 000 EUR.	Andreu <i>et al.</i> (2009) Brundu <i>et al.</i> (2012) E & H Marchante, pers. comm. (2010), Laranjeira & Naddais (2008)
<i>Eleusine indica</i> (Poaceae)	Spain	The management cost to remove nearly 200 000 tonnes of the plant was 14 680 000 EUR from 2005 to 2008 in the Guadiana river (for around 75 km of river).	Cifuentes <i>et al.</i> (2007)
<i>Eucalyptus camaldulensis</i> (Myrtaceae)	Spain	Managed in 4 autonomous communities and protected areas for an estimated direct cost of management of 6 700 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Eucalyptus gomphocephala</i> (Myrtaceae)	Tunisia Italy	Abundant in the Cap Bon, tillage management. Sardinia. Local mechanical removal from a Sites of Community Importance (Habitats Directive) (ITB020012 Barchida – Bidderosa).	A. Omezine, pers. comm. (2010) M. Manca, pers. comm. (2012)
<i>Eucalyptus</i> spp. (Myrtaceae)	Malta Malta	Widely planted but not yet established. The species is being mechanically removed. The species has been widely planted but is rarely established and is being mechanically removed.	D. Stevens, pers. comm. (2010) D. Stevens, pers. comm. (2010)
<i>Erigeron annuus</i> (Asteraceae)	Spain	Managed in 8 autonomous communities and protected areas for an estimated direct cost of management of 31 528 590 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Fallopia baldschuanica</i> (Polygonaceae, EPPO List of IAP)	Italy	Azienda agricola Valpredina. The presence of this plant reduces the floristic richness in natural meadows. It is frequently cut and monitored.	WWF Italy, pers. comm. (2010)
<i>Fallopia japonica</i> (Polygonaceae, EPPO List of IAP)	Spain	Castellón, Valencia and Alicante. The plant remains localized in ravines and river banks. It is manually removed and chemical trials are ongoing.	V. Deltoro, pers. comm. (2010)
<i>Galinsoga parviflora</i> (Asteraceae)	Spain Tunisia	Managed in 2 autonomous communities and protected areas. Abundant in the Cap Bon, tillage management.	Andreu <i>et al.</i> (2009) A. Omezine, pers. comm. (2010)
<i>Hakea sericea</i> (EPPO List of IAP)	Portugal Spain France	Localized. Mechanical control undertaken in some areas. Estimated direct cost of management of 2000 EUR over the past decade. Localized in the maritime Alps, and in the submediterranean mountainous area of Gard (Cevennes).	E & H Marchante, pers. comm. (2010) Andreu <i>et al.</i> (2009) G. Fried, pers. comm. (2013)
<i>Heracleum mantegazzianum</i>	Italy	Riserva Naturale Speciale Sacro Monte di Oropa (Piedmont Region). Control of a small infested area inside the protected area. At Pànace di Mantegazza (Courmayeur, Valle d'Aosta Region) control involves cutting flower heads during the summer region, and raising awareness in the local population.	Selvaggi <i>et al.</i> (2006); Tutino <i>et al.</i> (2010)

(continued)

Table 2 (continued)

Alien taxa	Country	Place and type of action	References
<i>Ipomoea</i> spp. (Convolvulaceae)	Spain	Managed in 3 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Kalanchoe daigremontiana</i> (Crassulaceae)	Malta	Very rare. Manually removed from protected areas where it is found.	D. Stevens, pers. comm. (2010)
<i>Kalanchoe</i> spp. (Crassulaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Lagarosiphon major</i> (Hydrocharitaceae, EPPO List of IAP)	France	Salagou Lake.	Conseil Général de l'Hérault (2011)
<i>Lavatera arborea</i> (Malvaceae)	Malta	Uncertain status (cryptogenic). Manually removed from selected protected areas.	D. Stevens, pers. comm. (2010)
<i>Lonicera japonica</i> (Caprifoliaceae)	Italy	Valle Cavanata (Regional Protected Area), chemical control.	P. Merluzzi, pers. comm. (2013)
<i>Ludwigia grandiflora</i> (Onagraceae, EPPO A2 List)	Spain	Castellón, Valencia and Alicante. Chemical control to contain its abundant presence in some wetlands and rivers.	V. Deltoro, pers. comm. (2010)
<i>Ludwigia peploides</i> (Onagraceae, EPPO A2 List)	France	In many sites in Camargue (Centre du Scamandre).	G. Fried, pers. comm. (2013)
	Corsica	Found in Figari since 2007 with several populations along a river. Uprooting campaigns are conducted annually.	G. Paradis, pers. comm. (2013)
<i>Ludwigia</i> spp. (Onagraceae, EPPO A2 List)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Melia azedarach</i> (Meliaceae)	Italy	Capraia Island (Toscana). Limited populations, cutting followed by chemical treatment is undertaken.	P. Sposimo and L. Lombardi, pers. comm. (2010)
<i>Mesembryanthemum crystallinum</i> (Mesembryanthemaceae)	Spain	Andalucía. Action undertaken on the sea cliffs of the Mediterranean coast.	Dana <i>et al.</i> (2009)
<i>Myoporum</i> spp. (Scrophulariaceae)	Spain	Managed in 4 autonomous communities and protected areas for an estimated direct cost of management of 400 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Nicotiana glauca</i> (Solanaceae)	Spain	Managed in 2 autonomous communities and protected areas for an estimated direct cost of management of 400 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Oenothera biennis</i> (Onagraceae)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Oenothera drummondii</i> (Onagraceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Oenothera glazioviana</i> (Onagraceae)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Opuntia ficus-indica</i> (Cactaceae)	Malta	Widespread. Mechanical removal.	D. Stevens, pers. comm. (2010)
<i>Opuntia maxima</i> (Cactaceae)	Spain	Castellón, Valencia and Alicante. The species is widely distributed and is mechanically and chemically removed in high natural value areas.	V. Deltoro, pers. comm. (2010)
<i>Opuntia stricta</i> (Cactaceae)	France	Salses-Leucate & Camargue Gardoise.	CEN LR, pers. comm. (2010)
<i>Opuntia vulgaris</i> (Cactaceae)	Malta	Rare. Mechanical removal.	D. Stevens, pers. comm. (2010)
<i>Opuntia</i> spp. (Cactaceae)	Spain	Managed in 4 autonomous communities and protected areas for an estimated direct cost of management of 4000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Oxalis pes-caprae</i> (Oxalidaceae)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Paspalum dilatatum</i> (Poaceae)	France	Widespread, Mayons, Var. Mechanical control is localized in temporary streams associated with species of high patrimonial value.	G. Fried, pers. comm. (2013)
<i>Pennisetum setaceum</i> (Poaceae)	Spain	Castellón, Valencia and Alicante. Monitoring and removal by hand as the species is localized.	V. Deltoro, pers. comm. (2010)
	Spain	Managed in 1 autonomous community and protected area for an estimated direct cost of management of 6 203 300 EUR over the past decade.	Andreu <i>et al.</i> (2009)

(continued)

Table 2 (continued)

Alien taxa	Country	Place and type of action	References
<i>P. villosum</i> (Poaceae)	Spain	Castellón, Valencia and Alicante. Monitoring and removal by hand as the species is found in small patches.	V. Deltoro, pers. comm. (2010)
	Spain	Balearics. The species was detected in areas which have been changed by human activities. Control was initiated to prevent the species from reaching the natural environment. After 2 years of treatment with herbicide (Glyphosate) there is a substantial reduction of the species.	C. Alvarez, pers. comm. (2010)
<i>Phyla filiformis</i> (Verbenaceae)	France	Basse plaine de l'Aude.	CEN LR, pers. comm. (2010)
<i>Physalis philadelphica</i> (Solanaceae)	Turkey	Very abundant in cotton and corn, managed chemically.	B. Bukun, pers. comm. (2010)
<i>Pitiosporum tobira</i> (Pittosporaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Pitiosporum undulatum</i> (Pittosporaceae)	Portugal	Widespread. Mechanical and chemical control undertaken in some areas.	E & H Marchante, pers. comm. (2010)
<i>Platanus hybrida</i> (Platanaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Plectranthus australis</i> (Lamiaceae)	Spain	Estimated direct cost of management of 6250 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Prunus serotina</i> (Rosaceae, EPPO List of IAP)	Italy	Riserva Naturale di Valpredina. Mechanical control.	WWF Italy, pers. comm. (2010)
<i>Ricinus communis</i> (Euphorbiaceae)	Malta	Common. Mechanical removal. Planting, propagation, sowing and sale of such species is illegal through the Trees and Woodlands Protection Regulations, 2001 (Legal Notice 12 of 2001).	D. Stevens, pers. comm. (2010)
<i>Robinia pseudoacacia</i> (Fabaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
	Italy	Capraia Island (Toscana). Limited populations. Mechanical followed by chemical treatment.	A. Perfétti, pers. comm. (2010)
	Italy	Ente Parco regionale Migliarino San Rossore Massaciuccoli Locally abundant in patch of 'near water' forest habitats. Mechanical followed by chemical treatment.	P. Sposimo and L. Lombardi, pers. comm. (2010)
	Italy	Giardino Botanico Litorale del Veneto (protected area). Manual and chemical control by the Regional Forest Service (LIFE project).	P. Virgilietti and A. Mar, pers. comm. (2013)
	Spain	Castellón, Valencia and Alicante. The species is widely distributed, and is mechanically and chemically removed in areas of high natural value.	V. Deltoro, pers. comm. (2010)
	Spain	Aragón. Containment.	J. Guerrero Campo, pers. comm. (2010)
	Spain	Managed in 3 autonomous communities and protected areas for an estimated direct cost of management of 2 886 680 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Rumex lunaria</i> (Polygonaceae)	Spain	Estimated direct cost of management of 86 000 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Sagittaria</i> spp. (Alismataceae)	Spain	Catalunia. Mandatory control.	Department d'Agricultura, ramaderia i pesca (2006)
<i>Salpichroa origanifolia</i> (Solanaceae)	Tunisia	Cap Bon and Maklar, chemical treatments.	A. Omezine, pers. comm. (2010)
<i>Senecio inaequidens</i> (Asteraceae)	France	Corsica. The species was first reported in Corsica in 1984 at Erbalunga where it disappeared. In 2000, it has been recorded and eradicated at Calvi and at the bridge of Fango. Since 2005, the species is regularly managed in two locations (Calvi, Arro) that helped stabilize populations.	G. Paradis, pers. comm. (2013)
	Italy	Valle Cavanata (Regional protected area), hand pulling.	P. Merluzzi, pers. comm. (2013)
	Spain	Estimated direct cost of management of 19 600 EUR over the past decade.	Andreu <i>et al.</i> (2009)
<i>Senecio</i> spp. (Asteraceae)	Spain	Managed in 3 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)

(continued)

Table 2 (continued)

Alien taxa	Country	Place and type of action	References
<i>Solanum carolinense</i> (Solanaceae)	Spain	Catalonia. Obligatory control.	Department d'Agricultura, ramaderia i pesca (2005b)
<i>Solanum elaeagnifolium</i> (Solanaceae, EPP0 A2 List)	Tunisia, Morocco France	Monitoring and management of the species.  Hérault. Two locations near Montpellier are currently known. After an alert note from the Plant Health laboratory (Anses), the Regional Direction of Agriculture launched an action plan in 2011 that aims first to map all locations in the Languedoc region and then to decide whether control or eradication is possible. Irrigated summer and perennial crops are mown every week to prevent the production of new shoots or the establishment of new seedlings during summer months.	Mekki <i>et al.</i> (2010); A. Omezine, pers. comm. (2010) G. Fried, pers. comm. (2013)
	Greece		Kotoula-Syka (2010)
	Iraq, Jordan, Lebanon, Syria	FAO is implementing a project to assist farmers in managing and preventing further spread of this weed through integrated weed management.	FAO Media Centre (2011)
<i>Tradescantia fluminensis</i> (Commelinaceae)	Spain	Castellón, Valencia and Alicante. The species has a scattered distribution and a low abundance and is restricted to degraded areas. It is removed manually. Managed in 3 autonomous communities and protected areas.	V. Deltoro, pers. comm. (2010)
<i>Tropaeolum majus</i> (Tropaeolaceae)	Spain	Managed in 1 autonomous community and protected area.	Andreu <i>et al.</i> (2009)
<i>Vitis vinifera</i> (Vitaceae)	Malta	Ir-Ramla. Limited distribution. Manual control on sand dunes.	Andreu <i>et al.</i> (2009)
<i>Yucca aloifolia</i> (Asparagaceae)	Spain	Castellón, Valencia and Alicante. The species has a scattered distribution and low abundance; it occupies maritime dunes. It is mechanically and chemically managed in high natural value areas.	D. Stevens, pers. comm. (2010) V. Deltoro, pers. comm. (2010)
<i>Yucca gloriosa</i> (Asparagaceae)	Italy	Ente Parco Regionale Migliarino San Rossore Massaciuccoli. The species is locally abundant in back dunes. Mechanical and chemical controls are being undertaken followed by monitoring.	A. Perfetti, pers. comm. (2010)
<i>Yucca</i> spp. (Asparagaceae)	Spain	Managed in 3 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)
<i>Xanthium strumarium</i> (Asteraceae)	Spain	Managed in 2 autonomous communities and protected areas.	Andreu <i>et al.</i> (2009)

reported as being the object of a control action, the listing in the EPPO framework at the time of submission of the article (A2 List, List of Invasive Alien Plants, Alert List, Observation List of Invasive Alien Plants), as well as the country and target area with indications and references.

The genus with the largest number of records of control actions in Mediterranean countries is *Carpobrotus*. Local actions to control and monitor *Carpobrotus* species have been undertaken, or are in progress, in Italy (e.g. Sardinia island – different localities; Montecristo island in Tuscany), France (e.g. Port Cros national park; Archipel de Riou nature reserve; île Lavezzi and île Mezzu Mare in the archipelago îles Sanguinaires in Corsica, see Paradis *et al.*, 2008), Malta, Portugal and Spain. In some cases, management actions are followed by scientific research and monitoring (e.g. Andreu *et al.*, 2010 in Andalusia, Spain). *Ailanthus altissima*, *Acacia saligna* and *Acacia* species are also frequently managed in several target areas in the Mediterranean Basin.

Although this inventory of species and control actions is far from exhaustive, the invasive alien species which are reported as being managed in more than one Mediterranean country can be divided in two main categories:

- well known and very widespread invasive aliens, e.g. *Acacia saligna*, *Ailanthus altissima*, *Amorpha fruticosa* and *Robinia pseudoacacia*;
- species that represent a serious threat, though not very widespread in the EPPO region, and which have been identified as emerging problems, e.g. *Baccharis halimifolia*, *E. crassipes* and *Solanum elaeagnifolium*.

Most control actions are undertaken by a single country. These actions target a wide range of species. As for eradication actions, control actions are most often undertaken within protected areas and in the countries of the northern rim of the Mediterranean Basin; Spain is the most active country.

Furthermore, many invasive alien species which cause crops losses are frequently managed, such as *Abutilon theophrasti* (Asteraceae) in Catalonia (Recasens *et al.*, 2005), *Orobancha* spp. in Turkey, *Ambrosia artemisiifolia* in France, and many other species. Unless complete eradication actions were documented (Table 1), such management actions on invasive alien plants in crops were not the target of the survey and are therefore not mentioned here.

While most actions seem to be localized in small areas, the programmes in Valencia, Malta and Corsica integrate systematic actions on some invasive alien plants over the territory, through the listing of species, early detection, and eradication or control actions. In Malta, a number of invasive alien plants are being removed from protected areas (MEPA, 2013). Preliminary efforts in the Maltese Islands have been undertaken or are ongoing, and aim to control the spread of *C. edulis* in sand dunes, *Arundo donax* and *Vitis vinifera* in Ir-Ramla l-Hamra, *Acacia saligna* in Ghajn Tuffieha (western coast of the island of Malta) and *Agave* spp. in Rdum tal-Madonna.

## Discussion

### Eradication actions on invasive alien plants

From the results of the survey, a non-negligible number of eradication actions (34) have been planned in the EPPO Mediterranean countries (Table 1). These occurred mainly on islands, or in small, defined areas when on continental land. Most of the actions took place in protected areas, particularly on sand dunes or in standing waters. The survey also highlighted the existence of several actions in agricultural areas, enhanced by the experience of the Plant Health sector to control quarantine pests as plants (Schrader *et al.*, 2010). In addition to eradication actions, a large number of invasive alien plants are controlled and monitored (Table 2). These controlled species are probably so widespread that eradication is no longer feasible (even at a local scale).

The progress made in the past few years on this front needs to be acknowledged. Genovesi (2005), when undertaking a review of eradications in Europe in 2005, noted that only some very localized removals of invasive alien plants had been completed in Europe. The results of this survey highlight that attempts to eradicate invasive alien plants in the Mediterranean are being undertaken in many countries, in particular in Spain. Furthermore, eradication and control actions in non-Mediterranean countries are expected to be more numerous, owing to increased awareness of the issue.

Although Genovesi (2005) also reported 37 successful eradications of mammals, and that dozens of eradications of invertebrates are also being undertaken in the framework of the Plant Health regulation (Directive 2000/29 in Europe, and other national regulations), the number of eradication actions for invasive alien plants remains lower than those undertaken for other organisms. However they seem to be increasing steadily. Although some invasive alien plants recommended for regulation are reported here as the object of eradication actions, such as *E. crassipes* (Pontederiaceae, EPPO A2 List) and *Solanum elaeagnifolium* (Solanaceae, EPPO A2 List), other emerging invasive alien plants, such as *Hydrocotyle ranunculoides* (Apiaceae, EPPO A2 List), *Ludwigia grandiflora* (Onagraceae, EPPO A2 List) and *Althernanthera philoxeroides* (Amaranthaceae, EPPO List of Invasive Alien Plants), were not the object of eradication actions.

Eradication of plant species is generally seen as extremely challenging. Although the eradication of plants may be seen as more difficult than for other groups or organisms, Pluess *et al.* (2012), when evaluating statistically the success of eradications, found no difference in success rates among taxonomic groups or geographical regions.

### Eradication and the criteria for success

In general, the final outcome of a management plan or of an eradication programme for an invasive alien plant is

determined by the interplay of biological, operational, economic, environmental and sociopolitical factors (Panetta & Timmins, 2004; Panetta *et al.*, 2011). If a set of criteria is not strictly met, failure is almost guaranteed (Gardener *et al.*, 2009 and references cited therein). In general, it is agreed that species with a known limited distribution, that are easily detectable, with a short-lived seed bank and low dispersal ability, and for which methods of control are known, are prime candidates for successful eradication. All known successful plant eradications have targeted invasions detected early, or alien plants that have invaded limited areas, and there is no known case of successful eradication of a well established alien plant (Genovesi, 2011). Pluess *et al.* (2012) confirmed that the spatial extent of the infestation was the criterion most significantly related to eradication outcomes. Local campaigns were therefore more successful than regional or national campaigns.

It is also agreed that sufficient funding must be available over the long term (e.g. for monitoring), but also quickly available for rapid intervention to guarantee the success of an eradication. In European countries, LIFE Nature projects are a source of funding for control actions on invasive alien plants, but not for rapid response in the narrower sense. This European programme is funding the eradication of *Ailanthus altissima* from Montecristo Island in Italy (2010–14), the eradication of *Nicotiana glauca* in France (Salses-Leucate), and the control of *Acacia saligna* in Cyprus (Conservation Management in Natura 2000 sites) as well as of *Carpobrotus* spp. in France (e.g. Salses-Leucate & Camargue gardoise) and Spain. These tools, requiring the elaboration of complex administrative descriptions, may nevertheless not be totally appropriate to the need for rapid eradication, in particular when an eradication has to be undertaken in an area which is not a site of community importance. Whether the provision of funds is available at the European or country level should not restrict the availability of resources at the local level (e.g. municipalities, road services, etc.). Having local stakeholders investing resources for eradication of invasive alien plants would initially mean a good understanding of the issue, therefore advocating increased awareness on the topic of invasive alien plants.

#### **A crucial need for increased awareness**

Ultimately, the most often overlooked requirement is the need for public support for the project of eradication (Mack & Forster, 2009). While Genovesi (2005) noted that the success of mammal eradication programmes is connected to the approval of animal activist groups (e.g. eradication of the grey squirrel, initially planned in Italy, was cancelled because of animal activist groups), this issue may be less relevant for actions undertaken on invasive alien plants, making plant eradications easier to organize. Popular opposition may nevertheless occur for established plants that have been integrated in the use and culture of an area and for which there is a conflict of interest (Andreu *et al.*, 2009). For

example, *Acacia* spp., widely introduced into many EPPO Mediterranean countries, have many beneficial uses (Griffin *et al.*, 2011) in rural areas, providing fuelwood, food, fodder and shelter (Kull *et al.*, 2011; Wilson *et al.*, 2011). Resistance to eradication or control actions may also be encountered when there is a perception that the ecosystem is being degraded when removing the invasive alien plant, as when leaving sand dunes prone to erosion while removing *Carpobrotus* spp. Dialogue with the different stakeholders using the territory on which an eradication is to occur needs to be carefully planned, and requires coordination.

#### **A lack of coordination across regions and countries**

A large number of eradication actions and management actions reported in this survey were undertaken in nature reserves. Nature reserve managers were a target of the survey, and are usually more aware of the threats posed by invasive alien plants than other stakeholders (e.g. municipalities). Every country, and often every region or protected area, seems to operate in complete autonomy, with special concerns regarding the alien species that are considered to represent a priority for action in their area. There is no coordination of these newly undertaken eradication actions among nature reserves and countries, nor is there an agreed method to decide which plant represents a priority for action at a given scale.

#### **Conclusions: how to enhance eradication actions?**

Although invasive alien plants are gaining increased attention within EPPO countries, there is no existing widely agreed method to identify those alien plants that are considered invasive and represent the highest priority for action.

The fact that a small size of infestation is crucial for the success of eradication calls for the identification and listing of emerging species (Pluess *et al.*, 2012). The EPPO prioritization process integrates such requirements (EPPO, 2012), and represents an initial basis to harmonize evaluations of priorities between the EPPO Mediterranean countries. It is a suitable tool to produce lists of invasive alien plants that are established, or potentially could establish, in the EPPO region, and to determine which of these have the highest priority for an EPPO pest risk analysis. It has already been used to identify emerging invasive alien plants for the Mediterranean (Brunel *et al.*, 2010), which are also listed in the EPPO system through the EPPO Alert List, the EPPO List of Invasive Alien Plants, and the EPPO A2 List. EPPO also provides technical guidance on eradication and management through its National Regulatory Control Measures. So far, recommendations are available for *Ambrosia artemisiifolia*, *E. crassipes*, *Heracleum* spp. and *Sicyos angulatus*; general measures for the management of aquatic invasive alien plants are in preparation. Sunley *et al.* (2012) have also developed a decision-

support scheme that generates contingency plans and prioritizes action during pest outbreaks. This tool is aimed at assisting national plant protection organizations (NPPOs) in addressing and justifying eradication and containment campaigns effectively. EPPO has also collaborated with the Bern Convention for the elaboration of Recommendation no. 126 (2007) of the Standing Committee on the eradication of some invasive alien plant species, adopted by the Standing Committee on 29 November 2007.

Such Standards and recommendations are of primary importance and need to be pursued, but the exchange of experiences through managers should also be an objective. This article providing information and encouraging eradication and management actions on invasive alien plants also aims to promote increased dialogue and cooperation among stakeholders involved in the topic. This invitation was well communicated based on the high attendance at the 2nd Workshop on Invasive Alien Plants in Mediterranean Type Regions of the World held in Trabzon (TR),<sup>2</sup> and will hopefully be even more successful at the 3rd workshop to be held in 2015.

The management of plant invasions in general, and eradications in particular, requires a level of public awareness and support, in particular when there are conflicts of interest, as well as supporting legislation (both hard and soft tools, such as codes of conduct) for the control of pathways responsible for potential re-introductions. While Genovesi (2005) identified key elements to enhance eradication actions, such as the review of national legislation to allow mitigation measures on invasive alien species, the establishment of procedures to allow early warning, and the availability of contingency plans, the first necessity is to promote education and public awareness programmes to engage local communities and appropriate sector groups in eradication.

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<sup>2</sup>see the presentations and proceedings at [http://archives.eppo.int/MEETINGS/2010\\_conferences/mediterranean\\_ias.htm](http://archives.eppo.int/MEETINGS/2010_conferences/mediterranean_ias.htm)

Life + LAG'Nature. Greece: C Dal Cin D'Agata, Park for the Preservation of Flora and Fauna, Technical University of Crete. Israel: T Yaacoby, Plant Protection & Inspection Services Ministry of Agriculture. Italy: F Mason, CNBF Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale 'Bosco Fontana' – Corpo Forestale dello Stato; A Perfetti, Ente Parco regionale Migliarino San Rossore Massaciuccoli; P Sposimo and L Lombardi, NEMO SRL; Riserva naturale – SIC – Oasi WWF – Valpredina. Malta: D Stevens, Malta environment & Planning Authority. Portugal: E and H Marchante, Centre for Functional Ecology, University of Coimbra. Serbia: L Matic, Galenika-Fitofarmacija. Spain: C Alvarez, SPE – Conselleria de Medi Ambient; V Deltoro, Servicio de Biodiversidad, Generalitat Valenciana; J Guerrero Campo, Gobierno de Aragón. Departamento de Medio Ambiente, Weed Research Group (University of Lleida); A Traveset, IMEDEA. Mediterranean Institute for Advanced Studies, Spanish Research Council; C Zaragoza, Centro de Investigación y Tecnología Agroalimentaria de Aragón. Tunisia: O Abdessatar, Institut Supérieur Agronomique de Chott Meriem; M Mekki, Institut Supérieur Agronomique de Chott Meriem. Turkey: N Aksoy, Duzce University; B Bukun, Harran University. Additional useful information has been provided by M Giardini, M Manca and P Merluzzi (Italy). V Deltoro is particularly acknowledged for providing the information in Boxes 1–3.

## Eradication et contrôle des plantes exotiques envahissantes dans le bassin méditerranéen: vers une meilleure coordination pour optimiser les initiatives existantes

L'Organisation Européenne et Méditerranéenne pour la Protection des Plantes (OEPP), dans le cadre de ses activités dans le bassin méditerranéen, a émis un questionnaire pour regrouper des informations sur les actions de contrôle et d'éradication des plantes exotiques envahissantes. 34 actions d'éradication ont été rapportées, 16 en Espagne, 7 en Italie, 7 en France, 1 au Portugal, 1 à Malte et 2 sur la rive sud de la Méditerranée avec 1 en Israël et 1 en Tunisie. Vingt-deux (22) espèces ont été ciblées et les habitats où ce type d'actions ont été le plus fréquemment entreprises étaient des dunes côtières, des littoraux sableux et des écosystèmes aquatiques. La plupart des espèces qui ont fait l'objet d'actions d'éradication étaient des espèces exotiques envahissantes inscrites sur les listes de l'OEPP telles que *Ailanthus altissima*, *Buddleia davidii*, *Carpobrotus* spp., *Eichhornia crassipes*, *Ludwigia peploides*, *Pennisetum setaceum*, *Pistia stratiotes*, *Solanum elaeagnifolium* et *Sicyos angulatus*. D'autres espèces éradiquées ont une répartition limitée dans l'ensemble de la région OEPP et peuvent être de nouvelles plantes exotiques envahissantes comme *Ambrosia confertifolia*, *Cylindropuntia rosea*, *Leersia oryzoides*, *Leptochloa fusca*

subsp. *uninervia* et *Marsilea drummondii*. Des actions de lutte contre 90 espèces furent également rapportées. De nombreuses d'actions d'éradication et de gestion sont ainsi mises en œuvre dans les pays du pourtour méditerranéen. Actuellement, les acteurs semblent opérer en totale autonomie, sans consulter les pays voisins, ou d'autres parties prenantes à l'intérieur du pays. Il existe donc un besoin de coordination des nouvelles actions d'éradication.

**Ликвидация инвазивных чужеродных растений и борьба с ними в Средиземноморском бассейне: стремление к лучшей координации, позволяющей повысить отдачу от имеющихся инициатив**

В рамках своей работы в Средиземноморском бассейне, Европейская и средиземноморская организация по карантину и защите растений (ЕОКЗР) провела анкетный опрос, позволяющий собрать информацию о действиях по ликвидации инвазивных чужеродных растений и борьбе с ними. Было отмечено тридцать четыре (34) действия по ликвидации: 16 — в Испании, 7 — в Италии, 7 — во Франции, 1 — в Португалии, 1 — в Мальте и 2 — на южном побережье Средиземноморья: 1 — в Израиле и 1 — в Тунисе. Действия были направлены на двадцать два (22) вида, причем чаще всего такие действия предпринимались в таких местах обитания как прибрежные дюны, песчаные побережья и водные экосистемы. Большинство видов, ставших объектом ликвидации, представляли собой известные инвазивные виды, значащиеся в списках ЕОКЗР, такие как *Ailanthus altissima*, *Buddleia davidii*, *Carpobrotus* spp., *Eichhornia crassipes*, *Ludwigia peploides*, *Pennisetum setaceum*, *Pistia stratiotes*, *Solanum elaeagnifolium* и *Sicyos angulatus*. Другие ликвидированные виды имели ограниченную распространенность в регионе ЕОКЗР и могут представлять собой новые инвазивные растения, такие как *Ambrosia confertifolia*, *Cylindropuntia rosea*, *Leersia oryzoides*, *Leptochloa fusca* subsp. *uninervia* и *Marsilea drummondii*. Сообщалось также о мерах борьбы в отношении 90 видов. Таким образом, большинство действий по ликвидации, а также действий по управлению, предпринимаются в средиземноморских странах. Похоже, что в настоящее время фитосанитарные и природоохранные органы стран работают в полной автономии, не консультируясь с соседними странами или другими субъектами в рамках страны. Таким образом, налицо потребность в координации новых действий по ликвидации.

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