Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology: Official Journal of the Societa Botanica Italiana
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tplb20

Non-native flora of Italy: Species distribution and threats

L. Celesti-Grapow [a], A. Alessandrini [b], P. V. Arrigoni [c], S. Assini [d], E. Banfi [e], E. Barni [f], M. Bovio [g], G. Brundu [h], M. R. Cagiotti [i], I. Camarda [h], E. Carli [a], F. Conti [j], E. Del Guacchio [k], G. Domina [l], S. Fascetti [m], G. Galasso [e], L. Gubellini [n], F. Lucchese [o], P. Medagli [p], N. G. Passalacqua [q], S. Peccenini [r], L. Poldini [s], F. Pretto [a], F. Prosser [t], M. Vidali [s], L. Viegi [u], M. C. Villani [v], T. Wilhalm [w] & C. Blasi [a]

[a] Department of Plant Biology, Sapienza University, Italy
[b] Cultural Heritage Institute, Italy
[c] Department of Plant Biology, University of Florence, Italy
[d] Department of Landscape Ecology, University of Pavia, Italy
[e] Museo di Storia Naturale di Milano, Italy
[f] Department of Plant Biology, University of Turin, Italy
[g] Regional Natural Sciences Museum of Aosta Valley, Italy
[h] Department of Botany, Ecology and Geology, University of Sassari, Italy
[i] Department of Applied Biology, University of Perugia, Italy
[j] Department of Environmental Sciences, University of Camerino, Italy
[k] via Nicola Aversano, 4, Salerno, Italy
[l] Department of Botany, University of Palermo, Italy
[m] Department of Biology, Basilicata University, Italy
[n] Floristic Research Centre of Marche, Italy
[o] Department of Biology, Roma Tre University, Italy
[p] Botanical Garden, University of Salento, Italy
[q] Botanical Garden, University of Calabria, Italy
[r] Department of Landscape Study, University of Genova, Italy
[s] Department of Life Sciences, University of Trieste, Italy
[t] Civic Museum, Italy
[u] Department of Biology, Unit of Botany, University of Pisa, Italy
[v] Department of Biology, University of Padova, Italy
[w] Museum of Nature South Tyrol, Italy

Available online: 29 Apr 2010

Plant Biosystems, Vol. 144, No. 1, March 2010, pp. 12–28

Taylor & Francis
Taylor & Francis Group

Non-native flora of Italy: Species distribution and threats

L. CELESTI-GRAPOW[1], A. ALESSANDRINI[2], P. V. ARRIGONI[3], S. ASSINI[4], E. BANFI[5], E. BARNI[6], M. BOVIO[7], G. BRUNDU[8], M. R. CAGIOTTI[9], I. CAMARDA[8], E. CARLI[1], F. CONTI[10], E. DEL GUACCHIO[11], G. DOMINA[12], S. FASCETTI[13], G. GALASSO[5], L. GUBELLINI[14], F. LUCCHESE[15], P. MEDAGLI[16], N. G. PASSALACQUA[17], S. PECCENINI[18], L. POLDINI[19], F. PRETTO[1], F. PROSSER[20], M. VIDALI[19], L. VIEGI[21], M. C. VILLANI[22], T. WILHALM[23], & C. BLASI[1]

[1]*Department of Plant Biology, Sapienza University, Italy,* [2]*Cultural Heritage Institute, Italy,* [3]*Department of Plant Biology, University of Florence, Italy,* [4]*Department of Landscape Ecology, University of Pavia, Italy,* [5]*Museo di Storia Naturale di Milano, Italy,* [6]*Department of Plant Biology, University of Turin, Italy,* [7]*Regional Natural Sciences Museum of Aosta Valley, Italy,* [8]*Department of Botany, Ecology and Geology, University of Sassari, Italy,* [9]*Department of Applied Biology, University of Perugia, Italy,* [10]*Department of Environmental Sciences, University of Camerino, Italy,* [11]*via Nicola Aversano, 4, Salerno, Italy,* [12]*Department of Botany, University of Palermo, Italy,* [13]*Department of Biology, Basilicata University, Italy,* [14]*Floristic Research Centre of Marche, Italy,* [15]*Department of Biology, Roma Tre University, Italy,* [16]*Botanical Garden, University of Salento, Italy,* [17]*Botanical Garden, University of Calabria, Italy,* [18]*Department of Landscape Study, University of Genova, Italy,* [19]*Department of Life Sciences, University of Trieste, Italy,* [20]*Civic Museum, Italy,* [21]*Department of Biology, Unit of Botany, University of Pisa, Italy,* [22]*Department of Biology, University of Padova, Italy and* [23]*Museum of Nature South Tyrol, Italy*

Abstract

In this paper, we provide an overview of the distribution and invasive status of non-native species in the Italian flora across its administrative regions, biogeographic regions and main land use types, and a synthesis of current knowledge on the threats they pose within the country. The information on non-native plant species collected during the project "A survey of the non-native Italian flora" was used to compile comprehensive regional and national databases. The number of non-native species within a given administrative region increases in proportion to its size, resident population density and latitude, reaching the highest values in the intensively cultivated, heavily industrialized and urbanized Po Plain in northern Italy. The number of casual species is positively correlated with the number of yearly visitors in each region and negatively correlated with the proportion of mountainous terrain within the region. If compared with the Continental and Mediterranean biogeographic regions, the Alpine region yields the lowest number of non-native species and lowest proportion of casual species. The number and density of introduced species is highest in artificial land use types, particularly in urban areas. A negative impact is reported to be exerted by 203 species, most of which are agricultural weeds.

Keywords: *Alien flora, biogeographic pattern, impacts, Italy, land use types, plant invasions*

Introduction

Biotic invasions, resulting from the intentional or accidental transfer of species outside their native range through human activity, have become one of the main drivers of global environmental changes (Vitousek et al. 1996; Ricciardi & Cohen 2007) and a major cause of the loss of global biodiversity (Mack et al. 2000). Besides its ecological impact, the spread of non-native species has negative, well-documented consequences on human health, as well as social and economic effects throughout the world (e.g. Mooney & Hobbs 2000; Perrings et al. 2000).

Although the impact of human-driven biological invasions has been most serious in the so-called New World and in remote oceanic islands (Lonsdale 1999; Sax & Brown 2000; Sax & Gaines 2003), it is

Correspondence: L. Celesti-Grapow, Department of Plant Biology, Sapienza University, Piazzale Aldo Moro, 5,00185 Rome, Italy. Tel: +39 0649912845. Fax: +39 0649912420. Email: laura.celesti@uniroma1.it

ISSN 1126-3504 print/ISSN 1724-5575 online
DOI: 10.1080/11263500903431870

also a widespread problem in Europe, where it currently poses a major threat to biodiversity conservation (DAISIE 2009).

However, not all introduced species exert a negative effect. Indeed, only a minority become invasive (see definitions in Table I), and few cause major damage to natural or managed systems (Williamson 1996; Rejmánek et al. 2004). Many non-native plant species have actually been of great value to humans in areas such as agriculture, forestry and medicine, and have been of vital importance to local economies, for example as a form of food supply, in many countries throughout the world (Hoyt 1992). In order to identify priorities in management interventions and gain a better understanding of plant invasion processes, it is thus crucial to distinguish, among the high number of plants that make up non-native floras, those species that pose a major threat to the environment or other aspects of human life owing to their high rate of spread and current or potential impact. One essential, basic step in this direction consists of gathering information on the distribution and invasion status of each species, on the differences in the land use in which they occur (e.g. man-made or natural) and on the type of impact they cause (e.g. ecological or socio-economic).

The aim of the project "A survey of the non-native flora of Italy", which was developed in the years 2005–08 and financed by the Italian Ministry for the Environment (Blasi 2006), was to report on the current status of the non-indigenous species in the country. The first phase of this programme yielded a comprehensive inventory of the Italian non-native vascular flora (Celesti-Grapow, Alessandrini et al. 2009). Here, we present a synthesis of the main results that have emerged from the second phase, whose aim was to gather the information obtained on the distribution and the threats posed by each of these non-native plant species into a comprehensive system of integrated regional and national databases. This information was used in the third and final phase of the project to identify the most relevant non-native Italian plant species on the basis of their invasive status, their distribution in natural habitats and their current or potential impact.

The main purpose of this paper is to provide an overview of the distribution and invasive status of non-native plant species in Italy, divided according to its administrative regions, biogeographic regions and land use types, and a synthesis of current knowledge on the impacts exerted by these species within the country. More specific aims are to present summarized information on the structure of Italian regional alien floras, to outline the main overall geographic patterns of plant invasion across Italy and to reveal the main large-scale environmental factors that influence the number of alien species in individual regions.

Materials and methods

Study area

Extending from the Alps down towards the coasts of Africa in the very centre of the Mediterranean, over an area of 301,338 km^2, Italy is a country of great geographic diversity. Its latitude ranges from 35°29′ to 47°05′ and its longitude from 6°37′ to 18°31′. The majority of the territory is covered by mountains or hills. There are two major mountain ranges: the Alps, whose watershed forms the northern border of the country, and the Apennines, a chain of mountains that stretch from north to south along the entire length of the peninsula, dividing its eastern and western sides. Mont Blanc (4810 m a.s.l.) is the highest point in the Alps, the Gran Sasso (2912 m a.s.l.) in the Apennines and Mount Etna (Sicily, 3343 m a.s.l.) in the islands.

The Po Plain extends from west to east between the Alps to the north and the Apennines to the south. The Po, the longest river in Italy, flows eastwards for 652 km through this very fertile plain,

Table I. Terminology adopted in the present study (Celesti-Grapow, Alessandrini et al. 2009, modified from Pyšek et al. 2004).

Non-native plants	(Synonyms: alien, allocthonous, introduced, non-indigenous, exotic, xenophytes) Plant taxa in a given area whose presence is due to intentional or unintentional human involvement.
Casual plants	(Synonym: not established) Alien plants that may flourish and even reproduce occasionally outside cultivation, but that eventually die out because they do not form self-replacing populations, and rely on repeated introductions for their persistence.
Naturalized plants	(Synonym: established) Alien plants that sustain self-replacing populations for at least 10 years, without the direct intervention of people, through the recruitment of seeds or ramets capable of independent growth.
Invasive plants	A subset of naturalized plants that produce reproductive offspring, often in very large numbers and at considerable distances from the parent plants, and thus have the potential to spread over a large area.
Archaeophytes	Alien plant species introduced before the year 1492, i.e. before the discovery of America by European colonizers. This date is conventionally rounded off to 1500.
Neophytes	Alien plant species introduced after the year 1492. This date is conventionally rounded off to 1500.
Doubtful aliens	(Synonym: cryptogenic) Species whose native or introduced (archaeophyte) status remains undefined owing to insufficient information.

almost all of which is either intensively cultivated or dominated by heavily urbanized or industrialized areas. The peninsula is surrounded by several islands, including Sicily and Sardinia, the largest islands in the Mediterranean (25,707 km^2 and 24,090 km^2, respectively), and numerous smaller islands and archipelagos.

The bioclimate of Italy is temperate (56% of the territory) and transitional temperate (15%) in northern Italy, along the Apennines and the areas adjacent to the Apennines in the peninsula, and at high altitudes in Sicily and Sardinia; transitional Mediterranean (9%); and Mediterranean (20%) along the coasts and on the islands (Blasi & Michetti 2007).

Italy has a population of 59.5 million people, with an average population density of 198 inhabitants per square kilometre. The majority of the inhabitants live in urban areas, largely in northern Italy in the Po Plain, where urbanization is more widespread; in central and southern Italy, by contrast, urbanization is concentrated in a few, large, densely populated agglomerations, such as the cities of Rome, Naples and Palermo (ISTAT 2005).

The vast heterogeneity of the landscape in Italy (Blasi 2007) determines the presence of a remarkable flora, comprising 7634 species and subspecies of vascular plants (Conti et al. 2005). Italy's long history of human impact and its position at the centre of the main trade routes ever since ancient times has promoted the introduction and the establishment of non-native plant species in the country dating back thousands of years. Non-native taxa account for 13.4% of the total Italian vascular flora and number 1023 spontaneously occurring vascular plant species and subspecies (hereafter referred to as "species"). Of these, 103 are regarded as archaeophytes (i.e. introduced before the period of European colonization following the discovery of America – see definitions in Table I) and 920 as neophytes (i.e. introduced since the discovery of America). A clear-cut definition of non-native species is, however, not yet possible owing to gaps in our knowledge on the origin and introduction of several taxa. Therefore, an additional 40 species of the Italian flora are considered doubtful aliens, as their classification as either native or non-native (archaeophytes) has yet to be defined (Celesti-Grapow, Alessandrini et al. 2009). Of the 1023 non-native plant species of the Italian flora, 438 are currently casual (i.e. they are not established), while 524 are naturalized (i.e. established); the latter include 163 species that are regarded as invasive (see definitions in Table I) (Celesti-Grapow, Alessandrini et al. 2009). Within the invasive species, we defined 12 taxa as "local invasive" that were only found to be invasive in one or two locations. Sixty-two species lack recent records – that is, they have not been detected since 1950.

The country is divided into 20 administrative regions (Figure 1) that differ considerably as regards size, geographical features, climate, human history and population density. In the present study, we treated the two autonomous provinces of Trento and Bolzano on their own because the special status of the Trentino-Alto Adige/Südtirol region allows these two provinces to manage their environmental resources autonomously (Prosser et al. 2005). We therefore based our survey on 21 administrative units, that is 19 regions and the two autonomous provinces of Trento and Bolzano (hereafter referred to as "regions"). Some basic information on these regions is provided in Table II.

Data collection

An information system that combines regional and national databases was built by integrating data collected at a regional level into a comprehensive national scheme. Information on the occurrence of each non-native plant taxa in the administrative and biogeographic regions and in the different land use types on their invasion status and on their impact were gathered in the years 2006–07, using the same standard approach and terminology, by one expert in each of the 21 administrative units (Table II). As the majority of these experts worked closely with a team of local collaborators, the overall survey involved a large number of botanists (for details on methods, see Celesti-Grapow, Alessandrini et al. 2009).

Figure 1. Map of Italy showing the location of the 21 administrative regions analysed in this study.

Table II. Capital, regional editor, surface area, population size, population density, biogeographic regions (Alp, Alpine; Cont, Continental; Med, Mediterranean) and number of species in the vascular flora in the 21 regions analysed in the present study.

Region	Code	Capital	Regional editor	Area (km^2)[1]	Population size[1]	Population density	Biogeographic regions	Total flora[2]
Valle d'Aosta	VDA	Aosta	Bovio M.	3264	125,800	39	Alp	2174
Piedmont	PIE	Turin	Siniscalco C.	25,399	4,394,304	173	Alp, Cont	3521
Lombardy	LOM	Milan	Banfi E.	23,861	9,623,493	403	Alp, Cont	3220
Alto Adige	AA	Bozen	Wilhalm T.	7477	493,165	66	Alp	2579
Trentino	TRE	Trento	Prosser F.	6207	512,354	83	Alp	2952
Veneto	VEN	Venice	Villani M.	18,379	4,821,355	262	Alp, Cont	3295
Friuli Venezia Giulia	FVG	Trieste	Poldini L.	7844	1,220,406	156	Alp, Cont	3335
Liguria	LIG	Genua	Peccenini S.	5421	1,609,552	297	Alp, Cont, Med	3132
Emilia Romagna	EMR	Bologna	Alessandrini A.	22,123	4,264,984	193	Cont	2726
Tuscany	TOS	Florence	Arrigoni P.V.	22,993	3,670,273	160	Cont, Med	3435
Marche	MAR	Ancona	Gubellini L.	9694	1,549,742	160	Cont, Med	2571
Umbria	UMB	Perugia	Cagiotti M.	8456	882,062	104	Cont, Med	2360
Lazio	LAZ	Rome	Celesti-Grapow L.	17,207	5,550,724	323	Alp, Cont, Med	3228
Abruzzo	ABR	L'Aquila	Conti F.	10,789	1,321,685	123	Alp, Cont, Med	3232
Molise	MOL	Campobasso	Lucchese F.	4438	320,661	72	Cont, Med	2412
Campania	CAM	Naples	La Valva V.	13,595	5,807,938	427	Cont, Med	2845
Puglia	PUG	Bari	Marchiori S.	19,363	4,076,164	211	Med	2287
Basilicata	BAS	Potenza	Fascetti S.	9992	591,337	59	Med	2638
Calabria	CAL	Catanzaro	Bernardo L.	15,080	2,007,441	133	Med	2630
Sicily	SIC	Palermo	Mazzola P.	25,707	5,028,512	196	Cont, Med	3012
Sardinia	SAR	Cagliari	Camarda I.	24,090	1,664,555	69	Med	2408
Italy		Rome		301,338	59,536,507	198	Alp, Cont, Med	

[1]Data from ISTAT (2005).

[2]Data on the regional floras are taken from Conti et al. (2005). The data for Trentino and AltoAdige/Südtyrol, which were considered together in Conti et al. (2005), are here taken from the Floristic Database of the Civic Museum of Rovereto (unpublished data, courtesy of F. Prosser) and from Wilhalm et al. (2006), respectively.

The compilation of regional databanks based on floristic data yielded by local research projects follows a consolidated tradition in Italy (Scoppola & Blasi 2005). In this project, a special effort was made to coordinate the information provided by the different teams into an integrated compendium: data and evaluations from different regions were compared and discussed by regional groups during the project.

This study deals with the distribution of the 1023 non-native vascular plant species of the Italian flora, that is those species that did not originate in Italy, which means that the statistics presented here exclude species that are native even to one Italian region alone, as well as the 40 taxa that are regarded as doubtful aliens.

Regional distribution and data analysis

The occurrence of each species in the 21 administrative regions was assessed using data published in the literature, integrated with herbaria records and some unpublished data, though an exhaustive field survey aimed at updating the distribution of the species throughout the country was not possible within the framework of this project. The level of knowledge on the alien flora in each region before the project varied considerably. Indeed, specific inventories on the non-native flora were already available in some regions (e.g. Poldini 1963; Abbà 1979; Viegi & Cela Renzoni 1981; Poldini & Vidali 1989; Viegi et al. 1990; Viegi 1992–93, 1999; Martini & Poldini 1995; Viegi, Vangelisti, D'Eugenio, & Rizzo 2003; Viegi, Vangelisti, D'Eugenio, Rizzo, & Brilli-Cattarini 2003).

In particular, the inventory and mapping project on the alien flora of the island of Sardinia called "Pilot project on the alien flora of the island of Sardinia" (2000–02), funded by the Nature Conservation Service of the Italian Ministry for the Environment, and coordinated by the Department of Botany and Plant Ecology at the University of Sassari (Camarda 2001; Brundu, Camarda et al. 2003; Camarda & Brundu 2004), was the first to specifically address alien species in Italy and one of the few based on floristic digital mapping (see Poldini 1991, 2002; Poldini et al. 1991, 1999). The project highlighted peculiar problems and stimulated the search for methodological solutions that could be extended to other Italian regions. In addition to mapping methodology and deliverables, it included a general analysis of the phenomenon, a list of about 900 taxa (including widely distributed planted-only taxa such as forestry trees, horticultural and ornamental taxa), an alien species-specific database, general information and identification guides for public administration bodies and land managers.

In other regions, extensive studies on the total regional flora, such as checklists or flora mapping projects, were either already available or were in progress (e.g. Poldini 1991; Peccenini 1992; Prosser & Festi 1993; Anzalone 1994, 1996; Lucchese 1995; Conti 1998; Poldini et al. 2001; Conti et al. 2002, 2006, 2008; Wilhalm et al. 2006, 2007; Giardina et al. 2007; Bovio et al. 2008). However, in most regions, the project on the Italian non-native flora represented the first opportunity to systematically collect information on alien species in a comprehensive database, using national inventories of alien species (Béguinot & Mazza 1916; Viegi et al. 1974; Viegi 1998) and national (Pignatti 1982; Conti et al. 2005) and local botanical works (see e.g. Scoppola & Magrini 2005) as the main source.

The data were standardized according to a common classification system in all the regions; the species in each region were classified as casual, naturalized or invasive, following Pyšek et al. (2004), on the basis of published data, recent surveys and expert knowledge. According to this scheme, the term "invasive species" is used in a strictly biological sense that is based on the rate of spread, regardless of whether or not the species has a negative environmental and economic impact (for details on the data sources, methods and terminology, see Celesti-Grapow, Alessandrini et al. 2009).

A statistical analysis was performed to identify the main drivers accounting for the differences in the number of alien species between regions. Four minimum adequate models were obtained by forward selection of the explanatory variables assuming a normal distribution of errors and identity link (Lambdon et al. 2008). The selected response variables were the number of (1) total aliens, (2) neophytes, (3) casual, and (4) established species (i.e. naturalized non-invasive and invasive species) in each region, square-root transformed.

As explanatory variables, we used characteristics of the geography, climate and human impact of each region found to be related to the level of invasion in previous studies (e.g. Lambdon et al. 2008): (1) region surface area, (2) geographic latitude, (3) proportion of mountainous land within the region (in relation to hilly terrain and plain), (4) proportion of plain within the region, (5) mean temperature in the coldest month, (6) continentality index, defined as the difference between the mean temperature in the hottest month and the mean temperature in the coldest month, (7) mean annual precipitation, (8) density of resident human population (number of inhabitants per square kilometre), and (9) density of yearly visitors (i.e. guests in accommodation facilities per square kilometre). This last variable is an indicator of the impact exerted by the non-resident population, as well as of the flow of people into/out of the country, which is particularly marked in Italy owing largely to the tourist industry, which accounts for 11.7% of the gross domestic product (GDP). Variables 1 and 8–9 were log transformed. If the final model included more than one explanatory variable, the interaction of the variables was also tested. The fitted models were checked by plotting standardized residuals against the fitted value and by normal probability plots (Crawley 1993). Analyses were performed using S-plus v. 6.2 (Insightful Corp.). The data were obtained from Blasi and Michetti (2007) and from the National Institute of Statistics, that is ISTAT (2008; http://www.istat.it).

Biogeographic distribution

Although they may serve to collect data, reveal large-scale latitudinal patterns and plan management strategies, the boundaries of the administrative regions do not reliably represent the biogeographic variations within the Italian territory. Thus, in order to provide a more accurate picture of the current distribution of the non-native flora in the main biogeographic units of the country, we adopted the classification of the "Map of the Biogeographical Regions of Europe" (http:/www.eea.europa.eu), according to which Italy comprises three regions: Alpine, Continental and Mediterranean. However, as regards the boundary between the Continental and the Mediterranean regions that runs down the Peninsula, we adapted the map so as to provide greater detail on a national scale by following the boundary of the Mediterranean region proposed in the "Biogeographic Map of Europe" of Rivas-Martinez et al. (2001). According to this adjustment, the Continental region descends the peninsula following the Apennine chain, including the internal, mountainous parts of Abruzzo, Molise and Campania, while the Mediterranean Region becomes narrower, including most of southern Italy and the islands, though only the coastal sectors in western and central Italy.

The classification of the species according to their distribution in the three biogeographic regions took into account a subset of 957 taxa, not recently recorded species being excluded because their attribution to one or more than one region is often unclear. Differences in the relative proportions of neophyte and archaeophytes and of casual, naturalized non-invasive and invasive species between biogeographic zones were evaluated using Pearson's chi-square test.

Land use distribution

The distribution of each species in land use types was recorded using the CORINE Land Cover classification system, a standard land cover classification for Europe (Bossard et al. 2000). A clear distinction between natural and artificial land use types makes this system particularly suited to recording the distribution of non-native species, as it allows taxa found exclusively in man-made sites to be identified from those that spread to natural areas. Moreover, an updated map of the distribution of land cover types, which covers the whole country and thus represents a national standard dataset, is available for Italy in GIS format (i.e. "The Map of Italy's Land Use and Vegetation Cover", APAT 2005). Since the CORINE categorization system is structured hierarchically in five levels, it also allows data available at varying levels of detail to be integrated. For instance, knowledge of species in some regions is sufficiently detailed to classify them to CORINE Level 5, whereas in others it is so sparse that classification does not go beyond Level 1. Furthermore, it is possible to relate the CORINE Land Cover legend to other European standards, such as the CORINE Biotopes and the European Nature Information System (EUNIS) legend (Brundu 2006; Vilà et al. 2007).

The occurrence of the species in land cover types was assessed by experts in each regional group on the basis of the literature, herbaria or field observations. When the information was transferred from the regional level onto a national scale, the data were simplified to Level 2, or, when such information was not available for all the regions, to Level 1, which comprises five main categories: artificial areas, agricultural areas, terrestrial natural and semi-natural areas, wetlands and water bodies. The more detailed CORINE Levels 4 or 5 were maintained on the national scale for forestry plantations of non-native species (3117; 31212; 31213; 3125) and artificial water bodies (water courses 5113, lakes 5122) in order to extract the former from Category 3 (terrestrial natural and semi-natural areas) and the latter from Category 5 (water bodies), which include above all natural and semi-natural environments, and to analyse them with agricultural and artificial areas, respectively.

The analysis of the distribution of land use types was carried out on a subset of 938 species. We excluded the 62 species not recorded since 1950 from this analysis because the information was ambiguous, and a further 23 species (21 casual and 2 naturalized) for which information was not available. The significance of differences in the relative proportions of neophytes and archaeophytes and in the level of invasiveness (casual, naturalized and invasive) between the main types of land use was assessed, as for the biogeographic regions, by Pearson's chi-square test.

Type of impact

In order to integrate the information available on impact, which varies greatly and is found scattered in a wide range of sources, into a unified system, we divided impacts into two broad categories, that is socio-economic and environmental, each of which was subdivided into several classes to obtain the following preliminary scheme:

(1) Socio-economic impact, including agricultural weeds – e.g. that cause losses in production or additional, control-related costs in arable land (crops), pastures, nurseries, greenhouses, plantations and water management); species that damage man-made constructions (e.g. buildings, infrastructures, monuments and archaeological remains); species that threaten livestock (e.g. toxic to farm animals); species that threat– human health (e.g. allergenic, toxic or poisonous species; species that cause dermatitis (e.g. urticants).
(2) Environmental impact, including target other biota, e.g. competition for space, nutrients, water and light, invasional meltdown (*sensu* Simberloff & Von Holle 1999), as described by Carta, Manca, Brundu, and Manca (2004), reduction of native plant diversity (e.g. Vilà et al. 2006), including threats to native fauna; hybridization with a related native species or variety (generally inducing a loss of genetic diversity in native plants), general risk of gene flow and introgression (e.g. from cultivated to native poplars in riparian habitats, Vilà et al. 2000; Ellstrand & Schierenbeck 2006); abiotic changes (e.g. modification of soil chemical–physical properties, soil litter, nutrient availability, ground water regime/balance, water bodies' chemical or physical properties).

We assigned each species to one or several of the aforementioned classes as long as they were included in specialized studies conducted on Italy, such as botanical (e.g. Leporatti et al. 1996; Brundu et al. 1998; Corbetta et al. 2002; Guarini et al. 2003; Lisci et al. 2003; Celesti-Grapow & Blasi 2004), ecological (e.g. Brundu, Cogoni et al. 2003; Brundu et al. 2004, 2005; Vilà et al. 2006), agronomical (e.g. Bassignana 2000; Romani & Tabacchi 2000; Zanin 2000; Covarelli 2002; Clabassi et al. 2003; Viggiani 2005a, 2005b, 2008), veterinary (e.g. Passalacqua et al. 2006; Viegi & Villetti 2008) and pharmacological (e.g. Lomagno et al. 1984; Bicchi et al. 1985; Ballero et al. 1986; Broggini et al. 1987; Ballero 1989; Poldini 1992; Dalla Torre & Pozzi 1997; Lorenzoni-Chiesura et al. 2000; Ballero et al. 2003; Leporatti 2004) accounts, or when they appeared in lists of species that are subject to control measures in Italy (e.g. http://www.agroselviter.unito.it; http://www.enterisi.it). Plant impacts on natural areas were obtained from specific studies on individual species (e.g. Scoppola & Avena 1987; Buffa & Ghirelli 1993; Caronni 1993; D'Auria & Zavagno 2000; Clabassi et al. 2003; Giardini 2004; Scarton et al. 2004; Iberite et al. 2008) or habitats (e.g. Assini 1998). In addition, we exploited the expertise of specialists involved in the project. Since quantitative and direct evaluations are not available, information on the impact of invasive species on biodiversity was often gleaned from the LIFE Natura projects (http://ec.europa.eu/environment/life) conducted in Italy. Indeed, these projects have proved to be useful tools when measures need to be taken to contain particularly aggressive species, and are currently the only means of controlling harmful invasive species in the country (Scalera & Zaghi 2004).

Information was collected from a wide range of sources at the national level (e.g. scientific papers, lists of weeds from agricultural consortiums) and, when available, also at the regional level. We only used reliable records for Italy, and did not thus include species that are known to have a serious impact in other countries but have not been reported to have a significant impact in Italy. Only accounts on impact exerted by established species (naturalized and invasive) were analysed. Although casual species may pose a potential threat to several aspects of human life (e.g. allergenic pollens), they were not considered in this paper. Moreover, as this project was aimed mainly at ecological and conservation issues, we paid most attention to the environmental impact of invasive species, and did not thoroughly analyse all the sources available on the impact of such species on the economy and human health.

Results

Distribution and status in the administrative regions

The results of our investigation are summarized in Tables III–VIII. More detailed information on the distribution, status and impact of each non-native species in Italy is available in Celesti-Grapow et al. (in press) and Celesti-Grapow, Pretto et al. (2009). The structure of the alien flora recorded in each of the 21 administrative regions is shown in Table III. The highest numbers of alien species (>500), the highest proportion of alien species in the flora of each region and the highest density of alien species within a given region, measured as the number of alien species/log area (Rejmánek 1996), were found in Lombardy, whereas the lowest values were found in Valle d'Aosta (<100).

Table III. Structure of the non-native flora in the 21 Italian administrative regions. N non-native, Number of non-native vascular plant species; % non-native, percentages of non-native species in the flora of each region, the latter is taken from Conti et al. (2005), Prosser (unpublished data) and Wilhalm et al. (2006), see Table II; density non-native, ratio between the number of non-native species and the logarithm of the surface area; Archaeo, number of archaeophytes; Neo, number of neophytes.

				Residence time		Invasion status			
	N non-native	% Non-native	Density of non-native	Archaeo	Neo	Not reported since 1950	Casual	Naturalized-non-invasive	Invasive
VDA	93	4.3	26.5	19	74	10	35	32	16
PIE	371	10.5	84.2	64	307	46	157	106	62
LOM	545	16.9	124.5	79	466	3	263	195	84
AA	266	10.3	68.7	55	211	39	130	66	31
TRE	329	11.1	86.7	59	270	69	166	62	32
VEN	388	11.8	91	61	327	22	214	133	19
FVG	331	9.9	85	55	276	13	161	119	38
LIG	315	10.1	84.4	48	267	42	191	64	18
EMR	333	12.2	76.6	68	265	31	164	114	24
TOS	308	9	70.6	66	242	40	187	67	14
MAR	271	10.5	68	63	208	30	139	63	39
UMB	202	8.6	51.4	62	140	0	144	46	12
LAZ	310	9.6	73.2	58	252	30	182	61	37
ABR	234	7.2	58	74	160	19	105	76	34
MOL	115	4.8	31.5	33	82	1	51	37	26
CAM	284	10	68.7	58	226	62	88	103	31
PUG	170	7.4	39.7	41	129	5	110	37	18
BAS	162	6.1	40.5	51	111	2	102	40	18
CAL	190	7.2	45.5	43	147	19	94	50	27
SIC	256	8.5	58	38	218	14	92	138	12
SAR	217	9	49.5	53	164	1	125	50	41

There are far more neophytes than archaeophytes in every region (Table III), with the latter accounting for less than 25% in all the regions but Umbria, Abruzzo, Molise and Basilicata. However, when interpreting these data, it should be borne in mind that the distinction between native species and archaeophytes in the present study was made on a national scale; this means that several Mediterranean species that are classified here as native because they are so in at least one location in the country were actually introduced into northern Italy in ancient times, and are considered archaeophytes at the local scale in the northern regions. Therefore, the values in Table III might be lower than those published in regional floras.

Given the small number of archaeophytes, the minimum adequate models for total number of aliens species and neophytes are, as expected, very close. The two models were highly significant ($F = 27.3$ and $F = 27.5$, respectively, $p < 0.001$) and accounted, for 82.8% and 82.9% respectively of the total variance. The explanatory variables include the surface area of the region ($t = 3.53$ and $t = 3.27$, $p < 0.01$), human population density ($t = 4.07$ and $t = 4.28$, $p < 0.001$) and latitude ($t = 5.73$ and $t = 5.77$, $p < 0.001$), while no interaction between the explanatory variables contributed significantly to the accounted variance.

The minimum adequate model of the casual species was significantly correlated ($F = 11.8$, $p < 0.001$) with the density of yearly visitors and with the surface area of the region. However, the latter correlation was shown to be exclusively due to two outliers by the plot of the residuals, and was thus rejected. A new forward selection procedure was performed, excluding surface area from the explaining variables, and the final model included the number of yearly visitors per square kilometre ($t = 4.27$, $p < 0.001$) and continentality ($t = 2.65$, $p < 0.05$), as direct effect, and the proportion of the regional surface classed as mountains as inverse effect ($t = -3.13$, $p < 0.01$). No significant interaction between the explanatory variables was detected. This model explained 67.6% of the variance.

In the fourth model ($F = 13.3$, $p < 0.001$), using the number of established species as response variable, both the human population density ($t = 3.88$, $p < 0.01$) and the continentality index ($t = 2.93$, $p < 0.01$) were included, but not their interaction. The model accounted for 59.6% of the variance.

Distribution and status in the three biogeographic regions

The number of non-native species in each of the three biogeographic regions is shown in Table IV. The highest numbers of non-native species and the highest

Table IV. Structure of the non-native flora in the three biogeographic regions in Italy. N non-native, Number of non-native vascular plant species; density of non-native, ratio between the number of non-native species and the logarithm of the surface area; Archaeo, number of archaeophytes, Neo, number of neophytes. Since several species are found in more than one biogeographic region, the sum of the numbers in each category is higher than the total number of species.

				Residence time				Invasion status					
Biogeographic region	Area (km^2)[1]	N non-native flora	Density of non-native	Archaeo	% Archaeo	Neo	% Neo	Casual	% Casual	Naturalized	% Naturalized	Invasive	% Invasive
Total Alpine	51,108	392	36.6	63	16.1	329	83.9	120	30.6	167	42.6	105	26.8
Total Continental	88,527	689	62.9	90	13.1	606	88.0	277	40.2	276	40.1	143	20.8
Total Mediterranean	162,446	606	54.1	81	13.4	525	86.6	244	40.3	231	38.1	131	21.6

[1]Data from Politecnico di Milano (2005).

non-native species density (measured as the number of species/log of the area) were recorded in the Continental region, followed by the Mediterranean region.

Of the 458 species found in only one region, 204 are exclusive to the Mediterranean region, 197 to the Continental region and 57 to the Alpine region; there are 238 species that occur in all three biogeographic regions and 261 species that occur in two regions (Table V).

The distribution of casual, naturalized and invasive species (Table IV) is significantly (χ^2 = 12.9, $p < 0.05$) different in the three biogeographic regions. In the Alpine region, the proportions of casual and invasive species are lower and higher, respectively, than in the other regions. No significant difference between the biogeographic regions was detected in the distribution of archaeophytes and neophytes.

Distribution and status in the land use types

Of the 938 species analysed, more than half (477) are found exclusively in man-made habitats (artificial surfaces, agricultural land, forestry plantations and artificial water bodies). The number of species in the different land cover types at CORINE Levels 1 and 2 is shown in Tables VI and VII, respectively. The largest number and the highest density (measured as the number of alien species/log area) of non-native species occur in artificial land use types (such as urban settlements, industrial areas, waste deposits, along roads and railways), followed by agricultural areas. The high values recorded in agricultural areas may in part be attributed to the large such surface areas cover in the country (Table VI). The distribution of the species in the five major categories of land use is significantly different both between archaeophytes and neophytes (χ^2 = 16.1, $p < 0.01$) and between casual, naturalized and invasive species (χ^2 = 126.2, $p < 0.001$). Artificial surfaces, natural and semi-natural areas and water bodies contain a higher proportion of neophytes, whereas agricultural areas and wetlands contain a higher proportion of archaeophytes. As regards the invasion status, the proportion of casual species is larger in artificial surfaces and smaller in wetlands, whereas the proportion of invasive species is larger than expected in natural and semi-natural areas, wetlands and water bodies.

Table V. Number of non-native plant species found exclusively in one, two or three biogeographic regions in Italy.

Biogeographic region	Non-native
Alpine	57
Alpine Continental	97
Alpine Continental Mediterranean	238
Continental	197
Continental Mediterranean	164
Mediterranean	204

Type of impact

Out of the total number of 524 established species of the non-native Italian flora, 203 have been documented to exert some form of negative impact in the country (Table VIII). We found records of 152 species that have some socio-economic impact, most of which (110) are agricultural/pastural weeds, and of 88 that have an environmental impact, consisting, in most cases (83), of competition with the native flora. The former include 42 species that are reported to have caused health hazards, mainly of an allergenic (26) or toxic (22) nature.

The vast majority of these 203 species are neophytes (190). The impact of almost all the archaeophytes is due to the damage they cause as agricultural weeds. As regards the invasion status of these species, most are invasive (142), including the 12 local invasive species.

Discussion

Despite the limited geographic resolution, the distribution of the species according to the Italian

Table VI. Distribution of non-native plant species in land use types according to the CORINE classification system (Level 1). N non-native, Number of non-native vascular plant species; density of non-native, ratio between the number of non-native species and the logarithm of the area covered by each land use type; Archaeo, number of archaeophytes; Neo, number of neophytes. If summed, the number of species in each category is higher than the total number of species of the flora analysed because some species are found in more than one land cover type.

				Residence time				Invasion status					
CORINE Land Cover	Area (km²)[1]	N non-native species	Density of non-native	Archaeo	% Archaeo	Neo	% Neo	casual	% casual	naturalized	% naturalized	invasive	% invasive
Artificial surfaces	1423	776	126.1	90	11.6	686	88.4	348	44.8	288	37.1	140	18.0
Agricultural areas	15,697	469	65.2	86	18.3	383	81.7	138	29.4	208	44.3	123	26.2
Natural and semi-natural areas	12,803	356	50.1	44	12.4	312	87.6	84	23.6	151	42.4	121	34.0
Wetlands	70	76	15.7	13	17.1	63	82.9	6	7.9	37	48.7	33	43.4
Water bodies	970	339	56.6	35	10.3	304	89.7	71	20.9	149	43.9	119	35.1

[1]Data from APAT (2005).

administrative regions, biogeographic regions and major types of land use provided an overall picture of the main large-scale patterns of plant invasion across the country, revealing the influence of geographic, climatic and anthropic factors in the distribution and spread of non-native species.

Table VII. Number of non-native plant species found in land use types according to the CORINE classification system. The more detailed CORINE Levels 4 or 5 were maintained on the national scale for forestry plantations of non-native species (3117; 31212; 31213; 3125) and artificial water bodies (water courses 5113, lakes 5122) in order to extract the former from Category 3 (terrestrial natural and semi-natural areas) and the latter from Category 5 (water bodies), which include all the above natural and semi-natural environments, and to analyse them with agricultural and artificial areas respectively.

CORINE land cover	N species
Artificial surfaces	
Urban fabric (11)	602
Industrial, commercial and transport units (12)	400
Mine, dump and construction sites (13)	209
Artificial, non-agricultural vegetated areas (14)	312
Important cultural sites (15)	51
Artificial water bodies (5113; 5122)	76
Agricultural areas	
Arable land (21)	311
Permanent crops (22)	104
Pastures (23)	27
Heterogeneous agricultural areas (24)	105
Forest plantation (3117; 31212; 31213; 3125)	57
Natural and semi-natural areas	
Forests (31)	161
Scrub and/or herbaceous vegetation associations (32)	163
Open spaces with little or no vegetation (33)	203
Wetlands	
Inland wetlands (41)	68
Maritime wetlands (42)	18
Water bodies	
Inland waters (51)	316
Marine waters (52)	5

In general, it emerges that the number of all non-native plant species, as well as the number of neophytes, increase in proportion to the size of the region, population density and latitude. Indeed, the highest values are reported in the largest, most densely populated regions in northern Italy, such as Lombardy, Veneto and Piedmont, which comprise a large part of the intensively cultivated and heavily industrialized Po Plain. Smaller, less densely inhabited regions, by contrast, have the lowest values.

The number and density of non-native species is highest in artificial land use types (Table VI), with almost half of the non-native Italian flora being confined to these man-made sites. By far, the highest number of introduced species in any land use type is recorded in urban areas, followed by industrial sites and communication routes (Table VII).

The effect of human impact on non-native species and the concentration of such species in man-made habitats, particularly in urban habitats, are renowned in the literature and are in keeping with data on non-native species on the European scale (Chytrý et al. 2005; Sádlo et al. 2007; Chytrý, Jarošík et al. 2008; Chytrý, Maskell et al. 2008; Lambdon et al. 2008). This is above all due to the high levels of human disturbance, which is known to play an important role in enhancing the species richness of non-native flora and in promoting its establishment. Human-mediated disturbance may also be the key factor in explaining the significant correlation between the number of established species and the resident population.

Besides disturbance, intense propagule pressure, defined as the rate of influx of alien propagules into the target site, that is the number of individuals introduced and the number of introduction attempts (Williamson 1996; Colautti et al. 2006), also contributes to the patterns we observed. Indeed, artificial habitats, particularly cities, act as centres in which non-native species are first introduced,

Table VIII. Number of non-native established species reported to have an impact in Italy. N non-native, Number of non-native plant species; Archaeo, number of archaeophytes; Neo, number of neophytes. If summed, the number of species in each category is higher than the total number of species of the flora analysed because some species are assigned to more than one class of impact.

Type of impact	N non-native	Archaeo	Neo	Naturalized	Invasive
Agricultural weeds	110	10	100	35	75
Damaging human constructions	30	3	27	5	25
Threatening livestock	23	2	21	5	18
Toxic or poisonous	22	2	20	10	12
Causing dermatitis	4	–	4	1	3
Allergenic	26	3	23	10	16
Total socio-economic	152	13	139	56	96
Direct on other biota	83	3	80	5	78
Hybridization	1	–	1	1	–
Abiotic changes	18	1	17	1	19
Total environmental	88	3	85	6	82
Total impacts	203	13	190	61	142

whether deliberately or accidentally, and then spread by humans, for example through the planting of exotic species, mainly for ornamental purposes, in parks and gardens (Kowarik 2003). The history of the introduction of many species into Italy via botanical gardens and acclimatizing gardens is well documented. A case in point is the historical botanic garden of Padova, through which renowned plant invaders such as *Oenothera biennis* (in 1612), *Erigeron canadensis* (in 1644), *Robinia pseudoacacia* (in 1662), *Ailanthus altissima* (in 1760) and *Reynoutria japonica* (in mid-1800) were first introduced into the country. Another interesting example is the nursery of Villa d'Orri, in Sardinia, which was the most important nursery of the island in the second half of the nineteenth century, with a list of more than 900 taxa for sale (including fruit tree cultivars) and species directly imported from the acclimatizing gardens of Paris.

Communication routes, such as roads and railways, also afford excellent opportunities for secondary dispersal of invasive species (e.g. Kowarik & Von der Lippe 2007). Invasive species are known to spread quickly and extensively along roadside verges and embankments; one such example is *Senecio inaequidens*, whose rapid spread along major motorways has been recorded since the 1950s, while another more recent example is *Oxalis pes-caprae*.

The key role of increased propagule pressure in enhancing the number of aliens is also reflected in the relatively higher proportion of casual species in artificial surfaces (44.8%) compared to other types of land use, as well as in the correlation between the number of casual species and the density of yearly visitors in individual regions. A marked presence of casuals (>180) is found in regions such as Lombardy, Veneto, Liguria, Tuscany and Lazio, where large cities (Milan, Venice, Florence, Genoa and Rome, respectively, see Table II) are also centres of intense propagule movement owing to intense trade exchanges and tourism; indeed, historical cities are the second most important tourist destinations in Italy after coastal areas (Strazzeri 2009).

Another finding that supports this hypothesis is the correlation between the number of casual species and the morphology of the region – that is, the decrease in casual species as the proportion of mountainous terrain increases. This may be due to the lower degree of human impact and the lower propagule pressure in mountain areas, where new non-native species are concentrated almost exclusively in settlements and along communication routes in the main valleys, and dramatically decrease in number as the altitude increases (see e.g. Barni et al. 2008; Bovio in press; Prosser in press; Wilhalm in press). Indeed, the correlation between a decrease in the number of alien species and higher altitudes is widely acknowledged in the literature (e.g. Pauchard & Alaback 2004; Becker et al. 2005; Chytrý et al. 2005; McDougall et al. 2005; Chytrý, Jarošík et al. 2008; Mallen-Cooper & Pickering 2008). Nevertheless, a key role in determining the distribution of alien plants in mountain areas may also be played by climate, particularly by low winter temperatures.

Surprisingly, however, the total number of non-native species was not found to be significantly correlated with the morphology of the region, nor did any of the other variables analysed (i.e. the number of neophytes, and casual and established species in each region) appear to be significantly affected by either the mean temperature in the coldest month, which is generally a key factor in the distribution of plants, or the mean annual precipitation, which was instead found to be correlated with the number of established species on the European scale (Lambdon et al. 2008). This is probably due to the diversity of the morphology and altitude in Italy, which in the vast majority of regions ranges from sea level to high peaks in the Alps or Apennines, and thus determines a marked climatic heterogeneity within the Italian regions. The continentality index was the only climatic factor analysed that was found to significantly affect the number of aliens at this scale, there being an increase in the number of both casual and established species. Indeed, the Continental biogeographic region contains the highest species number and density of non-native species. It might, nevertheless, be misleading to ascribe this trend exclusively to climatic features, as it could be due to the fact that it is in the Continental region, particularly in the continental Po Plain, that industrialization, urbanization, communication routes and intensive agriculture have developed most in Italy.

By contrast, the Alpine region yields the lowest numbers of non-native species. This may, once again, reflect the lower degree of human disturbance and propagule pressure, as well as the more extreme climatic conditions in the Alps. It should, however, be borne in mind that the lower numbers of all non-native species need not necessarily be interpreted as an indicator of the level of invasion in the three biogeographic regions. Indeed, while most of the non-native flora in the Continental and Mediterranean regions is made up of casuals (40.2% and 40.3%, respectively), in the Alpine region casuals account for a significantly lower proportion of the non-native flora, whereas invasive species account for a significantly larger proportion of the non-native flora than in the other two regions.

This biogeographic variety within the country clearly enhances the richness of the non-native Italian flora; indeed, although many species (238), comprising mainly widespread urban and agricultural weeds, do occur in all three biogeographic regions (Table V), an even larger number of species (458) is currently limited to one region, with 204 being found in the Mediterranean region, 197 in the Continental region and 57 in the Alpine region.

Although most aliens are found on man-made habitats, as many as 461 species occur in relatively more natural terrestrial and freshwater habitats. If compared with artificial surfaces and agricultural areas, the alien flora in natural and semi-natural areas, wetlands and water bodies is numerically lower, but proportionally harbours more invasive than casual species. These results may indicate a high degree of plant invasion in such habitats, though specific studies are warranted to assess its effective impact. Besides these differences in the number of aliens and their invasive status, the land use types analysed also differ significantly in the relative contributions of archaeophytes, whose occurrence is higher in agricultural areas, and neophytes, whose occurrence is higher in artificial surfaces, natural and semi-natural areas and water bodies. The differences in the habitat affinities between old and recent introductions, and in particular the association of archaeophytes with agricultural systems (mainly with arable land) and of neophytes with ruderal habitats (mainly with settlements), which has often been reported in studies on other regions in Europe, are believed to be due to differences in their invasion history and in the type of habitat in which they originated (Kühn et al. 2003; Lososová et al. 2006).

The significant contribution of latitude to the number of alien species appears to reflect the strong north–south climatic gradient found in Italy, which separates the temperate climate from the summer dry Mediterranean climate. Such a conclusion at this stage would, however, be speculative, as the effect of latitude cannot, as has previously been pointed out (Lambdon et al. 2008), be easily distinguished from that of other environmental factors, such as, in the case of Italy, the location of the most industrialized and urbanized areas in the north of the peninsula.

Lastly, besides the geographic, climatic and anthropic factors described so far, it must be borne in mind that the differences in the number of recorded species may also partly depend on the level of knowledge within individual regions (Scoppola & Blasi 2005). The presence of detailed studies on the non-native flora, based on a tradition of botanical recording or updated floristic databases as well as on research institutes, botanical gardens and important Herbaria dating back a long time, all undoubtedly play an important role (Celesti-Grapow et al. in press). It should also be pointed out that the project on the non-native flora of Italy has acted as a major incentive in this field of research: it has encouraged the sharing of information among regions and highlighted those areas and/or species that have been studied less, or are only described in old botanical works, and thus urgently need updating through exhaustive field surveys. Indeed, we expect more studies to appear on the subject in the coming years. One example of the interest being aroused by the project is the section dedicated to new records of alien plants that has recently been launched by *Informatore Botanico Italiano*, the official Journal of the Italian Botany Society. This section will, through reports on the arrival of new taxa and updates on their distribution within the country, make an important contribution to the national early warning network of alien plants, and thus play a major role in the management of plant invasion in Italy.

As information on the impact of non-native flora in Italy proved to be scarce and fragmentary, only a qualitative classification of the data available could be attempted at this stage. The fact that there are few studies dedicated specifically to the impact of alien species meant that the vast majority of information had to be extracted from studies regarding the overall flora, which comprises prevalently native species. The list of weeds compiled by the Italian Weed Research Society (S.I.R.F.I. Società Italiana per la Ricerca sulla Flora Infestante, http://www.sirfi.it/), for instance, lists 36 non-native species out of a total of 208 weeds. The statistics summarized in Table VIII show that the impact is not limited to invasive species, with 61 naturalized species being reported to pose some kind of threat. It is also noteworthy that all 12 species classified as local invasive – that is, currently restricted to one or two localities (Celesti-Grapow, Alessandrini et al. 2009) – are reported to exert a negative impact. The detection of these species will be particularly relevant for management purposes, as they might be in the initial stages of the invasion process and may have the potential to spread explosively, rapidly becoming major pests.

The tendency of non-native species to occupy human environments is also reflected in the impact: more that half of the 203 species reported to have a negative impact are agricultural weeds, though this may partly be due to a major awareness of this issue – that is, in contrast to other types of impact, agriculture-damaging plants have generally received more attention. Percentages of non-native weeds are higher in corn and rice fields than in wheat crops: 34 out of a total of 141 corn field weeds are non-native, while only 8 out of a total of 184 wheat crop weeds are non-native (Viggiani 2005a, 2005b, 2008). The incidence of non-native flora among agricultural weeds (i.e. the proportion of aliens in the total number of weeds) has, in general, increased in the last 40 years (Covarelli 2002).

Owing to the wealth of historical monuments and archaeological remains, a particularly relevant issue in Italy consists in the biodeterioration of the historical heritage. Although the number of alien species was found to be particularly low in the flora of archaeological sites, some species can be particularly detrimental owing to the mechanical and chemical biodeterioration induced by the root system. A few fast growing and vigorous woody species, such as *Ailanthus altissima* and *Acer negundo*, have spread extensively on valuable remains in recent decades; as these species are dispersed by either wind or birds, their seeds are easily transported onto the tops of monuments, thereby rendering any control measures (usually limited to mowing) particularly difficult and expensive (Celesti-Grapow & Blasi 2004). Another significant socio-economic problem is the threat posed by toxic species to farm animals; for instance, a list of 100 plant species that are toxic for horses (Viegi and Villetti 2008) included 20 non-native taxa.

Although our study focused on environmental issues, and only marginally investigated detrimental effects on human health, a preliminary survey of the sources available found 45 species that do have such an effect. However, specific studies on this aspect of alien plants are also lacking; Leporatti et al. (1996) listed a total of 136 toxic plants species growing in the wild in the Lazio region, including 21 aliens. One of the most remarkable examples of allergenic species is *Ambrosia artemisiifolia*, which has become a significant cause of allergic pathologies in northern Italy, as it already has in other European countries (e.g. http://www.ambroisie.info/; http://www.ambrosiainfo.de/; http://www.cps-skew.ch/english/info_ invasive_plants.htm). Although most of the allergenic content in the atmosphere derives from native herbaceous species that are widespread in ruderal habitats, such as *Parietaria judaica* and *P. officinalis*, the introduction of ornamental woody species in urban areas has recently led to an increase in the amount of pollen from these species in the air in such areas (Lorenzoni-Chiesura et al. 2000). The so-called "new pollens" derived from species or families were considered, until only a few years ago, not to be implicated in the incidence of these respiratory disorders, such as the pollen of Cupressaceae; however, after receiving increasing attention, these pollens have been shown to be responsible for a growing number of cases of pollinosis in Mediterranean countries, including Italy where an increase in the incidence of this allergy has also been reported (Mandrioli et al. 2000). The main threats are posed by the introduction of woody species that produce large amounts of pollen, such as Conifers, whose windborne seeds are easily dispersed (Ballero et al. 1986; Leporatti 2004).

A considerable number of species (88) were reported to have an ecological impact, 83 of which are believed to directly threaten biodiversity conservation. Although results are preliminary, the studies undertaken so far indicate that riparian (e.g. Assini 1998), forest (e.g. Caronni 1993), wetland (e.g. Giardini 2004) and coastal (e.g. Carta, Manca, & Brundu 2004) habitats are those threatened most. The species most often included in control projects (e.g. Life Projects) were *Robinia pseudoacacia*, *Ailanthus altissima* and *Amorpha fruticosa*. Some projects also include *Carpobrotus acinaciformis* (Carta, Manca, & Brundu 2004), *Nelumbo nucifera* (Scoppola & Avena 1987), *Lemna minuta* (Iberite et al. 2008), *Myoporum tenuifolium* and *Yucca* spp. Additional information came from a few botanical studies, which recorded the spread of invasive species into natural ecosystems and the consequent displacement of native plant species; examples include *Opuntia humifusa*, which is seriously threatening the survival of one of only eight known populations of the endemic *Goniolinum italicum* (Pirone et al. 2001; Conti et al. 2002), and *Lagarosiphon major*, a water plant spreading fast in a few localities of the Insubrian Lakes in northern Italy that has led to the local extinction of the only known population of *Ranunculus circinnatus* in the Trento region (Monguzzi et al. 2004; Prosser in press). Studies that deal with the effect of alien plant species on the abiotic environment in natural ecosystems are even more scarce, practically only including *A. altissima*, *C. acinaciformis* and *Oxalis pes-caprae* (Vilà et al. 2006).

On the whole, the impact exerted by non-native species outlined in this report warrants further analysis in specific studies, the most urgently needed research being a quantitative evaluation of the impact of plant invasion in Italy aimed at setting priorities for intervention. Despite this limitation and the aforementioned need to update some information on the distribution and status of the species by means of field surveys, this study has made an important step forward in plant invasion research in the country. By working on both the national and regional level contemporarily, we addressed the need to integrate data yielded by local research into a national scheme, thereby laying the foundations for coordinated local actions within a national strategy. Through the synthetic presentation of information on the distribution of non-native species in the Italian flora across regions, in the main types of land use and on the threats they pose, this study not only provides an initial database and a framework for further research but also raises awareness of a problem that has all too often been overlooked in Italy.

Acknowledgements

Although we have only cited one author per region, we wish to express our gratitude to all those people who helped gather, from the great variety of sources available, the data upon which this project is based. In particular, this work would never have been completed without the help of the following experts who lead regional groups: Liliana Bernardo (Calabria), Vincenzo La Valva (Campania), Pietro Mazzola (Sicily), Silvano Marchiori (Puglia), Consolata Siniscalco (Piedmont) and Noemi Tornadore (Veneto).

We would also like to thank the following local collaborators for their contribution to the regional teams: Rita Accogli, Antonella Albano, Giuseppina Barberis, Alessio Bertolli, Giacomo Bracchi, Guido Brusa, Mario Calbi, Luisa Carta, Rosanna De Mattei, Alessandra Di Turi, Giulio Ferretti, Francesco Festi, Carmen Gangale, Luca Gariboldi, Gruppo Botanico Milanese, Gruppo Flora Alpina Bergamasca, Flavia Landucci, Manuela Manca, Aurelio Manzi, Francesca Marinangeli, Concetta Mele, Maria Francesca Palla, Mauro Pellizzari, Aldo Ranfa, Arcangelo Schiappacasse, Adriano Soldano, Gianni Tognon and Dimiter Uzunov.

We wish to thank Mauro Ballero (aerobiology), Mauro Bassignana (agronomy), Maria Lucia Leporatti (toxicity), Mauro Serafini (toxicity, EFSA, European Food Safety Authority), Francesco Vidotto (agronomy) and Pasquale Viggiani (agronomy) for providing publications, unpublished records and information on the impact of the invasive plants.

We are very grateful to Giovanna Abbate, Lewis Baker, Sandro Bonacquisti, Barbara Dalla Bona, Piera di Marzio, Enzo Dominici, Aldo Marchetto, Francesca Pauselli and Francesca Pavesi for their contribution to various aspects of the project. We also wish to thank Petr Pyšek and Ingo Kowarik for their helpful advice and precious comments throughout the project.

This study is a part of "A survey of the non-native flora of Italy", a research project developed in the years 2005–08, funded by the Italian Ministry for the Environment, Land and Sea Protection, directed by Professor Carlo Blasi, coordinated by Laura Celesti-Grapow, Giuseppe Brundu, Ignazio Camarda, Lucia Viegi and Carlo Blasi, and by the Inter-university Biodiversity, Plant Sociology and Landscape Ecology Research Centre (CIRBFEP – Centro di Ricerca Interuniversitario Biodiversità, Fitosociologia ed Ecologia del Paesaggio) of the Sapienza University of Rome.

References

Abbà G. 1979. Flora esotica del Piemonte. Specie coltivate e spontaneizzate e specie avventizie. Atti Soc Tosc Sci Nat Mem Serie B 86(1): 263–302.

Anzalone B. 1994. Prodromo della Flora Romana: Aggiornamento. Parte 1ª. Ann Bot 52(suppl. 1): 1–82.

Anzalone B. 1996. Prodromo della Flora Romana: Aggiornamento. Parte 2ª. Ann Bot 54: 7–47.

APAT. 2005. La realizzazione in Italia del progetto europeo Corine Land Cover 2000. Rapporti 36/2005. p. 86. Roma: APAT.

Assini S. 1998. Le specie esotiche nella gestione delle aree fluviali di pianura: Indagine geobotanica. Arch Geobot 4(1): 123–130.

Ballero M. 1989. Airborne pollens analysis in Cagliari (south Sardinia): Observations on *Ailanthus altissima* (Miller) Swingle, *Casuarina equisetifolia* J.R. & G. Foster and *Schinus molle* L. Centro 1(4): 22–27.

Ballero M, Ariu A, Falagiani P, Piu G. 2003. Allergy to *Ailanthus altissima* (tree of heaven) pollen. Allergy 58(6): 532–533.

Ballero M, Piu G, Sechi P. 1986. Ricerche sulle concentrazioni aeropolliniche di Cupressaceae e Pinaceae nell'atmosfera di Cagliari e considerazioni sul loro potere allergizzante. Aerobiologia 2: 41–45.

Barni E, Falzoi S, Sitzia L, Spanna F, Siniscalco C. 2008. Invasioni di piante esotiche lungo il gradiente altitudinale nelle Alpi. In: Galasso G, Chiozzi G, Azuma M, Banfi E, editors.

Le specie alloctone in Italia. Mem Soc It Sc Nat Mus Civ St Nat Milano 35(1): 43.

Bassignana M. 2000. Infestanti nel vigneto. L'Informatore Agricolo 8–9: 12–14.

Becker T, Dietz H, Billeter R, Buschmann H, Edwards PJ. 2005. Altitudinal distribution of alien plant species in the Swiss Alps. Perspect Plant Ecol 7: 173–183.

Béguinot A, Mazza O. 1916. Le avventizie esotiche della flora italiana e le leggi che ne regolano l'introduzione e la naturalizzazione. Nuovo Giorn Bot Ital 23: 403–465; 495–540.

Bicchi C, D'Amato A, Cappelletti E. 1985. Determination of pyrrolizidine alkaloids in *Senecio inaequidens* D.C. by capillary gas chromatography. J Chromatogr 349: 23–29.

Blasi C. 2006. *Primo contributo al censimento della Flora Esotica in Italia e caratterizzazione della sua invasività con particolare riferimento alla fascia costiera marina e alle piccole isole* (Convenzione tra il Ministero dell'Ambiente e della Tutela del Territorio – Direzione per la Protezione della Natura e il Centro di Ricerca Interuniversitario Biodiversità, Fitosociologia ed Ecologia del Paesaggio), Fitosociologia ed Ecologia del Paesaggio)). Roma: Dipartimento di Biologia Vegetale Università "La Sapienza" di Roma.

Blasi C. 2007. Biodiversity and landscape. In: Blasi C, Boitani L, La Posta S, Manes F, Marchetti M, editors. Biodiversity in Italy. Roma: Palombi & Partner. pp. 97–103.

Blasi C, Michetti L. 2007. Biodiversity and climate. In: Blasi C, Boitani L, La Posta S, Manes F, Marchetti M, editors. Biodiversity in Italy. Roma: Palombi & Partner. pp. 57–66.

Bossard M, Feranec J, Otahel J. 2000. CORINE Land Cover technical guide: Addendum 2000 (Technical Report No. 40). Copenhagen: European Environmental Agency.

Bovio M. In press. Flora alloctona della Valle d'Aosta. In: Celesti-Grapow L, Pretto F, Blasi C, editors. Flora alloctona d'Italia. Roma: Palombi & Partner.

Bovio M, Broglio M, Poggio L. 2008. Guida alla flora della Valle d'Aosta. Torino: Blu Edizioni. p. 335.

Broggini M, Lorenzini A, Reina A, Bottà V, Mezzetti MG. 1987. Intossicazione acuta da *Datura stramonium*. Acta Anaesth Ital 83: 639–643.

Brundu G. 2006. A review on geomatic tools for assessing, inventorying and mapping alien plant invasions in the Mediterranean basin. In: Brunel S, editor. Invasive plants in Mediterranean type regions of the world: Proceedings (Environmental Encounters Series, no. 59, 25–27 May 2005). Mèze, France: Council of Europe. pp. 65–87.

Brundu G, Camarda I, Brunu A. 2004. *Solanum sisymbrifolium* Lam., neofita invasiva in Sardegna (Riassunti 99° Congresso Nazionale della Società Botanica Italiana, 22–24 September 2004, Torino). Cascine Vica, Italy: Ed. Neos. p. 192.

Brundu G, Camarda I, Carta L, Manca M. 2005. Invasion of Sardinian coastal habitats by the exotic *Cortaderia selloana* (Schultes) Asch. et Gr. Paper presented at the International workshop on "Invasive plants in the Mediterranean type regions of the world", 25–27 May 2005, Mèze, France. (Book of abstracts, p. 43.)

Brundu G, Camarda I, Satta V. 2003a. A methodological approach for mapping alien plants in Sardinia (Italy). In: Child L, Brock JH, Brundu G, Prach K, Pyšek P, Wade PM, Williamson M, editors. Plant invasions: Ecological threats and management solutions. Leiden: Backhuys. pp. 41–62.

Brundu G, Cogoni A, Flore F, Zedda L. 2003. Influence of *Carpobrotus* spp. on epigeous cryptogamic communities on coastal sand dunes of Sardinia (Italy). Paper presented at the conference on "Invasive Plants in Natural and Managed Systems: Linking Science and Management" in conjunction with the 7th International Conference on the Ecology and Management of Alien Plant Invasions, 3–7 November, 2003, Ft. Lauderdale, FL, USA. (Book of abstracts, p. 13.)

Brundu G, Satta V, Venditti T. 1998. *Eclipta prostrata* (L.) L. as a new weed of rice fields in Sardinia (Italy). In: Starfinger U, Edwards K, Kowarik I, Williamson M, editors. Plant invasions: Ecological mechanisms and human responses. Leiden: Backhuys. pp. 137–141.

Buffa G, Ghirelli L. 1993. Primo contributo alla conoscenza dell'ecologia di *Robinia pseudoacacia* L. sui Colli Euganei. Ecologia della Regione euganea. Atti X convegno Gruppo "G.Gadio" per l'ecologia di base. Padova: La Garangola. pp. 67–76.

Camarda I. 2001. Ricerca sulle specie vegetali aliene della Sardegna (Rapporto Finale, DBEV Università di Sassari, Servizio Conservazione della Natura – Ministero dell'Ambiente, Roma). Sassari: DBEV Università di Sassari.

Camarda I, Brundu G. 2004. Inventario e Sistema Informativo delle Specie Esotiche della Sardegna. Atti "Informatizzazione degli Erbari e Banche Dati". Inform Bot Ital 36(1): 134–138.

Caronni F. 1993. Alcuni aspetti corologici ed ecologici della diffusione del prugnolo tardivo (*Prunus serotina* Ehrh.) in Italia. Inform Bot Ital 24(1–2): 8–18.

Carta L, Manca M, Brundu G. 2004. Removal of *Carpobrotus acinaciformis* (L.) L. Bolus from environmental sensitive areas in Sardinia, Italy. In: Arianoutsou M, Papanastasis V, editors. Ecology, conservation and management of Mediterranean climate ecosystems (Proceedings of the 10th MEDECOS conference, 25 April–1 May 2004, Rhodes, Greece). Rotterdam: Millpress. p. 136.

Carta L, Manca M, Brundu G, Manca I. 2004. Invasional meltdown: The case study of *Gomphocarpus fruticosus* and *Danaus chrysippus* in Sardinia, Italy. In: Arianoutsou M, Papanastasis V, editors. Ecology, conservation and management of Mediterranean climate ecosystems (Proceedings of the 10th MEDECOS conference, 25 Apr 25–1 May 2004, Rhodes, Greece). Rotterdam: Millpress. p. 136.

Celesti-Grapow L, Alessandrini A, Arrigoni PV, Banfi E, Bovio M, Brundu G, et al. 2009. The inventory of the alien flora of Italy. Plant Biosys 143(2): 386–430.

Celesti-Grapow L, Blasi C. 2004. The role of alien and native weeds in the deterioration of archaeological remains in Italy. Weed Technol 18: 1508–1513.

Celesti-Grapow L, Pretto F, Blasi C, editors. In press. Flora alloctona d'Italia. Roma: Palombi & Partner.

Celesti-Grapow L, Pretto F, Brundu G, Carli E, Blasi C, editors. 2009. Plant invasion in Italy: An overview. Roma: Palombi & Partner. p. 33.

Chytrý M, Jarošík V, Pyšek P, Hájek O, Knollová I, Tichý L, et al. 2008. Separating habitat invasibility by alien plants from the actual level of invasion. Ecology 89: 1541–1553.

Chytrý M, Maskell L, Pino J, Pyšek P, Vila M, Font X, et al. 2008. Habitat invasions by alien plants: A quantitative comparison between Mediterranean, subcontinental and oceanic regions of Europe. J App Ecol 45: 448–458.

Chytrý M, Pyšek P, Tichý L, Knollová I, Danihelka J. 2005. Invasions by alien plants in the Czech Republic: A quantitative assessment across habitats. Preslia 77: 339–354.

Clabassi I, Tomè A, Otto S, Zanin G. 2003. Segnalazione di una nuova potenziale pianta infestante. Notiziario ERSA 16(4): 10–12.

Colautti RI, Ricciardi A, Grigorovich IA, MacIsaac HJ. 2006. Propagule pressure: A null model for biological invasions. Biol Invasions 8: 1023–1037.

Conti F. 1998. An annotated checklist of the flora of the Abruzzo. Bocconea 10: 1–276.

Conti F, Abbate G, Alessandrini A, Blasi C, editors. 2005. An annotated checklist of the Italian vascular flora. Roma: Palombi & Partner. p. 420.

Conti F, Bartolucci F, Catonica C, D'Orazio G, Londrillo I, Manzi A, et al. 2006. Aggiunte alla flora d'Abruzzo. II contributo. Inform Bot Ital 38(1): 113–116.

Conti F, Bartolucci F, Manzi A, Miglio M, Tinti D. 2008. Aggiunte alla flora d'Abruzzo. III contributo. Ann Mus Civ Rovereto 23: 127–140.

Conti F, Manzi A, Tinti D. 2002. Aggiunte alla Flora d'Abruzzo. I° contributo. Inform Bot Ital 34(1): 55–61.

Corbetta F, Pavone P, Spampinato G, Tomaselli V, Trigilia A. 2002. Studio della vegetazione dell'area archeologica della Neapolis (Siracusa, Sicilia) finalizzato alla conservazione dei manufatti architettonici. Fitosociologia 39(2): 3–24.

Covarelli G. 2002. Evoluzione della flora e della vegetazione infestante le principali colture agrarie in Italia. Fitosociologia 39(1): 3–13.

Crawley MJ. 1993. GLIM for ecologists. Oxford: Blackwell Science. p. 304.

DAISIE. 2009. Handbook of alien species in Europe. Berlin: Springer. p. 200.

Dalla Torre F, Pozzi PL. 1997. La crescente importanza allergenica dell'Ambrosia in Italia. Asma Allergia Immunopat 96: 5–16.

D'Auria S, Zavagno F. 2000. Componente alloctona e aree protette: ruolo dinamico e inquadramento sintassonomico delle cenosi ad *Amorpha fruticosa* L. in ambiente planiziario padano. Arch Geobot Pavia 4(1): 131–136.

Ellstrand NC, Schierenbeck KA. 2006. Hybridization as a stimulus for the evolution of invasiveness in plants? Euphytica 148: 35–46.

Giardina G, Raimondo FM, Spadaro V. 2007. A catalogue of plants growing in Sicily. Bocconea 20: 5–582.

Giardini M. 2004. *Salvinia molesta* D.S. Mitchell (Salviniaceae): The second record for Italy (Latium) and consideration about the control of this invasive species. Webbia 59(2): 457–467.

Guarini C, Napolitano F, Spadaro V. 2003. Allergenic flora of the national park of Vesuvio. Quad Bot Ambientale Appl 14: 135–149.

Hoyt E. 1992. Conserving the wild relatives of crops. 2nd ed. Rome: IBPGR/IUCN/WWF. p. 45.

Iberite M, Abati S, Abbate G, Iamonico D, Pelliccioni I. 2008. Notulae alla checklist della flora vascolare italiana: 5. 1428. Specie esotica invasiva nuova per il Lazio. Inform Bot Ital 40(1): 100.

ISTAT. 2005. 14° censimento generale della popolazione e delle abitazioni, 29 September 2005. Available: http://dawinci.istat.it/MD/. Accessed Nov 2007.

ISTAT. 2008. Annuario statistico italiano 2008. Roma: ISTAT. p. 864.

Kowarik I. 2003. Human agency in biological invasions: Secondary releases foster naturalisation and population expansion of alien plant species. Biol Invasions 5: 293–312.

Kowarik I, Von der Lippe M. 2007. Pathways in plant invasion. In: Nentwig W, editor. Biological invasions: Ecological studies 193. Berlin: Springer Verlag. pp. 29–47.

Kühn I, Brandl R, May R, Klotz S. 2003. Plant distribution patterns in Germany: Will aliens match natives? Feddes Repertorium 114(7–8): 599–573.

Lambdon PW, Pyšek P, Basnou C, Arianoutsou M, Essl F, Hejda F, et al. 2008. Alien flora of Europe: Species diversity, temporal trends, geographical patterns and research needs. Preslia 80: 101–149.

Leporatti ML. 2004. Considerazioni su verde urbano ornamentale e pollinosi: Ecosistema Roma. Atti dei Convegni Lincei 218: 479.

Leporatti ML, Guarrera P, De Giacomo M. 1996. Wild and ornamental toxic plants in Latium region (Central Italy). Fitoterapia 67(6): 513–534.

Lisci M, Monte M, Pacini E. 2003. Lichens and higher plants on stone: A review. Int Biodeter Biodegr 51: 1–17.

Lomagno R, Montacchini F, Polini V, Gallesio MT, Furno F. 1984. Diffusione del genere *Ambrosia* in Piemonte e nota preliminare della sua rilevanza allergologica nella nostra casistica. Folia Allergol Immunol Clin 31: 151–158.

Lonsdale M. 1999. Global patterns of plant invasions and the concept of invasibility. Ecology 80: 1522–1536.

Lorenzoni-Chiesura F, Giorato M, Marcer G. 2000. Allergy to pollen of urban cultivated plants. Aerobiologia 16: 313–316.

Lososová Z, Chytrý M, Kühn I, Hájek O, Horáková V, Pyšek P, et al. 2006. Patterns of plant traits in annual vegetation of man-made habitats in Central Europe. Perspect Plant Ecol 8: 69–81.

Lucchese F. 1995. Elenco preliminare della flora spontanea del Molise. Ann Bot 53, Studi sul territorio(suppl 12): 1–386.

Mack RN, Simberloff D, Londsdale WM, Evans H, Clout M, Bazzaz FA. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. Ecol Appl 10(3): 689–710.

Mallen-Cooper J, Pickering CM. 2008. Linear declines in exotic and native plant species richness along an increasing altitudinal gradient in the Snowy Mountains, Australia. Austral Ecol 33: 684–690.

Mandrioli P, De Nuntiis P, Ariatti A, Magnani R. 2000. Cypress in Italy: Landscape and pollen monitoring. Allergy Immunol 31: 116–121.

Martini F, Poldini L. 1995. The hemerophytic flora of Friuli-Venezia Giulia (NE Italy). Flora Mediterranea 5: 229–246.

McDougall KL, Morgan JW, Walsh NG, Williams RJ. 2005. Plant invasions in treeless vegetation of the Australian Alps. Perspect Plant Ecol 7: 159–171.

Monguzzi C, Buraschi E, Di Pasquale D, Luchelli M, Rossi S, Bartesaghi G, et al. 2004. Primo rapporto dell'Osservatorio dei laghi Lombardi. Lombardia: ARPA Lombardia, Fondazione Lombardia per l'ambiente. p. 18.

Mooney HA, Hobbs RJ, editors. 2000. Invasive species in a changing world. Washington, DC: Island Press. p. 459.

Passalacqua NG, De Fine G, Guarrera PM. 2006. Contribution to the knowledge of the veterinary science and of the ethnobotany in Calabria region (Southern Italy). J Ethnobiol Ethnomed 2: 52.

Pauchard A, Alaback PB. 2004. Influence of elevation, land use, and landscape context on patterns of alien plant invasions along roadsides in protected areas of South-Central Chile. Conserv Biol 18: 238–248.

Peccenini S. 1992. Exotic species naturalized in Liguria (Atti Coll. "Man and the Environment", 24 October 1989, Roma). Firenze, Roma: Società Botanica Italiana – ENEL. pp. 33–47.

Perrings C, Williamson M, Dalmazzone S, editors. 2000. The economics of biological invasions. Northampton: Edward Elgar. p. 249.

Pignatti S. 1982. Flora d'Italia. 3 vols. Bologna: Edagricole.

Pirone G, Corbetta F, Ciaschetti G, Frattaroli AR, Burri E. 2001. Contributo alla conoscenza della serie di vegetazione nel piano collinare della Valle del Tirino (Abruzzo, Italia Centrale). Fitosociologia 38(2): 3–23.

Poldini L. 1963. Nuove segnalazioni per la flora advena di Trieste. Trieste: Univ. Studi Trieste Fac. Sci. Ist. Botanica 13: 1–16.

Poldini L. 1991. Atlante corologico delle piante vascolari nel Friuli-Venezia Giulia. Inventario floristico regionale. Region. auton. Friuli-Venezia Giulia. Udine: Direz. Reg. Foreste e Parchi/Trieste: Univ. Studi Trieste – Dipart. Biologia. p. 900.

Poldini L. 1992. Environmental alteration and allergophytes. Aerobiologia 8(1): 127–132.

Poldini L. 2002. Nuovo atlante corologico delle piante vascolari nel Friuli-Venezia Giulia. Regione Autonoma Friuli-Venezia Giulia, Azienda Parchi e Foreste Regionali. Udine: Arti Grafiche Friulane. p. 529.

Poldini L, Martini F, Ganis P, Vidali M. 1991. Floristic databanks and the phytogeographic analysis of a territory. An example concerning northeastern Italy. In: Nimis PL, Crovello TJ,

editors. Quantitative Approaches to Phytogeography: Tasks for Vegetation Science 24: 159–181.
Poldini L, Oriolo G, Vidali M. 2001. Vascular flora of Friuli-Venezia Giulia. An annotated catalogue and synonymic index. Studia Geobot 21: 3–227.
Poldini L, Vidali M. 1989. Studio dell'antropizzazione del Carso triestino e goriziano mediante l'uso della Banca Dati Floristica. Inform Bot Ital 21(1–3): 224–234.
Poldini L, Vidali M, Oriolo G. 1999. Chorological atlas of Friuli-Venezia Giulia, NE Italy: A territorial information system. Acta Botanica Fennica 162: 75–78.
Politecnico di Milano. 2005. GIS NATURA. Il GIS delle conoscenze naturalistiche in Italia. Ministero dell'Ambiente e della Tutela del Territorio. CD-rom.
Prosser F. In press. Flora alloctona del Trentino. In: Celesti-Grapow L, Pretto F, Blasi C, editors. Flora alloctona d'Italia. Roma: Palombi & Partner.
Prosser F, Festi F. 1993. Cartografia floristica in Trentino. Inform Bot Ital 24: 23–31.
Prosser F, Wilhalm T, Festi F, Bertolli A. 2005. Tentativo di valutazione del progresso e del grado di conoscenza floristica dal 1970 al 2005 per il Trentino-Alto Adige/Südtirol. In: Scoppola A, Blasi C, editors. Stato delle conoscenze sulla Flora Vascolare d'Italia. Roma: Palombi & Partner. pp. 109–115.
Pyšek P, Richardson DM, Rejmánek M, Webster GL, Williamson M, Kirschner J. 2004. Alien plants in checklist and floras: Towards better communication between taxonomists and ecologists. Taxon 53(1): 131–143.
Rejmánek M. 1996. Species richness and resistance to invasions. In: Orians G, Dirzo R, Cushman JH, editors. Biodiversity and ecosystem processes in tropical forests. Ecol Stud 122: 153–172.
Rejmánek M, Richardson DM, Pyšek P. 2004. Plant invasion and invasibility of plant communities. In: Maarel VD, editor. Vegetation Ecology. Malden: Blackwell Scientific. pp. 332–355.
Ricciardi A, Cohen J. 2007. The invasiveness of an introduced species does not predict its impact. Biol Invasions 9: 309–315.
Rivas-Martinez S, Penas A, Diaz TE. 2001. Biogeographic map of Europe 1:16.000. Leon: University of Leon.
Romani M, Tabacchi M. 2000. *Leptochloa fascicularis* nuova infestante del riso. L'Informatore Agrario 36: 65–66.
Sádlo J, Chytrý M, Pyšek P. 2007. Regional species pools of vascular plants in habitats of the Czech Republic. Preslia 79: 303–321.
Sax DF, Brown JH. 2000. The paradox of invasion. Global Ecology and Biogeography 9: 363–371.
Sax DF, Gaines SD. 2003. Species diversity: From global decreases to local increases. Trends Ecol Evol 18(11): 561–566.
Scalera R, Zaghi D. 2004. LIFE focus. Alien species and nature conservation in the EU: The role of the LIFE program. Luxembourg: Office for Official Publications of the European Communities. p. 55.
Scarton F, Ghirelli L, Cavalli I, Cazzin M, Scattolin M. 2004. *Spartina × townsendii* H. and J. Groves, nuova alofita per la Laguna di Venezia: distribuzione al 2003. Boll Mus St Nat Venezia 55: 17–28.
Scoppola A, Avena G. 1987. Indagini ecologiche-fitogeografiche sulle zone umide interne del Lazio. 3: Variazioni cenologiche indotte da *Nelumbo nucifera* sulle comunità vegetali del Lago di Monterosi. Ann Bot Studi sul territorio 65(5): 145–156.
Scoppola A, Blasi C, editors. 2005. Stato delle conoscenze sulla Flora Vascolare d'Italia. Roma: Palombi & Partner. p. 256.
Scoppola A, Magrini S. 2005. Bibliografia floristica per gli anni 1950–2005. In: Scoppola A, Blasi C, editors. Stato delle conoscenze sulla Flora Vascolare d'Italia. Roma: Palombi & Partner. pp. 217–226.
Simberloff D, Von Holle B. 1999. Positive interactions of nonindigenous species: Invasional meltdown. Biol Invasions 1(1): 21–32.
Strazzeri R. 2009. Eurispes: dal turismo l'11,7% del PIL nazionale. Turismo e finanza [serial on line]. Available: http://www.turismoefinanza.it/step.jsp?page=69735. Accessed Mar 2009 06.
Viegi L. 1992–93. Contributo alla conoscenza della biologia delle infestanti delle colture della Sardegna nordoccidentale. I. Censimento delle specie esotiche della Sardegna. Boll Soc Sarda Sci Nat 29: 131–234.
Viegi L. 1998. Observations sur la distribution d'entités exotiques (en particulier adventices et envahissantes) dans differentes regions d'Italie. Biocosme Mésogéen 15(1): 69–88.
Viegi L. 1999. Le entità esotiche in Piemonte nell'erbario di Giacinto Abbà. In: Pistarino A, Forneris G, Fossa V, editors. Le collezioni di Giacinto Abbà. Catalogo e note critiche delle raccolte botaniche in Piemonte (1965–1999). Cataloghi XII. Museo Regionale di Scienze Naturali Torino 1: 149–162.
Viegi L, Cela Renzoni G. 1981. Flora esotica d'Italia: Le specie presenti in Toscana. Collana del programma finalizzato CNR "Promozione della qualità dell'ambiente". AQ/1/132. Pavia: CNR. p. 97.
Viegi L, Cela Renzoni G, D'Eugenio ML, Rizzo AM. 1990. Flora esotica d'Italia: Le specie presenti in Abruzzo e in Molise (revisione bibliografica e d'erbario). Arch Bot Ital 66(1–2): 1–128.
Viegi L, Cela Renzoni G, Garbari F. 1974. Flora esotica d'Italia. Lav Soc Ital Biogeogr ns 4: 125–220.
Viegi L, Vangelisti R, D'Eugenio ML, Rizzo AM. 2003. Contributo alla conoscenza della flora esotica d'Italia: Le specie presenti in Umbria. Atti Soc Tosc Sci Nat Pisa Mem Serie B 110: 163–188.
Viegi L, Vangelisti R, D'Eugenio ML, Rizzo AM, Brilli-Cattarini A. 2003. Contributo alla conoscenza della flora esotica d'Italia: Le specie presenti nelle Marche. Atti Soc Tosc Sci Nat Pisa Mem Serie B 110: 97–162.
Viegi L, Villetti F. 2008. Guida alle piante della Flora italiana tossiche per i cavalli. Pisa: SEU – Servizio Editoriale Universitario di Pisa. p. 115.
Viggiani P. 2005a. L'evoluzione della tecnica colturale influenza le infestanti del grano. L'Informatore Agrario 49: 67–74.
Viggiani P. 2005b. Weed flora in Italian rice fields. Proceedings of 13th EWRS symposium, 19–23 June 2005, Bari, Italy.
Viggiani P. 2008. Come cambiano le infestanti del mais. L'Informatore Agrario 10: 55–59.
Vilà M, Pino J, Font X. 2007. Regional assessment of plant invasions across different habitat types. J Veg Sci 18: 35–42.
Vilà M, Tessier M, Suehs CM, Brundu G, Manca L, Galanidis A, et al. 2006. Local and regional assessment of the impacts of plant invaders on vegetation structure and soil properties of Mediterranean islands. J Biogeogr 33: 853–861.
Vilà M, Weber E, D'Antonio CM. 2000. Conservation implications of invasion by plant hybridization. Biol Invasions 2: 207–217.
Vitousek PM, D'Antonio CM, Loope LL, Westbrooks R. 1996. Biological invasions as global environmental change. Am Sci 84(5): 468–78.
Wilhalm T. In press. Flora alloctona del Alto Adige. In: Celesti-Grapow L, Pretto F, Blasi C, editors. Flora alloctona d'Italia. Roma: Palombi & Partner.
Wilhalm T, Hilpold A, Stockner W, Tratter W. 2007. Für die Flora Südtirols neue Gefäßpflanzen (4): Ergebnisse der floristischen Kartierung. Gredleriana 7: 99–126.
Wilhalm T, Niklfeld H, Gutermann W. 2006. Katalog der Gefäßpflanzen Südtirols: Veröffentlichungen des Naturmuseums Südtirol. Folio Verlag: Wien. p. 216.
Williamson M. 1996. Biological invasions. London: Chapman & Hall. p. 244.
Zanin G. 2000. Caratteristiche ed evoluzione della flora infestante del mais. L'Informatore Agrario 23: 79–82.