

A taxonomic, biogeographical and ecological overview of invasive woody plants

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Abstract. Invasive plants are considered to be a major threat to the earth's biodiversity, but have not been sufficiently investigated. To address this problem a relational database on invasive woody plants has been set up. It is based on 2045 bibliographical references and contains records on 653 species representing 110 families. The families with the largest number of invasive species are: *Rosaceae*, *Mimosaceae*, *Papilionaceae* and *Pinaceae*. Out of 1060 recorded invasive events an equal number are reported from continents and oceanic islands. The highest number of invasive woody species are recorded from Europe, followed by the Pacific islands, North America, New Zealand, Australia, Indian Ocean islands and southern Africa. Included in these regions are areas which have fewer highly invasive species, e.g. islands on continental shelves, such as the British Isles. Although most invasions occur in disturbed habitats, most natural communities are susceptible to woody plant invasions. Data on species attributes are only available for a minority of species but indicate that invasive woody plant species may be either insect or wind-pollinated, have a wide array of fruit types, fruit and seed sizes, number of seeds per fruit and dispersal agents. The relative frequency of several attributes varies with the degree of invasiveness. Thus it is not yet possible to determine which set of attributes favours invasiveness and therefore it is difficult to make predictions.

Keywords: Database; Invasion; Life form; Species attribute.

Introduction

The structure and functioning of ecosystems are often dramatically affected by invasive species which are therefore considered to be one of the major threats to the earth's biodiversity. Despite the SCOPE programme of the 1980s there is no overall picture of, for instance, the type and number of invasive species or invaded habitats (e.g. Drake et al. 1989). Although the book by Cronk & Fuller (1995) provides a much broader review of plant invasions, including a large number of case studies, their study is not comprehensive. This results chiefly from the difficulties in gathering information relating to biological invasions, which are often anecdotal or published in a rather scattered and obscure literature (Healy et al. 1995). In the plant kingdom a large

number of invasive species are woody and they are the focus of an ongoing project which includes the setting up of a relational database. Here, preliminary results are presented in order to provide an overview of the main taxonomic, biogeographical and ecological attributes of invasive woody plant species (including sub-shrubs with stems which are woody at the base).

The database

The Invasive Woody Plant Database was set up between 1990 and 1993 (using R:Base run on a PC-compatible 386 notebook) and is based on information gathered over 12 years. The database consists of a bibliographical reference database and a relational database on invasive woody plant species. The relational database consists of four tables, two of which contain information for 653 species on 42 species attributes and 10 ecosystem attributes respectively. All information entered in the database, based on 2045 bibliographical references, is linked to a source in the reference database. (For further details, as well as results from the reference database and an overview of tropical invasive woody plant species, see Healey et al. 1995.)

Published information on invasive woody plants is often subjective and therefore difficult to interpret. For the purpose of this study, an invasive woody plant is defined as the establishment of self-regenerating, usually expanding, populations of an introduced species in a free-living state in nature (Binggeli 1994). Data for a number of attributes (e.g. degree of invasiveness, purpose of introduction and habitat types) have been amalgamated into a small number of broad categories. Wherever possible, invasive events are scored as possibly/potentially, moderately or highly invasive. Introduced species recorded as possibly/potentially invasive are locally regenerating but the extent of spread is not known or is limited. Moderately invasive species are spreading but they still occur in low densities and are not considered an immediate problem. Highly invasive species have become dominant or co-dominant in the

Table 1. Families with the largest number of invasive woody species. DI = degree of invasiveness; DI 1 = possibly/potentially invasive; DI 2 = moderately invasive; DI 3 = highly invasive; *N* = number of species.

Total Family	<i>N</i>	DI 1 Family	<i>N</i>	DI 2 Family	<i>N</i>	DI 3 Family	<i>N</i>
<i>Rosaceae</i>	98	<i>Rosaceae</i>	34	<i>Rosaceae</i>	50	<i>Mimosaceae</i>	17
<i>Mimosaceae</i>	49	<i>Papilionaceae</i>	12	<i>Mimosaceae</i>	21	<i>Rosaceae</i>	14
<i>Papilionaceae</i>	27	<i>Mimosaceae</i>	11	<i>Myrtaceae</i>	13	<i>Asteraceae</i>	7
<i>Pinaceae</i>	27	<i>Pinaceae</i>	8	<i>Pinaceae</i>	12	<i>Pinaceae</i>	7
<i>Caesalpiniaceae</i>	21	<i>Salicaceae</i>	7	<i>Caesalpiniaceae</i>	11	<i>Myrtaceae</i>	6
<i>Myrtaceae</i>	20	<i>Caesalpiniaceae</i>	7	<i>Ericaceae</i>	11	<i>Papilionaceae</i>	5
<i>Asteraceae</i>	17	<i>Caprifoliaceae</i>	6	<i>Oleaceae</i>	11	<i>Caprifoliaceae</i>	4
<i>Ericaceae</i>	17	<i>Berberidaceae</i>	5	<i>Solanaceae</i>	11	<i>Melastomataceae</i>	4
<i>Oleaceae</i>	17	<i>Cornaceae</i>	4	<i>Papilionaceae</i>	10	<i>Solanaceae</i>	4

invaded region and are considered a threat to the native flora and ecosystem. These species are usually subjected to some form of control. Out of 1198 invasive events it has been possible to assess the degree of invasiveness in 1060 cases.

Throughout, the data are presented in relation to the degree of invasiveness. As each species can be invasive in more than one region with differing degrees of invasiveness, the highest degree of invasiveness is used for each species in the presentation of the data dealing with species attributes. Results are presented for attributes where data are currently (1/3/1995) available for at least 30% of the species.

Results

Taxonomy

Worldwide, 653 woody plant species, belonging to 315 genera and 110 families, have been recorded as being invasive. The *Rosaceae* and legume families, and to a lesser extent the *Pinaceae* and *Myrtaceae*, contain a large number of invasive woody plants (Table 1). However most species of the *Rosaceae* are possibly/potentially or moderately invasive and relatively fewer are highly invasive. On the other hand, families such as the *Asteraceae* and *Myrtaceae* have a number of highly invasive species but few possibly/potentially invasive species.

Biogeography

The biogeographical distribution of known invasions is presented in Table 2. In the temperate zone a large number of invasions have been reported from most regions with the exception of southern America and Asia. In the tropical zone most invasions are reported from Pacific and Indian Ocean islands, without any records from South America! Worldwide the same number of invasions of continents and oceanic islands

Table 2. Biogeographical distributions of invasive events. DI as in Table 1, DI available for 1060 invasive events, *N* = number of invasive events.

Region	Total <i>N</i>	DI 1 <i>N</i>	DI 2 <i>N</i>	DI 3 <i>N</i>
Europe	250	107	122	21
Pacific Islands	155	31	83	41
North America	143	37	82	24
New Zealand	134	43	78	13
Australia	83	35	33	15
Indian Ocean Islands	74	9	50	15
Southern Africa	62	13	29	20
Tropical Africa	57	13	32	12
Asia	42	7	22	13
Southern America	27	4	18	5
West Indies	12	1	10	1
Atlantic Islands	11	3	8	-
Madagascar	8	-	4	4
Others	2	-	2	-

has been reported (Table 3). When the degree of invasiveness is taken into account, the ratio between possibly/potentially, moderately and highly invasive species is similar on continents and islands (Table 3). However, there are relatively fewer highly invasive woody species on islands situated on continental shelves (e.g. British Isles) than isolated ones (e.g. Hawaii).

Table 3. Relative incidence of invasions on continents and oceanic islands. DI as in Table 1; DI available for 1060 invasive events; *N* = number of invasive events.

	<i>N</i>	DI 1 %	DI 2 %	DI 3 %
Continents	529	30	52	18
Oceanic islands	531	27	56	17
Oceanic islands				
- isolated	396	22	58	20
- continental shelf	135	41	50	9

Table 4. Life forms of invasive woody species. DI as in Table 1; *N* = number of species.

	Height	Total		DI 1		DI 2		DI 3	
		<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Trees	> 15 m	166	25	34	20	102	28	30	25
Small trees	5 - 15 m	181	28	32	18	115	32	34	29
Shrubs	< 5 m	264	41	97	56	125	35	42	35
Climbers		42	6	11	6	18	5	13	11

Ecology

Species attributes

Shrubs (height < 5 m) are the commonest invasive life form followed by 'small trees' (height 5 - 15 m) and 'trees' (height > 15 m) (Table 4). The relative importance of shrub species is much greater among possibly/potentially invasive species than in the other two categories. There are few invasive woody climbers.

The relative proportion of evergreen and thorny species increases with the degree of invasiveness, although the total number of thorny species is low (Table 5). Wind-pollination is commoner in possibly/potentially invasive species and insect-pollination more frequent in moderately and highly invasive species (Table 5). Some moderately and highly invasive species are amphophilous, bird-pollinated or self-pollinated. A variety of fruit types characterize invasive woody plants including in decreasing degree of importance: berries, pods, capsules, drupes and cones. Birds are the main dispersal agent, followed by wind. The relative importance of wind-dispersed species decreases with the degree of invasiveness (Table 5).

In the majority of species, fruit size (to the nearest cm) was 1 cm and 3 cm with a greater variation for pods (1 - 60 cm) than other fruit types (1 - 15 cm). Most fruits contained one or two seeds, but a few had a larger number of seeds (up to a thousand). The size of most seeds was between 1 and 6 mm with a few reaching a size of up to 50 mm.

Why humans have introduced species - which have become invasive - is not known for a large number of invasive events. Introductions for amenity purposes and to a lesser extent for forestry and agricultural purposes have been responsible for most reported cases of invasions (Table 6). Agricultural introductions result in relatively fewer cases of highly invasive species whereas the reverse is true for forestry introductions.

Ecosystem attributes

In only half of the reported invasive events it is possible to determine the invaded habitat (Table 7).

Most invasions occur in forests, both natural and disturbed ones. The majority of invaded habitats are highly disturbed and this has mostly resulted from human disturbance. Forests appear to be the natural habitats most susceptible to invasions by woody plants.

Conclusion

As this 'Invasive Woody Plant Database' project is still at an early stage, the available data have been presented as frequency tables of species and ecosystem attributes. The data show that all investigated attributes

Table 5. Various species attributes characterising invasive woody plants. DI as in Table 1; sample size in brackets, *N* = number of species.

		DI 1		DI 2		DI 3	
		<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Deciduousness (383)	deciduous	58	57	100	47	27	39
	evergreen	36	35	100	47	35	51
	semi-evergreen	8	8	12	6	7	10
Thorniness (220)	thornless	36	97	114	90	41	73
	thorny	1	3	13	10	15	27
Pollinating agent (161)	amphiphilous	-	-	-	-	3	7
	bird	-	-	1	1	1	2
	insect	11	38	57	63	22	54
	wind	18	62	32	35	14	35
	self-pollinated	-	-	1	1	1	2
Fruit type (524)	achene	2	1	11	4	7	7
	berry	32	23	59	21	27	27
	capsule	20	15	55	19	19	19
	catkin	8	6	8	3	1	1
	cone	10	7	18	6	9	9
	drupe	17	13	63	22	11	11
	follicle	10	7	13	5	1	1
	nut	2	1	6	2	-	-
	pod	26	19	37	13	23	23
	pome	7	5	7	2	1	1
	samara	4	3	9	3	1	1
Dispersal agent (288)	animal (mixture)	2	3	9	6	4	5
	bird	29	49	71	46	38	48
	explosive	-	-	1	1	3	4
	insect	-	-	-	-	2	3
	mammal	-	-	3	3	6	8
	water	1	2	2	1	3	8
	wind	27	46	65	43	22	28

Table 6. Main purpose of introductions. DI as in Table 1; *N* = number of invasive events.

	DI 1		DI 2		DI 3		Total	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Agriculture	37	3.5	67	6.3	16	1.5	120	11.3
Botanic gardens	3	0.3	11	1.0	6	0.6	20	1.9
Forestry	27	2.5	70	6.6	34	3.2	131	12.3
Amenity	114	10.8	164	15.5	49	4.6	327	30.9
Landscape	7	0.7	11	1.0	6	0.6	24	2.3
Accidental	1	0.1	-	-	1	0.1	2	0.2
Unknown	114	10.7	250	23.6	72	6.8	436	41.1
Total	303	28.6	573	54.0	184	17.4	1060	100.0

Table 7. Habitat types invaded by invasive woody plants. DI as in Table 1; *N* = number of invasive events.

	DI 1		DI 2		DI 3		Total	
	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%	<i>N</i>	%
Disturbed grounds	35	3.3	71	6.7	36	3.4	142	13.4
Forests - natural	10	0.9	30	2.8	19	1.8	59	5.5
- disturbed	26	2.4	82	7.7	40	3.8	148	13.9
- plantation	4	0.4	7	0.7	3	0.3	14	1.4
Hedges	2	0.2	5	0.5	1	0.1	8	0.8
Grasslands	12	1.1	23	2.1	18	1.7	53	4.9
River banks	9	0.9	23	2.1	10	0.9	42	3.9
Road sides	11	1.0	23	2.1	3	0.3	37	3.4
Swamps	4	0.4	4	0.4	2	0.2	10	1.0
Dunes	5	0.5	8	0.8	3	0.3	16	1.6
Bogs/heathland/fynbos	1	0.1	9	0.9	7	0.7	17	1.7
Cliffs	3	0.3	5	0.5	-	0	8	0.8
Unknown	181	17.1	283	26.7	42	3.9	506	47.7
Total	303	28.6	573	54.0	184	17.4	1060	100.0

exhibit much variation, indicating that there is not a consistent set of attributes describing an invasive woody plant. It is intended to expand the data set and to increase the number of attributes investigated. In order to provide an understanding of the relationships between attributes, a multivariate analysis of the data set will be carried out. Special attention will be paid to the differing degree of invasiveness (species being ranked as possibly/potentially, moderately and highly invasive). The data relating to invasive species will be compared to introduced, but non-invasive, species and a sub-set of native woody floras; however, this work has yet to be initiated. The results should allow us to make tentative predictions as to the species attributes, and the ecological and climatic characteristics which promote or hinder the invasive potential of wide array of woody plants.

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