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Invasive alien woody plants of the southern and southwestern Cape region, South Africa

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Keywords: alien invasive plants, Forest Biome, Fynbos Biome, roadside survey, Savanna Biome, southern and southwestern Cape, Succulent Karoo Biome

ABSTRACT

The frequency and abundance of invasive alien plants were recorded along roadsides and at watercourse crossings in 82.9% (145/175) of the quarter degree squares in the study area (31–35°S, 17–25°E and covering ± 90 000 km²). The survey yielded 102 species of which the most prominent (in order of prominence) in roadside and veld (natural and modified) habitats were: *Acacia cyclops*, *A. saligna* and *A. mearnsii*. The most prominent species (in order of prominence) in streambank habitats were: *A. mearnsii*, *A. saligna* and *Populus* × *canescens*.

The greatest intensity of invasion was recorded in forest and fynbos vegetation types in the relatively narrow belt stretching from the coastline to the tops of the coastal mountain ranges. In the coastal lowlands *Acacia cyclops* and *A. saligna* form the most extensive and continuous stands of alien vegetation recorded anywhere in South Africa. In the arid interior invasion was largely confined to watercourses.

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INTRODUCTION

Survey history and objectives

This study of the southern and southwestern Cape is the sixth of eight regional surveys which together are designed to reflect invasion by woody alien plants in South Africa as a whole. Surveys have been completed for the former Transvaal (Henderson & Musil 1984), Natal and northeastern Orange Free State (Henderson 1989), Orange Free State (Henderson 1991a), northern Cape (Henderson 1991b) and eastern Cape (Henderson 1992). The survey of this area was undertaken from east to west and during the months of March and October 1990, January and December 1991, February and November 1992, and May 1993.

The objectives of the survey were: to produce a checklist of the major invasive alien woody plants of streambank, roadside and veld habitats in the study area; to determine the pattern of alien woody invasion as a whole and for individual species; to attempt to relate distribution to environmental factors and to determine which are the most prominent and potentially important invaders.

The study area

The study area lies between latitudes 31° and 35°S and longitudes 17° and 25°E (Figure 1), and occupies an area of approximately 90 000 km². It is bounded in the south by the Indian Ocean and in the southwest by the Atlantic Ocean. The topography is dominated by the mountains of the Cape Fold Belt. These mountains occur for the most part in subparallel ranges with an average height of 1 000 to 1 500 m and with individual peaks reaching over 2 000 m. In the south these ranges strike from east to west whereas in the west the strike is more

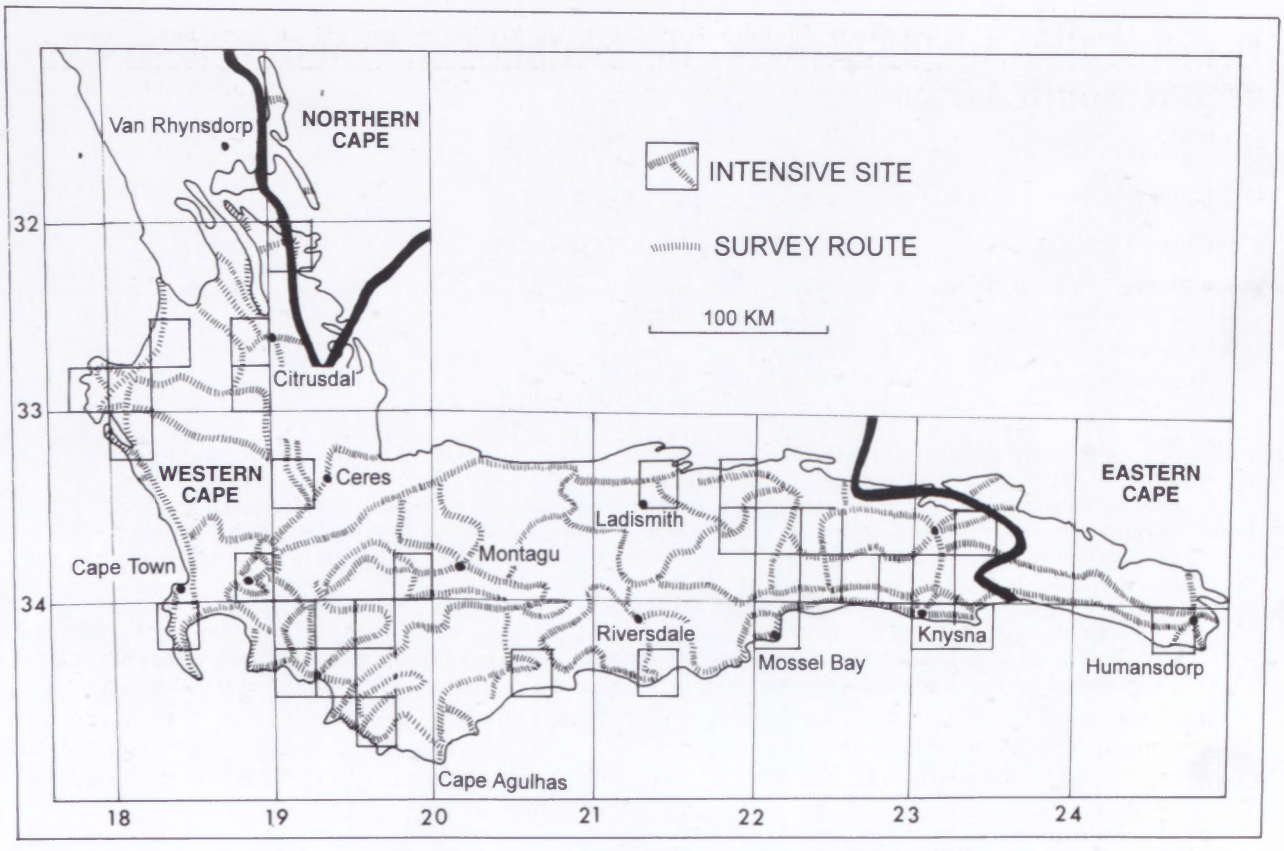

FIGURE 1.—The study area showing survey routes and intensive sites.

nearly north-north-west (Taylor 1978). The ranges are separated by wide intermontane valleys. There are many river systems in the study area which contains about 17% of the major mountain catchments of South Africa, Lesotho and Swaziland (Van der Zel 1981).

Rainfall ranges from 200 mm in the arid interior to 3 600 mm per annum on some of the higher mountains. To the west of 20°E a Mediterranean-type climate prevails with cool wet winters and warm dry summers. In the east, rainfall is more consistent through the year.

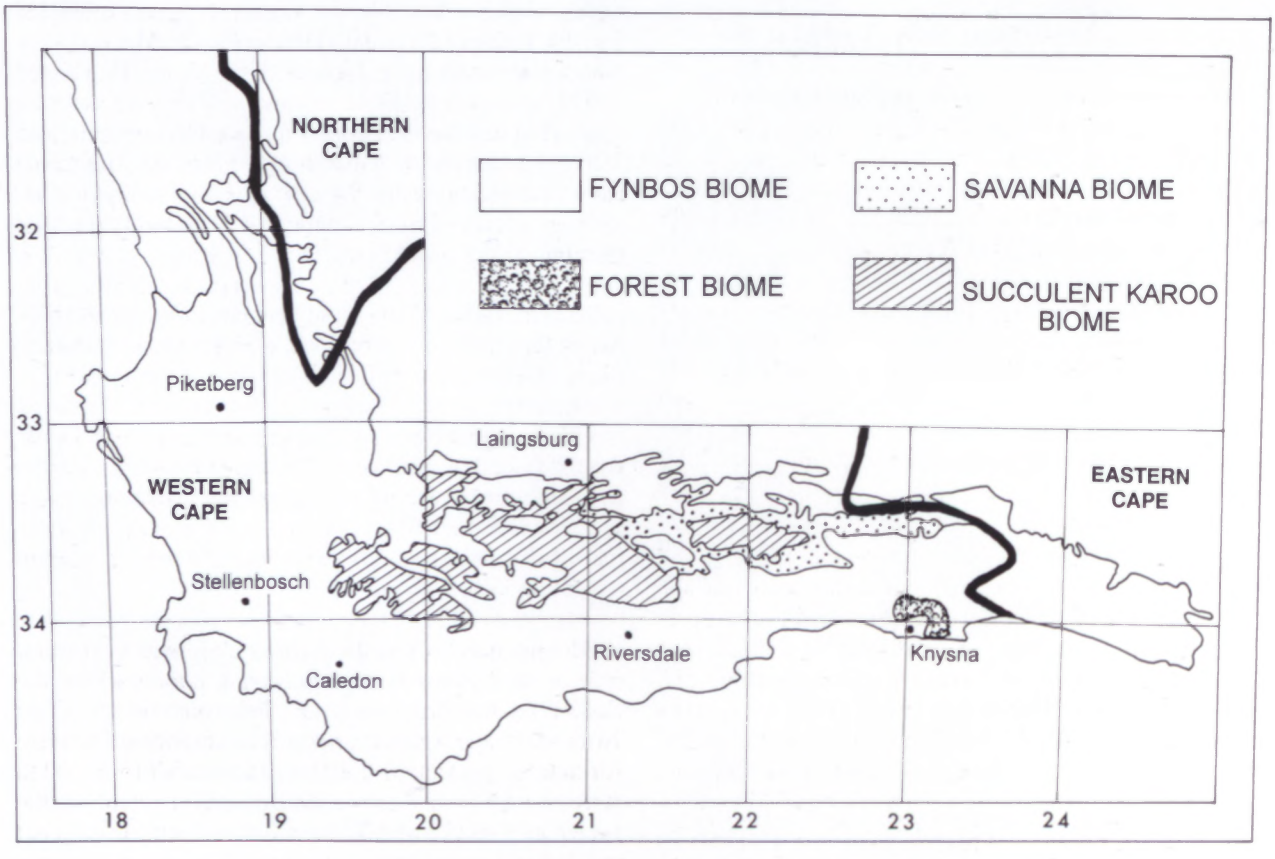

FIGURE 2.—The biomes in the study area after Rutherford & Westfall (1986).

TABLE 1.—Veld type categories in study area and equivalent Acocks Veld Type groupings and Veld Type numbers

Biome† and veld type category*	Acocks Veld Type grouping	Acocks Veld Type No.
Succulent Karoo Biome	IV. Karoo and Karroid Types	26, 31
	IVA. False Karoo Types	43
Savanna Biome	IV. Karoo and Karroid Types	25
Forest Biome	I. Coastal Tropical Forest Types	4
Fynbos Biome		
Strandveld*	IV. Karoo and Karroid Types	34
Mountain renosterveld*	IVA. False Karoo Types	43
Coastal renosterveld*	IV. Karoo and Karroid Types	23
	V. Temperate and Transitional Forest and Scrub Types	46
Coastal fynbos*	V. Temperate and Transitional Forest and Scrub Types	47
Mountain fynbos*	VII. Sclerophyllous Bush Types	69
	VIII. False Sclerophyllous Bush Types	70
Mountain fynbos and forest*	I. Coastal Tropical Forest Types	4

* according to Henderson; †according to Rutherford & Westfall 1986.

Changes in the rainfall can be very abrupt, and are usually associated with the topography. During winter, snow falls regularly on the higher mountains, but the lowlands enjoy an equable climate and frost is rare except in some of the deep valleys of the interior (Taylor 1978; Linder 1991; Jury 1993).

For the purposes of this survey and in keeping with previous surveys, the vegetation of the study area has been subdivided according to the biomes of southern Africa defined by Rutherford & Westfall (1986) and Acocks's *Veld types of South Africa* (1988). There are four biomes in the study area, namely the Succulent Karoo, Savanna, Forest and Fynbos Biomes (Figure 2). Eleven Acocks Veld Types occur in the study area and have been grouped into nine broad veld type categories for the purposes of this survey (Table 1; Figure 2).

Succulent karoo occupies the region commonly known as the Little Karoo. The vegetation has a predominance of succulents, and dwarf trees and shrubs are numerous. It occupies rocky, hilly country, at elevations ranging from 300–600 m, receiving 150–300 mm of rain per annum (Acocks 1988).

Savanna is represented by a vegetation type commonly known as succulent mountain scrub which occurs on steep mountain slopes. It is typically a dense scrub dominated by *Portulacaria afra*. The altitude ranges from 400–1 060 m, and rainfall ranges from 250–300 mm per annum (Acocks 1988; Low & Rebelo 1996).

The only forest area of biome dimension in South Africa occurs in the southern Cape at Knysna (Rutherford & Westfall 1986). Before the southern Cape forests were heavily exploited and reduced to their present remnant areas, they covered most of the southern Cape coastal region between Mossel Bay and Humansdorp (Von Breitenbach 1972). Today the Knysna Forest and many smaller forest patches occur in a narrow, irregular belt along the southern coastal shelf and foothills of the Outeniqua and Tsitsikamma Mountains (Von Breitenbach 1972). Forest growth is favoured by mild temperatures and a high, well-distributed rainfall (Von Breitenbach 1972). The mean annual rainfall is 800–1 000 mm (Schulze & McGee 1978), but ranges from 500–1 200 mm (Geldenhuys 1993). Altitude ranges from sea level to 1 220 m at the tops of the mountains only 10–37 km inland (Geldenhuys 1993). Small forest outliers occur in fire-free habitats westwards towards the Cape Peninsula (Taylor 1978).

Strandveld is a low-growing, semisucculent and shrubby vegetation type confined to the sandy coastal plains of the west coast. It is transitional between coastal fynbos and succulent karoo. It receives 50–300 mm of rain per annum, mainly in winter (Acocks 1988).

Mountain renosterveld is a karroid-like veld type dominated by renosterbos, *Elytropappus rhinocerotis* (Acocks 1988). It is usually situated between succulent karoo and mountain fynbos and receives 250–400 mm of rain per annum (Low & Rebelo 1996).

Coastal renosterveld occurs in a western and southern belt and is situated between the fynbos of the mountains and of the coastal plain. The terrain is undulating and the soils are clayey. Rainfall ranges from 300–600 mm per annum. Most of the original vegetation has been ploughed up for the growing of wheat. Scrub relics that remain are dense, thorny and semisucculent. Elsewhere the scrub has been replaced mainly by renosterbos (Acocks 1988).

Coastal fynbos occurs on sand and limestone in the west and south coastal belts. The vegetation is a more or less open scrub lacking the dense thorniness and semisucculence of the previous veld type. The altitude ranges from 0–300 m and rainfall from 300–500 mm per annum (Acocks 1988).

Mountain fynbos is the most widespread vegetation type in the Fynbos Biome, occurring mainly along the Cape Fold Belt from north of Nieuwoudtville to Cape Town and Cape Agulhas and to Humansdorp in the east. Altitude ranges from 0–2 200 m, and rainfall from 200 to more than 2 000 mm per annum, occurring mainly in the winter months (Low & Rebelo 1996). Summers are hot and dry and conducive to veld fires. The vegetation is an open to closed shrubland.

Mountain fynbos & forest occurs outside the Forest Biome defined by Rutherford and Westfall (1986) but within the original limits of the Knysna Forest, Acocks Veld Type 4, mapped by Acocks (1988). This region contains wet mountain fynbos (National Committee for Remote Sensing, CSIR 1983), numerous small patches of forest, including the Tsitsikamma Forest, and extensive timber plantations of mainly pine, but also gums and *Acacia melanoxylon* (Van der Zel 1988). The mean annual rainfall is 800–1 000 mm (Schulze & McGee 1978) and uniformly distributed throughout the year.

METHOD

Sampling method

The method used in this survey was the same as in the previous survey of the eastern Cape (Henderson 1992). The presence and abundance of all alien trees, large shrubs and conspicuous climbers which appeared to be spreading spontaneously (naturalised) were recorded for each veld type category, habitat type (roadsides and adjoining veld, and streambanks) and quarter degree/fifteen minute square traversed by road. Thirty three quarter degree squares were selected for more intensive surveying (Figure 1). They may be used at a later date for a quick resurvey of the study area to assess any changes that may have taken place.

Recordings of roadside and veld invaders were made from a moving vehicle along road transects of between five and 10 km in length. The average transect length was 6.4 km for the general survey area and 5.0 km for the intensive sites. Recordings of streambank invaders were made at virtually all watercourse crossings on the survey route. Details of the roads traversed are lodged in the Plant Protection Research Institute (PPRI), Pretoria. As on the previous occasions the survey was undertaken in a minibus, with one driver and one recorder (the author). The average speed was 60 km/h but ranged from about 20 km/h in densely vegetated areas to 100 km/h in sparsely vegetated areas.

All the raw data for this survey as well as the previously completed regional surveys have been computerized using the data management system DataEase. This database is housed in Pretoria at the PPRI.

Abundance ratings

The abundance ratings for roadside and veld habitats and streambank habitats are given in Table 2.

Sampling level achieved

The sampling level achieved was 82.9% (145 out of the total 175 quarter degree squares) at an average of 44.5 km travelled per square. An average of 29.3 km of road transects were sampled per quarter degree square for abundance estimates of roadside and veld invaders.

The veld type coverage in terms of quarter degree squares and road transects sampled, kilometres travelled and watercourse recordings made, is given in Table 3. Statistics for streambank, roadside and veld habitats are given in Tables 4 and 5.

Data treatment—formulae used

Frequency

The percentage frequency of occurrence of a species x in a given category (veld type, biome or study area) y was calculated as follows:

$$\text{frequency} = \frac{\text{no. of watercourse recordings/road transects in category y having species x}}{\text{total no. of watercourse recordings/road transects in category y}} \times 100$$

Prominence value

The prominence value is a combined measure of a species' frequency and abundance relative to that of all

TABLE 2.—Abundance ratings

Rating	Roadsides and veld	No. *	Streambanks	Rating
9	A virtually continuous, almost pure stand	1000+	Any number, with cover more than 75% of the reference area	7
8	The commonest species in a generally continuous tree or shrub layer	500–999	Any number, with 50–75% cover	6
7	Less abundant than above but greater than 20 individuals or groups per km	200–499	Any number, with 25–50% cover	5
6	10–20 individuals or groups per km	100–199	Any number, with 5–25% cover	4
5	5–10 individuals or groups per km	50–99	Numerous, but less than 5% cover or scattered, with cover up to 5%	3
4	2–5 individuals or groups per km	20–49	Few, with small cover	2
3	± 1 individual or group per km	5–19	Solitary, with small cover	1
2	Less abundant than above but more than 1 individual or group per 5 km	2–4		
1	± 1 plant or group per 5–10 km	1		

* approximate numbers of individuals or groups per 10 km transect

other species, within a given vegetation category (veld type, biome or study area).

In streambank habitats the prominence value for a species x in category y was calculated as follows:

$$\text{prominence value} = \frac{\text{total weighted abundance of species x in category y}}{\text{sum of the weighted abundances of all species in category y}} \times 100 + \frac{\text{frequency of species x in category y}}{\text{sum frequency of all species in category y}} \times 100$$

The abundance ratings were weighted according to the minimum percentage cover in each scale rating (see Table 2). Thus ratings 7, 6, 5 and 4 had weighted values of 75, 50, 25 and 5 respectively. Ratings 1, 2 and 3 each had weighted values of 1.

In roadside and veld habitats the prominence value for a species x in category y was calculated as follows:

$$\text{prominence value} = \frac{\text{total abundance* of species x in category y}}{\text{sum of the abundances* of all species in category y}} \times 100 + \frac{\text{frequency of species x in category y}}{\text{sum frequencies of all species in category y}} \times 100$$

The highest prominence values in a given category which add up to approximately 160 points out of a total of 200 are printed in bold in Tables 6, 7, 8 and 9. The cut-off point of 160 points is arbitrary but represents 80% of the summed prominence values.

Mean species abundance rating in roadside and veld habitats (Tables 8 & 9)

The mean species abundance rating** of a species x in a given category (veld type, biome or study area) y was calculated as follows:

$$\text{mean no. of individuals or groups per 10 km} = \frac{\text{total no. of individuals or groups of species x in category y}}{\text{total distance along which species x was rated in category y}} \times 10$$

Mean abundance of invaders per km in roadside and veld habitats (Table 5)

The mean abundance of invaders per km in a given category (veld type, biome or study area) y/quarter degree square z was calculated as follows:

$$\text{mean abundance} = \frac{\text{total abundance* of all species in category y/quarter degree square z}}{\text{total kilometres rated for abundance estimates in category y/quarter degree square z}}$$

* each abundance rating was expressed in numbers of individuals or groups recorded per transect (Table 2). To be both conservative and consistent the minimum number was used in each instance, e.g. an abundance rating of 5 over 10 km = 50 and an abundance rating of 5 over 5 km = 25.

** mean no. of individuals or groups per 10 km converted to rating (Table 2).

RESULTS

The survey yielded 102 naturalised alien species. These species are listed in the Appendix together with a further 34 species which were obtained from various literature and other sources. The distributions of 20 of the most prominent species are given in Figures 6 and 7 and a further 10 potentially important species are given in Figure 8.

The streambank habitat

The whole study area

One thousand and thirty-six watercourse crossings were sampled in which 75 species were recorded, with up to eight species in one sample. Invaders were present at 73.5% of all crossings and 30.9% of all crossings were heavily invaded (Table 4).

Analysis according to veld type

Overall the Fynbos Biome was the most heavily invaded in terms of percentage crossings invaded and percentage crossings heavily invaded. Invasion was most intense in mountain and coastal fynbos where the highest percentages of heavily invaded crossings were recorded. Very few watercourses were sampled in the Forest Biome. Most recordings were of small streams and it was difficult to see beyond 10 m.

Analysis according to species

Frequency

Acacia mearnsii was the most frequently recorded invader in the study area (29.4%). Only this species, *A. saligna* (20.7%) and *Populus* × *canescens* (13.6%) were recorded at 10% or more crossings in the whole study area (Table 7).

In the Fynbos Biome the most frequently recorded species were *Acacia mearnsii* (40.4%), *A. saligna* (30.7%), *Populus* × *canescens* (17.1%) and *A. cyclops* (11.2%). In the Forest Biome *A. melanoxylon* (70.6%), *A. mearnsii* (35.3%) and *Eucalyptus diversicolor* (23.5%) were the most frequent invaders. In the Savanna Biome *Nicotiana glauca* (14.1%), *Arundo donax* (11.1%), *Populus* × *canescens* (11.1%) and *Ricinus communis* (11.1%) were the most frequently recorded species. In the Succulent Karoo Biome *Acacia saligna* (15.6%) and *Nicotiana glauca* (15.6%) were the most frequent invaders.

Prominence

The most prominent invader in the whole study area was *Acacia mearnsii* with a prominence value of 61.6 out of a combined total for all species of 200 (Table 7). The next most prominent invaders were *A. saligna* (36.9) and *Populus* × *canescens* (19.5).

In the Fynbos Biome *Acacia mearnsii* was the most prominent invader in four of the six veld type categories, namely mountain fynbos, mountain fynbos & forest,

TABLE 3.—Sampling coverage of each biome, veld type category and study area

Biome‡ and veld type category†	¼ degree squares	Road transects	Distance (km)*	Watercourse recordings
Succulent Karoo Biome	29	77	569	224
Savanna Biome	14	36	219	99
Forest Biome	4	27	132	17
Fynbos Biome	133	520	3332	696
Strandveld†	14	38	190	7
Mountain renosterveld†	32	57	418	89
Coastal renosterveld†	52	133	921	250
Coastal fynbos†	30	72	499	71
Mountain fynbos†	64	169	1042	214
Mountain fynbos & forest†	15	51	262	65
Study area	145	660	4252	1036

* this represents the distance along which abundance recordings were made. Total distance along which observations were made is approximately one and a half times that given; † according to Henderson; ‡ according to Rutherford & Westfall 1986.

TABLE 4.—Statistics for streambanks in each biome, veld type category and study area

Biome‡ and veld type category†	Total no. of spp.	Average no. of spp./crossing	Max. no. of spp./crossing	% crossings heavily invaded*	%crossings invaded**
Succulent Karoo Biome	26	1.0	6	11.6	51.8
Savanna Biome	22	0.9	6	2.0	45.5
Forest Biome	8	1.5	4	17.6	76.5
Fynbos Biome	70	1.8	8	41.5	84.3
Strandveld†	7	1.3	4	28.6	71.4
Mountain renosterveld†	23	0.9	5	19.1	55.1
Coastal renosterveld†	50	1.9	8	39.0	83.2
Coastal fynbos†	22	2.0	6	50.7	94.4
Mountain fynbos†	52	1.9	6	54.7	91.6
Mountain fynbos & forest†	21	2.0	6	30.8	95.4
Study area	75	1.5	8	30.9	73.5

* one or more species scored an abundance rating of 5 or more; ** invaders present; † according to Henderson; ‡ according to Rutherford & Westfall 1986.

TABLE 5.—Statistics for roadside and veld habitats in each biome, veld type category and study area

Biome‡ and veld type category†	Total no. of spp.	Average no. of spp./¼° sq.	Max. no. of spp./¼° sq.	% transects invaded	% transects heavily invaded*	Mean abundance of invaders per km**
Succulent Karoo Biome	28	5.6	14	93.5	3.9	1.4
Savanna Biome	18	4.8	9	86.1	0.0	0.9
Forest Biome	31	14.3	28	96.3	88.9	25.1
Fynbos Biome	92	8.5	45	94.2	52.9	14.2
Strandveld†	12	3.4	7	94.7	28.9	5.9
Mountain renosterveld†	35	3.9	11	84.2	7.0	1.8
Coastal renosterveld†	71	9.3	45	96.2	46.6	9.5
Coastal fynbos†	41	6.6	18	100.0	75.0	29.8
Mountain fynbos†	70	10.8	38	91.7	56.2	14.2
Mountain fynbos & forest†	49	14.9	29	100.0	96.1	27.4
Study area	96	8.1	45	93.8	45.8	12.2

* one or more species scored an abundance rating of 5 or more; ** see data treatment–formulae used; † according to Henderson; ‡ according to Rutherford & Westfall 1986.

TABLE 6.—Alien species occurring in streambank habitats of Succulent Karoo, Savanna and Forest Biomes and in strandveld and mountain renosterveld of Fynbos Biome

Biome and veld type category	Succulent Karoo Biome			Savanna Biome			Forest Biome			Fynbos Biome Strandveld			Fynbos Biome Mountain renosterveld		
No. watercourse crossings	224			99			17			7			89		
	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P
Acacia															
cyclops	2.7		3.2							14.3		12.0	6.7	2.2	11.0
dealbata													3.4		5.0
mearnsii	7.6	2.7	**25.3**	1.0		1.6	35.3	5.9	**51.8**				23.6	9.0	**81.1**
melanoxylon	*			*			70.6	17.6	**116.9**	14.3		12.0			
saligna	15.6	4.0	**53.1**							42.9	14.3	**80.2**	7.9	1.1	**15.7**
Agave americana	1.8		2.1										2.2		2.6
Ailanthus altissima	*			1.0		1.6									
Arundo donax	9.4	1.8	**19.1**	11.1		**19.4**							1.1		1.3
Atriplex nummularia	2.7		3.2	2.0		5.0							*		
Casuarina sp.	0.4		0.5												
Eucalyptus															
cf. *camaldulensis*	8.0	2.7	**21.5**	3.0		**8.4**							1.1		1.3
cladocalyx	*			1.0		1.6									
diversicolor							23.5		17.9						
exserta										28.6	14.3	**71.8**			
leucoxylon	*														
spp.	1.3		1.6	3.0		4.8							*		
Ficus carica	0.4		0.5	3.0		4.8									
Melia azedarach	0.9		1.1	1.0		1.6									
Morus alba				1.0		1.6									
Nerium oleander	0.4		0.5	4.0		6.3							1.1		1.3
Nicotiana glauca	15.6		**18.6**	14.1		**22.3**				*			2.2		2.6
Opuntia ficus-indica	0.4		0.5										1.1		1.3
Phoenix canariensis	0.4		0.5												
Pinus															
pinaster							5.9		4.5				1.1		1.3
radiata							*								
Populus															
× *canescens*	4.9	0.9	**10.6**	11.1	2.0	**66.2**				14.3		12.0	16.9	6.7	**45.5**
deltoides				1.0		1.6							1.1		1.3
nigra 'italica'				*									1.1		1.3
Prosopis spp.	1.8		2.1							14.3		12.0			
Prunus persica				1.0		1.6							1.1		1.3
Pyrus sp.													*		
Quercus robur				1.0		1.6	5.9		4.5						
Ricinus communis	7.6		9.0	11.1		**17.6**							1.1		1.3
Robinia pseudoacacia													*		
Rubus fruticosus							5.9		4.5						
Salix babylonica	2.2	0.4	5.1	8.1		**14.6**	*						11.2	1.1	**16.5**
Schinus molle	3.1		3.7	8.1		**12.8**							5.6		6.7
Sesbania punicea	7.1	0.4	**12.6**												
Tamarix spp.	4.5		5.7	2.0		5.0							1.1		1.3

F, % frequency of occurrence; I, % crossings heavily invaded; P, prominence value; * species occurring in the given category but not included in a formal recording at a watercourse crossing. Bold numbers: the highest prominence values in a given category which add up to ± 80% of the summed values (see text).

coastal renosterveld and mountain renosterveld. *A. saligna* was the most prominent invader in the remaining two categories, namely strandveld and coastal fynbos. *A. cyclops* was a close second in coastal fynbos.

Acacia melanoxylon was the most prominent invader in the Forest Biome, followed by *Acacia mearnsii*. *Populus* × *canescens* was the most prominent invader in the Savanna Biome and *A. saligna* was the most prominent invader in the Succulent Karoo Biome.

Roadside and veld habitats

The whole study area

One hundred and forty-five quarter degree squares and 660 road transects were sampled in which 96 species were recorded. Up to 45 species were recorded per quarter degree square. Naturalised species were recorded in 93.8% of all transects sampled and 45.8% of all transects were heavily invaded (Table 5).

Analysis according to veld type

The most intense invasion was recorded in mountain fynbos & forest in the Fynbos Biome, closely followed by the Forest Biome where the highest percentages of transects (96.1% and 88.9% respectively) were heavily invaded. The mean abundance of invaders per km reached a maximum in coastal fynbos (29.8). The least invasion was recorded in the Savanna Biome, where no transects were heavily invaded.

It must be noted here that although invasion was intense in the Forest Biome, most invasion was recorded in the dis-

TABLE 7.—Alien species occurring in streambank habitats in coastal renosterveld, coastal fynbos, mountain fynbos, mountain fynbos & forest of Fynbos Biome and study area

Biome and veld type category	Fynbos Biome: Coastal renosterveld			Coastal fynbos			Mountain fynbos			Mountain fynbos & forest			Total			Total study area		
No. watercourse crossings	250			71			214			65			696			1036		
	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P
Acacia baileyana	*						0.5		0.3	6.2		3.4	0.1		0.1	0.1		0.1
cyclops	11.2	1.2	**8.7**	54.9	16.9	**53.4**	12.6	1.9	**8.3**				11.2	2.4	**11.3**	8.1	1.6	**10.0**
dealbata	1.2	0.8	1.5				7.0	6.1	**12.1**				3.0	2.2	**5.4**	2.0	1.4	**4.7**
elata							*						*			*		
longifolia	6.4	3.6	**9.9**	15.5	5.6	**15.6**	11.7	5.6	**11.9**	1.5		1.2	7.6	3.6	**9.8**	5.1	2.4	**8.5**
mearnsii	36.4	21.2	**63.5**	5.6	2.8	9.0	51.4	32.2	**76.7**	84.6	27.7	**118.6**	40.4	21.6	**67.1**	29.4	15.2	**61.6**
melanoxylon	3.2	0.4	2.8	1.4		0.8	3.3	0.5	2.5	38.5	6.2	**31.1**	6.0	0.9	**4.9**	5.2	0.9	**5.7**
podalyriifolia	*						0.5		0.3				0.1		0.1	0.1		0.1
pycnantha							1.9		1.2				0.6		0.4	0.4		0.3
saligna	34.0	11.6	**46.6**	46.5	25.3	**73.2**	23.8	10.3	**27.3**	*			30.7	11.5	**39.8**	20.7	7.7	**36.9**
Agave americana	0.4		0.2				0.5		0.3				0.6		0.4	0.8		0.6
Ailanthus altissima																0.1		0.1
Arundo donax	6.4	0.4	**4.3**	8.5	1.4	5.9	4.2		2.4	1.5		0.8	4.7	0.3	3.2	6.3	0.6	**5.5**
Atriplex nummularia																0.8		0.6
Bambusa balcooa				2.8		1.5	*						0.3		0.2	0.2		0.1
Bambuseae sp.										1.5		0.8	0.1		0.1	0.1		0.1
Canna sp.		*											*			*		
Casuarina sp.																0.1		0.1
Colocasia cf. *esculenta*	*						0.5		0.3				0.1		0.1	0.1		0.1
Cortaderia selloana							0.5		0.3	1.5		0.8	0.3		0.2	0.2		0.1
Eucalyptus																		
cf. *camaldulensis*	4.0	0.8	3.6	1.4		0.8	4.2	1.4	3.5				3.0	0.7	2.7	4.1	1.1	**4.7**
cladocalyx	2.4		1.4	*			2.3		1.3				1.6		1.0	1.2		0.9
diversicolor	0.8		0.5	*			1.4		0.8	15.4	1.5	**10.4**	2.2	0.1	1.4	1.8	0.1	1.4
exserta													0.3	0.1	0.5	0.2	0.1	0.4
globulus							0.5		0.3				0.1		0.1	0.1		0.1
gomphocephala							*						*			*		
lehmannii	1.6		0.9	4.2		2.5	0.5		0.3				1.1		0.7	0.8		0.6
leucoxylon																*		
regnans	0.4		0.2				*						0.1		0.1	0.1		0.1
spp.	1.6		0.9				1.4		0.8				1.0		0.6	1.3		0.9
Ficus carica	0.4		0.2	1.4		0.8	*						0.3		0.2	0.6		0.4
Hakea sericea							0.5		0.3	3.1		1.7	0.4		0.2	0.3		0.2
Ipomoea nil	*												*			*		
cf. *purpurea*	0.4		0.2										0.1		0.1	0.1		0.1
Lantana camara	0.4		0.2				0.9		0.5				0.4		0.2	0.3		0.2
Melia azedarach	0.8		0.5										0.3		0.2	0.5		0.4
Morus alba																0.1		0.1
Myoporum tenuifolium							*						*			*		
Nerium oleander	0.4		0.2										0.3		0.2	0.7		0.5
Nicotiana glauca	4.4		2.5	4.2		2.3	0.5		0.3				2.4		1.4	6.4		**4.6**
Opuntia ficus-indica	4.8		2.8	1.4		0.8	0.5		0.3				2.2		1.3	1.5		1.1
vulgaris				1.4		0.8	0.5		0.3				0.3		0.2	0.2		0.1
Paraserianthes lophantha	4.8		3.0	5.6		3.0	6.5	0.5	4.0	4.6		2.9	4.7		0.1	3.2	0.1	2.6
Passiflora caerulea	2.4		1.4										0.9		0.5	0.6		0.4
Phoenix canariensis	*			1.4		0.8							0.1		0.1	0.2		0.1
dactylifera	0.8		0.5										0.3		0.2	0.2		0.1
Phytolacca dioica	2.4		1.4				*						0.9		0.5	0.6		0.4
Pinus halepensis							0.5		0.3				0.1		0.1	0.1		0.1
pinaster	0.8		0.5				2.3		1.3	16.9		9.6	2.7		1.7	1.9		1.4
pinea	*												*			*		
radiata	0.4		0.2				0.9		0.5	6.2		3.4	1.0		0.6	0.7		0.5
Pittosporum undulatum	0.4		0.2										0.1		0.1	0.1		0.1
Populus × *canescens*	17.6	6.8	**18.3**	22.5	5.6	**18.5**	18.7	7.9	**21.1**	4.6	1.5	6.9	17.1	6.5	**19.9**	13.6	4.7	**19.5**
deltoides							0.9		0.5				0.4		0.2	0.4		0.3
nigra 'italica'							0.5		0.3				0.3		0.2	0.2		0.1
Prosopis spp.	4.0		2.3				1.4		0.8				2.0		1.2	1.7		1.2
Prunus persica	2.0		1.1	1.4		0.8	0.9		0.5				1.3		0.8	1.0		0.7
Psidium guajava	0.4		0.2	2.8		1.5	0.5		0.3				0.6		0.4	0.4		0.3
Punica granatum	*												*			*		
Pyrus sp.							0.5		0.3				0.1		0.1	0.1		0.1
Quercus robur	2.8		1.7				3.7		2.0	3.1		1.7	2.4		1.5	1.8		1.3
spp.	0.8		0.5										0.3		0.2	0.2		0.2

TABLE 7 (cont.).—Alien species occurring in streambank habitats in coastal renosterveld, coastal fynbos, mountain fynbos, mountain fynbos & forest of Fynbos Biome and study area

Biome and veld type category	Fynbos Biome															Total study area		
	Coastal renosterveld			Coastal fynbos			Mountain fynbos			Mountain fynbos and forest			Total					
No. watercourse crossings	250			71			214			65			696			1036		
	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P
Ricinus communis	6.8		3.9	7.0		3.8	4.7		2.6	3.1		1.7	5.0		3.0	6.1		4.4
Robinia pseudoacacia													*			*		
Rosa eglanteria							0.9		0.5				0.3		0.2	0.2		0.1
Rubus																		
flagellaris										1.5		0.8	0.1		0.1	0.1		0.1
fruticosus	6.4	0.8	**4.7**				9.3	0.9	**6.0**	3.1		1.7	5.5	0.6	4.0	3.8	0.4	3.4
Salix																		
babylonica	3.2		1.8	8.5		4.6	3.3	0.5	2.2	1.5		0.8	4.6	0.3	3.1	4.3	0.3	3.6
cf. *fragilis*							0.5	0.5	0.6				0.1	0.1	0.2	0.1	0.1	0.2
Schinus molle	0.4		0.2				*						0.9		0.5	2.0		1.4
Senna sp.	0.4		0.2										0.1		0.1	0.1		0.1
Sesbania punicea	5.6	0.4	**3.9**				7.0	0.5	4.3	*			4.2	0.3	2.9	4.3	0.3	3.8
Solanum mauritianum	2.4		1.4				*			3.1		1.7	1.1		0.7	0.8		0.6
Spartium junceum							*						*			*		
Tamarix spp.	0.8		0.5										0.4		0.3	1.4		1.1

F, % frequency of occurrence; I, % crossings heavily invaded; P, prominence value; * species occurring in the given category but not included in a formal recording at a watercourse crossing. Bold numbers: the highest prominence values in a given category which add up to ± 80% of the summed values (see text).

turbed areas between the remaining indigenous forest patches. Only small sections of forest are accessible by road. The following species were recorded along roadsides, margins or other gaps in indigenous forest: *Acacia mearnsii, A. melanoxylon, Cinnamomum camphora, Cortaderia selloana, Eucalyptus diversicolor, Pinus pinaster, P. radiata,* and *Rubus fruticosus*. They were never abundant but occurred as single plants or small groups.

Most of the higher parts of the mountain fynbos were inaccessible by road and therefore undersampled in this survey. As a consequence the mountain species such as *Hakea* spp., particularly *H. sericea*, and *Pinus* spp. were no doubt under-recorded in this survey. The accessible parts of mountain fynbos were the valleys and this is where most recordings were done. The best data on the extent of woody plant invasions in the higher altitude areas can be obtained from studies of the Cape Peninsula mountains (Moll & Trinder-Smith 1992; Richardson *et al.* 1996).

Analysis according to species

Frequency

The most frequently recorded species in the whole study area were *Opuntia ficus-indica* (71.5%), *Acacia saligna* (67.0%), *A. cyclops* (63.6%), *Nicotiana glauca* (63.6%), *A. mearnsii* (52.9%), *Pinus pinaster* (38.8%) and *A. melanoxylon* (33.5%).

The most frequently recorded species in the Fynbos Biome were *Acacia cyclops, A. saligna* and *A. mearnsii*. In the Forest Biome *A. melanoxylon, A. mearnsii, Pinus pinaster* and *P. radiata* were the most frequent species. In the Savanna Biome *Nicotiana glauca, Opuntia ficus-indica* and *Agave americana* were the most frequent species. In the Succulent Karoo Biome *Nicotiana glauca, Opuntia ficus-indica* and *A. saligna* were the most frequent species.

Prominence

Acacia cyclops scored the highest prominence value of 45.2 in the study area. The next most prominent species were *Acacia saligna* (24.8) and *A. mearnsii* (24.0) (Table 9).

In the Fynbos Biome, the three aforementioned species were the most prominent invaders, followed by *Pinus pinaster*. In the Forest Biome *Acacia melanoxylon* was the most prominent invader followed by *A. mearnsii, Pinus pinaster* and *P. radiata*. In the Savanna Biome *Nicotiana glauca* and *Opuntia ficus-indica* were the most prominent species. In the Succulent Karoo Biome *A. saligna* was the most prominent species.

Patterns of invasion

Alien plant invasion was recorded in streambank, roadside and veld habitats throughout the southern and southwestern Cape (Figures 3, 4 & 5). Most invasion, however, was encountered within the relatively narrow belt stretching from the coastline to the tops of the coastal mountain ranges.

A comparison of Figures 3 and 4 shows that similar patterns of invasion were recorded in streambank, roadside and veld habitats except that in the dry inland areas of the Little Karoo, centred around Ladismith and Oudtshoorn, there was more severe invasion of the streambank habitat than of roadside and veld habitats.

DISCUSSION

Prominent and potentially important species

Acacia species were overall the most prominent invaders in the study area with one or more species being the most prominent in every vegetation category with the

TABLE 8.—Alien species occurring in roadside and veld habitats of Succulent Karoo, Savanna and Forest Biomes and in strandveld and mountain renosterveld of Fynbos Biome

Biome and veld type category	Succulent Karoo Biome			Savanna Biome			Forest Biome			Fynbos Biome Strandveld			Fynbos Biome Mountain renosterveld		
No. road transects	77			36			27			38			57		
	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P
Acacia															
baileyana							*						*		
cyclops	18.2	3.0	**20.8**				25.9	3.0	5.8	89.5	4.0	**112.3**	17.5	4.0	**45.4**
elata							7.4	2.0	1.5						
longifolia							7.4	3.0	1.8						
mearnsii	13.0	3.0	**11.8**				81.5	5.0	**37.0**				35.1	3.0	**33.7**
melanoxylon							88.9	6.0	**60.8**						
pycnantha	*														
saligna	29.9	3.0	**38.5**				11.1	3.0	2.5	42.1	3.0	**25.9**	17.5	3.0	**15.3**
Agave americana	26.0	2.0	**15.5**	33.3	1.0	**23.6**							22.8	2.0	**13.0**
Arundo donax	5.2	1.0	2.5	2.8	1.0	1.8							*		
Atriplex nummularia	10.4	2.0	**6.7**	2.8	2.0	2.3				7.9	2.0	4.1	1.8	1.0	1.0
Brugmansia × *candida*							3.7	1.0	0.7				*		
Canna sp.							*								
Cereus jamacaru													1.8	1.0	1.0
Cestrum cf. *laevigatum*										*					
Cinnamomum camphora							3.7	1.0	0.7						
Cortaderia selloana							7.4	1.0	1.5				*		
Echinopsis spachiana	1.3	1.0	1.1	*									*		
Eucalyptus															
camaldulensis	2.6	1.0	1.3										*		
cladocalyx	1.3	1.0	1.1				*						7.0	1.0	3.5
diversicolor							29.6	4.0	**11.1**						
globulus							*								
gomphocephala										2.6	2.0	1.4			
spp.	5.2	1.0	2.7	2.8	1.0	1.8	48.1	3.0	**11.5**				10.5	2.0	**6.7**
Ficus carica	3.9	2.0	2.0	5.6	1.0	3.6							3.5	1.0	1.8
Fraxinus angustifolia	1.3	1.0	1.1	2.8	1.0	1.8									
Gleditsia triacanthos													1.8	2.0	1.0
Grevillea robusta							3.7	1.0	0.7						
Hakea sericea							7.4	3.0	1.8				3.5	2.0	1.9
Ipomoea cf. *purpurea*							3.7	1.0	0.7						
Lavatera arborea										10.5	4.0	10.1			
Leptospermum laevigatum							3.7	1.0	0.7						
Melia azedarach	2.6	2.0	1.4										*		
Myoporum tenuifolium							*			13.2	2.0	6.6			
Nerium oleander				2.8	1.0	1.8									
Nicotiana glauca	42.9	2.0	**31.6**	61.1	3.0	**67.1**				29.0	4.0	**28.7**	7.0	3.0	5.9
Opuntia															
ficus-indica	37.7	2.0	**28.7**	55.6	2.0	**59.5**				*			49.1	3.0	**38.6**
imbricata	2.6	1.0	1.3	2.8	1.0	1.8							1.8	1.0	1.0
microdasys				*											
robusta cvs	7.8	2.0	4.3	5.6	1.0	4.1							1.8	2.0	1.0
vulgaris	2.6	1.0	1.3												
Paraserianthes lophantha							*			*			*		
Phytolacca dioica							3.7	1.0	0.7						
Pinus															
halepensis				*									8.8	2.0	**6.0**
pinaster							74.1	5.0	**29.5**				1.8	2.0	1.0
radiata							70.4	4.0	**20.7**				3.5	1.0	1.8
sp.													1.8	1.0	1.0
Populus × *canescens*	*			2.8	1.0	1.8	*						3.5	2.0	1.9
Prosopis spp.	2.6	1.0	1.3							13.2	2.0	6.7	1.8	1.0	1.0
Prunus															
armeniaca	2.6	2.0	1.4										5.3	2.0	2.8
persica	3.9	1.0	1.9				3.7	1.0	0.7				10.5	1.0	5.5
Pyracantha angustifolia							3.7	1.0	0.7						
Pyrus sp.													3.5	2.0	2.0
Quercus robur							3.7	1.0	0.7						
Ricinus communis	13.0	3.0	**10.1**	16.7	2.0	**15.4**	3.7	1.0	0.7	10.5	2.0	5.5			
Robinia pseudoacacia							3.7	1.0	0.7						
Rubus fruticosus	2.6	4.0	2.6				22.2	3.0	5.7				3.5	1.0	1.9
Schinus molle	6.5	2.0	3.4	13.9	2.0	10.0							7.0	1.0	3.6
Sesbania punicea	11.7	1.0	5.9				3.7	1.0	0.7						
Tamarix spp.	2.6	1.0	1.3	5.6	1.0	3.6							1.8	1.0	1.0

F, % frequency of occurrence; A, mean abundance rating; P, prominence value; * species occurring in the given category but not included in a formal recording in a road transect. Bold numbers: the highest prominence values in a given category which add up to ± 80% of the summed values (see text).

TABLE 9.—Alien species occurring in roadside and veld habitats in coastal renosterveld, coastal fynbos, mountain fynbos, mountain fynbos & forest of Fynbos Biome and study area

Biome and veld type category	Fynbos Biome															Total study area		
	Coastal renosterveld			Coastal fynbos			Mountain fynbos			Mountain fynbos & forest			Total					
No. road transects	133			72			169			51			520			660		
	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P
Acacia																		
baileyana	0.8	1.0	0.2				4.7	2.0	0.9	2.0	1.0	0.3	1.9	2.0	0.4	1.5	2.0	0.2
cyclops	66.2	5.0	**51.0**	100.0	6.0	**89.5**	55.6	5.0	**35.9**	45.1	5.0	**20.9**	61.7	5.0	**52.8**	63.6	5.0	**45.2**
dealbata							3.6	2.0	1.2	2.0	1.0	0.3	1.3	3.0	0.5	1.1	3.0	0.3
elata	1.5	1.0	0.3				2.4	3.0	0.5	9.8	2.0	1.5	2.1	2.0	0.5	2.0	2.0	0.3
longifolia	9.8	5.0	**6.2**	20.8	5.0	**9.5**	27.2	4.0	**11.6**	13.7	3.0	4.4	15.6	4.0	**7.9**	12.6	4.0	**5.9**
mearnsii	58.6	4.0	**32.5**	4.2	3.0	1.2	59.2	5.0	**33.3**	100.0	6.0	**51.8**	48.5	2.0	**27.2**	52.9	5.0	**24.0**
melanoxylon	16.5	4.0	**9.2**				21.3	3.0	**5.2**	90.2	4.0	**28.0**	20.0	4.0	**8.0**	33.5	4.0	**10.8**
podalyriifolia	3.0	1.0	0.7	2.8	1.0	0.7	1.8	1.0	0.3	*			1.7	2.0	0.4	1.4	2.0	0.2
pycnantha	1.5	3.0	0.5	5.6	3.0	1.7	11.8	4.0	**4.2**	3.9	1.0	0.6	5.4	4.0	1.9	4.2	4.0	1.3
saligna	60.2	4.0	**30.7**	70.8	5.0	**38.8**	60.9	4.0	**28.1**	29.4	5.0	**11.2**	52.9	4.0	**28.0**	67.0	4.0	**24.8**
Agave																		
americana	5.3	1.0	1.2	8.3	2.0	2.2	2.4	1.0	0.5				5.8	2.0	1.4	9.4	2.0	1.5
sisalana	1.5	1.0	0.3				*						0.4	1.0	0.1	0.3	1.0	0.1
Ailanthus altissima				*			0.6	1.0	0.1	*			0.2	1.0	0.1	0.2	1.0	0.1
Arundo donax	3.8	2.0	0.9	*			0.6	1.0	0.1	3.9	1.0	0.6	1.5	2.0	0.4	6.5	2.0	0.9
Atriplex nummularia				*			0.6	2.0	0.1				1.0	2.0	0.2	11.7	2.0	1.7
Bambusa balcooa										*			*			*		
Brugmansia × *candida*	*									*			*			0.8	1.0	0.1
Canna sp.	*									*			*			*		
Cereus jamacaru	0.8	1.0	0.2										0.4	1.0	0.1	0.3	1.0	0.1
Cestrum cf. *laevigatum*	*												*			*		
Cinnamomum camphora	*												*			0.8	1.0	0.1
Cortaderia selloana	0.8	3.0	0.2				1.2	1.0	0.2	5.9	2.0	1.0	1.2	2.0	0.3	2.4	2.0	0.4
Cupressus cf. *arizonica*							0.6	1.0	0.1				0.2	1.0	0.1	0.2	1.0	0.1
Cydonia oblonga	0.8	1.0	0.2				0.6	1.0	0.1				0.4	2.0	0.1	0.3	2.0	0.1
Echinopsis spachiana																1.5	1.0	0.2
Eriobotrya japonica	*												*			*		
Eucalyptus																		
camaldulensis	2.3	2.0	0.6				1.2	2.0	0.3				1.0	2.0	0.2	3.8	2.0	0.6
cladocalyx	10.5	2.0	2.7	15.3	2.0	4.0	11.2	3.0	2.6	2.0	4.0	0.4	9.4	3.0	2.4	8.9	3.0	1.5
diversicolor	9.0	2.0	2.3	1.4	1.0	0.4	16.6	3.0	**4.0**	43.1	3.0	**8.7**	12.1	3.0	**3.4**	15.6	3.0	3.1
ficifolia							0.6	1.0	0.1				0.2	1.0	0.1	0.2	1.0	0.1
globulus	*						1.8	1.0	0.3	3.9	1.0	0.6	1.0	2.0	0.2	0.8	2.0	0.1
gomphocephala	0.8	4.0	0.3				1.8	3.0	0.5				1.0	4.0	0.3	0.8	4.0	0.2
lehmannii	9.8	2.0	2.5	29.2	4.0	**10.1**	12.4	4.0	**3.8**	2.0	1.0	0.3	10.8	4.0	**3.8**	8.5	4.0	2.5
microcorys										3.9	1.0	0.6	0.4	1.0	0.1	0.3	1.0	0.1
regnans	0.8	1.0	0.2				0.6	2.0	0.1				0.4	1.0	0.1	0.3	1.0	0.1
spp.	7.5	2.0	2.0	4.2	3.0	1.1	13.6	2.0	2.8	27.5	2.0	4.5	10.8	2.0	2.6	23.9	3.0	**3.8**
Ficus carica							*						0.4	1.0	0.1	5.6	1.0	0.8
Fraxinus angustifolia										2.0	1.0	0.3	0.2	1.0	0.1	2.4	1.0	0.3
Gleditsia triacanthos													0.2	2.0	0.1	0.2	2.0	0.1
Grevillea robusta																0.8	1.0	0.1
Hakea																		
drupacea	0.8	1.0	0.2	1.4	4.0	1.1	4.7	4.0	1.5				1.9	4.0	0.6	1.5	4.0	0.4
gibbosa				4.2	2.0	1.1	2.4	4.0	0.7				1.3	3.0	0.4	1.1	3.0	0.3
sericea	6.0	3.0	1.8	1.4	1.0	0.4	14.8	3.0	**4.1**	19.6	2.0	3.1	8.8	3.0	2.5	8.5	3.0	1.7
Hedychium sp.							*						*			*		
Ipomoea cf. *purpurea*	*						*						*			0.8	1.0	0.1
Lantana camara	3.0	2.0	0.7	1.4	1.0	0.4	0.6	1.0	0.1	2.0	1.0	0.3	1.3	1.0	0.3	1.1	1.0	0.2
Lavatera arborea	1.5	1.0	0.3	1.4	1.0	0.4	*						1.3	3.0	0.4	1.1	3.0	0.3
Leptospermum laevigatum	2.3	4.0	1.1	16.7	5.0	**7.1**	7.1	4.0	2.4	3.9	2.0	0.6	5.6	4.0	2.6	5.2	4.0	2.0
Malus sp.							*			2.0	1.0	0.3	0.2	1.0	0.1	0.2	1.0	0.1
Melia azedarach	4.5	1.0	1.1	2.8	1.0	0.7	5.9	1.0	1.1	2.0	1.0	0.3	3.7	1.0	0.9	5.2	1.0	0.8
Metrosideros excelsa							1.8	1.0	0.3				0.6	1.0	0.1	0.5	1.0	0.1
Morus alba				1.4	1.0	0.4							0.2	1.0	0.1	0.2	1.0	0.1
Myoporum tenuifolium	1.5	2.0	0.4	11.1	1.0	2.9	2.4	2.0	0.5				3.7	2.0	0.9	2.9	2.0	0.5
Nerium oleander																1.5	1.0	0.2
Nicotiana glauca	6.0	2.0	1.5	8.3	3.0	2.2	0.6	2.0	0.1				5.8	3.0	1.8	63.6	3.0	**9.7**
Opuntia																		
ficus-indica	29.3	3.0	**8.0**	19.4	2.0	5.1	16.0	2.0	3.5	13.7	2.0	2.2	22.1	3.0	**5.7**	71.5	3.0	**11.1**
imbricata	0.8	1.0	0.2										0.4	1.0	0.1	4.1	1.0	0.6
microdasys																*		
robusta cvs	1.5	1.0	0.3	*			0.6	1.0	0.1	2.0	1.0	0.3	1.0	1.0	0.2	10.9	1.0	1.6
vulgaris	0.8	4.0	0.3	2.8	1.0	0.7	1.8	1.0	0.3	3.9	1.0	0.6	1.5	2.0	0.4	2.7	2.0	0.4
Paraserianthes lophantha	4.5	2.0	1.1	8.3	4.0	2.2	15.4	3.0	3.6	19.6	3.0	4.1	9.2	3.0	2.6	7.3	3.0	1.6
Passiflora																		
caerulea	0.8	1.0	0.2										0.2	1.0	0.1	0.2	1.0	0.1
edulis	*												*			*		
Pereskia aculeata										2.0	1.0	0.3	0.2	1.0	0.1	0.2	1.0	0.1

TABLE 9 (cont.).—Alien species occurring in roadside and veld habitats in coastal renosterveld, coastal fynbos, mountain fynbos, mountain fynbos & forest of Fynbos Biome and study area

Biome and veld type category	Fynbos Biome												Total study area					
	Coastal renosterveld			Coastal fynbos			Mountain fynbos			Mountain fynbos and forest			Total					
No. road transects	133			72			169			51			520			660		
	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P
Phytolacca dioica	0.8	2.0	0.2				1.2	1.0	0.2	2.0	1.0	0.3	0.8	2.0	0.2	1.4	2.0	0.2
Pinus																		
cf. *canariensis*	0.8	5.0	0.5				3.0	3.0	0.8				1.2	3.0	0.4	0.9	3.0	0.2
halepensis	1.5	1.0	0.3	4.2	2.0	1.1	13.0	2.0	2.7	3.9	3.0	0.7	6.5	2.0	1.6	5.2	2.0	0.9
pinaster	23.3	4.0	**10.3**	18.1	5.0	**7.2**	40.8	4.0	**16.5**	82.4	4.0	**22.2**	30.0	4.0	**12.7**	38.8	4.0	**12.0**
pinea	3.0	3.0	0.8	*			5.3	3.0	1.1				2.5	2.0	0.6	2.0	2.0	0.3
radiata	17.3	3.0	**5.0**	2.8	3.0	0.8	26.6	3.0	**7.1**	54.9	3.0	**10.7**	19.2	3.0	**5.5**	29.5	3.0	**5.8**
spp.	0.8	1.0	0.2				5.3	3.0	1.3				2.1	3.0	0.6	1.7	3.0	0.3
Pittosporum undulatum	1.5	2.0	0.3				0.6	1.0	0.1				0.6	3.0	0.1	0.5	3.0	0.1
Platanus sp.	*												*			*		
Populus × *canescens*	6.0	2.0	1.4	*			5.9	2.0	1.2	3.9	3.0	0.7	4.2	2.0	1.0	4.1	2.0	0.7
Prosopis spp.	7.5	3.0	1.7	2.8	2.0	0.7	3.0	3.0	0.7				4.4	3.0	1.2	5.3	3.0	0.9
Prunus																		
armeniaca							1.2	1.0	0.2				1.0	2.0	0.2	2.3	2.0	0.4
persica	10.5	1.0	2.5	2.8	1.0	0.7	8.3	2.0	1.6	5.9	1.0	0.9	7.5	2.0	1.7	9.7	2.0	1.5
Psidium guajava	0.8	1.0	0.2	2.8	2.0	0.7				2.0	1.0	0.3	0.8	2.0	0.2	0.6	2.0	0.1
Punica granatum	0.8	1.0	0.2				0.6	1.0	0.1				0.4	1.0	0.1	0.3	1.0	0.1
Pyracantha angustifolia	*						0.6	1.0	0.1				0.2	1.0	0.1	0.9	1.0	0.1
Pyrus sp.							0.6	2.0	0.1				0.6	2.0	0.1	0.5	2.0	0.1
Quercus																		
robur	5.3	3.0	1.4				4.1	2.0	0.9	5.9	2.0	0.9	3.3	2.0	0.8	3.3	2.0	0.5
spp.	0.8	2.0	0.2										0.2	1.0	0.1	0.2	1.0	0.1
Ricinus communis	17.3	2.0	**4.2**	13.9	3.0	3.8	5.9	1.0	1.2	5.9	3.0	1.0	9.6	2.0	2.3	25.0	2.0	**3.8**
Robinia pseudoacacia				*						*			*			0.8	1.0	0.1
Rosa eglanteria							1.8	3.0	0.4	2.0	1.0	0.3	0.8	2.0	0.2	0.6	2.0	0.1
Rubus																		
flagellaris							*			*			*			*		
fruticosus	13.5	3.0	**4.5**				21.3	3.0	**5.9**	39.2	4.0	**12.3**	14.6	4.0	**5.1**	17.9	3.0	**4.4**
Schinus molle	1.5	2.0	0.3	1.4	2.0	0.4	2.4	2.0	0.5				2.1	2.0	0.5	11.1	2.0	1.6
Senna didymobotrya	*												*			*		
Sesbania punicea	3.8	1.0	0.9	1.4	1.0	0.4	1.2	1.0	0.2	3.9	3.0	0.7	1.9	2.0	0.5	11.7	2.0	1.7
Solanum mauritianum	3.0	2.0	0.7				2.4	2.0	0.5	2.0	1.0	0.3	1.7	2.0	0.4	1.4	2.0	0.2
Spartium junceum	2.3	1.0	0.5	2.8	1.0	0.7	2.4	2.0	0.5				1.7	1.0	0.4	1.4	1.0	0.2
Tamarix spp.	0.8	1.0	0.2										0.4	1.0	0.1	5.6	1.0	0.8
Vitis cvs	*						2.4	2.0	0.5	2.0	1.0	0.3	1.0	2.0	0.2	0.8	2.0	0.1
Wigandia caracasana	0.8	1.0	0.2										0.2	1.0	0.1	0.2	1.0	0.1

F, % frequency of occurrence; A, mean abundance rating; P, prominence value; * species occurring in the given category but not included in a formal recording in a road transect. Bold numbers: the highest prominence values in a given category which add up to ± 80% of the summed values (see text).

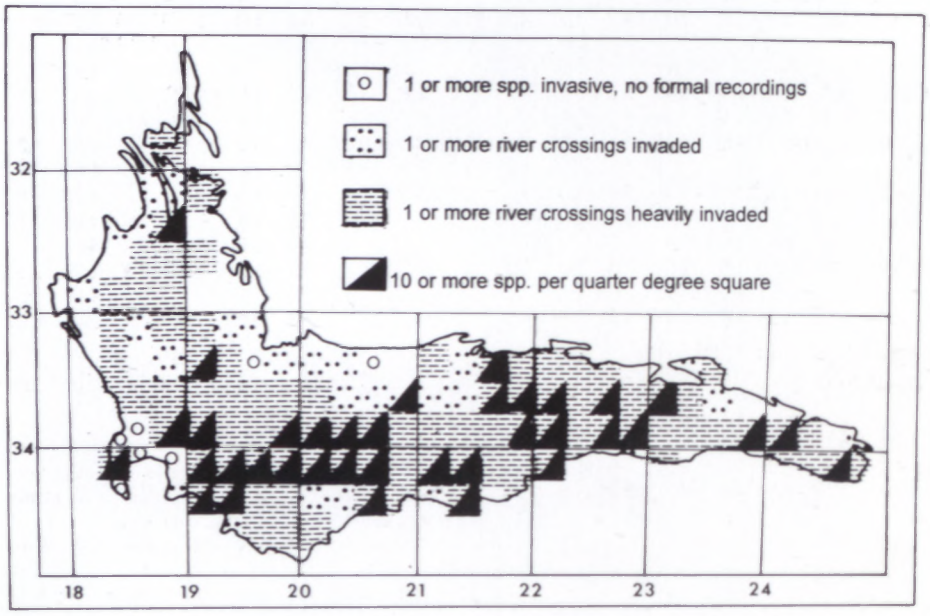

FIGURE 3.—Invasion in stream-bank habitats in terms of the intensity of invasion of watercourse crossings and species diversity per quarter degree square.

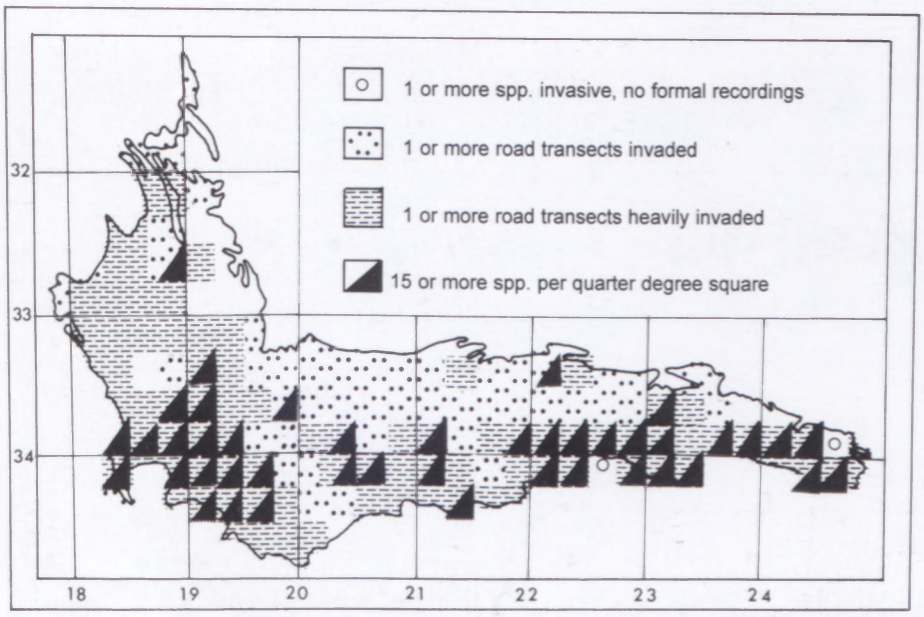

FIGURE 4.—Invasion in roadside and veld habitats in terms of the intensity of invasion of road transects and species diversity per quarter degree square.

exception of savanna. *Acacia mearnsii, A. saligna* and *A. cyclops* were the top three most prominent invaders with their combined prominence values amounting to 201 out of a total of 400 points for all species. In streambank habitats the *Acacia* species were dominant with five species (*A. mearnsii, A. saligna, A. cyclops, A. longifolia, A. melanoxylon*) amongst the top six most prominent species. In roadside and veld habitats four of the top six most prominent species were *Acacia* species (*A. cyclops, A. saligna, A. mearnsii* and *A. melanoxylon*).

Acacia mearnsii (Figure 6D) was a prominent invader in all vegetation categories with the exception of savanna, strandveld and coastal fynbos. It was recorded predominantly along watercourses and was the most prominent riverine invader in the Fynbos Biome and the whole study area. Unlike in Mpumalanga (of the former Transvaal) and KwaZulu-Natal, where it has been cultivated on a grand scale for tannin, it has been cultivated only on a small scale in the Cape, yet has spread widely. This is a reflection of its aggressiveness as an invader.

Acacia saligna (Figure 6G) was a prominent invader in all vegetation categories with the exception of savanna and forest. It was the next most prominent riverine invader in the study area after *A. mearnsii* and unlike *A. mearnsii* was prominent in strandveld and coastal fynbos. It was the second most prominent invader of roadsides and veld in the Fynbos Biome, after *A. cyclops*. Together with *A. cyclops* it formed extensive stands on the Cape Flats, where it was used for the stabilization of driftsands and was grown for tannin from 1850 until 1910 (Stirton 1978). It was most abundant in a broad band stretching from Bredasdorp northwestwards to Clanwilliam. It scored a highest abundance rating of 8 in the vicinity of Robberg (Plettenberg Bay) and Bredasdorp. A gall-forming rust fungus *Uromycladium tepperianum*, introduced for the biocontrol of *A. saligna* (Morris 1991), was only noted as abundant north of Cape Town between Atlantis and Kalkbaskraal in May 1993. Four years later, in 1997, it is abundant throughout the range of *A. saligna*.

Acacia cyclops (Figure 6A) was the most prominent invader in roadside and veld habitats in the Fynbos

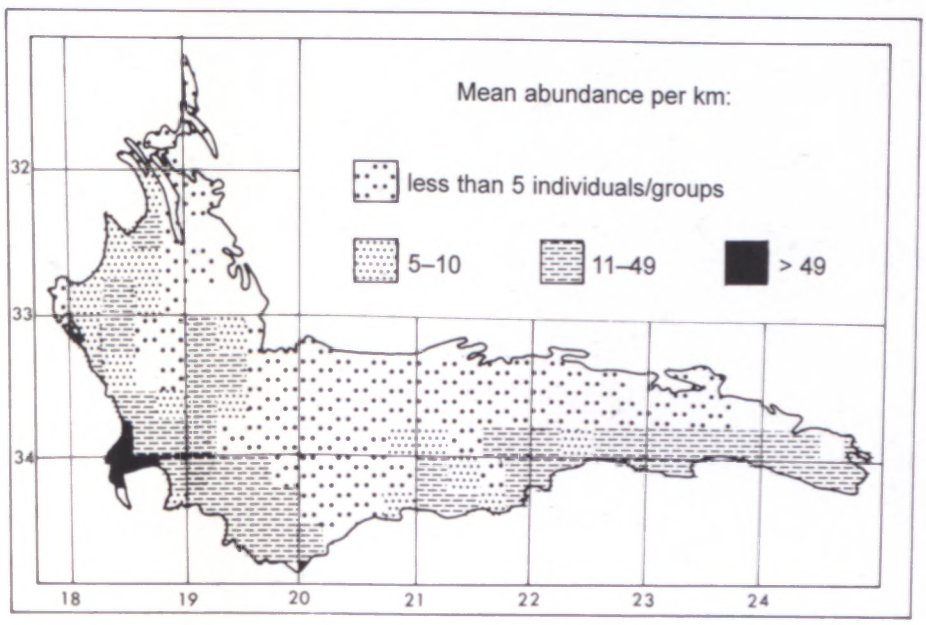

FIGURE 5.—Invasion in roadside and veld habitats in terms of the mean abundance of invaders per kilometre in each quarter degree square.

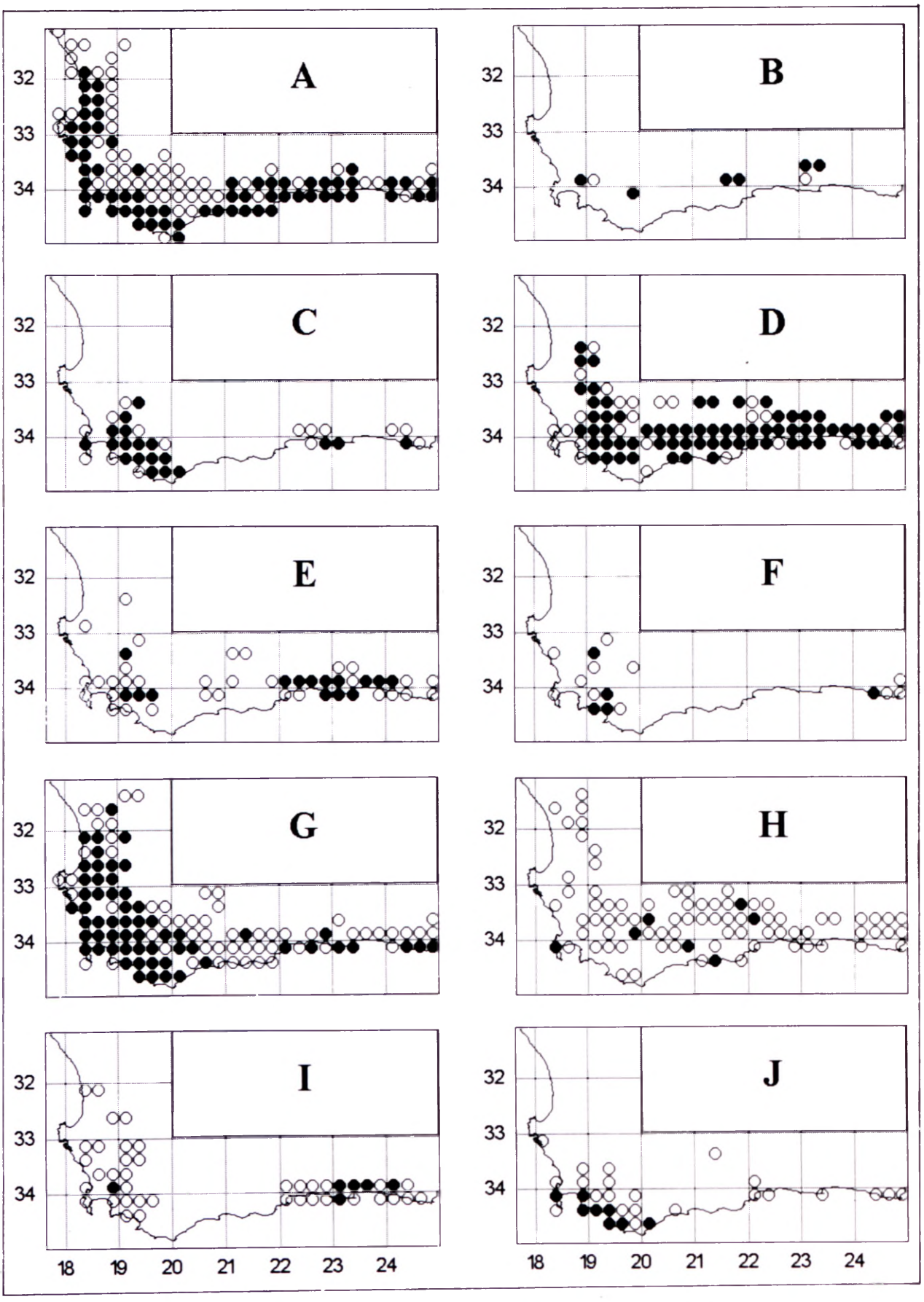

FIGURE 6.—Distribution of the most prominent species: A, *Acacia cyclops*; B, *A. dealbata*; C, *A. longifolia*; D, *A. mearnsii*; E, *A. melanoxylon*; F, *A. pycnantha*; G, *A. saligna*; H, *Arundo donax*; I, *Eucalyptus diversicolor*; J, *E. lehmannii*. Highest abundance rating of 4 or less, ❍; highest abundance rating of 5 or more, ●.

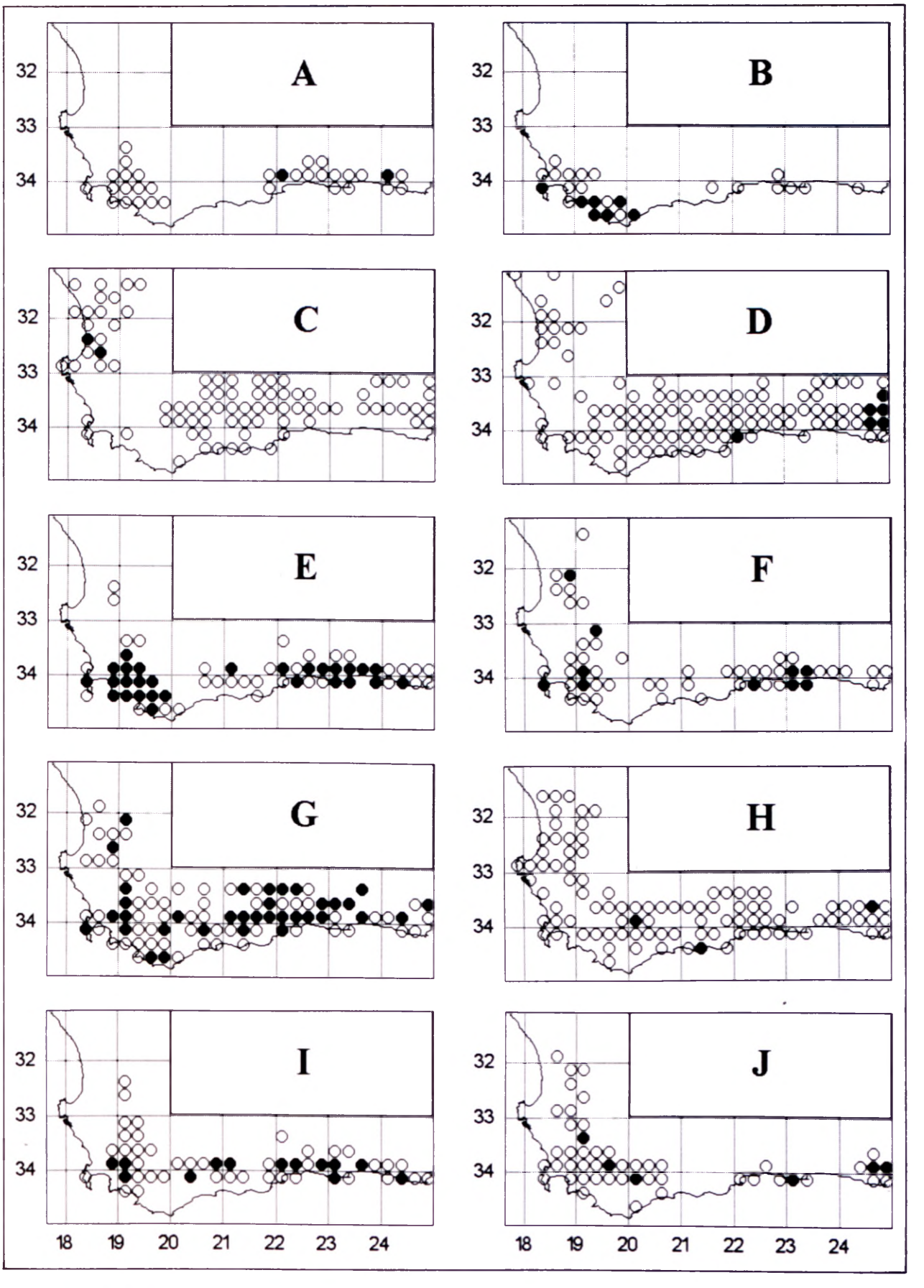

FIGURE 7.—Distribution of the most prominent species: A, *Hakea sericea*; B, *Leptospermum laevigatum*; C, *Nicotiana glauca*; D, *Opuntia ficus-indica*; E, *Pinus pinaster*; F, *P. radiata*; G, *Populus* × *canescens*; H, *Ricinus communis*; I, *Rubus fruticosus*; J, *Sesbania punicea*. Highest abundance rating of 4 or less, ❍; highest abundance rating of 5 or more, ●.

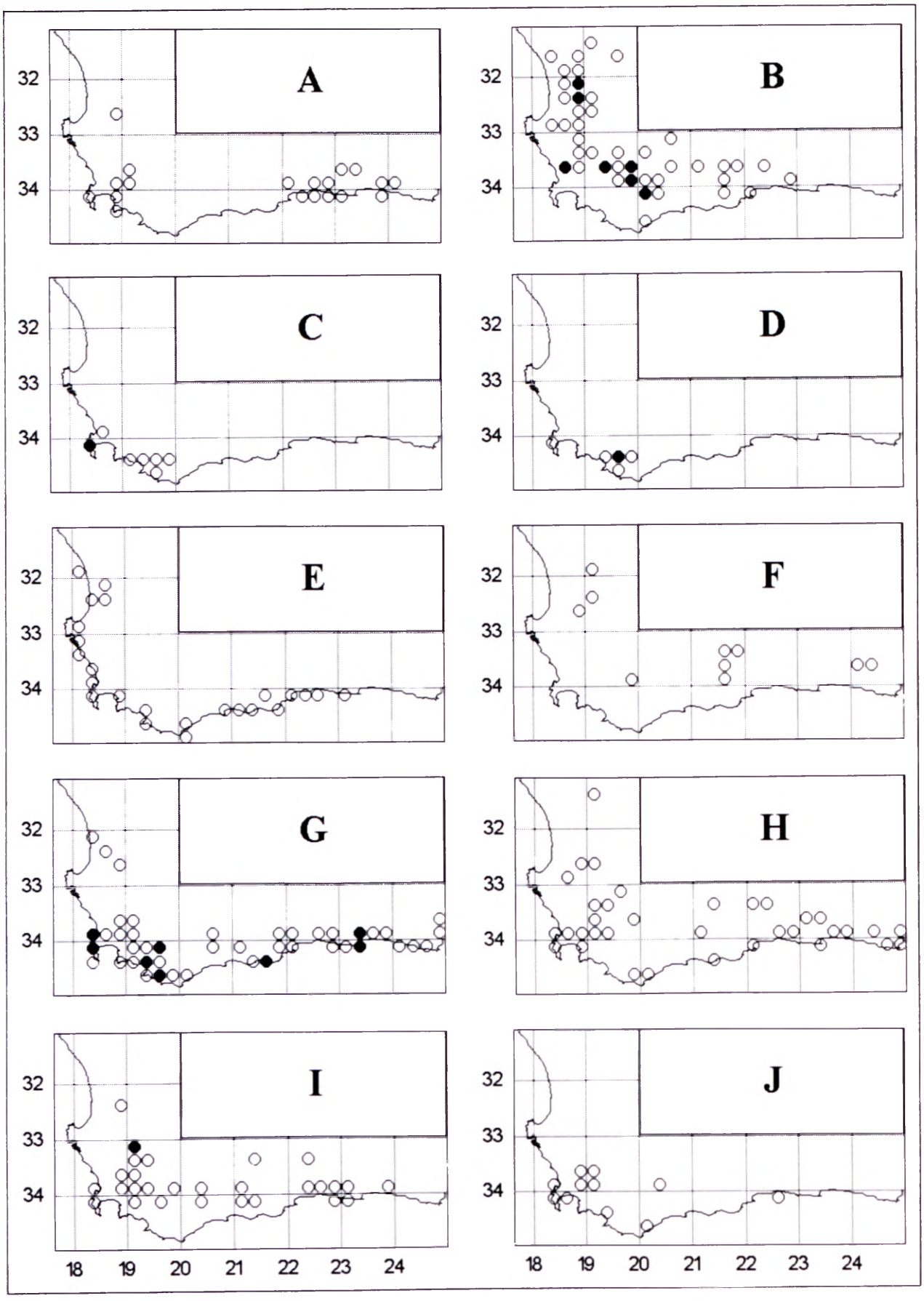

FIGURE 8.—Distribution of less prominent and potentially important species: A, *Acacia elata*; B, *Eucalyptus* cf. *camaldulensis*; C, *Hakea drupacea*; D, *H. gibbosa*; E, *Myoporum tenuifolium*; F, *Nerium oleander*; G, *Paraserianthes lophantha*; H, *Pinus halepensis*; I, *Quercus robur*; J, *Spartium junceum*. Highest abundance rating of 4 or less, ❍; highest abundance rating of 5 or more, ●.

Biome and in the whole study area. It was prominent along watercourses only in coastal fynbos. It formed very extensive stands on the Cape Flats, where it was established as a sand-binder from 1876–1886 (Stirton 1978). In the vicinity of Mitchell's Plain, Strandfontein and Muizenberg it formed almost pure stands for distances up to 10 km or more, thereby scoring the maximum abundance rating. It also scored the maximum rating in the vicinity of Cape Agulhas, Struisbaai and Quoin Point. It was exceedingly abundant (scoring an abundance rating of 7 or more) in coastal areas stretching all the way from Saldanha Bay in the west to Humansdorp in the east, a distance of approximately 1 000 km.

Acacia melanoxylon (Figure 6E) was concentrated in the forested area defined by the limits of Acocks's Veld Type 4, Knysna Forest. It was exceedingly abundant and the most prominent invader in the Forest Biome. The only other areas where it was recorded as abundant were in the vicinity of Wolseley and in the Riviersonderend Valley near Greyton. The abundance of this species around Knysna can be attributed to its use as a commercial timber tree and its consequent spread. It was used extensively from 1856 as a forest replacement species in the Knysna Forest, where it was planted in gaps created by the felling of indigenous trees (Stirton 1978). The indigenous forest pioneer tree, *Virgilia oroboides* was a widespread weed of roadsides and probably provides strong competition for *A. melanoxylon* and *A. mearnsii*.

Acacia longifolia (Figure 6C) was concentrated in a broad belt from Bredasdorp westwards to Cape Town and northwards as far as Ceres. Two other foci occurred eastwards around Knysna and Klipdrif, east of Storms River. It was absent from succulent karoo, savanna, strandveld and mountain renosterveld. In the remaining wetter vegetation categories, particularly coastal and mountain fynbos, it was more prominent in streambank habitats than roadside and veld habitats. Overall for the Fynbos Biome, it rated fifth and sixth most prominent in streambanks and roadsides/veld respectively. Galled plants, caused by the introduced wasp *Trichilogaster acaciaelongifoliae* for biocontrol (Dennill & Donnelly 1991), were very much in evidence throughout its distribution.

The biocontrol programme against *A. longifolia* has reduced seed production and the overall biomass of populations; in some instances it has caused mortality of adult trees (Dennill & Donnelly 1991). Now there also appears to be a reduction in the extent and abundance of this invader. Comparison of the distribution of *A. longifolia* in Richardson *et al.* (1992), which was based on reports from the mid 1980's, and with the present survey, shows a marked reduction in the extent and abundance of *A. longifolia* in the southern Cape.

Acacia dealbata (Figure 6B) was virtually restricted to watercourses in mountain fynbos. Although recorded at very few localities it was almost always abundant, forming dense stands. These localities were: Bergkloof River, near Herbertsdale; Uniondale Poort, Holdrif River; Riviersonderend; Dwars River tributary, near Stellenbosch. *Acacia pycnantha* (Figure 6F) was restricted to the Fynbos Biome and was most prominent in roadsides and veld habitats in mountain fynbos. It was exceedingly abundant i.e. scoring a 7 in the vicinity of Wolseley.

Populus × *canescens* (Figure 7G) was a widespread invader of watercourses and was recorded in all vegetation categories with the exception of the Forest Biome. It was the third most prominent riverine invader in the whole study area and in the Fynbos Biome.

Pinus pinaster (Figure 7E) was a prominent invader of mountain slopes in both the Forest and Fynbos Biomes. It has been used extensively for afforestation and its distribution is a reflection of planting patterns (Stirton 1978). *Pinus radiata* (Figure 7F) has been planted on a smaller scale and was less prominent than *P. pinaster*. These two species were the third and fourth most prominent invaders of roadside and veld habitats in the Forest Biome. They are the most prevalent species on the Cape Peninsula mountains (Moll & Trinder-Smith 1992).

Rubus fruticosus (Figure 7I) occurred mainly in the wetter vegetation types. It was most prominent in mountain fynbos & forest where it formed thickets along roadsides and on the margins of plantations or forest. In previous publications (Henderson 1989; Henderson 1992) reference was made to *R. affinis*. This is one of about 2 000 species belonging to the *Rubus fruticosus* complex (Tutin *et al.* 1968) and was regarded by Spies & Du Plessis (1985) to occur in South Africa. In this publication reference is made only to *R. fruticosus* L. aggregate which is in keeping with the Pretoria National Herbarium.

Hakea sericea (Figure 7A) was only rated tenth most prominent invader in mountain fynbos. This is an underestimate and resulted from the undersampling of mountain slopes. From a distance *Hakea* spp. are also more difficult to distinguish from the fynbos than for example the *Pinus* spp., which invade the same habitats. Richardson *et al.* (1992) gives a very different picture of the distribution and abundance of *H. sericea*, which they said occurred in 30% of the quarter degree squares in the Fynbos Biome and formed dense stands in 19% of squares. These records are based on Macdonald *et al.* (1985) but updated from various sources (D.M. Richardson pers. comm.).

Eucalyptus spp. were prominent invaders of the Forest Biome and mountain fynbos & forest. *E. diversicolor* (Figure 6I) has been cultivated commercially around Knysna and was the most prominent species in this region. It was often difficult to distinguish the *Eucalyptus* spp. and then they were recorded collectively. In the Knysna area it was not clear how abundant *E. cladocalyx* was. It was, however, regarded as one of the three problem species in the area, together with *E. diversicolor* and *E. microcorys* (forester at Woodville State Forest pers. comm.).

Eucalyptus lehmannii (Figure 6J) was the third most prominent invader in roadsides and veld habitats in coastal fynbos. It was most abundant in the coastal belt stretching from Bredasdorp westwards to the Cape

Peninsula. *E.* cf. *camaldulensis* (Figure 8B) was mainly an invader of watercourses and was most prominent in the Succulent Karoo Biome along the Breë River. It was also abundant along some watercourses in the Fynbos Biome, such as the Olifants River near Clanwilliam, Riviersonderend and Berg Rivers. *E. exserta*, which could be mistaken for *E. camaldulensis* was abundant on the Berg River near Langebaan and locally prominent on the Breë River near Robertson.

Leptospermum laevigatum (Figure 7B) was the sixth most prominent invader in roadside and veld habitats in coastal fynbos. It has been used mainly as a hedge or windbreak in coastal towns from where it has spread into the adjacent fynbos. It was most abundant on sandy soils from Bredasdorp westwards to Fish Hoek on the Cape Peninsula. It was exceedingly abundant around Hermanus and Kleinmond.

Sesbania punicea (Figure 7J) was recorded in all vegetation categories except savanna, strandveld and mountain renosterveld. It was most abundant along watercourses and in particular the Breë River in the Succulent Karoo Biome near Worcester. This species could have been underestimated in this survey as it is easily overlooked when not in flower.

Opuntia ficus-indica (Figure 7D) was by far the most widespread invader in the study area, being recorded in 71.5% of all road transects. It rated as the fifth most prominent invader in roadside and veld habitats in the study area but it was rarely abundant. It was only in the dry coastal bush around Mossel Bay that it scored an abundance rating of 5; elsewhere it occurred only as scattered individuals or small clumps.

Nicotiana glauca (Figure 7C) was the second most widespread invader, being recorded in 63.6% of all road transects. It was only recorded in disturbed sites such as along roads, railway lines, river banks, dry river beds, and in quarries and rubble heaps. It was a prominent invader of watercourses in the Succulent Karoo and Savanna Biomes but was never abundant. The only places where it was recorded as very abundant was on the roadside and floodplain adjacent to the Verlorevlei, north of Piketberg and near Elandsbaai.

Arundo donax (Figure 6H) was a widespread invader and was absent only from strandveld and forest. It was a prominent invader of watercourses in coastal renosterveld, succulent karoo and savanna. Flowering plants were only seen in the coastal belt near Humansdorp, Knysna and Wellington.

Ricinus communis (Figure 7H) was a widespread invader of roadside, veld and streambank habitats and was prominent in coastal renosterveld, savanna and succulent karoo. It was recorded in all vegetation categories but was only abundant in the Kogmanskloof near Montagu and in the Kafferkuilsrivier valley near Stilbaai.

Agave americana was prominent in succulent karoo and savanna but was never abundant. Its distribution is a reflection of where it has been planted. It appeared to have spread from seed in two localities within the succulent karoo. These were north of Barrydale between the Anysberg and Warmwaterberg and in the Touws River valley south of Ladismith.

Atriplex nummularia was most frequently recorded in roadside and veld habitats in the succulent karoo, but it was never abundant. Judging from observations in the Great Karoo in the central Cape (Henderson in prep.) it is likely to become a prominent invader of seasonal and episodic watercourses in the succulent karoo of the Western Cape.

Salix babylonica was recorded along watercourses in all vegetation categories with the exception of strandveld. It was seldom abundant and its distribution was largely a reflection of where it has been planted. It was most prominent in mountain renosterveld where it was ranked third after *Acacia mearnsii* and *Populus* × *canescens*.

Species which scored abundance ratings of 5 or more but were not rated as prominent were: *Hakea gibbosa* and *H. drupacea* (= *H. suaveolens*), *Paraserianthes lophantha*, *Pinus* cf. *canariensis*, *Prosopis* spp. and *Lavatera arborea*. *Hakea gibbosa* (Figure 8D) was only recorded as abundant near Stanford on the Akkedisberg Pass. *H. drupacea* (Figure 8C) was only recorded as abundant on the Cape Peninsula between Simonstown and Smitswinkelbaai. If one compares the distributions of *H. gibbosa* and *H. drupacea* with those in Stirton (1978) they appear to have changed little in the past twenty years.

Paraserianthes lophantha (Figure 8G) was most frequently recorded in mountain fynbos & forest and mountain fynbos. It has a preference for moist, low-lying sites. *Pinus* cf. *canariensis* was only recorded as abundant on dry mountain slopes near Paarl on the road to Franschhoek. It was locally common around Ceres and Tulbagh. *Prosopis* spp. were only locally abundant on the plains to the east of Piketberg. They have been planted in this area and were just starting to spread as mostly small plants were seen along roadsides and along watercourses. *Lavatera arborea* was recorded along roadsides in many coastal towns; it was common to abundant near Saldanha Bay on the west coast.

Species that were only locally common (i.e. scoring abundance ratings of 4) were: *Tamarix* spp. along watercourses in succulent karoo and savanna near Oudtshoorn and in coastal renosterveld on the Gouritz River south of Mossel Bay; *Quercus robur* (Figure 8I) and *Quercus* spp. along watercourses near Stellenbosch and Swellendam; *Eucalyptus cladocalyx* and *E. gomphocephala* in several localities in mountain fynbos and coastal renosterveld; *Opuntia vulgaris* in coastal renosterveld near Mossel Bay; *Passiflora caerulea* along watercourses in coastal renosterveld near Riversdale; *Pinus pinea* in coastal renosterveld near Stellenbosch; and *P. halepensis* (Figure 8H) in mountain fynbos near Joubertina in the Lang Kloof. According to D.M. Richardson, pers. comm., *P. halepensis* has been underestimated in this study and it forms dense stands in the Jonkershoek Valley and on the Cape Peninsula near Miller's Point.

Several other species were locally common but were not included in formal recordings. These were: *Hedychium* sp., *Ipomoea* cf. *purpurea*, *Solanum mauritianum* and *Spartium junceum* on the Constantia Nek Road near Hout Bay on the Cape Peninsula. *Spartium junceum* (Figure 8J) was recorded in several localities, but mainly close to habitation and plantings. This species should be closely watched as it is showing signs of becoming invasive. *Phytolacca dioica* was locally common around Knysna.

Metrosideros excelsa is a potentially important invader of fynbos on moist, peaty soils. It was locally common at Betty's Bay where it has spread from plantings and threatens about three km of fynbos on the seafront, but has been controlled at least since the early 1980's (R. Attwell pers. comm.). It has also spread from plantings around Hermanus (M.J. Wells pers. comm.). Small groups of naturalised plants were recorded on roadsides in the Cape Peninsula. These were on the Ou Kaapseweg, on the Steenberg; and on Boyes Drive between Muizenberg and Kalkbaai. In both cases they were in close proximity to suburban gardens and cultivated plants.

Pittosporum undulatum is a potentially important invader of fire-free, wooded or forested areas. It is a common hedge and ornamental garden plant in the Western Cape. In this survey it was seldom recorded as naturalised, but this could partly be due to its inconspicuousness in the habitats it invades. It was recorded in the river valley between Stellenbosch and Jonkershoek, and also on the Cape Peninsula on Boyes Drive at Kalk Bay. According to D.M. Richardson, pers. comm., it forms dense stands in the Jonkershoek State Forest and also at Newlands and Tokai State Forests on the Cape Peninsula. This species has become an important invader of forests in many parts of the world including Jamaica, New Zealand and even in Australia, where it is indigenous, but has invaded vegetation outside of its natural range (Gleadow & Ashton 1981). Recent reports of diseased plants caused by a pathogen in the Western Cape may help to curb the invasiveness of *P. undulatum* in South Africa (M.J. Morris pers. comm.).

Myoporum tenuifolium (Figure 8E), a tree with somewhat succulent leaves and adapted to windy, salt-laden air, has been planted as a windbreak and for shade in all coastal towns in the study area. Occasional seedling spread was recorded throughout its range but was most noticeable in strandveld from the Cape Peninsula northwards to the west coast. It appeared to be better adapted to the more arid and semisucculence of the strandveld rather than coastal fynbos.

Nerium oleander (Figure 8F) has invaded watercourses in dry mountain valleys in several parts of the study area. It was most evident along the Gamka, Huis and Gouritz Rivers in the Ladismith and Calitzdorp Districts. It was also recorded near Robertson along the Breë River, at Citrusdal through the Piekenierskloof (Grey's Pass), and at Wuppertal on the Tra-Tra River. It is known to occur in the Cederberg (Stirton 1978) but this region was not surveyed due to bad weather conditions at the time.

Acacia elata (Figure 8A) was most frequently recorded in the mountain fynbos & forest and forest vegetation categories. Virtually all recordings were of seedling spread from plantings in urban areas or close to habitation. On a few occasions, however, seedlings were noted on roadsides far from any plantings e.g. on the Franschhoek and Du Toits Kloof Passes.

Relation of invasion to historical and environmental factors

Alien plant invasion in the southern and southwestern Cape has been greatly influenced by the deliberate introduction and large scale planting of alien plant species which were adapted to the prevailing environmental conditions. For the first 150 years after the colonisation of the Cape in 1652, plants of mainly European origin were introduced. Only a few of these plants have become invasive such as *Pinus pinaster* a native of the Mediterranean and adapted to the climate and soils of the southern Cape. It was only after 1830, when tree and shrub species were intentionally imported from areas of similar climate, especially southern and western Australia, and were extensively propagated, that most of the important invaders of natural vegetation became established (Richardson *et al.* 1992).

By 1865 all of the most prominent *Acacia*, *Hakea* and *Pinus* species mentioned in this survey, had been introduced to the Cape Town region (McGibbon 1858; Shaugnessy 1986). The government forestry authority played a major role in attempting to establish many of these plants both on the Cape Flats and on Table Mountain and adjoining mountains (Shaugnessy 1986). They also encouraged private growers to establish alien plantations. The reasons for the plantings were various: timber, fuel, shelter, driftsand stabilisation, tannin production and simply beautification of a landscape that was perceived at the time to be 'bleak and naked' (Shaugnessy 1986). Forestry officials even justified the afforestation of Table Mountain in terms of improved water supply and fire control (Shaugnessy 1986) which is exactly opposite to today's thinking.

In the southern Cape forests, fast-growing alien trees, particularly *Acacia*, *Eucalyptus*, *Pinus* and *Quercus* species, were planted in forest gaps and in plantations along the margins of forests. *Acacia melanoxylon*, the most prominent invader in the forested areas of the southern Cape today, occurred as large trees around George and Knysna by 1876 (Geldenhuys *et al.* 1986).

The pattern of invasion of several of the most widespread species today, such as *Pinus pinaster*, *Acacia cyclops* and *A. saligna* is a reflection of where they were planted. The disturbance of the soil and destruction of indigenous vegetation when establishing plantations of these alien species would have created conditions favourable for their further spread and also for the spread of other alien species. Later the abandonment of many of the plantations left stands of aliens which could act as a seed source for future generations of these species (Shaugnessy 1986).

Successful invaders in the Fynbos Biome have to be either tolerant of, or adapted to, nutrient-poor sandy soils and periodic high-intensity fires, particularly in mountain fynbos. Fire may encourage invasion by activating mass seed release from serotinous cones (as in *Hakea sericea* and *Pinus pinaster*), and by stimulating germination of soil-stored seeds as in *Acacia saligna* and *A. longifolia* (Richardson *et al.* 1992). The aforementioned *Acacia* species show a further adaptation which enables their seeds to avoid destruction by fire on the soil surface. Their seeds, with fleshy attachments that are eaten by ants, are buried in caches below the soil surface (Dean *et al.* 1986). *A. saligna* also has the ability to coppice after fire.

The Fynbos Biome is subjected to strong winds throughout the year and this has facilitated the rapid spread of species with winged seeds, mainly those of the *Hakea* and *Pinus* species. Whereas seed dispersal in mountain fynbos is mainly by wind and water; in the lowlands birds, mammals (including humans and their implements), ants and water are important. For example, *Acacia cyclops* seed is dispersed by mammals, such as the striped field mouse and the chacma baboon (Stirton 1978), and many indigenous birds as well as the introduced European starling (Glyphis *et al.* 1981). The large seeds of *Pinus pinea* are dispersed by the grey squirrel (Richardson *et al.* 1994).

Watercourses have played an important role in the long-range dispersal of alien plants throughout the study area. Species that have depended mainly on water dispersal include the hard-seeded legumes which are not bird- or ant-dispersed and are otherwise relatively immobile such as *Acacia dealbata, A. mearnsii, Paraserianthes lophantha* and *Sesbania punicea*. Watercourses have also enabled some species, for example, *A. saligna* and *A. mearnsii*, to penetrate the dry interior of the Succulent Karoo and Savanna Biomes. *Nerium oleander* is confined to riverbeds and is dependant on moisture for the germination and survival of its seedlings.

SOME IDEAS FOR THE FUTURE

Since this survey was completed in 1993, a national programme for the removal of alien plant invaders in the water catchments of South Africa has been initiated. The project is government-aided and is called the *Working for Water* Programme of the Department of Water Affairs and Forestry. The 1997/98 budget stands at R115 million and the prospects for further funding are promising (Preston 1997). It is envisaged that a large proportion of the funds will be derived from water levies which are likely to become a long-term source of funding (H.G. Zimmermann pers. comm.). The proposed 'interception of water levy' is aimed primarily at the forestry industry which is one of the major water users in the country (Yeld 1997). Clearing operations were started in October 1995 and by the end of March 1997, 71 289 hectares had been cleared (Willems 1997). However the ultimate success of the project will depend on very strict follow-up operations over an extended period of time. If these conditions are not met then the problem could be exacerbated rather than improved.

Many of the problem species are also useful plants and several are major commercial forestry crops. There is a growing call for instituting the 'polluter pays' principle, whereby the parties that benefit through the propagation of these species must contribute to the costs of controlling their spread from sites of propagation (Ivey & Heydenrych 1995; Richardson *et al.* 1997; Yeld 1997).

Prevention is better than cure! Every attempt should be made to prevent other, new species from becoming invasive. The possibility of developing sterile cultivars of commercially important species needs investigating. The most important step should be the screening of alien plant species for potential invasiveness before they are introduced and widely planted. To this end, an expert system has been developed to assist authorities in screening plants for their invasive potential (Tucker & Richardson 1995).

Biological control using mainly introduced insects and pathogens could play an increasingly important role in the long-term and sustainable control of invasive plant species in the study area. Some programmes have already been so successful, especially those against *Acacia saligna* and *A. longifolia*, that they could ultimately lead to the destruction of all the dense infestations of these species and severely restrict any further spread.

This paper has focused on woody plants which are the most prominent invaders of fynbos. However herbaceous alien plants are also important in some systems (Vlok 1988). There is an urgent need to assess the extent of invasions by alien herbs, especially in the remaining vegetation on the lowlands, and to determine what impacts they are having.

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APPENDIX

The names of 136 species of naturalised alien trees, shrubs and climbers are listed. Some non-woody species are included. Names and dates in brackets indicate literature references. (PRE): cited on Pretoria National Herbarium specimen labels.

Acacia
baileyana F.Muell., Bailey's wattle
cultriformis A.Cunn. (Buys *et al.* 1991), knife-leaved wattle
cyclops A.Cunn. ex G.Don, red eye/rooikrans
dealbata Link, silver wattle
elata A.Cunn. ex Benth., peppertree wattle
implexa Benth. (Buys *et al.* 1991), screw-pod wattle
longifolia (Andr.) Willd., long-leaved wattle
mearnsii De Wild., black wattle
melanoxylon R.Br., Australian blackwood
podalyriifolia A.Cunn., pearl acacia
pycnantha Benth., golden wattle

Acacia cont.
saligna (Labill.) H.L.Wendl., Port Jackson willow
viscidula A.Cunn. ex Benth. (Moll & Scott 1981)
Agave
americana L., American agave
sisalana Perrine, sisal
Ageratina adenophora (Spreng.) R.M.King & H.Rob. (Buys *et al.* 1991), crofton weed
Ailanthus altissima (Mill.) Swingle, tree-of-heaven
Alhagi maurorum Medik. (= *A. camelorum* Fisch.) (PRE), camelthorn bush
Alnus glutinosa (L.) Gaertn. (Moll & Scott 1981), black alder
Anredera baselloides (Kunth) Baill. (Buys *et al.* 1991), bridal wreath
Araujia sericifera Brot. (Bond & Goldblatt 1984), moth catcher
Arundo donax L., giant reed
Atriplex nummularia Lindl. subsp. *nummularia*, old man's salt bush
Bambusa balcooa Roxb. ex Roxb., common bamboo
Bambuseae sp., small unidentified bamboo
Brugmansia × *candida* Pers. [= *Datura* × *candida* (Pers.) Saff.], angel's trumpet
Callistemon rigidus R.Br. (Macdonald *et al.* 1987), Australian bottlebrush
Canna indica L. (Adamson & Salter 1950), canna
Cardiospermum grandiflorum Sw. (Buys *et al.* 1991), balloon vine
Castanea dentata (Marshall) Borkh. (Moll & Scott 1981), American chestnut
Casuarina sp., beefwood tree
Cereus jamacaru DC. [*C. peruvianus* (L.) Mill. misapplied in SA], queen of the night
Cestrum cf. *laevigatum* Schltdl., inkberry
Cinnamomum camphora (L.) J.Presl, camphor tree
Colocasia cf. *esculenta* (L.) Schott, taro
Cortaderia selloana (Schult.) Asch. & Graebn., Pampas grass
Cupressus
cf. *arizonica* Greene, Arizona cypress
macrocarpa Hartw. (Macdonald *et al.* 1987), black cypress
Cydonia oblonga Mill., quince
Cytisus
monspessulanus L. [= *C. candicans* (L.) Lam. (Buys *et al.* 1991)], Montpellier broom
scoparius L. (Buys *et al.* 1991), Scotch broom
Echinopsis spachiana (Lem.) Friedr. & Rowley [= *Trichocereus spachianus* (Lem.) Riccob.], torch cactus
Eriobotrya japonica (Thunb.) Lindl., loquat
Eucalyptus
camaldulensis Dehnh., red river gum
cladocalyx F.Muell., sugar gum
diversicolor F.Muell., karri
exserta F.Muell.
ficifolia F.Muell., red flowering gum
globulus Labill., blue gum
gomphocephala A.DC., tuart
lehmannii (Schauer) Benth., spider gum
leucoxylon F.Muell., white ironbark
microcorys F.Muell., tallow gum
regnans F.Muell., giant gum
sideroxylon A.Cunn. ex Woolls (Macdonald *et al.* 1987), black ironbark
Ficus carica L., edible fig
Fraxinus angustifolia Vahl, Algerian ash
Gleditsia triacanthos L., honey locust
Grevillea robusta A.Cunn., Australian silky oak
Hakea
drupacea (Gaertn.f.) Roem. & Schult. (= *H. suaveolens* R.Br.), sweet hakea
gibbosa (Sm.) Cav., rock hakea
sericea Schrad., silky hakea
Hedychium coronarium J.König (Adamson & Salter 1950), white ginger lily
Hypericum perforatum L. (Buys *et al.* 1991), St John's wort
Ipomoea
nil (L.) Roth.
purpurea (L.) Roth. (Bond & Goldblatt 1984), morning glory
Lantana camara L., lantana
Lavatera
arborea L., tree mallow
cretica L. (Moll & Scott 1981)
Leptospermum laevigatum (Gaertn.) F.Muell., Australian myrtle
Ligustrum
japonicum Thunb. (Adamson & Salter 1950), Japanese wax-leaved privet
sinense Lour. (Adamson & Salter 1950), Chinese privet
Malus sp., apple tree
Melia azedarach L., syringa or Persian lilac
Metrosideros excelsa Sol. ex Gaertn., New Zealand bottlebrush
Morus alba L., white mulberry
Myoporum tenuifolium Forst.f. subsp. *montanum* (R.Br.) Chinnock (*M. acuminatum* R.Br. misapplied in SA), manatoka
Nerium oleander L., oleander
Nicotiana glauca Graham, wild tobacco
Opuntia
ficus-indica (L.) Mill., sweet prickly pear
imbricata (Haw.) DC., imbricate prickly pear
microdasys (Lehm.) Pfeiff., bunny-ears
robusta cvs, spineless prickly pears
vulgaris Mill., cochineal prickly pear
Paraserianthes lophantha (Willd.) Nielsen subsp. *lophantha* [= *Albizia lophantha* (Willd.) Benth.], stink bean
Passiflora
caerulea L., blue passion flower
edulis Sims, purple granadilla
mollissima (Kunth) L.H.Bailey (Macdonald 1987), banana poka
cf. *quadrangularis* L. (McDonald & Morley 1988), giant granadilla
Pereskia aculeata Mill., Barbados gooseberry
Phoenix
canariensis Hort. ex Chabaud, Canary date palm
dactylifera L., real date palm
sp. (Moll & Scott 1981), palm
Phytolacca dioica L., belhambra
Pinus
cf. *canariensis* Sweet ex Spreng., Canary pine
halepensis Mill., Aleppo pine
pinaster Aiton, cluster pine
pinea L., umbrella pine
radiata D.Don, radiata pine
Pittosporum undulatum Vent., Australian cheesewood
Platanus sp., plane tree
Populus
× *canescens* (Aiton) Sm., grey poplar
deltoides W.Bartram ex Marshall, match poplar
nigra L. '*italica*', Lombardy poplar
Prosopis spp., mesquite trees
Prunus
armeniaca L., apricot
persica (L.) Batsch, peach
Psidium guajava L., guava
Punica granatum L., pomegranate
Pyracantha angustifolia (Franch.) C.K.Schneid., yellow firethorn
Pyrus sp., pear tree
Quercus
canariensis Willd. (= *Q. mirbeckii* Durieu) (Moll & Scott 1981), Algerian oak
cerris L. (Moll & Scott 1981), Turkey oak
palustris Münchh. (Moll & Scott 1981), pin oak
robur L., English oak
suber L. (Moll & Scott 1981), cork oak
Ricinus communis L., castor-oil plant
Robinia pseudoacacia L., black locust
Rosa eglanteria L., eglantine
Rubus
flagellaris Willd.
fruticosus L. agg., European blackberry; this includes *R. affinis* Weihe & Nees according to Spies & Du Plessis (1985)
rosifolius Sm. (Moll & Scott 1981)
Salix
babylonica L. weeping willow
caprea L. (Moll & Scott 1981), pussy willow
cf. *fragilis* L., crack willow
Schinus molle L., pepper tree
Senna didymobotrya (Fresen.) Irwin & Barneby (= *Cassia didymobotrya* Fresen.), peanut butter cassia
Sesbania punicea (Cav.) Benth., red sesbania
Solanum
hermannii Dunal (Bond & Goldblatt 1984), bitter apple
mauritianum Scop., bugweed
Spartium junceum L., Spanish broom
Tamarix
ramosissima Ledeb. (PRE), pink tamarisk
spp., tamarisks
Tetraclinis articulata (Vahl) Mast. (Rourke 1991), arar tree
Vitis cultivars, grapes
Wigandia caracasana Kunth