

Invasive alien woody plants of the eastern Cape

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Keywords: alien invasive plants, eastern Cape, Fynbos Biome, Grassland Biome, Nama-Karoo Biome, roadside survey, Savanna Biome

ABSTRACT

The frequency and abundance of invasive alien woody plants were recorded along roadsides and at watercourse crossings in 69.9% (151/216) of the quarter degree squares in the study area. The survey yielded 101 species of which the most prominent (in order of prominence) in roadside and veld habitats were: *Opuntia ficus-indica*, *Acacia mearnsii* and *A. cyclops*. The most prominent species (in order of prominence) in streambank habitats were: *A. mearnsii*, *Populus* × *canescens*, *Salix babylonica* and *S. fragilis* (fide R.D. Meikle).

The greatest intensity of invasion was recorded in the wetter eastern parts and particularly in the vicinity of Port Elizabeth, Uitenhage, East London, Grahamstown, Hogsback and Stutterheim. There was relatively little invasion in the central and western dry interior except along watercourses.

UITTREKSEL

Die frekwensie en voorkomsgigtheid van uitheemse houtagtige indringerplante is langs paaie en by oorgange oor waterlope in 69.9% (151/216) van die kwartgraadvierkante in die studiegebied aangeteken. Daar is 101 spesies aangetref waarvan die mees prominente (in volgorde van prominensie) langs paaie en in veldhabitats, *Opuntia ficus-indica*, *Acacia mearnsii* en *A. cyclops* was. Die mees prominente spesies (in volgorde van prominensie) langs stroomoewers, was *A. mearnsii*, *Populus* × *canescens*, *Salix babylonica* en *S. fragilis* (fide R.D. Meikle).

Die ergste indringing is in die vogtiger oostelike gebiede aangetref, veral in die omgewing van Port Elizabeth, Uitenhage, Oos-Londen, Grahamstad, Hogsback en Stutterheim. Behalwe langs waterstrome, was daar betreklik min indringing in die sentrale en westelike droë binneland.

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INTRODUCTION

Survey history and objectives

This study of the eastern Cape is the fifth of eight regional surveys which together are designed to reflect invasion by woody alien plants in the Republic of South Africa as a whole. Surveys have been completed for the Transvaal (Henderson & Musil 1984), Natal (Henderson 1989), Orange Free State (Henderson 1991a) and northern Cape (Henderson 1991b). This survey of the eastern Cape was undertaken in March, October and November 1988 and March 1990.

The objectives of the survey are: 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 30° and 34°S and 23° and 29°E (Figure 1). The altitude rises in successive terraces from sea level on the Indian Ocean in the south and southeast to 3 000 m in the Drakensberg in the north-east. Four major physical divisions can be delimited (Nicol 1988). These are the coastal subregion stretching inland

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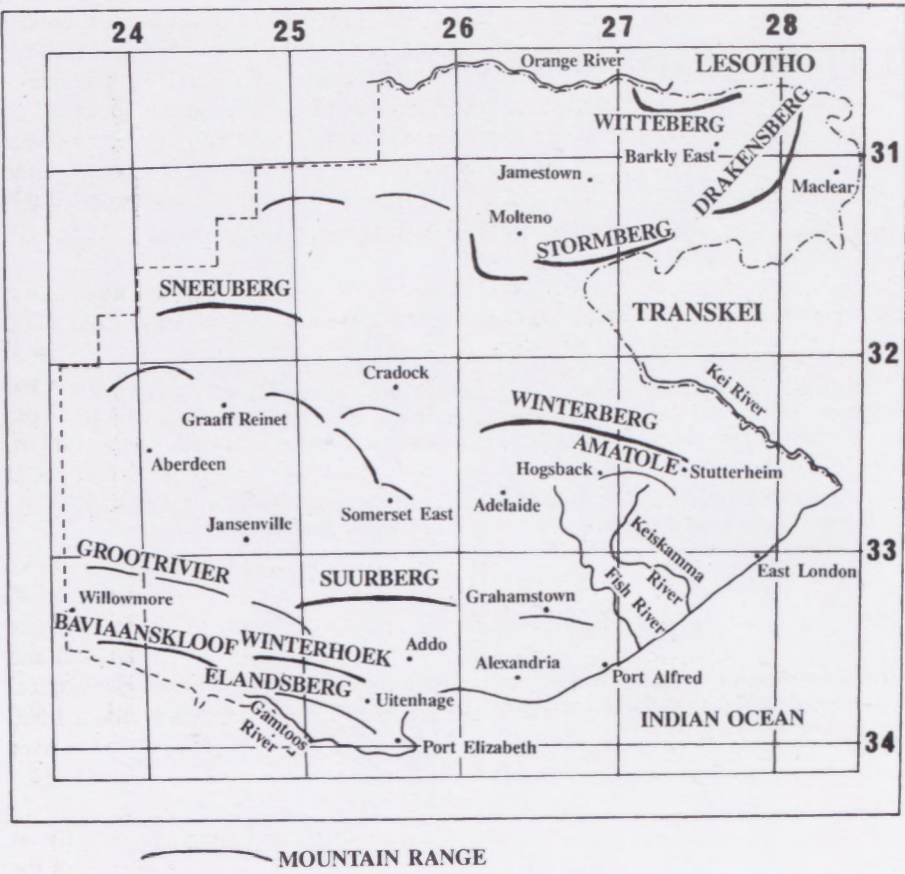


FIGURE 1.—The study area, showing the major physical features, and its relation to surrounding territories.

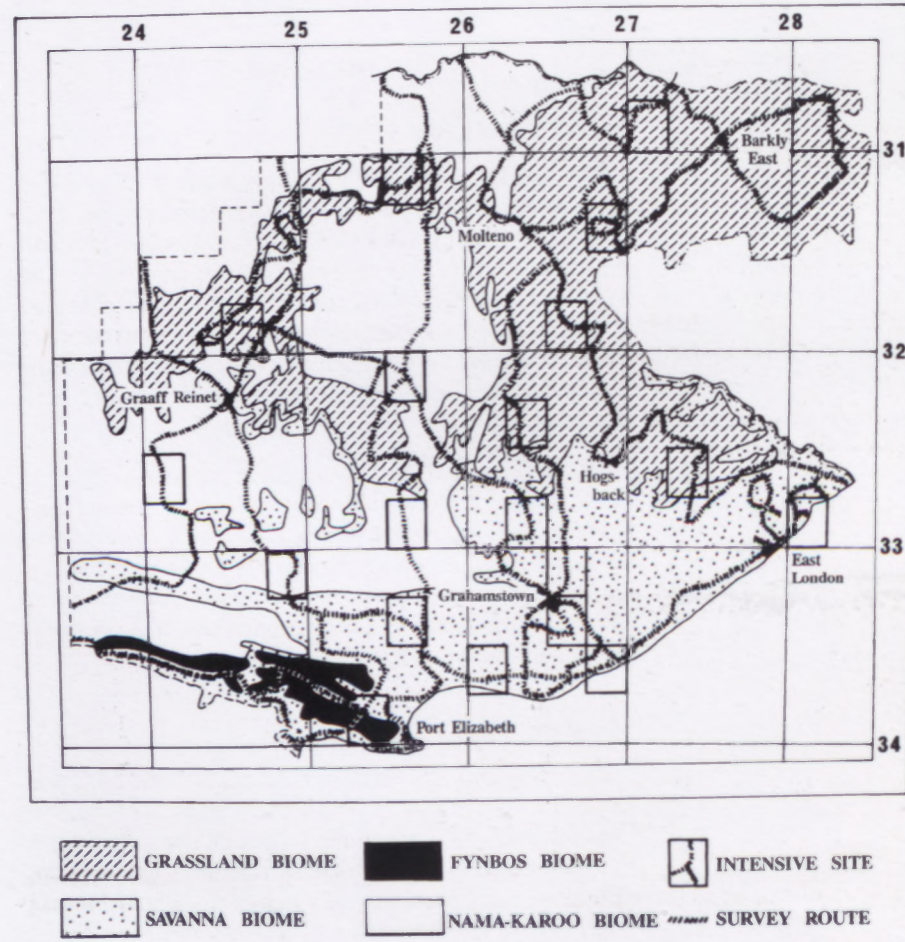


FIGURE 2.—The study area, showing its biomes (Rutherford & Westfall 1986), survey routes and intensive sites.

to the 300 m contour; the southern coastal mountains up to 1 500 m high lying west, north and northeast of Port Elizabeth; the midland region which is hilly to mountainous country and includes the Winterberg with a maximum height of 2 369 m; and the northern mountain region which extends from the Sneeuwberg in the west to the Stormberg and Drakensberg in the east. Seven major river systems arise in, and drain, the study area.

Rainfall ranges from 150 mm per annum in the extreme western interior to 1 700 mm in the Amatole Mountains (Dent *et al.* 1989). Most of the western and central regions receive less than 500 mm per annum (Kopke 1988). The seasonal distribution of rainfall ranges from a winter maximum on the coast between Port Elizabeth and Port Alfred through to a summer maximum in the northern interior (Kopke 1988).

Temperatures vary greatly from the coast inland. The coastal zone is mild in both winter and summer (Kopke 1988). The climate becomes progressively more temperate towards the arid west and with increasing altitude in the north. The interior above the Winterberg escarpment is characterized by hot summers, cold winters and widespread frost (Kopke 1988). Snow has been recorded occasionally for a few localities at low altitudes (e.g. Grahamstown) and is regular in mountainous parts (Gibbs Russell & Robinson 1981).

Four major vegetation units or biomes and 21 vegetation categories have been described in the eastern Cape by Lubke *et al.* (1986). 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). The Grassland, Savanna, Fynbos and Nama-Karoo Biomes converge in the eastern Cape (Figure 2). Twenty-six Acocks Veld Types occur in the study area and have been grouped into seven broad veld type categories for the purposes of this survey (Table 1 and Figure 3).

Temperate grassland occupies the highest and coldest parts of the study area at elevations of 1 500 m to 3 000 m. Rainfall ranges from 300 mm in the west to 1 000 mm in the extreme northeast. Moist subtropical grassland occurs on the cool and wet eastern and southeastern slopes of the Drakensberg at elevations from 600 m to 2 000 m. Rainfall ranges from 500 mm to 1 700 mm. Pockets of Afromontane forest occur in favourable localities.

Coastal 'forest' occupies the mild coastal belt with an annual rainfall ranging from 600 mm in the south to 1 000 mm in the north. Vegetation types occurring in this zone are forest, dune thicket, Acacia savanna, grassland and littoral strand vegetation (Lubke *et al.* 1986). Subtropical thicket and savanna occurs from sea level to about 1 500 m. Rainfall ranges from 200 mm in the hot and dry river valleys to 900 mm on the foothills of the Winterberg.

Fynbos shrublands, hereafter referred to broadly as mountain fynbos, occur along the tops and slopes of the southern coastal mountains at an altitude ranging from 300 m to 1 500 m. Small outliers are situated within the Savanna Biome along the Suurberg and on the Grahamstown hills. Rainfall ranges from 500 mm to 900 mm per annum.

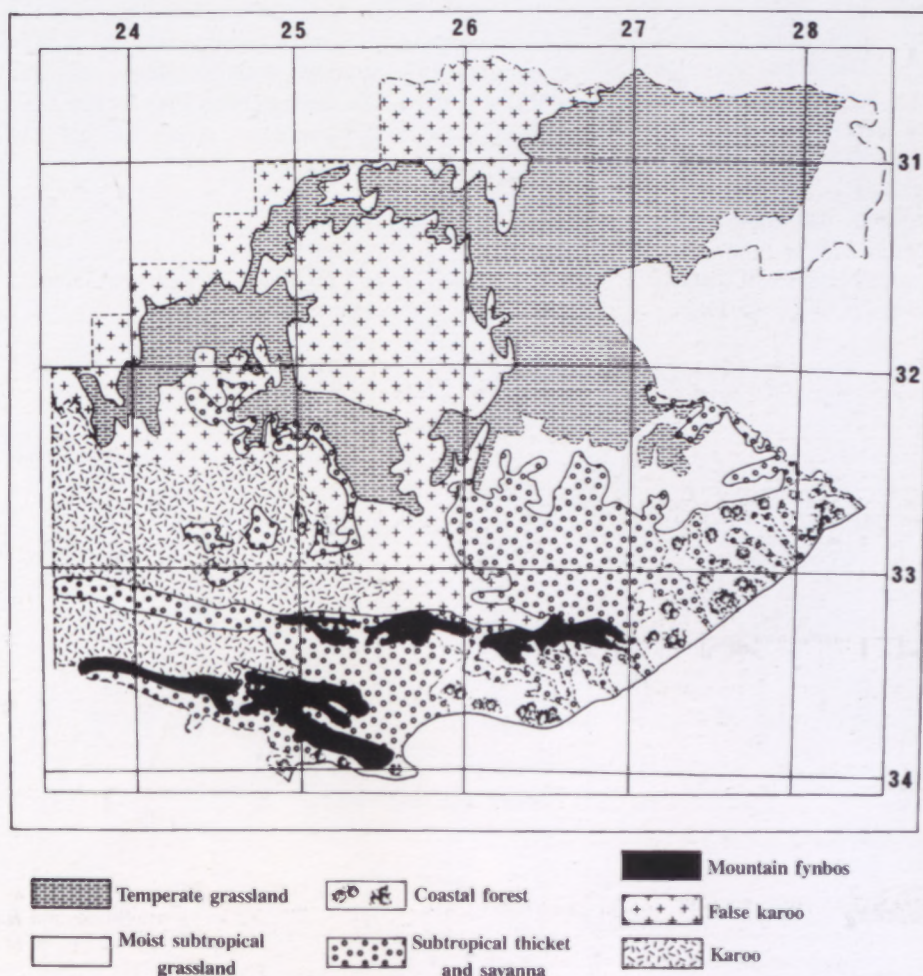


FIGURE 3.—The seven broad veld type categories in the study area (after Acocks 1988).

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

Biome† and veld type category*	Acocks Veld Type grouping	Acocks Veld Type No.
Grassland Biome		
Temperate grassland	VI. Pure Grassveld Types	48, 50, 58, 59, 60
	IIIA. False Bushveld Types	22
Moist subtropical grassland	V. Temperate and Transitional Forest and Scrub Types	44
Savanna Biome		
Coastal 'forest'	I. Coastal Tropical Forest Types	1, 2, 7
Subtropical thicket and savanna	IV. Karoo and Karroid Types	23, 24, 25, 26
	IIIA. False Bushveld Types	21
	IVA. False Karoo Types	36, 37
Fynbos Biome		
Mountain fynbos	VIIA. False Sclerophyllous Bush Types	70
Nama-Karoo Biome		
False karoo	IVA. False Karoo Types	36, 37, 38, 42
Karoo	IV. Karoo and Karroid Types	24, 25, 26, 30, 31

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

False karoo, at an altitude of between 1 000 m and 1 500 m, occupies areas formerly covered by grassland. Annual rainfall ranges from 200 mm to 500 mm. Karoo or dwarf shrubland occupies the very arid and western interior at an altitude of between 500 m and 1 000 m with an annual rainfall of between 150 mm and 400 mm.

METHOD

Sampling method

The method used in this survey was basically the same as that used in previous surveys. The changes to the abundance scale for streambank habitats adopted by Henderson (1991b) have also been followed here (see next subheading). The presence and abundance of all alien trees, large shrubs and conspicuous climbers which appeared to be spreading spontaneously (naturalized) were recorded for each veld type category, habitat type (roadsides and adjoining veld, and streambanks) and quarter degree/fifteen minute square traversed by road. Twenty

quarter degree squares were selected for more intensive surveying (Figure 2). 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 ten kilometres in length. The average transect length was 7.3 km for the general survey area and 5.0 km for intensive sites. Recordings of streambank invaders were made at virtually all watercourse crossings on the road transects. Details of the roads traversed are lodged in the P.P.R.I., Pretoria. As on 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.

Abundance ratings

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

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.

Sampling level achieved

The sampling level achieved was 69.9% (151 out of the total 216 quarter degree squares) at an average of 29.9 km travelled per square. An average of 18.5 km of road transects were sampled per quarter degree square for abundance estimates of roadside and veld invaders. The mean surface area of each of the quarter degree squares, in which 20 intensive sampling sites are situated, is 646 km² (23.39 × 27.62 km).

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 & 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:

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 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:

prominence value =
$$\frac{\frac{\text{total weighted abundance of species x in category y}}{\text{sum of the weighted abundances of all species in category y}} + \frac{\text{frequency of species x in category y}}{\text{sum frequency of all species in category y}}}{2} \times 100$$

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:

* each abundance rating was expressed in numbers of individuals or groups recorded per transect (see Table 2). To be both conservative and consistent the minimum number was used in each instance, e.g. an abundance rating of 5 over ten kilometres = 50 and an abundance rating of 5 over five kilometres = 25.
** mean no. of individuals or groups per 10 km converted to rating (see Table 2).

prominence value =
$$\frac{\frac{\text{total abundance* of species x in category y}}{\text{sum of the abundances* of all species in category y}} + \frac{\text{frequency of species x in category y}}{\text{sum frequencies of all species in category y}}}{2} \times 100$$

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 (see Tables 8 and 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:

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 (see Table 5)

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

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

RESULTS

The survey yielded 101 naturalized alien species. These species are listed in the Appendix together with a further 29 species which were obtained from various literature and other sources. The distributions of 30 of the most prominent species are given in Figures 7 and 8.

The streambank habitat

The whole study area

Six hundred and thirty-eight watercourse crossings were sampled in which 72 species were recorded, with up to nine species in one sample. Invaders were present at 61.0% of all crossings and 9.1% of all crossings were heavily invaded (Table 4).

Analysis according to veld type

Invasion was intense in both mountain fynbos and moist subtropical grassland where the highest percentages of river crossings were recorded as invaded and heavily invaded. The greatest number of species was recorded in subtropical thicket and savanna but few crossings were heavily invaded in this veld type category. Overall the Fynbos Biome was the most heavily invaded in terms of percentage crossings invaded and percentage crossings

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

Biome [‡] and veld type category [†]	1/4 degree squares	Road transects	Distance (km)*	Watercourse recordings
Grassland Biome	64	128	978	215
Temperate grassland [†]	52	98	785	188
Moist subtropical grassland [†]	19	30	193	27
Savanna Biome	65	147	998	231
Coastal 'forest' [†]	30	62	343	56
Subtropical thicket and savanna [†]	51	85	655	175
Fynbos Biome	10	15	90	16
Mountain fynbos [†]	10	15	90	16
Nama-Karoo Biome	57	94	725	176
False karoo [†]	46	66	532	131
Karoo [†]	12	28	193	45
Study area	151	384	2791	638

* 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 veld type category, biome and the 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**
Grassland Biome	39	1.5	6	17.7	74.0
Temperate grassland [†]	31	1.4	6	13.8	70.7
Moist subtropical grassland [†]	21	2.3	6	44.4	96.3
Savanna Biome	45	1.5	9	3.0	59.3
Coastal 'forest' [†]	27	2.2	8	3.6	80.4
Subtropical thicket and savanna [†]	38	1.3	9	2.9	52.6
Fynbos Biome	19	2.0	5	68.8	93.8
Mountain fynbos [†]	19	2.0	5	68.8	93.8
Nama-Karoo Biome	24	0.7	9	1.1	44.3
False karoo [†]	20	0.8	9	1.5	47.3
Karoo [†]	10	0.5	4	0.0	35.6
Study area	72	1.3	9	9.1	61.0

* 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 veld type category, biome and the study area

Biome [‡] and veld type category [†]	Total no. of spp.	Average no. of spp./1/4° sq.	Max. no. of spp./1/4° sq.	% transects invaded	% transects heavily invaded*	Mean abundance of invaders per km**
Grassland Biome	54	6.0	18	100.0	21.1	3.4
Temperate grassland [†]	40	5.1	13	100.0	15.3	2.2
Moist subtropical grassland [†]	37	7.1	18	100.0	40.0	8.0
Savanna Biome	62	7.2	20	98.0	44.9	8.3
Coastal 'forest' [†]	48	8.5	19	96.8	45.2	9.9
Subtropical thicket and savanna [†]	43	5.6	12	98.8	44.7	7.4
Fynbos Biome	31	8.8	19	93.3	73.3	23.8
Mountain fynbos [†]	31	8.8	19	93.3	73.3	23.8
Nama-Karoo Biome	29	4.4	13	96.8	4.3	1.4
False karoo [†]	29	4.5	13	95.5	4.5	1.4
Karoo [†]	9	4.2	8	100.0	3.6	1.3
Study area	94	7.3	25	98.2	28.1	5.3

* 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.

heavily invaded. The Grassland Biome was the next most heavily invaded followed by the Savanna Biome and lastly the Nama-Karoo Biome (Table 4).

Analysis according to species

Frequency

Salix babylonica was the most frequently recorded invader in the study area (19.6%). Only this species and *Populus × canescens* (11.8%) 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* (75.0%), *A. saligna* (37.5%) and *Populus × canescens* (31.3%). In the Nama-Karoo Biome *Salix babylonica* (13.1%) was the most frequent invader. In the Grassland Biome the most frequently recorded species were *S. babylonica* (44.2%), *Populus × canescens* (27.9%) and *S. fragilis* (20.9%). In the Savanna Biome the most frequently recorded species was *Ricinus communis* (22.5%).

Other species which were recorded at 10% or more crossings in a veld type category were: *Acacia cyclops* and *Eucalyptus* spp. in mountain fynbos; *Atriplex* cf. *nummularia* in karoo; *Acacia dealbata*, *A. mearnsii*, *Prunus persica* and *Salix caprea* in moist subtropical grassland; *A. cyclops*, *A. mearnsii*, *Cestrum laevigatum*, *Sesbania punicea* and *Solanum hispidum* in coastal 'forest'; and *Arundo donax* and *Nicotiana glauca* in subtropical thicket and savanna.

Prominence

The most prominent invader in the whole study area was *Acacia mearnsii* with a prominence value of 32.2 out of a combined total for all species of 200 (Table 7). The next most prominent invaders were *Populus × canescens* (28.7) and *Salix babylonica* (28.2).

In the Fynbos Biome *Acacia mearnsii* was by far the most prominent invader followed by *Populus × canescens* and *A. saligna*. In the Nama-Karoo Biome *Atriplex* cf. *nummularia* was the most prominent invader in the karoo veld type category. *Salix babylonica* was the most prominent invader in false karoo and the whole of the Nama-Karoo Biome.

In the Grassland Biome *Salix babylonica*, *Populus × canescens* and *S. fragilis* were the most prominent invaders. The same species were also the most prominent invaders in temperate grassland. *Acacia mearnsii*, *S. babylonica* and *A. dealbata* were the most prominent invaders in moist subtropical grassland.

In the Savanna Biome *Sesbania punicea*, *Arundo donax*, *Ricinus communis* and *Acacia mearnsii* were the most prominent invaders. *A. cyclops* was most prominent in coastal 'forest' and *Arundo donax* was most prominent in subtropical thicket and savanna.

Roadside and veld habitats

The whole study area

One hundred and fifty one quarter degree squares and 384 road transects were sampled in which 94 species were

recorded. Up to 25 species were recorded per quarter degree square. Naturalized species were recorded in 98.2% of all transects sampled and 28.1% of all transects were heavily invaded (Table 5).

Analysis according to veld type

Invasion was most intense in mountain fynbos where the highest percentage of transects was heavily invaded and the mean abundance of invaders per km reached a maximum (Table 5). The next most heavily invaded categories were coastal 'forest', subtropical thicket and savanna, and moist subtropical grassland. The greatest number of species was recorded in coastal 'forest'.

Analysis according to species

Frequency

The most frequently recorded species in the whole study area were *Opuntia ficus-indica* (67.4%), *Agave americana* (28.4%), *O. cf. robusta* cultivars (26.8%) and *Acacia mearnsii* (20.3%) (Table 9). Other species which were recorded in 10% or more transects were *Acacia cyclops*, *Eucalyptus* spp., *Nicotiana glauca*, *Prunus persica*, *Ricinus communis* and *Rosa eglanteria*.

The most frequently recorded species in the Fynbos Biome were *Acacia mearnsii*, *A. cyclops*, *Eucalyptus* spp. and *Opuntia ficus-indica*. In the Nama-Karoo Biome, *O. ficus-indica*, *O. cf. robusta* cultivars and *Agave americana* were the most frequent species. In the Grassland Biome, *O. ficus-indica* and *Rosa eglanteria* were the most frequent invaders. In the Savanna Biome, *O. ficus-indica* was the most frequent invader.

Prominence

Opuntia ficus-indica scored the highest prominence value of 58.4 in the study area. The next most prominent species were *Acacia mearnsii* (20.8) and *A. cyclops* (15.2) (Table 9).

In the Fynbos Biome, *Acacia mearnsii*, *A. saligna*, *A. cyclops* and *Pinus pinaster* were the most prominent species. In the Nama-Karoo Biome, *Opuntia ficus-indica* was the most prominent species followed by *O. cf. robusta* cultivars and *Agave americana*.

In the Grassland Biome, *Rosa eglanteria*, *Acacia mearnsii* and *Opuntia ficus-indica* were the most prominent invaders. In the Savanna Biome, *O. ficus-indica* was by far the most prominent invader followed by *A. cyclops* and *A. mearnsii*.

Acacia dealbata and *Rubus affinis* deserve mention as the second and third most prominent invaders after *A. mearnsii* in moist subtropical grassland. *Psidium guajava* was ranked fourth in coastal 'forest' after *A. cyclops*, *A. mearnsii* and *Opuntia ficus-indica*. *A. longifolia* and *Hakea sericea* were abundant in places within mountain fynbos.

Patterns of invasion

Alien plant invasion was recorded in streambank, roadside and veld habitats throughout the eastern Cape (Figures 4 & 5). However, most invasion in terms of species

TABLE 6. — Alien species occurring in streambank habitats of the Nama-Karoo Biome

Veld type category	False karoo			Karoo			Total		
No. watercourse crossings	131			45			176		
	F	I	P	F	I	P	F	I	P
<i>Acacia dealbata</i>	0.8		1.6				0.6		1.4
<i>Agave americana</i>	4.6		9.4	8.9		34.8	5.7		13.1
<i>Arundo donax</i>	6.1		12.5	2.2		8.7	5.1		11.8
<i>Atriplex</i> sp. cf. <i>nummularia</i>				11.1		43.5	2.8		6.5
<i>Cupressus arizonica</i>	0.8		1.6				0.6		1.4
<i>Eucalyptus</i> sp. cf. <i>camaldulensis</i>				2.2		8.7	0.6		1.4
<i>Eucalyptus</i> spp.	6.9		14.1				5.1		11.8
<i>Gleditsia triacanthos</i>	1.5		3.1				1.1		2.6
<i>Melia azedarach</i>				2.2		8.7	0.6		1.4
<i>Nicotiana glauca</i>	5.3		10.9	8.9		34.8	6.3		14.5
<i>Opuntia ficus-indica</i>	5.3		10.9				4.0		9.2
<i>Opuntia</i> sp. cf. <i>robusta</i>	0.8		1.6				0.6		1.4
<i>Populus</i> × <i>canescens</i>	5.3		13.3				4.0		11.3
<i>Populus</i> sp. cf. <i>deltoidea</i>	2.3		4.7				1.7		3.9
<i>Populus</i> sp. cf. <i>nigra</i>	6.1		12.5				4.5		10.4
<i>Prosopis</i> sp.				2.2		8.7	0.6		1.4
<i>Prunus persica</i>	0.8		1.6				0.6		1.4
<i>Ricinus communis</i>	1.5		3.1	2.2		8.7	1.7		3.9
<i>Robinia pseudoacacia</i>	1.5		3.1				1.1		2.6
<i>Salix babylonica</i>	17.6	1.5	69.8				13.1	1.1	60.0
<i>Schinus molle</i>	9.9		20.2	2.2		8.7	8.0		18.4
<i>Sesbania punicea</i>	*						*		
<i>Tamarix</i> sp. cf. <i>ramosissima</i>	2.3		4.7	8.9		34.8	4.0		9.2
<i>Yucca</i> sp. cf. <i>aloifolia</i>	0.8		1.6				0.6		1.4

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 prominence values (see text).

diversity and abundance of invaders was recorded in the wetter eastern parts. In roadside and veld habitats invasion was most severe in the districts of Port Elizabeth, Uitenhage, Grahamstown, East London, Hogsback (Amatole Mountains) and Stutterheim (Figures 5 & 6). Invasion was less, but still considerable, in the high altitude grassland areas of Barkly East and Maclear.

A comparison of Figures 4 and 5 shows that similar patterns of invasion were recorded in streambank, roadside and veld habitats, except that in the western dry mountain areas there was more severe invasion of the streambank habitat than of roadside and veld habitats. This pattern of streambank invasion in the dry mountain areas was almost

entirely due to *Populus* × *canescens* (Figure 8C) and *Salix babylonica* (Figure 8K).

DISCUSSION

Prominent and potentially important species

Several *Opuntia* species have been, or still are, troublesome invaders in the eastern Cape. *O. vulgaris* was a major weed at the end of the nineteenth century but today is of minor importance following a very successful biological control programme (Zimmermann *et al.* 1986). Species infesting large areas at present are *O. ficus-indica* and

TABLE 7.—Alien species occurring in streambank habitats of the Grassland, Savanna and Fynbos Biomes and the study area

Biome and veld type category	Grassland Biome						Savanna Biome						Fynbos Biome												
	Temperate grassland			Moist subtropical grassland			Total			Coastal 'forest'			Subtropical thickets & savanna			Total			Mountain fynbos			Total study area			
	188			27			215			56			175			231			16			638			
	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	
<i>Acacia</i> <i>cyclops</i> <i>dealbata</i> <i>longifolia</i> <i>mearnsii</i> <i>melanoxylon</i> <i>saligna</i> <i>Agave</i> <i>americana</i> <i>Atlantus</i> <i>altissima</i> <i>Arundo</i> <i>donax</i> <i>Atriplex</i> sp. cf. <i>nummularia</i> <i>Bambusa</i> sp. cf. <i>balcooa</i> <i>Caesalpinia</i> <i>gilliesii</i> <i>Cardiospermum</i> sp. <i>Casuarina</i> <i>cunninghamiana</i> sp. <i>Cestrum</i> <i>laevigatum</i> <i>Cortaderia</i> sp. <i>Cupressus</i> <i>arizonica</i> <i>Cydonia</i> <i>oblonga</i> <i>Eucalyptus</i> sp. cf. <i>camaldulensis</i> spp. <i>Gledissia</i> <i>triacanthos</i>	2.7	1.1	6.7	25.9	11.1	28.5	5.6	2.3	11.7	37.5		37.2	2.3		2.6	10.8		14.1	12.5		6.5	4.2		4.4	
																						2.0	0.8	6.2	
											3.6	1.8	15.2				0.9	0.4	4.8	6.3		3.8	0.5	0.2	1.3
		2.1	1.1	4.8	25.9	18.5	57.4	5.1	3.3	17.8	23.2		19.9	9.1	0.6	22.1	12.6	0.4	21.6	75.0	62.5	115.8	8.2	2.8	32.2
					*			*			5.4		3.8	0.6		0.7	1.7		1.7	37.5		20.0	*		1.6
		3.2						2.8		2.2				1.1		1.3	0.9		0.9	*			2.8		2.7
		*						*														*			
		1.6						1.4		1.0	1.8		1.3	13.7	1.1	33.0	10.8	0.9	22.7	6.3		3.3	6.0	0.3	7.6
														2.3		2.6	1.7		1.7			1.4			1.3
											*			*			*					*			
														0.6		0.7	0.4		0.4			0.2			0.2
											1.8		1.3	0.6		0.7	0.9		0.9	0.3			0.3		0.3
														2.3		2.6	1.7		1.7			0.6			0.6
														0.6		0.7	0.4		0.4			0.2			0.2
											10.7		7.5	1.1		1.3	3.5		3.4		*		1.3		1.2
																			*		*				
	0.5		0.4				0.5		0.4													0.3		0.3	
	*						*														*				
	0.5		0.4				0.5		0.4													0.6		0.6	
	1.1		0.9	*			0.9		0.7	5.4		5.6	7.4		9.3	6.9		8.0	18.8	6.3	13.9	4.7	0.2	5.3	
	*						*															0.3		0.3	

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 prominence values (see text).

TABLE 7.—Alien species occurring in streambank habitats of the Grassland, Savanna and Fynbos Biomes and the study area (continued)

Biome and veld type category	Temperate grassland			Grassland Biome Moist subtropical grassland			Total			Coastal 'forest'			Savanna Biome Subtropical thicket & savanna			Total			Fynbos Biome Mountain fynbos			Total study area		
	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P	F	I	P
No. watercourse crossings	188			27			215			56			175			231			16			638		
<i>Solanum</i> <i>hispidum</i> <i>mauritianum</i> <i>seaforthianum</i> <i>Tamarix</i> sp. cf. <i>ramosissima</i> <i>Ulmus</i> sp. <i>Washingtonia</i> sp. <i>Yucca</i> sp. cf. <i>aloifolia</i>										10.7 7.1		7.5 5.0	2.9 2.3 0.6	3.3 3.4 0.7		4.8 3.5 0.4		4.7 4.0 0.4	*			1.7 1.3 0.2		1.6 1.3 0.2
	0.5		0.4				0.5		0.4				0.6			0.4		0.4				0.2		0.2
	*						*															0.2		2.0

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 prominence values (see text).

TABLE 8.—Alien species occurring in roadside and veld habitats of the Nama-Karoo Biome

Veld type category	False karoo			Karoo			Total		
No. road transects	66			28			94		
	F	A	P	F	A	P	F	A	P
<i>Agave</i>									
<i>americana</i>	42.4	2.0	21.9	39.3	2.0	25.3	41.5	2.0	22.7
<i>Arundo</i>									
<i>donax</i>	3.0	1.0	1.3				2.1	1.0	0.9
<i>Atriplex</i>									
<i>sp. cf. nummularia</i>	10.6	2.0	5.6	42.9	2.0	27.0	20.2	2.0	11.4
<i>Caesalpinia</i>									
<i>gilliesii</i>	*						*		
<i>Cupressus</i>									
<i>arizonica</i>	1.5	1.0	0.6				1.1	1.0	0.5
<i>Eucalyptus</i>									
spp.	6.1	2.0	3.3				4.3	2.0	2.4
<i>Gleditsia</i>									
<i>triacanthos</i>	10.6	1.0	4.8				7.4	1.0	3.5
<i>Melia</i>									
<i>azedarach</i>	*			*			*		
<i>Nicotiana</i>									
<i>glauca</i>	10.6	1.0	5.1	39.3	3.0	40.6	19.1	3.0	14.4
<i>Opuntia</i>									
<i>figus-indica</i>	78.8	3.0	90.0	85.7	3.0	69.2	80.9	3.0	84.8
<i>imbricata</i>	1.5	2.0	0.8				1.1	2.0	0.6
<i>lindheimeri</i>	1.5	2.0	0.8				1.1	2.0	0.6
<i>sp. cf. robusta</i>	65.2	2.0	35.5	46.4	2.0	25.5	59.6	2.0	32.8
<i>Parkinsonia</i>									
<i>aculeata</i>	*						*		
<i>Pinus</i>									
<i>halepensis</i>	1.5	2.0	0.8				1.1	2.0	0.6
<i>Populus</i>									
× <i>canescens</i>	*						*		
<i>sp. cf. deltoides</i>	1.5	1.0	0.6				1.1	1.0	0.5
<i>sp. cf. nigra</i>	*						*		
<i>Prosopis</i>									
spp.	9.1	1.0	4.0	14.3	2.0	8.7	10.6	2.0	5.3
<i>Prunus</i>									
<i>armeniaca</i>	*						*		
<i>persica</i>	7.6	1.0	3.4				5.3	1.0	2.4
<i>Pyracantha</i>									
<i>angustifolia</i>	6.1	1.0	2.7				4.3	1.0	2.0
<i>Ricinus</i>									
<i>communis</i>	*			3.6	1.0	1.7	1.1	1.0	0.5
<i>Robinia</i>									
<i>pseudoacacia</i>	1.5	1.0	0.6				1.1	1.0	0.5
<i>Rosa</i>									
<i>eglanteria</i>	1.5	2.0	0.8				1.1	2.0	0.6
<i>Schinus</i>									
<i>molle</i>	24.2	2.0	12.8				17.0	2.0	9.3
<i>Tamarix</i>									
<i>sp. cf. ramosissima</i>	3.0	1.0	1.3				2.1	1.0	0.9
<i>Trichocereus</i>									
<i>sp. cf. spachianus</i>	6.1	1.0	2.6	3.6	2.0	2.1	5.3	1.0	2.4
<i>Ulmus</i>									
spp.	1.5	2.0	0.8				1.1	2.0	0.6

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 prominence values (see text).

O. aurantiaca (Zimmermann *et al.* 1986). The latter species, known as jointed cactus, is an inconspicuous low-growing species and was excluded from this survey because it was easily overlooked.

Opuntia ficus-indica (Figure 7N) has been naturalized in the eastern Cape for more than 200 years. According to MacDonald (1891) it was first introduced to this region in 1750. Although it was found growing wild between 1772 and 1775 it seems that until at least 1834 it remained largely within the confines of cultivation. By 1859 it had infested a few farms. Thereafter it spread rapidly and by

1891 it had infested 282 000 ha of land in the districts of Graaff-Reinet, Aberdeen, Jansenville, Somerset East and Willowmore. Localized infestations were found in many other districts. By 1932, prior to a biological control campaign, it occurred on 800 000 ha of land in the Cape Province; 400 000 ha in the eastern Cape and Karoo were densely infested (Stirton 1978).

Cochineal (*Dactylopius opuntiae*) aided by felling, caused the collapse of 80% of the 400 000 ha of dense infestations (Stirton 1978). The moth *Cactoblastis cactorum* was effective in killing a substantial proportion of the

TABLE 9.—Alien species occurring in roadside and veld habitats of the Grassland, Savanna and Fynbos Biomes and the study area

Biome and veld type category	Grassland Biome						Savanna Biome						Fynbos Biome					
	Temperate grassland			Moist subtropical grassland			Coastal 'forest'			Subtropical thicket & savanna			Total			Mountain fynbos		
No. road transects	98			30			62			85			147			15		
	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P
<i>Acacia</i>																		
<i>baileyana</i>	2.0	2.0	0.9	10.0	1.0	2.7	1.6	1.0	0.5				0.7	1.0	0.2	*		
<i>cyclops</i>							40.3	5.0	47.3	7.1	4.0	6.5	21.1	5.0	23.7	66.7	4.0	27.2
<i>dealbata</i>	1.0	1.0	0.4	26.7	4.0	21.1				1.2	2.0	0.4	0.7	2.0	0.2			
<i>decurrens</i>				3.3	3.0	1.1												
<i>longifolia</i>							4.8	2.0	1.4	*			2.0	2.0	0.6	33.3	5.0	14.9
<i>melarsii</i>	5.1	3.0	4.3	70.0	5.0	66.9	56.5	4.0	33.3	4.7	2.0	1.7	26.5	4.0	15.4	86.7	5.0	48.6
<i>melanoxylon</i>	3.1	1.0	1.4	26.7	3.0	9.3	4.8	1.0	1.4	1.2	1.0	0.4	2.7	1.0	0.8	*		
<i>pycnantha</i>							1.6	2.0	0.5				0.7	2.0	0.2			
<i>saligna</i>							19.4	4.0	10.9	*			8.2	4.0	4.7	40.0	6.0	32.4
<i>Agave</i>																		
<i>americana</i>				*			*			48.2	2.0	17.4	27.9	2.0	9.4	13.3	2.0	2.9
<i>sisalana</i>	27.6	2.0	12.4				6.5	2.0	1.9	2.4	1.0	0.8	4.1	2.0	1.3			
sp.							*						*			*		
<i>Ailanthus</i>																		
<i>altissima</i>																*		
<i>Arundo</i>																		
<i>donax</i>							*			7.1	1.0	2.4	4.1	1.0	1.3			
<i>Atriplex</i>																		
sp. cf. <i>nummularia</i>																		
Bambuseae	1.0	1.0	0.4							8.2	2.0	2.9	4.8	2.0	1.6			
sp.							*						*			*		
<i>Caesalpinia</i>																		
<i>decapetala</i>																		
<i>gilliesii</i>																		
<i>Casuarina</i>	1.0	2.0	0.4															
<i>cunninghamiana</i>																		
sp.				*			*			1.2	4.0	0.6	0.7	4.0	0.3			
<i>Cereus</i>													*			6.7	2.0	1.4
<i>peruvianus</i>																		
<i>Cestrum</i>	*						1.6	2.0	0.5	4.7	1.0	*1.6	3.4	1.0	1.1			
<i>laevigatum</i>																		
<i>Cortaderia</i>							4.8	2.0	1.4	*			2.0	2.0	0.6			
sp.																*		
<i>Cotoneaster</i>				6.7	1.0	1.7	*						*					
sp.																		
<i>Crotalaria</i>				6.7	2.0	1.8												
sp.							1.6	2.0	0.5				0.7	2.0	0.2			

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 prominence values (see text).

TABLE 9.—Alien species occurring in roadside and veld habitats of the Grassland, Savanna and Fynbos Biomes and the study area (continued)

Biome and veld type category	Temperate grassland			Grassland Biome Moist subtropical grassland			Total			Coastal 'forest'			Savanna Biome Subtropical thicket & savanna			Total			Fynbos Biome Mountain fynbos			Total study area		
	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P	F	A	P
No. road transects	98			30			128			62			85			147			15			384		
<i>Nerium</i>																								
<i>oleander</i>																								
<i>Nicotiana</i>																								
<i>glauca</i>	4.1	2.0	1.9																					
<i>Opuntia</i>																								
<i>figus-indica</i>	61.2	3.0	47.8	23.3	2.0	6.7	52.3	3.0	30.9	40.3	4.0	19.3	97.6	5.0	116.2	73.5	5.0	75.3	53.3	3.0	12.5	67.4	4.0	58.4
<i>imbricata</i>	2.0	2.0	0.9				1.6	2.0	0.6				*									0.8	2.0	0.3
<i>lindeheimeri</i>													2.4	3.0	1.0	1.4	3.0	0.5				0.8	3.0	0.3
<i>stricta</i>	*			3.3	2.0	0.9	0.8	2.0	0.3				2.4	3.0	1.2	1.4	3.0	0.7				0.5	3.0	0.3
<i>vulgaris</i>										8.1	3.0	3.0	3.5	2.0	1.3	5.4	3.0	2.0				2.1	3.0	0.9
sp. cf. <i>robusta</i>	34.7	2.0	15.6				26.6	2.0	10.2	*			15.3	1.0	5.2	8.8	1.0	2.8				26.8	2.0	9.6
<i>Paraserianthes</i>																								
<i>lophantha</i>																								
<i>Parkinsonia</i>																								
<i>aculeata</i>																								
<i>Passiflora</i>																								
<i>caerulea</i>																								
<i>Pennisetum</i>																								
<i>purpureum</i>																								
<i>Phytolacca</i>																								
<i>dioica</i>																								
<i>Pinus</i>																								
<i>?elliotii</i>	1.0	1.0	0.4																					
<i>halepensis</i>	8.2	3.0	6.3	20.0	2.0	5.3	0.8	1.0	0.3															
<i>patula</i>				13.3	4.0	6.9	10.9	3.0	5.5	22.6	3.0	8.9	1.2	1.0	0.4	10.2	3.0	4.2	46.7	3.0	10.3	9.6	3.0	4.3
<i>pinaster</i>							3.1	4.0	2.7	*						*						1.0	4.0	0.7
<i>pinex</i>	*			10.0	2.0	2.6	2.3	2.0	0.9	3.2	2.0	0.9				1.4	2.0	0.4	46.7	5.0	22.0	2.3	5.0	2.6
<i>radiata</i>				6.7	3.0	3.5	1.6	3.0	1.0	1.6	1.0	0.5				0.7	1.0	0.2	6.7	3.0	1.5	0.8	2.0	0.3
<i>roxburghii</i>	*						*															*		0.4
spp.																								
<i>Populus</i>	1.0	2.0	0.4	10.0	3.0	2.9	3.1	2.0	1.3	4.8	2.0	1.5	*			2.0	2.0	0.7	6.7	2.0	1.4	0.8	2.0	0.4
× <i>canescens</i>																								
sp. cf. <i>deltoides</i>	5.1	1.0	2.3	3.3	1.0	0.8	4.7	1.0	1.8				*			*			*			1.6	1.0	0.6
sp. cf. <i>nigra</i>	1.0	1.0	0.4				0.8	1.0	0.3													0.5	1.0	0.2
<i>Prosopis</i>	1.0	2.0	0.5	3.3	1.0	0.8	1.6	2.0	0.6													0.5	2.0	0.2
spp.																								
<i>Prunus</i>													*									2.6	2.0	0.9
<i>armeniaca</i>	4.1	1.0	1.7				3.1	1.0	1.1													1.0	1.0	0.3

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 $\pm 80\%$ of the summed prominence values (see text).

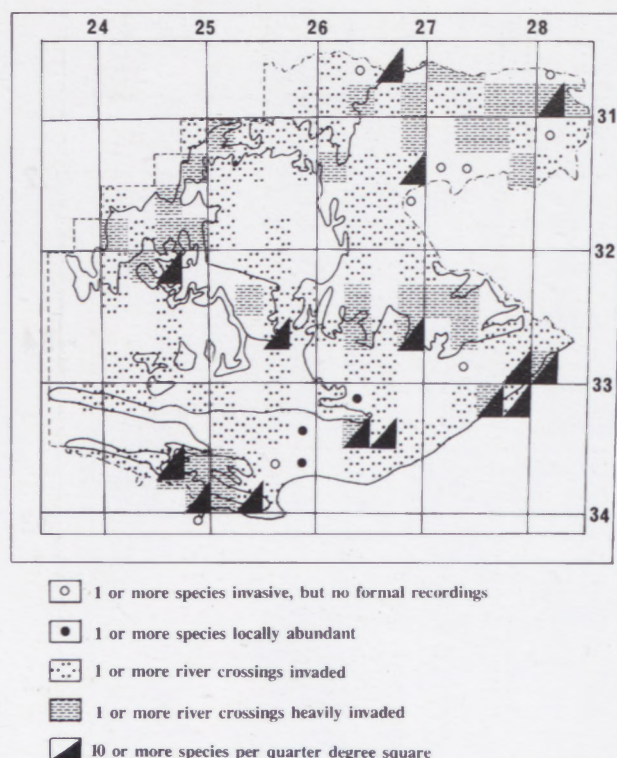


FIGURE 4.—Invasion in streambank habitats in terms of the intensity of invasion of watercourse crossings and species diversity per quarter degree square.

more isolated plants (Zimmermann *et al.* 1986). The present distribution of *Opuntia ficus-indica* is mainly a reflection of the effects of climate on the insect herbivores, particularly *Dactylopius opuntiae*, and not a direct influence of climate on the plant itself (Zimmermann *et al.* 1986). The insects are most effective under hot and dry conditions and least effective under cool and moist conditions (Zimmermann *et al.* 1986).

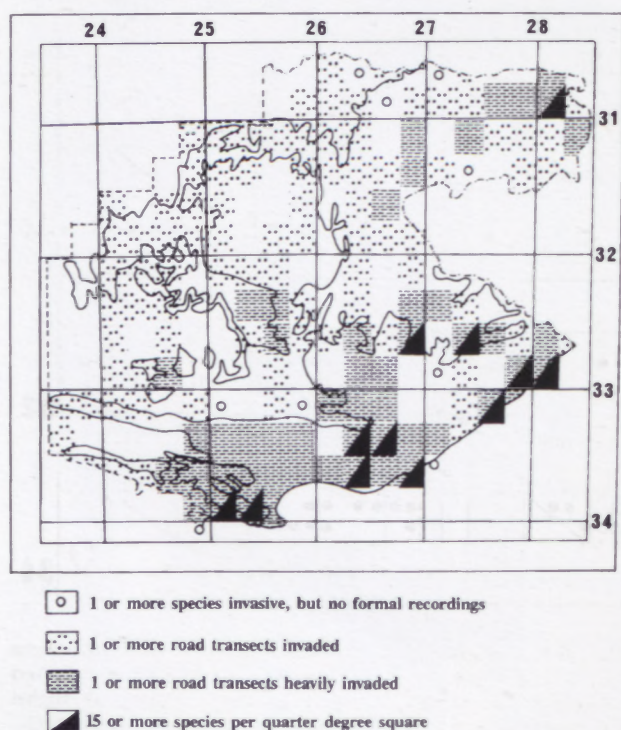


FIGURE 5.—Invasion in roadside and veld habitats in terms of the intensity of invasion of road transects and species diversity per quarter degree square.

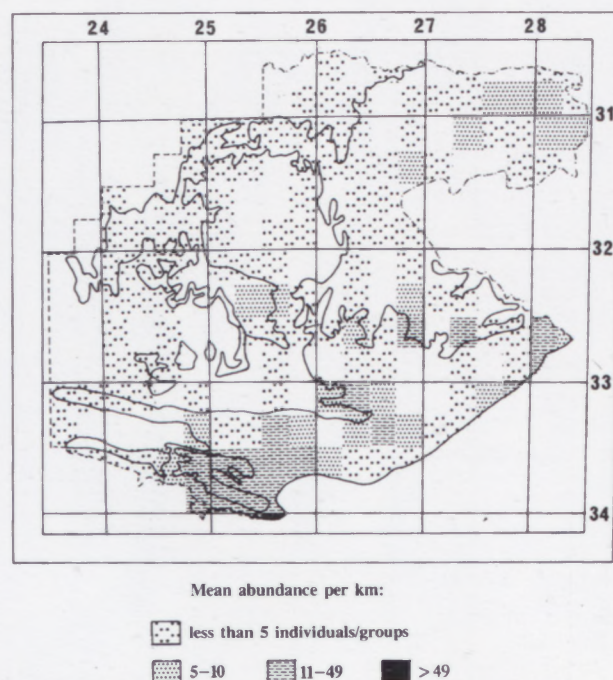


FIGURE 6.—Invasion in roadside and veld habitats in terms of the mean abundance of invaders per kilometre in each quarter degree square.

In this survey the densest populations of *Opuntia ficus-indica* were recorded in the districts of Uitenhage, Port Elizabeth, Addo and Grahamstown (Helspoort and Woodroad Kloof in the Fish River valley). Less dense populations were recorded in the districts of Patensie and Hankey (Gamtoos River valley), Kirkwood, Glenconnor, Kleinpoort (foothills of Kleinwinterhoek and Suurberg ranges), Alexandria, Kenton-on-Sea, Grahamstown (Kariega and Kafferskral River valleys), Adelaide and Fort Beaufort (Koonap River valley), Seymour, Somerset East and Cradock.

Acacia mearnsii (Figure 7D) was the next most prominent invader after *Opuntia ficus-indica* in roadside and veld habitats and the most prominent species in streambank habitats. It was most abundant in the cool and moist regions which support mountain fynbos and moist subtropical grassland. It was frequently recorded in the warmer coastal lowlands but its average abundance was less than in the previous categories.

Whereas *Opuntia ficus-indica* is being kept in check by its natural insect herbivores, *Acacia mearnsii* has tremendous potential to spread. This is largely due to its ability to produce large quantities of long-lived seeds and the absence of natural seed predators. Seed can remain viable for more than 50 years and over 20 000 seeds per square metre can accumulate under an old tree (Stirton 1978). Seed is very efficiently dispersed by water along watercourses, but judging from the dense stands which develop along roadsides, it can also be dispersed in soil by road-building activities and possibly vehicle tyres. I predict that *Acacia mearnsii* will continue to expand its range and that all the cool and moist mountain regions are particularly susceptible to invasion, as well as all watercourses within the Fynbos, Grassland and Savanna Biomes.

In this survey *Acacia cyclops* (Figure 7A) was found to be restricted to the coastal lowlands and mountains. It was

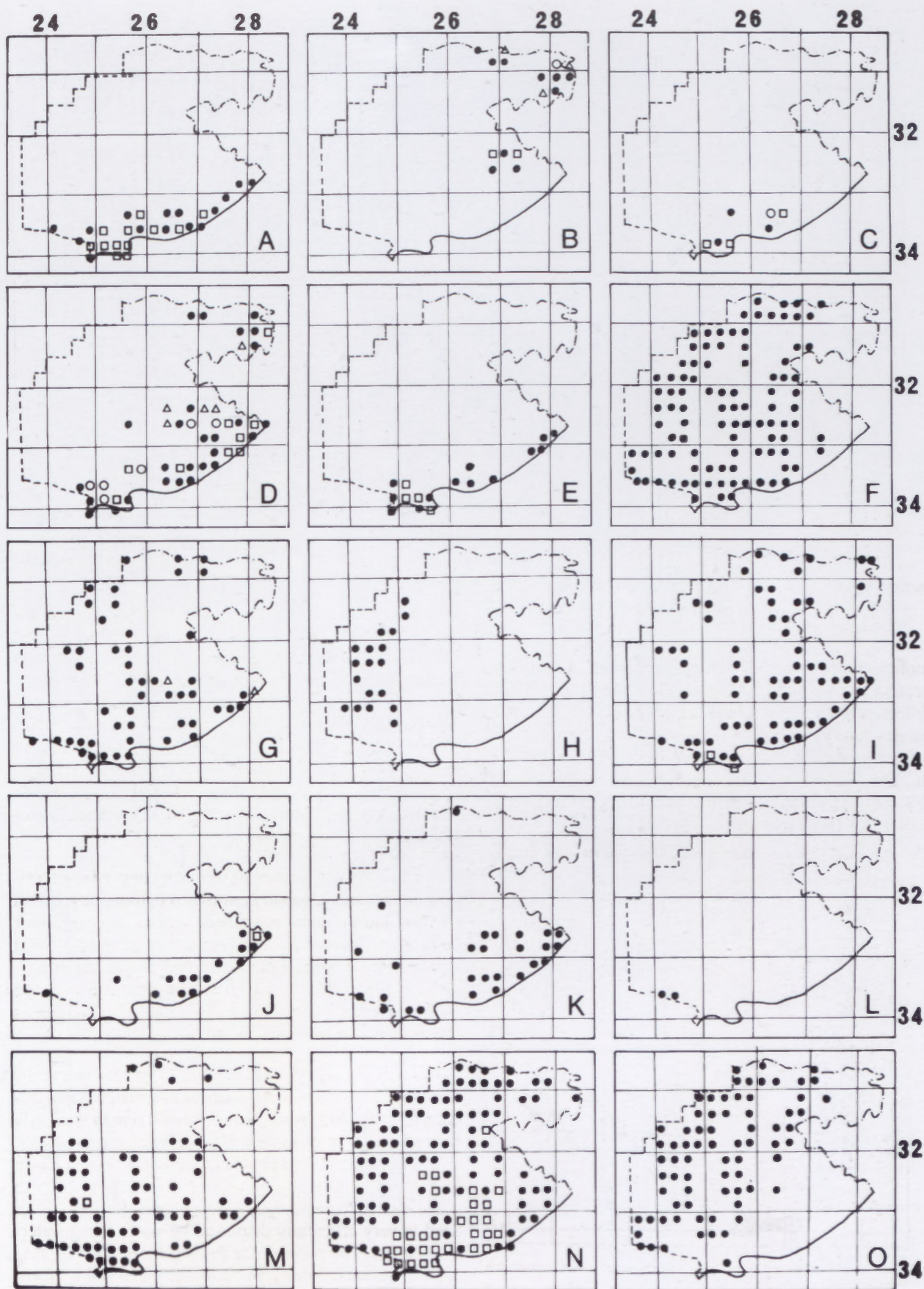


FIGURE 7.—Distribution of the most prominent species: A, *Acacia cyclops*; B, *A. dealbata*; C, *A. longifolia*; D, *A. mearnsii*; E, *A. saligna*; F, *Agave americana*; G, *Arundo donax*; H, *Atriplex* cf. *nummularia*; I, *Eucalyptus* spp.; J, *Lantana camara*; K, *Melia azedarach*; L, *Nerium oleander*; M, *Nicotiana glauca*; N, *Opuntia ficus-indica*; O, *O. cf. robusta* cultivars. Highest abundance rating of 4 or less: ●. Highest abundance rating of 5 or more: roadside and veld habitats, □; streambank habitats, △; streambank, roadside and veld habitats, ○.

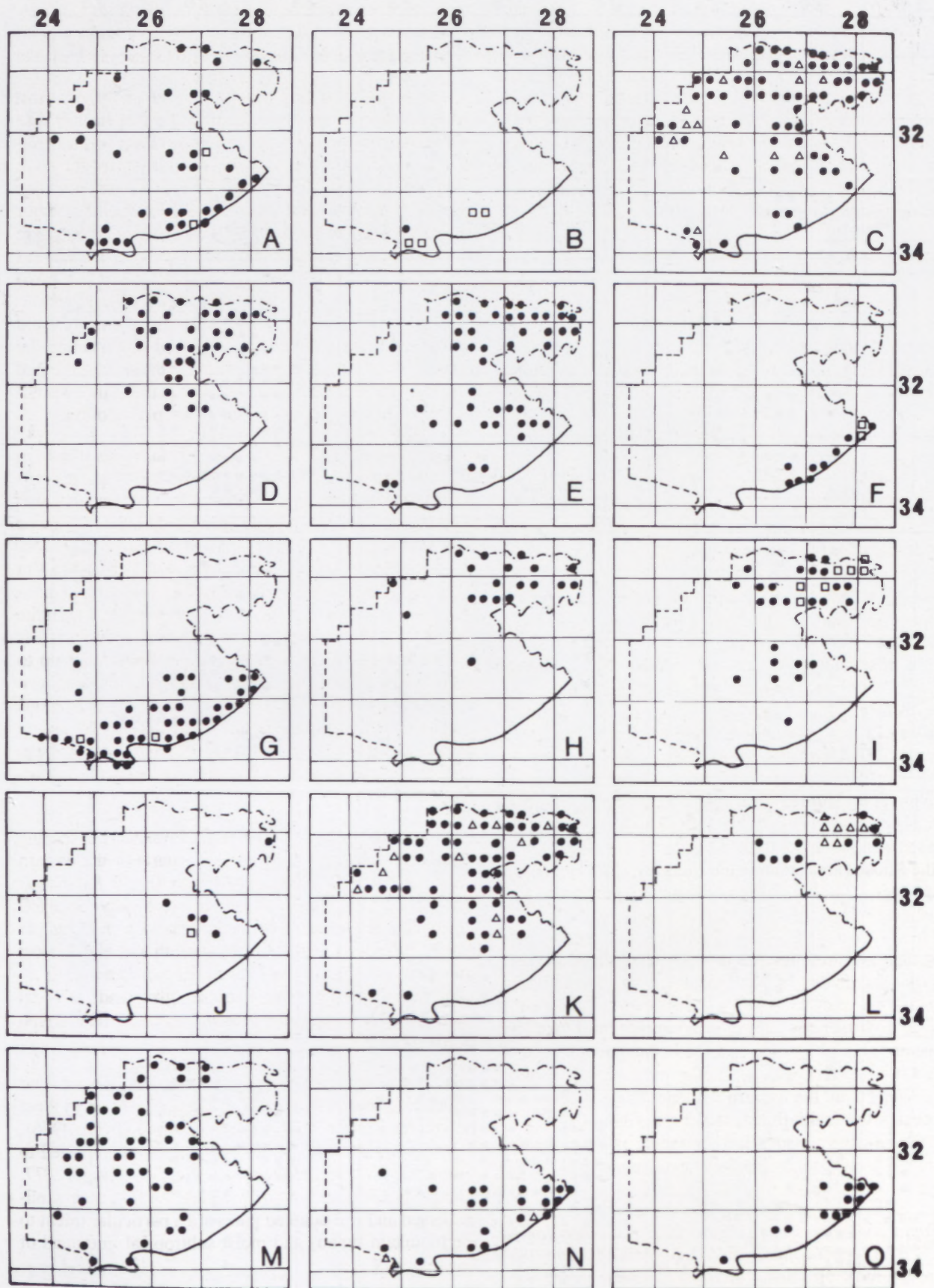


FIGURE 8.—Distribution of the most prominent species: A, *Pinus halepensis*; B, *P. pinaster*; C, *Populus × canescens*; D, *Populus cf. nigra*; E, *Prunus persica*; F, *Psidium guajava*; G, *Ricinus communis*; H, *Robinia pseudoacacia*; I, *Rosa eglanteria*; J, *Rubus affinis*; K, *Salix babylonica*; L, *S. fragilis*; M, *Schinus molle*; N, *Sesbania punicea*; O, *Solanum mauritianum*. Highest abundance rating of 4 or less: ●. Highest abundance rating of 5 or more: roadside and veld habitats, □; streambank habitats, △; streambank, roadside and veld habitats, ○.

heavily invasive in parts of coastal 'forest', subtropical thicket and savanna, and mountain fynbos. It was particularly abundant in coastal dune vegetation around Port Elizabeth where it appeared to be the commonest woody species. Its presence in this area dates back to at least the 1890's when it, *A. saligna*, *A. pycnantha* and *Pinus halepensis* were used in a sand dune reclamation scheme (Stirton 1978). Taylor & Morris (1981) are of the opinion that *A. cyclops* threatens to destroy the structure of indigenous forest precursor communities, grassland and fynbos in coastal vegetation near Port Elizabeth.

Acacia saligna (Figure 7E) had a similar distribution to *A. cyclops*, being restricted to the coastal belt. However, it was only abundant in the Port Elizabeth area in mountain fynbos on the lower slopes of the Vanstadensberg and Elandsberg and in dune vegetation surrounding the airport. It is spreading rapidly in the Grahamstown area and needs to be closely watched (A. Jacot Guillarmod pers. comm.).

Rosa eglanteria (Figure 8I), the sweet brier rose of Europe and Britain, was brought to the eastern Cape by English settlers during the 1820's and shortly afterwards (Palmer 1985). By 1937 it was reported to be a nuisance in the mountainous parts of Barkly East and a possible threat to the indigenous vegetation (National Herbarium, Pretoria). Like many other members of the family Rosaceae it appears to require low winter temperatures to terminate seed dormancy. Its present distribution as a naturalized plant in southern Africa is largely confined to the mountainous districts of Lesotho, Natal, Orange Free State and northeastern Cape (Jacot Guillarmod 1971; National Herbarium, Pretoria). These regions experience the highest frequencies of below-freezing minimum temperatures in southern Africa (Tyson 1986).

This survey showed *Rosa eglanteria* to be heavily invasive in the districts of Barkly East, Rhodes, Naudesnek, Rossouw and Jamestown. It is said to be spreading rapidly in the Rhodes area and that the fruits are eaten by people, Angora goats and birds (W.A. Steynberg pers. comm.).

I predict that *Rosa eglanteria* will become increasingly abundant and troublesome throughout the high altitude grasslands situated on the Stormberg and Drakensberg plateaus, i.e. from Molteno northeastwards to the Lesotho border. However any control programmes must take into account its possible value as a food plant and a source of revenue for local people. According to Palmer (1985) there is a factory in the eastern Orange Free State which processes the fruits (hips), making a vitamin syrup. In Lesotho every rose area has its annual rosehip holiday when the children pick the fruits to raise money for their schools.

Populus × canescens (Figure 8C), *Salix babylonica* (Figure 8K) and *S. fragilis* (fide R.D. Meikle) (Figure 8L) were the most prominent invaders of watercourses after *Acacia mearnsii*. All three species are large (up to 20 m and more in the case of *P. × canescens*), long-lived and can form pure stands along watercourses. *P. × canescens*, unlike the other two species, only reproduces by suckering from the roots and in this way can form dense stands. *S. babylonica*, and apparently *S. fragilis*, reproduce only vegetatively in southern Africa from severed branches (Henderson 1991c). Fast-flowing watercourses in the

mountainous districts favour the propagation of all three species as well as the dispersal of the *Salix* species. Humans have also assisted the dispersal of *Salix* species by planting truncheons along riverbanks and in riverbeds.

Acacia dealbata (Figure 7B) is potentially the most important invader of watercourses in the Grassland Biome of the eastern Cape. This judgement is based on its invasiveness in the grasslands of the Transvaal (Henderson & Musil 1984), Natal (Henderson 1989), Orange Free State (Henderson 1991a) and Lesotho (Talukdar 1981). Major factors contributing to its success as a riverine invader are its massive production of long-lived seed and the efficient dispersal of seed along watercourses. Dean *et al.* (1986) report a seed longevity of 100 years for *A. dealbata*. Biological control using seed attacking enemies would probably be the most effective method of curtailing the spread of both this species and *A. mearnsii*. Conflicts of interest with the Wattle Industry have halted any research in this direction (H.G. Zimmermann pers. comm.).

Acacia longifolia (Figure 7C) and *Hakea sericea* have invaded mountain fynbos in the eastern Cape. In this survey both species were recorded in the Grahamstown area but only *A. longifolia* was recorded on the mountains near Port Elizabeth. The National Herbarium in Pretoria has a record of *H. sericea* dating back to 1976 on the Van Staden's Mountain. Biological control programmes started in the 1970's (for *H. sericea*) and in the 1980's (for *A. longifolia*) offer a means of reducing their vigour and curtailing their spread. Reductions of up to 80% in annual seed production of both species have been recorded (Dennill 1987; Gordon 1990). An indigenous fungus causing gummosis and death in *H. sericea* is particularly devastating (Morris 1982) and has now been used to produce the world's first mycoherbicide (M.J. Morris pers. comm.).

Three *Pinus* species were heavily invasive (i.e. scoring abundance ratings of 5 or more) in parts of the eastern Cape. These were *P. pinaster* (Figure 8B), *P. halepensis* (Figure 8A) and *P. patula*. *P. radiata* was locally abundant. Macdonald & Jarman (1984) ranked *P. pinaster*, *P. radiata* and *P. halepensis* as the fourth, seventh and eighth most important invaders of the Fynbos Biome. *P. patula* is an important invader of moist montane grasslands in Natal (Macdonald & Jarman 1985) and the Transvaal (Henderson & Musil 1984).

All these pines have winged seeds adapted to wind dispersal. *Pinus radiata* seed is able to travel up to three kilometres from its source (Richardson & Brown 1986). *P. radiata*, *P. pinaster* and *P. patula* are all reported to regenerate profusely from seed after a fire (Kruger 1977; Richardson & Brown 1986; Wormald 1975). These wind-dispersed and fire-adapted pines are a particular threat to the mountain fynbos and moist subtropical grassland of the eastern Cape.

Rubus affinis (Figure 8J), recorded during this survey, and *R. phoenicolasius* reported by Phillipson (1990) are potentially important invaders in moist subtropical grassland. Both species are well-established near Hogsback in the Amatole Mountains.

Several species which are heavily invasive along the coastline of Natal in Acocks's Coastal Forest and

Thornveld (Henderson 1989), are also invasive in the eastern Cape at the southern limit of the same veld type. These species are *Psidium guajava* (Figure 8F), *Lantana camara* (Figure 7J), *Solanum mauritianum* (Figure 8O) and *Cestrum laevigatum*. They could become serious invaders within this veld type in the eastern Cape which stretches from the Transkei border to about 50 km south of East London near the Keiskamma River.

Chromolaena odorata, not recorded in this survey, is potentially the most important invader of the stretch of coastline just mentioned. It has been rated as the most important invader in Natal (Macdonald & Jarman 1985) and is largely confined to Acocks's Coastal Forest and Thornveld (Henderson 1989).

Pereskia aculeata, a climbing cactus, is another important invader of coastal forest in Natal (Macdonald & Jarman 1985) and a potentially important invader in the eastern Cape. It was not recorded in this survey but has been reported to be spreading in the Grahamstown and Bathurst areas by Jacot Guillarmod (1988).

Leucaena leucocephala, not recorded in this survey, is a potentially valuable fodder and firewood plant, and is also a potential invader of the coastal lowlands of the eastern Cape. This species is invasive in Natal (Macdonald & Jarman 1985) and is a serious weed in several countries in the tropics (Holm *et al.* 1979). The Department of Agricultural Development has up till now prevented the importation of commercial quantities of seed but it does recognise that *Leucaena* has much potential and should be exploited (V.D. Wassermann pers. comm.). Certain cultivars should be promoted in specific areas but this should exclude the Hawaiian type because of its prolific seeding. Consideration is being given to the introduction of suitable seed-eating insects with a view to curbing further spread of this species in affected areas (V.D. Wassermann pers. comm.).

Opuntia stricta commonly known in South Africa as the Australian Pest Pear because it reached pest proportions in Australia (Mann 1970) is another potentially important invader. It was seldom recorded during this survey but it could have been overlooked because of its low stature. It is said to be spreading in the Savanna Biome between Alexandria on the coast and Grahamstown (H.G. Zimmermann pers. comm.). It is also an invader of savanna vegetation in the northern Cape (Henderson 1991), Natal (Henderson 1989), Transvaal (pers. observ.) and Namibia (Brown & Gubb 1986). It has invaded an area of approximately 10 000 ha south of Skukuza in the Kruger National Park situated in the Transvaal (K. Maggs pers. comm.).

Apart from the riverine invaders already mentioned, only a further four species were recorded as heavily invasive (i.e. scoring abundance ratings of 5 or more) in one or more localities. These were *Acacia longifolia* in Howison's Poort near Grahamstown; *Arundo donax* (Figure 7G) on the coast near East London and in *Acacia* savanna near Adelaide; *Ligustrum* sp. in moist subtropical grassland in the Amatole Mountains; and *Sesbania punicea* (Figure 8N) on the coast near East London and along the Gamtoos River valley in the Hankey and Patensie Districts. The latter infestations are being cleared with the use of herbicides (H.G. Zimmermann pers. comm.). There is

much confidence that a biological control programme, initiated in the 1980's and using three species of introduced weevils, will halt the invasive spread of this plant in South Africa (Hoffmann & Moran 1988).

Species which have not already been discussed and which were heavily invasive in one or more localities in roadside and veld habitats were: *Eucalyptus diversicolor* on the Elandsberg near Port Elizabeth, and unidentified species of *Eucalyptus* (possibly relics of a dune stabilization programme) in dune vegetation near Port Elizabeth (Figure 7I); *Nicotiana glauca* in karoo vegetation near Jansenville (Figure 7M); *Pennisetum* sp. in coastal vegetation near Kidd's Beach (East London District), and *Ricinus communis* in coastal vegetation near Alexandria and in the Gamtoos River valley near Patensie (Figure 8G).

Ricinus communis has generally been regarded as an introduced species in southern Africa possibly from elsewhere in Africa. However, seeds in excess of 1 200 years old have been discovered in archaeological diggings in the Baviaanskloof near Patensie (Brink 1988). This evidence suggests that, if indeed introduced, primitive hunter-gatherers were the agents (Brink 1988). This is in sharp contrast to the majority of our alien weeds which have been introduced since the colonization of the Cape 300 years ago (Brink 1988; Wells *et al.* 1986).

Fifteen species were locally common in one or more localities. These were *Acacia melanoxylon*, *Pinus radiata* and *Solanum mauritianum* in the Amatole Mountains near Stutterheim (all three spp.) and Hogsback (*A. melanoxylon*); *Robinia pseudoacacia* (Figure 8H) (watercourses), *Populus* cf. *nigra* (Figure 8D) (watercourses), *Agave americana* (Figure 7F) (watercourses) and *Prunus persica* (Figure 8E) in temperate grassland; *Agave americana* and *Trichocereus* cf. *spachianus* in arid savanna in the Jansenville District; *Atriplex* cf. *nummularia* (Figure 7H) and *Tamarix* cf. *ramosissima* along watercourses in the karroid western parts; *Nerium oleander* (Figure 7L) along the Baviaanskloof River; *Casuarina cunninghamiana* and *Phytolacca dioica* in the Gamtoos River valley in the Hankey and Patensie Districts; *Melia azedarach* (Figure 7K) in disturbed vegetation around East London; *Opuntia vulgaris* in coastal thicket between Port Elizabeth and Alexandria and *Eucalyptus* spp. (Figure 7I) around Grahamstown. Martin & Noel (1960) estimated that between 15 and 20 *Eucalyptus* spp., as well as hybrids, grow in and around Grahamstown. It was not possible to say how many were cultivated only and how many were naturalized.

Agave americana appeared to be spreading from seed in the Kamferspoort and surrounding areas in the Groot-rivierberge southwest of Jansenville. Several scattered plants were seen growing in high rocky clefts far from any planted specimens. Large plants with copious seed were seen on the plains below the mountains. This was an unusual sighting since *A. americana* usually spreads only very locally by suckering (pers. obs.). It may also be capable of limited spread from bulbils (small plants produced in the axils of the inflorescence).

Relation of invasion to environmental factors

From historical data it is clear that vast retrogressive and even radical changes have taken place in the indigenous

vegetation of the eastern Cape' (Roux & Van der Vyver 1988). These changes have occurred largely since the settlement of European farmers in this region in about 1770 (Jacot Guillarmod 1988). The deterioration of the indigenous vegetation has been associated with overgrazing, poor management practices, bush-clearing and alien plant invasion (Lubke *et al.* 1986; Roux & Van der Vyver 1988; Teague 1988).

Already by 1776 there were reports that the grazing had started to deteriorate rapidly after only seven or eight years of settlement with cattle in the Camdeboo region near Graaff-Reinet (Jacot Guillarmod 1988). It is in the same region that the prickly pear *Opuntia ficus-indica* was first introduced to the eastern Cape and in which it became a serious problem (MacDonald 1891).

While degradation of the indigenous vegetation opened the way for alien plant invasion, there were other factors which influenced the success of individual species. The successful spread and invasion of large areas by *Opuntia ficus-indica* and *O. aurantiaca* can be largely attributed to their adaptability to the prevailing climatic conditions, their efficient dispersal mechanisms and to the absence of natural predators. MacDonald (1891) reported that the seeds of *O. ficus-indica* were spread in the excreta of humans, baboons, birds, cattle, sheep and goats. Even the Addo elephants, before they were fenced in at the Addo Elephant Park, were reported to eat the fruit of *O. ficus-indica* (Archibald 1955). Today the elephants have virtually eliminated *O. ficus-indica* from the Addo Park (Macdonald 1984). *O. aurantiaca* spreads only vegetatively by detached stem sections. These sections are very spiny and readily attach themselves to animals, clothing, shoes and even vehicles. Stem sections of both *O. ficus-indica* and *O. aurantiaca* are dispersed by water.

The absence of natural predators appears to have been one of the most important factors in the successful invasion of *Opuntia ficus-indica*, *O. aurantiaca* and *O. vulgaris* in South Africa. This was demonstrated by the dramatic destruction of dense populations of these species, including the almost complete eradication of *O. vulgaris* following the introduction of their natural insect herbivores (Zimmermann *et al.* 1986). Zimmermann *et al.* (1986) conclude that insect herbivores are also likely to play an important role in determining the abundance and distribution of other alien plant species in South Africa.

The success of some invasive species in the eastern Cape has no doubt been aided by their establishment in large plantations. This certainly seems to be the case with species of *Pinus* and *Acacia*. Notable species which have become invasive are *Pinus pinaster*, *P. halepensis* and *Acacia mearnsii*, all of which have been cultivated commercially for their timber and in the case of *A. mearnsii*, for the tannin in its bark. *P. halepensis*, *A. cyclops*, *A. saligna* and *A. pycnantha* were used for drift-sand reclamation at Port Elizabeth between 1893 and 1897 (Stirton 1978).

Water, or the lack thereof, has possibly been the most important abiotic factor influencing alien plant invasion in the eastern Cape. In terrestrial habitats, most invasion in terms of species diversity and abundance of invaders was recorded in the wetter eastern parts. With the excep-

tion of invasion by a few drought-adapted species, most invasion of the arid central and western interior has been noted only along watercourses.

Watercourses have enabled the long-range dispersal of many species including those which otherwise would be relatively immobile, such as *Acacia mearnsii*, *A. dealbata*, *Sesbania punicea* and *Ricinus communis*. *Salix babylonica* and *S. fragilis* are restricted to watercourses and depend on flowing water for their vegetative dispersal.

Invaders which have successfully invaded fynbos (a fire-adapted vegetation type) have various adaptations which enable them to survive periodic high intensity fires. These adaptations include serotiny (seeds held in heat resistant cones) in *Hakea sericea* and *Pinus pinaster*, and fire-stimulated seed germination in *Acacia longifolia* and *A. mearnsii*.

SOME IDEAS FOR THE FUTURE

Alien plant invasion is likely to increase in all parts of the eastern Cape and particularly in the wetter eastern parts from sea level to an altitude of about 1 300 m. The subregions and their indigenous vegetation types which are most at risk are the coastal belt between the Kei and Keiskamma Rivers (coastal 'forest'), the coastal mountain ranges (mountain fynbos) and southern interior mountain ranges extending from Stutterheim to Somerset East (moist subtropical grassland).

Many invasive species are so well established that their eradication is probably not possible nor feasible. Efforts should however be made to contain their spread and prevent their invasion of new sites. Control programmes should take into account the species complexes which occur in all vegetation categories. The removal of one problem species could simply open the way for other problem species.

Urgent attention should be given to the control, or if possible, the eradication of potentially important invaders which are relatively scarce at this stage. These include *Opuntia stricta* and *Pereskia aculeata*. Steps should be taken to prevent the spread of *Leucaena leucocephala* from plantations. *Chromolaena odorata*, not yet recorded in the eastern Cape, is a potentially serious invader of the coastal belt between the Kei and Keiskamma Rivers. This species must not be allowed to establish itself in the eastern Cape.

Some research priorities suggested are the hydrological impacts of alien plant invaders along watercourses and in mountain catchment areas; the breeding of sterile cultivars of useful but invasive species and methods for the control and utilization of invader species.

ACKNOWLEDGEMENTS

I thank Miss C. Craemer and Mrs J. Greyling of the Plant Protection Research Institute, and Mrs H. Joffe of the National Botanical Institute for their assistance and companionship in the field.

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APPENDIX

The names of 130 species of naturalized alien trees, shrubs and climbers are listed. Some non-woody species are included. Names and dates in brackets indicate literature references. (PRE): cited on National Herbarium specimen labels.

Acacia

baileyana F.J. Muell., Bailey's wattle
cyclops A. Cunn. ex G. Don, red eye

dealbata Link, silver wattle
decurrens (J.C. Wendl.) Willd., green wattle
fimbriata A. Cunn. ex G. Don (PRE)

- longifolia* (Andr.) Willd., long-leaved wattle
mearnsii De Wild., black wattle
melanoxylon R. Br., blackwood
pycnantha Benth. (Stirton 1978), golden wattle
saligna (Labill.) H.L. Wendl., port jackson willow
- Agave*
americana L., century plant
sisalana Perrine, sisal
- Ailanthus altissima* (Mill.) Swingle, tree-of-heaven
Alhagi maurorum Medik. (= *A. camelorum* Fisch.) (PRE), camel thorn bush
- Anredera baselloides* (H.B.K.) Baill. (Martin & Noel 1960)
Araujia sericifera Brot. (Martin & Noel 1960), moth catcher
Arundo donax L., giant reed
Atriplex cf. *nummularia* Lindl., old man saltbush
Bambusa cf. *balcooa* Roxb. ex Roxb., common bamboo
Bambuseae sp. (small unidentified bamboo)
- Caesalpinia*
decapetala (Roth) Alston, Mauritius thorn
gilliesii (Wallich. ex Hook.) Benth., bird-of-paradise
Callistemon citrinus (Curtis) Stapf (PRE), lemon bottlebrush
Canna indica L. (Martin & Noel 1960), canna
Cardiospermum grandiflorum Schwartz (PRE), balloon vine
Casuarina cunninghamiana Miq., beefwood
Cereus peruvianus (L.) Mill. [= cf. *jamacaru* DC. (fide H.F. Glen, pers. comm.)], queen of the night
Cestrum laevigatum Schlecht., inkberry
Citrus sp. (Martin & Noel 1960)
Cortaderia sp., pampas grass
Cotoneaster sp., cotoneaster
Crataegus monogyna Jacq. (PRE), English hawthorn
Crotalaria sp.
Cupressus arizonica Greene, Arizona cypress
Cydonia oblonga Mill., quince
Cyphomandra betacea (Cav.) Sendtn. (Stirton 1979), tree tomato
Cytisus scoparius L. (PRE), Scotch broom
- Eucalyptus*
cladocalyx F.J. Muell., sugar gum
diversicolor F.J. Muell., karri gum
ficifolia F.J. Muell., red flowering gum
globulus Labill. (Salisbury 1919)
grandis Hill. ex Maid. (= *E. saligna* Sm.) (Stirton 1979), saligna gum
lehmannii (Schauer) Benth., spider gum
sp. cf. *camaldulensis* Dehnh., red gum
- Ficus*
carica L., edible fig
?sp., fig
Fraxinus cf. *americana* L., American ash
Gleditsia triacanthos L., honey locust
Glycyrrhiza glabra L. (PRE), liquorice
Grevillea robusta A. Cunn. (L. Henderson, pers. observ. 1981), Australian silky oak
Hakea sericea Schrad., silky hakea
? *Hylocereus* sp.
- Ipomoea*
alba L. (PRE), moon flower
congesta R. Br. (Martin & Noel 1960)
purpurea (L.) Roth (Phillipson 1987), common morning glory
Jacaranda mimosifolia D. Don, jacaranda
? *Juniperus* sp., juniper
? *Lagerstroemia indica* L., pride-of-India
Lantana camara L., lantana
Lavatera arborea L. (Salisbury 1919), tree mallow
Leptospermum laevigatum (Soland. ex Gaertn.) F.J. Muell., Australian myrtle
- Ligustrum*
japonicum Thunb. (PRE), Japanese privet
sinense Lour., privet
?sp., privet
- Melia azedarach* L., syringa
Morus alba L., white mulberry
Myoporum tenuifolium Forst. f. subsp. *montanum* (R. Br.) Chinnock (PRE), manatoka tree
Nerium oleander L., oleander
Nicotiana glauca R.C. Grah., wild tobacco
- Opuntia*
aurantiaca Lindl. (Stirton 1978), jointed cactus
ficus-indica (L.) Mill., sweet prickly pear
imbricata (Haw.) DC., chain-link cactus
lindheimeri Engelm., small round-leaved prickly pear
stricta Haw., pest pear of Australia
vulgaris Mill., cochineal prickly pear
sp. cf. *robusta* cultivars, spineless prickly pears
Paraserianthes lophantha (Willd.) Nielsen subsp. *lophantha*, stinkbean
Parkinsonia aculeata L., Jerusalem thorn
Passiflora caerulea L., blue passionflower
Pennisetum sp.
Pereskia aculeata Mill. (Martin & Noel 1960), Barbados gooseberry
Phoenix cf. *dactylifera* L., real date palm
Phytolacca dioica L., belhambra
- Pinus*
?elliottii Engelm., slash pine
halepensis Mill., aleppo pine
patula Schlecht. & Cham., patula pine
pinaster Ait., cluster pine
pinea L., umbrella pine
radiata D. Don., radiata pine
roxburghii Sarg., chir pine
- Populus*
× *canescens* (Ait.) J.E. Sm., grey poplar
sp. cf. *deltoides* Bartr. ex Marsh., match poplar
sp. cf. *nigra* var. *italica* Muenchh., Lombardy poplar
Prosopis spp. (*P. glandulosa* Torr. var. *torreyana*, mesquite; and possibly other taxa)
- Prunus*
armeniaca L., common apricot
persica (L.) Batsch, peach
sp. cf. *japonica* Thunb. (PRE), Japanese bush cherry
- Psidium guajava* L., guava
- Pyracantha*
angustifolia (Franch.) C.K. Schneid., yellow firethorn
?crenulata (D. Don) M.J. Roem., firethorn
- Quercus robur* L. (Phillipson 1987), English oak
Ricinus communis L., castor-oil plant
Robinia pseudoacacia L., black locust
- Rosa*
eglanteria L., eglantine
odorata (Andr.) Sweet (Phillipson 1987), tea rose
- Rubus*
affinis Weihe & Nees, blackberry
phoenicolasius Maxim. (Phillipson 1990), wineberry
- Salix*
babylonica L., weeping willow
caprea L., pussy willow
fragilis L. (fide R.D. Meikle pers. comm.), basket willow
Sambucus sp., elder
Schinus molle L., pepper tree
- Senna*
corymbosa (Lam.) Irwin & Barneby (Gordon-Gray 1977), autumn 'cassia'
didymobotrya (Fresen.) Irwin & Barneby, peanut-butter 'cassia'
multiglandulosa (Jacq.) Irwin & Barneby (Gordon-Gray 1977)
occidentalis (L.) Link (Schonland 1919), wild coffee
septemtrionalis (Viv.) Irwin & Barneby, arsenic bush
- Sesbania*
punicea (Cav.) Benth., red sesbania
virgata (Cav.) Persoon. (Jacot Guillarmod 1988)
- Solanum*
hispidum Pers., devil's fig
mauritanum Scop., bug tree
pseudocapsicum L. (Phillipson 1987), Jerusalem cherry
sarrachoides Sendtn. (Phillipson 1990)
seafortianum Andr., potato creeper
Tamarix cf. *ramosissima* Ledeb., pink tamarisk
Trichocereus cf. *spachianus* (Lemaire) Riccobono, torch cactus
Ulex europaeus L. (Phillipson 1987), gorse
Ulmus spp., elms; at least two spp.
? *Washingtonia* sp., petticoat palm
Yucca aloifolia L. (Martin & Noel 1960), Spanish bayonet

