

# Exotic woody plant invaders of the Transvaal

L. HENDERSON\* and K. J. MUSIL\*

**Keywords:** alien, checklist, distribution, woody invader, survey, Transvaal

## ABSTRACT

The frequency and abundance of exotic, woody plant invaders were recorded in 60% of the quarter degree squares in the study area. Sixty-one invaders were encountered of which the most important and aggressive were *Acacia dealbata*, *Populus* spp., *Melia azedarach*, *Opuntia ficus-indica*, *Salix babylonica* and *Acacia mearnsii*.

Invasion patterns are discussed and an attempt is made to correlate distribution with environmental factors. Attention is drawn to the areas of greatest invasion and the areas that are liable to show the greatest expansion in the future.

## 1 INTRODUCTION

### 1.1 Survey history and objectives

The objectives of this survey are: to produce a checklist of the major exotic, woody invaders of streambank, roadside and veld habitats in the Transvaal (see Appendix); to determine the pattern of exotic woody invasion as a whole and for individual species; to attempt to correlate distribution with environmental factors; to determine which are the most important and aggressive invaders.

The first part of the Transvaal that was surveyed was the south central region, 10 000 km<sup>2</sup> (Wells *et al.*, 1980). The survey was then extended to include the section east of Pretoria to the Kruger National Park, and stretching from Volksrust in the south to Louis Trichardt in the north (Duggan & Henderson, 1982). The survey has now been completed with the inclusion of 113 samples in the western sector and a further 58 samples in the eastern sector (Fig. 1).

### 1.2 The study area

The Transvaal covers an area of approximately 262 449 km<sup>2</sup>. The greater part of the province consists of table lands (highveld) ranging from 600 – 1 800 m in altitude, the highest point being in the east where the Drakensberg overlooks the lowveld. The lowveld (altitude range of 200 – 600 m) and the low-lying portions of the northern and central sections of the province have a tropical to sub-tropical climate. The southern highveld and the upper slopes of the escarpment are more temperate and experience frost in winter.

The highest rainfall in the Transvaal occurs along the upper slopes of the Drakensberg escarpment and the average rainfall can exceed 2 000 mm per annum.

The driest parts of the Transvaal occur along the Limpopo River Valley in the north and surrounding country, the eastern lowveld and the south-western Transvaal. These parts experience a mean annual rainfall of 250 – 500 mm.

The rest of the Transvaal receives a mean annual rainfall of 500 – 900 mm, with the rainfall generally increasing from west to east.

Indigenous woody vegetation is concentrated on the wet escarpment face, where tropical forests occur (Acocks Veld Types 8, 9) and in the hot, drier lowveld and middleveld where bush and savanna types occur (Acocks Veld Types 10, 11, 12, 13, 14, 15, 16, 18, 19, 20). The cooler highveld is mostly covered by grassveld (Acocks Veld Types 48, 50, 52, 53, 54, 55, 57) and false grassveld (Acocks Veld Types 61, 62, 63, 64, 67) with scrub and woodland fringing the streams (Fig. 2) (Acocks, 1975).

## 2 METHOD

### 2.1 Sampling method and intensity

The sampling method was specifically designed to make use of otherwise unproductive travelling time whilst officers are engaged on other projects.

The method consisted of making continuous recordings of roadside and veld invaders from a moving vehicle and of streambank invaders at water-course crossings (preferably while the vehicle was stationary). Abundance ratings were based on frequency of encounter within each sample unit (the quarter degree square). Abundance ratings for streambank habitats were based on estimates at specific sites.

### 2.2 Abundance ratings

Since the last publication (Duggan & Henderson, 1982) changes have been made to the abundance ratings for roadside and veld habitats. Two ratings have been inserted between the original 5 and 6 ratings and 2 have been inserted below the old rating 1, i.e. there are now 11 abundance ratings. This was done because the gap between the 5 and 6 ratings was too large and the rating 1 was not low enough to accommodate the most infrequently occurring species.

The abundance ratings for roadside and veld habitats and streambank habitats are given in Table 1.

\* Botanical Research Institute, Department of Agriculture, Private Bag X101, Pretoria 0001.



TABLE 1. — Abundance ratings

Rating	Roadsides and veld	Streambanks	Rating
9	A virtually continuous, almost pure stand		7
8	The commonest species in a generally continuous tree or shrub layer		6
7	Less abundant than above but greater than 20 individuals or groups per km		
6	10–20 individuals or groups per km		
5	5–10 individuals or groups per km	1 of the 2–3 commonest species in a generally continuous tree or shrub layer	5
4	2–5 individuals or groups per km	1 of the 4–6 commonest species in a generally continuous tree or shrub layer	4
3	± 1 individual or group per km	1 of the 7–11 commonest species in a generally continuous tree or shrub layer	3
2	Less abundant than above but more than 1 individual or group per 5 km	Less abundant than above but more than 1 individual present	2
1	± 1 plant or group per 5–10 km	1 plant in a sample	1
<1	1 plant or group per 10–30 km		
<<1	1 plant or group per 30–64 km or more		

### 2.3 Sampling level envisaged and achieved

The minimum sampling level that was envisaged for the Transvaal was 40% of the total quarter degree squares at an average of 64 km per square. This was based on an analysis of the effectivity of sampling at various levels (Henderson & Duggan, unpublished report).

The sampling level that has been achieved is: 60% (248 of the total 410 quarter degree squares) at an average of 33 km per square. That is, a greater number of sampling units was sampled but at a less intensive level. Twenty-two out of the total of 24 veld types recognized by Acocks (1975) as being present in the Transvaal were sampled. The smallest veld types, numbers 53 and 55 were unsampled.

TABLE 2.—Veld type coverage, excluding pilot study area

Veld type	No. ¼ degree squares sampled	Kilometres travelled
8	23	408
9	17	387
10	13	306
11	12	272
12	12	279
13	5	139
14	23	505
15	18	382
16	14	366
18	62	1 424
19	52	948
20	8	153
48	13	288
50	19	461
52	9	168
54	3	101
57	21	480
61	22	640
62	3	53
63	13	327
64	1	20
67	6	161
Total:	248	8 268

Invader species were recorded separately in each veld type passed through in each sample unit.

The sampling coverage for each Acocks veld type in terms of quarter degree squares sampled and total kilometres travelled is shown in Table 2. The number of water-course recordings, quarter degree squares sampled and kilometres travelled in each of the four broad veld type categories, tropical veld types, temperate veld types and the whole survey area are shown in Table 3.

TABLE 3.—Veld type coverage, excluding pilot study area

Veld type category	Mileage (km)	¼ degree squares	Stream-bank recordings
I Inland tropical forest types	795	33	72
II Tropical bush and savanna types	4 774	156	166
III Pure grassveld types	1 498	61	86
IV False grassveld types	1 201	43	86
Tropical veld types (I + II)	5 569	171	238
Temperate veld types (III + IV)	2 699	95	172
Total:		248	410

### 3 RESULTS

Sixty-one invaders were encountered in the Transvaal. These species are listed in the checklist together with a further 17 which were obtained from various literature and other sources (see Appendix).

#### 3.1 The streambank habitat

Four hundred and ten recordings were made in which 40 different exotic, woody invader species were recorded, with up to 9 species in one sample.

##### 3.1.1 Analysis according to veld type

The number and abundance of invader species recorded in streambank samples in each of the four broad veld type categories are given in Table 4.



TABLE 4.—The number and abundance of invader species recorded in streambank samples

	Total no. of species	Average no. of species per sample	Abundance ratio
Forest	30	2,9	1,9
Bushveld	27	2,0	1,1
False grassveld	17	1,8	1,2
Pure grassveld	14	1,4	1,0

### 3.1.2 Analysis according to species

3.1.2.1 *Frequency*: The percentage frequency of occurrence of exotic woody invader species along streambanks in forest, bushveld, false grassveld, pure grassveld, as well as in tropical and temperate veld types and in the whole survey area is shown in Figs 3 – 9. Fig. 9 (whole survey area) confirms the earlier finding (Duggan & Henderson, 1982) that the most widespread invaders are: *Salix babylonica*, *Populus alba/canescens* (see checklist for explanation), *Acacia dealbata* and *Melia azedarach*. The latest sampling, however, has shown that:

1. *Salix babylonica* is not the most frequent invader throughout the temperate veld types but in the false grassveld it is superseded by *Acacia dealbata* and joined by *Populus alba/canescens* and *Acacia mearnsii* (Fig. 5),

2. *Melia azedarach* is not the most frequent invader throughout the tropical veld types, there being several more frequent invader species in the forest veld types,

3. *Acacia dealbata* and *Acacia mearnsii* are more frequent, particularly in the temperate veld types, than was previously recorded. Although these species (together with *Psidium guajava* and *Caesalpinia decapetala*) were not recorded in the western Transvaal — a total of 113 quarter degree squares — this is most likely due to unavailability of source plants and not unsuitability to the environmental conditions,

4. An additional 18 exotic, woody invader species have been recorded since our last report. These include: *Agave* spp., *Eucalyptus* spp., *Pinus* spp. including *P. patula*, *Opuntia ficus-indica*, *Toona ciliata*, *Populus nigra*, *Pyracantha angustifolia* and *Bambusa balcooa*.

3.1.2.2 *Importance*: The importance value for each species was calculated as follows:

$$\text{importance value} = \frac{\frac{\text{total abundance of a sp.}}{\text{sum of the abundance values of all spp.}} \times \frac{100}{1} + \frac{\text{frequency of a sp.}}{\text{sum frequency of all spp.}} \times \frac{100}{1}}$$

The species with the highest importance values and which collectively added up to a total of approximately 160 points (out of a maximum of 200 points) were plotted in Figs 10, 11 & 12.

A comparison of the percentage frequency histogram Fig. 9 and importance histogram Fig. 12 for the whole survey area shows that *Salix*

*babylonica* retains its position at the top, but *Acacia dealbata* supersedes *Populus alba/canescens* to take second place. The gap between the latter species and *Melia azedarach* is lengthened and *Acacia mearnsii* supersedes *Ricinus communis* to take 5th position.

In the temperate veld types *Salix babylonica* retains top position but the gap between this species and *Acacia dealbata* is reduced. *Populus alba/canescens* retains third position. In the tropical veld types *Melia azedarach* and *Populus alba/canescens* retain first and second positions respectively. *Acacia dealbata* supersedes *Salix babylonica* and *Ricinus communis* to take third position.

3.1.2.3 *Aggressiveness*: If species aggressiveness is gauged by its ability to penetrate and suppress existing vegetation (Duggan & Henderson, 1982) then the most aggressive species overall, in order, are *Acacia dealbata*, *Melia azedarach*, *Populus alba/canescens*, *Salix babylonica* and *Acacia mearnsii*. Locally aggressive species include *Caesalpinia decapetala*, *Psidium guajava*, *Arundo donax*, *Jacarana mimosifolia* and *Sesbania punicea*.

### 3.2 Roadside and veld habitats

Exotic woody invaders were encountered in 212 (86%) of the 248 quarter degree squares sampled.

Sixty invader species were recorded, with an additional 24 species being recorded since the last publication. The new species include in the western Transvaal: *Opuntia* cultivar with round, blue-green cladodes, *Gleditsia triacanthos*, *Prosopis velutina*, *Schinus molle* and *Trichocereus* sp. and in the eastern Transvaal: *Toona ciliata*, *Tecoma stans*, *Bauhinia variegata*, *Bambusa balcooa*, *Passiflora edulis* and *Rosa* sp.

#### 3.2.1 Analysis according to veld type

The number and abundance of invader species recorded in roadside and veld samples in each of the four broad veld type categories are shown in Table 5.

TABLE 5.—The number and abundance of invader species recorded in roadside and veld samples

	Total no. of species	Average no. of species per sample unit	Abundance ratio
Forest	39	7,6	4,2
Bushveld	43	3,6	1,1
False grassveld	34	5,3	1,8
Pure grassveld	28	3,4	1,0

#### 3.2.2 Analysis according to species

3.2.2.1 *Frequency*: The recorded percentage frequency of occurrence of invader species in the veld type groupings and in the whole survey area are shown in Figs 13 – 19. The most frequent and widespread invaders are *Opuntia ficus-indica*, *Melia azedarach* and *Eucalyptus* spp. In the temperate veld types *Eucalyptus* spp., *Opuntia ficus-indica*, *Acacia dealbata*, *A. mearnsii*, *Melia azedarach* and *A. decurrens* are the most widespread species. *Melia azedarach* and *Opuntia ficus-indica* are by far the



most widespread invaders in the tropical veld types, particularly the bushveld which occupies the greatest area.

A comparison of Fig. 13 (forest) and Fig. 14 (bushveld) reveals great differences:

1. In forest, approximately 24 species have a percentage frequency greater than 10% compared with only about 10 species in bushveld.

2. In bushveld only *Opuntia ficus-indica* and *Melia azedarach* were recorded in more than 30% of the sample units, whereas in forest at least 11 species were recorded in more than 30% of the sample units.

3. A number of species which are well represented (27% frequency and higher) in forest namely *Solanum mauritianum*, *Rubus* spp., *Caesalpinia decapetala*, *Pinus* spp. and *Acacia mearnsii* are poorly represented in bushveld.

These differences indicate that invasion has progressed furthest in forests and that the bushveld has a greater resistance to invasion. The greater degree of invasion in forest can be attributed mainly to the more favourable growing conditions throughout and the greater disturbance that these veld types have been subjected to. Large tracts of bushveld are very dry and inhospitable to the more mesic invader species such as those mentioned under point 3 above.

**3.2.2.2 Importance:** The importance values for roadside and veld invader species were calculated in the same way as for streambank invaders. Again, the species with the highest values and which collectively added up to a total of approximately 160 points were plotted (Figs 20, 21 & 22).

A comparison of the percentage frequency histogram Fig. 19 and importance histogram Fig. 22 shows that for the whole survey area *Opuntia ficus-indica*, *Melia azedarach* and *Eucalyptus* spp. retain first, second, and third positions respectively. *Solanum mauritianum* climbs from about 11th position to 4th position. *Acacia dealbata* and *A. mearnsii* shift from 6th to 5th position. Both *Agave* spp. and *Ricinus communis* drop considerably.

*Solanum mauritianum* climbed from obscurity in the percentage frequency histogram to prominence in the importance histogram because of the very large numbers of individuals that were recorded in a few quarter degree squares along the Drakensberg escarpment. In contrast the *Agave* spp. and *Ricinus communis* plummeted in position because they generally occurred in small numbers.

In the temperate veld types *Acacia dealbata* and *A. mearnsii* overtake *Eucalyptus* spp. to take first and second positions respectively, thus indicating that they are very much more abundant than the *Eucalyptus* spp. In the tropical veld types *Opuntia ficus-indica* and *Melia azedarach* retain first and second positions respectively. *Solanum mauritianum* and *Eucalyptus* spp. climb to third and fifth positions respectively. *Jacaranda mimosifolia* drops one position to fourth place and *Agave* spp. and *Ricinus communis* drop to tenth and eighth positions respectively.

**3.2.2.3 Aggressiveness:** Overall, the most aggressive species are *Melia azedarach*, *Acacia dealbata* and *Opuntia ficus-indica*. Locally aggressive species include: *Lantana camara*, *A. mearnsii*, *A. melanoxylon*, *Pinus patula*, *Solanum mauritianum*, *Jacaranda mimosifolia*, *Psidium guajava*, *Toona ciliata* and *Eucalyptus* spp.

### 3.3 Invasion patterns

The pattern of invasion for the Transvaal as a whole is uneven with respect to both diversity and abundance of species. The high diversity and abundance areas occur in and around major towns and cities, and in the eastern Transvaal along the foothills and slopes of the Drakensberg escarpment.

The pattern of species diversity for the Transvaal is illustrated in Fig. 23, which gives the distribution of quarter degree squares in which 6 or more roadside and veld invader species were recorded. A similar pattern was obtained for streambank invaders.

The distribution maps of the most important species (Figs 23 – 32) also illustrate an uneven invasion pattern. The high abundance areas of all the species overlap to the greatest extent in the degree squares 2330 (Tzaneen District), 2430 (Pilgrims Rest District) 2530 (Lydenburg District) and 2630 (Carolina District).

Overall the degree square with the greatest abundance and diversity of invader species was 2530 — which includes the towns of Lydenburg, Belfast, Machadodorp, Sabie and Nelspruit. This degree square is also one of the most variable in the Transvaal with respect to topography, climate and indigenous veld types. It has a high rainfall and has been greatly disturbed.

The western parts of the Transvaal have been subject to much less invasion than the eastern parts. Contributing factors include less disturbance, the absence of large and extensive plantations of invader species, a drier climate and a landscape that offers a smaller range of habitats and niches for invading species.

## 4 DISCUSSION AND CONCLUSIONS

### 4.1 Sampling

As mentioned in the previous paper (Duggan & Henderson, 1982), the sampling method has its limitations such as the undersampling of certain habitats and the less distinctive species. The method, however, has proved successful and economical in obtaining information that otherwise would have been unobtainable. It has also provided an initial broad survey which can serve as a basis for further intensive work on more restricted areas.

One recommendation that we have with regard to the sampling method is that a standard roadside transect length of about 10 km be used within each veld type or sample unit in recording abundance values of roadside and veld species. This would enable all the records obtained to be compared directly and simplify the computation of average and total abundance values. If this recommendation is adopted, the abundance ratings <1 and <<1 will fall



away. In addition, the use of many short standard transect lengths instead of one or a few long ones, will also provide more recordings which is statistically desirable and would also reveal variation that otherwise would not be apparent.

#### 4.2 Important species

This survey has underlined the invasive importance of *Acacia dealbata*, *Melia azedarach*, *Opuntia ficus-indica*, *Acacia mearnsii*, *Salix babylonica* and *Populus alba/canescens*.

All these species, with the exception of *Opuntia ficus-indica*, are invaders of the streambank habitat and two of them (*Salix babylonica* and *Populus alba/canescens*) are virtually restricted to the streambank habitat. *Acacia dealbata*, *A. mearnsii*, *Melia azedarach* and *Opuntia ficus-indica* are all important invaders of roadside and veld habitats.

Further sampling since the last publication has confirmed the observation that *Acacia dealbata* is an aggressive and dangerous invader. *Acacia mearnsii* has proved to be of greater importance than was previously believed, particularly in the moist forested and false grassveld areas. Both these species are either absent or very rarely encountered in the western Transvaal. If seed was made available, however, both species could extend their range into these parts mainly along water-courses and into the moister bushveld areas, e.g. the Waterberg.

*Melia azedarach* and *Opuntia ficus-indica* have proved to be the most widespread invader species in the Transvaal as a whole. Both species are highly penetrative and are found far from any plantings.

Several potentially important invaders have been recorded since the last publication. These include *Pinus patula*, *Toona ciliata*, *Prosopis velutina*, *Schinus molle* and *Trichocereus* sp.

*Pinus patula* is an extremely aggressive invader of the moist and cool, forested regions of the Drakensberg escarpment. This species seeds prolifically, colonizing roadsides, road cuttings and other disturbed places, plantations of other tree species and indigenous forest, scrub and grassland. At least one other species of pine is also invasive in these parts. (According to the Sabie regional forestry office, *P. taeda* and *P. elliotii* are also naturalized in places.)

*Toona ciliata* is a tree similar in appearance to *Melia azedarach* and belonging to the same family, Meliaceae. *T. ciliata* is naturalized in the Barberton, Nelspruit and Duiwelskloof areas and possibly elsewhere. Like *Melia azedarach*, it has become a roadside weed and has invaded watercourses, bushveld and forest. This species, however, is less drought and frost resistant than *Melia azedarach* and therefore has a potentially smaller distribution.

*Passiflora edulis* is another species that has become naturalized in the moist bushveld and forests of the eastern Transvaal. The climbing growth habit of the species, however, made it difficult to record and therefore we have little information on its percentage frequency and abundance. Mr M. J. Wells of the Botanical

Research Institute (pers. comm.) reports that it is very frequent, particularly in remnant forests that survive between plantations.

*Prosopis velutina*, *Schinus molle* and *Trichocereus* sp. have been recorded in the dry south western Transvaal. At present these species are very localized but have the potential to spread.

*Pyracantha angustifolia*, which was recorded in the pilot study area, has been recorded since the last publication. At present this species occurs in small numbers at scattered localities, mainly in the southern grassland areas of the Transvaal. This species, together with the *Cotoneaster* spp. (*C. pannosa* recorded in pilot study area) are potentially important invaders in the colder parts of the Transvaal where they have been planted because of their resistance to cold and for their attractive berries.

The berries of these species are well-liked by birds particularly since they are produced in winter when there is very little other food available on the cold highveld. The dispersal of the fruits by birds enables these species, and other suitable fruit-bearing plants such as *Ligustrum* spp., *Lantana camara*, *Melia azedarach*, *Morus alba*, *Psidium guajava* and *Solanum mauritianum*, to spread far afield and to reach inaccessible places from which reinfestation can take place.

Species which have assumed greater importance, as a result of better recording, since the last publication include *Acacia melanoxylon*, *Solanum mauritianum* and *Eucalyptus* spp. All these species are the most abundant in the cool, moist forested regions of the eastern Transvaal.

*Solanum mauritianum* is a species which we suspect has been undersampled. It was seldom seen except in the eastern Transvaal where it occurred in greater numbers than any other exotic woody invader in the Transvaal. It is particularly bad as an understorey weed in pine plantations, being able to tolerate considerable shading.

At present *Acacia melanoxylon* is fairly localized but has a potentially wide distribution coinciding with the cool, moist parts of the Transvaal. Small plants were often seen far from any planting, particularly along roadsides and in clearings in plantations and forests.

The *Eucalyptus* spp. are, on the whole, relatively unaggressive species. In the forestry areas of the eastern Transvaal, however, they assume their greatest importance. Several species seed themselves, of which the most prolific is *E. grandis*.

#### 4.3 Correlation of invasion with environmental factors

Overall the warmer tropical forest, bush and savanna veld types were generally more subject to invasion by exotic, woody species than were the cooler, temperate grassveld and false grassveld types.

In the streambank habitat, 36 of the 40 species recorded occurred in the tropical veld types compared with 20 species in the temperate veld types.



In roadside and veld habitats, 53 of the 60 species occurred in the tropical veld types compared with 42 species in the temperate veld types.

Further sampling since the 1982 publication has allowed for a more in-depth study of the correlation between invasion and veld type. The results have shown that considerable differences exist between the inland tropical forest types, tropical bush and savanna types, false grassveld and pure grassveld types.

If the degree of invasion is gauged by the abundance and species diversity of invaders per sampling unit and water-course recording then the inland tropical forest types show the greatest invasion in streambanks, roadside and veld habitats. The false grassveld types take second place in roadside and veld habitats followed by the tropical bush and savanna and pure grassveld types.

Although the tropical bush and savanna types have the most recorded invader species, they occupy the largest area and account for 63% of the samples. Invasion of the bushveld is also very patchy — with large tracts of dry veld relatively undisturbed while other parts again have been severely disturbed, for example the moist bushveld, Acocks 10, in the eastern Transvaal.

In the streambank habitat there is little difference in the abundance and species diversity values for the bushveld and false grassveld types. The pure grassveld types have the least number of exotic, woody invader species, and the lowest species abundance and diversity values.

#### 4.4. Prospects for the future

Invasion is expected to increase in all parts of the Transvaal. The greatest expansion is liable to occur in the moist and warm areas which are favourable for plant growth — namely the forests, moist bushveld and warmer false grassveld areas (south-eastern Transvaal).

The stability of the forests has been so weakened by clearing for afforestation that they have been made exceedingly vulnerable to invasion by a wide spectrum of exotic invaders. The moist bushveld has been disturbed to a lesser extent, but the climatic conditions are favourable for the growth of many exotic species. The false grassveld is favourable for fewer exotic species, but offers much less competition to invading species because of its relatively few indigenous woody species.

The very dry bushveld areas of the Transvaal are probably in the least danger from invading exotics. The combination of unfavourable climatic conditions and a well-adapted indigenous woody component act as barriers to exotic species. Rivers and streams, however, are more vulnerable to invasion and permit the entry of moisture-loving species into an otherwise inhospitable environment.

Although severe frosts help to limit the spread of many potential invader species in the cold grassveld areas, these veld types are vulnerable because of their lack of a natural woody component. Frost-hardy, exotic species are therefore able to invade unoccupied niches with relatively little competition.

The ultimate prospects for the future if action is not taken against the invading species are very bleak indeed:

1. The few remaining relics of natural forest are liable to be almost totally replaced by exotics.
2. In the moist bushveld exotic species will replace many of the indigenous species, altering the basic appearance and character of the veld.
3. In the dry bushveld one can expect fewer exotic invaders but one or a few dominant species which will take over large tracts of land at the expense of the indigenous species.
4. The grassveld and false grassveld areas will probably undergo the greatest change in appearance by acquiring a woody element that was either totally lacking or poorly represented before.
5. The indigenous streambank vegetation throughout the Transvaal is in grave danger of being almost totally replaced by exotic, woody invaders.

#### UITTREKSEL

*Die frekwensie en getalsterkte van uitheemse houtagtige plantindringers was in 60% van die kwartgradevierkante in die studiegebied opgeteken. Een-en-sestig indringers is aangetref waarvan die belangrikste en die aggressiefste Acacia dealbata, Populus spp., Melia azedarach, Opuntia ficus-indica, Salix babylonica en Acacia mearnsii was.*

*Indringingspatrone word bespreek en 'n poging word aangewend om verspreiding met omgewingsfaktore in verband te bring. Die gebiede van grootste indringing en die gebiede waar die grootste uitbreiding in die toekoms sal voorkom is onder die aandag gebring.*

#### REFERENCES

- ACOCKS, J. P. H., 1975. Veld types of South Africa. *Mem. bot. Surv. S. Afr.* 40: 1-128.
- BAILEY, L. H., 1963. *The standard cyclopedia of horticulture*. Vols 1-3. New York: Macmillan.
- BAILEY, L. H. & BAILEY, E. Z., 1976. *Hortus third*. New York, London: Macmillan.
- BRICE BRUCE, A. P., 1979. *A key to the eucalypts in southern Africa*. Pietermaritzburg: University of Natal.
- BRITTON, N. L. & ROSE, N. J., 1963. *The Cactaceae; descriptions and illustrations of plants of the cactus family*. Vol 2. New York: Dover Publications.
- BURGER, G., 1972. Rochdale. *Trees S. Afr.* 24: 58-66.
- DE WINTER, B., VAHRMEIJER, J. & VON BREITENBACH, F., 1978. *The national list of trees*. Pretoria: Van Schaik.
- DUGGAN, K. J. & HENDERSON, L., 1982. Progress with a survey of exotic, woody plant invaders of the Transvaal. *Proceedings of the fourth National Weeds Conference of South Africa, 1981*. Cape Town: Balkema.
- HENDERSON, L. & DUGGAN, K. J., 1981. The minimum effective sampling level for the determination of the major exotic, woody plant invaders, the frequency of occurrence and relative importance and major invasion trends in the central Transvaal. Unpublished.
- HUBBARD, C. S., 1926. A review of the species of *Populus* introduced into South Africa. *S. Afr. J. Sci.* 23: 340-365.
- PALGRAVE, K. C., 1977. *Trees of southern Africa*. Cape Town: Struik.
- PURSEGLOVE, J. W., 1968. *Tropical crops, dicotyledons*. Vols 1 & 2. London: Longmans.
- ROSS J. H., 1975. The naturalized and cultivated exotic *Acacia* species in South Africa. *Bothalia* 11: 463-470.



- ROSS, J. H., 1975. Mimosoideae. In J. H. Ross, *Fl. S. Afr.* 16, 1: 6-7.
- STIRTON, C. H., 1978. *Plant invaders, beautiful but dangerous*. Cape Town: Department of Nature and Environmental Conservation of the Cape Provincial Administration.
- WELLS, M. J., DUGGAN, K. J. & HENDERSON, L., 1980. Woody plant invaders of the central Transvaal. *Proceedings of the third National Weeds Conference of South Africa, 1979*. Cape Town: Balkema.

# APPENDIX

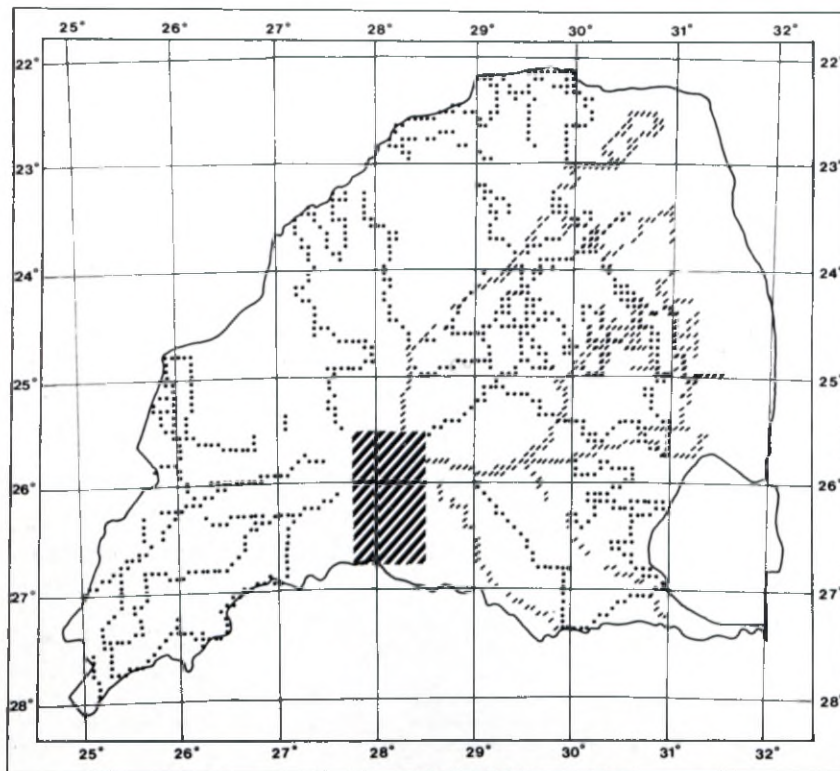
## SPECIES CHECKLIST

- \* Species recorded in pilot study area only  
 \*\* Species recorded in pilot study area subsequent to survey  
 + Personal communication — not supported by herbarium specimens  
 ++ Cited on national herbarium specimen labels  
 × Cited in various literature sources

<i>Acacia baileyana</i> F.J. Muell.	Bailey's wattle
<i>dealbata</i> Link	Silver wattle
<i>decurrens</i> (Wendl.) Willd.	Green wattle
* <i>elata</i> A. Cunn. ex Benth.	Cedar wattle
<i>longifolia</i> (Andr.) Willd.	Golden wattle
<i>meurnsii</i> De Wild.	Black wattle
<i>melanoxylon</i> R. Br.	Blackwood
<i>podalyrifolia</i> A. Cunn. ex G. Don	Pearl acacia
<i>Agave</i> spp. ( <i>A. americana</i> L., <i>A. sisalana</i> Perrine and possibly other species)	Century plants/ Sisal hemp
<i>Arundo donax</i> L.	Giant/Spanish reed
<i>Bambusa balcooa</i> Roxb.	Indian bamboo
<i>Bauhinia variegata</i> L.	Orchid tree
<i>Caesalpinia decapetala</i> (Roth.) Alston	Mauritius thorn
<i>gilliesii</i> (Wallich ex Hook.) Benth.	Bird-of-paradise
<i>Carica papaya</i> L.	Paw paw/papaya
<i>Cassia didymobotrya</i> Fresen.	Peanut butter cassia
<i>floribunda</i> Cav.	
<i>Casuarina</i> sp.	Beefwood
<i>Cereus peruvianus</i> (L.) Mill.	Apple cactus
<i>Citrus</i> sp.	Orange
++ <i>Cotoneaster glaucophylla</i> Franch.	Cotoneaster
* <i>pannosa</i> Franch.	Cotoneaster
++ <i>Crataegus crenulata</i> Roxb.	Hawthorn
<i>Crotalaria agatiflora</i> Schweinf.	Canary-bird bush
+ <i>Cupressus lusitanica</i> Mill.	Mexican cypress
<i>Cupressus</i> sp.	Cypress
++ <i>Duranta repens</i> L.	Forget-me-not tree
* <i>Eucalyptus cinerea</i> F. Muell. ex Benth.	Argyle apple
+ <i>cloeziana</i> F. Muell.	Queensland messmate
+ <i>fastigata</i> Deane & Maid.	Cut-tail
+ <i>grandis</i> Hill ex Maid.	Flooded/Rose gum
+ <i>paniculata</i> Sm.	Grey iron bark
<i>Eucalyptus</i> spp.	Gums
<i>Gleditsia triacanthos</i> L.	Honey locust
<i>Grevillea robusta</i> A. Cunn.	Silver/Silky oak
<i>Jacaranda mimosifolia</i> Don	Jacaranda
× <i>Jatropha curcas</i> L.	Physic nut

<i>Lantana camara</i> L.	Lantana
* <i>Ligustrum japonicum</i> Thunb.	Japanese privet
** <i>sinense</i> Lour.	Privet
**;++ <i>vulgare</i> L.	Common pri-vet
<i>Melia azedarach</i> L.	Syringa/Persian lilac
× <i>Moringa oleifera</i> Lam.	Horse-radish tree
<i>Morus alba</i> L.	White mulberry
<i>Nicotiana glauca</i> Grah.	Wild tobacco
<i>Opuntia ficus-indica</i> (L.) Mill. (including a green, spineless cultivar)	Prickly pear
<i>imbricata</i> (Haw.) DC.	Imbricate cactus
+ <i>rosea</i> DC.	Rosea cactus
<i>Opuntia</i> sp. (spineless cultivar, round, blue-green cladodes)	
× <i>Parkinsonia aculeata</i> L.	Jerusalem thorn
<i>Passiflora edulis</i> Sm.	Purple granadilla
× <i>Pereskia aculeata</i> Mill.	Barbados gooseberry
+ <i>Pinus elliotii</i> Engelm.	Slash pine
<i>patula</i> Schlecht. & Cham.	Patula pine
+ <i>taeda</i> L.	Loblolly pine
<i>Pinus</i> spp.	Pines
<i>Populus</i> sp. (both <i>P. alba</i> L. and <i>P. canadensis</i> (Ait.) J.E. Sm. are present, but cannot be readily distinguished in the field)	White and grey poplars
<i>deltoidea</i> Marsh.	Match poplar/cotton-wood
<i>nigra</i> L.	Lombardy/Black poplar
× <i>Prosopis glandulosa</i> Torr.	Mesquite
<i>velutina</i> Wooton	Velvet mesquite
<i>Prunus armeniaca</i> L.	Apricot
<i>persica</i> (L.) Batsch.	Peach
** <i>serotina</i> Ehrh.	Wild black cherry
<i>Psidium guajava</i> L.	Guava
<i>Pyracantha angustifolia</i> Schneid.	Yellow firethorn
* <i>coccinea</i> Roem.	Firethorn
++ <i>rogersiana</i> (A.B. Jacks.) Bean	Firethorn
<i>Ricinus communis</i> L.	Caster oil plant
<i>Robinia pseudo-acacia</i> L.	Black locust/false acacia
<i>Rosa</i> sp. (perhaps <i>R. canina</i> )	Dog rose
<i>Rubus</i> spp. (3 species are known to occur in the eastern Transvaal, but only 2 species were recorded with certainty)	Bramble
<i>Salix babylonica</i> L. (and possibly other species)	Weeping willow
<i>Schinus molle</i> L.	Pepper tree
<i>Sesbania punicea</i> (Cav.) Benth.	Brazilian glory pea
<i>Solanum mauritianum</i> Scop.	Bug tree
** <i>Sophora japonica</i> L.	Japanese pagoda tree
<i>Tecoma stans</i> (L.) HBK	Yellow bells
<i>Tipuana tipu</i> (Benth.) O. Kuntze.	Tipuana
<i>Toona ciliata</i> Roem.	Toon tree/cedrela
<i>Trichocereus</i> sp.	
* <i>Ulmus parvifolia</i> Jacq.	Chinese elm
* <i>procera</i> Salisb.	English elm
<i>Vitis</i> sp.	Grape
<i>Yucca</i> sp.	Yucca





Pilot study area



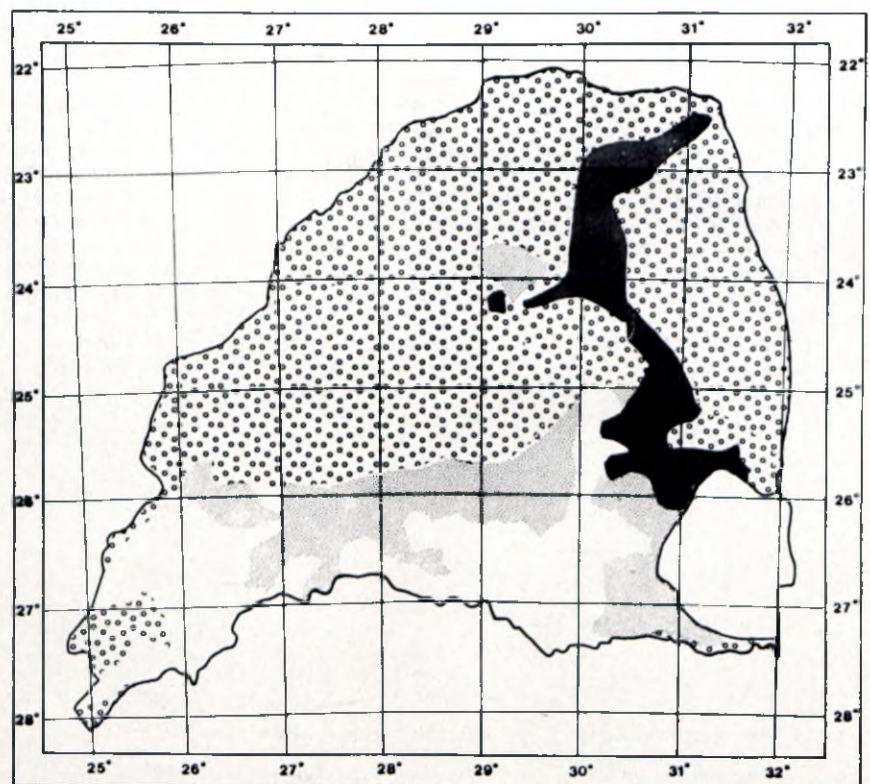
Sampled for previous publication



Sampled since previous publication

Each • and/or / represents a  $\frac{1}{16}$  degree square that was traversed.

FIG. 1.—Study area and sampling routes.



Inland tropical forest types



Tropical bush and savanna types



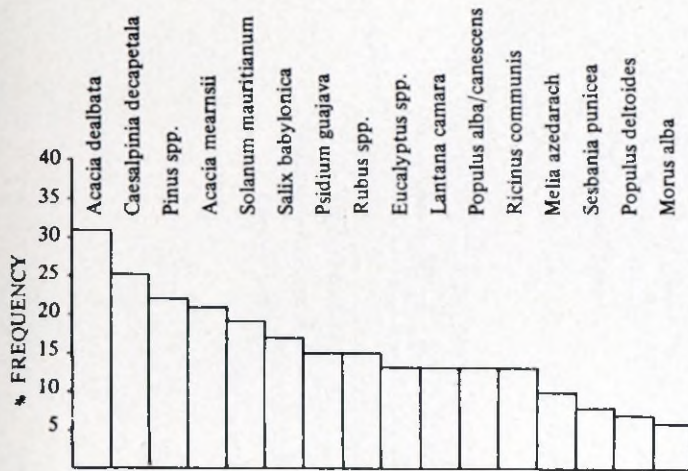
False grassveld types



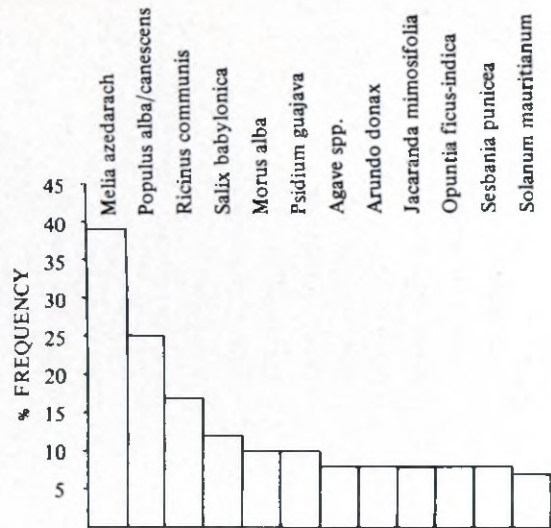
Pure grassveld types

FIG. 2.—The four broad veld type categories in the Transvaal.

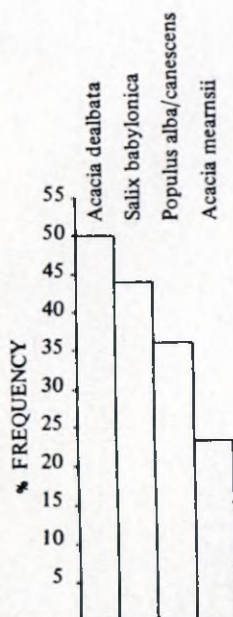




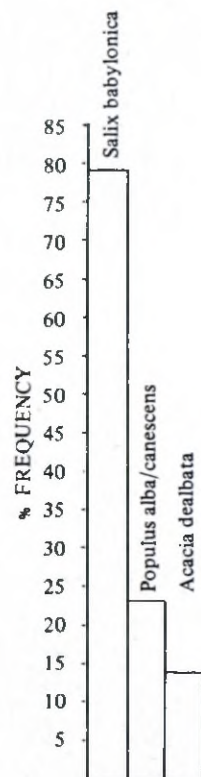
3. Less frequent species: *Agave* spp., *Arundo donax*, *Bambusa balcooa*, *Cassia didymobotrya*, *C. floribunda*, *Cupressus* sp., *Grevillea robusta*, *Jacaranda mimosifolia*, *Nicotiana glauca*, *Prunus persica*, *Rosa* sp., *Toona ciliata*.



4. Less frequent species: *Acacia dealbata*, *Caesalpinia decapetala*, *Cassia didymobotrya*, *C. floribunda*, *Crotalaria agatiflora*, *Eucalyptus* spp., *Lantana camara*, *Nicotiana glauca*, *Opuntia imbricata*, *Populus deltoides*, *P. nigra*, *Prunus persica*, *Robinia pseudo-acacia*, *Rubus* spp.



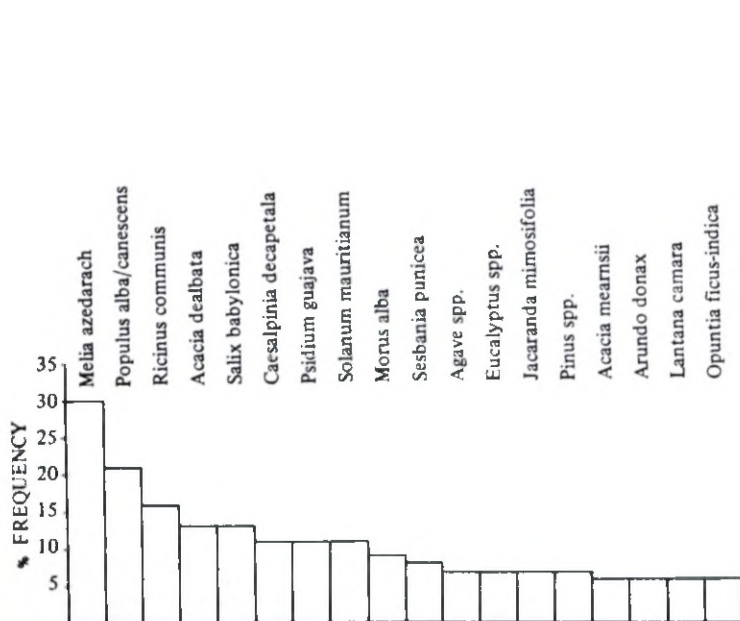
5. Less frequent species: *Acacia baileyana*, *A. decurrens*, *Citrus* sp., *Eucalyptus* spp., *Lantana camara*, *Melia azedarach*, *Opuntia ficus-indica*, *Pinus* spp., *Populus deltoides*, *Psidium guajava*, *Pyracantha angustifolia*, *Sesbania punicea*.



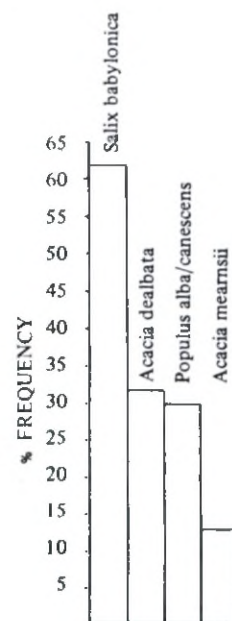
6. Less frequent species: *Acacia decurrens*, *A. mearnsii*, *Agave* spp., *Caesalpinia decapetala*, *Eucalyptus* spp., *Melia azedarach*, *Opuntia ficus-indica*, *Pinus* spp., *Populus deltoides*, *Prunus persica*, *Pyracantha angustifolia*.

FIGS 3-6.—Percentage frequency of streambank species in: 3, forest veld types; 4, bushveld veld types; 5, false grassveld veld types; 6, pure grassveld veld types.

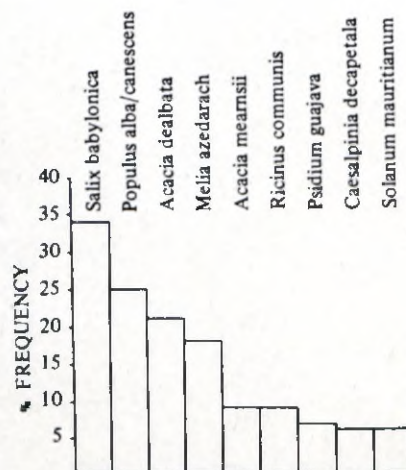




7. Less frequent species: *Bambusa balcooa*, *Cassia didymobotrya*, *C. floribunda*, *Crotalaria agatiflora*, *Cupressus* sp., *Grevillea robusta*, *Nicotiana glauca*, *Opuntia imbricata*, *Populus deltoides*, *P. nigra*, *Prunus persica*, *Robinia pseudo-acacia*, *Rosa* sp., *Rubus* spp., *Toona ciliata*.



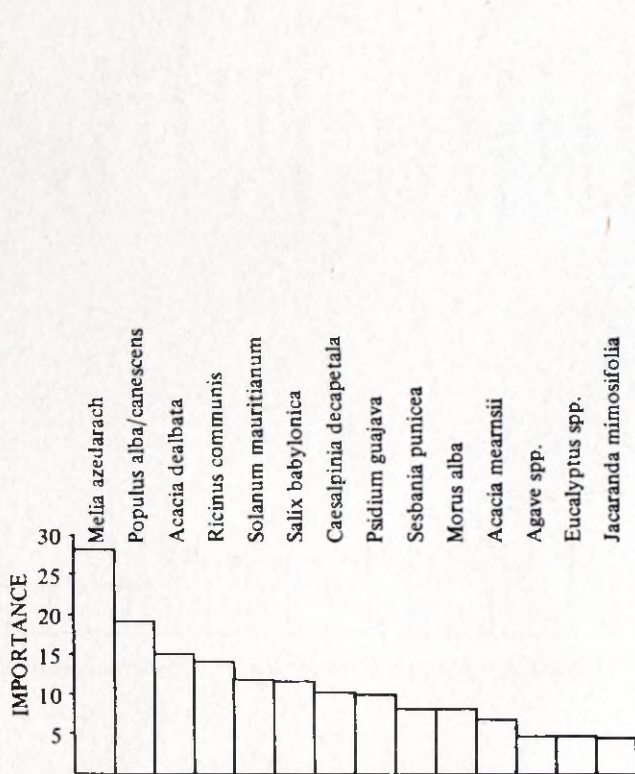
8. Less frequent species: *Acacia baileyana*, *A. decurrens*, *Agave* spp., *Caesalpinia decapetala*, *Citrus* sp., *Eucalyptus* spp., *Lantana camara*, *Melia azedarach*, *Opuntia ficus-indica*, *Pinus* spp., *Populus deltoides*, *Prunus persica*, *Psidium guajava*, *Pyracantha angustifolia*, *Sesbania punicea*.



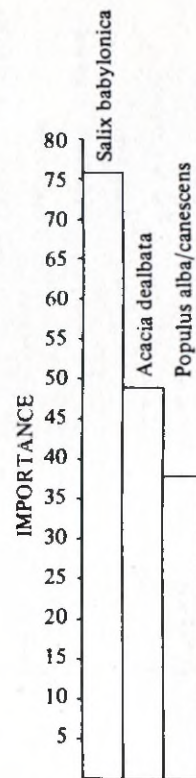
9. Less frequent species: *Acacia baileyana*, *A. decurrens*, *Agave* spp., *Arundo donax*, *Bambusa balcooa*, *Cassia didymobotrya*, *C. floribunda*, *Citrus* sp., *Crotalaria agatiflora*, *Cupressus* sp., *Eucalyptus* spp., *Grevillea robusta*, *Jacaranda mimosifolia*, *Lantana camara*, *Morus alba*, *Nicotiana glauca*, *Opuntia ficus-indica*, *O. imbricata*, *Pinus* spp., *Populus deltoides*, *P. nigra*, *Prunus persica*, *Pyracantha angustifolia*, *Robinia pseudo-acacia*, *Rosa* sp., *Rubus* spp., *Sesbania punicea*, *Toona ciliata*.

FIGS 7-9.—Percentage frequency of streambank species in: 7, tropical veld types; 8, temperate veld types; 9, the whole survey area.

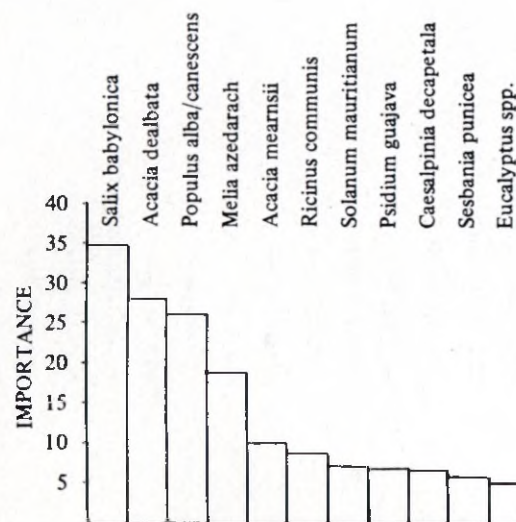




10. Importance values add up to 200. Only those adding up to 160 are plotted. The others include: *Arundo donax*, *Bambusa balcooa*, *Cassia didymobotrya*, *C. floribunda*, *Crotalaria agatiflora*, *Cupressus* sp., *Grevillea robusta*, *Lantana camara*, *Nicotiana glauca*, *Opuntia ficus-indica*, *O. imbricata*, *Pinus* spp., *Populus deltoides*, *P. nigra*, *Prunus persica*, *Rosa* sp., *Rubus* spp., *Toona ciliata*.



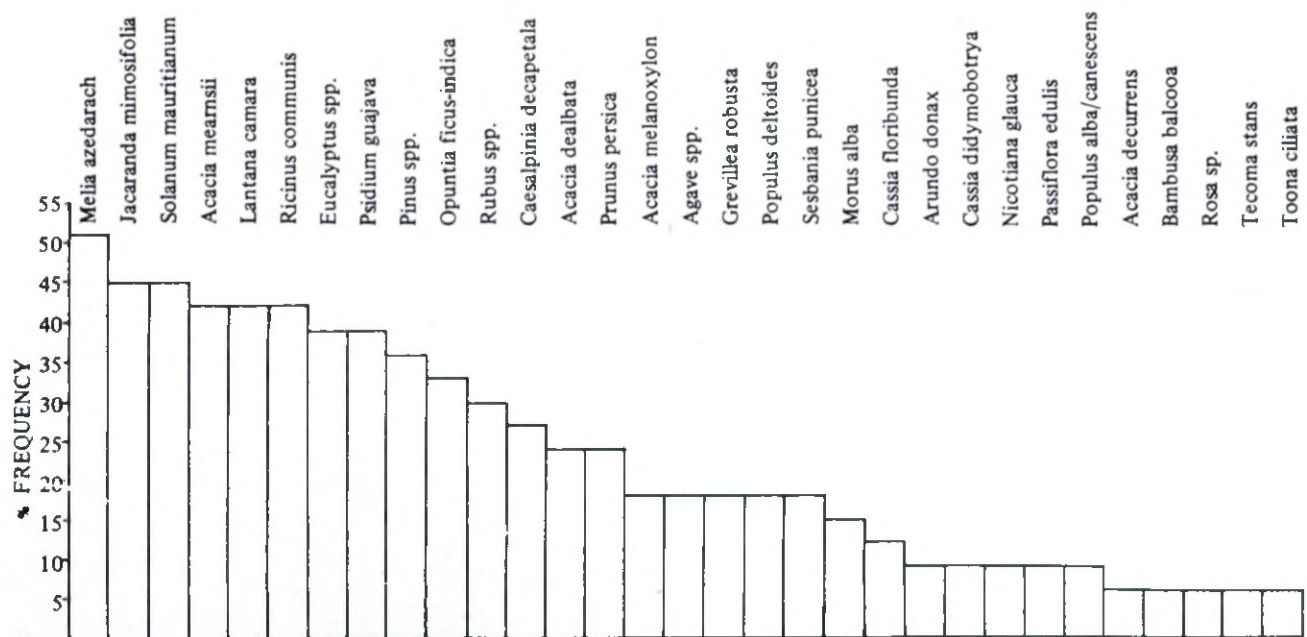
11. Less important species: *Acacia baileyana*, *A. decurrens*, *A. mearnsii*, *Agave* spp., *Caesalpinia decapetala*, *Citrus* sp., *Eucalyptus* spp., *Lantana camara*, *Melia azedarach*, *Opuntia ficus-indica*, *Pinus* spp., *Populus deltoides*, *Prunus persica*, *Psidium guajava*, *Pyracantha angustifolia*, *Sesbania punicea*.



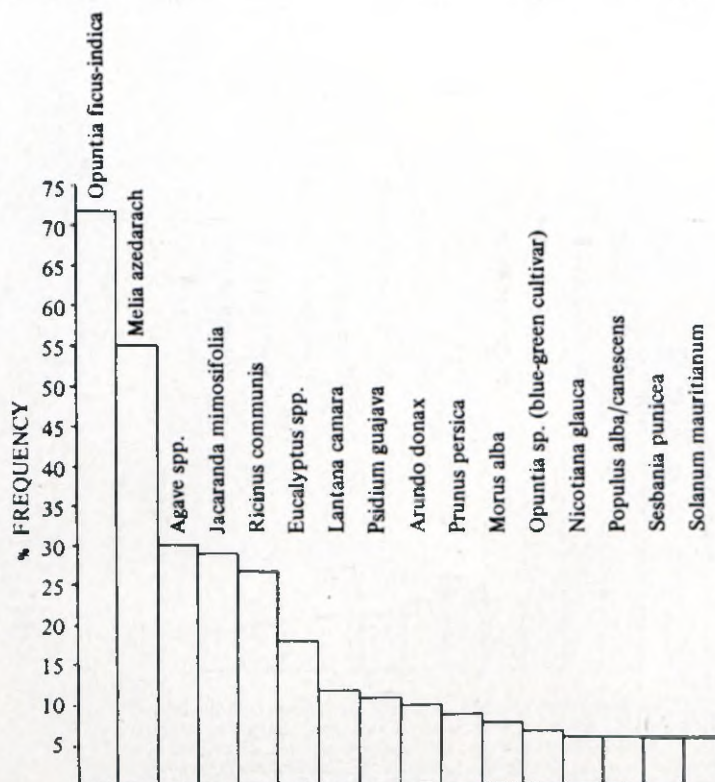
12. Less important species: *Acacia baileyana*, *A. decurrens*, *Agave* spp., *Arundo donax*, *Bambusa balcooa*, *Cassia didymobotrya*, *C. floribunda*, *Citrus* sp., *Crotalaria agatiflora*, *Cupressus* sp., *Grevillea robusta*, *Jacaranda mimosifolia*, *Lantana camara*, *Morus alba*, *Nicotiana glauca*, *Opuntia ficus-indica*, *O. imbricata*, *Pinus* spp., *Populus deltoides*, *P. nigra*, *Prunus persica*, *Pyracantha angustifolia*, *Rosa* sp., *Rubus* spp., *Toona ciliata*.

FIGS 10-12.—Importance of streambank species in: 10, tropical veld types; 11, temperate veld types; 12, the whole survey area.





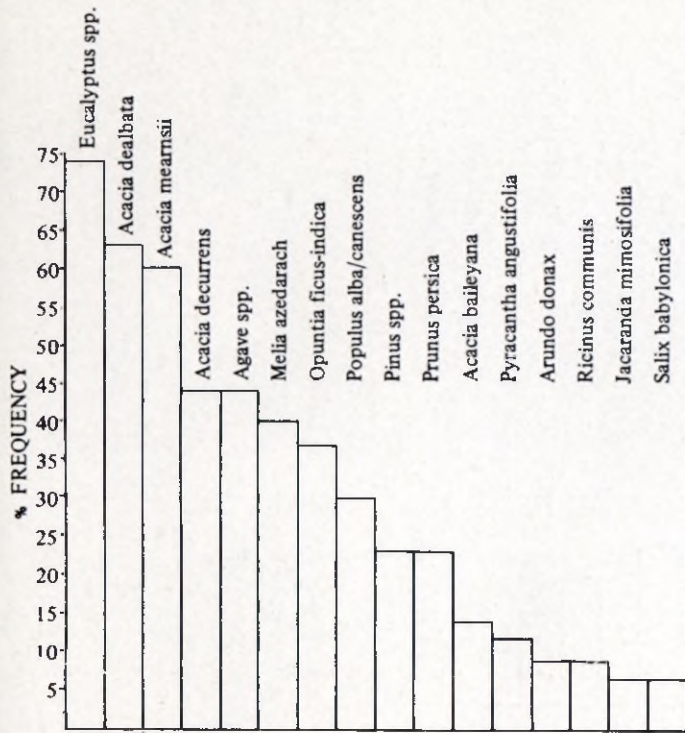
13. Less frequent species: *Bauhinia variegata*, *Casuarina* sp., *Crotalaria agatiflora*, *Ligustrum japonicum*, *Pyracantha angustifolia*, *Vitis* sp.



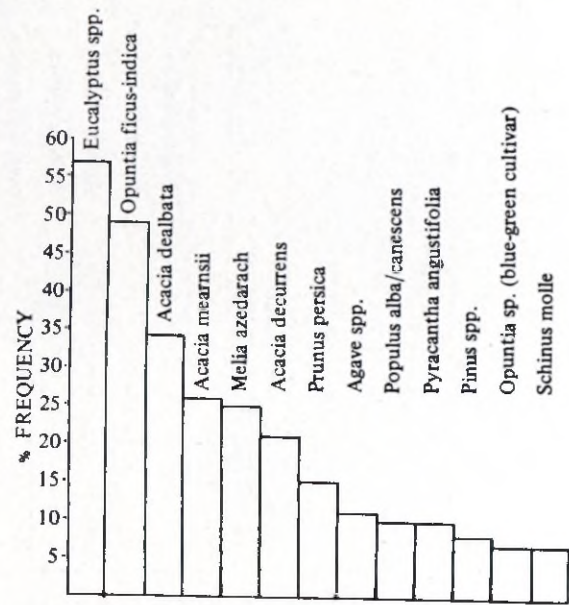
14. Less frequent species: *Acacia baileyana*, *A. dealbata*, *A. decurrens*, *A. mearnsii*, *A. podalyriifolia*, *Caesalpinia decapetala*, *Carica* sp., *Cassia didymobotrya*, *C. floribunda*, *Cereus peruvianus*, *Crotalaria agatiflora*, *Grevillea robusta*, *Opuntia imbricata*, *Pinus* spp., *Populus deltoides*, *Prosopis velutina*, *Prunus armeniaca*, *Rosa* sp., *Rubus* spp., *Salix babylonica*, *Schinus molle*, *Tecoma stans*, *Tipuana tipu*, *Toona ciliata*, *Trichocereus* sp.

FIGS 13-14.—Percentage frequency of roadside and veld species in: 13, forest veld types; 14, bushveld veld types.

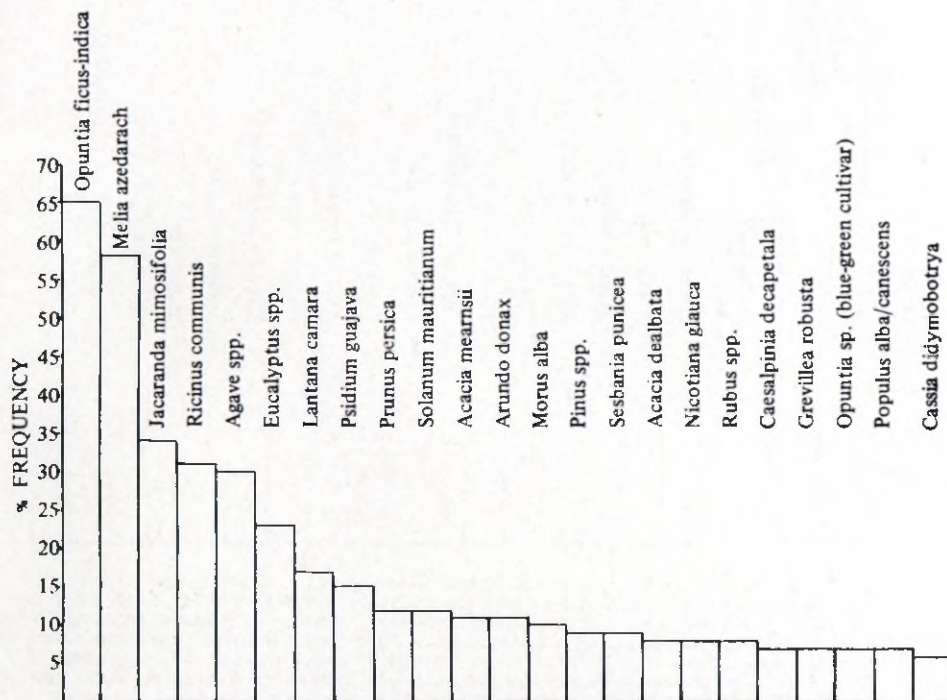




15. Less frequent species: *Acacia longifolia*, *A. melanoxylon*, *A. podalyriifolia*, *Citrus* sp., *Gleditsia triacanthos*, *Grevillea robusta*, *Lantana camara*, *Morus alba*, *Nicotiana glauca*, *Psidium guajava*, *Robinia pseudo-acacia*, *Rubus* spp., *Sesbania punicea*, *Solanum mauritianum*, *Yucca* sp.



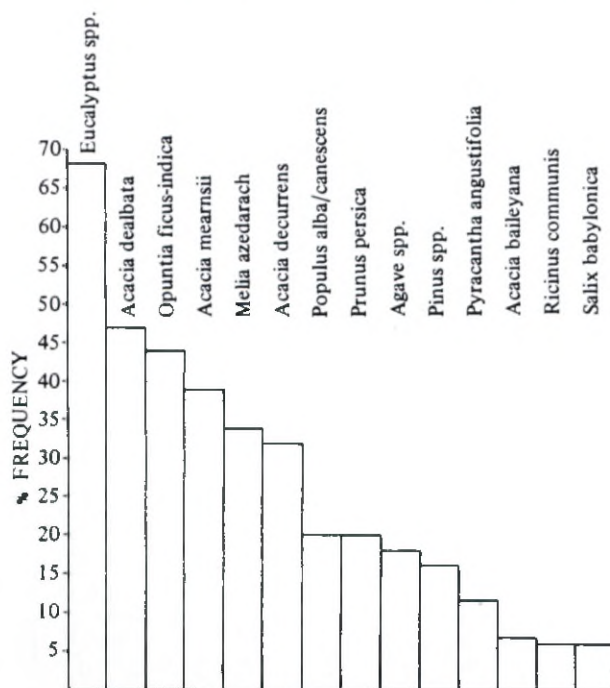
16. Less frequent species: *Acacia baileyana*, *A. podalyriifolia*, *Arundo donax*, *Cereus peruvianus*, *Cupressus* sp., *Gleditsia triacanthos*, *Nicotiana glauca*, *Populus deltoides*, *Prosopis velutina*, *Ricinus communis*, *Robinia pseudo-acacia*, *Salix babylonica*, *Sesbania punicea*, *Solanum mauritianum*, *Yucca* sp.



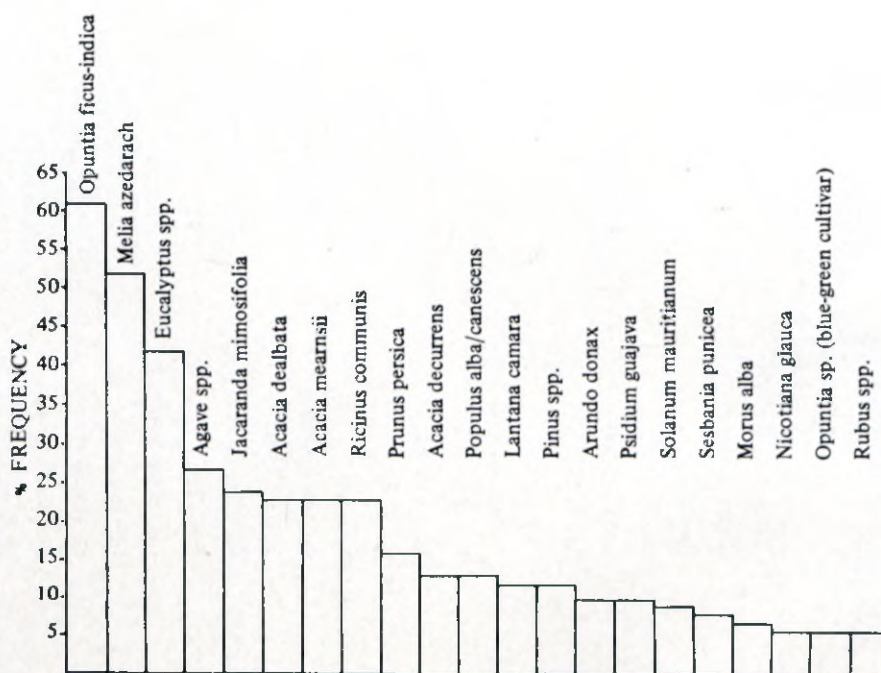
17. Less frequent species: *Acacia baileyana*, *A. decurrens*, *A. melanoxylon*, *A. podalyriifolia*, *Bambusa balcooa*, *Bauhinia variegata*, *Carica* sp., *Cassia floribunda*, *Casuarina* sp., *Cereus peruvianus*, *Crotalaria agatiflora*, *Ligustrum japonicum*, *Opuntia imbricata*, *Passiflora edulis*, *Populus deltoides*, *Prosopis velutina*, *Prunus armeniaca*, *Pyracantha angustifolia*, *Rosa* sp., *Salix babylonica*, *Schinus molle*, *Tecoma stans*, *Tipuana tipu*, *Toona ciliata*, *Trichocereus* sp., *Vitis* sp.

FIGS 15–17.—Percentage frequency of roadside and veld species in: 15, false grassveld veld types; 16, pure grassveld veld types; 17, tropical veld types.





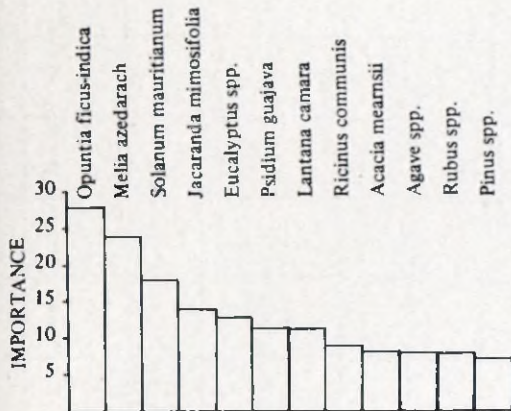
18. Less frequent species: *Acacia longifolia*, *A. melanoxylon*, *A. podalyriifolia*, *Arundo donax*, *Cereus peruvianus*, *Citrus* sp., *Cupressus* sp., *Gleditsia triacanthos*, *Grevillea robusta*, *Jacaranda mimosifolia*, *Lantana camara*, *Morus alba*, *Nicotiana glauca*, *Opuntia* sp. (blue-green cultivar), *Populus deltoides*, *Prosopis velutina*, *Psidium guajava*, *Robinia pseudo-acacia*, *Rubus* spp., *Schinus molle*, *Sesbania punicea*, *Solanum mauritianum*, *Yucca* sp.



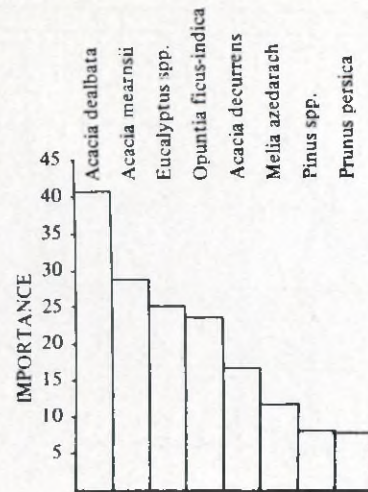
19. Less frequent species: *Acacia baileyana*, *A. longifolia*, *A. melanoxylon*, *A. podalyriifolia*, *Bambusa balcooa*, *Bauhinia variegata*, *Cacsalpinia decapetala*, *Carica* sp., *Cassia didymobotrya*, *C. floribunda*, *Casuarina* sp., *Cereus peruvianus*, *Citrus* sp., *Crotalaria agatiflora*, *Cupressus* sp., *Gleditsia triacanthos*, *Grevillea robusta*, *Ligustrum japonicum*, *Opuntia imbricata*, *Passiflora edulis*, *Populus deltoides*, *Prosopis velutina*, *Prunus armeniaca*, *Pyracantha angustifolia*, *Robinia pseudo-acacia*, *Rosa* sp., *Salix babylonica*, *Schinus molle*, *Tecoma stans*, *Tipuana tipu*, *Toona ciliata*, *Trichocereus* sp., *Vitis* sp., *Yucca* sp.

FIGS 18-19.—Percentage frequency of roadside and veld species in: 18, temperate veld types; 19, the whole survey area.

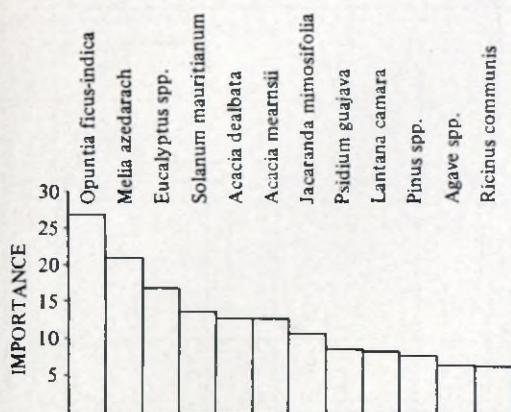




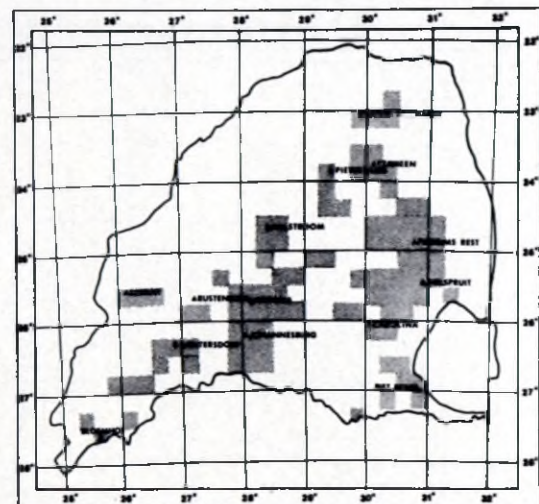
20. Importance values add up to 200. Only those adding up to 160 are plotted. The rest include: *Acacia baileyana*, *A. dealbata*, *A. decurrens*, *A. melanoxylon*, *A. podalyriifolia*, *Arundo donax*, *Bambusa balcooa*, *Bauhinia variegata*, *Caesalpinia decapetala*, *Carica* sp., *Cassia didymobotrya*, *C. floribunda*, *Casuarina* sp., *Cereus peruvianus*, *Crotalaria agatiflora*, *Grevillea robusta*, *Ligustrum japonicum*, *Morus alba*, *Nicotiana glauca*, *Opuntia* sp. (blue-green cultivar), *O. imbricata*, *Passiflora edulis*, *Populus alba/canescens*, *P. deltoides*, *Prosopis velutina*, *Prunus armeniaca*, *P. persica*, *Pyracantha angustifolia*, *Robinia pseudo-acacia*, *Rosa* sp., *Salix babylonica*, *Schinus molle*, *Sesbania punicea*, *Tecoma stans*, *Tipuana tipu*, *Toona ciliata*, *Trichocereus* sp., *Vitis* sp.



21. Less important species: *Acacia baileyana*, *A. longifolia*, *A. melanoxylon*, *A. podalyriifolia*, *Agave* spp., *Arundo donax*, *Cereus peruvianus*, *Citrus* sp., *Cupressus* sp., *Gleditsia triacanthos*, *Grevillea robusta*, *Jacaranda mimosifolia*, *Lantana camara*, *Morus alba*, *Nicotiana glauca*, *Opuntia* sp. (blue-green cultivar), *Populus alba/canescens*, *P. deltoides*, *Prosopis velutina*, *Psidium guajava*, *Pyracantha angustifolia*, *Ricinus communis*, *Robinia pseudo-acacia*, *Rubus* spp., *Salix babylonica*, *Schinus molle*, *Sesbania punicea*, *Solanum mauritianum*, *Yucca* sp.



22. Less important species: *Acacia baileyana*, *A. decurrens*, *A. longifolia*, *A. melanoxylon*, *A. podalyriifolia*, *Arundo donax*, *Bambusa balcooa*, *Bauhinia variegata*, *Caesalpinia decapetala*, *Carica* sp., *Cassia didymobotrya*, *C. floribunda*, *Casuarina* sp., *Cereus peruvianus*, *Citrus* sp., *Crotalaria agatiflora*, *Cupressus* sp., *Gleditsia triacanthos*, *Grevillea robusta*, *Ligustrum japonicum*, *Morus alba*, *Nicotiana glauca*, *Opuntia* sp. (blue-green cultivar), *O. imbricata*, *Passiflora edulis*, *Populus alba/canescens*, *P. deltoides*, *Prosopis velutina*, *Prunus armeniaca*, *P. persica*, *Pyracantha angustifolia*, *Robinia pseudo-acacia*, *Rosa* sp., *Rubus* spp., *Salix babylonica*, *Schinus molle*, *Sesbania punicea*, *Tecoma stans*, *Tipuana tipu*, *Toona ciliata*, *Trichocereus* sp., *Vitis* sp., *Yucca* sp.

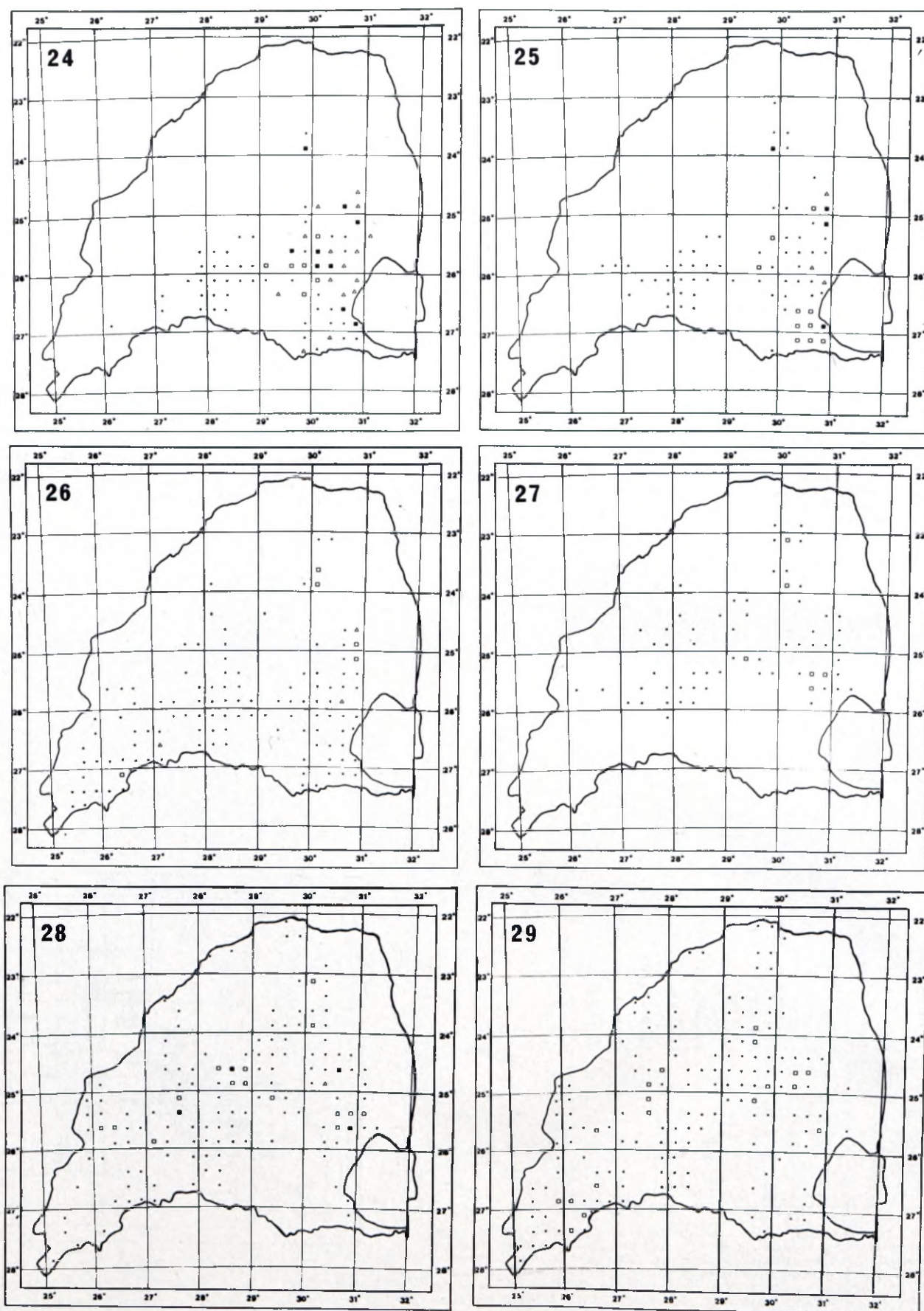


23

† Degree squares in which 6 or more species occurred.

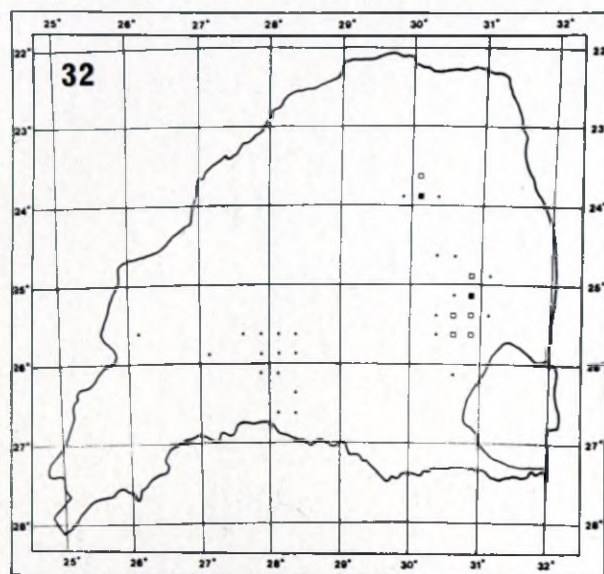
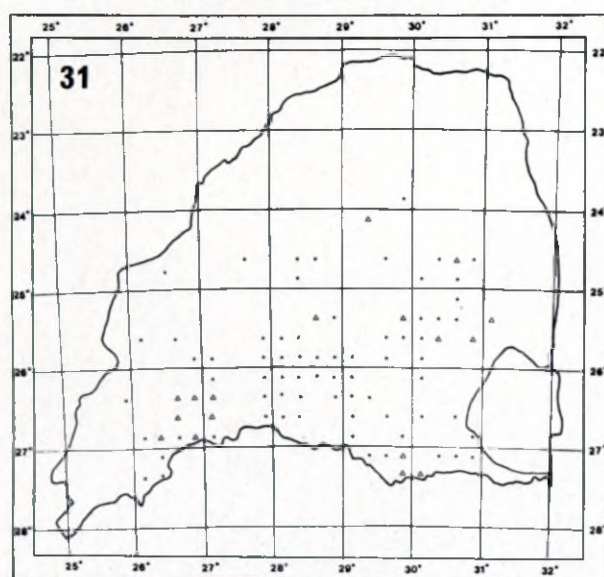
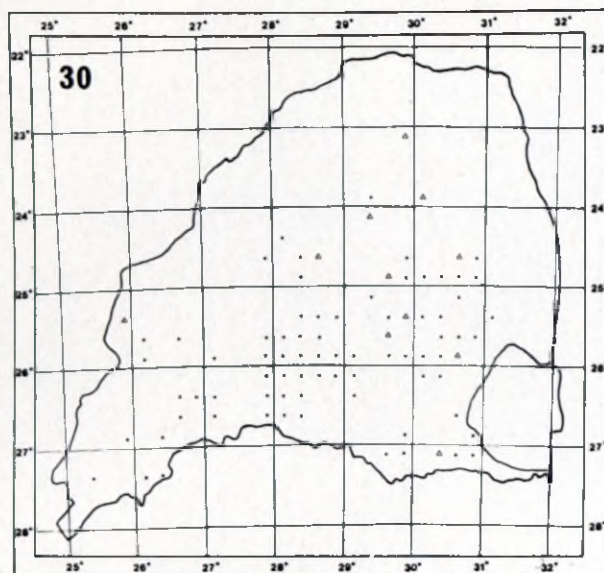
FIGS 20–23.—Importance of roadside and veld species in: 20, tropical veld types; 21, temperate veld types; 22, the whole survey area; 23, areas of high species diversity in roadside and veld habitats.





FIGS 24–29.—Distribution and high abundance areas of the most important species. 24, *Acacia dealbata*; 25, *Acacia mearnsii*; 26, *Eucalyptus* spp; 27, *Jacaranda mimosifolia*; 28, *Melia azedarach*; 29, *Opuntia ficus-indica* and spineless cultivar. □, roadside and veld habitats, abundance values 3 or more per 20 km or 4 or more per 15 km; △, streambank habitat, abundance values 4 or more; ■, streambank, roadside and veld habitats with aforementioned values.





FIGS 30–32.—Distribution and high abundance areas of the most important species. 30, *Populus alba/canescens*; 31, *Salix babylonica*; 32, *Solanum mauritianum*. □, roadside and veld habitats, abundance values 3 or more per 20 km or 4 or more per 15 km; Δ, streambank habitat, abundance values 4 or more; ■, streambank, roadside and veld habitats with aforementioned values.



