Technical Memorandum 23

Alien plants in the Alligator Rivers Region, Northern Territory, Australia

I.D.Cowie, C.M.Finlayson and B.J.Bailey

Supervising Scientist for
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CONTENTS

PLATES

ABSTRACT

Cowie, I.D., Finlayson, C.M. & Bailey, B.J. (1988). Alien plants in the Alligator Rivers Region, Northern Territory, Australia. Technical Memorandum 23, Supervising Scientist for the Alligator Rivers Region.

This is a report on the presence, distribution and frequency of occurrence of alien plant species naturalised in the Alligator Rivers Region, N.T. A survey of 44 sites was carried out over 33 months and a total of 71 alien species, representing 5.3% of the flora, was recorded. Since 1948, when 14 species were recorded, the number of alien species recorded in the Region has increased exponentially. The major weed species invading wetlands are *Salvinia molesta*, *Mimosa pigra* and *Urochloa mutica*. The most successful (and generally longest resident) colonisers of disturbed sites and riparian habitats are *Hyptis suaveolens*, *Sida acuta*, *Passiflora foetida* and *Sida cordifolia*. *Pennisetum polystachion*, a recent introduction, is one of the few aliens which may have the ability to invade undisturbed *Eucalyptus* dominated communities. Many of the species recorded are recent arrivals and are expected to continue to spread. Species richness (and size of site) explained most of the structure in the data. The larger, comparatively species rich sites in active use (settlements and mines) are expected to be the areas most susceptible to further introduction of alien species.

1 INTRODUCTION

Interest and development in the Alligator Rivers Region (ARR) of northern Australia increased following the discovery of four large uranium deposits - Ranger, Nabarlek, Jabiluka and Koongarra (Hegge et al. 1980) and the declaration of Kakadu National Park. Stage I of the Park was gazetted in April 1979 and Stage II in February 1984. Declaration of Stage III of the park was not gazetted until July 1987. Stage I and Stage II have been included on the UNESCO World Heritage List. Mines have been developed at Nabarlek and at Ranger, while the Jabiluka and Koongarra deposits remain unexploited. All four deposits have been excised from the Park. Government approval for these mining activities was largely dependent on conditions and guidelines established by the Ranger Uranium Environmental Inquiry (Fox et al. 1977).

Management of Kakadu National Park is the responsibility of the Australian National Parks and Wildlife Service (ANPWS). In the current plan of management for the park, invasion by alien plants and weed species is identified as a major problem (Australian National Parks and Wildlife Service 1986). Responsibility for approval of the introduction of plants to Kakadu rests with the Director ANPWS under section 6(a) and (b) of the Environment Requirements for the Ranger Project and pursuant to regulations under the *National Parks and Conservation Act* 1975. An extensive list of approved plants has been prepared: any plant not on this list or in the current edition of the checklist of the Flora of Kakadu National Park (Lazarides & Craven 1980) is not permitted to be introduced. A similar authority over Arnhem Land is exercised by the Director, Conservation Commission of the Northern Territory.

In those parts of the ARR not included, nor intended for inclusion in the park, nor in Arnhem Land the introduction of plants is not controlled unless they are subject to the provisions of the N.T. *Noxious Weed Act* administered by the N.T. Department of Primary Production.

The number of alien species present in south-eastern Australia has been documented (Specht 1981), but the numbers present in the north and north-west of the continent have not. A small proportion of the naturalised alien plant species of an area can become important weeds (Johnson 1986), i.e. have a major and unwanted ecological, aesthetic or economic impact. Early recognition of the presence of these species can increase the success of control measures.

This paper reports the results of a survey of naturalised alien plant species present in the ARR. The aims of this initial survey was to document the presence of alien species, to examine whether any pattern was apparent in their occurrence, and to identify and describe the major weed species in the ARR. Alien plant species are of concern in mining revegetation schemes as they can compete with species more effective in stabilising soil, or because they can prevent the re-establishment of stable communities of native plants (Cowie & Finlayson 1987). Alien grass species e.g. *Chloris gayana* are currently used in revegetation (Armstrong 1987) and soil stabilisation schemes (Applegate 1983) in the Region. It is generally anticipated that such species will only persist for one year after planting (Armstrong 1987), though recent observations suggest that not only can they persist for a longer period, but that they can spread to other areas (D. Lindner pers. comm.). Furthermore, changes to the environment caused by activities such as those associated with mining activities can provide conditions that enable rapid colonisation by alien species (Johnson 1986). In relation to mining developments in the ARR, alien plants could be introduced accidently in commercially available grass seed, in hay-mulch used for revegetation, in imported soils and construction materials, and on vehicles (Cowie & Finlayson 1987). As very little information on the occurrence of alien plants at mine sites in the Top End (that part of the N.T. north of 15°S) is available, two sites outside the ARR

(Moline and Rum Jungle) were also surveyed. Both are abandoned uranium mines and, at least initially, no attempts were made to revegetate the waste dumps or mining and processing areas.

2 ALLIGATOR RIVERS REGION

2.1 Physical features

The Alligator Rivers Region (Fig. 1) comprises an area of about 28 000 km^2 of relatively undisturbed native vegetation in the far north of the Northern Territory. Some land surface disturbance has been caused by feral Asiatic water buffalo (*Bubalus bubalis*) (Braithwaite et al. 1984). The Region includes the catchments of the East Alligator, South Alligator and West Alligator rivers, and encompasses Kakadu National Park. The physical features of the region have been described by Galloway (1976) and Christian & Aldrick (1977). In the south and east is the Arnhem Land Plateau, a deeply dissected, rugged sandstone terrain some 200-300 m above sea level. The edges of the plateau form an escarpment which rises up to 250 m above the undulating plains of the lowlands. Extensive flood plains occur along the major rivers and creeks and eventually merge into the estuaries.

2.2 Vegetation

The flora of the Alligator Rivers Region (ARR) was comprehensively described first by Specht & Mountford (1958). These authors compiled a report on botanical collections made as part of the American-Australian Scientific Expedition to Arnhem Land in 1948, and also presented a list of plants collected on a 1928 expedition by Mackay (1929). The vegetation of the ARR is closely allied to that of the Adelaide River (Story 1969; 1976) and the Darwin-Katherine areas (Christian & Stewart 1953) (see Fig. 1). The flora is dominated by *Eucalyptus tetrodonta* and *Eucalyptus miniata* woodland and open forest, with an understorey of tall annual and perennial grasses. There are small areas of monsoon forest, and extensive seasonally inundated sub-coastal alluvial plains, often fringed by *Melaleuca* spp. forests.

2.3 Climate

The Region has a monsoonal climate with two dominant seasons, known locally as the Wet and the Dry. The Wet generally commences late in the year (November-December) and lasts for 3-4 months; both the onset and duration vary from year-to-year. The most significant feature of the season is the rainfall from thunderstorms, tropical cyclones and rain depressions. The early part of the Wet is characterised by thunderstorms with localised but very heavy rain whereas thunderstorms during March and April do not produce prolonged rain and indicate the approach of the Dry season. The Dry season is characterised by south-east trade winds.

The mean annual rainfall at Jabiru is 1565 mm. The wettest months are January-March with 250-350 mm per month, though November and December have over 150 mm on average. When considering a monsoonal climate, however, it is also useful to be aware of daily or individual events. As an example, during November 1984 a single daily recording accounted for 125 mm of the total 224 mm of rainfall recorded for the month.

The range of average monthly maximum temperatures is 31-37°C. The warmest month is October (i.e. in the build-up to the Wet) and the coolest period is June-July. The average minimum temperatures are lowest in July (18°C) and highest from November-March (24°C).

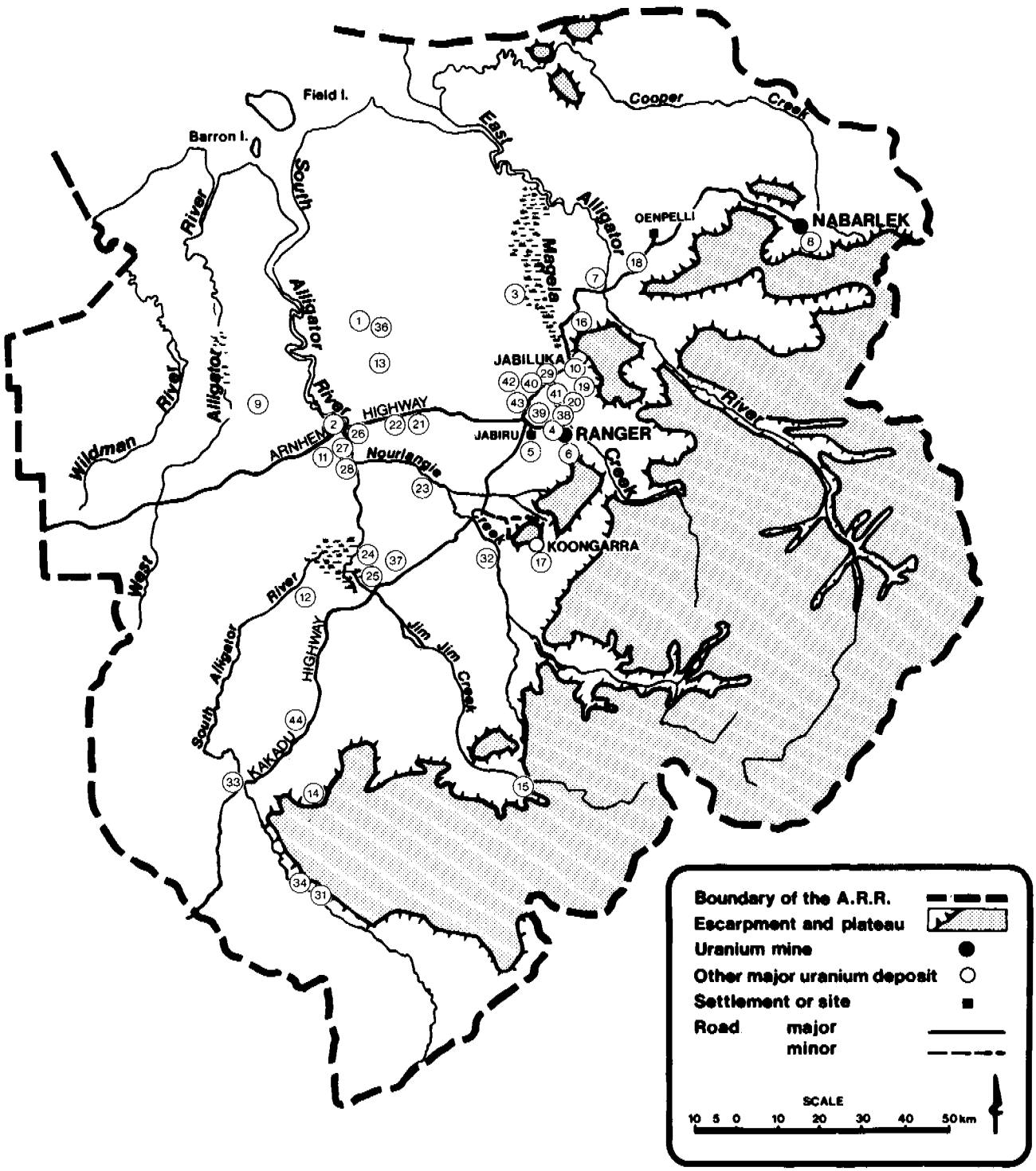


Figure 1. Map of the Alligator Rivers Region[1] showing the survey sites
Key to the sites is given in Table 1. Sites 30 and 35 are not in the ARR and are not shown.

1. Outline of the Region is shown as it was at the time of the study, it has since been extended. [ed.]

2.4 Land use

Before 1965, non-Aboriginal land use and settlement in the area was restricted to buffalo hunting, the cattle station and Aboriginal mission at Oenpelli, and several small uranium mines in the upper reaches of the South Alligator River. Pastoral leases were granted for Mudginberri and Munmarlary stations in 1969; these stations are included in the area now covered by Stage II of Kakadu. Buffalo-catching to supply the abattoir at Mudginberri continues to take place. Oenpelli, in the east of the area, has been occupied intermittently by Europeans since 1906 (O'Ferrall 1969).

Many small uranium deposits were mined in the upper catchment of the South Alligator River in the early 1950s but these mines had closed by 1964 (Needham & Roarty 1980). A town of 1200 people has been developed at Jabiru, near the Ranger Uranium Mine. Tourist and recreational use of the park has increased considerably in recent years, with an estimated 46 000 visitors in 1982 increasing to 100 000 in 1985 (Australian National Parks and Wildlife Service 1986).

3 METHODS

3.1 Survey of alien plants

To document changes in the number of alien plant species in the ARR as a function of time, the lists and inventories of earlier collectors in the ARR (Specht 1958; Adams et al. 1973; Dames & Moore 1978; Lazarides & Craven 1980; Morley 1981; Russell-Smith 1984; Taylor & Dunlop 1985) and herbarium label data from specimens held at the Australian National Herbarium, Canberra, the Darwin Herbarium and the herbarium of the Office of the Supervising Scientist, Jabiru, N.T. have been consulted. In deciding whether or not a plant species was alien, additional authorities were consulted including Dunlop (pers. comm.), Jacobs & Pickard (1981) and Kleinschmidt & Johnson (1977). The status of some species is uncertain (e.g. *Malachra fasciata*, *Sida rhombifolia* and *Echinochloa colona*). Several species (*Phyla nodiflora*, *Cardiospermum halicacabum* and *Vigna vexillata*) regarded as alien to Australia by some authors (Jacobs & Pickard 1981) are regarded locally (Taylor & Dunlop 1985; Dunlop pers. comm.) as native to the ARR and have thus been excluded. *Aeschynomene aspera* as recognised in this study, may also include *Aeschynomene americana*, another alien species. Plant species were regarded as naturalised if they were capable of reproducing (either sexually or vegetatively) and establishing without human assistance.

The survey of alien species was concentrated at sites of disturbance, along the edges of flood plains and water courses and in the areas frequented by buffalo. A description of the sites surveyed, between October 1983 and June 1986, is given in Table 1 and their location is shown in Fig. 1. Some alien plants have also invaded wetlands in the Region. The presence of these species was noted although, except for the Magela Creek flood plain, this habitat type was not extensively surveyed.

Most sites were visited, where possible, in the Late-wet-Early-dry season (April-June), as this period coincides with the main flowering and seeding time of alien plants. Where only Dry season visits to a site were possible, owing to extensive Wet season flooding, dead standing plants and dried inflorescences generally proved sufficient to detect the presence of annual species. At these sites, the grass species *Pennisetum pedicellatum* and *Pennisetum polystachion*, which have inflorescences which break up and disperse at maturity, may have been missed, as may the soft herb *Euphorbia hirta*. Sites which had been recently burned or heavily trampled were excluded from the analysis or revisited at a later date although alien species present were noted. Some closely related species (*Bidens bipinnata* and *Bidens pilosa*, *Stylosanthes humilis* and *Stylosanthes hamata*) were not taxonomically separated until part way through the field work and were grouped for the purpose of the analysis.

Table 1. Description of survey sites included in the TWINSPAN and DCA analyses

Location of the sites is given on Figure 1.

Site No.	Map grid reference (Zone 53) Easting	Northing	Site description
1	228260	8619630	Abandoned abattoir and yards, Munmarlary, *Eucalyptus miniata* woodland/ monsoon forest, partly cleared
2	228900	8598890	Boat landing on levee bank of South Alligator River, *Bombax ceiba* forest and sedgeland
3	266500	8624300	Abandoned stockyards, Magela Point, woodland fringing edge of flood plain
4	271500	8599300	Settlement, Jabiru East, *Eucalyptus miniata* woodland, partly cleared
5	264500	8597500	Settlement, Jabiru, formerly *Eucalyptus miniata* woodland
6	273750	8596970	Mine and associated facilities (Ranger), formerly *Eucalyptus miniata* woodland
7	278510	8625600	Roadside and boat landing, bank of East Alligator River, *Eucalyptus miniata* woodland/ monsoon forest, partly cleared
8	316950	8637850	Mine and associated facilities (Nabarlek), formerly *Eucalyptus miniata* woodland
9	214200	8594600	Settlement, Kapalga, *Eucalyptus miniata* woodland near billabong, partly cleared
10	270440	8514470	Settlement, Ja Ja (Pancontinental Mining Ltd), woodland fringing edge of flood plain, partly cleared
11	226500	8597650	Roadside, formerly monsoon forest, adjacent to existing monsoon forest
12	223350	8565620	Stream bank near Spring Peak, riparian woodland
13	228270	8618710	Stream bank, creek at 24 km on road to Munmarlary, riparian forest
14	222000	8528000	Stream bank, Barramundie Gorge, riparian woodland
15	264800	8531400	Parking area near Jim Jim Falls, *Eucalyptus miniata* woodland, sandy soil
16	274020	8620490	Base of escarpment, Ngarradj, *Eucalyptus miniata* woodland, sandy soil
17	266670	8576630	Settlement, Koongarra (Noranda Aust. Ltd), *Eucalyptus miniata* woodland
18	263700	8605500	Abandoned stockyards, north of Oenpelli Road, *Eucalyptus miniata* woodland, partly cleared
19	268500	8603600	Abandoned stockyards, near Corndorl Billabong, *Eucalyptus miniata* woodland, partly cleared
20	267350	8605220	Around water tank near Mudginberri, woodland, cleared
21	249260	8601380	Roadside edge at Nanambu Creek, Arnhem Highway
22	242920	8602250	Roadside edge at creek, Arnhem Highway near Munmarlary Road
23	245900	8588000	Settlement, Nourlangie Camp Ranger Station, monsoon and *Callitris intratropica* forest, partly cleared
24	230800	8571800	Settlement, Cooinda Motel, woodland near billabong, cleared
25	236400	8568600	Settlement, Jim Jim Ranger Station, *Eucalyptus miniata* woodland, partly cleared
26	226200	869800	Roadside, Arnhem Highway at South Alligator flood plain
27	228480	8596120	Flood plain fringe, 3 km south of Arnhem Highway, fringing woodland/monsoon forest
28	231240	8591990	Levee bank, opposite junction of Nourlangie Creek and South Alligator River, *Bombax ceiba* forest
29	266430	8606140	Abandoned pastoral area, broad drainage line, north of Oenpelli Road, formerly woodland
30[a]	192500	8487000	Abandoned mine processing area, Moline, old tailings and ore processing
31	220200	8513200	Camping area, near UDP Falls, riparian woodland, sandy and gravelly soils
32	258510	8577460	Abandoned safari camp, Muirella Park, *Eucalyptus miniata* woodland, partly cleared
33	210000	8530300	River bank at crossing of South Alligator River, Kakadu Highway, riparian woodland on levee bank
34	220800	8514600	Stream bank, Waterfall Creek, on sandstone plateau
35[b]	717800	8563200	Abandoned (1964) overburden heaps, Rum Jungle South Open Cut Mine, *Eucalyptus miniata* woodland (riparian)
36	228250	8620560	Dam at edge of flood plain, Munmarlary, dam wall

Table 1. Description of survey sites included in the TWINSPAN and DCA analyses continued

Site No.	Map grid reference (Zone 53) Easting	Northing	Site description
37	232700	8569300	Camping area, near Mardugal Billabong, woodland, partly cleared
38	270560	8600170	Roadside at Jabiru East turn off, Arnhem Highway
39	263310	8600120	Roadside at Corndorl Creek, Arnhem Highway
40	268700	8608000	Abandoned stockyards near Magela Creek, riparian woodland
41	269000	8606800	Stockyards at Mudginberri, woodland, cleared
42	264140	8609810	Woodland, abandoned paddock, Four Gate Road
43	264590	8609350	Woodland, abandoned paddock, at gateway, Four Gate Road
44	224100	8547400	Abandoned settlement, old Barramundi homestead, woodland near creek, gravelly soil

[a] located outside the ARR, Map Grid Zone 53; [b] located outside the ARR, Map Grid Zone 52

Two abandoned mine sites outside the Region were also included in the analysis of sites. Notes were made on the type of land disturbance on the site and the habitat preferences of each species. A site was delimited either by the area of disturbance or, in the case of linear features such as roads and flood plain edges, by an area of approximately 0.2 ha. Sites were classified by area as < 0.2 ha, 0.2-1 ha, 1-5 ha, 5-20 ha, 20-100 ha, or > 100 ha.

3.2 Data analysis

Multivariate analysis techniques were chosen for the analysis of weed species presence/absence data because they can be used to summarise major trends of variation among samples, reduce 'noise', elucidate relationships and identify outliers (Gauch 1982). Ordination and classification techniques were chosen as complementary techniques for data analysis. In using ordination no assumptions are made about whether groupings exist among the entities (Clifford & Stephenson 1975) and the technique reduces the dimensionality of the data structure (Gauch 1982). Numerical classification techniques can divide continuous, near continuous or discontinuous data into groups of similar entities.

The ordination technique used was detrended correspondence analysis (DCA) (Hill 1979*a*) which is robust and distortion free (Gauch 1982) making it an effective ordination technique for the analysis of community data. As the occurrence of rare species is regarded as more a matter of chance than an indication of ecological conditions at any site, and because they tend to be regarded as outliers by many ordination techniques their importance in the analysis is reduced. This was done to prevent their presence in the data obscuring the analysis of the data set as a whole.

The classification technique chosen was TWINSPAN (two-way indicator species analysis (Hill 1979*b*)). This hierarchical polythetic divisive technique first ordinates the data using reciprocal averaging and subsequently divides the data into groups with reclassification after each division. Data are then re-ordinated before the next division. Polythetic divisive strategies offer the advantage of division over all attributes of the data. The TWINSPAN technique also identifies differential (or 'indicator') species with clear ecological preferences (high fidelity to one group) and preferential species with weaker ecological preferences (Hill 1979*b*). As rare species were reduced in importance in the DCA analysis, a facility not available with TWINSPAN, the ordination results were used as the basis for re-allocation of sites with rare species.

The ordination axes were tested for correlations between ordination scores (average standard deviation of species turn-over) and species richness of sites to establish if species richness was an underlying gradient in the data. ANOVAs were used to examine whether species richness was independent of the groupings of sites produced by the ordination and classification analyses. The data were also tested for correlations between the area and species richness of sites. If sample area (known to be generally correlated with species richness [Mueller-Dombois & Ellenberg 1974]) explains the observed groupings of sites produced by ordination and classification then it would be expected that sample area would also be correlated with the ordination axes and that it would not be independent of the groupings of sites. Spearman rank correlations and chi-squared tests were used to test these possibilites.

Regressions were calculated for data on the number of sites at which species were found and the length of time that species had been recorded from the ARR and the Top End, as well as for total number of species recorded over time. The size of the non-Aboriginal population was expected to be an indicator of the level of development activity occurring in the ARR. However, a curve was not fitted to the data because of the low number of points. Data from the 1971 census were not used because the Aboriginal and non-Aboriginal population were not separated in that census. The Aboriginal population was not included in the analysis because it was expected to have remained relatively stable and because no census figures for the Aboriginal population were available before 1976.

4 RESULTS AND DISCUSSION

4.1 Alien plant numbers and distribution

A total of 71 alien plant species (which represents 5.3% of the known ARR flora [Cowie & Finlayson 1986]) was recorded (Table 2). This proportion is similar to that found by Mitchell (1978) for alien species in the N.T. (5.1%) but is lower than that (10%) for Australia as a whole (Michael 1981). Most of the alien species recorded in the ARR have previously been recorded as naturalised elsewhere in the Top End.

The alien species came from 21 families, the major ones being the Poaceae, Fabaceae and Asteraceae. These families are also dominant in the alien floras of other regions of Australia (Specht 1981) and, after the Orchidaceae, are the world's largest plant families (Heywood 1978).

The cumulative occurrence of alien plant species in the ARR was plotted against time (Fig. 2). The regression line explained 86% of the variation in the data. There is some doubt as to the accuracy of the figures from some of the earlier surveys that were restricted to small areas or to one season only (e.g. Specht 1958). The flora of south-eastern Australia (southern Queensland, Victoria, New South Wales and South Australia) has had an average increase of almost 6 naturalised alien species per year for the last 150 years (Specht 1981). Ross (1976) reported a similar rate of increase in the Victorian flora over the last 100 years. Since 1948 the ARR has had an exponential rate of increase in the numbers of alien species, with 14 known in 1948 and 71 identified in the present survey. Historically though, the industrial and agricultural development of south-eastern Australia and the ARR have been very different, that of the ARR having been more recent and much less intensive.

The number and percentage of survey sites at which the recorded 71 species have been found are given in an arranged matrix produced by the TWINSPAN classification (Table 3). *Hyptis suaveolens* was the most widespread species occurring at 96% of the sites surveyed, reflecting the long period (since 1845) it has had for dispersal in the Top End and its

Table 2. List of naturalised alien plants recorded in the Alligator Rivers Region

In columns 2 and 3, the letter after the date denotes the reference for date of introduction or first record. Codes for the references are: A = Holtze (1892); B = Specht (1958); C = Miller (1983); D = Finlayson (1984*a*); E = Chippendale (1971); F = Mitchell (1978); G = Morley (1981); H = Adams et al. (1973); I = Miller et al. (1982); J = Chippendale (1964); K = this study/herbarium records; L = Cameron et al. (1984); M = Russell-Smith (1984).

Abbreviations in column 4 (habitat) are: D = disturbed areas; FF = fringe of flood plain, river bank; G = garden; AQ = aquatic.

Abbreviations in column 5 (habit) are: T = tree; SA = shrub, annual; SE = shrub, evergreen perennial; GA = grass, annual; GP = grass, perennial; FA = forb, annual; FE = forb, evergreen perennial; FG = forb, geophytic perennial; CA = climber, annual; CE = climber, evergreen perennial; A = floating aquatic.

Family and species	Date of introduction or first record		Habitat	Habit
	Top End	ARR		
Acanthaceae				
Ruellia tuberosa L.	1984 K	1984 K	D	FG
Aizoaceae				
Trianthema portulacastrum L.	1961 K	1973 K	D	FA
Amaranthaceae				
Alternanthera pungens Kunth	1983 K	1984 K	G, D	FA
Amaranthus viridis L.	1891 A	1948 B	D	FA
Gomphrena celosioides Mart.	1972 K	1981 G	D	FE
Asclepiadaceae				
Calotropis procera (Willd.) R.Br. ex Aiton f.	1948 K	1984 K	D	SE
Asteraceae				
Acanthospermum hispidum DC.	1948 B	1973 H	FF	FA
Bidens bipinnata L.	1961 K	1973 H	D	FA
Bidens pilosa L.	1948 B	1965 K	D	FA
Emilia sonchifolia (L.) DC	1948 B	1981 G	D	FA
Synedrella nodiflora (L.) Gaertner	1958 K	1984 K	D	FA
Tridax procumbens L.	1948 B	1973 H	G, D	FE
Boraginaceae				
Heliotropium indicum L.	1964 K	1973 H	FF	FA
Brassicaceae				
Coronopus didymus (L.) SM.	1971 E	1981G	D	FA
Caesalpiniaceae				
Cassia alata L.	1891 A	1967 K	FF	SP
Cassia fistula L.	1984 M	1984 M	FF	T
Cassia obtusifolia L.	1928 B	1977 K	D, FF	SA
Cassia occidentalis L.	1948 B	1948 H	D, FF	SA
Convolvulaceae				
Ipomoea quamoclit L.	1891 A	1984 K	D	CA
Merremia dissecta (Jacq.) Hallier f.	1948 B	1948 B	G, D	CE
Cucurbitaceae				
Cucurbita maxima	1984 K	1984 K	D	CA
Euphorbiaceae				
Euphorbia hirta L.	1948 B	1948 B	G, D, FF	FA
Fabaceae				
Aeschynomene aspera L.	1976 L	1977 K	FF	SA
Alysicarpus vaginalis (L.) DC.	1948 B	1980 K	D, FF	FA
Calopogonium mucunoides Desv.	1966 L	1980 K	D, FF	CA

Table 2. List of naturalised alien plants recorded in the Alligator Rivers Region continued

Family and species	Date of introduction or first record: Top End	ARR	Habitat	Habit
Fabaceae (contd)				
Centrosema brazilianum Benth.	1971 L	1984 M	FF	CA
Crotalaria goreensis Guillemin & Perrottet	1971 E	1984 K	D	SA
Desmodium tortuosum (Sw.) DC	1971 E	1984 K	D	SA
Indigofera hirsuta L.	1948 B	1948 B	D	FA
Macroptilium atropurpureum DC. Urban	1891 A	1984 K	D	CE
Macroptilium lathroides (L.) Urban	1954 L	1984 K	D	SA
Stylosanthes guianensis (Aublet) Sw.	1960 L	1967 K	D	SA
Stylosanthes hamata (L.) Taub.	1969 L	1984 K	D	FE
Stylosanthes humilis Kunth	1954 L	1980 K	D	FA
Stylosanthes viscosa Sw.	1969 L	1986 K	D	SA
Lamiaceae				
Hyptis suaveolens (L.) Poit.	1845 A	1948 B	D, FF	SE
Malvaceae				
Gossypium hirsutum L.	1948 B	1948 B	FF	SE
Hibiscus sabdariffa L.	1891 A	1967 K	D	SA
Malachra fasciata Jacq.	1959 J	1975 K	FF	SA
Sida acuta Burm. f.	1948 B	1948 B	D, FF	SE
Sida cordifolia L.	1948 B	1948 B	D, FF	SE
Sida rhombifolia L.	1958 K	1984 K	FF	SE
Mimosaceae				
Mimosa pigra L.	1892 A	1981 K	AQ	SE
Mimosa pudica L.	1891 A	1985 K	D	FE
Passifloraceae				
Passiflora foetida L.	c. 1880 A	1970 H	D, FF	CE
Pedaliaceae				
Sesamum indicum L.	1890 A	1984 K	D	FA
Poaceae				
Andropogon gayanus Kunth	1954 L	1984 K	D	GP
Axonopus compressus (Swartz) Beauv.	1983 K	1984 K	G	GP?
Cenchrus ciliaris L.	1954 L	1984 K	D	GP
Cenchrus echinatus L.	1948 B	1973 H	D	GA
Chloris barbata Sw.	1948 B	1980 K	D, FF	GP
Chloris gayana Kunth	1954 L	1984 K	D	GP
Cynodon arcuatus J.S. Presl ex C. Presl	1947 K	1974 K	D	GP
Cynodon dactylon (L.) Pers.	1948 B	1948 B	D	GP
Dactyloctenium aegyptium (L.) Beauv.	1948 B	1973 K	D	GA
Digitaria bicornis (Lam.) Roemer & Schultes	1946 K	1973 K	D, FF	GA
Echinochloa colona (L.) Link	1948 B	1973 K	D, FF	GA
Eleusine indica (L.) Gaertner	1948 B	1948 B	D, FF	GA
Pennisetum pedicellatum Trin.	1960 L	1972 K	D	GA
Pennisetum polystachion (L.) Schultes	1971 E	1980 K	D	GP
Rhynchelytrum repens (Willd.) C.E. Hubb.	1913 F	1981 G	D	GP
Themeda quadrivalvis (L.) Kuntze	1968 I	1968 I	D	GA
Urochloa mosambicensis (Hackel) Dandy	1966 L	1967 K	G, D	GP
Urochloa mutica (Forssk.) Nguyen	1948 B	1948 B	AQ	GP
Primulaceae				
Anagallis pumila Sw.	1948 B	1973 H	D	FA
Rubiaceae				
Mitracarpus hirtus (L.) DC	1968 K	1973 K	D	FA

Table 2. List of naturalised alien plants recorded in the Alligator Rivers Region continued

Family and species	Date of introduction or first record		Habitat	Habit
	Top End	ARR		
Salviniaceae				
Salvinia molesta D. Mitch.	1976 D	1983 F	AQ	A
Solanaceae				
Physalis minima L.	1948 B	1948 B	D	FA
Tiliaceae				
Corchorus aestuans L.	1961 K	1969 K	D, FF	SA
Verbenaceae				
Stachytarpheta urticifolia (Salisb.) Sims	1891 A	1984 K	D	SP

adaptability to different habitats. *Sida acuta*, the next most widespread species was found on 91% of the sites. Like *Hyptis suaveolens* it was first recorded in the ARR in 1948. A further eight taxa (*Passiflora foetida*, *Sida cordifolia*, *Stylosanthes* spp., *Euphorbia hirta*, *Alysicarpus vaginalis*, *Digitaria bicornis*, *Pennisetum pedicellatum*, and *Dactyloctenium aegyptium*) were recorded at more than 50% of sites. Except for *Pennisetum pedicellatum* and *Stylosanthes* spp. these species have been recorded from the ARR or Top End for more than 30 years. The majority of taxa (44) were found at fewer than 50% of sites, while 23 taxa were found at less than 10% of sites.

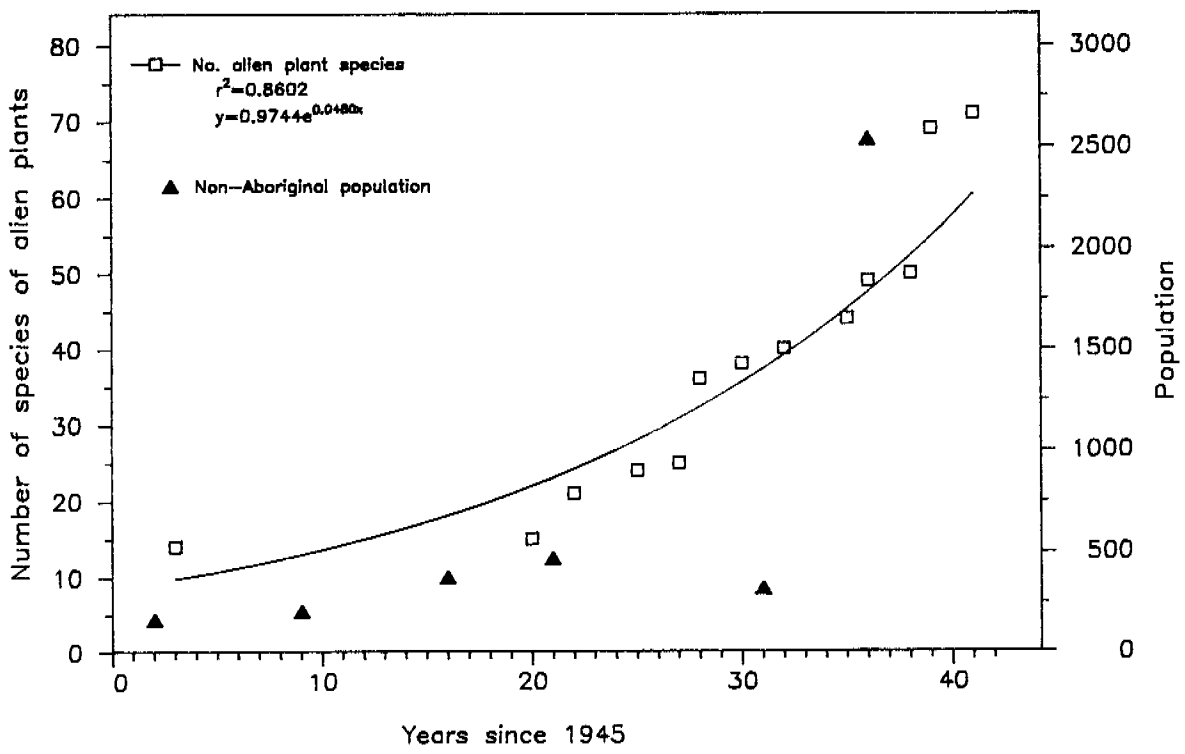


Figure 2. Number of alien plant species and non-Aboriginal population recorded in the Alligator Rivers Region from 1945 to 1986

The number of sites from which a particular alien species was recorded was regressed against the length of time that that species had been recorded from the Region. The regression model ($y = 5.19 + 0.40x$) accounted for a small but significant proportion of the variation in the data ($r^2 = 0.16$; df = 52; $P < 0.01$). The number of occurrences recorded for each taxon was also correlated with the length of time that the species had been known to occur in the Top End ($r = 0.30$; df = 52; $P < 0.05$). However, the predictability of the regression model is low and there are many species which appear to have been either much less successful or much more successful than suggested by the model (e.g. *Pennisetum pedicellatum*). Some of these differences may be a result of species being unreported for many years after first being introduced to the Region. Others are expected to relate to certain attributes (e.g. dispersal mechanisms) of particular species and to suitability of the local habitat. Some recently introduced plants are expected to become much more widespread with time. Both *Andropogon gayanus* and *Pennisetum polystachion* are established at a few localities in the ARR but are common weeds of road sides and disturbed woodland around Darwin. *Stylosanthes hamata* was probably introduced to the Region during the early 1970s but has already proved a highly successful coloniser of disturbed places.

The occurrence of some species can be traced either directly or by circumstantial evidence to introductions for specific purposes. *Chloris gayana*, *Cenchrus ciliaris*, *Stylosanthes hamata* and *Cynodon dactylon* have been introduced for soil stabilisation at the Ranger Uranium Mine and the settlement at Jabiru East (A. Armstrong pers. comm.), while *Themeda quadrivalvis* appears to have been a contaminant in pasture seed. Several pasture species were planted in trials at Mudginberri and Munmarlary stations in the late 1960s and early 1970s (I. Miller pers. comm.). *Stylosanthes guianensis*, *Stylosanthes humilis*, *Macroptilium atropurpureum*, *Macroptilium lathyroides*, *Cenchrus ciliaris*, *Urochloa mutica* and *Urochloa mosambicensis* are known to have been planted as part of these trials, while *Calopogonium mucunoides* and *Stylosanthes viscosa* are pasture species which are thought to have first occurred in the Region during the same period.

A wide range of species appear to be able to invade riparian habitats and disturbed areas. The most widespread species in this category are *Hyptis suaveolens*, *Sida acuta*, *Passiflora foetida*, and *Sida cordifolia*. *Pennisetum polystachion* is one of a few species that appear to be able to invade undisturbed woodland and open forest communities, even when these communities have been burned.

4.2 Analysis of sites

Alien plant species richness was found to be positively correlated with area of site ($r = 0.461$; df = 42; $P < 0.01$). However, although axis 1 of the DCA ordination (Fig. 3) was correlated with area of site it was not significantly correlated with species richness. Axis 2 was correlated with species richness. Therefore, the relationship between species richness, area of site and the groupings produced by TWINSPAN was more closely examined.

An ANOVA of species richness between site groups recognised by TWINSPAN was significant ($F = 12.16$; df = 3,40; $P < 0.001$), indicating differences in species richness between some groups. Least Significant Differences for species richness of site groups revealed that groups 3 and 4 were not significantly different, while groups 1 and 2 were significantly different from each other and from groups 3 and 4.

Since area of site is correlated with species richness and with Axis 1 it was expected that area of site might also explain the observed groupings. A chi-squared test of area of site and site groups recognised by TWINSPAN was significant ($\chi^2 = 17.44$; df = 6; $P < 0.01$). Chi-squared tests of area of site for pairs of groups showed that group 4 was significantly different from groups 1, 2 and 3 which were not significantly different from each other. Group 4 comprised the largest sites.

Table 3. An arranged matrix produced by TWINSPAN showing species and the sites at which they occurred. The number of occurrences for each species and the percentage of sites at which each species occurred are also given.

- = absence; + = presence; • = indicator species for site groups 3 and 4

Site group			1							2														3												4							
Site no.	No. of occurrences	% of sites	28	11	30	14	15	16	34	23	7	12	22	26	27	10	35	39	20	42	44	43	31	19	36	1	3	21	13	18	29	32	40	41	2	24	25	37	9	33	6	8	17	38	4	5
Species																																													
Calopogonium mucunoides	9	20.5	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	•	•	•	•	-	-	•	•	-	-	•	-	-	-	-	-	-	-	-	-	-	+	-
Mimosa pigra	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Urochloa mutica	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andropogon gayanus	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stylosanthes guianensis	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sesamum indicum	2	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera hirsuta	9	20.5	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	•	•	•	•	-	-	•	•	-	-	-	-	-	-	-	-	-	-	-	-	-
Axonopus compressus	1	2.3	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cucurbita sp.	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stylosanthes viscosa	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corchorus aestuans	8	18.2	+	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Cassia occidentalis	13	29.5	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	•	•	•	•	-	•	•	-	-	•	•	+	-	-	-	-	+	-	-	-	-	-	-
Crotolaria goreensis	6	13.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Malachra fasciata	8	18.2	+	-	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Heliotropium indicum	7	15.9	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Bidens spp.	3	6.8	-	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Passiflora foetida	27	61.4	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	+	+	-	+	-	-	+	-	-	-	-	+	-
Physalis minima	5	11.4	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Sida rhombifolia	3	6.8	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cassia obtusifolia	19	43.2	+	+	-	-	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	+	+	+	-	-	+	+	-	-	-	-	+	-
Hyptis suaveolens	42	95.5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-
Sida acuta	40	90.9	+	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Trianthema portulacastrum	7	15.9	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-
Sida cordifolia	30	68.2	-	-	-	-	-	-	-	+	-	+	+	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+
Stylosanthes spp.	28	63.6	-	-	-	-	-	-	-	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+
Euphorbia hirta	28	63.6	+	-	+	-	-	-	-	+	+	+	+	+	-	+	+	+	+	-	-	-	-	-	+	-	+	+	+	+	-	-	-	+	•	•	•	-	•	•	•	•	•	•	•	•
Alysicarpus vaginalis	28	63.6	-	-	-	-	-	-	-	-	+	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	+	+	+	+	-	+	+	+	+	+	-	+	+	+	+	-	+	+	-
Digitaria bicornis	34	77.3	-	-	-	-	-	-	-	+	+	+	+	-	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pennisetum pedicellatum	28	63.6	-	+	-	-	-	-	-	+	+	+	+	+	-	+	+	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	-	+	+	+	+	+	-
Urochloa mosambicensis	3	6.8	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-

Dactyloctenium aegyptium	25	56.8	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	+	+	-	-	+	-	+	+	+	-	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+
Amaranthus viridis	6	13.6	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+
Cassia alata	3	6.8	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
Hibiscus sabdariffa	18	40.9	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	+	-	•	-	-	•	-	•	•	•	•	•	•	+	+	+	+	-	-	-	+	-	-	+	+
Echinochloa colona	11	25.0	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	•	-	-	•	•	•	•	-	-	•	-	+	-	-	-	-	+	-	-	-	-	+	+
Cenchrus echinatus	4	9.1	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
Rhynchelytrum repens	10	22.7	-	-	+	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	+	+	-	+	-	+
Cynodon arcuatus	13	29.5	-	-	-	-	-	-	-	+	+	+	-	-	-	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	+	+	+	+	-	-	-	+	+	-
Eleusine indica	6	13.6	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-
Mitracarpus hirtus	12	27.3	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	+	+	+	-	+	-	-	+	+	-	+	-
Tridax procumbens	4	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-
Chloris barbata	15	34.1	+	-	-	-	-	-	-	+	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	-	•	•	•	•	•	•	-	•	•	•
Desmodium tortuosum	3	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-
Macroptilium lathyroides	5	11.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	-
Cynodon dactylon	8	18.2	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	•	•	•	•	-	•	•
Pennisetum polystachion	4	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	-	-	+	-
Cenchrus ciliaris	3	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	+	-
Chloris gayana	4	9.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	+	+
Themeda quadrivalvis	2	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
Ipomoea quamoclit	2	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Stachytarpheta urticifolia	2	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Macroptilium atropurpureum	6	13.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+	-	-	+	+	+
Gomphrena celosioides	9	20.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	•	•	•	•	-	•	-	•	-	-	•	•
Ruellia tuberosa	3	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-
Alternanthera pungens	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Synedrella nodiflora	2	4.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Acanthospermum hispidum	1	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-

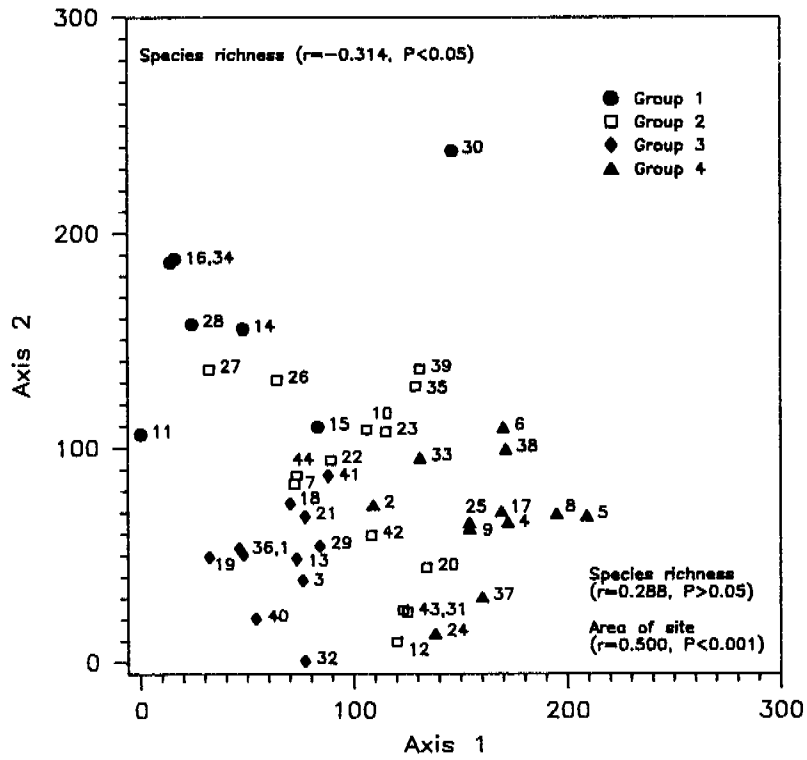


Figure 3. Results of detrended correspondence analysis (DCA) of survey sites with groups recognised by the TWINSPAN analysis.

The amount of variability in the data explained by the analysis is 21% for axis 1 and 13% for axis 2. Correlates and their significance levels for each axis are shown. Axis units are standard deviations of species turn over multiplied by 100. Site numbers given correspond to those in Table 1.

The species composition of the groups recognised from the TWINSPAN analysis can be seen in Table 3, together with indicator species for each group. The flora of the sites surveyed is relatively heterogeneous. A dendrogram of the site classification with indicator species at each division is shown in Fig. 4. The first division separated from all other sites the comparatively species rich, larger sites consisting mostly of settlements and mines (Group 4). TWINSPAN recognised 4 indicator species, *Chloris barbata*, *Cynodon dactylon*, *Gomphrena celosioides* and *Euphorbia hirta*, for group 4 (Table 3). The next division split off small, species-poor sites which mostly have minimal disturbance (Group 1) and an outlier (the extreme environment of fine grained mine tailings). There were no indicator species associated with this group. The third division split off sites once used for stock handling activities (Group 3) from the remainder of sites. Group 3 had 5 indicator species: *Calopogonium mucunoides*, *Indigofera hirsuta*, *Cassia occidentalis*, *Hibiscus sabdariffa* and *Echinochloa colona*. The remaining group, Group 2, had none.

The arrangement of sites produced by ordination and classification can be largely explained by differences in species richness (which was in turn related to area of site) (Group 1, 2 and 4) and floristic composition (Groups 3 and 4). The comparatively high species richness of Group 3 was not associated with a large site size.

Studies of other plant communities have shown that the number of species recorded is related to size of sample area and the recency of disturbance (Muller-Dombois & Ellenberg 1974; Rice & Westoby 1983). Thus it is not surprising that large disturbed areas had more alien species than did small areas. The ARR survey results also indicate that there is an association between size-of-site and land use - the larger sites are generally settlements, but also include the mines. Since these large sites are species rich (in terms of naturalised aliens) and are still in use it is expected that they will be the sites of major concern so far as the introduction of new alien species is concerned. The abandoned stock-handling sites are also comparatively species rich but are unlikely to be the focus of future introductions of new alien species. Plant species on these latter sites may continue to spread.

It is expected that some of the relatively minor differences in species composition (see Table 3) are related to the type and intensity of disturbance which occurred at sites in each of these two groups. The relationship between particular site factors and floristic composition is not known. The recency of arrival of many species means that they have not invaded all potentially available habitats, a factor which may further influence the result of any classification or ordination.

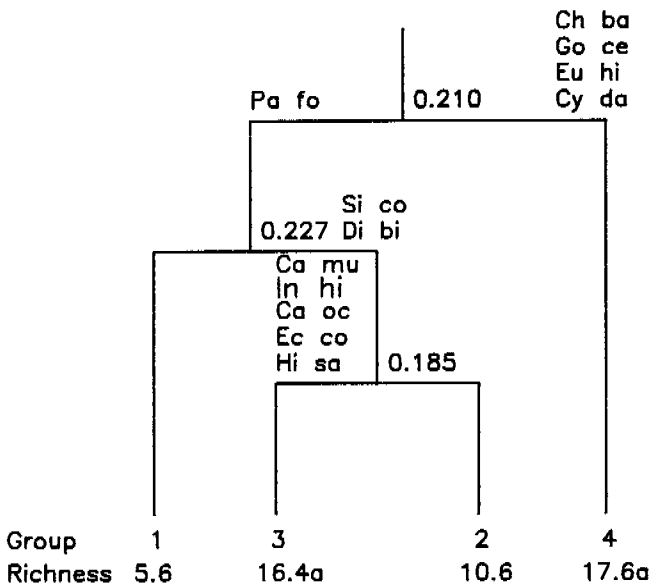


Figure 4. Dendrogram of divisions produced by the two-way indicator species analysis (TWINSPAN) of site data, showing indicator species and eigenvalues at each division and mean species richness for groups. Groups with the same letter are not significantly different in richness. Species names have been abbreviated to the first two letters of the generic and specific names.

4.3 Major weed species

Determination of which species were major weeds was based on an assessment of the noxious weed list of the N.T. Department of Primary Production and concerns expressed in the management plan for Kakadu National Park (Australian National Parks and Wildlife Service 1986). *Salvinia molesta* and *Mimosa pigra* are on Schedule 1 and 2 of the N.T. *Noxious Weeds Act* (Appendix 1), while *Hyptis suaveolens*, *Sida* spp., *Pistia stratiotes* and *Pennisetum polystachion* are on Schedule 2. *Urochloa mutica* is viewed with concern by the park authority and *Passiflora foetida* is widespread throughout the Region. General ecological features of these species are described below.

Salvinia molesta (salvinia)

This floating aquatic weed was found in the southern part of the Magela flood plain in September 1983 (Finlayson 1984*a*). It spread further during the 1983-84 Wet season and by the end of the following Dry season completely covered several billabongs (Plate 1a). Depressions (including buffalo wallows and swim channels) and moist soil amongst the *Melaleuca* communities on the western side of the flood plain harboured many plants (Plate 1b).

Extensive chemical control measures such as those used elsewhere in Australia (Finlayson & Mitchell 1982) were ruled unsuitable owing to accessibility problems and expense. Populations of the weevil *Cyrtobagous salviniae*, used for biological control (Room et al. 1984), were collected elsewhere in the N.T. and introduced by the Department of Primary Production (N.T.) to the flood plain. Evidence of weevil damage and spreading weevil populations were detected in June 1985 (C. Wilson pers. comm.).

This plant species has the potential to rapidly colonise areas of open water (Finlayson 1984*b*) and to cover all billabongs for at least the Dry season and possibly alter their biological and chemical nature. Wet season water flow generally flushes out the bulk of the plants and redistributes them over the flood plain. Survival of the plants on the flood plain is dependent on the availability of surface water over the Dry season.

Mimosa pigra (mimosa)

This species is a thorny, woody shrub (Plate 1c,d), up to 6 m high, of South-central American origin (Miller 1983) and possibly poses the greatest threat to the present plant and animal communities of the flood plains of the ARR. It has a seed production rate of about 12 000 seed m^{-2} y^{-1}, with seed-set primarily occurring between the middle of the Wet season and the middle of the Dry season (M. Lonsdale pers. comm.). The seeds are small (0.01 g) and are dispersed by water and in mud adhering to vehicles and animals. They are short-lived in the soil, but the high seed output, persistence of seedlings and resprouting of mature plants can result in rapid regeneration or establishment.

Known occurrences in the ARR include Kapalga, Munmarlary, Yellow Water (Cooinda), Nankeen Billabong (on Magela Creek), permanent swamps on the West Alligator and Wildman rivers, and near Oenpelli in Arnhem Land (A. Skeat pers. comm.). The Australian National Parks and Wildlife Service currently has four people employed in Kakadu National Park to survey the park and manually remove or spray with herbicide all detected occurrences. This program has proved effective in reducing the size of infestations, but continued success is jeopardised by the large extent of infestations on land adjoining the Park. Quantitative information on the ecology of *Mimosa pigra* in the N.T. is currently being collected by CSIRO Division of Entomology and biological control projects have been underway for a few years (Miller 1983; M. Lonsdale pers. comm.). Seed-feeding *Acanthoscelides* spp. beetles and the foliage feeder, *Chlamisus* sp., were released in 1983 and

1984 respectively but no quantitative assessment of their effect is yet available (Miller 1983; M. Lonsdale pers. comm.).

Some experience of *Mimosa pigra* infestations is available from the Adelaide River where it covers an estimated 8000 ha (M. Lonsdale pers. comm.). It generally occurs in monospecific stands and can form extensive and impenetrable thickets of up to 200-300 plants per ha (Miller et al. 1981), effectively changing the grassland and sedgeland habitats into shrubland.

Hyptis suaveolens (hyptis, hore hound)

This species is prevalent along road verges, around camping areas and along the edge of flood plains, sandy creeks and channels. In Venezuela, it is described by Wulff & Medina (1971) as an aggressive annual weed restricted to profoundly disturbed soils such as road verges and abandoned fields. It is an erect annual, 1.5 m high shrub (Plate 1e) with a characteristic aromatic smell and can grow in most soil types except those that are permanently waterlogged (Miller 1982). It was first recorded in the N.T. at Port Essington by Leichhardt in 1845, having been brought from Timor, but is of tropical American origin. By 1891 it was regarded as a serious weed in the Darwin area (from a separate introduction) (Holtze 1892) and has continued to spread throughout the wet-dry tropical parts of the N.T., presumably as a consequence of land clearing and cultivation (Hall 1967).

In the ARR its distribution indicates that it is adept at invading disturbed areas and may be spread by adhering to buffalo. Its extremely wide occurrence might be viewed by some as aesthetically displeasing in a national park, but no evidence is available to suggest it is detrimental to native plant species except a note by Holtze (1892) that it competes with undergrowth in forests.

Sida spp. (spinyhead sida, flannel weed and paddy's lucerne)

Three species of *Sida* are recognised weeds: *Sida acuta* (Plate 2a), *Sida rhombifolia* and *Sida cordifolia* (Plate 2b). *Sida acuta* (spinyhead sida) is the most common in the ARR. It is a woody perennial or annual, about 1 m high and of Central American origin (Miller 1982). The fruit capsule segments have two points that attach to fur and hair of animals and hence aid in dispersal. It is common along roadsides and in grazed areas. About 30% of its seed remains dormant at the end of the Dry season (Mott 1980) leading to the carry over of seed to the following year and maintenance of a pool of viable seed in the soil. *Sida cordifolia* (flannel weed) and *Sida rhombifolia* (paddy's lucerne) are not usually as common, but are found in similar habitats to *Sida acuta*.

Passiflora foetida (wild passionfruit)

This species, of South American origin, is a thin-stemmed perennial vine (Plate 2c) with round orange fruit containing a sweet pulp (Kleinschmidt & Johnson 1977). It is common along sandy stream banks, flood plain fringes, the margins of monsoon forest and disturbed places. Along with *Hyptis suaveolens* and *Sida acuta* it is one of the most widespread alien plants in the ARR, a situation largely foreseen by Holtze (1892) who noted that 'as the fruit is relished by birds and natives, this plant promises to become a great nuisance'. Holtze (1892) also noted that, as *Hyptis suaveolens*, it competed with native forest undergrowth.

Plate 1. *(This page)* (a) and (b) *Salvinia molesta*; (c) and (d) *Mimosa pigra*; (e) *Hyptis suaveolens*

Plate 2. *(Opposite)* (a) *Sida acuta*; (b) *Sida cordifolia*; (c) *Passiflora foetida*; (d) *Brachiaria mutica*; (e) *Pistia stratiotes*; (f) *Pennisetum polystachion*

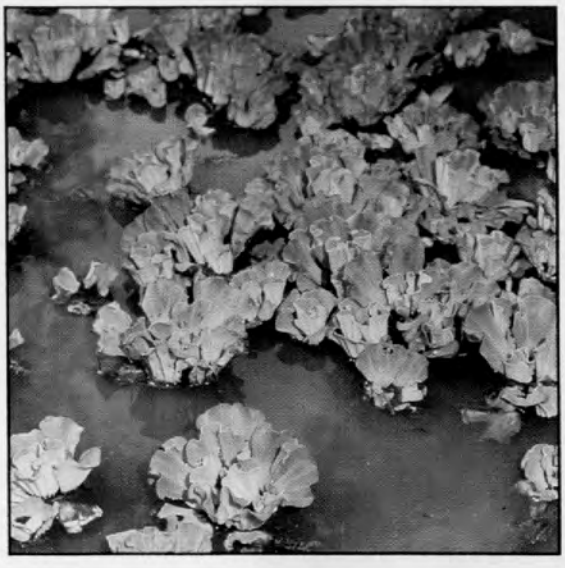
a

b

c

d

e



f

Urochloa mutica (paragrass)

This decumbent perennial grass species (Plate 2d) was introduced to the ARR for pasture improvement. It has been present in the Oenpelli region since before 1948 (Specht 1958). With the gradual removal of feral buffalo from the flood plains it appears that *Urochloa mutica* is more responsive (by increased growth) to the reduction in trampling and grazing pressure than are native grass species. In the Magela Plain (commonly referred to as Western Plains) area of the Magela Creek flood plain its distribution has expanded since it was first noticed in relatively shallow water amongst the native *Hymenachne acutigluma* in 1982-83. In other flood plain areas the formerly dominant *Phragmites karka* has not responded (by expanding) to the reduction in buffalo pressure to the same extent as *Urochloa mutica* (D. Lindner pers. comm.). On the East Alligator flood plain, it has invaded large areas formerly occupied by native sedges and grasses.

Pistia stratiotes (water lettuce)

This floating aquatic species (Plate 2e) has been recorded at Didygeegee Swamp, East Alligator flood plain and on a back swamp of the South Alligator River flood plain (M. Armstrong pers. comm.) - the only known occurrences in the ARR. It is found further west (Wildman, Mary, Adelaide, Finniss, Reynolds and Daly rivers) and east (e.g. Arafura Swamp) of the ARR. Under current legislation it is listed on Schedule 2 (growing and spread of these species to be controlled) of the N.T. *Noxious Weeds Act*. It is listed as a noxious weed in Queensland where it forms troublesome mats in creeks and billabongs (Mitchell 1977), usually those with high nutrient levels (S. Jacobs pers. comm.).

There is some question as to whether this species is alien or native. Currently it is thought that it may be native to the Top End because it is widely distributed (but not common) in inaccessible areas, and because it has not become a problem, as has occurred in other places. However, there is little definitive evidence to verify this speculation. It is important to note, though, that under suitable conditions it can become a major weed.

Pennisetum polystachion (mission grass)

This tall robust, tufted perennial grass (Plate 2f) has only recently been recorded at four localities in the ARR but is well established around Darwin, where it was first recorded in 1974. It is a weed of roadsides in coastal Queensland (Kleinschmidt & Johnson 1977). *Pennisetum polystachion* has been observed to produce a high fuel-load which does not cure until well into the Dry season and thus may have the capacity to alter fire regimes in areas where it has displaced the native annual, *Sorghum intrans*. The occurrence of more and hotter late Dry season fires (which may be promoted by the presence of this species) could have important consequences for the management of the vegetation in Kakadu National Park, in revegetated areas and on the outskirts of settlements (Braithwaite & Estbergs 1985; Hoare et al. 1980). As this species has a light, probably wind dispersed diaspore it is expected that it will spread quickly in the ARR. The related, but less robust annual, *Pennisetum pedicellatum*, is more widespread and was found at 60% of the sites surveyed in this study.

Pennisetum polystachion has recently (January 1985) been declared a Schedule 2 noxious weed in the Northern Territory.

5 ACKNOWLEDGMENTS

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APPENDIX 1

NORTHERN TERRITORY *NOXIOUS WEED ACT* (1985)

SCHEDULE 1 - necessary to eradicate

Botanical name	Common name	Location
Acacia catechu	Cutch tree	All N.T.
Acacia nilotica	Prickly acacia	All N.T.
Asphodelus fistulosus	Onion weed	All N.T.
Datura ferox	Longspine thornapple	All N.T.
Echium plantagineum	Patterson's curse	All N.T.
Eichhornia crassipes	Water hyacinth	All N.T.
Jatropha curcas	Physic nut	All N.T.
Lycium ferocissimum	African boxthorn	All N.T.
Martynia annua	Devil's Claw	All N.T.
Mimosa pigra	Mimosa	South of 14°S
Parthenium hysterophorus	Parthenium weed	All N.T.
Salvinia molesta	Salvinia	All N.T.

SCHEDULE 2 - desirable to control the growth and spread

Botanical name	Common name	Location
Acanthospermum hispidum	Star burr, goat's head	All N.T.
Alternanthera pungens	Khaki weed	All N.T.
Calotropis procera	Rubber bush	Barkly and Alice Springs regions
Carthamus lanatus	Saffron thistle	All N.T.
Cassia obtusifolia	Sicklepod	All N.T.
Cassia occidentalis	Coffee senna	All N.T.
Cenchrus echinatus	Mossman River grass	All N.T.
Emex australis	Spiny emex	All N.T.
Hyptis suaveolens	Hyptis	All N.T.
Jatropha gossypifolia	Bellyache bush	All N.T.
Lantana camara	Common lantana	Outside town areas
Lantana montevidensis	Creeping lantana	Outside town areas
Leonotis nepetifolia	Lion's tail	All N.T.
Mimosa pigra	Mimosa	North of 14°S
Mimosa pudica	Common sensitive plant	All N.T.
Opuntia spp.	Prickly pears	South of 18°S, outside town areas
Pennisetum polystachion	Mission grass	All N.T.
Pistia stratiotes	Water lettuce	All N.T.
Parkinsonia aculeata	Parkinsonia	All N.T.
Prosopis limensis	Mesquite, algaroba	All N.T.
Salvinia molesta	Salvinia	All N.T.
Sida acuta	Spinyhead sida	All N.T.
Sida cordifolia	Flannel weed	All N.T.
Sida rhombifolia	Paddy's lucerne	All N.T.
Stachytarpheta spp.	Snake weeds	Outside town areas
Themeda quadrivalvis	Grader grass	All N.T.
Tribulus cistoides	Caltrop	All N.T.
Tribulus terrestris	Caltrop	All N.T.
Xanthium pungens	Noogoora burr	All N.T.
Xanthium spinosum	Bathurst burr	All N.T.

SCHEDULE 3 - desirable to control the introduction into the Northern Territory

Botanical name	Common name
Acroptilon repens	Creeping knapweed
Ageratina riparia	Mistflower
Alternanthera philoxeroides	Alligator weed
Ambrosia artemisiifolia	Annual ragweed
Ambrosia psilostachya	Perennial ragweed
Baccharis halimifolia	Groundsel bush
Cryptostegia grandiflora	Rubbervine
Datura spp.	Thornapples
Egeria densa	Dense waterweed
Elodea canadensis	Canadian pondweed
Eriocereus martinii	Harrisia cactus
Hyptis capitata	Knobweed
Lagarosiphon major	Lagarosiphon
Mimosa invisa	Giant sensitive plant
Prosopis spp.	Mesquite
Xanthium spp.	Burrs

SUPERVISING SCIENTIST FOR THE ALLIGATOR RIVERS REGION

RESEARCH PUBLICATIONS

Alligator Rivers Region Research Institute Research Report 1983-84
Alligator Rivers Region Research Institute Annual Research Summary 1984-85
Alligator Rivers Region Research Institute Annual Research Summary 1985-86
Alligator Rivers Region Research Institute Annual Research Summary 1986-87

Research Reports (RR) and Technical Memoranda (TM)

RR 1	The macroinvertebrates of Magela Creek, Northern Territory. April 1982 (pb, mf - 46 pp.)	R. Marchant
RR 2	Water quality characteristics of eight billabongs in the Magela Creek catchment. December 1982 (pb, mf - 60 pp.)	B.T. Hart & R.J. McGregor
RR 3	A limnological survey of the Alligator Rivers Region. I. Diatoms (Bacillariophyceae) of the Region. August 1983 (pb, mf - 160 pp.)	D.P. Thomas
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