ENVIRONMENTAL WEEDS OF THE WET TROPICS BIOREGION: RISK ASSESSMENT & PRIORITY RANKING

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January 2001

Report prepared for the Wet Tropics Management Authority, Cairns

EXECUTIVE SUMMARY

An examination of the issue of alien plant species invasions of the Wet Tropics Bioregion was conducted in order to consider management implications for the Wet Tropics of Queensland World Heritage Area. The **terms of reference** for the project comprised the development of a computer-based weed Risk Assessment System encompassing (i) **inventory** of existing weeds, plants presently found in the region that may constitute 'sleeper' weeds and plants not presently found in the region that are proven environmental weeds in similar environments elsewhere; (ii) **prioritisation of potential environmental threat** based on explicit biogeographic/historical and biological/ecological criteria; (iii) **categorisation** into management categories - eg, species targeted for prevention, eradication and containment control; and (iv) consideration of **appropriate management actions**.

This Report presents **a review of Risk Assessment Systems (RASs)** currently being applied or developed with the view to formulating a robust system to screen alien species that have naturalised within the bioregion. Systems reviewed were: (1) RASs for Preventative Quarantine Purposes – ie, International protocols (FAO 1996, 1998a, 1998b); Prevention or minimisation of risk of introductions to countries with comparable habitats/vulnerabilities (eg, Virtue et al. in press, Williams et al. in press); Australian protocols (Pheloung 1995, Steinke & Walton 1999); State initiatives – various (eg, Hall 1999, Keighery 1999, Carter 2000); and (2) RASs for Prioritising Existing Weed Incursions - ie, Exotic Species Ranking System (ESRS) of US Department of Interior, National Parks Service (Hiebert & Stubbendieck 1993); Australian WRA Protocol Details (Pheluong 1995, Virtue et al. in press); Wildland Weed Priority Ranking System of US Nature Conservancy (Randall et al., in press); Weed Risk Assessment in Hawaii (Teytaud 1998; Thomas, in press); Weed Risk Assessment in the Galapagos Islands (Tye, in press); Determination of Weeds of National Significance (WONS) (Thorp 1999); and Weed Assessment Scoresheet of the Animal and Plant Control Commission of South Australia (Virtue 2000). The **rationale behind the proposed Wet Tropics RAS**, which was derived from existing systems, is considered, pending its acceptance and application by the Wet Tropics Management Authority.

The Queensland Herbarium's HERBRECS list of naturalised species occurring within the region was refined by (i) concatenating closely related taxa; (ii) incorporating nomenclatural changes and taxonomic revisions; and (iii) by adding those species known to have naturalised but which have not been incorporated officially due to lack of collection, etc. This resulted in a list of at least **504 species of exotic (alien) plants** that have established self-maintaining populations in the Wet Tropics.

This Report contains **a preliminary ranking, employing the proposed RAS, of 57 wet tropics weed species**. These were drawn from a list of 26 terrestrial species compiled by DNR (Land Protection), including a single native species, supplemented with a further 24 representing a variety of other taxonomic and life

form groups, together with seven naturalised aquatics. They are thus a **sample embracing those major weeds that have already been identified by a range of interest groups**. This then is addressing an existing problem of target species for priority control.

The two species that ranked highest were *Annona glabra* (Pond Apple) and *Leucaena leucocephala* (Leucaena). The former is classified as a Weed of National Significance, while the latter has demonstrated gross weedy tendencies overseas and is among the 32 land plants in the list of the world's 100 worst invasive species.

Species that ranked next highest comprised: ***Chromolaena odorata*** (Siam Weed), ***Sphagneticola trilobata*** (Singapore Daisy), ***Miconia calvescens*** (Miconia), ***Hymenachne amplexicaulis*** (Hymenachne), ***Psidium guajava*** (Guava), ***Thunbergia* spp.** (includes Blue Trumpet Vine), ***Mikania micrantha*** (Mile-a-minute), ***Brachiaria mutica*** (Pará Grass) and ***Panicum maximum*** (Guinea Grass).

Several are also included amongst the world's worst alien invaders. All have exhibited extremely aggressive weedy tendencies elsewhere and/or are currently extremely aggressive weeds of the region, and, in the case of Hymenachne, Pará Grass and Guinea Grass, are very aggressive and greatly impair ecosystem function. These are considered to be **'transformer species'** – ie, invasive species that can change the character, condition, form or nature of a natural ecosystem over a substantial area

Some consideration was given to weed management issues, although for management there are many other considerations beyond ecological risk. Therefore, management feasibility screening of species is argued to constitute the next phase of the assessment process. There is some indication that others are in the early stages of invasion (ie, prior to exponential rates of increase) and likely constitute 'sleeper' weeds deserving of early detection and eradication. Arguably the first management action is to seek an **embargo on further exotic species introductions to the region and agency cooperation in the cessation of promotion** of perceived 'useful' species such as Leucaena that already have proven to be major environmental weeds.

The Report also presents **recommendations for further research**. These include:

- **peer review and sensitivity testing** of the Wet Tropics RAS;
- procuring **additional biological/ecological information** on the remaining naturalised exotics and their assessment using the RAS;
- **mapping of infestations** – especially high scoring weeds with comparatively limited distributions in the region to assist management deliberations; and,
- **formulation of a secondary screening system** to explicitly take into account feasibility, costs and strategic matters associated with weed control and eradication.

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"Biological diversity faces many threats throughout the world. One of the major threats to native biological diversity is now acknowledged by scientists and governments to be biological invasions caused by alien invasive species. The impacts of alien invasive species are immense, insidious, and usually irreversible. They may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats."

SSC Invasive Species Specialist Group of IUCN (2000)

1.0 Introduction

Lövei (1997:627), noting that the scale of species introduction has vastly increased, argued that alien species invasion must be recognised as "an important component of human-induced global change and as a serious threat to biodiversity". Introduction of alien organisms frequently produces drastic impacts on the receiving biota and systems. Long term global effects comprise both decreasing the local distinctiveness of floras and faunas and the breaking down of geographic isolation that promotes and maintains global biodiversity generally. In fact, Willis *et al.* (2000:275) claim that threat to biodiversity posed by alien species invasions is second only to habitat loss.

It is estimated (Virtue *et al.* in press) that approximately 15% of the vascular flora of Australia (or over 2 200 species) has been introduced. Those introductions have been both deliberate (ie, for purposes of agricultural production, ornamental amenity and for other reasons) and accidental (as in contaminants in imported pasture seed or stock, via various modes of human transport, and the like). A significant subset of these exotic species has subsequently naturalised in the new host environment to impose major impacts on Australian ecosystems, both natural/semi-natural and anthropogenic (including intensive agro-ecosystems and extensive rangelands). These subsets are referred to as 'environmental' and 'agricultural' weeds respectively.

The vascular flora of the Wet Tropics Bioregion alone, is estimated to be 4 664 species (WTMA 2000:25). With a total of 508 exotic taxa noted by the Queensland Herbarium to be naturalised within the region (see Appendix 2 below) – which itself is a likely underestimate (see Section 5.5.1) – this amounts to almost 11% of the region's native flora. Despite the exotic component being a slightly lower proportion than the national average (Virtue *et al.*, in press), the existence of a high level of endemism and the fact that much of the region (approximately 9 000 km^2) has been inscribed on the World Heritage list as the Wet Tropics of Queensland World Heritage Area (Werren & King 1991) predicates a high priority on weed control within area management. This has prompted the present initiative for the development of an environmental weed 'risk assessment system' (RAS) for the Wet Tropics Region as a means of contributing to the meeting of Australia's international obligations under the *World Heritage Convention*. The RAS will incorporate an ecologically based, logistically and economically feasible system for identifying priorities for weed prevention, eradication, containment or control.

While there are many pests of the agricultural and pastoral industry and others (particularly ponded pasture species) that constitute both pests of agricultural and natural systems, it is the 'environmental weed' component that is the subject of the current investigation. '**Environmental weeds**' are defined as "**introduced species capable of establishing, or are considered to have a high probability of establishing self-sustaining populations by invading native communities or ecosystems and are capable of causing major modification to species richness, abundance or ecosystem function**" (Goosem 1993). Williams & West (2000:429) note that these can "come in all shapes and sizes, and grow in all niches in an ecosystem". This component includes (i) plants that have already demonstrated a capacity to institute such changes within the region and (ii) others that occur in the region and, due to certain inherent traits or because of their demonstrated weediness elsewhere, constitute potential threats to native communities and ecosystems. The latter might be referred to as 'sleeper weeds' (Groves 1999).

It is proposed to adopt terminology consistent with that employed by Richardson *et al.* (2000) within this report. This avoids the plethora of confusing ascriptions - eg, 'immigrants' *vs* 'aliens' to describe benign *vs* serious weeds respectively (Bazzaz 1986:97) - and the various synonyms and synonymous phrases such as "neosynanthropic plant" of Heywood (1989:32).

In the report that follows, consideration is initially given to the ecology of invasions of exotic species (Section 2.1). Given that some countries and places are more prone to invasion than others, the subject area (Australia's Wet Tropics) is examined (Sections 2.2, 2.3) with regard to establishing principles of invasion proneness. Furthermore, prior considerations of invasive species within the region were examined (Section 2.4) as were various landscape components deemed to be particularly at risk (Section 2.5).

In Section 3, the various weed Risk Assessment Systems (RASs) were reviewed and the basic elements identified (Section 3.3) for the purpose of devising an appropriate system for use in the Wet Tropics. The task of tailoring a RAS explicitly for this region is explored in Section 4. This is set out in four parts – ie, guidance from insights into weed invasions in tropical settings (4.1), consideration of intrinsic (biological) traits (4.2) and extrinsic factors (4.3), resulting in a derivative ranking methodology as detailed in 4.4.

Section 5 consists of an attempt to provide a current inventory of alien plant species present in the region, with exotic species recorded as naturalised regionally within the database of the Queensland Herbarium (HERBRECS) forming the basic data set (Section 5.1). This list of exotic naturalised plant taxa has been emended to incorporate recent nomenclatural changes and to deal with individual species rather than infraspecific taxa such as subspecies, varieties and varietal cultivars and to take into account exotic species known locally to have naturalised or in the process of doing so but which have not been included to date in the collection. The newly formulated RAS was trialed using a >10% sample including weeds widely held to be the most significant regionally and the outcomes of the assessment compared with what is known regarding some of the most invasive species both globally (Sections 5.3, 5.4) and nationally (5.5). Species regarded to be 'sleepers' or those in the early phases of a potentially explosive invasion are specified in Section 5.6.

Broad management considerations are examined in Section 6. Management responses considered required comprise introduction prevention (6.1), early control intervention (6.2), the importance of efforts being ecologically integrated (6.3), strategic control/containment (6.4) and the need for further research (6.5). The conclusions and recommendations arising from this investigation are outlined in the final section (7.0) and additional information is set out in the form of four appendices – ie, project specifics (Appendix 1), list of naturalised exotic plants (Appendix 2), an interactive species database (Appendix 3), together with a visual presentation of basic elements and outcomes of the project (Appendix 4).

2.0 Background

The current study was recently commissioned by the agency responsible for overarching management of the Wet Tropics World Heritage Area – ie, the Wet Tropics Management Authority (WTMA). Day-to-day management of the Area is the responsibility of State partner agencies that include the Environment Protection Authority's (EPA) Queensland Parks and Wildlife Service (QPWS), Department of Natural Resources (DNR) and others. What follows is designed to inform WTMA decisions regarding allocation of priorities and resources to weed control within the wider gamut of area management and management activities of partner agencies.

2.1 Invasion Ecology

Invasion issues came to the forefront of a developing natural science with the publication in 1958 of Elton's seminal book called *"The Ecology of Invasions by Animals and Plants"*. This prompted not only an interest in plants and animals that have impacts on agriculture but also a greater scientific emphasis on the rapid changes that increased biotic exchange was imposing on indigenous systems and the adverse implications for the survival of native species.

Investigation of exotic species invasions was complemented by the work of Grime (1977) who identified three primary reproductive strategies in plants and discussed the theoretical ramifications for ecology and evolution. He linked external factors such as stress and disturbance and considered the four permutations of (i) high stress-high disturbance, (ii) high stress-low disturbance, (iii) low stress-low disturbance and (iv) low stress-high disturbance and determined that only three provided viable plant habitats since the first scenario is inhospitable to plant growth. Accordingly, scenario '(ii)' is associated with stress-tolerant plants, '(iii)' with competitive plants, and '(iv)' with ruderal or annual plants that are physiologically/reproductively adjusted for rapid life cycles attuned to regular or periodic disturbances. It is the latter category that provides most of the known agricultural weeds – ie, plants that can cope with, or are advantaged by, disturbances associated with cultivation and/or grazing. Environmental weeds, however, belong predominantly but not exclusively to groups of plants associated with scenario '(iii)'. These are species with superior competitive abilities including rapid and highly plastic stress responses (Grime 1977:1184) or such as may arise from the lack of natural enemies in the novel environment (Markin 1989:70) that tend to maximise vegetative growth.

Competitive superiority can arise from various biological/autecological attributes. For instance, rapid acclimation to sudden light increases brought about by canopy gap formation is demonstrated to advantage exotic tree species establishment in subtropical island forests of Japan (Yamashita *et al.* 2000). Incidentally, the tree species in question, Java Cedar (*Bischofia javanica*) is a native rainforest tree of the Australian Wet Tropics. It exhibits a capacity for superior performance in photosynthetic rates of existing shade leaves and rapid deployment of new sun leaves when transferred from shade to sun commensurate with an ability to outperform natives in habitats prone to typhoon (cyclone) disturbance.

Heywood (1989:44-45) argues that invasion of tropical forests is triggered by widespread disruption or conversion of the primary forest to secondary successional communities. The history of widespread logging of the rainforests, combined with cyclone disturbance, has brought about such a situation regionally and, accordingly, an increase in invasion proneness.

Genetic screening may offer possibilities for weed detection since it appears that some non-indigenous plant species grow taller and exhibit a higher reproductive capacity in a host environment compared with their performance in the native environments. Willis *et al.* (2000) investigate the possibility that this is more of a genetic change rather than the traditional proposition of a plastic response to a benign new environment. By comparing several weeds in Australia and New Zealand with their counterparts in Britain and continental Europe these workers failed to find "evidence that increased plant size, where it occurs, is a genetically determined characteristic of of invasive plants, or that the phenomenon is widespread among invasive species" (Willis *et al.* 2000:282). It is, thus, more likely to be a plastic response to a novel environment.

Chemical defences are also associated with the frequently observed superior performance of alien plant species. These defences may be in the form chemical agents such as those that occur in the Neem Tree (*Azadirachta indica*) that reduce herbivory, therefore maximising photsynthetic sequestration and growth. Callaway & Aschehoug (2000) and Ridenour & Callaway (2001), in studies of root exudates of a noxious weed in America, have demonstrated a much greater negative effects on American native grasses than on their counterparts in communities from which the weed originates. In commenting on this work, Jensen (2000:421) claims that "the invader apparently gains an edge in its adopted home not only by ditching its herbivores but by wielding [chemical] weaponry … that hampers its new neighbors' (sic) growth". This has significant repurcussions regarding competition for resources and, of course, implications for invasiveness potential.

Davis *et al.* (2000) attempt to replace andectodal study of the invasion process by considering the availability of resources to a potential invader. These workers suggest that invasion is influenced by three major factors: ie, (i) 'propagule pressure' (the numbers of seeds/fragments, repeated introductions, etc.), (ii) characteristics of the introduced species, and (iii) the invasibility of the new (host) environment. While the second factor pertains to intrinsic or biological traits of the prospective invader, the third is an emergent property that derives from climate, disturbance regimes and the competitive abilities of resident plants. They further argue that a more integrative approach to invasibility and the invasion process might be proposed with respect to fluctuating resource availability. The proposition is that "a plant community becomes more susceptible to invasion whenever there is an increase in the amount of unused resources" (Davis *et al.*2000:529) and that a community's suceptibility to invasion is not static.

Disturbance – whether regular or episodic – is a natural feature of dynamic ecosystems (Sousa 1984) but also facilitates the invasion process by eliminating/reducing the cover and/or vigour of native competitors and/or by increasing resource levels. This is especially so when it coincides with ready availability of the invading species' propagules. Consequently, the following predictions can be made:

- environments subject to to pronounced fluctuations in resource supply (eg, either by periodic fluxes of resources (eg, nutrients, water, etc.) are more susceptible to invasion than comparable systems with more stable resource supply;
- environments are more susceptible to invasion immediately following abrupt disturbances that cause increases/decreases in resource availability (eg, following cyclone damage, fires, etc.);

- invasability will increase when the interval is long between increase in resource supply and eventual capture/recapture of sites by native vegetation;
- nutrient-rich communities, in particular, that are subjected to increased grazing pressures are suceptible to invasion;
- there is no necessary relationship between the species diversity of a plant community and its resilience to invasion; and,
- there will be no general relationship between the primary productivity of a community and its susceptibility to invasion (Davis *et al.* 2000:532).

These predictions appear to be well substantiated, assist in understanding the great variability of the invasion process in both temporally and spatially, and have a direct bearing on the other side of the alien invasion issue – ie, consideration of ecosystems at risk.

Lövei (1997:627) notes that invading plant (and animal) species have caused "drastic changes in the receiving biota", especially in island floras, but continental areas are also greatly impacted. Alien invaders firstly decrease the distinctiveness of local floras/faunas and, secondly, break down the geographic isolation of separate biotic regions that maintains global biodiversity. In some places such as New Zealand, introductions of new plants and animals has dramatically increased species diversity; but as it has become more 'diverse' it has lost and decreased the survivability of many endemic species and has generally become more similar to the rest of the world. The extent of impacts, Lövei argues, renders introduced species invasion as a serious threat to global biodiversity to that of human-induced climatic change (ie, ozone depletion and carbon dioxide enrichment), and possibly second only to vegetation clearing.

A multitude of impacts can derive from environmental weeds. Williams & West (2000:429) succinctly tabulate these impacts (Table 1) but also comment that few quantitative measures of impact have been documented.

Table 1: Potential impacts of environmental weeds on indigenous ecosystems (after Williams & West 2000:Table 5).

competition with native plants for light, nutrients, moisture, pollinators, & they smother/crowd the soil
replacement of native plant communities
prevention/inhibition of natural regeneration
change in the movement of water in both soil & watercourses (see Bunn *et al.* 1998)
increase of soil eroision by shading out ground plants which would normally hold surface soil together
change in the shape of the land (eg, different grass types on coastal dune systems may introduce poisons into the soil that prevent other stabilising plants from growing & may be toxic to animals)
provision of food/shelter for pest animals (including indigenous pest animals such as cane rats)
change in water quality/characteristics (eg, willow (*Salix*) spp. & aquatic habitat)
introduction of foreign genes into local populations by hybridisation (cross breeding & gene swamping)
changes in fire behaviour by altering quantity & flammability of fuel loads
alteration of disturbance regimes

In a review of exotic plant species in Hawaii, Smith (1989:61-62) also details five major impacts in comparable tropical landscapes other than simple physical displacement of native species. These are (i) formation of monotypic stands that results in biodiversity loss and can have devastating effects on the survival of endemic species with limited ranges and small population sizes; (ii) changing fire characteristics (especially due to fire-promoting exotic pasture grasses); (iii) changing soil-water regimes (often due to lack of phenological synchronicity with host environment's climate); (iv) changing nutrient status (associated with introduced N-fixing pasture legumes); and (v) promotion of mutually beneficial interaction between alien plants and feral animals. Also, it should be recognised that impacts can amplify as "the cumulative effects of multiple, low probability events" (Levins 1989:426).

King (1987) reviewed the multiple-staged process of extinction and identified 13 milestones – the final being "excessive competition from introduced species" – that are eventually responsible for pushing organisms irretrievably over the edge. Incidentally, an earlier milestone was "hybridisation and genetic swamping" that may be due to exotics as well as translocated natives. Within Australia, invasive exotic species have been primarily implicated in the presumed extinction of at least four plant species "and have the potential to force many more native plants to extinction" (Groves & Willis 1999:164). The highly restricted nature of many endemic plant species distributions within the Wet Tropics Bioregion (Werren *et al.* 1995; Goosem *et al.* 1999) renders this regional flora particularly vulnerable to extinction due to threatening processes such as pest invasion.

It must be noted, however, that the impacts on native biodiversity associated with alien invaders are not exclusively negative. Groves & Willis (1999:169) point out that impacts can, in fact, be "positive, negative or neutral, depending on the biotic group measured". A tropical example – ie, that of the invasion of *Mimosa pigra* into wetlands of the Northern Territory – was employed. This showed that some plant groups, birds and lizards sustained negative biodiversity impacts, but positive benefits were felt by the rare marsupial mouse *Sminthopsis virginiae* and no changes in frog numbers were detected. It is evident that some invasive exotic species in the wet tropics also produce some benefits to at least nectarivorous native insects, given numbers of butterflies observed foraging on *Lantana camara* and *Asclepias currasavica*. There are, however, strong indications that specialist host-specific insects are impacted greatly with the replacement of native vegetation with exotics supporting greatly reduced arthropod numbers with significant repercussions for predatory mites, spiders, wasps and other parasitic insects and insectivorous frogs, reptiles, birds and mammals (McFadyen 2000).

2.2 Subject Area

The Wet Tropics Bioregion is situated along the tropical east coast of northern Queensland. Its western boundary is shared with the Einasleigh Uplands Bioregion, which lies in the rainshadow of high and wet coastal ranges that dominate the Wet Tropics. In the north the region is bordered by the eastern part of Cape York Peninsula, and in the south grades into the northern coastal extremity of the Brigalow Belt. With an area of 1 849 725 ha, the Wet Tropics Bioregion covers approximately 1% of Queensland (Goosem *et al.* 1999:7/5).

The region is distinguished among Australian bioregions by the extraordinary richness of its flora and vegetation. It is recognised as one of the world's 'centres of plant diversity' (Werren *et al.* 1995) and supports the most extensive tracts of closed forest (vine forest or rainforest) on the continent. It is the second most floristically rich[1] of Australia's biogeographic provinces with in excess of 4 660 species recorded (WTMA 2000:25) of which 25% or over 1 150 species are endemic. The level of generic endemicity in the Wet Tropics Bioregion is second only to New Caledonia in terms of endemic genera conserved per unit area (Webb & Tracey 1981, Morat *et al.* 1986).

In addition, many terrestrial vertebrates are known from the Wet Tropics Bioregion (Williams *et al.* 1996). Of these, 20 are introduced. Excluding these, the total of 566 species represents 28% of all Australian terrestrial vertebrates. At least 12% of these are endemic (i.e., entirely restricted to the region), although this is highly variable between taxonomic groups (4-39% - Williams *et al.*,1996). The region also supports a rich freshwater fish fauna, with 40% of the Australian species' complement represented here, and the Russell-Mulgrave system, in particular, being extraordinarily important to this group (Pusey, pers. comm.). In addition, the invertebrate fauna is very diverse. This is indicated by the fact that 60% of the total Australian species within a single invertebrate group - the butterflies - occurs within this region. Such faunal diversity is similarly threatened by invasive alien species, including both plants and animals.

2.2.1 Climate

Many of the distinctive features of the region relate to the high rainfall and terrain diversity. The mean annual rainfall ranges from about 1 200 mm to over 8 000 mm. However, Mt Bellenden Ker, at an altitude of 1 561 metres, has recorded as much as 10 472 mm over an eight month period (during January to August 1979) and has received 1 140 mm of rain in a 24 hour period (Tracey 1982). Rainfall intensities at this station are amongst the highest recorded in the world. The rainfall is distinctly seasonal with over 60% falling in the summer months of December to March. By comparison with other tropical rainforested areas of the world, the wetter parts of the region lie at the 'extremely wet' end of the hydrological spectrum. The occurrence of widespread overland flow also appears to be rare in wet tropical rainforests elsewhere.

Intense tropical cyclones are a natural disturbance feature of the region's climate, with an average of one severe cyclone occurring every three years. This region has the highest incidence of such tropical cyclones with over 40% of all systems so classified impinging on the Wet Tropics. This is a major factor shaping the structural and floristic differentiation of the vegetation - particularly with respect to the mosaics of the coastal lowlands (Werren *et al.* 1995).

The coastal belt experiences a mean daily temperature from a January maximum of 31^{o}C to a minimum of 23^{o}C with a 5C^{o} reduction in these figures during a very mild winter. The uplands/tablelands are cooler with mean daily temperatures ranging from 28^{o}C to 17^{o}C with mean daily winter temperatures ranging from 22^{o}C to 9^{o}C.

2.2.2 Physiography, geology and soils

The uplands or tableland unit consists of undulating country at an altitude of around 900m, with rounded summits rising to more than 1 200m. The highest peak is Mt Bartle Frere which reaches 1 622m. To the east of the tablelands the Eastern Escarpment marks the limit of headwards erosion into the uplifted erosion surface from the coastal lowlands. This is a unit typified by rugged topography, rapid geomorphic

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[1] The south-western province of Western Australia is the foremost species-rich region of Australia with an estimated 5 500 species (Beard 1995:484), although the generic and familial diversity of the Wet Tropics far exceeds that of this region.

processes and great environmental diversity. The coastal lowlands comprise an alluvial plain of variable width interrupted by ridges of the Great Divide and several large perennial rivers such as the Herbert, North and South Johnstone, Tully, Russell-Mulgrave, Barron, Daintree and Bloomfield, which drain from headwaters on the tablelands/uplands.

The main lithotypes (slates and greywackes) beneath the region comprise marine Silurian, Devonian and Carboniferous sediments of the Hodgkinson Basin and the Broken River Embayment. The greatest concentration of volcanics and granitic parent materials occur at the southern margin of the Hodgkinson Basin where it intersects the trend of the Broken River Embayment. The volcanics of the tablelands and adjacent basaltic/rhyolitic provinces which formed from around 12 million years ago are characterised by scoria cones, lava cones and maars. The tablelands and some portions of the coast were subject to basalt flows throughout the Pliocene-Pleistocene. The high nutrient status of the basalt-derived soils makes them readily to invasion by more nutrient-demanding alien plant species. Climatic change and geomorphic processes during the Quaternary led to repeated coastal transgressions and retreat leading to the attainment of present sea level approximately 4 500 years ago (Werren *et al.* 1995).

2.2.3 Landscape configuration and native vegetation cover

The bioregion is dominated by rugged rainforested mountains, including the highest in Queensland. It also includes extensive plateaux areas along its western margin, as well as low-lying coastal plains. The most extensive lowlands are in the south, associated with the floodplains of the Tully and Herbert Rivers. Most of the bioregion's streams debouche into the Coral Sea section of the Great Barrier Reef Lagoon from small coastal catchments, but higher western areas drain in the south into the Burdekin River, and in the north into tributaries of the Mitchell River.

The major vegetation formation represented within the region is the closed canopy mesic forest or 'rainforest'. The combination of a diversity of rainfall, soil type, drainage and altitude, together with a complex evolutionary history, has resulted in a wide variety of identifiable rainforest communities which is recognised as being floristically and structurally the most diverse of any in Australia. The region's rainforests have been classified into 13 major structural types (Tracey 1982) as follows:

- complex mesophyll vine forest (types 1a, 1b, 1c)
- mesophyll vine forest (types 2a, 2b)
- mesophyll vine forest with dominant palms (types 3a, 3b)
- semi-deciduous mesophyll vine forest (type 4)
- complex notophyll vine forest (types 5a, 5b)
- complex notophyll vine forest with emergent *Agathis robusta* (type 6)
- notophyll vine forest - rarely without *Acacia* spp. (types 7a, 7b)
- simple notophyll vine forest - often with *Agathis microstachya* (type 8)
- simple microphyll vine-fern forest - often with *A. atropurpurea* (type 9)
- simple microphyll vine-fern thicket (type 10)
- deciduous microphyll vine thicket (type 11)
- closed forest with wattle (*Acacia* spp.) emergents/co-dominants (types 12a, 12b, 12c, 12d)
- closed forest with sclerophyll (particularly *Eucalyptus* spp. and some wattles) emergents and co-dominants (types 13a, 13b, 13c, 13d, 13e, 13f).

Each forest type can be correlated with climatic type, soil parent material, altitude and disturbance regimes. The floristic composition within each type varies from one locality to another and reflects, amongst other things, past expansions and contractions of rainforests due to climatic perturbations.

Rainforests attain their peak development as complex mesophyll vine forests on the very wet and wet lowlands and foothills where parent materials range from basalts, basic volcanics, mixed colluvia and riverine alluvia. These communities exhibit an uneven canopy extending to between 20 to 40 metres and there is much stratification and many emergents with large spreading crowns (eg, figs, *Ficus* spp.). Floristic composition and variety of life forms are the most complex of any terrestrial vegetation type on the continent. Exposed sites such as foothill ridges and seaward slope facets often exhibit cyclone disturbed or broken canopies with 'climber towers' and dense vine tangles. These are locally known as 'cyclone scrubs' (Webb 1958). These systems appear vulnerable to exotic species infestations, especially along edges adjacent to agricultural lands. Within complex mesophyll vine forest communities variation in site factors induces conspicuous structural differentiation such as the increase in palms on sites with impeded drainage and gingers and aroids in gullies and along creek banks which are permanently saturated with water (Tracey 1982).

The notophyll vine forest category embraces a structurally and floristically diverse group of communities (types 5, 6, 7, 8 of Tracey 1982). These occur on small areas of basic volcanic parent materials on cool wet uplands and highlands (ie, type 5a) and on a range of drier sites at various elevations (type 5b), the western and northern fringes of the main rainforest massif from Cardwell extending to Julatten, the Hann Tableland and to the north of Bloomfield (type 6), on sandy beach ridges in drier coastal zones and exposed sites backed by foothills north of Cairns (type 7), and as one of the most extensive, an even-canopy mountain forest assemblage (type 8) on granitic ranges rising from 400 to 1 000 metres altitude between Ingham and Cooktown. These communities, while extraordinarily variable, are characterised by a canopy range of 12-45 metres in height, the occurrence of rattans or palm lianes, strangler figs, frequently conspicuous epiphytes and variable amounts of ferns, walking stick palms (*Linospadix* spp.) and fleshy herbs.

Towards the upper end of the altitudinal spectrum on the summits and upper slopes of the higher peaks which are frequently enshrouded by cloud (hence horizontal interception or 'fog-drip' is characteristic) and often exposed to strong winds, simple microphyll fern forests or thickets dominate. These often possess a strong aerially suspended moss component and are sometimes referred to as 'cloud' or 'elfin' forests, or more precisely 'wet montane forests'.

Many sites experience significant water stress during the dry season and support closed forest/thicket communities characterised by the occurrence of taxa which are semi-deciduous to deciduous. Semi-deciduous mesophyll vine forest (type 4) is restricted to minor occurrences to the north-west of Cairns, and to foothills between the Bloomfield River and Cooktown (Tracey 1982). Sporadic occurrences of deciduous microphyll vine thicket (type 11) occur on fire-free rocky sites and exposed headlands. Constituents are mainly multi-stemmed and fully deciduous. Vine forest with sclerophyll emergents (types 12, 13) are also encountered. These represent different stages of post-disturbance (eg, fire, logging and/or cyclones) succession and vary considerably in floristic composition, with each sub-type characterised by the dominance/co-dominance of certain sclerophylls (ie, eucalypts and wattles).

Non-rainforest communities typify approximately one-third of the property listed as the WHA. These include: tall open forest (wet sclerophyll communities - types 14a, 14b - typified by the occurrence of *Eucalyptus grandis*, *E. resinifera* respectively, and a mesic understorey); medium open sclerophyll forest and woodland (types 14c, 14d, 15, 16, 17, 18, 19) dominated by a variety of eucalypts and the bloodwood genus *Corymbia*, together with *Lophostemon suaveolens*, *Melaleuca quinquenervia*; heathy shrublands characterised by *Allocasuarina, Banksia* and *Acacia* etc. about mountain rock pavements (type 21); and various species of wattle and other paperbarks (*Melaleuca* spp.) swamp communities. Stunted paperbark (*M. viridiflora*) low forest/woodland (type 20) occurs on acid soils with impeded drainage adjacent to mangroves (type 22a) which, with around 31 species (Le Cussan, pers. comm.), are amongst the richest, and certainly those exhibiting the greatest vertical development, in the world. Patches of samphire flat almost exclusively dominated by salt-tolerant chenopods (type 22b) are also a feature of the coastal mosaics.

2.3 Consideration of Peculiarities of the Host Environment

The Wet Tropics of Queensland is distinguished by virtue of the fact that in 1988, as an initiative of the Commonwealth Government, some 9 000 km^2 of this bioregion have been inscribed on the World Heritage List (Werren & King 1991). This means that Australia has entered into an international agreement to “protect, conserve and present” the area's World Heritage values for present and future generations. This constitutes an international obligation to protect those outstanding universal natural (and cultural) values for which the Area was listed. These values relate to the four criteria for listing an area – ie:

- *outstanding examples representing major stages of the earth’s evolutionary history (eg, Age of Pteridophytes/Conifers and Cycads/Angiosperms, etc.);*
- *outstanding examples representing significant ongoing ecological and biological processes (ie, processes generating high endemism, speciation);*
- *contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; and*
- *most important and significant habitats for in situ conservation of biological diversity, including those containing threatened species* (WTMA 1999:23-25).

It is easily demonstrated that these values are concentrated in the native vegetation communities and that their protection, conservation and presentation is reliant upon the ongoing integrity of these systems. Clearly, weed invasion represents a threat to this and is identified as a ‘pressure’ affecting ‘condition’ that warrants a management ‘response’ (in ‘Condition, Pressure, Reponse’ models) and as a threatening process to the survival of threatened species and REs (WTMA 1999:22). Those REs at risk are listed in Table 2.

The tropicality of the region – ie, its warm to hot, humid climate – is a situation that can be exploited by alien plant species, particularly species adapted to similarly warm, moist climatic conditions. Conditions so conducive to rapid plant growth can greatly accelerate the invasion process. Rejmánek (1989:383) clearly demonstrates that plant communities in mesic environments are more invasible compared with those in more extreme environments.

Table 2: Wet Tropics Regional Ecosystems at risk (after Goosem *et al.*1999:Table 7.4)

Summary of conservation status	
Endangered	24
Of concern	17
No concern at present	64
TOTAL	105

Endangered Regional Ecosystems

7.2.1	Mesophyll rainforest on coastal beach sands;	provinces 3, 9
7.2.2	Notophyll rainforest with *Acacia* emergents on coastal beach sands;	province **8**
7.3.1	Sedgeland ± grassland freshwater swamp on coastal lowlands;	provinces 1, 2, 3, 9
7.3.2	Sedgeland ± grassland freshwater peat swamps of volcanic craters;	province **4**
7.3.3	Alexandra palm (*Archontophoenix alexandrae*) on poorly drained lowlands;	provinces 1, 2, 3, 9
7.3.4	Fan palm (*Licuala ramsayi*) swamp rainforest on poorly drained lowlands;	provinces 2, 3, 9
7.3.6	Melaleuca open forest/rainforest complex on poorly drained lowlands;	provinces 1, 2, 3, 9
7.3.7	Eucalyptus/Melaleuca open forest complex on poorly drained lowlands;	provinces 1, 2, 3
7.3.10	Complex mesophyll rainforest on well drained fertile lowland alluvials;	provinces 2, 3, 9
7.3.12	Blue gum (*Eucalyptus tereticornis*) woodland on well drained lowland alluvials;	provinces 2, 3, 9
7.3.13	*Corymbia nesophila* woodland on well drained lowland gravelly alluvial soils;	province **9**
7.3.22	Complex mesophyll riparian rainforest on well drained lowland alluvial levees;	provinces 2, 6, 9
7.3.24	*Melaleuca dealbata* riparian open forest on lowland alluvia;	provinces 1, 2
7.3.25	*Melaleuca*, eucalypt and notophyll rainforest spp. riparian forest,	province **1**
7.3.26	River Oak (*Casuarina cunninghamiana*) riparian forest,	province **1**
7.3.28	Herbfield and shrubland of river sandbars and river beds,	provinces 1, 2, 3, 9
7.8.2	Complex mesophyll rainforest on basalt uplands;	province **4**
7.8.3	Complex notophyll rainforest on basalt lowlands, foothills and uplands;	provinces 4, 9
7.8.6	Semi-deciduous mesophyll rainforest on basalt foothills;	provinces 3, 9
7.8.7	Blue gum (*Eucalyptus tereticornis*) tall open forest on basalt uplands and highlands;	province **4**
7.8.8	*Eucalyptus phaeotricha* woodland on basalt uplands and highlands;	province **4**
7.11.2	Fan palm (*Licuala ramsayi*) forest on poorly drained metamorphic tablelands;	province **8**
7.11.8	Notophyll rainforest with *Acacia* on metamorphic lowlands and foothills;	provinces 2, 3, 8
7.12.12	Notophyll rainforest with *Acacia* emergents on granite lowlands and foothills;	provinces 5, 8

Regional Ecosystems of concern

7.1.3	Bulkuru (*Elaeocaharis dulcis*) swamp on poorly drained acid peats;	provinces 1, 2, 3
7.2.4	Open forests and woodlands on old dune ridges;	provinces 1, 2, 3
7.3.5	Swamp paperbark (*Melaleuca quinquenervia*) on poorly drained lowlands;	provinces 1, 2, 3, 9
7.3.23	Semi-deciduous notophyll riparian rainforest on well drained alluvial levees;	provinces 1, 5, 8
7.3.27	Eucalypt and swamp mahogany (*Lophostemon suaveolens*) riparian forest,	provinces 1, 2, 3
7.8.1	Complex mesophyll rainforest on basalt lowlands and foothills;	provinces 3, 4, 9
7.8.4	Complex notophyll rainforest on basalt uplands and highlands;	province **4**
7.8.9	Molloy red box (*Eucalyptus leptophleba*) woodland on dry basalt uplands;	province **4**
7.11.16	Tall open pink bloodwood woodland on moist metamorphic uplands;	provinces 5, 6
7.11.20	*Corymbia nesophila* forest on metamorphic lowlands and foothills;	province **9**
7.12.2	Fan palm (*Licuala ramsayi*) mesophyll rainforest on poorly drained granite foothills;	provinces 3, 9
7.12.10	Notophyll rainforest with hoop pine (*Araucaria cunninghamii*) on granite uplands;	province **5**
7.12.18	Microphyll rainforest with hoop pine (*Araucaria cunninghamii*) on granite uplands;	province **5**
7.12.21	Flooded gum (*Eucalyptus grandis*) forest on granite and rhyolite uplands;	provinces 5, 6, 7, 9
7.12.22	Red mahogany *(Eucalyptus resinifera*) forest on granite and rhyolite uplands;	provinces 5, 6, 7, 9
7.12.23	Pink bloodwood (*Corymbia intermedia*) woodland on granite and rhyolite uplands;	provinces 5, 6
7.12.24	White mahogany (*Eucalyptus acmenoides*) woodland on granite foothills;	provinces 2, 3, 6.

The region also is characterised by high local relief exceeding 1 600m and its ecological diversity, promotes mostly year-round plant growth in a range of environments. This range of conditions, from tropical analogues of cool temperate forests and high montane summit areas, through hot-dry tropical open woodlands to very wet tropical lowland communities, is present, allowing a commensurate range of environments for the establishment of an array of alien plants.

The subject area is highly biodiverse (Werren *et al.* 1995, WTMA 2000). High biodiversity means that a large number of resident organisms are present that might present a hindrance to weed establishment, or, on the other hand, that can pollinate and/or disperse an alien species (Orians 1986:135) potentially facilitating its invasion. It is generally contended that intact forested areas – particularly those that are highly biodiverse – are particularly resistant to weed invasion (eg, Humphries & Stanton 1992). However, this contention is not supported by the work of Higgins *et al.* (1998:303) in Cape Peninsula, South Africa, which indicates that "species richness and invasibility are positively correlated and that species richness is a poor indicator of invasive resistance in the study site". Further, they argue soundly for "spatially explicit approach to quantifying threats to biodiversity" as the basic information required to prioritise threats from alien species and the sites that need urgent management attention. Similarly, Lavorel *et al.* 1999:41) demonstrated that there was "no strong relationship" between invasibility and functional or species richness.

Such conflicting understandings arising from both anecdotal information and intensive scientific study of particular groups of weeds at particular locations are as problematic as the 'paradox' of weed invasion itself. Sax & Brown (2000:363) note that it is "paradoxical that exotic species invade and displace native species that are well adapted to local environments" and go on to offer an explanation of the invasibility of continental regions that is a function of "pre-adaptation to human-modified environments and escape from co-evolved enemies". In contrast the greater invasibility of islands is considered to reflect the peculiar evolutionary dynamics of insular species.

The greater susceptibility of island habitats to alien invasions is well documented (Heywood 1989, Rejmánek 1989, Lövei 1997, Sax & Brown 2000, Thomas in press). Various workers, have commented on the natural 'insularity' of many Australian rainforest patches, coining phrases such as "islands in a sea of sclerophyll vegetation" (Webb & Tracey 1981), or "islands of green in a land of fire" (Bowman 2000). It is reasonable to assume, therefore, that increased susceptibility to invasion is associated with such a spatial configuration.

Moreover, the extent of fragmentation of a variety of vegetation types within the region, including non-rainforest communities, is great. This includes the disproportionate loss of wetlands (Russell *et al.* 1996) and "priority coastal communities" of the *FNQ 2010 Plan*. It is notable that Groves & Willis (1999:164) argue that "increasing fragmentation of natural vegetation is a major factor that allows weeds to establish and dominate and thereby threaten still further the continued existence of native plant species and the Australian ecosystems in which they occur."

Given the above, we are clearly contending with a situation equivalent to the title of a paper by Timmins & Owens (in press) – ie, "scary weeds and superlative places". Those superlative natural values that justified inscription of much of the region on the World Heritage List are potentially at risk from a suite of highly invasive alien weeds that exceeds 500 species. The task, therefore, of determining the aggressive invaders amongst the host of alien plant species introductions is a vital but daunting one. Based on studies of what traits might confer invasive potential among closely related species, Radford & Cousens (2000:531) even suggest that "invasiveness is essentially unpredictable". What is evident, however, is that both intrinsic biological and host environmental factors are involved and that it is dependent on some habitat/plant specific interactions between a prospective invader and location of the introduction.

2.4 Previous Consideration of Weeds within the Wet Tropics Bioregion

Just after its inception, WTMA commissioned a comprehensive review of the region's weeds that was undertaken by Humphries & Stanton (1992). These workers considered that large tracts of rainforest did not appear to be particularly vulnerable to significant weed incursions even after natural disturbance but that riparian systems, freshwater wetlands and paperbark swamps were being extensively invaded by a suite of major environmental weeds. Eight of these weeds were identified as being of priority concern due to their capacity to spread into intact communities without being assisted by human disturbance. These are *Annona glabra, Clitoria laurifolia, Coffea arabica, Harungana madagascariensis, Lantana camara, Sanchezia parvibracteata, Thunbergia grandiflora* and *Turbina corymbosa*. A subset (5) of these was considered particularly problematic and consultancies were offered to Swarbrick (1993a, 1993b, 1993c) and Swarbrick & Skarratt (1994) to investigate extent of infestations, potential areas of infestation and options for control. The concerning subset comprised *A. glabra, H. madagascariensis, T. corymbosa, S. parvibrateata* and *C. arabica*. Mechanical and chemical control trials were also undertaken to produce recommendations for treatment.

Subsequently, intensive control efforts targetting Harungana were implemented resulting in control of around 60% of the infestations (Walton pers. comm.). Unfortunately, resources were not allocated to extend treatments and to provide follow-up so infestations have rebounded and the weed continues to invade forests along the eastern fall of the Bellenden Ker massif and along the Graham Range.

Pond Apple – a species that has been elevated to a Weed of National Significance (WONS) - has been subjected to strategic control within only one sensitive protected area to date. This is Eubenangee Swamp National Park where a combination of mechanical, chemical and fire management treatments have been applied by QPWS staff. The invasive vines, *Thunbergia grandiflora* and *Turbina corymbosa* have also been subjected to strategic control; the former by QPWS staff in Mulgrave River National Park in concert with Pest Management crews of Cairns City Council (CCC), and the latter within Kamerunga Conservation Park by CCC personnel.

The discovery in 1994 of Siam Weed (*Chromolaena odorata*) in the Mission Beach area and later as significant infestations along the Tully River led to a major Commonwealth initiative aimed at its eradication. A nationally funded joint effort led by DNR entitled a Strategic Weed Eradication and Education Program (SWEEP) was instigated, with major infestations treated and monitored. A follow-up treatment and monitoring program remains current in Cardwell Shire and nearby parts of Johnstone Shire where outbreaks were documented.

Currently, weed control is practiced throughout much of the region by the cane industry (Cane Pests & Productivity Board) along with individual landholders. These efforts primarily target agricultural weeds (cf. BSES 1989) although some can also be invasive of other land uses including conservation. More integrated efforts are expended by local government pest management and environmental repair (ie, Wet Tropics Tree Planting Scheme) crews. DNR Land Protection officers assist this activity through provision of advice on priorities, control treatment and by extension work generally. Research on both weed autecology and chemical control are underway at DNR's South Johnstone research centre. There is some involvement of the Rainforest CRC in these ventures, along with this current initiative.

2.5 Consideration of Landscape Components at Risk

As argued by Humphries & Stanton (1992:viii), riparian systems and wetlands have a very high functional significance yet are particularly vulnerable landscape features to weed invasion. Pysek & Prach (1993) document the high susceptibility of riparian vegetation elsewhere in the world to invasion by exotic plants. Baker (1986:48) also confirms this and other workers such as Décamps *et al.* (1988, 1995) also discuss this issue in detail. They also report on the enhancement of exotic species invasion of such systems when human-induced disturbances significantly modify the hydrologic regime. In the Mackay district of the Central Queensland Coast that is often referred to as a southerly outlier of the Wet Tropics proper, Batianoff & Franks (1998:123) specified riparian forest as "the most susceptible vegetation type to environmental weed invasion" and that "disturbed habitats support 95% of the environmental weeds".

Both riparian systems and wetlands have been disproportionately lost and degraded within the Wet Tropics. The condition of the region's wetlands varies greatly and a great proportion - estimated from 1992 aerial photography to be 46% of their recorded extent in 1952 in the centrally located Russell-Mulgrave Catchment alone (Russell *et al.* 1996:13) - have been drained and lost. Lagoons have been filled and turned into canefields with their feeder streams and flowpaths transformed into cane drains, with many conduits for the march of Pond Apple and many other weeds across the landscape. Ewel (1986:222) notes that drainage of, and dike construction within, the northern reaches of the Everglades marshes rendered them more invasible.

As a result, the regional ecosystems (REs) associated with these features have become correspondingly rare and/or threatened (see Table 2 above). They too can be considered to be at further risk from threatening processes, among which are those posed by exotic plant and animal invasion. These considerations are incorporated in components of the proposed RAS in Section 4.3, below.

In addition, there are some 363 species of plants within those communities that are at rare and/or threatened (Goosem *et al.* 1999:7/60). Weed invasion may constitute a threatening process in some situations where Pond Apple is replacing paperbark wetlands that support the vulnerable Ant Plant (*Myrmecodia beccari*) which, in turn, hosts the ant larval symbionts of the endangered Apollo Jewel Butterfly (*Hypochrysops apollo apollo*).

It is not known exactly which species of animals are specifically at risk from weed invasion. In fact, in certain circumstances, the proliferation of rank exotic grasses has advantaged some species such as the vulnerable Crimson Finch (*Neochmia phaeton phaeton*). McFadyen (2000) argues strongly that the ongoing habitat degradation associated with weed invasion, however, does pose considerable risks to survival of a host of animal species. She demonstrates that alien plants displace native flora on which an entire complex native food web is dependent. They can, as in the case of exotic species of *Aristolochia*, contain toxins that kill host-specific native species such as the Cairns Birdwing Butterfly (*Ornithoptera priamus euphorion*) that deposit eggs on native species (eg, *A. tagala*), or may be unpalatable to generalist herbivores, thus decreasing food resources. Similarly, nectarivores can be greatly impacted with the displacement of nectar-producing native plants resulting in the disruption or displacement of guilds of organisms. The point is made that there are great flow-on effects, many of which are entirely unpredictable.

3.0 Weed Risk Assessment Systems

Various authorities throughout the world employ a variety of pest 'risk assessment systems' (RAS) for two basic purposes. The first is to minimise the risk of introduction of invasive alien organisms and is the province of international trade (eg, International Standards for Phytosanitary Measures – FAO 1996, 1998a, 1998b), quarantine and national border control. The second, which is more relevant to the present task, is related to prioritising established pest species for control, including the detection of naturalised exotic species in their early stages of invasion that may constitute future major weed problems. The two approaches share many elements, therefore both types of approach may have relevance to the formulation of a risk assessment system (RAS) for the Wet Tropics Bioregion and consideration of each is warranted.

3.1 RAS for Preventative Quarantine Purposes

Pest risk assessment was originally designed primarily to avoid importing pest organisms and, with the great increase in global trade, is increasingly a focus of quarantine and trade control authority activity. The Australian Quarantine Inspection Service (AQIS) has a major responsibility to ensure that further introduction of pest species to this country is kept to an absolute minimum. This organisation employs a RAS to screen proposed plant imports and to provide an early warning system of potential pest species and source areas. Individual states also influence the process of screening proposed plant and animal introductions.

Risk assessment is fundamental to any initiative aimed at reducing the chance of weed introductions. Waterhouse & Mitchell (1998), in setting out 'target species' for monitoring and survey associated with the Northern Australian Quarantine Strategy, rely upon recorded weediness in the literature. Factors such as that associated with a plant's weediness elsewhere are usually the first 'filter' in such introduction-screening protocols.

Species purportedly not yet present in Australia but which are recorded in neighbouring countries are ranked according to (i) potential to have serious economic impacts, (ii) potential to have significant environmental impacts, (iii) likelihood of accidental dispersal from adjacent land masses, (iv) a history of rapid recent spread in Indonesia or Papua New Guinea, and (v) likelihood of successful establishment in northern Australia (Waterhouse & Mitchell 1998:10). The resultant list of 41 species includes two (ie, *Chromalaena odorata* and *Mikania micrantha*) that pose very serious threats and which have been recorded within the Wet Tropics region. Both have been subjected to intensive control measures.

3.1.1 International protocols (FAO 1996, 1998a, 1999)

Organisations such as the IUCN and FAO now clearly recognise the major threat posed by alien species invasions to the world's biodiversity. The Invasive Species Specialist Group of the former claims that "impacts of alien species are immense, insidious, and usually irreversible … [and] may be as damaging to native species and ecosystems on a global scale as the loss and degradation of habitats" (SSC 2000:1). Accordingly, the Food and Agricultural Organisation (FAO) of the United Nations has set in place various protocols to address such threats.

"Guidelines for Pest Risk Analysis" (PRA) were published by the FAO in 1996. These cover (i) PRA process initiation, (ii) the risk analysis process itself, and (iii) managing pest risk (FAO 1996:6). The second of these stages of the process (PRA) is of direct relevance to the present task. After identification of a pest, this second stage examines individual pests to evaluate whether the criteria for 'quarantine pest status' are satisfied. These cover "pests of potential economic importance" (FAO 1996:11), considering geographical distribution, biology and economic importance, and is reliant on expert judgement in the assessment of establishment, spread and economic importance potential. If this assessment suggests that a pest has significant economic importance and introduction potential then quarantine protocols for risk management are set in train. These cover a range of options (eg, inclusion on lists of prohibited pests, inspection and certification prior to export, inspection at entry, etc. – FAO 1996:16). They also provide for a process of monitoring and evaluating the various options in relation to this pest. Subsequent guidelines cover protocols for the determination of pest status in an area (FAO 1998a) and guidelines for pest eradication (FAO 1998b). These guidelines are currently established under the name of "International Standards for Phytosanitary Measures (FAO 1999) and fall under the auspices of the *International Plant Protection Convention.* It is notable that the 'economic' component of PRA includes "effects on ongoing integrated pest management (IPM) programmes, **environmental damage**, capacity to act as a vector for other pests," *inter alia* (FAO 1999:11, emphasis added).

3.1.2 Prevention/minimisation of risk of introductions to various countries

Other countries have instituted a variety of RASs to prevent or minimise pest introductions and for purposes of prioritising pests for management. While such systems have been developed for often very different situations, these can inform the task at hand. Reichard (in press:56) points out that in assessing patterns to improve the predictabilty of invasive potential that "differences found between North America, which is mostly temperate, and Hawai'i, which is tropical, except for some high altitudes". Consequently she concludes, "different traits may affect invasive ability between tropical and temperate areas and that where weed risk assessment is concerned, perhaps 'one size does not fit all'". Despite the qualification, she suggests that the following considerations are important in diagnosing invasive potential:

(i) various plant traits should be "fairly easy and quick to determine' (ie, self-compatability and number of seeds per plant may be not easy to establish and can be avoided);

(ii) traits should be clearly measurable (cf. breadth of ecological niche or phenotypic plasticity can be difficult to etermine);

(iii) use as few traits as possible while retaining accuracy;

(iv) the positive traits (eg, utility as stock forage, ornamental amenity) should be considered quite separately from invasive potential;

(v) assume that an introduction to a country will be distributed throughout the country (viz. an introduction may be considered relatively benign at point of introduction or where it is intended to cultivate the plant, but it can, and likely will spread or be spread, beyond); and

(vi) whatever methods/traits are chosen, they should be flexible enough to incorporate new information.

Weed protocols remain state-based in the U.S.A. and generally focus upon dealing with existing pest problems (eg, Hiebert & Stubbendieck 1993).

Thomas (in press) comments upon weed RAS development in Hawaii, which, in many aspects hosts similar environments to those existing within the Wet Tropics Bioregion. Invasive species entry prevention is a 'hot topic' in Hawaii, with importation essentially agriculture-based (Thomas in press:43, Mitchell pers. comm.). It is likely that elements of the Hawaiian weed RAS (Teytaud 1998) such as are under development under the auspices of a project dubbed HEAR – "Hawaiian Ecosystems at Risk". Nominally it is an "asset based" (*sensu* Hall 1999:82) approach but it has will have significant implications for quarantine protocols, especially assessment of intrinsic attributes after Cronk & Fuller (1995) (see Section 3.2.4 below) and should be compliant with IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasion (Thomas in press:44).

Protocols associated with weed risk assessment operating in New Zealand are informative, particularly with respect to aquatic weed risk assessment (Champion & Clayton, in press). It is notable that those that were developed by New Zealand's Department of Conservation underpin weed risk assessment in other places such as Galapagos Islands (Tye in press:25) and has been considered in RAS development in Hawaii (Thomas in press).

3.1.3 Australian protocols (Pheloung 1995)

The *Environmental Indicators for National State of the Environment Reporting: Biodiversity* states that exotic and alien organisms outside cultivation or captivity are a major pressure on biological diversity (Pheloung 1995). While the number of such organisms outside cultivation and captivity is reasonably well known for vertebrates, higher plants and some invertebrates, knowledge is poor for most other organisms. The role of the Commonwealth in invasive species management has traditionally been barrier control through the *Quarantine Act (1908),* the assessment of environmental impacts on native species through the *Wildlife Protection (Regulation of Exports and Imports) Act (1982)* and is otherwise restricted to Commonwealth lands.

Pheloung (1995) has reviewed weed risk assessment systems for the prevention of noxious species introductions to Australia. These systems have provided a numerical scoring protocol as a basis for rejection, acceptance or further evaluation of proposed exotic plant imports. He sets out guidelines for a three-tiered screening system to assess weed potential of plant introductions. Plant species which pass the first tier (they are not present on prohibited or allowed lists of species, and are potential quarantine pests) are to be assessed before entry by a formal Weed Risk Assessment (WRA) system, which is the second tier. In this system, answers are sought for questions on historical, biogeographical and biological/ecological details of the candidate species. A score generated by the procedure (Table 3) determines which of three recommendations, *reject, evaluate* or *accept*, will result.

The WRA system was tested by analysis of its performance for 370 plant species, representing weeds from agricultural, environmental and other sectors, and useful plants. It was assessed on its ability to correctly *reject* weeds, *accept* non-weeds and generate a low proportion of species requiring *evaluation*. Performance of the system was compared to that of two simpler systems – ie, species were also scored using the AQIS (Hazard 1988) and Panetta (1993) systems. In the optimised WRA system, all serious weeds, and most minor weeds, were rejected or required *evaluation* while only 7% of non-weeds were rejected. Less than 30% of the species required *evaluation*. Although simpler systems were effective, the WRA system performed best. Simpler systems produced too many *evaluate* recommendations or rejected many non-weeds.

They were constrained by their lack of flexibility. The ability of the WRA system to make reliable recommendations has a sound quantitative basis, and the mechanism is transparent. These features are basic requirements for establishing phytosanitary conditions in accordance with the General Agreement on Tarrifs and Trade (GATT) SPS agreement.

Table 3: Scoring system employed by AQIS for decision-making on the importation of plants (after Hazard 1988 in Pheloung 1995)

	Criterion	*Points*
1:	Is the species a free-floating (surface or submerged) aquatic or can it survive, grow and reproduce as a free-floating aquatic?	20
2:	Does the species have a history of being a major weed elsewhere in similar habiats (remember Australia is a big country of diverse habitats)	20
3:	Does the species have a close relative of similar biology with a history of weediness in simalr habitats?	10
4:	Are the plants spiny?	10
5:	Does the plant have spiny diaspores (ie, burrs)?	10
6:	Are the plants harmful to animals (including humans)?	8
7:	Do the plants produce stolons?	5
8:	Do the plants have other forms of vegetative reproduction?	8
9:	Are the diaspores wind dispersed?	8
10:	Are the diaspores dispersed by animals and/or machinery?	8
11:	Are the diaspores dispersed by water?	5
12:	Are the diaspores dispersed by birds?	5

Scores totalling $\geq$ 20, between 12 and 19, or <12 indicate grounds for rejection, further evaluation, or acceptance, respectively.

3.1.4 State initiatives

Local and State Governments have a range of legislation and regulatory mechanisms covering invasive species. The management of invasive species within Australia is primarily the responsibility of individual landowners or land managers. Carter (2000) provides a useful review of the legislation underpinning weed management in Australia. It is notable that here has been a focus in the past on managing invasive species that threaten economic production rather than environmental values. This however is changing as States and Territories, through threat abatement processes, aim to reduce invasive species pressure on threatened or endangered flora or fauna. There has also been a shift towards classifying invasive species by their impact on biodiversity rather than their economic effects.

Hall (1999) outlines the system of strategic weed management operating in Tasmania. This system is "asset-based" where priorities are set according to the degree of threat posed to natural (and cultural) assets (Hall 1999:82). It involves mapping of infestations, considering and preparing a risk assessment of each weed outbreak, accommodating both consideration of the significant of each outbreak and feasibility of control. It is based on the Exotic Species Ranking System (ESRS) of Hiebert & Stubbendieck (1993) developed in the U.S.A. (see Section 3.2.1 below).

The South Australian Pest Animal and Plant Board has a particularly explicit system for weed assessment. This will be examined in detail in Section 3.2.7 below with view to its applicability for the development of a Wet Tropics-explicit RAS.

In the State of Queensland the Department of Natural Resources (DNR) is the lead agency in pest management. Over the past four years, DNR has facilitated the development of Local Government Pest Management Plans (PMPs) throughout the

State, including in all ten[2] local government areas within the bioregion. In the PMP process, both weeds of agriculture and environmental weeds that occur within each local government area are considered and ranked according to agricultural and/or environmental risk and control potential. This allows the targetting of weeds of highest priority that are considered to be 'controllable' so that limited resources can be strategically allocated in Councils' works programs.

In order to rank those species of highest priority for research, staff of the Alan Fletcher Weeds Research Institute have collated those listed in the region's local government PMPs and have utilised a Multi-Objective Decision Support System (MODSS) (Bebawi pers. comm.). This excercise resulted in the ranking of 31 species (including one assumed native species, *Rottboellia cochinchinensis*) that emerged as the highest priorities for control within the collective areas covered by the PMPs. These are set out in Figure 1.

It is important to note that the outcome of DNR exercise is quite different from that which is required from the current exercise. Inspection of Figure 1 will reveal that application of the MODSS incorporated considerations other than invasive risk. While this was accommodated within the first of two main discrimination components (ie, 'impact' and 'research'), other factors such as economic and socio-cultural impacts were also included, along with various factors associated with research activities, against which the species were ranked. Of relevance here is the fact that the species that emerged as priority weeds for research are likely candidates for problematic environmental weed standing since they have been identified by a range of individuals reflecting a variety of interests throughout the region. Accordingly, those inclusions formed the basis of the sample screened utilising the proposed Wet Tropics RAS (see Section 5.2.5 below)

3.2 RAS for Prioritising Existing Weed Incursions

Once a pest plant has arrived in a new host environment both long-term environmental and economic benefits can accrue from its early detection and control and/or eradication. This prompts a need for a systematic assessment of large numbers of species whose impact may not be evident now but which may be in early stages of invasion.

Virtue *et al.* (in press) point out that qualitative differences exist between decision support systems for preventing introductions of unwanted species and those concerning selection of species for control management. They claim that quarantine decisions proceed on the basis of **predicted negative impacts and potential area over which that impact may be sustained**, while control prioritisation will involve similar considerations plus others that are associated with ease of treatment and potential for control success. In addition, if the focus is on management for biodiversity conservation, other factors such as the **particular suceptibility of constituent native species, assemblages and functionally significant landscape features such as waterways and wetlands**, needs to be accommodated.

2 The 10 local government areas comprise Atherton Shire, Cairns City, Cardwell Shire, Cook Shire, Douglas Shire, Eacham Shire, Herberton Shire, Hinchinbrook Shire, Johnstone Shire and Mareeba Shire. Thuringowa City takes in part of the southernmost protion of the bioregion but is largely marginal and not considered here.

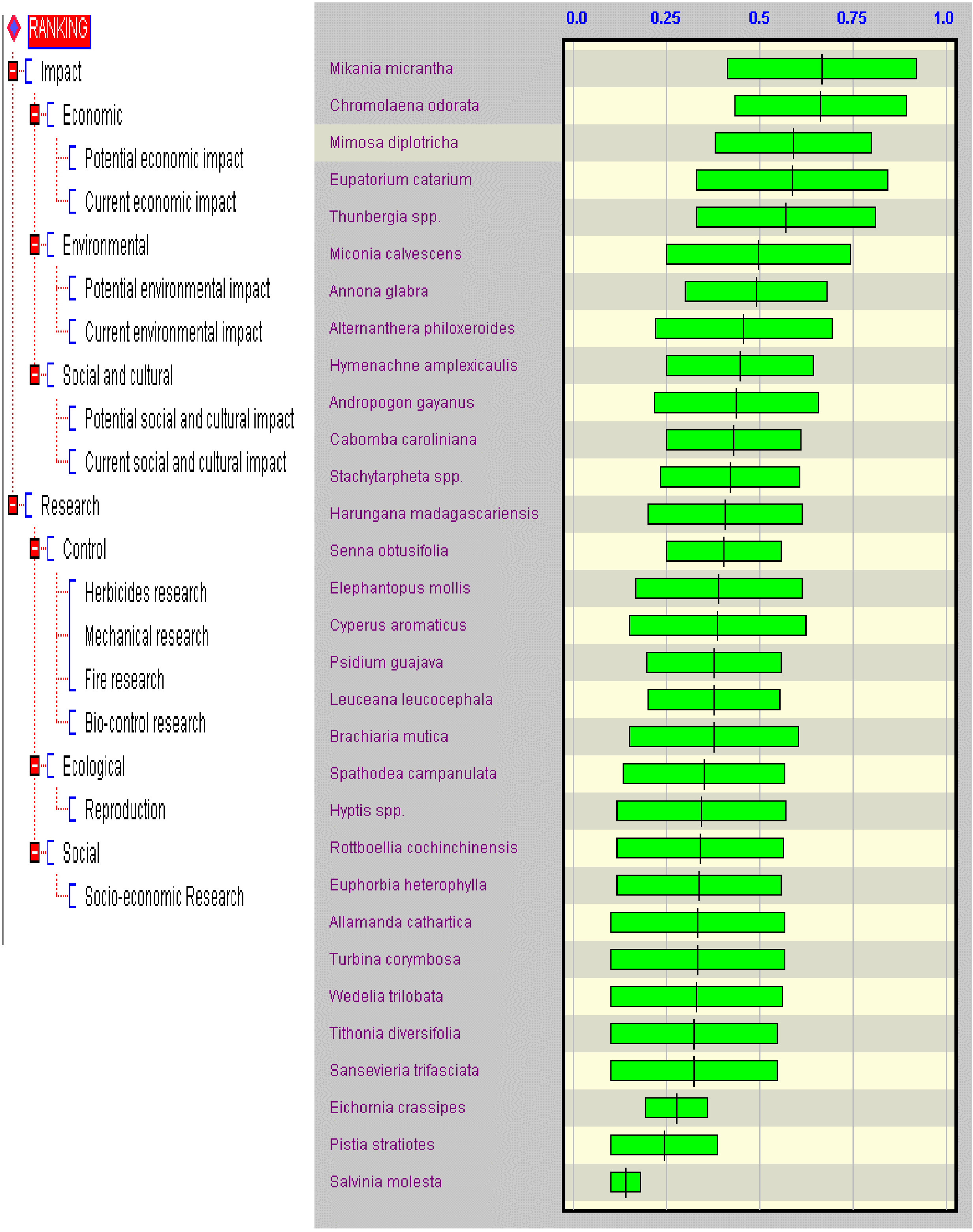

Figure 1: MODSS wet tropics weeds list prioritised by DNR researchers

(after draft document supplied by Bebawi pers. comm.)

3.2.1 Exotic Species Ranking System of US Department of Interior National Parks Service (Hiebert & Stubbendieck 1993)

A ranking system has been developed specifically for US conservation area managers to classify exotic plants within protected areas according to the level of impact of a species and its innate ability to become a pest (Hiebert & Stubbendieck 1993). The *Exotic Species Ranking System* (ESRS) is designed to first separate innocuous species from disruptive species. The separation allows researchers to then concentrate further efforts on species in the disruptive category. It relies on consideration of significance of impacts on protected area resources and on the ranking of biological attributes such as life history characteristics (high seed output, long-distance dispersal adaptation, ability to reproduce vegetatively) that are consistent with weediness (Box 1). Ranked species lists are then classified according to perceived feasibility or ease of control. The system is designed also to identify species that are not presently a serious threat but have the potential to become a threat and which should be monitored closely. The system also considers the potential costs associated with delaying control action.

Box 1. Criteria and scores of the ESRS (Hiebert & Stubbendieck 1993)

I. Significance of Impact	
A. Current Level of Impact	
1. Distribution relative to disturbance regime	
a. found only within sites disturbed within the last 3 years	-10
b. found in sites disturbed within the last 10 years	1
c. found in mid-successional sites disturbed 11-50 years before present (BP)	2
d. found in late-successional sites disturbed 51-100 years BP	5
e. found in high-quality natural areas with no major disturbance for 100 years	10
2. Abundance	
a. number of populations (stands)	
(1) few; scattered (<5)	1
(2) intermediate number; patchy (6-10)	3
(3) several; widespread and dense (>10)	5
b. areal extent of populations	
(1) <5 ha	
(2) 5-10 ha	2
(3) 11-50 ha	3
(4) >50 ha	5
3. Effect on natural processes and character	
a. plant species having little or no effect	0
b. delays establishment of native species in disturbed sites up to 10 years	3
c. long-term (more than 10 years) modification or retardation of succession 7	
d. invades and modifies existing native communities	10
e. invades and replaces native communities	15
4. Significance of threat to park resources	
a. threat to secondary resources negligible	0
b. threat to areas' secondary (successional) resources	2
c. endangerment to areas' secondary (successional) resources	4
d. threat to areas' primary resources	8
e. endangerment to areas' primary resources	10
5. Level of visual impact to an ecologist	
a. little or no visual impact on landscape	0
b. minor visual impact on natural landscape	2
c. significant visual impact on natural landscape	4
d. major visual impact on natural landscape	5
Total Possible =	**50**
B. Innate Ability of Species to Become a Pest	
1. Ability to complete reproductive cycle in area of concern	
a. not observed to complete reproductive cycle	0
b. observed to complete reproductive cycle	5

2.	**Mode of reproduction**		
	a.	reproduces almost entirely by vegetative means	1
	b.	reproduces only by seeds	3
	c.	reproduces vegetatively and by seed	5
3.	**Vegetative reproduction**		
	a.	no vegetative reproduction	0
	b.	vegetative reproduction rate maintains population	1
	c.	vegetative reproduction rate results in moderate increase in population size	3
	d.	vegetative reproduction rate results in rapid increase in population size	5
4.	**Frequency of sexual reproduction for mature plant**		
	a.	almost never reproduces sexually in area	0
	b.	once every five or more years	1
	c.	every other year	3
	d.	one or more times a year	5
5.	**Number of seeds per plant**		
	a.	few (0-10)	1
	b.	moderate (11-1,000)	3
	c.	many-seeded (>1,000)	5
6.	**Dispersal ability**		
	a.	little potential for long-distance dispersal	0
	b.	great potential for long-distance dispersal	5
7.	**Germination requirements**		
	a.	requires open soil and disturbance to germinate	0
	b.	can germinate in vegetated areas but in a narrow range or in special conditions	3
	c.	can germinate in existing vegetation in a wide range of conditions	5
8.	**Competitive ability**		
	a.	poor competitor for limiting factors	0
	b.	moderately competitive for limiting factors	3
	c.	highly competitive for limiting factors	5
9.	**Known level of impact in natural areas**		
	a.	not known to cause impacts in any other natural area	0
	b.	known to cause impacts but in other habitats and different climate zones	1
	c.	known to cause low impact in natural areas in similar habitats and climate zones	3
	d.	known to cause moderate impact in similar habitats and climate zones	5
	e.	known to cause high impact in natural areas in similar habitats and climate zones	10
		Total Possible =	**50**

3.2.2 Australian WRAS Protocol Details (Pheluong 1995)

While primarily designed for assessing proposed plant introductions to Australia, Pheloung (1995) sets out details of the development of a national protocol for screening weediness that can have a direct bearing on the derivation of a regional RAS. This comprises a three-tiered screening system to evaluate the invasive potential of proposed plant introductions. Species that pass the first tier – ie, are not present on prohibited or allowed lists and are potential quarantine risks – are assessed before entry is permitted by a second formal Weed Risk Assessment System (WRAS) tier.

The system involves posing 49 questions regarding the species' historical, biogeographical and biological/ecological characteristics (Box 2). Responses are weighted according to weediness risk resulting in a final numerical score. These scores permit the list of species to be sorted into a triage of classes. These are (i) those to be rejected as imports; (ii) those requiring further evaluation; and (iii) those that appear benign and can be accepted for entry into Australia. A final tier involves the further evaluation of those species that fell into the second class - a process that usually involves re-running the existing system with additional, more precise information or by designating a candidate species for temporary import clearance pending post-entry evaluations (Pheloung 1995:1).

Box 2. WRAS question sheet commissioned by the Australian Weeds Committee & Plant Industries Committee (Pheloung 1995)

Botanical Name: ………………………………..	**Outcome:** ……………………………	
Common Name: …………………………………	**Score:** …………………………………	
Answer *yes* or *no*, or leave blank unless indicated. Scores for a question typically 1=yes, -1 or 0=no, 0=don't know. The climate & weed elsewhere sections generate a score using a weighting system: a better climate match increases the climate weight and a poorer quality match also increases the weight because of greater uncertainty and, therefore, greater risk. Weed elsewhere responses are multiplied by the climate weight to generate the final score for each question. (Note: A = agricultural, E = environmental, N = nuisance, C = combined.)		
Biogeography/Historical		
1. *Domestication/Cultivation*	1.01 Is the species highly domesticated?	(A)
	1.02 Has the species become naturalised where grown?	(C)
	1.03 Does the species have weedy races?	(C)
2. *Climate/Distribution*	2.01 Species suited to Australian climates (0-low, 1-intermediate, 2-high)	
	2.02 Quality of climate match data (0-low, 1-intermediate, 2-high)	
	2.03 Broad climate suitability (environmental versatility)	(C)
	2.04 Native/naturalised in regions with extended dry periods	(C)
	2.05 Does it have history of repeated introductions outside of its natural range?	
3. *Weed Elsewhere*	3.01 Naturalised beyond native range	(C)
	3.02 Garden/amenity/disturbance weed	(N)
	3.03 Weed of agriculture	(A)
	3.04 Environmental weed	(E)
	3.05 Congeneric weed	
Biology/Ecology		
4. *Undesirable traits*	4.01 Produces spines, thorns, burrs	(A)
	4.02 Allelopathic	(C)
	4.03 Parasitic	(C)
	4.04 Unpalatable to grazing animals	(A)
	4.05 Toxic to animals	(C)
	4.06 Host for recognised pests/pathogens	(C)
	4.07 Causes allergies or otherwise toxic to humans	(N)
	4.08 Creates a fire hazard in natural ecosystems	(E)
	4.09 Is shade tolerant at some stage of its life cycle	(E)
	4.10 Grows on infertile soils	(E)
	4.11 Climbing or smothering habit	(E)
	4.12 Forms dense thickets	(E)
5. *Plant type*	5.01 Aquatic	(E)
	5.02 Grass	(C)
	5.03 Nitrogen fixing woody plant	(E)
	5.04 Geophyte	(C)
6. *Reproduction*	6.01 Evidence of substantial reproductive failure in native habitat	(C)
	6.02 Produces viable seed	(C)
	6.03 Hybridises naturally	(C)
	6.04 Self-compatible or apomictic	(C)
	6.05 Requires specialist pollinators	(C)
	6.06 Reproduction by vegetative fragmentation	(C)
	6.07 Minimum generative time (years)	(C)
7. *Dispersal Mechanisms*	7.01 Propagules likely to be dispersed unintentionally	(A)
	7.02 Propagules dispersed intentionally by people	(C)
	7.03 Propagules likely to disperse as a produce contaminant	(A)
	7.04 Propagules adapted to wind dispersal	(C)
	7.05 Propagules bouyant	(E)
	7.06 Propagules bird dispersed	(E)
	7.07 Propagules dispersed by other animals (externally)	(C)
	7.08 Propagules survive passage through the gut	(C)
8. *Persistance attributes*	8.01 Prolific seed production (> 2 000 m^2)	(C)
	8.02 Evidence that a persistent propagule bank is formed (> 1 yr)	(A)
	8.03 Well controlled by herbicides	(A)
	8.04 Tolerates, or benefits from, mutilation/cultivation (A)	
	8.05 Effective natural enemies present in Australia	(E)

3.2.3 Wildland Weed Priority Ranking System of US Nature Conservancy (Randall et al., in press)

In an attempt to ensure some consistency in ascribing priority to control of existing alien species infestations within relatively undisturbed native communities – referred to here as "wildlands" – Randall *et al.* (in press) have developed a set of criteria to objectively rank weeds. These criteria relate to four components of a species' invasiveness significance – ie, (1) impact on native species, habitats and systems, (2) ecological characteristics and dispersal capability, (3) distribution and abundance, and (4) difficulty of management. The system relies on a four-ranked ordinal classification of I=insignificant, L=low (species represent low threat to native communities), M=medium (ie, represent a moderate threat), and H=high (species severely degrades native species and communities or threatens to do so). Scores are associated with these ranks. It is noted that species that score the highest (i) alter ecosystem processes, (ii) invade relatively undisturbed native communities, (iii) readily disperse to new areas, (iv) are widely distributed and abundant where present, and (v) are difficult to control (Box 3).

Box 3. Criteria and scores of the WWPRS of the US Nature Conservancy (Randall *et al.*, in press)

SECTION 1 – IMPACT ON NATIVE SPECIES, HABITATS & ECOSYSTEMS

A. Ability to invade natural systems

I. not known to spread into wildlands on its own (eg, species may persist from former cultivation, as in tea, *Camelia sinensis*, in the Wet Tropics)

L. establishes only in areas where major disturbance has occurred in the last 20 years (eg, cyclone damaged sites and along utility corridors such as highways, powerlines)

M. often establishes in mid- to late-successional wildlands where minor disturbances such as tree falls and/or bank slumping may occur but with no major disturbance in 20-75 years

H. often establishes in intact or otherwise healthy native communities with no major disturbance for at least 75 years.

B. Impact on ecosystem processes

I. no perceivable impact on ecosystem processes

L. influences ecosystems processes (eg, has perceivable but mild influence on soil nutrient availability

M. significant alteration of ecosystem processes (eg, increases sedimentation rates along coastlines, reducing open water areas important to waterfowl)

H. major, possibly irreversible alteration/disruption of ecosystem processes (eg, species drains water from wetland systems making system more fire-prone and incapble of supporting wetland species; species fixes nitrogen into a nutrient-poor situation making soil less capable of supporting oligotrophic native species)

C. Impact on natural community structure

I. no impact – establishes in an existing stratum without altering structure

L. influences structure in one stratum (eg, changes density within that layer)

M. significant impact on at least one stratum (eg, creates new layer; eliminates existing stratum)

H. major alteration of structure (eg, covers canopy, eradicating all or most layers)

D. Impact on natural community composition

I. no perceivable impact on native populations

L. some influence on community composition (eg, reduces number of individuals in one or more native populations by reducing recruitment, etc.)

M. significantly alters community composition (eg, produces a significant reduction in the population size of of one or more species in the community by displacement)

H. causes major alteration in community composition (eg, results in extirpation of one or several constituent native species, reduces biodiversity or changes community composition to species exotic to the native community

E. Conservation of wildland(s) and native species threatened

I. conservation status of area/constituent species insignificant (eg, extent of human disturbance great and lacks any rare and/or threatened (r&t) native communities and/or species)

L. target area contains communities of low significance (ie, habitats are common, widespread and not known to be r&t nor contain r&t species)

M. target area is of moderate significance (eg, may contain some high value regional ecosystems and/or species or good representative examples of intact native communities)

H. target area is highly significant (eg, contains one or more r&t regional ecosystems and/or r&t species)

Impact ranking is achieved by scoring responses addressing parts A. and B. and at least one other part in this section according to the following:
HIGH = H in A and B; H in A. or B. and M-H in at least one other category; M in A. and B. and H in at least one other category.
MEDIUM = M in A. or B. and M-H in at least one other category; L in A. or B. and H in at least one other category.
LOW = if species scores M in at least one other category.
INSIGNIFICANT = all other combination of ascriptions.

SECTION 2 – BIOLOGICAL CHARACTERISTICS/DISPERSAL CAPABILITY

A. Autecology

Reproduction (tick following checklist)

[] reproduces readily both vegetatively and by seed
[] if reproduces by seed, produces >1 000 seeds annually
[] reproduces more than once per year
[] rapid growth to reproductive maturity
[] seeds remain viable in soil for 2 or more years
[] possesses rapidly spreading culms/stolons/rhizomes that may root at nodes
[] resprouts readily when cut, grazed or burnt
[] other.

Competitive ability

[] highly successful competitor for limiting resources
[] tolerates a wide range of environmental conditions and/or stress tolerant
[] ability to germinate in naturally vegetated areas under a wide range of conditions
[] allelopathic
[] known to hybridise with native species
[] lack of predators/control agents in host environment
[] other

Dispersal

[] rapid local proliferation of seeds
[] adapted to long distance dispersal (eg, dispersed by birds; has small water-borne seeds)
[] other

Impact ranking is achieved by scoring response in the following manner:

I. - not aggressive – has none of the above characteristics or only one or two to a very small extent
L. - somewhat aggressive – has one or two of the above to a small extent
M. - aggressive – has >2 of the above but only 1-2 to a great extent
H. - extremely aggressive – has 3 or more of the above characteristics to a great extent.

B. Other regions invaded

Is the species known to be invasive beyond its native range in other areas? [list other areas]

C. Dispersal ability & speed of spread

Speed of spread once reported to have escaped

I. does not spread
L. slow – doubling time (new local reports) > 50 years
M. moderate – doubling time (new local reports) 10-50 years
H. rapid – doubling time (new local reports) < 10 years.

Current trend in total range within new host country

I. declining or historical
L. stable
M. increasing
H. increasing rapidly

Potential to be spread by human activity

Is this species frequently distributed or has a high potential to be spread by humans (eg, species is sold commercially or is spread along transportation/disturbance corridors and/or along waterways)?

Impact ranking is achieved by scoring at least 4 of the 5 response in the following manner: 3 points for H, 2 for M., 1 for L. and 2 for 'yes' – highest score = 13
HIGH = score 9-13; MEDIUM = score 6-8; LOW = score 3-5; INSIGNIFICANT = score <3.

SECTION 3 – DISTRIBUTION & ABUNDANCE IN NEW HOST COUNTRY

A. Current range in host country

I. isolated or disjunct range < 100 square miles [260 km^2]
L. range 100-10 000 square miles [260 - 26 000 km^2]
M. range 10 000 – 1 000 000 square miles [26 000 – 26 000 000 km^2]
H. widespread (> 1 000 000 square miles [> 26 000 000 km^2])

B. Number of distinct protected or similar areas infested in host country

I < 5 (few, scattered)

I 5-20 areas
M. 21-100 areas
H > 100 areas

C. Extent of range that has been identified as problematic by land managers

I. 0-5%
L. 6-20%
M. 21-50%
H. >50%

D. Potential cover of species in strata where it occurs

J. infrequent (< 10%)
L. fair coverage but < 50%
M. dominant (50-90%)
H. grows in monospecific stands (90-100%)

Impact ranking is achieved by scoring responses addressing part A. and at least two other parts in this section according to the following:
HIGH = H in A and M-H in at least one other category; M in A. and H in at least one other category.
MEDIUM = H in A. and L-I in all other categories; M in A. and M in at least one other category; M in A. and L-I in all other categories; L in A. but H in at least one other category
LOW = if species scores L in A. and M in at least one other category; if scores I in A but H in at least one other category.
INSIGNIFICANT = all other combination of ascriptions.

SECTION 4 – MANAGEMENT POTENTIAL

I. management not required
L. management relatively easy and inexpensive; requires minor human and financial resources
M. management requires major short-term or moderate long-term investment of resources
N. management requires major long-term investment of resources

Final wildland weed priority ranking is obtained according to the following:

Impact	**H=4, M=3, L=2, I=0**
Autecology	**H=3, M=2, L=1, I=0**
Distribution	**H=2, M=1, L=0, I=0**
Management	**H=1, M=0, L=0, I=0**

OVERALL SCORE (maximum 10):

0-2 Insignificant threat posed to native communities
3-4 Low threat posed to native communities
5-6 Moderate threat posed to native communties
7-10 High - species represents a major threat to native communities.

While this system addresses a comparable issue to the task at hand, it presupposes a considerable body of knowledge for any given taxon. This necessitates an understanding of both species biology and current distribution. Since control feasibility is a secondary consideration to innate weediness, only sections I and II are directly relevant to weed risk assessment *per se*.

3.2.4 Weed Risk Assessment in Hawaii (Teytaud 1998; Thomas, in press)

Tropical oceanic islands such as Hawaii are typified by a great degree of endemism, contain disproportionate numbers of rare and/or threatened species and are particularly vulnerable to exotic species invasion. Given the extent of risks posed by alien species, computer-based modelling approaches were developed to assist in prioritising control actions for already-established weeds. The Hawaiian Ecosystems at Risk (HEAR) protocol consists of two basic components: (1) a map-based geographic information system (GIS) incorporating worldwide occurrence and climatic envelope modelling of host environment to aid in the determination of a weed's potential distribution, and (2) a multi-factored scoring spreadsheet incorporating Cronk & Fuller's (1995) invasive categories to determine its 'relative risk' (Box 4). The system is heavily reliant upon a species' exhibited invasiveness elsewhere which, it is claimed (Thomas, in press:41), "seems to have produced the most useful results of any weed risk assessment used in Hawaii to date".

Box 4. Categories and ranking system of the Hawaiian WRAS (Teytaud 1998)

A. INVASIVE CATEGORY ELSEWHERE (after Cronk & Fuller 1995)
1.0 minor weed of highly disturbed or cultivated land (man-made artificial landscapes)
1.5 serious or widespread weeds of highly disturbed or cultvated land (man-made/artificial landscapes)
2.0 weeds of pastures managed for livestock, forestry plantations or artificial waterways
2.5 serious or widespread weeds of pastures managed for livestock, etc.
3.0 invading semi-natural or natural habitats
3.5 serious or widespread invaders of semi-natural or natural habitats
4.0 invading important natural or semi-natural habitats (ie, species-rich vegetation, nature reserves, areas containing rare or endemic species)
4.5 serious or widespread invaders of important natural or semi-natural habitats (see above)
5.0 invasion threatening other species of plants or animals with extinction

B. HEARINVASIVE CATEGORIES FOR ALIEN SPECIES PRESENT
I. invading 'disturbed' land or 'early successional' land other than agricultural landsscapes (ie, whether disturbed by 'natural' or 'human-mediated' causes)
II. invading cultivated crops, or man-made pastures managed for livestock
III. invading forestry plantations
IV. invading 'relatively undisturbed', non-cultivated, 'middle to late successional', 'semi-natural' or 'natural' open habitats (eg, bogs, dunes, grassland, shrubland, savanna, etc.)
V. invading 'relatively undisturbed', non-cultivated, 'middle to late successional', 'semi-natural' or 'natural' open woodland habitats
VI. invading 'relatively undisturbed', non-cultivated, 'middle to late successional', 'semi-natural' or 'natural' closed forest habitats

C. NEGATIVE IMPACT CATEGORIES FOR INVASIVE ALIEN SPECIES PRESENT
1. invasion of this species is known or expected to cause economic losses on 'developed' agricultural lands, housing, commercial or industrial areas, developed parklands or recreational areas, or any other lands whose primary values lie in their socio-economic/cultural rather than ecological features and assets
2. invasion of this species is known or suspected to cause significant alterations of the natural fire regime of ecosystems and/or landscapes; and/or invasion of this species is presently known to cause significant alterations of energy flows, materials and nutrients cycling, moisture relationships and/or other critical processes of ecosystems; and/or invasion of this species is presently known to cause significant alterations of the soil chemistry or the soil erosion characteristics of ecosystems and/or landscapes
3. invasion of this species is known or suspected to cause replacement of natural and/or semi-natural systems of high diversity and/or ecological value with systems of significantly lower diversity and/or ecological value, when considered under community, ecosystem, landscape, and/or macro-climatic zone (vegetation zone or biome) criteria; and/or invasion of this species is presently known to pose some significant direct threat to the well-being of native faunal or floral communities in general, or of species with some special conservation (eg, rare, threatened, endangered, etc) or ecological (eg, 'keystone' species) status
4. invasion of this species is known or suspected to pose some significant threat of local, regional, insular, state-wide, or global extinction(s) of native species; and/or species having some special special conservation or ecological status.

SCORING SYSTEM FOR USE WITH THE HEAR RISK ASSESSMENT MODEL (Note: leave categories blank only if information is unavailable)

Score #1 HIGHEST Cronk & Fuller Invasive Category (for number codes, see above) presently known for this species ELSEWHERE IN THE WORLD, based on information obtained from Cronk & Fuller (1995) and/or other literature and/or experet opinion

Score #2 TOTAL NUMBER of different types of Cronk & Fuller Climate Zones presently known to be occupied by this species ELSEWHERE IN THE WORLD, based on Cronk & Fuller, etc (as above)

Score #3 HIGHEST HEAR Invasive Category presently known for this species on the main Hawaiian islands based on information from from the literature and/or expert opinion

Score #4 HIGHEST HEAR Negative Impact Category presently known for this species on the main Hawaiian island based on information from from the literature and/or expert opinion

Score #5 TOTAL NUMBER of different types of HEAR Climate Zones within the environmental envelope of the species in Hawaii, and presently/potentially invaded by this species on the main Hawaiian islands calculated using information from the HEAR climate envelope GIS model

Score #6 TOTAL LAND AREA (square miles) of HEAR Climate Zones within the environmental envelope of the species in Hawaii, and presently/potentially invaded by this species on the main Hawaiian islands calculated using information from the HEAR climate envelope GIS model

Score #7 TOTAL LAND AREA (square miles) of existing Natural/Semi-natural Physiognomic Vegetation Types (ie, Ecoregional Sub-units or the equivalent to Regional Ecosystems in the Wet Tropics Bioregion) calculated by intersecting the HEAR climate envelope GIS model with digital map of Ecoregional Sub-units – enter 0 if no such area is believed to be threatened

Score #8 TOTAL LAND AREA (square miles) of Managed Areas potentially invadable if this species were to attain its potential distribution on the main Hawaiian islands calculated by intersecting the HEAR climate envelope GIS model with digital map of Ecoregional Sub-units – enter 0 if no such area is believed to be threatened

Although comparable bioregional subdivision of broad environmental zones of the Wet Tropics (eg, Tracey 1982:2) and native vegetation classification (Tracey 1982; Goosem *et al.* 1999) exists, the requirement for sophisticated GIS-based information and accurate global distributional data limit the applicability of this protocol. The system, however, is instructive in the ranking categories used and may serve as a model for future development of computer-based RASs in this and other regions of Australia.

3.2.5 Weed Risk Assessment in the Galapagos Islands (Tye in press)

With a similar situation to Hawaii of a tropical volcanic island archipelago beset by problems associated with "an enormous number of new introductions of alien plants and animals" (Tye in press:19), consideration of an objective weed risk assessment in the Galapagos is pertinent here. The emphasis here is on 'naturalised plants' – ie, those that are "capable of maintaining a population without additional interference" (Tye in press:20) – of natural areas, although it is stated that this should not imply neglect of agricultural pest plants, with the settled areas as major staging points for invasion into the Galapagos National Park that comprises 96.4% of the total land area.

While most introduced plants appear not to have significantly impaired the ecological equilibrium of the island over 30 species have established over "large areas and/or appear to be adversely affecting the natural ecosystem to a degree more than simply occupying space within an existing community (eg, altering community composition or threatening individual species), or (in a few cases) are already naturalised and known to be extremely serious invasives in other parts of the world" (Tye in press:22). More than 50 others have naturalised and are not common but have demonstrated invasive tendencies in other parts of the world. Those considered the worst plants - especially woody species - are grouped according to the characteristics of their invasions, particularly area occupied and the nature of their ecological effects.

Tye (in press:22-23) specifies that the groups comprise:

(1) herbaceous or shrubby plants that are invading slowly but whose main effect is to dominate and replace the native shrub/herb layer (comprising species that were probable early introductions that have spread widely and other that are either more recent arrivals or spread more slowly)

(2) herbaceous species including fleshy herbs and grasses that have spread faster or more extensively that not only replace the herb layer with monospecific stands but form such a dense carpet severely inhibiting regeneration of shrub/tree layers

(3) scramblers and climbers that have spread rapidly and widely and which have integrated to some extent into natural communities but which exert at least intermittent competition and may be having more insidious effects by diminishing light levels for subordinate native species

(4) shrubs or small trees that mostly spread by a combination of seeds and vegetative means to form dense stands preventing other herbaceous or woody growth (incidently, this group contains species of *Leucaena, Lantana* and *Rubus* that pose similar problems to native communities of the Wet Tropics)

(5) trees that are invading slowly because they are in the early stages of expansion and/or have heavy seeds that reduce their dispersal capability but which, because of their size, will have dramatic impacts on lower growing native vegetation (*Mangifera indica*, and to a lesser extent *Persea americana*, may be considered to be natural members of this group within the Wet Tropics)

(6) trees that spread rapidy by small wind or animal (particularly bird) dispersed seeds and which form dense stands (eg, in the Wet Tropics, *Spathodea campanulata* is representative of the former sub-group and *Psidium guajava* of the latter), and

(7) a single herbaceous species – the tomato (*Lycopersicon esculentum*) – that is having a unique environemental impact through hybridising with the native *L. cheesmanii* and threatening its survival on some islands.

These groups are based on a subjective assessment of what is known of their invasions and impacts and, in the absence of a formal RAS, can be further ranked in decreasing order of importance as Group 6 > Group 5, Group 2 > Group 1, with some within each group meriting higher ranking than others, and so forth. A more objective RAS would permit more precise comparisons and relative ranking than is possible with this approach. To this end, an alien plant RAS for Galapagos is currently being developed based on quarantine screening protocols and a recently formulated system being implemented in New Zealand (NZDC 1997). The latter, in particular, includes the following components:

1. susceptibility of community type potentially affected to specific species invasion;
2. significance of effect on system – ie, degree of impact on species composition, regeneration suppression, life-span persistence, etc.;
3. biological success rating that includes maturation rate, seed production, seed viability, dispersal capability, establishment and growth rate, importance of vegetative reproduction; and
4. additional information including fire risk, competitive ability and resistance to management (Box 5).

Initiatives currently underway to assist weed control in the Galapagos Islands can inform the formulation of a Wet Tropics regional RAS. They include a comprehensive review of pertinent factors (see parts 1-4 of Box 5). It is considered that factors affecting ability to control a given alien species need not be included in the initial phase of weed risk assessment to be applied regionally but, rather, are a secondary consideration. It is first of all important to focus on (1) which species are having or will have the greatest ecological impact and (2) to reveal which of those species that are currently restricted, uncommon and/or relatively innocuous that are virtual 'time bombs' and capable of doing much more than using space (Tye in press:30).

Box 5. Criteria included in WRA proposed for Galapagos (Tye, in press)

1.	**FACTORS CONTRIBUTING TO ECOLOGICAL/BIOLOGICAL IMPACT OF INVADER**
(a)	relatively restricted humid areas more susceptible to invasion by the majority of introduced plants – ie, species capable of invading more than one vegetation zone pose a much greater threat – inclusive of 'community type potentially affected', 'distribution and impact' and 'bioclimatic zones invaded' of the NZ system (NZDC 1997)
(b)	life-history characteristics of components of vegetation potentially at risk from invasion – eg, endemic species that exhibit periodic seed production and/or germination and/or natural cycles of death and recovery (boom-bust cycles) can be at risk of invasion during low seed set and/or during periods where majority of mass mortality
(c)	natural perturbations such as storm and fire damage or human-mediated disturbances such as logging may predispose a system to invasion by species that, for example, exploit canopy gaps.
2.	**PHYLOGENETIC CONSIDERATIONS – TAXONOMIC UNIQUENESS RATING**
(a)	taxonomic disharmony (ie, representation of families different from that on neighbouring mainland) of island floras – such that novel taxonomic introductions have the potential to induce profound changes in the character of the flora
(b)	control of invasive species may be limited due to occurrence of close native relatives
(c)	hybridisation threats such as in the case of the edible and native tomatos.
3.	**BIOLOGY – PLANT CHARACTERISTICS THAT AFFECT ABILITY TO INVADE or BIOLOGICAL SUCCESS RATING**
(a)	habitat range
(b)	rapidity of growth and attainment of maturity
(c)	self-compatibility
(d)	dispersal ability/vegetative reproduction
(e)	life history strategy
(f)	other aspects of competitive ability such as allelopathy
4.	**ECOLOGICAL EFFECTS – as in "EFFECT ON SYSTEM' OF NZ PROTOCOL (NZDC 1997)**
(a)	growth habit/tendancy to form monospecific stands – eg, trees cause conspicuous and drastic changes in species composition and habitat structure by suppressing regeneration of subordinate species, allelopathy and/or by changing the nutrient status (as in N-fixing legumes) or soil water relations
(b)	cryptic effects such as tree introductions to treeless habitats that can induce additional species (eg, insect pest hosts) invasions
(c)	effect on individual native species – eg, alien species may impacts severely r&t native species if they are syntopic and share similar niches
5.	**FACTORS AFFECTING ABILITY TO CONTROL**
(a)	availability of control methods
(b)	effectiveness and ecological effects of the control methods
(c)	cost
(d)	social factors – eg, as in the political difficulty of removal of one of the most invasive grasses *Pennesetum purpureum* that is a valued pasture grass which is also present in the Wet Tropics
(e)	possibility of eradication *versus* continued control – ie, strategic eradication of incipient invasions compared with continued efforts to control widespread species or feasibility considerations of abundance and spatial distribution

3.2.6 Assessment to determine Weeds of National Significance (WONS) (www.weeds.org.au ; Thorp 1999)

Although at a greatly different scale, the system devised to differentiate those of national significance among the large number of weeds already present in Australia is also analogous to that currently being formulated to rank weeds of the Wet Tropics region. Prospective WONS are initially nominated by State and Territory agencies and then independently assessed according to four basic criteria (Box 6). Highest scoring species are considered and agreement is sought at three ministerial councils on a final list of twenty species purported to be those of highest national priority. An agreed national approach comprising the formulation of a national control strategy, which includes specific action projects, is triggered for each WONS.

Box 6. Criteria and weightings allowing identification of WONS

1. **Invasiveness** – based on an assessment of the biology of the weed and its life history (maximum weighting 1)
2. **impact characteristics** (maximum weighting 1)
3. **potential and current area of spread** (maximum weighting 0.5: comprising (i) current distribution maximum weighting 0.25, and (ii) potential distribution maximum weighting 0.5)
4. **current primary industry, environmental and socio-economic impacts** (maximum weighting 0.75 comprising: (i) current cost of control for agriculture and forestry maximum weighting 0.25, (ii) environmental index maximum weighting 0.25 [itself comprising species – up to 0.0625; communities – up to 0.0625; Interim Biogeographic Regions of Australia 'regions' – up to 0.0625; and monoculture – up to 0.0625], and (iii) social index maximum weighting 0.25.

MAXIMUM SCORE = 3.25

3.2.7 Weed Assessment Scoresheet of the Animal and Plant Control Commission of South Australia (Virtue 2000)

The system developed by the Animal and Plant Control Commission of South Australia provides for a 'land use-based' treatment of the various weeds within an area for which responsibility rests with individual Animal and Plant Control Boards. It employs a series of questions (Box 7) against which responses relating to invasiveness, impacts and potential distribution of a particular taxon are scored. Provision is made for a 'don't know' response that is scored zero so as to avoid biases reflecting information differentials.

Scores ranging from 0-10 are multiplied to provide a 'weed importance' measure with a maximum value of 1 000. It is recognised that the importance of a particular weed is a totally separate issue to its feasibility of control and development of a similar scoring system to direct management efforts is also required.

Since conservation (and tourist presentation) management consititutes a primary land use for the subject area, provision for such a variety of land uses within the RAS currently being formulated need not be as explicit. For ease of interpretation, the "Board" has been replaced with "Area" since the focus of the present exercise is to provide for a RAS pertaining to the World Heritage 'Area'.

Box 7. Criteria and scores of the South Australian WAS (Virtue 2000)

INVASIVENESS		
1. **What is the weed's ability to establish amongst existing plants?**		**SCORE**
☐ **very high**	"Seedlings" readily establish within dense vegetation, or amongst thick infestations of other weeds.	*3*
☐ **high**	"Seedlings" readily establish within more open vegetation, or amongst average infestations of other weeds.	*2*
☐ **medium**	"Seedlings" mainly establish when there has been moderate disturbance to existing vegetation, which substantially reduces competition. This could include intensive grazing, mowing, light cultivations, clearing of trees, temporary floods or summer droughts.	*1*
☐ **low**	"Seedlings" mainly need bare ground to establish, including removal of stubble/leaf litter. This will occur after major disturbances such as deep cultivation, overgrazing, hot fires, bulldozing, long-term floods or long droughts.	*0*
☐ **don't know**	**Note: "seedlings" include vegetative growth forms and those from spores.**	*?*
2. **What is the weed's tolerance to average weed management practices in the landscape?**		**SCORE**
☐ **very high**	Over 95% of weeds survive commonly used weed management practices.	*3*
☐ **high**	More than 50% of weeds survive.	*2*
☐ **medium**	Less than 50% of weeds survive.	*1*
☐ **low**	Less than 5% of weeds survive.	*0*
☐ **don't know**		*?*

3. What is the reproductive ability of the weed in the landscape?							Total (a+b+c)	**SCORE**
(a) Time to seeding		*(b) Seed set*		*(c) Vegetative reproduction*		☐ **high**	5 or 6	*3*
☐ 1 year	*2*	☐ high	*2*	☐ fast	*2*	☐ **med.-high**	3 or 4	*2*
☐ 2-3 yrs	*1*	☐ low	*1*	☐ slow	*1*	☐ **medium-low**	1 or 2	*1*
☐ >3 yrs/never	*0*	☐ none	*0*	☐ none	*0*	☐ **low**	0	*0*
☐ don't know	*?*	☐ don't know	*?*	☐ don't know	*?*	☐ **don't know**		*?*

4. How likely is long-distance dispersal (>100m) by natural means?								Total (a+b+c+d)	**SCORE**
(a) Flying birds		*(b) Other animals*		*(c) Water*		*(d) Wind*		6, 7, 8	*3*
☐ common	*2*	☐ common	*2*	☐ common	*2*	☐ common	*2*	3, 4, 5	*2*
☐ occasional	*1*	☐ occasional	*1*	☐ occasional	*1*	☐ occasional	*1*	1 or 2	*1*
☐ unlikely	*0*	☐ unlikely	*0*	☐ unlikely	*0*	☐ unlikely	*0*	0	*0*
☐ don't know	*?*	☐ don't know	*?*	☐ don't know	*?*	☐ don't know	*?*		*?*

5. How likely is long-distance dispersal (>100m) by human means?								Total (a+b+c+d)	**SCORE**
(a) Deliberate spread by people		*(b) Accidentally by people and vehicles*		*(c) contaminated produce*		*(d) Domestic/ farm animals*		6, 7, 8	*3*
☐ common	*2*	☐ common	*2*	☐ common	*2*	☐ common	*2*	3, 4, 5	*2*
☐ occasional	*1*	☐ occasional	*1*	☐ occasional	*1*	☐ occasional	*1*	1 or 2	*1*
☐ unlikely	*0*	☐ unlikely	*0*	☐ unlikely	*0*	☐ unlikely	*0*	0	*0*
☐ don't know	*?*	☐ don't know	*?*	☐ don't know	*?*	☐ don't know	*?*		*?*

IMPACTS

6. Does the weed reduce the establishment of desired plants?		**SCORE**
☐ **>50% reduction**	Weed prevents establishment of more than 50% of desired plants (eg. regenerating pasture, crops, planted trees, regenerating native vegetation), by preventing germination and/or killing seedlings.	*3*
☐ **10-50% reduction**	Weed prevents establishment of between 10-50% of desired plants.	*2*
☐ **<10% reduction**	Weed prevents establishment of <10% of desired plants.	*1*
☐ **none**	Weed does not affect germination and survival of desired plants.	*0*
☐ **don't know**		*?*

7.Does the weed reduce the yield or amount of desired vegetation?		**SCORE**
☐ **>50% reduction**	Weed reduces crop, pasture or forestry yield, or the amount of mature native vegetation by over 50%.	*4*
☐ **25-50% reduction**	Weed reduces yield/amount of desired vegetation by 25-50%.	*3*
☐ **10-25% reduction**	Weed reduces yield/amount of desired vegetation by 10-25%.	*2*
☐ **<10% reduction**	Weed reduces yield/amount of desired vegetation by up to 10%.	*1*
☐ **none**	The weed has no effect on growth of the desired vegetation. Or the weed may become desirable vegetation at certain times of year (eg. providing useful summer feed), which balances out its reduction in the growth of other desirable plants.	*0*
☐ **don't know**		*?*

7. Does the weed reduce the quality of products or services obtained from the landscape?		**SCORE**
☐ **high**	Weed severely reduces product quality by severe contamination, toxicity, tainting and/or abnormalities (chemical and/or physical) such that it cannot be sold. For native vegetation, the weed severely reduces biodiversity such that it is not suitable for nature conservation and/or nature-based tourism.	*3*
☐ **medium**	The weed substantially reduces product quality such that it is sold at a much lower price for a low-grade use. For native vegetation, the weed substantially reduces biodiversity such that it is given lower priority for nature conservation and/or nature-based tourism.	*2*
☐ **low**	The weed slightly reduces product quality, lowering its price but still passing as first grade product. For native vegetation, the weed has only marginal effects on biodiversity but is visually obvious and degrades the natural appearance of the landscape.	*1*
☐ **none**	The weed does not effect product quality.	*0*
☐ **don't know**		*?*

8. Does the weed restrict the physical movement of people, animals, vehicles, machinery and/or water?		**SCORE**
☐ **high**	Weed infestations are impenetrable throughout the year, preventing the physical movement of people, animals, vehicles, machinery and/or water.	*3*
☐ **medium**	Weed infestations are rarely impenetrable, but slow the physical movement of people, animals, vehicles, machinery and/or water throughout the year.	*2*
☐ **low**	Weed infestations never impenetrable, but slow movement of people, animals, vehicles, machinery and/or water at certain times of the year.	*1*
☐ **none**	The weed has no effect on physical movement.	*0*
☐ **don't know**		*?*

9. Does the weed affect the health of animals and/or people?		**SCORE**
☐ **high**	The weed is highly toxic and frequently causes death and/or severe illness in people, stock, and/or native animals.	*3*
☐ **medium**	The weed frequently causes significant physical injuries (due to spines or barbs) and/or significant illness (chronic poisoning, strong allergies) in people, stock, and/or native animals, occasionally resulting in death.	*2*
☐ **low**	The weed occasionally causes slight physical injuries or mild illness in people, stock, and/or native animals, with no lasting effects.	*1*
☐ **none**	The weed does not affect the health of animals or people.	*0*
☐ **don't know**		*?*

10. Does the weed have major, positive or negative effects on environmental health?

	☐ **major positive effect**	☐ **major negative effect**	☐ **minor or no effect**	☐ **don't know**
scoring for (a) - (f):	*–1*	*1*	*0*	*?*
(a) food/shelter?	*Examples of negative effects are Blackberry (Rubus fruticosis) harbouring rabbits and grass weeds hosting wheat root diseases. An example of a positive effect is exotic trees providing stock shelter. Ignore pasture for livestock.*			
(b) fire regime?	*This includes changes to the normal frequency, intensity, and/or timing of fires. Examples of weeds having major effects include exotic grasses invading shrubby native vegetation.*			
(b) increase nutrient levels?	*Eg, legumes can increase soil nitrogen. This may make native vegetation more prone to weed invasion, but would be beneficial in agriculture. Ignore competition for nutrients (decreased nutrient levels) as this was covered indirectly above.*			
(d) soil salinity?	*Are the leaves of the weed high in salt? Leaf decomposition may increase salinity at the soil surface. Example plants are iceplant and tamarix.*			
(e) soil stability?	*Does weed increase soil erosion, or silting of waterways?*			
(f) soil water table?	*Does weed substantially raise or lower the soil water table compared to other plants present? Is this positive or negative? Ignore competition for water.*			
Total (a + b + c + d + e + f)	>3	2 or 3	1	0 or less
SCORE FOR 6.	*3*	*2*	*1*	*0*

11. What proportion of the area is suitable for the weed?		**SCORE**
☐ **> 80%**	The weed has a potential to spread to more than 80% of the Area	*10*
☐ **60-80%**	The weed has a potential to spread to 60-80% of the Area	*8*
☐ **40-60%**	The weed has a potential to spread to 40%-60% of the Area	*6*
☐ **20-40%**	The weed has a potential to spread to 20%-40% of the Area	*4*
☐ **10-20%**	The weed has a potential to spread to 10%-20% of the Area	*2*
☐ **5-10%**	The weed has a potential to spread to 5% and 10% of the Area	*1*
☐ **<5%**	The weed has a potential to spread to less than 5% of the Area	*0.5*
☐ **unsuited**	The weed is not suited to growing in any part of the Area	*0*
☐ **don't know**		*?*

WEED IMPORTANCE SCORE

Adjusting invasiveness, impacts and potential distribution scores to range from 0 to 10, and then multiplying these provide the score for weed importance. The spreadsheet does this. The logic of multiplying is described below.

To calculate manually then adjust the raw scores as follows:

Invasiveness:	Divide by 15 and multiply by 10. Round off to one decimal place.
Impacts:	Divide by 19 and multiply by 10. Round off to one decimal place.
Potential distribution:	Leave unchanged.

Weed Importance = Invasiveness × Impacts × Potential distribution

Weed importance will have a maximum of 1 000, and a minimum of 0. However, the worst weeds in an Area will probably score between 250 and 500, and most weeds will score less than 100.

Weeds can be listed from highest to lowest importance score within any given area. However, given the scores are simply an aid to decision-making, it is best to group weeds with similar importance scores, with respect to different land uses. Weeds could be grouped as follows:

Groupings for Weed Importance score :

1	*401-1000*	↓ *DECREASING SIGNIFICANCE*
2	*201-400*	
3	*101-200*	
4	*50-100*	
5	*26-50*	
6	*0-25*	

Why multiply the invasiveness, impacts and potential distribution scores?

- Multiplying gives a greater spread in scores than adding (ie. range from 0-1 000 compared to 0-30).
- Multiplying is logical, as it recognises the interactions between the criteria. If the impacts of a weed can be measured in dollars per hectare per year, the potential distribution is known in hectares, and the invasiveness (ie. rate of spread) is measured in terms of the increase in hectares compared to the previous year:

Impact	×	**Potential Distribution**	×	**Invasiveness**
$ / hectares / year		*hectares*		*hectares(current year) / hectares (previous year)*

When multiplying, all of the hectare units cancel so that weed importance is measured in total dollars per year. In multiplying the invasiveness, impacts and potential distribution criteria scores, we are mimicking the above calculation, without having the actual dollar and hectare figures.

3.3 Basic Elements of a Weed RAS

Some workers (eg, Swarbrick, in Binggeli *et al.* 1998:22) in the area express considerable doubt as to whether invasiveness can be adequately predicted and claim that, given the right set of circumstances, any plant can become a weed. Despite the justifiable skepticism, it is important to formulate systems that can provide some indication of weediness risk. Any potentially useful system must include a basic set of elements against which potential or existing plant introductions can be assessed.

Three basic factors – ie, species characteristics, disturbance regimes and environmental factors - are critical considerations in weed assessment (Binggeli *et al.* 1998:2). In addition there are various other aspects of the host environment (or extrinsic factors) that require evaluation in any system designed to rank exotic plants according to risks posed, especially in light of the conservation management obligations within the Wet Tropics region. Moreover, the manner in which an exotic species is introduced to the recipient land (Maillet & Lopez 2000:12) can, along with the basic attributes of the plant, the ecological characteristics of the host environment and the extent of disturbance, determine the nature and speed of invasion.

Clearly there are certain intrinsic biological traits predisposing species to potential invasiveness (Goodwin *et al.* 1999:423). However, it has been demonstrated by Maillet & Lopez (2000:23) that no set of characters is common to weedy exotic species. The 'ideal weed', it is argued by Noble (1989:302), is "a plastic perennial which will germinate in a wide range of physical conditions, grow quickly, flower early, is self-compatible (ie, not possessing a specialised pollination system), produces many [persistent] seeds that disperse widely, reproduces vegetatively and is a good competitor". Goodwin *et al.* (1999:423) note also that it is important for successful invaders to possess seeds that can germinate without pretreatment (as in vernalisation) and that there should be short intervals between large seed crops. Noble (1989:308) goes on to argue that the perenniality of a plant is little evidence of its invasive potential in stable environments". Moreover, species that have long-lived seed pools may pose great problems for weed control/eradication but that is a separate issue from the prediction of invasiveness itself. Patently, traits relating to a species' reproductive and growth system, dispersal capability[3] and competitive ability are valuable indicators of potential invasiveness and should feature prominently in any effective RAS. Competitive ability, however, is not easily established precisely without field trials under a range of conditions and other experiments. It may be inferred from extensive observations elsewhere, and it is more likely that aspects of a plant's gross biology, that includes observations on life form, growth, reproduction and dispersal, will be better documented in the existing literature and, therefore, more readily accommodated within a RAS. Consideration of intrinsic traits for use in the proposed Wet Tropics RAS is included within Section 4.2 below.

Despite the enormity of the problem of weed invasion, it is evident that most exotic species tend to remain associated with areas of gross human disturbance, "whereas only a few establish in stable, natural vegetation" (Maillet & Lopez 2000:12). However, these do indeed pose major threats. Noble (1989:309) stresses that "it is the invaded environment, as much as the properties of the invading species itself, that determine invasion success". These are of particular pertinence in the HEAR system (see Box 4 above), are included in the ESRS (Box 1) and the WWPRS (Box 3), and not only relate to degrees of disturbance that predispose systems to invasion, but also relate to the special conservation status of species and ecological communities. Specific host environment or extrinsic factors are incorporated within the proposed Wet Tropics RAS as set out in Section 4.3 below).

Weediness elsewhere is regarded widely as one of the best predictors of invasiveness. Citing Reichard's (1994) work, Binggeli *et al.* (1998:23) reinforce this determination on the basis of a comparison of 235 invasive species with 114 other introdutions that failed to establish and spread. They claim that "at present, species known to be invasive elsewhere in he world under similar climatic conditions is still the best predictor of invasiveness". It is appropriate that, immediately subsequent to establishing whether a species is indeed native or exotic (as is the case with some agricultural weeds rather than alien species that are environmental weeds within natural systems), the extent to which it or a related (congeneric) species has demonstrated invasiveness elsewhere must be evaluated.

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3 Noble (1989:310) comments that while short-distance dispersal will increase both the predictability and rate of invasion, that absence of inherent long-distance dispersal capacity is not a hindrance to invasiveness since humans are the main vector. In short, it seems that species with a high reproductive output (even if unsuccessful) in native habitat have high invasive potential, with large flowering and fruiting effort being the first clue to a successful invader (Noble 1989:306).

4.0 Tailoring a Weed Risk Assessment System for the Wet Tropics Bioregion

The basic requirement of this exercise is not to screen potential imports but to evaluate species already present that currently or potentially constitute major environmental weeds. This is to serve as a basis for allocation of limited area management resources within (and presumably about) the Wet Tropics WHA. In fact, this exercise can be considered analogous to the calibration/validation testing of the WRA system proposed for import screening use (Pheloung 1995:8). Analagous also, albeit at a different scale, is national assessment of weeds already present in Australia.

Just as two critical numeric scores are used by import screening authorities to reject, further evaluate or accept proposed introductions, a similar approach to ranking exotic species may allow the differentiation among highest priority, 'sleeper' and relatively benign weeds that can prompt control and/or eradication, careful monitoring and minimal strategic control management actions, respectively. The fact that protected area boundaries – and especially those often irregular and discontinuous ones that characterise the Wet Tropics WHA - are not recognised by plants (and most animals) means that the evaluation was conducted on a bioregional basis rather than confining attention strictly to the WHA itself. Also any RAS that will have explicit management utility "must be tailored to fit both the invader and the invadee: ie, the autecological and life history attributes of the species as well as the biotic and abiotic attributes of the ecosystems being protected" (Ewell 1986:228).

In the proposed RAS it is appropriate to aim at consistency with other approaches and to derive a system that is robust, simple to apply and transparent. Hence, there is good reason for a useful system being highly derivative, drawing closely upon those elements of RASs in use or under development elsewhere to benefit from earlier expert opinion. Moreover, data now being gathered on a vast range of plant taxa in such compendia as the 'Global Invasive Species Database' (Fondation d'Entreprise Total 2000 issg@auckland.ac.nz), and others associated with tropical woody weeds (eg, Binggeli *et al.* 1998), are compatible with such systems and therefore more amenable for inclusion in any purpose-built RAS when screening species not known locally.

In an assessment of invasiveness there are two fundamental questions: (1) what are the biological characteristics of an invasive species; and, (2) how does that allow us to predict what species will be invasive? Biological traits including reproduction, establishment, growth, dispersal, and competitive ability, genetic plasticity are know to be fundamentally indicative of invasive potential (see Section 3.3). While there are many gaps in detail, these are explicit, whereas 'impacts' and extrinsic attributes of the host environment are less so. Williams & West (2000:428) list a group of key attributes of plants that indicate a potential for weediness in native ecosystems. These are set out in Table 4.

As well as intrinsic (known biological attribute) factors there are extrinsic (environmental, etc) factors that require consideration – ie, critical landscape features and species and communities at risk. Consideration is given below as to how such attributes are employed within existing systems that are used to determine environmental weed risk. It is, however, intended that more explicit understanding of the peculiarities of the subject region and special aspects of its ecology and constitutent communities and species be explicitly accommodated in the RAS.

Table 4: Characteristics of plants that are indicative of a potential for weediness in natural ecosystems (after Williams & West 2000:Table 3).

high input of viable propagules
short (<2 years) development time to reproductive maturity
seeds/other reproductive units with prolonged (>5 years) periods of dormancy/residency in seed bank
high rate of aerial or subterranean biomass production, particularly under conditions of low light, water and/or nutrient availability
dense and spreading foliage/canopy
efficient long distance (>1 km) dispersal capaiblity
presence of interspecific allelopathic properties and/or absence of intraspecific allelopathic properties
successful coloniser of disturbed or bare ground
reproductive strategies that facilitate survival in fire-prone environments
broad distribution over a range of distinct climatic types
low suceptibility to attack by phytophagous organisms

4.1 Insights into Weed Invasions in the Tropics

With respect to woody weed invasion in the tropics, Goodland *et al.* (1998:8/2) argue that "every invasive event is unique and is affected by the species' distinctive set of attributes and specific local environmental factors and biological communities". There are, however, certain characteristics that predispose plants for weedy behaviour. In fact, these traits are often those for which plants have been introduced as robust agricultural or ornamental adventives. Consideration of the most diagnostic of those intrinsic traits is a fundamental requirement of any effective RAS.

In a major global review of woody invasive species in the tropics, Binggeli *et al.* (1998:14-15) note that birds are the major dispersal agents of the most invasive weeds and are implicated in the spread of 43% of those species considered. Wind dispersal is of secondary significance, accounting for dispersal of 20% of those species. It is appropriate, therefore, that dispersal mode and distance (along with some measure of propagule production) be incorporated into the Wet Tropics RAS. 'Pointers' to invasiveness in tropical environments include (i) high habitat disturbance and broad ecological amplitude; (ii) short generation time; (iii) high reproductive output; (iv) high diffusivity (dispersal capability); and (v) high numbers of invading individuals (Binggeli *et al.* 1998:22).

4.2 Consideration of Intrinsic (Biological) Traits

Selection of critical assessment criteria and elements thereof is vital to a successful RAS. From the review of the various systems above it was possible to consider the extent of incorporation of critical intrinsic biological attributes (Table 5).

Inspection of Table 5 suggests that attributes directly related to reproductive capacity and mode are most commonly used indicators of invasiveness. These traits, along with those associated with dispersal capability and mode, are used in all but one of the systems reviewed. Demonstrated weediness of a species or its congener elsewhere is also frequently used to assess weed risk. Establishment needs and life form/niche are less common components, but are nonetheless diagnostic in some RASs.

Table 5: Treatment of intrinsic traits amongst the various risk assessment systems reviewed

	Intrinsic Attribute				
Specific Assessment System	**it/congener elsewhere a weed**	**life form and/or niche**	**reproductive capacity and mode**	**dispersal mode and capability**	**establish-ment needs**
ESRS of US Department of Interior National Parks Service (Hiebert & Stubbendieck 1993)	• known level of impact in natural areas, habitats, climates		• extent of completion of reproductive cycle • mode • extent of vegetative reprod. • frequency of sexual reprod. • No. of seeds per plant	• potential of long distance dispersal	• ditribution in relation to disturbance regime • germination requirements
Australian WRA protocols (Pheloung 1995)	• climates in distribution • introduction history • extent naturalised beyond native range • congeneric weed • type of weediness exhibited	• existence of undesirable traits (eg, thorns, burrs) • plant type (aquatic, grass, geophyte, N-fixer) • climbing or smothering growth habit	• reproductive success • seed production, longevity & viability • self-compatibility • reproduces by vegetative fragmentation • pollination • minimum generative time	• dispersal mode (wind, water, bird and/or intentional/ unintentional human dispersal)	• weed of disturbed areas, agriculture or environmental weed • tolerant of or benefits from mutilation and/or cultivation
WWPRS of US Nature Conservancy (Randall et al., in press)	• is species known to be invasive elsewhere?		• mode • seed production • seed viability • rate of spread	• extent of local proliferation • long distance dispersal potential	• extent to which it establishes in disturbed and.or successional areas
Weed Risk Assessment in Hawaii (Teytaud, 1998; Thomas, in press)	• invasive category elsewhere • where invading				• dependence on disturbance
Weed Risk Assessment in the Galapagos Islands (Tye, in press)	[habitat range]	• life history strategy • [habitat range]	• rapidity of growth & attainment of maturity • vegetative reproduction • self-compatibility	• dispersal ability	
Assessment to determine WONS (Thorp 1999)			[component of invasiveness criterion]	[component of invasiveness criterion]	
Weed Assessment Scoresheet of the SA Animal/Plant Control Commission (Virtue 2000)			• maturation time • extent of ssed set • rate of vegetative reproduction	• likelihood & mode of long-distance dispersal • likelihood & mode of human-induced dispersal	• dependence on disturbance

4.3 Consideration of Extrinsic Factors

Appreciation of the fact that invasiveness and risk is not only dictated by inherent alien plant qualities but also by attributes of the host environment led also to an evaluation on the extent to which these were utilised among the various screening/ranking systems (Table 6). All systems reviewed included an assessment of impact or threat to native communities (and generally to native species) or alluded to attributes such as sociability (as in 'able to grow in monospecific stands') and/or allelopathy and toxicity.

Table 6: Treatment of extrinsic traits amongst the various risk assessment systems reviewed

	Extrinsic Attribute				
Specific Assessment System	**distribution**	**abundance**	**environmental tolerance**	**effect on native communities and/or species**	**effect on system processes**
ESRS of US Department of Interior National Parks Service (Hiebert & Stubbendieck 1993)	• spatial pattern of infestation (ie, widespread, scattered) • areal extent	[incorporated in distribution attribute]	[related to disturbance regimes & successional status]	• threat to or endangerment of park resources • modification of system succession or ecosystem replacement	[related to system successional modification or replacement]
Australian WRA protocols (Pheloung 1995)			• climate match • environmental versatility • shade tolerance • grows on infertile soils	• forms dense thickets • allelopathic • toxic to animals	• creates a fire hazard in natural ecosystems
WWPRS of US Nature Conservancy (Randall et al., in press)	• current range (area) • No. of infestations	[incorporated partly in rate of spread]	• competitive ability includes tolerance of a range of conditions	• influence on community structure • potential cover of species in strata where it occurs (able to grow in monospecific stands) • influence on community composition • conservation status/significance of community or species at risk	• degree of alteration of system processes (eg, soil nutrients, & water, sedimentation rates, fire-proneness)
Weed Risk Assessment in Hawaii (Teytaud, 1998; Thomas, in press)			[partly included in assessment of economic losses on developed agricultural, housing, commercial & industrial lands]	• known/suspected to cause replacement of natural/semi-natural of high diversity, etc. • known/suspected to pose significant threats or extinction to native floral or faunal communities or species with special conservation status	• known/suspected to cause significant alterations of natural fire regimes of native communities, energy flows, materials or mineral cycling, moisture relationships or other critical eco-system processes
Weed Risk Assessment in the Galapagos Islands (Tye, in press)		[incoporated in abilty to grow in monospecific stands]	• habitat range • capability of invading >1 veg. zone	• cause conspicuous or drastic changes in community composition • has cryptic effects (eg, trees in treeless communities) • severely impacts on native r&t species	• cause drastic changes in habitat structure (eg tendency to form monospecific stands) by suppressing recruit-ment or by allelo-pathy or changing nutrient status
Assessment to determine WONS (Thorp 1999)	• current area of spread		• potential area of spread	[weighting imposed proportional to bio-regional significance of species or communities]	[possibly incorporated in previous attribute]
Weed Assessment Scoresheet of the SA Animal/Plant Control Commission (Virtue 2000)				• does weed prevent establishment of desired vegetation? • extent of reduction in biodiversity so as make area unsuitable for nature conservation • toxicity to native animals	• does weed have effect on food, shelter, fire regime, nutrient levels, soil salinity/erosion, silting of waterways or soil watertable?

Most systems also incorporated assessment of actual or potential impact on system processes – particularly with regard to modifications of fire regimes – and to a lesser extent to nutrient and moisture relations. In the Hawaiian WRAS (Teytaud 1998) there is also reference to the 'criticality' or significance of ecosystem processes that operate and that are, or can be, modified by invasion of exotic species. Clearly, this is a vital component of an appropriate RAS against which invasive species can be ranked. However, in the cases of exotic species that have yet to establish in the novel environment, assessment depends upon the existence of information about their occurrence in other places and ecosystem impacts that have occurred as a result.

'Environmental tolerance', while interpretable as an intrinsic rather than extrinsic attribute, can relate to properties of the host environment as well as to an exotic species' capacity to exploit those properties. Such attributes are indicative of plant-environment interactions that reflect not only autecological aspects but also host environment properties. In some instances this factor is included as a matching exercise between the climates or landsystems of a plant's native range and those of the host environment. The HEAR system employs a sophisticated GIS matching of such factors and similar comparative systems (eg, BIOCLIM/ANUCLIM, CLIMATE, CLIMEX – Kriticos & Randall in press) are either employed or under development in Australia for the prediction of potential weed distributions that can be used to rank species and to direct management efforts. In the interest of ease of application, inclusion of this attribute in the proposed RAS is explicitly confined to assessment of exotic aquatic plants as the 'versatility' component, although it is, in part, associated with the intrinsic attribute, 'competitive ability', in that part of the RAS applied to terrestrial species.

Other factors that are again somewhat equivocally included in the extrinsic category relate to properties of populations of exotic plants already present in a recipient environment. Factors such as distribution and abundance, therefore, differentially contribute to the assessment process and are dependent upon the stage of invasion of a species. These attributes are occasionally employed in RASs but are more commonly encountered in ranking schemes to inform weed management priorities. Despite this, assessment of current distribution and abundance of existing weeds can reflect not only stage of invasion but propensity to invade (and therefore point to risk) and can provide a link between weed risk assessment and management.

4.4 Ranking Methodology

The proposed Wet Tropics RAS constitutes a scoresheet or questionnarie that is comparable to those utilised in the various systems reviewed. Each species is allocated a score dependent upon whether or not it possesses certain attributes or according to responses to various questions relating to pertinent attributes. Details of the system are set out explicitly in Table 7.

A staged or stepped approach that permits the elimination of low risk taxa was adopted that allowed the segregation of native species from exotics, and thereafter the separation of species of disrupted systems (that are themselves a symptom rather than a cause of change) from species that are causal agents of change. The system was designed to be consistent with other approaches, robust, relatively simple to apply (especially given limited biological information for some taxa) and transparent. Moreover, a scoring system was incorporated whereby numeric values were proportionate to environmental risk with a maximum possible value of 100 providing a useful notional percentage score that is generally interpretable by a range of people.

Table 7: Proposed Wet Tropics Weed RAS

STEP 1: **Determine whether species is native**. YES ➔ STOP NO ➔ go to step 2
STEP 2: **Is the species a weed elsewhere?**
YES widespread major weed (score 5) known to be weedy (score 4) ➔ go to step 3
NO **Does it have one or more congeners that are weedy?**
YES congener(s) aggressive (score 3) congener(s) weeds only of disturbed systems (score 2) ➔ go to step 3
NO (score1) ➔ go to step 3
STEP 3: **Is the species aquatic?** YES ➔ go to 3A NO ➔ go to 3B

3A ASSESSMENT OF AQUATIC TAXA

A1: Mode of reproduction: rhizome ! fragmentation ! budding! turions ! stolons ! tubers! seeds !
Total checked ______ [maximum = 5]

A2: Numbers of reproductive organs produced year $^{-1}$ individual $^{-1}$
very high - >1000 (score 10); high - 100-1000 (score 7); medium – 10-100 (score 3); low - <10 (score 1)

A3: Dispersal capability

Dispersal outside catchment by natural agents (score maximum of 5 if propagule is well adapted for wind/bird dispersal; score 1 if it could be spread in a bird crop or on feathers and intermediate values conforming to degree of adaptation)
Dispersal outside catchment by accidental means (score max. of 3 if spread by three means (drainage machinery, boat trailers, nets)

Dispersal outside catchment by deliberate introduction (score max. of 2 if attractive as ornamental or aquarium plant to humans)

A4: Versatility

Temperature: (score 0-3) maximum score if frost tolerant; 2 if growth checked in winter; 1 if dies back in winter; 0 if killed
Depth tolerance: (score 1-3) max. if grows from deep (>5m) water to dry land; 2 if shallow water -wetland; 1 if restricted by either
Substrate tolerance: (score 1-2) max. if grows on a range of substrates and/or oligotrophic/eutrophic water; 1 if restricted by either
Water clarity: (score 0-2) maximum if unaffected by water clarity (as in case of floating macrophytes); 1 if growth diminished by turbid water; 0 if drastically reduced.

A5: Damage to Natural Areas/Systems

Biodiversity reduction (0-5) maximum for forming monospecific rafts/patches and displacing native species with reducing score for lessening impact
Water quality reduction: (0-3) maximum for major impacts, particularly deoxygenation of waterbodies by floating aquatics with reducing score for lessening impact
Impairment of physical processes: (0-2) maximum for significant impacts on hydraulic capacity, substrate stability, sedimentation and/or flooding with reduced score for lessening impact

ADD SCORES FOR STEPS 2 & THEN A3-A5 - MULTIPLY BY 2 TO PROVIDE A TOTAL SCORE OUT OF 100

STEP 3B ASSESSMENT OF TERRESTRIAL (including SEMI-AQUATIC) TAXA
STEP 3 **Gross invasiveness: What is the species' ability to establish among existing plants?**
very high – seedlings readily establish within dense vegetation or amongst thick infestation of other weeds (score 5) ➔ go to step 5
high – seedlings readily establish within more open vegetation or amongst average infestations of other weeds (score 4) ➔ go to step 5
medium – seedlings mainly establish when there has been disturbance (tree clearing, mowing, temporary floods or droughts) to existing vegetation (score 3) ➔ go to step 5
low – seedlings mainly need bare ground to establish - eg, litter removal with cultivation, overgrazing, fire (score 2) ➔ go to step 4
don't know (score 1) ➔ go to step 4
– Note: 'seedlings include vegetative growth forms and, as in ferns, those from spores.
STEP 4 **Does the species pose specific problems for native wildlife?** NO – STOP Yes ➔ go to step 5
STEP 5 ASSESSMENT OF INTRINSIC (BIOLOGICAL) TRAITS
Tick the following checklist:

5.1 Reproduction:
! reproduces readily both vegetatively and by seed ! if reproduces by seed produces >1000 p.a.
! reproduces more than once per year ! rapid growth to reproductive maturity ! seeds remain viable for ≥ 2 years
! possesses rapidly spreading culms/stolons/rhizomes that may root at the nodes ! resprouts readily when cut! other

5.2 Competitive ability: ! highly successful competitor for limited resources ! tolerates a wide range of environmental conditions and/or is stress tolerant ! has ability to germinate in naturally vegetated areas under a wide range of conditions
! is allelopathic ! lacks predators/control agents in its host environment! other

5.3 <u>Dispersal capability</u>: ! rapid local proliferation of seeds ! adapted to long distance (eg, dispersed by birds; has small water-borne or wind-borne seeds) ! other (eg, is adapted to medium distance dispersal by other animal vectors)

ADD EACH TICK to give an accumulated score and rank accordingly:

extremely aggressive – has ≥ 10 of the above traits and several (≥ 5) to a great extent – score 15; ➔ go to step 6
very aggressive – ie, has 5-9 of the above characteristics with ≥ 3 to a great extent – score 10; ➔ go to step 6
potentially aggressive – ie, has >3 of the above but only 1-2 to a great extent – score 5; ➔ go to step 6
rarely aggressive – ie, has 1-2 of the above to some extent – score 2; ➔ go to step 6
relatively benign – ie, has none of the above characteristics on only 1-2 to a very small extent – score 1 ➔ STOP

STEP 6 <u>ASSESSMENT OF EXTRINSIC (HOST ENVIRONMENT) FACTORS</u>

6.1 <u>Conservation status of communities/species at risk from invader</u>

area at risk from invasion is highly significant – ie contains ≥1 endangered Regional Ecosystem/species – score 5
area at risk is significant – ie, contains ≥1 'of concern'/vulnerable Regional Ecosystem/species – score 4
area at risk is of moderate significance – ie, may contain endemic species/good representative ecosystems – score 3
area at risk contains communities of low significance – eg common/widespread habitats, no r&t species – score 2
conservation status of area insignificant – ie, extent of human impact considerable, native species residual – score 1.

6.2 <u>Ability to disrupt native ecosystem function</u>

major, possibly irreversible alteration/disruption of ecosystem processes (eg, fire-sensitive system more fire-prone, chokes drainage channels, fixes nitrogen in oligotrophic system, drains wetland) – score 5
significant alteration of system processes (eg, increases sedimentation rates, reduces open water habitat, shades canopy, understorey and/or groundcover) – score 3
some influence on ecosystem properties (eg, a perceivable but mild influence on soil nutrients) – score 1
no perceivable impact on ecosystems processes/impact unknown – score 0

6.3 <u>Ability to disrupt ecosystem structure</u>

major alteration of structure – ie, covers canopy, forms monospecific stands eradicating most layers – score 5
significant impact on one or more strata – creates new layer or eliminates an existing stratum - score 4
significantly invades/replaces a single stratum - eg invades/eliminates groundcover or understorey – score 3
influences structure in one stratum – eg, changes density within a layer – score 2
no structural impact – establishes in existing stratum without altering stratification/density greatly – score 1

6.4 <u>Ability to disrupt native ecosystem composition</u>

causes major alteration in floristics – ie, results in extirpation of one or more native species, reduces native biodiversity or facilitates increased exotic species representation – score 5
significantly alters community composition – ie, produces a significant population reduction in one or more native species by displacement – score 4
produces some influence on floristic composition – reduces one or more native species population by reducing recruitment – score 3
little perceivable impact on native populations – score 1

6.5 <u>Current abundance in area</u>

large populations with extensive (>20% of region) distributions – score 5
large populations with widespread (10-20% of region) distributions – score 4
moderate populations with relatively restricted and/or patchy distributions –score 3
small populations with few significant infestations –score 2
small populations with limited and/or very sparse distributions – score 1

ADD SCORES FOR STEPS 2-3 & 5-6, MULTIPLY BY 2 TO PROVIDE A TOTAL SCORE OUT OF 100

The primacy of the 'weed elsewhere' attribute is clearly acknowledged by Reichard (in press). Similarly, Rejmánek (in press) argues the importance of a species or a congener of a species having demonstrated weediness in similar environments and that "this knowledge is very powerful" in predicting invasive potential. Accordingly, immediately after the initial screening step to dispense with native species, a ranking was given to taxa that have exhibited weedy tendencies elsewhere (and to what extent) or have congeners that are known weeds.

Champion & Clayton (in press:192) argue clearly for the basic distinction between obligate aquatic and terrestrial species, especially given that many of the attributes scored in general RAS models are not relevant to aquatic plant assessment, and provide a risk assessment model specifically designed for the former. Hence, once preliminary screening was conducted to determine exotic status and whether a species or its congener(s) exhibited weediness, the aquatics and terrestrials (including some emergent wetland species of non-obligate hydrophytes) were dealt with separately.

The relative importance of each attribute's contribution to overall risk is not well understood. Therefore each is regarded as basically equivalent in the ranking system. The rationale here is that relative weightings introduce greater measures of subjectivity into the system and, thus, were avoided/underplayed. Thereafter the system regards each component attribute as generally equivalent but incorporates an ordinal measure of relative significance using staged scores (eg, extremely aggressive – score 15; very aggressive –10; potentially aggressive – 5, and so forth) within a specified range.

With regard to extrinsic factors, it may be argued that one attribute, eg, ability to disrupt ecosystem function or relative significance of the conservation status (ie, 'endangered', 'vulnerable/of concern') of communities and/or species at risk, is of higher significance than others. In the absence of any accepted means to differentiate, each was scored iteratively to contribute to a final score.

Assessment of conservation status allowing invasion risk to be scored according to communities and/or species at risk from the alien invader – ie, 'endangered' *versus* 'of concern' in the case of Regional Ecosystems (REs) or 'endangered' and 'vulnerable' in the case of species, were drawn from official lists. These are Goosem *et al.* (1999) for communities (REs) as in the *Vegetation Management Act (1999*) or according to *Wildlife Schedules* of the *Nature Conservation Act (1994*) for species (also listed in Goosem *et al.* 1999).

There was a certain dilemma regarding the inclusion of attribute 6.5 – ie, 'current abundance' (Table 7) – since this normally is associated with control feasibility than risk *per se*. In this case, however, it served as a measure of host environment susceptibility to date to this invader and a useful extrinsic criterion to score against.

The omission of economic impact, management costs and similar socio-economic criteria that are often incorporated into other weed screening systems (eg, Randall *et al.* in press, Tye in press, Virtue 2000) was intentional. Intuitively, these are secondary considerations to inherent invasiveness potential and more appropriately considered subsequently to environmental risk *per se* in order to prioritise weed species for management action. Moreover, this is the approach generally employed to rank agricultural pests where monetary values of crop production and pest control are more tangible rather than in assessing environmental weeds.

The extent to which the proposed RAS provides a sensitive indication of environmental weed risk now requires evaluation. Consequently, it is intended to screen a sample of exotic species that have naturalised within the bioregion as a first step in this evaluation process. Relative rankings can then be considered in comparison with existing lists of prioritised invasive species such as those identified as the world's worst species (Fondation d'Entreprise Total 2000), species classified as WONS and the results from the application of other similar weed classification systems. Furthermore, it is intended that eventually all naturalised species within the Wet Tropics Bioregion will be processed using this system so that a greater number of comparative rankings can be evaluated. It is also suggested that the proposed system be circulated for expert comment in order that any deficiencies can be identified and remedied prior to its wider application.

5.0 Evaluation of Plant Species Naturalised within the Wet Tropics Bioregion

5.1 Emendations to Current List of Regionally Naturalised Species

Current assessment of weeds within the Wet Tropics Bioregion and the extensive portion of that bioregion that comprises the Wet Tropics World Heritage Area was based initially on the provision of a list of naturalised exotics from the EPA's WildNet database. This was subsequently revised and replaced with a list based on interrogation of the HERBRECS – "herbarium records" – database. The list contained 508 taxa comprising 475 species. Subsequently, 29 other exotics known locally to have naturalised were included, resulting in a total of 504 species (Appendix 2)

Taxonomic nomenclatural changes are ongoing and frequently confound comprehensive listing and assessment of plants. While it is not proposed to include nomenclatural authorities with those taxa examined, an attempt has been made to incorporate the most up-to-date taxonomic revisions and nomenclatural changes. This process has been assisted greatly by B. Waterhouse (pers. comm.). Nomenclatural changes include *Wedelia trilobata* to *Sphagneticola trilobata*, *Duranta repens* to *D. erecta*; *Praxelis clematidea* is known now as *Eupatorium catarium* and *E. riparium* is replaced by *Ageratina riparia*; *Hiptage madablota* is also no longer current and has been superceded by *H. benghalensis*. Since the Queensland Herbarium is yet to endorse the shift of genus to *Urochloa* (Waterhouse, pers. comm.), Pará Grass will continue to be referred to as *Brachiaria mutica* pending taxonomic reconsideration.

5.1.1 Additional Inclusions

Other species known locally to be naturalised, but due to lag time for processing specimens and/or lack of collection, were not included on the official list have been added to the list of taxa to be evaluated (Appendix 2). This process was based on the author's knowledge of species' occurrences within the region and was assisted greatly by the extensive knowledge of exotic species possessed by colleagues (especially B. Waterhouse of AQIS, D. Boorman and A. Small). Species not officially noted as 'naturalised' within the bioregion but included for risk assessment are listed in Table 8. Several are regarded as 'doubtfully naturalised' by the Queensland Herbarium.

5.1.2 Exclusions

No attempt was made to evaluate those infra-specific taxa that were included on the official list of naturalised exotics. This somewhat masks important genotypic differences that may have a bearing on invasiveness; however, due to resource limitations it was not considered appropriate to differentiate.

Such exclusions include, for example, the three varieties of *Mimosa pudica*, and similarly those for *Emilia sonchifolia* and others, that have been treated as a single taxon. In addition, *M. invisa* is synonymous with *M. diplotricha*, and therefore is excluded from the evaluation, and so forth.

Concatenation of infraspecifics reduces the original list of 508 taxa to 475 (including hybrids). With the addition of the 29 species known locally to have naturalised but not officially recorded (Table 8), **a grand total of 504 exotics** require evaluation using the RAS (see Appendix 2). It should be recognised, however, that this total is almost certainly an underestimate and the list should be reviewed regularly to remain current.

Table 8: Additional taxa known to have naturalised within the Wet Tropics Bioregion but not recorded in 'official' (Queensland Herbarium) list of naturalised exotics.

FAMILY	SPECIES	Common Name	Origin	Comments
ACANTHACEAE	*Barleria rosea*		South-east Asia?	noted naturalising in Cairns area from ornamental roadside plantings (Boorman pers. comm.)
ANACARDIACEAE	*Schinus terebinthifolia*	Pepper Tree	Central America	infestations about the Wild River, Herberton
APOCYNACEAE	*Cascabela thevetia*	Yelow Oleander, Captain Cook Tree	South America	syn. *Thevetia peruviana* – patchy infestations known
ARACEAE	*Epipremnum aureum* (syn. *Scindapsus aurea*)	Golden Devil's Ivy	South-east Asia	garden escapee establishing along creeks
ARECACEAE	*Syagrus romanzoffiana*	Queen Palm	Trop. America	invasive along Priors Ck and about Atherton
ASTERACEAE	*Mikania micrantha*	Mile-a-minute	Trop. America	one of world's worst weeds – infestations in Mission Beach area treated
COMMENLINACEAE	*Zebrina pendula*		Central America	garden escapee establishing as groundcover in forested gullies
CUCURBITACEAE	*Momordica charantia*	Balsam Pear	(palaeotropics)	widespread weedy vine
FABACEAE	*Inga* sp.	Icecream Bean	Trop. America	escapee from cultivation – introduced as food plant
FABACEAE	*Macroptilium atropurpureum*	Siratro	Trop. America	widespread introduced pasture legume
HYDROCHARITACEAE	*Elodea canadensis*	Pondweed	North America	second record only for Qld from Mazlin Ck, Atherton (Werren , unpub. data)
MARANTACEAE	*Thaumatococcus daniellii*	Sweet Prayer Plant	Tropical (West) Africa	natural sweetener; - showing signs of invasion of Whyanbeel area (Stanton pers. comm.)
MELIACEAE	*Azadirachta indica*	Neem Tree	India	invasive in drier areas
MELIACEAE	*Chukrasia velutina*	Mahogany	Indo-malaysia	escapee from plantations
MIMOSACEAE	*Acacia nilotica*	Prickly Acacia	Tropical Africa	WONS - as above (noted by Boorman, pers. comm.)
MORACEAE	*Artocarpus ?communis*	Jackfruit	Indo-malaysia	noted in area by Boorman (pes. comm.)
MYRSINACEAE	*Ardisia* sp.cf. *humilis* (may be = *A. solanacea*)		South Asia?	invading about Cairns City (Boorman, pers. comm.)
MYRTACEAE	*Eugenia dombeyi*	Gramachama Cherry	Trop. America	Stanton (unpub.) notes this food plant as naturalising
MYRTACEAE	*Eugenia uniflora*	Brazil Cherry	Trop. America	naturalising in various places (see Werren 1998)
PINACEAE	*Pinus caribaea*	Caribaean Pine	Trop. America	widely planted timber tree spreading from plantations
POACEAE	*Andropogon gayanus*	Gamba Grass	Tropical Africa	introduced pasture grass
POACEAE	*Hymenachne amplexicaulis*	Hymenachne	Trop. America	ponded pasture species – now a WONS
POACEAE	*Saccharum spontaneum*	Wild Cane	Indo-malaysia	noted 'doubtfully naturalised' by Qld Herbarium
POACEAE	*Sporobolus pyramidalis*	Giant Rats-tail	Africa	recorded on Tableland by Sullivan (Little pers. comm.)
POLYGONACEAE	*Triplaris surinamensis* and/or *T. americana*	Ant Tree	South America	naturalising in Bramston Beach area – noted in Cairns CC PMP
RUBIACEAE	*Coffea liberica*	Tree Coffee	Tropical Africa	spreading in Daintree area (Boorman, pers. comm.) – noted by Herbarium as 'doubtfully naturalised' (Guymer pers. comm.)
RUBIACEAE	*Musenda frondosa*		Tropical Africa	naturalising in Bramston Beach area (Jensen, pers. comm.)
SAPINDACEAE	*Blighia sapida*	Akee	Tropical Africa	spreading in forests along footslopes of the McAlister Range behind Palm Cove (Small pers. comm.)
SAPOTACEAE	*Chysophyllum cainito*	Star Apple	South America	tropical fruit plant nvading about Kamerunga (Stanton pers. comm.)

5.2 Existing Species that Pose Major Area Management Problems

Earlier consideration of the extent of weeds in the bioregion (Humphries & Stanton 1992) resulted in a list of eight species that were viewed as current or potential major environmental weeds. Swarbrick (1993a, 1993b, 1993c) focussed on five of those high priority weeds in subsquent investigations of distributions, autecologies and control treatments. While all eight were discovered invading native vegetation communities without being assisted by gross disturbance, some appear more problematic than others (eg, Pond Apple) and risks associated with some (eg, *Clitoria laurifolia, Sanchezia parvibracteata*) seem, at least subjectively, to have been over-emphasised. This constitutes a problem in the weed risk assessment field since different expert approaches will apply different experiences and approaches to the same task. What is required is a system that is less subjective, and while qualitative rather than quantitative, can be applied by a range of individuals according to an agreed protocol.

A more recent exercise (Bebawi pers. comm.) has imposed some ranking of a subset of the >500 introduced species known to have naturalised within the Wet Tropics region. This has involved the ranking using a Multiple Objective Decision Support System (MODSS) of the range of species addressed in ten Pest Management Plans (PMPs) developed by the various local governments that span the bioregion (Table 9)

Table 9: List of the top 31 (30 exotics and 1 native species) Wet Tropics weeds that were prioritised by MODSS. Species selection was based on the priority ratings given in the shires' and Cairns City's Pest Management Plans (Bebawi pers. comm.).

	Scientific name	Common name
1	*Mikania micrantha*	Mikania
2	*Chromolaena odorata*	Siam weed
3	*Mimosa diplotricha*	Giant sensitive plant
4	*Eupatorium catarium*	Praxelis (syn. *Praxelis clematidea*)
5	*Thunbergia* spp.	Thunbergia
6	*Miconia calvescens*	Miconia
7	*Annona glabra*	Pond apple
8	*Alternanthera philoxeroides*	Alligator weed
9	*Hymenachne amplexicaulis*	Hymenachne; Ponded pasture grass
10	*Andropogon gayanus*	Gamba grass
11	*Cabomba caroliniana*	Cabomba
12	*Stachtarpheta* spp.	Snakeweed
13	*Harungana madagascariensis*	Harungana
14	*Senna obtusifolia*	Sicklepod
15	*Elephantopus mollis*	Tobacco weed
16	*Cyperus aromaticus*	Navua sedge
17	*Psidium guajava*	Guava
18	*Leucaena leucocephala*	Leucaena
19	*Brachiaria mutica*	Para grass
20	*Spathodea campanulata*	African tulip tree
21	*Hyptis* spp.	Knob weed; Stinking roger; Comb hyptis
22	*Rottboellia cochinchinensis*	Itch grass (Note: considered by most to be native)
23	*Euphorbia heterophylla*	Milk weed
24	*Allamanda cathartica*	Yellow allamanda vine
25	*Turbina corymbosa*	Turbine vine
26	*Sphagneticola trilobata*	Singapore daisy
27	*Tithonia diversifolia*	Thithonia
28	*Sansevieria trifasciata*	Mother-in-laws tongue
29	*Eichhornia crassipes*	Water hyacinth
30	*Pistia stratiotes*	Water lettuce
31	*Salvinia molesta*	Salvinia

Some of the more aggressive species that were deliberately introduced for stock forage (except Hymenachne, Gamba Grass and Leucaena) are missing from this list (Table 7). This is understandable since there has been a certain retiscence within local government PMPs to consider 'useful' (agricultural) plants – especially pasture grasses and legumes - that can also contitute major 'environmental' weeds, either because of policical (constituency) considerations and/or because of their ubiquity. However, consideration of these within any comprehensive RAS is certainly warranted and it is intended to supplement the test sample with examples of these taxa.

5.2.1 Natural groups of naturalised species – based on habit/life forms

The primary division of plants is into aquatic *versus* terrestrial categories. Champion & Clayton (in press) argue for the distinctiveness of aquatic plants and for this primary differentiation. Naturalised exotic aquatics within the region are set out in Table 10. The seven aquatic macrophytes listed comprise three floating, two submerged and two semi-emergent, species. Introduced ponded pasture species are essentially semi-aquatic and will be considered within the larger group of terrestrial species. Emergent semi-aquatic introduced species are also not included.

Table 10: Exotic aquatic macrophytes that have naturalised within the Wet Tropics region.

SPECIES	FAMILY	Common Name	Comments
Alternanthera philoxeroides	AMARANTHACEAE	Alligator weed	semi-emergent
Cabomba caroliniana	CABOMBACEAE	Cambomba	submerged – a WONS
Eichhornia crassipes	PONTEDERIACEAE	Water hyacinth	floating
Elodea canadensis	HYDROCHARITACEAE	Pondweed	submerged
Pistia stratiotes	ARACEAE	Water lettuce	floating
Sagittaria graminea ssp. *platyphylla*	ALISMATACEAE	Arrowhead	semi-emergent
Salvinia molesta	SALVINIACEAE	Salvinia	floating

The larger group of terrestrial plants can be further subdivided into natural groups based on life form or habit. In a major review of tropical woody weeds, Binggeli *et al.* (1998) have classified a provisional list of 235 invasive species into (1) trees > 15m tall, (2) small trees 5-15m, (3) shrubs < 5m, (4) sub-shrubs (some parts somewhat woody), and (5) vines. Non-woody species can be subdivided similarly into meaningful groups such as herbs/forbs, graminoids and ferns.

More or less informal functional groups might be identified for the Wet Tropics in a manner similar to those identified as indicative of different levels of risk and invasiveness in the Galapagos (Tye in press:22-23). These comprise:

(i) herbaceous/shrubby plants that are invading relatively slowly and whose main effect is to dominate/replace the natural shrub/herb layer of more open communities – eg, *Stachytarpheta* spp., *Hyptis* spp.;

(ii) graminoids and herbaceous species that are spreading rapidly or more extensively replacing the herb layer with a monospecific stand and seriously inhibiting or precluding recruitment of tree and shrub layers – eg, Guinea Grass, Gamba Grass, Molasses Grass and other introduced pasture grasses (note also that these promote highly modified fire regimes);

(iii) scramblers and climbers that have spread widely and, to some extent, have become integrated into the natural communities – the foremost of these being *Chromoleana odorata, Mikania micrantha, Turbina corymbosa, Thunbergia* spp., *Sphagneticola trilobata* and *Solanum seaforthianum* that have insidious effects, while others such as exotic *Passiflora* spp., *Mimosa diplotricha, Momordica charantia* and *Allamanda cathartica* exert at least intermittent competition and can form dense mats to adversely affect the growth of a range of native species;

(iv) shrubs and small trees that form dense stands preventing other herbaceous or woody growth – eg, *Leucaena leucocephala, Lantana camara, Miconia calvescens* and *Murraya paniculata* cv *exotica* (in the case of Leucanea and Lantana, invasion can also cause major modifications to the natural fire regime);

(v) trees that are invading slowly and/or more insidiously because they are 'sleepers' in the early stages of invasion or are more cryptic/less conspicous – eg, *Parmentiera aculeata, Mangifera indica, Flacourtia jangomas, Blighia sapida* - that, while most have not yet necessarily caused serious ecological damage, pose major threats by virtue of their size, or in the case of some such as Cucumber Tree, can form dense monospecific stands displacing native species;

(vi) trees which spread rapidly by small wind-borne or animal (particularly bird – see Wilkinson 1999) dispersal and which can form dense stands – eg, Pond Apple, *Spathodea campanulata, Castilla elastica, Pinus caribaea, Psidium guajava* and *Harungana madagascariensis* – that may have already established over wide areas and threaten to displace native communities; and

(vii) a miscellanous group or category that has particularly adverse interactions with native species, as in the case of exotic species of *Aristolochia* that is toxic to native papillionids such as the Ulysses Butterfly, or as for non-native congeners that may be able to hybridise with native species.

Plants can also be grouped into taxonomically related groups that may also have consistent morphological/physiological expression. These groups may also share attributes that confer a measure of invasiveness. Grasses – ie, the family Poaceae – are one such group. During development of the AQIS system, expert comments such as "grasses should not be grouped together as guilty of weediness by association" (Pheloung 1995:16) were contributed. Some criticism of this approach was also apparent during course of the weed risk assessment workshop held in Adelaide during 1999 (see Virtue in press). This was noted but not generally accepted because of the comparative reliability as an indicator of risk given the large proportion of weedy species within this natural group.

It is assumed here that this conclusion will apply to the large number of Wet Tropics plant introductions. For instance, African C4 grasses have been implicated in significant and often debilitating changes to the natural fire regimes of host environments (Baker 1986, Vitousek 1986, Mooney & Drake 1989, Macdonald *et al.* 1989, Smith 1989). Wallmer (1994) has documented the high flammability of Molasses Grass (*Melinus minutiflora*) and, to a slightly lesser extent, Guinea Grass within this region. It is likely that a host of other related exotic grass species will produce similar modifications to natural fire regimes.

Asteraceae is another family that contributes a disproportionate number of weedy taxa, including at least 830 species from 224 genera (Heywood 1989:35). Asteraceous species are advanced from an evolutionary viewpoint and, due to the development of biological features that ensure survival under adverse conditions and a high reproductive rate, combined with complicated and efficient dispersal systems, are often highly invasive. Chemical factors, including anti-herbivore agents and toxins and allelopathic constituents, area also important to this family's competitive success.

Heywood (1989) further specifies that after these two leading plant families in terms of weedy species contributions, Fabaceae (and related legume families Caesalpineaceae and Mimosaceae) comes next, contributiong more than 400 species from over 85 genera). Thereafter, there is a list of 11 families that each contributes over 100 weed species. These are the Euphorbiaceae, Lamiaceae, Brassicaceae, Convolvulaceae, Cyperacaeae, Solanaceae, Apiaceae, Rosaceae, Scrophulariaceae, Polygonaceae and Malvaceae.

In the *Draft Wet Tropics Plan* (WTMA 1995), some "undesirable plants" in the World Heritage Area are specified according to taxonomic association. Examples include "all non-native species from the family Acanthaceae … *Passiflora* spp. (exotics)". This approach was enshrined on Schedule 2 in subordinate legislation 1998-161 of the *Wet Tropics World Heritage Protection and Management Act (1993)* with ratification of the Plan in 1998 (Queensland Government 1998).

An initial classification was performed on the terrestrial species according to their predominant life form (Appendices 2 and 3). The categories comprised trees, shrubs (including scandent shrubs such as *Chromoleana odorata*), vines, herbs (including fleshy herbs such as aroids and gingers), grasses and others (predominantly ferns, fern allies). Although widely planted as ornamentals within the region, only a single exotic palm species is considered to possess weedy tendencies. This is the Queen Palm, *Syagarus romanzoffiana*. It has naturalised about Atherton and is invasive of both rainforests and more open forests about creek lines such as along Priors Creek.

5.2.2 Natural groups of naturalised species – based on origins

It is apparent from quarantine risk surveys (Williams *et al.* in press) that particular locations furnish disproportionate numbers of invasive species. Williams & West (2000:427) note that since the onset of European settlement there has been a gradual shift over time in the countries of origin of most Australian weeds. Initially, European countries were major sources and reflected the cultural biases and the need to be surrounded by 'familiar plants' and animals from the 'mother countries' that was enshrined in institutions such as 'acclimatisation societies'. More recently, weeds of American origin predominate in Queensland and, in Australia as a whole, Africa and the Americas are the source continents of plants naturalised over the past three decades (Williams & West 2000:427).

One of the reasons for undertaking the current exercise is that the Wet Tropics is rather anomalous when compared with the rest of Australia and the RASs developed in other parts of the country are unlikely to be directly applicable here. Correspondingly, the origins of invasive species within this region are also likely to be different when compared to those characterising other parts of Australia - particularly temperate south-east regions. While some species with temperate origins will flourish on the region's cooler Tablelands, and expansive dry country ones along the drier western fringes of the bioregion combined with tropical stock forage grasses and legumes throughout, more exotic ornamental garden escapees are likely to be candidates for environmental weed classification. These can come from a range of different continents that impinge on tropical latitudes, particularly tropical America, Asia and Africa. For example, of the 29 additional plant species known to have naturalised regionally but not recorded on the Herbarium's list (Table 6), 13 (45%) are from tropical (ie, Central and South) America and seven (24%) each from Indo-Malaysia (extending from India to South-East Asia) and tropical Africa. None are from 'traditional' sources such as Europe (including the Mediterranean) and western Asia.

5.2.3 Other groups of naturalised species – based on predisposition to invade systems at risk

Ponded pasture species such as Hymenachne and Pará Grass, along with other extremely aggressive species such as Pond Apple and Leucaena, present particular problems due to their ability to invade wetland (including riparian) systems. These (see Section 2.5 above) are not only especially vulnerable to exotic species invasion but have been disproportionately cleared and/or disrupted regionally and support many of the endangered and 'of concern' REs (see Table 2). Vines are also problematic due to their ability to invade riparian systems and to blanket valuable rainforest remnants.

5.2.4 Groups of naturalised species resulting from application of the RAS to the sample

Weed assessment is regarded by most agencies (eg, Pheloung 1995:1) to require between 1-2 days per individual taxon. Time and resource limitations therefore precluded the assessment of all alien plant species known to have naturalised within the Wet Tropics region (Appendix 2, including additional taxa in Table 8). Since there are only seven aquatic plant species known to have naturalised within the region, all were processed using the proposed system. The results of this are set out in Table 11.

Table 11: Ranking of exotic aquatic macrophytes (excluding ponded pasture species) using the proposed Wet Tropics RAS

SPECIES	Common Name	Weed else-where	Reprod. mode	Nos of reprod organs	Dispers. capacity	Versa-tility	Damage	Score (%)
Alternanthera philoxeroides	Alligator Weed	5	2	3	3	7	8	56
Cabomba caroliniana	Cambomba	5	2	3	6	7	8	62
Eichhornia crassipes	Water Hyacinth	5	4	3	6	9	10	74
Elodea canadensis	Pondweed	5	5	7	4	6	5	64
Pistia stratiotes	Water Lettuce	5	3	3	6	9	8	68
Sagittaria graminea ssp. *platyphylla*	Arrowhead	5	4	3	5	7	8	64
Salvinia molesta	Salvinia	5	2	3	5	9	9	66

For the terrestrial (including semi-aquatic) species, it was proposed initially to rank every tenth taxon (ie, a 10% sample) on the emended list. In consultation with the Senior Principal Scientist of the Wet Tropics Management Authority, a revised approach was determined. It was agreed that a useful sample of taxa to trial a pilot run of the scheme would be those identified by DNR as the 31 taxa (excluding the aquatics) drawn from regional shire-based Pest Management Plans rated as highest priorities for weed research (Table 9). These taxa were supplemented to a maximum of 50 taxa with additional species drawn from the emended list of naturalised aliens to represent other better known species from some apparently underrepresented groups (eg, the single weedy palm tree, fruit plants and other ornamentals). The sample assessed with the proposed Wet Tropics RAS is set out in Table 12.

Table12: Sample of terrestrial species, *sensu lato*, assessed using the RAS specifically developed for the Wet Tropics region.

Species	Family	Common name	Habit[4]	Step 1	Step 2	Step 3	Step 4	5.1	5.2	5.3	Score 5	6.1	6.2	6.3	6.4	6.5	Score 6	Total X 2 (%)
1. *Thunbergia* spp.	Acanthaceae	laurel vines	V	➡	4	5	➡	3	4	1	10	5	3	5	4	2	19	76
2. *Sansevieria trifasciata*	Agavaceae	Mother-in-laws Tongue	H	➡	1	4	➡	4	2	1	5	3	1	3	4	3	14	48
3. *Mangifera indica*	Anacardiaceae	Mango	TT	➡	4	5	➡	2	3	2	5	4	3	3	4	4	18	64
4. *Annona glabra*	Annonaceae	Pond Apple	TT	➡	4	5	➡	5	5	3	15	5	3	5	5	3	21	90
5. *Allamanda cathartica*	Apocynaceae	Yellow Allamanda	V	➡	1	3	➡	4	3	2	5	3	0	2	3	2	10	38
6. *Syngonium podophyllum*	Araceae		V	➡	4	3	➡	5	3	1	10	3	0	2	1	2	8	50
7. *Syagrus romanzoffiana*	Arecaceae	Queen Palm	TT	➡	4	3	➡	2	2	2	5	3	1	2	3	1	10	44
8. *Aristolochia ringens*	Aristolochiaceae	Dutchman's Pipe	V	➡	4	2	special ➡	3	1	2	2	3	3	1	3	1	11	38
9. *Ageratina riparia*	Asteraceae	Mistflower	SS	➡	4	5	➡	4	3	2	10	4	1	4	3	1	13	64
10. *Ageratum conyzoides*	Asteraceae	Bluetop	H	➡	2	2	stop	-	-	-	-	-	-	-	-	-	-	8
11. *Chromolaena odorata*	Asteraceae	Siam Weed	SS	➡	5	5	➡	6	4	3	15	4	3	4	4	1	16	82
12. *Elephantopus mollis*	Asteraceae	Tobacco Weed	H	➡	5	3	➡	4	2	2	5	2	0	2	1	1	6	38
13. *Eupatorium catarium*	Asteraceae	Praxelis	Ss	➡	3	3	➡	4	2	3	10	3	0	2	4	4	13	58
14. *Mikania micrantha*	Asteraceae	Mile-a-minute	V	➡	5	3	➡	7	2	3	15	4	1	4	4	1	14	74
15. *Tithonia diversifolia*	Asteraceae	Japanese Sunflower	SS	➡	3	3	➡	4	3	2	10	2	3	3	3	4	15	62
16. *Sphagneticola trilobata*	Asteraceae	Singapore Daisy	H	➡	5	4	➡	6	4	2	15	4	3	4	4	4	17	82
17. *Parmentiera aculeata*	Bignoniaceae	Cucumber Tree	TT	➡	3	4	➡	5	3	2	10	4	3	5	4	2	18	70
18. *Spathodea campanulata*	Bignoniaceae	African Tulip	TT	➡	5	4	➡	5	3	2	10	3	1	2	3	3	12	62
19. *Bauhinia monandra*	Caesalpiniaceae	ButterflyTree	Tt	➡	4	3	➡	3	2	1	5	3	1	2	3	2	11	46
20. *Senna obtusifolia*	Caesalpiniaceae	Sicklepod	Ss	➡	3	3	➡	4	3	1	5	2	3	3	3	3	14	50
21. *Cleome aculeata*	Capparaceae	Spiderweed	Ss	➡	1	2	stop	-	-	-	-	-	-	-	-	-	-	6
22. *Turbina corymbosa*	Convolvulaceae	Turbine Vine	V	➡	1	5	➡	4	3	2	10	5	3	4	3	3	18	68
23. *Momordica charantia*	Cucurbitaceae	Balsam Pear	V	➡	1	3	➡	2	2	1	5	3	0	3	3	3	12	42
24. *Cyperus aromaticus*	Cyperaceae	Navua Sedge	H	➡	4	4	➡	4	2	2	5	2	0	1	1	3	7	40

[4] Codes used to specify life-forms/habits are as follows: TT = large tree; Tt = small tree/tall shrub; SS = often tall woody shrub; Ss = subshrub and/or non-woody shrub; H = herb (including fleshy herbs and graminoids); and, V = vine (including some very scandent shrubs).

Species	Family	Common name	Habit[4]	Step 1	Step 2	Step 3	Step 4	5.1	5.2	5.3	Score 5	6.1	6.2	6.3	6.4	6.5	Score 6	Total X 2 (%)
25. *Euphorbia heterophylla*	Euphorbiaceae	Milkweed	Ss	➡	2	2	stop	-	-	-	-	-	-	-	-	-	-	8
26. *Clitoria ternatea*	Fabaceae	Butterfly Pea	V	➡	2	2	stop	-	-	-	-	-	-	-	-	-	-	8
27. *Macroptilium atropurpureum*	Fabaceae	Siratro	V	➡	4	3	➡	3	2	1	2 stop	-	-	-	-	-	-	18
28. *Harungana madagascariensis*	Clusiaceae	Harungana	TT	➡	1	5	➡	5	4	1	10	4	0	3	3	2	12	56
29. *Hyptis* spp.	Lamiaceae	knob weeds	Ss	➡	4	3	➡	3	2	1	5	2	0	3	3	3	11	46
30. *Salvia coccinea*	Lamiaceae	Red Salvia	H	➡	2	3	➡	1	1	0	1 stop	-	-	-	-	-	-	12
31. *Persea americana*	Lauraceae	Avocado	TT	➡	4	3	➡	1	1	1	1 stop	-	-	-	-	-	-	16
32. *Miconia calvescens*	Melastomataceae	Miconia	Tt	➡	5	5	➡	4	4	1	15	4	1	5	4	1	15	80
33. *Azadirachta indica*	Meliaceae	Neem Tree	Tt	➡	5	3	➡	4	2	2	10	2	3	2	3	1	11	58
34. *Leucaena leucocephala*	Mimosaceae	Leucaena	Tt	➡	5	4	➡	6	3	2	15	4	3	5	4	4	20	88
35. *Mimosa diplotricha*	Mimosaceae	Giant Sensitive Plant	Ss	➡	3	3	➡	3	3	1	5	2	0	3	3	3	11	44
36. *Eugenia uniflora*	Myrtaceae	Brazil Cherry	SS	➡	2	3	➡	3	2	1	5	3	0	2	1	1	7	34
37. *Psidium guajava*	Myrtaceae	Guava	Tt	➡	5	4	➡	4	3	1	10	4	5	3	4	4	20	78
38. *Passiflora foetida*	Passifloraceae	Stinking Passionfruit	V	➡	3	3	➡	2	1	2	5	2	0	2	1	4	9	40
39. *Andropogon gayanus*	Poaceae	Gamba Grass	H	➡	5	4	➡	4	1	1	5	3	5	4	4	2	18	64
40. *Brachiaria mutica*	Poaceae	Pará Grass	H	➡	3	3	➡	6	3	2	10	3	5	4	4	5	21	74
41. *Hymenachne amplexicaulis*	Poaceae	Hymenachne	H	➡	5	3	➡	6	3	2	10	5	5	4	5	3	22	80
42. *Panicum maximum*	Poaceae	Guinea Grass	H	➡	3	3	➡	4	2	2	10	3	5	3	4	5	20	72
43. *Rottboellia cochinchinensis*	Poaceae	Itch Grass	H	stop	-	-	-	-	-	-	-	-	-	-	-	-	-	0
44. *Murraya paniculata cv exotica*	Rutaceae	Mock Orange	SS	➡	1	3	➡	3	2	1	5	3	0	3	3	2	11	40
45. *Cardiospermum halicacabum*	Sapindaceae	Balloon Vine	V	➡	5	3	➡	1	1	1	2 stop	-	-	-	-	-	-	20
46. *Selaginella vogelii*	Selaginellaceae	Peacock “Fern”	H	➡	2	2	stop	-	-	-	-	-	-	-	-	-	-	8
47. *Solanum seaforthianum*	Solanaceae	Brazilian Nightshade	V	➡	3	4	➡	3	2	2	10	5	0	2	3	3	13	60
48. *Mutingia calabura*	Tiliaceae	Tree Strawberry	Tt	➡	4	3	➡	2	1	2	5	3	0	1	3	1	8	40
49. *Duranta erecta*	Verbenceae	Golden Dewdrops	SS	➡	1	3	➡	3	1	2	10	3	0	2	3	2	10	48
50. *Stachytarpheta* spp.	Verbenaceae	snakeweeds	Ss	➡	3	4	➡	3	2	1	5	2	3	3	3	4	15	54

5.3 Consideration of Aquatic Weeds

It was decided at the outset to consider aquatic plants separately from the terrestrial species utilising a different RAS. All seven exotic aquatic macrophytes known to have naturalised within the Wet Tropics region are weeds elsewhere and therefore receive the maximum score for this criterion of the RAS. Each differs slightly in relation to other criteria and although the range of resulting scores (56-74 - Table 11) is not nearly as large as for the terrestrial (including some wetland) species, there is some indication that Water Hyacinth poses the greatest risk followed by the other two floating aquatics, Water Lettuce and Salvinia. The submerged species rank intermediately with the semi-emergent Alligator Weed ranking lowest. It is notable, however, that all scores exceed 50 which is, in the case of the terrestrial species, a high score indicative of significant environmental risk. Regionally, however, this risk posed may not be as serious when compared with that in other regions owing to the reliable Wet Season flood flows that normally flush the stream systems of the floating aquatics and scour the semi-emergent and submerged ones.

5.4 Consideration of the Worst Terrestrial Weeds

Those 11 species from the sample with the highest scores (ie, _ 70) from an environmental weed viewpoint, are those posing the greatest risks to natural systems of the Wet Tropics Bioregion. These are, in decreasing order of assessed risk, Pond Apple, Leucaena, Siam Weed, Singapore Daisy, Miconia, Hymenachne, Guava, *Thunbergia* spp., Mikania, Pará Grass, Guinea Grass and Cucumber Tree. The top risk cohort includes two weeds that have been rated as 'of national significance' (Section 5.5 below). All have exhibited extremely aggressive weedy tendencies elsewhere and/or are currently extremely aggressive weeds of the region, and, in the case of Hymenachne, Pará Grass and Guinea Grass, are very aggressive and greatly impair ecosystem function. Arguably, these are clearly 'transformer species' (*sensu* Richardson *et al.* 2000:102) – ie, invasive species that can change the character, condition, form or nature of a natural ecosystem over a substantial area.

Several of these are also included a list of the world's 100 worst alien invaders (Fondation d'Entreprise Total 2000) that includes 32 terrestrial plant species[5]. These are Siam Weed (ranked 23rd), Leucaena (ranked 45th), Miconia (ranked 52nd), Mikania (ranked 54th) and Singapore Daisy (which ranked 100th). Moreover, two of these species were included on a highest-priority quarantine risk target list compiled by AQIS (Waterhouse & Mitchell 1998) either prior to their entry to Australia as in the case of Mikania, or because of the serious risk of reintroduction of Siam Weed. In the latter case, its relatively restricted infestations were targetted by an eradication program and, assuming the possibility of eradication, 'quarantine weed status' was required to ensure vigilence against its re-entry (Waterhouse pers. comm.).

The prevalence of purposefully introduced stock fodder species in the highest scoring risk cohort is alarming, particularly in view of the continued promotion of Leucana by primary industry support agencies and the continued cultivation and distribution of seeds of Pará Grass and Guinea Grass within the region. Prior to its elevation to WONS status in 2000, Hymenachne was also promoted for use as a ponded pasture species and was cultivated for distribution of its seeds.

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5 The list of the world's 100 worst invasive species comprises 32 land plants, 4 aquatic plants, 8 species of micororganism (eg, banana buncy top virus), 26 invertebrate species, 8 fishes, 3 amphibians, 2 reptiles, 3 bird species and 14 mammals (Fondation d'Entreprise Total 2000).

Those species that ranked with scores between 60-69 comprise *Turbina corymbosa, Parmentiera aculeata, Mangifera indica, Ageratina riparia, Andropogon gayanus, Tithonia diversifolia, Spathodea campanulata* and *Solanum seaforthianum*. Some have demonstrated aggressive invasive properties elsewhere (eg, Mango, Gamba Grass and African Tulip – Noble 1989, Binggeli *et al.*2000), all but Cucumber Tree, and to a lesser extent, Turbine Vine, are relatively widespread, and all have demonstrated a high measure of invasiveness in relatively intact forest systems of the region. The use of fruit from Cucumber Tree and Mango, as well as the widespread dispersal of at least the latter by cassowaries (*Casuarius casuarius johnsonii*), fruit-bats (*Pteropus* spp.) and Feral Pigs (*Sus scrofa*), accounts for its very extensive distribution within moderately intact forests of the region. Ecologically, this constitutes factor reinforcement that often sees mutually advantageous interaction of alien species – in this case, a plant and animal (Vitousek 1986:172). The ornamental African Tulip and Brazilian Nightshade also possess well-developed long distance dispersal capabilities (wind and bird dispersed seeds respectively) and are already greatly invasive of intact native communities.

Taxa that ranked in the next score cohort (ie, 50-59) include *Eupatorium catarium, Azadirachta indica, Harungana madagascariensis, Stachytarpheta* spp.*, Syngonium podophyllum* and *Senna obtusifolia*. This group corresponds to either widespread invasive species of disturbed forest (as in the case of Praxelis, Snakeweed and Sicklepod) or to invasive species occurring over a moderately limited area (eg, Mistflower, Neem Tree, Harungana, *S. podophyllum*). Since Groves (1999:635) argues that "sleeper weeds fall somewhere between those recent incursions with a high invasive potential known from their behaviour in other regions and the species that have already become weeds of national significance", it is likely that these, and some others in the previous group (ie, scores 60-69), are such.

Those species scoring between 40-49 include *Sansevieria trifasciata, Duranta erecta, Bauhinia monandra, Hyptis* spp.*, Syagrus romanzoffiana, Mimosa diplotricha, Momordica charantia, Cyperus aromaticus, Passiflora foetida, Murraya paniculata* cv *exotica* and *Mutingia calabura.* Several of these species exhibit invasiveness in comparatively limited areas within the region and may be considered 'sleeper weeds'; while others (eg, the sedge, *Hyptis* spp., *M. diplotricha*, Balsam Pear[6] and the passionfruit) occur over more extensive areas where it is likely that disturbance has enhanced their proliferation advantaging their invasive potential. It is considered that below the score of 50 obtained by screening taxa using the newly devised RAS, the environmental risk appears to be less serious and/or less pervasive.

A small group of four species fell in the range of scores just below 40 to 34 whereupon there was a significant natural gap in the ranked distribution. These comprise *Allamanda cathartica, Aristolochia ringens, Elephantopis mollis* and *Eugenia uniflora*. This is a diverse group comprising two ornamentals (Allamanda and Dutchman's Pipe), a predominantly agricultural weed (*E. mollis*) and the bird-dispersed fruiting shrub, Brazil Cherry that is known to be naturalising at various locations (eg, Werren 1998). These, and many others awaiting assessment, may warrant consideration as 'sleeper' weeds (see 5.6 below).

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6 It is important to note that Balsam Pear (*Momordica charantia*) is the favoured host of the Melon-fly (*Batroceras cucurbitae*) that is a quarantine pest occasionally incurring in islands of the Torres Strait (Waterhouse pers. comm.). Should this insect reach the Wet Tropics, infestations of Balsam Pear would almost certainly facilitate its invasion and greatly reduce the likelihood of success of any eradication program such as that which was successfully mounted against its congener the Papaya Fruit-fly (*B. papayae*) within the region. This observation may confer more importance on the control of this exotic plant regionally.

Those lowest ranked species (with scores ≤ 20) are, with the exception of the Avocado (*Persea americana*), essentially exotic ruderals, annual garden escapees or weeds of disturbed places (eg, *Cleome aculeata, Macroptilium atropurpureum*). The native *Rottboellia cochinchinensis*, that is almost exclusively an agricultural weed of canefields, scored zero. The risk of any of these becoming major environmental weeds appears to be inconsequential. Conspicuous infestations may constitute aesthetic problems and inhibit the presentation of World Heritage values but are assessed as little more than that.

5.5 Assessment Results and 'Weeds of National Significance'(WONS)

Nine species accorded 'Weeds of National Significance' (WONS) status have naturalised with the Wet Tropics Bioregion. These are *Acacia nilotica, Alternanthera philoxeroides, Annona glabra Cabomba caroliniana, Cryptostegia grandiflora, Hymenachne amplexicaulis, Lantana camara, Parthenium hysterophorus* and *Salvinia molesta* (Williams & West 2000:430). Those five representatives in the sample of the nine weeds present in the region so classified scored highly due to their inherently invasive traits and, secondarily, their extent of infestations. Those scored in the trial run were *A. glabra* (90 – the highest scoring of the 50 terrestrial species rated), *H. amplexicaulis* (80), and the three aquatic species - *Salvinia molesta* (66), *Cabomba caroliniana* (62) and *Alternanthera philoxeroides* (56). Reasons for the low scores for the aquatics were set out in Section 5.2.4 above). Four WONS species (ie, *Acacia nilotica, C. grandiflora, L. camara* and *P. hysterophorus*) were not included in the trial sample. It is therefore argued that the trail of the proposed Wet Tropics RAS has produced plausible results with respect to the WONS component of the species trial.

5.6 Consideration of 'Sleeper Weeds'

Maillez & Lopez-Garcia (2000:12-13) note that there is clearly a lag time between introduction and commencement of invasion and that "a minor weed today may become a major one" in the future. The term 'sleeper weeds' is defined as "those invasive plants that have naturalised in a region but not yet increased their population size exponentially" (Groves 1999:632). These are species which, while currently not considered problematic, may be in the early phases of an explosive invasion. Groves (1999:632) considers that these 'sleepers' comprise a numerically large subset of the invasive biota of Australia and deserve "enhanced attention from research scientists and resource agencies". Rozefelds & MacKenzie (1999:581), in their review of the history of weed invasion of Tasmania, conclude by stating "the seed for the next wave of weed invasions … has, unfortunately, already been sown" and that most of the previously considered 'adventives', 'sparingly established species' or species with 'status uncertain' (ie, comparable to 'doubtfully naturalised' category currently used by the Queensland Herbarium) will eventually become established as weeds.

Given their current status, many sleeper weeds are not readily identifiable within the list of >500 naturalised exotics in the region without further scrutiny. These, if not identified as major problems elsewhere, may be detected by careful evaluation of their intrinsic biological traits, including their environmental versatility and by seeking a match between native and host environments.

Of those species screened, several appear to conform to the definition of 'sleepers'. These comprise *Syagrus romanzoffiana*, *Bauhinia monandra, Eugenia uniflora, Murraya paniculata* cv *exotica, Muntingia calabura* and *Duranta erecta*. Most have not yet become widespread problems, although several are considered problems at particular localities, but since all but one have fleshy fruits that are bird-dispersed, they are are likely to become so in the not too distant future.

It was previously noted that *Allamanda cathartica, Aristolochia ringens,* and *Elephantopis mollis* may also belong to such a category. It is significant that Elephant Weed and Yellow Allamanda are, along with Golden Dewdrops and Brazil Cherry, already regarded as invasive in Micronesia (Space 2001).

While it is appropriate to await formal assessment, other species not assessed may be considered to belong to such a category. These include the introduced South American tree, *Schinus terebinthifolia*. This species exhibited a considerable lag time before an explosive invasion of South Florida (Ewel 1986:220). It is also ranked 84th in the list of the world's 100 worst invasive species (Fondation d'Entreprise Total 2000:6). Already causing concern in and about Herberton, this bird-dispersed plant may constitute a 'sleeper' at least in parts of the Wet Tropics region.

Another regionally naturalised alien plant species are noted to be amongst the world's most serious invasive species (Fondation d'Entreprise Total 2000). This is *Hiptage benghalensis*. It is also listed by Space (2001) as invasive in Pacific Island ecosystems. A watching brief is required to ensure that this species does not become a major problem here.

Similarly, 326 species, some of which are native Wet Tropics plants, are listed (Space 2001) as invasive in ecosystems of the Pacific Islands (ie, Micronesia, American Samoa or Niue). Inspection of this list reveals species that are in the process of naturalising within the Wet Tropics that may also constitute 'sleeper' weeds. These include those previously noted, along with *Andropogon gayanus, Anredera cordifolia, Argyreia nervosa, Azadirachta indica, Bauhinia monandra, Bidens pilosa, Brillantasia lamium, Buddleja madagascariensis, Caesalpinia decapetala, Canna indica, Cardiospermum halicacabum, Cascabella thevetia, Castilla elastica, Cenchrus ciliaris, C. echinatus, Centrosema pubescens, Cinnamomum camphora, Clitoria terneata, Coccinia grandis, Coffea arabica, Cyperus rotundus, Digitaria ciliaris, Echinochloa polystachya, Epipremnum aureum, Hedychium coronarium, Hyparrhenia rufa, Hypochaeris radicata, Hyptis capitata, H. pectinata, H. suaveolens, Jatropha gossypifolia, Macroptilium atropurpureum, Melinus repens, Mimosa diplotricha, M. pudica, Momordica charantia, Montanoa hibiscifolia, Muntingia calabura, Neonotonia wightii, Odontonema tubaeforme, Paspalum conjugatum, P. dilitatum, P. paniculatum, P. urvillei, Passiflora edulis, P. foetida, P. laurifolia, P. quadrangularis, P. suberosa, Pennisetum purpureum, Pinus caribaea, Psidium cattleianum, Rubus alceifolius, Samanea saman, Sanchezia parvibrachteata, Sanseviera trifasciata, Senna alata, Senna obtusifolia, Solanum mauritianum, S. seaforthianum, S. torvum, Sorghum halapense, Stylosanthes guianensis, Syngonium podophyllum, Thunbergia alata* (together with other known invasives belonging to this genus), *Tradescantia spathacea, Triumphetta rhomboidea* and *Urena lobata*. This list also includes references to a host of known weeds in the Wet Tropics and also to species such as *Rhodomyrtus tomentosa* and to others (eg, *Piper auritum*) that are known to occur within the region (Waterhouse pers. comm.) but which have not yet naturalised.

While the extent to which the plant has naturalised is limited and essentially confined to highly disturbed situations, the extensive ornamental plantings of *Bixa orellana* may, in time, prove problematic. This is so because the species is included by Binggeli *et al.* (1998:29) on a provisional list of small (5-15m) invasive tropical trees.

6.0 Consideration of Implications for Weed Management

While factors explicit to management priority ranking (such as feasibility and cost of control) were not incorporated into the proposed Wet Tropics RAS, it was important to consider the implications of the putative priorities derived from a review of weeds present and a preliminary assessment of a 10%+ sample of those. Resources allocated to the project did not permit the time-consuming assessment of all 504 naturalised exotic species with a 'routine assessment' estimated at 1-2 days per species (Pheloung in press:119). Remaining taxa need to be ranked employing the RAS for a comprehensive regional environmental weed risk assessment. It is only then that management priorities can be effectively and comprehensively considered. In the interim, there are some implications for management that do emerge. These are discussed briefly below.

6.1 Prevention of Weed Entry

The foremost of these implications for management is the importance of ensuring that potentially invasive plants are not imported for agricultural (particularly pastoral) and ornamental purposes. Randall (pers. comm.) notes that "the numbers of intentionally introduced plants well outnumber any unintentional introductions", and that more than 67% of all plant species that have naturalised in Australia over the last 25 or so years were intentionally introduced for horticultural reasons. This commends as a highest priority action for any country to "put in place a basic system to control deliberate species importations" (Warren pers. comm.), "and to strongly urge people to include screening all new introductions for invasive potential" (Randall pers. comm.).

Despite advances in quarantine screening protocols, very aggressive weeds such as Leucaena is, and, prior to its elevation to the list of WONS, Hymenachne was, being actively promoted for pastoral use. Thus, government land management agencies have provided conflicting advice regarding such plants – on the one hand promoting weed spread and on the other, advising the exclusion of such plants from permitted import lists, and subsequently for containment and control of these pest species. Devices such as Memoranda of Understanding (MOUs) and properly constituted quarantine exclusion systems are required to overcome the cost of control and myopia (*sensu* Mooney & Drake 1989:504) practised to date facilitating such importations.

Considerable problems are also posed by the introduction of attractive ornamentals such as Miconia. The Cairns City Council Pest Management Working Group is currently aware of a range of other potentially problematic species introductions that are undertaken for ornamental amenity reasons. These include *Triplaris ?surinamensis*, the eradication of which is accorded priority in the City's PMP. Other ornamentals such as *Clerodendrum quadriloculare* that are weedy in Micronesia (Waterhouse pers. comm.) are currently cultivated in the Cairns area and may present problems if they are permitted to escape.

To a lesser extent some potentially invasive alien species are cultivated and distributed for food or medicinal properties. Apparently, the proliferation of Mikania about the Bingil Bay area, and Sweet Prayer Plant (*Thaumatococcus daniellii*) are cases in point (Luxton pers. comm.). Waterhouse (pers. comm.) has also noted the availability of food plants such as Downy Rose Myrtle/Ceylon Hill Cherry (*Rhodomyrtus tomentosa*) in nurseries from Rockhampton to Cairns. This plant is highly problematic in Hawaii and Tahiti and may be another 'sleeper' in this region.

Other species that have proved to be invasive within the region such as *Allamanda cathartica, Duranta erecta* and *Sanchezia parvibracteata* continue to be cultivated and sold by nurseries. In order to combat such problems, a combination of consultation with the nursery industry (and encouragement of self-regulation) and sound contributions to wider public wider public awareness campaigns is required.

6.2 The Importance of Early Intervention

Of almost equal importance is instigating control programs where a weed is new, not widespread and control is feasible (Carter 2000:92). It is vital, therefore, to identify and control 'nascent foci' (Goodland *et al.* 1998:12) or incipient invasions of 'sleeper weeds'– ie, plants in initial stages of invasion before their rate of spread is exponential (Groves 1999) (see Section 5.6).

A number of authors argue strongly for early intervention when incursions are limited. Braithwaite & Timmins (1999) commend weed surveillance and early detection to confine weed control to the least cost and that will involve minimal impact on conservation values. Carter (1999:92) takes a diagrammatic approach to demonstrate that control is feasible generally only in the early stages of invasion. Groves (1999:634) demonstrates the cost efficiencies of eradicating new incursions. Similarly, Panetta (1999:144) argues that, to be effective, weed control actions must be triggered at low environmental weed densities. Loope (2000:61), in reviewing a European book on plant invasions, is critical of the authors' lack of appreciation of the importance of "rapid response to incipient invasions". The references to 'weed-led' control programs of Williams & White (2000:436) further confirm the value of treatment in early phases of infestation. Earlier, MacDonald *et al.* (1989:243) warned that successful control of weeds in nature reserves is uncommon unless control action is instigated in the earliest phases of the invasion process.

It is instructive to consider management action directed towards species naturalising in the region considered by Csurhes & Edwards (1998) to be 'potential' (if not actual) environmental weeds. Six taxa have been identified that are in the initial phase of invasion and are considered, at this stage, to be amenable to eradication (Table 13).

Table 13: Taxa naturalised in the wet tropics, known to be major weeds elsewhere and considered susceptible to eradication as they are in the initial phases of establishment (Groves 1999:635; species and assessment of probability of eradication extracted from Csurhes & Edwards 1998:20-21)

SPECIES	FAMILY	Probability of eradication	CURRENT REGIONAL DISTRIBUTION
Ardisia humilis (note: species in region may be *A. solanacea* – pending taxonomic clarification)	Myrsinaceae	medium	invading from Cairns City residential areas – note that its congener *A. elliptica* is considered to be one of the world's worst alien invasives ranking 9/100 (Fondation d'Entreprise Total 2000:2)
Brillantasia lamium	Acanthaceae	low	infestations localised in Douglas Shire
Chromolaena odorata	Asteraceae	low	infestations treated in Bingil Bay & Tully-Murray districts
Miconia calvescens	Melastomataceae	high	scattered individuals about Kuranda, Babinda, Bramston Beach, Miriwinni
Mikania spp.	Asteraceae	high	treated in Innisfail, Bramston Beach areas
Thunbergia grandiflora	Acanthaceae	low	long established infestations about Mossman, Northern Beaches, Freshwater Creek, Little Mulgrave, Babinda & along many creeks south of the Mulgrave River

The effective control of Panama Rubber (*Castilla elastica*) by the Cairns City Council's Pest Management Unit and the Wet Tropics Tree Planting Scheme team is a case in point. In 1998, incipient infestations of this tree that was originally imported and maintained at the former Tropical Horticultural Collection of DPI at Kamerunga, as a producer of a rubber substitute, were noted establishing under the closed canopies of nearby riparian and adjacent rainforest. Although mainly confined to Kamerunga Environment Park, the management of which is a joint Cairns City Council and QPWS responsibility, and on private freehold land, some infestations were also flourishing in the Barron Gorge National Park section of the World Heritage Area. This species was afforded highest priority in the Council's Pest Management Plan and infestations, including 25m tall mature trees, were treated. Currently, follow-up control is being undertaken by the Pest Management Unit, including searches for additional seedlings and ongoing monitoring of treated sites, to ensure no resurgence.

The prospects of eradicating this highly invasive alien species from the region are now very good. This is due to the foresight of the Pest Management Working Group and the diligence of the Pest Management Unit, the personnel of which understand that weeds do not respect property lines and do not remain confined awaiting cumbersome bureaucratic determinations, including resource allocations. They also recognise that weed control must be timely, transcend tenure boundaries and that effort will be wasted entirely if there is no follow-up activity.

Particular mention is warranted of the importance (and cost-effectiveness) of strategic control of incipient infestations of serious weeds such as *Miconia calvescens* and *Mikania* spp., especially in light of the treatment of incursions of Siam Weed, in the Wet Tropics. This might be extended to several other species. Given its high-risk rating, the current, relatively restricted distribution of Cucumber Tree suggests that it is a species that should be targeted for priority control.

6.3 The Importance of Ecologically Integrated Weed Management

Control strategies also need to be "ecologically integrated" (Williams & West 2000:436) as well as coordinated amongst the various agencies. Those species that are implicated in gross disturbance of ecosystem processes or those that are displacing threatened communities and/or species must be targeted for priority control.

An understanding of landscape ecology also points to the fact that eradication and/or containment control of a water-dispersed invader of riparian systems, must proceed downstream from upstream sources to avoid reinvasion. There is also the recognition that invasion/reinvasion proceeds rapidly on disturbed and/or unoccupied sites. Therefore, it is likely that removal of exotic species infestations must be followed by efforts to revegetate these sites using native species that are normally found growing locally on such sites.

An ecological understanding of the resilience of invasive alien species, some of which can reinvade from a persistent soil seed bank or from subterranean tubers and/or root suckers, or simply from individuals that escaped initial treatment, as in the case of *Thunbergia grandiflora* in Mulgrave River National Park and Harungana infestations over a wider area, is vital. This requires that there is a commitment to judicious monitoring, or surveillance, particularly of disturbed areas and along roads, other utility corridors and streams that are avenues for weed invasion, and follow-up treatment within a control program to optimise chances of success.

Weed control frequently involves removal of target species together with site disturbance. It has been demonstrated (see Section 2.1) that disturbance facilitates further alien invasion. It is an ecological reality that reinvasion is more likely to occur when sites are not occupied. Therefore, weed resurgence is less likely to occur where sites have been replanted with native species and weed control may need to be accompanied by revegetation efforts to ensure best results. In the Wet Tropics region, this is likely to require inter-agency cooperation, for example, between DNR or Council Pest Management Units and environmental repair teams such as those operating within the Wet Tropics Tree Planting Scheme.

6.4 The Importance of Control or Containment of Existing Weed Problems

Recognition of the serious risks posed by invasive alien species that have established widespread populations within the area such that eradication is simply not feasible requires that these be strategically controlled or contained. Control/containment is primarily required at logistically critical locations in areas that have high conservation value and/or that contain endandered REs or species. Control may involve local (as against regional) eradication efforts or judicious containment of, for instance, Pará Grass or Pond Apple infestations adjacent to important wetland reserves.

It is argued that target species for highest priority control should be those rated using the RAS with scores ≥50. Some 25 terrestrial taxa (or 30+ species) pose the most serious environmental risk. These are set out in Table 14.

Table 14: Alien plant taxa adjudged to pose serious environmental risk in the Wet Tropics region ranked according to risk score ('habit' codes as in Table 12)

Species	Family	Common name	Habit	Score (%)
Annona glabra	Annonaceae	Pond Apple	TT	90
Leucaena leucocephala	Mimosaceae	Leucaena	Tt	88
Chromolaena odorata	Asteraceae	Siam Weed	SS	82
Sphagneticola trilobata	Asteraceae	Singapore Daisy	H	82
Hymenachne amplexicaulis	Poaceae	Hymenachne	H	80
Miconia calvescens	Melastomataceae	Miconia	Tt	80
Psidium guajava	Myrtaceae	Guava	Tt	78
Thunbergia spp.	Acanthaceae	laurel vines	V	76
Mikania micrantha	Asteraceae	Mile-a-minute	V	74
Brachiaria mutica	Poaceae	Pará Grass	H	74
Panicum maximum	Poaceae	Guinea Grass	H	72
Parmentiera aculeata	Bignoniaceae	Cucumber Tree	TT	70
Turbina corymbosa	Convolvulaceae	Turbine Vine	V	68
Ageratina riparia	Asteraceae	Mistflower	SS	64
Mangifera indica	Anacardiaceae	Mango	TT	64
Eupatorium catarium	Asteraceae	Praxelis	Ss	58
Andropogon gayanus	Poaceae	Gamba Grass	H	64
Spathodea campanulata	Bignoniaceae	African Tulip	TT	62
Tithonia diversifolia	Asteraceae	Japanese Sunflower	SS	62
Solanum seaforthianum	Solanaceae	Brazilian Nightshade	V	60
Azadirachta indica	Meliaceae	Neem Tree	Tt	58
Harungana madagascariensis	Clusiaceae	Harungana	TT	56
Stachytarpheta spp.	Verbenaceae	Snakeweeds	Ss	54
Senna obtusifolia	Caesalpiniaceae	Sicklepod	Ss	50
Syngonium podophyllum	Araceae		V	50

6.5 Research Requirements

It is evident also that any effective weed management system must be founded on a reliable information base. The necessary information is not always in existence, particularly regarding weed species autecology and even the status of current distributions of major weed species. To remedy this deficiency research is required in particular areas. These include:

(i) assessment of the potential environmental weed risk of those remaining exotic naturalised plant species not already screened (448 species) employing the newly devised Wet Tropics RAS;

(ii) sensitivity testing of the relative risk ranking obtained using the RAS with the view to its further refinement;

(iii) identification of the determinants of and investigation of the autecology of likely 'sleeper weeds';

(iv) mapping of the distribution of infestations of major weed species with the view to instigating strategic control actions;

(v) development of best practice, integrated and coordinated weed control that takes regard of risks to significant native communities and species; and

(vi) investigation of biological control prospects to deal with the highest priority environmental weeds currently and for other invasive species that have no or few closely related native species.

7.0 Conclusions and Recommendations

Loope (2000:61) reiterates the frequent warning that "given time and resistance to management, invasive plants will undoubtedly contribute to the biological impoverishment of continents, especially in the areas of significant local endemism", as is the case in the case of the Wet Tropics Bioregion of north-eastern Queensland. Therefore, this is not only a serious threat, but also one that cannot be ignored by authorities, as it will lead to the breaching of Australia's international obligations as a signatory nation to the *World Heritage Convention*.

The problem of alien invasive species within the context of the Wet Tropics Bioregion (in particular, management of the World Heritage Area) was considered. This drew upon an understanding that alien species invasions – especially of environmental weeds - constitute perhaps the second most serious threat to the survival and integrity of natural systems worldwide. Central also to considerations was the high conservation significance ascribed to much of the area's vegetation, flora and fauna and a particular susceptibility of tropical systems and to communities, that by virtue of their inherent nature, or due to disruption and forest fragmentation, had become 'quasi-insular' (MacDonald *et al.*1989:246) in character, rendering them even more invasion-prone.

An official list of regionally naturalised species obtained from the Queensland Herbarium was refined to aggregate infraspecific taxa (ie, subspecies/varieties) into a single taxon, accommodate taxonomic nomenclatural changes and to incorporate at least 29 species not recorded as naturalised in the collection. These included some of the region's actually or potentially problematic environmental weeds such as *Mikania micrantha, Schinus terebinthifolia, Hymenachne amplexicaulis, Azadirachta indica* and *Pinus caribaea*. It is estimated that over 500 exotic species including several interspecific hybrids have become naturalised in the Wet Tropics Bioregion.

Existing RASs, including some currently being developed, were reviewed and the most appropriate properties incorporated into a RAS designed explicitly to consider alien environmental weed risks to the Wet Tropics Bioregion. The RAS specifically designed to take into account weeds documented for tropical areas, inherent invasiveness and significance of systems at risk, was proposed and the rationale underpinning its formulation clarified. Components assessed include 'gross invasiveness' (ecesis/establishment in native vegetation, to what extent a species is advantaged by disturbance), a range of intrinsic (biological) attributes predisposing species to invasiveness (ie, reproductive capacity/mode; dispersal capacity; competitive ability and ecesis needs) and extrinsic (host environment) factors (important in the context of World Heritage Area management and regional ecosystems/species at risk). The latter constitutes the basis for 'asset-based' management systems that are employed in other states such as Tasmania (Hall 1999) and South Australia (Virtue 2000) and elsewhere (eg, Hiebert & Stubbendieck 1993). Incidentally, the Tasmanian system is based on the 'Exotic Plant Ranking System' of Hiebert & Stubbendieck (1993). Control feasibility, that is frequently incorporated as a basic element of weed risk assessment systems, was considered secondary from risk assessment *per se*. Accordingly, it was treated separately in subsequent management considerations.

This RAS was tested on all seven exotic aquatic species naturalised within the bioregion and 50 species of terrestrial weeds drawn from a list of 25 derived from local government Pest Management Plans by DNR (Bebawi, pers. comm.) and supplemented by 25 other species representative of a range of different weed groups. Screening of this sample using the new RAS provided plausible results. Notably, the known worst weeds (eg, Pond Apple and Hymenachne - both WONS – together with Siam Weed, Miconia, Singapore Daisy, Guava, Thunbergia vines and Mikania, that are known as particularly invasive in other tropical settings) ranked very highly.

Leucaena also ranked the second highest environmental weed risk regionally. It, along with other deliberately introduced stock forage species such as Pará Grass, Guinea Grass and Gamba Grass, together with pasture legumes, present serious environmental problems for natural area management. It is argued that urgent provisions should be made by government and associated pastoral support agencies to preclude further releases of potentially serious weeds by ensuring observance of the precautionary principle (see Rozefelds & Mackenzie 1999:583). Therefore, action to prevent further and continued introduction of highly invasive but considered 'useful' plants to the region is sorely needed.

Other pertinent management issues are also addressed. These include the urgent need for a rapid control response to incipient environmental weed incursions, identification and treatment of 'sleeper weeds' and ecologically integrated control efforts to instigate containment and reduction of infestations of the worst weeds, especially those that threaten endangered communities and species. It was also argued that research is urgently required in some areas and that such research must be regarded as an intrinsic component of weed management.

Recommendations for further research include peer review and sensitivity testing of the Wet Tropics RAS and the procurement of additional biological/ecological information on the 448 naturalised exotics remaining and their assessment using the RAS. It was also recommended that research also include mapping of infestations (especially of high scoring weeds with comparatively limited distributions) throughout the region to assist management deliberations. Lastly, the formulation of a secondary screening system to explicitly take into account feasibility, costs and strategic matters associated with weed control and eradication is required urgently if the serious problem of invasive alien plants is to be addressed effectively within this and other regions.

Acknowledgments

Special appreciation is extended to Barbara Waterhouse (of AQIS), Des Boorman (of the Nurseryman's Association), Anton vanderSchaan (of SitePlan), Rigel Jensen (of JCU), Andrew Small (of GHD) and to Eric Higgins (of the Wet Tropics Tree-Planting Scheme, Cardwell Shire) for extremely valuable explicit comments on exotic species that have naturalised in the region. I am indebted also to Faiz Bebawi, Peter James, Alice Beilby and Rebecca Hosking of DNR (Land Protection) for facilitating access to some material and to Rachel McFadyen, Dane Panetta and Vic Little (also of DNR) for their support and useful comments. Gordon Guymer, Peter Bostock, Bill McDonald and George Batianoff (Queensland Herbarium) were most helpful in providing access to plant records and for clarifying the taxonomic status of some problematic species. Access to the alien species Internet chat line - http://indaba.iucn.org/archives/aliens-1/wwwmsgs/ - which is a most useful information source permitting valuable exchanges with people such as Rod Randall, a Weed Profiler of the Department of Agriculture, WA, and Paula Warren of the Department of Conservation, NZ - is also gratefully acknowledged.

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Appendix 1 – Project Specifics

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PROJECT TITLE
Environmental Weeds of the Wet Tropics: Risk Assessment and Prioritisation

Background

Environmental weeds are introduced species (including translocated native species) capable of establishing self-sustaining populations by invading natural ecosystems. Such plants are generally perennial species capable of displacing vegetation strata and/or are capable of inducing overt modifications to the function of the system by changing, for example, light, fire or hydrological regimes. Environmental weeds therefore, are potentially capable of causing large-scale pervasive modifications to natural processes and ecosystems and are considered to be major threats to locally restricted endemic plant and animal species and communities modifying patterns of species richness, abundance or ecosystem function.

The list of perceived environmental weeds in the region has been increasing rapidly in recent times. Species lists on their own are, however, of limited land management use. To enable a more efficient use of limited resources and to focus research and control programs where they are likely to achieve the greatest environmental benefit requires the development of an explicit system of environmental risk assessment and prioritisation. Different types of strategies will be required for different categories of risk. If species have been recognised as target weeds then prevention and early intervention is possible, logistically feasible and cost effective.

Purpose of the contract

To develop an environmental weed 'risk assessment system' (RAS) for the Wet Tropics region. The RAS will incorporate an ecologically based, logistically and economically feasible system for identifying priorities for weed prevention, eradication, containment or control. The emphasis is to be on gauging the potential threat or environmental impact of weeds on World Heritage values and biodiversity.

It is envisioned that the approach to be taken will develop explicit biogeographic/historical and biological/ecological criteria to assess the potential environmental threat posed by a wide range of both presently occurring or potential introductions to the region.

WTMA needs a robust RAS to help:
1. prevent the development of new weed problems;
2. reduce the impacts of existing weed problems of regional significance; and
3. provide the decision-making framework for on-going management of the weed problem.

Objectives
To establish a robust decision making model for strategic weed management through the development of a targeted approach which will:
- facilitate the collation of relevant reference materials
- focus on a small proportion of the enormous pool of potential weeds
- direct ecological and weed control research
- enhance the probability of early detection and response
- enable pro-active contingency planning and swift response
- aid in the preparation of public awareness materials
- determine WTMA's immediate to medium-term weed management priorities and funding needs

Tasks
Develop a computer based environmental weed risk assessment system tailored to the Wet Tropics region encompassing inventory, prioritisation, categorisation and management action components.

<u>Inventory</u>
Develop a database of :
- existing Wet Tropics environmental weeds
- plants presently found in the region which are considered 'sleeper' weeds
- plants not presently in the region but which are proven environmental weeds in similar environments elsewhere

<u>Prioritisation</u>
Develop a comprehensive set of explicit biogeographic/historical and biological/ecological criteria and an associated weighting scheme to assess the potential environmental threat posed by a wide range of both presently occurring or likely introductions to the region.

Categorisation

Develop a system that allows discriminate prioritisation of species into categories applicable to a range of management purposes, such as prevention, eradication, containment or control

Management Actions

'Management Actions' - Arriving at a 5-year costed program is a logical next stage (phase 2) of a program once that the desk-top study of weed management priorities/risk assessment has been completed. For a properly considered 5-year costed management program to be forthcoming there would need to be more expansive consultation with Land Protection and related personnel more familiar with hands-on control techniques, changing availability of control chemicals and registration protocols, developments in control investigations and distribution and abundance of target species than is provided for in the current project time frame. Moreover, there are many unknowables that would militate against this task - for instance, the continually changing funding sources and conditions for control efforts, failures to commit to recurrent expenditures that jeopardise initial allocations by not funding follow-up control efforts, and the generally dynamic nature of weed risk.

In view of these factors it is argued that a 5-year costed program is beyond the scope of the project at this stage, and instead it may be proposed that once the inventory, prioritisation and management classification tasks have been completed, a first draft of a Strategic Action Plan be developed for the WTWHA based on consideration of control, containment and eradication options.

Appendix 2 – List of exotic plants that have naturalised within the Wet Tropics Bioregion – arranged alphabetically by family

(Source: Queensland Herbarium records (HERBRECS) to November 2000; emended by concatenating conspecific subspecies/varieties (indicated by strikethrough), and inserting additional species (in red font) otherwise known to have naturalised within the region)

Category	Family	Taxon	Comments
higher dicots	Acanthaceae	*Asystasia gangetica*	
higher dicots	Acanthaceae	*Barleria rosea*	Ornamental (noted to be naturalising by Boorman, pers. comm.)
higher dicots	Acanthaceae	*Barleria strigosa*	
higher dicots	Acanthaceae	*Brillantaisia lamium*	Ornamental
higher dicots	Acanthaceae	*Crossandra infundibuliformis*	
higher dicots	Acanthaceae	*Hemigraphis alternata*	
higher dicots	Acanthaceae	*Justicia betonica*	
higher dicots	Acanthaceae	*Odontonema tubaeforme*	Ornamental
higher dicots	Acanthaceae	*Ruellia malacosperma*	Ornamental
higher dicots	Acanthaceae	*Sanchezia parvibracteata*	Ornamental
higher dicots	Acanthaceae	*Stephanophysum longifolium*	Ornamental
higher dicots	Acanthaceae	*Thunbergia alata*	Ornamental
higher dicots	Acanthaceae	*Thunbergia grandiflora*	Ornamental
higher dicots	Acanthaceae	*Thunbergia laurifolia*	Ornamental
higher dicots	Acanthaceae	*Thunbergia mysorensis*	Ornamental
ferns	Adiantaceae	*Pityrogramma calomelanos var. calomelanos*	
monocots	Agavaceae	*Sansevieria trifasciata*	Ornamental
higher dicots	Aizoaceae	*Galenia pubescens*	
monocots	Alismataceae	*Sagittaria graminea*	Ornamental pondweed
~~monocots~~	~~Alismataceae~~	~~*Sagittaria graminea var. platyphylla*~~	~~Ornamental pondweed~~
higher dicots	Amaranthaceae	*Alternanthera bettzickiana*	
higher dicots	Amaranthaceae	*Alternanthera dentata*	
higher dicots	Amaranthaceae	*Alternanthera ficoidea*	
higher dicots	Amaranthaceae	*Alternanthera philoxeroides*	Alligator Weed – a WONS
higher dicots	Amaranthaceae	*Amaranthus hybridus*	
higher dicots	Amaranthaceae	*Amaranthus spinosus*	
higher dicots	Amaranthaceae	*Amaranthus viridis*	
higher dicots	Amaranthaceae	*Celosia argentea*	
higher dicots	Amaranthaceae	*Gomphrena celosioides*	
higher dicots	Amaryllidaceae	*Zephyranthes grandiflora*	Ornamental
higher dicots	Anacardiaceae	*Anacardium occidentale*	Fruit tree (Cashew Nut)
higher dicots	Anacardiaceae	*Harpephyllum caffrum*	
higher dicots	Anacardiaceae	*Mangifera indica*	Fruit tree
higher dicots	Anacardiaceae	*Schinus terebinthifolia*	Ornamental – naturalising about Herberton area (pers. obs)
lower dicots	Annonaceae	*Annona glabra*	Root stock for fruit tree – WONS
lower dicots	Annonaceae	*Annona reticulata*	Fruit tree (Custard Apple)
higher dicots	Apiaceae	*Cyclospermum leptophyllum*	
higher dicots	Apocynaceae	*Allamanda blanchettii*	Ornamental
higher dicots	Apocynaceae	*Allamanda cathartica*	Ornamental
higher dicots	Apocynaceae	*Cascabela thevetia*	Ornamental – naturalising in various places throughout region (pers. obs)
higher dicots	Apocynaceae	*Catharanthus roseus*	Ornamental
higher dicots	Apocynaceae	*Chonemorpha fragrans*	
monocots	Araceae	*Aglaonema commutatum*	?ornamental
monocots	Araceae	*Colocasia esculenta*	Food plant
monocots	Araceae	*Epipremnum aureum*	Ornamental – syn. *Scindapsis aurea* – listed by Qld Herbarium as 'doubtfully naturalised' but frequently encountered
monocots	Araceae	*Syngonium podophyllum*	Ornamental
monocots	Arecaceae	*Syagrus romanzoffiana*	Ornamental – invasive of mixed forest along Priors Ck, Atherton (pers. obs)
lower dicots	Aristolochiaceae	*Aristolochia elegans*	Ornamental
lower dicots	Aristolochiaceae	*Aristolochia odoratissima*	Ornamental
lower dicots	Aristolochiaceae	*Aristolochia ringens*	Ornamental
higher dicots	Asclepiadaceae	*Asclepias curassavica*	?ornamental
higher dicots	Asclepiadaceae	*Calotropis gigantea*	
higher dicots	Asclepiadaceae	*Calotropis procera*	

Category	Family	Taxon	Comments
higher dicots	Asclepiadaceae	*Gomphocarpus physocarpus*	
higher dicots	Asteraceae	*Acanthospermum hispidum*	
higher dicots	Asteraceae	*Ageratina riparia (*syn. *Eupatorium. riparium)*	note nomenclatural change
higher dicots	Asteraceae	*Ageratum conyzoides* subsp. *conyzoides*	Bluetop/Billygoat Weed
higher dicots	Asteraceae	*Ageratum houstonianum*	as above
higher dicots	Asteraceae	*Ambrosia artemisiifolia*	
higher dicots	Asteraceae	*Arctotheca calendula*	Ornamental
higher dicots	Asteraceae	*Aster subulatus*	
higher dicots	Asteraceae	*Bidens alba var. radiata*	
higher dicots	Asteraceae	*Bidens pilosa ~~var. pilosa~~*	
higher dicots	Asteraceae	*Carpesium cernuum*	
higher dicots	Asteraceae	*Centaurea melitensis*	
higher dicots	Asteraceae	*Centratherum punctatum*	
higher dicots	Asteraceae	*Chromolaena odorata*	considered to be one of the world's worse weeds –'quarantine weed' – target of SWEEP
higher dicots	Asteraceae	*Cichorium intybus*	Food plant
higher dicots	Asteraceae	*Cirsium vulgare*	
higher dicots	Asteraceae	*Conyza bonariensis*	
higher dicots	Asteraceae	*Conyza canadensis ~~var. canadensis~~*	
~~higher dicots~~	~~Asteraceae~~	*~~Conyza canadensis var. pusilla~~*	
higher dicots	Asteraceae	*Conyza leucantha*	
higher dicots	Asteraceae	*Conyza sumatrensis*	
higher dicots	Asteraceae	*Cosmos caudatus*	Ornamental
higher dicots	Asteraceae	*Crassocephalum crepidioides*	
higher dicots	Asteraceae	*Elephantopus mollis*	
higher dicots	Asteraceae	*Eleutheranthera ruderalis*	
higher dicots	Asteraceae	*Emilia sonchifolia ~~var. javanica~~*	
~~higher dicots~~	~~Asteraceae~~	*~~Emilia sonchifolia var. sonchifolia~~*	
higher dicots	Asteraceae	*Erechtites valerianifolia forma valerianifolia*	Brazilian Fireweed
higher dicots	Asteraceae	*Eupatorium catarium (*syn. *Praxelis clematidea)*	Mistflower – note change in taxonomic nomenclature
higher dicots	Asteraceae	*Galinsoga parviflora*	
higher dicots	Asteraceae	*Gamochaeta pensylvanica*	
higher dicots	Asteraceae	*Hypochaeris radicata*	
higher dicots	Asteraceae	*Mikania micrantha*	Medicinal herb – one of the world's worst invasives – controlled in Bramston Beach area
higher dicots	Asteraceae	*Montanoa hibiscifolia*	Ornamental
higher dicots	Asteraceae	*Parthenium hysterophorus*	Pasture seed contaminant – WONS
higher dicots	Asteraceae	*Pseudelephantopus spicatus*	
higher dicots	Asteraceae	*Sigesbeckia orientalis*	
higher dicots	Asteraceae	*Silybum marianum*	
higher dicots	Asteraceae	*Solidago canadensis var. scabra*	Goldenrod
higher dicots	Asteraceae	*Sonchus oleraceus*	
higher dicots	Asteraceae	*Sphagneticola trilobata*	Ornamental – bank stabiliser – Singapore Daisy = *Wedelia trilobata*
higher dicots	Asteraceae	*Synedrella nodiflora*	Cinderalla weed
higher dicots	Asteraceae	*Tagetes minuta*	
higher dicots	Asteraceae	*Tithonia diversifolia*	Ornamental
higher dicots	Asteraceae	*Tithonia rotundifolia*	Ornamental
higher dicots	Asteraceae	*Tridax procumbens*	
higher dicots	Asteraceae	*Xanthium occidentale*	Noogoora Burr – injurious fruits = *X. pungens*
higher dicots	Balsaminaceae	*Impatiens walleriana*	Ornamental
higher dicots	Basellaceae	*Anredera cordifolia*	Ornamental
higher dicots	Bignoniaceae	*Macfadyena unuis-cati*	Cat's-claw creeper - ornamental
higher dicots	Bignoniaceae	*Parmentiera aculeata*	Cucumber Tree = *P. edulis*
higher dicots	Bignoniaceae	*Spathodea campanulata*	Ornamental
higher dicots	Bignoniaceae	*Tecoma capensis*	
higher dicots	Bixaceae	*Bixa orellana*	Ornamental
higher dicots	Boraginaceae	*Echium plantagineum*	Ornamental – honey plant
higher dicots	Boraginaceae	*Heliotropium indicum*	
higher dicots	Brassicaceae	*Brassica juncea*	
higher dicots	Brassicaceae	*Brassica nigra*	
higher dicots	Brassicaceae	*Brassica rapa subsp. sylvestris*	
higher dicots	Brassicaceae	*Cardamine flexuosa*	
higher dicots	Brassicaceae	*Coronopus didymus*	
higher dicots	Brassicaceae	*Coronopus integrifolius*	
higher dicots	Brassicaceae	*Lepidium virginicum*	

Category	Family	Taxon	Comments
higher dicots	Brassicaceae	*Raphanus raphanistrum*	Food plant
higher dicots	Brassicaceae	*Rorippa palustris*	
higher dicots	Brassicaceae	*Sisymbrium thellungii*	
monocots	Bromeliaceae	*Ananas comosus*	Food plant (Pineapple)
higher dicots	Buddlejaceae	*Buddleja madagascariensis*	Ornamental
lower dicots	Cabombaceae	*Cabomba caroliniana*	Aquarium escapee
higher dicots	Cactaceae	*Opuntia vulgaris*	Food plant – formerly greatly invasive
higher dicots	Cactaceae	*Pereskia aculeata*	
higher dicots	Caesalpiniaceae	*Bauhinia monandra*	
higher dicots	Caesalpiniaceae	*Caesalpinia decapetala*	
higher dicots	Caesalpiniaceae	*Cassia fistula*	Ornamental – invasive in region
higher dicots	Caesalpiniaceae	*Cassia grandis*	
higher dicots	Caesalpiniaceae	*Chamaecrista rotundifolia*	
higher dicots	Caesalpiniaceae	*Gliricidia sepium*	Forage legume
higher dicots	Caesalpiniaceae	*Haematoxylum campechianum*	
higher dicots	Caesalpiniaceae	*Senna alata*	
higher dicots	Caesalpiniaceae	*Senna hirsuta*	
higher dicots	Caesalpiniaceae	*Senna obtusifolia*	Sicklepod - major agricultural weed
higher dicots	Caesalpiniaceae	*Senna occidentalis*	
higher dicots	Caesalpiniaceae	*Senna septemptrionalis*	
higher dicots	Caesalpiniaceae	*Senna siamea*	
higher dicots	Caesalpiniaceae	*Senna tora*	
higher dicots	Caesalpiniaceae	*Sindora supa*	
higher dicots	Caesalpineaceae	*Tamarindus indica*	Fruit-bearing plant (Tamarind) – long-established in Australia from Maccassan trader times
higher dicots	Campanulaceae	*Hippobroma longiflora*	
higher dicots	Cannabaceae	*Cannabis sativa*	grown for psychotropic properties
monocots	Cannaceae	*Canna indica*	Canna Lily – ornamental
higher dicots	Capparaceae	*Cleome aculeata*	
higher dicots	Capparaceae	*Cleome gynandra*	
higher dicots	Capparaceae	*Cleome hassleriana*	
higher dicots	Capparaceae	*Cleome monophylla*	
higher dicots	Caprifoliaceae	*Lonicera japonica*	Japanese honeysuckle - ornamental
higher dicots	Caprifoliaceae	*Lonicera periclymenum*	?ornamental
higher dicots	Caprifoliaceae	*Sambucus canadensis*	
higher dicots	Caricaceae	*Carica papaya*	Food plant
higher dicots	Caryophyllaceae	*Cerastium vulgare*	
higher dicots	Caryophyllaceae	*Stellaria media*	Chickweed
higher dicots	Chenopodiaceae	*Chenopodium ambrosioides*	
higher dicots	Clusiaceae	*Garcinia xanthchymus*	
higher dicots	Clusiaceae	*Harungana madagascariensis*	
monocots	Commelinaceae	*Commelina benghalensis*	
monocots	Commelinaceae	*Tradescantia spathacea*	
monocots	Commelinaceae	*Zebrina pendula*	Ornamental – invasive of gullies in and about urban areas (pers. obs)
higher dicots	Convolvulaceae	*Argyreia nervosa*	
higher dicots	Convolvulaceae	*Cuscuta campestris*	
higher dicots	Convolvulaceae	*Ipomoea caraica*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea hederifolia*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea indica*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea nil*	
higher dicots	Convolvulaceae	*Ipomoea obscura*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea purpurea*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea quamoclit*	Ornamental
higher dicots	Convolvulaceae	*Ipomoea triloba*	
higher dicots	Convolvulaceae	*Merremia dissecta*	
higher dicots	Convolvulaceae	*Merremia quinquefolia*	
higher dicots	Convolvulaceae	*Merremia tuberosa*	
higher dicots	Convolvulaceae	*Turbina corymbosa*	Ornamental/drug plant
higher dicots	Crassulaceae	*Bryophyllum daigremontianum*	
higher dicots	Crassulaceae	*Bryophyllum pinnatum*	
higher dicots	Cucurbitaceae	*Coccinia grandis*	
higher dicots	Cucurbitaceae	*Cucumis anguria*	
higher dicots	Cucurbitaceae	*Cucumis metuliferus*	
higher dicots	Cucurbitaceae	*Momordica charantia*	?ornamental –widespread and rampant along forest edges (pers. obs)
higher dicots	Cyperaceae	*Cyperus aromaticus*	Navua sedge – lawn contaminant
monocots	Cyperaceae	*Cyperus brevifolius*	
monocots	Cyperaceae	*Cyperus compressus*	

Category	Family	Taxon	Comments
monocots	Cyperaceae	*Cyperus esculentus*	
monocots	Cyperaceae	*Cyperus involucratus*	
monocots	Cyperaceae	*Cyperus metzii*	
monocots	Cyperaceae	*Cyperus rotundus*	
monocots	Cyperaceae	*Cyperus tuberosus*	
monocots	Cyperaceae	*Eleocharis minuta*	
monocots	Dioscoreaceae	*Dioscorea alata*	Food plant
higher dicots	Euphorbiaceae	*Acalypha wilkesiana*	Ornamental
higher dicots	Euphorbiaceae	*Chamaesyce hirta*	
higher dicots	Euphorbiaceae	*Chamaesyce hyssopifolia*	
higher dicots	Euphorbiaceae	*Chamaesyce maculata*	
higher dicots	Euphorbiaceae	*Chamaesyce prostrata*	
higher dicots	Euphorbiaceae	*Euphorbia cyathophora*	
higher dicots	Euphorbiaceae	*Euphorbia heterophylla*	
higher dicots	Euphorbiaceae	*Hevea brasiliensis*	Rubber
higher dicots	Euphorbiaceae	*Jatropha curcas*	
higher dicots	Euphorbiaceae	*Jatropha gossypiifolia*	
higher dicots	Euphorbiaceae	*Manihot esculenta*	Food plant
higher dicots	Euphorbiaceae	*Manihot glaziovii*	Food plant
higher dicots	Euphorbiaceae	*Pedilanthus tithymaloides subsp. smallii*	
higher dicots	Euphorbiaceae	*Phyllanthus amarus*	
higher dicots	Euphorbiaceae	*Phyllanthus tenellus*	
higher dicots	Fabaceae	*Aeschynomene americana*	Pasture legume
~~higher dicots~~	~~Fabaceae~~	~~*Aeschynomene americana var. americana*~~	~~Pasture legume~~
higher dicots	Fabaceae	*Aeschynomene indica*	Pasture legume
higher dicots	Fabaceae	*Aeschynomene micranthos*	Pasture legume
higher dicots	Fabaceae	*Aeschynomene villosa*	Pasture legume
higher dicots	Fabaceae	*Alysicarpus bupleurifolius*	
higher dicots	Fabaceae	*Alysicarpus ovalifolius*	
higher dicots	Fabaceae	*Alysicarpus vaginalis*	
higher dicots	Fabaceae	*Cajanus cajan*	
higher dicots	Fabaceae	*Calopogonium mucunoides*	Pasture legume
higher dicots	Fabaceae	*Centrosema pascuorum*	Pasture legume
higher dicots	Fabaceae	*Centrosema pubescens*	Pasture legume
higher dicots	Fabaceae	*Clitoria laurifolia*	
higher dicots	Fabaceae	*Clitoria ternatea*	Pasture legume (Butterfly Pea)
higher dicots	Fabaceae	*Crotalaria goreensis*	
higher dicots	Fabaceae	*Crotalaria incana subsp. purpurascens*	
higher dicots	Fabaceae	*Crotalaria lanceolata subsp. lanceolata*	
higher dicots	Fabaceae	*Crotalaria lunata*	
higher dicots	Fabaceae	*Crotalaria ochroleuca*	
higher dicots	Fabaceae	*Crotalaria pallida var. obovata*	
higher dicots	Fabaceae	*Crotalaria retusa*	
higher dicots	Fabaceae	*Crotalaria spectabilis*	
higher dicots	Fabaceae	*Crotalaria virgulata subsp. grantiana*	
higher dicots	Fabaceae	*Crotalaria zanzibarica*	
higher dicots	Fabaceae	*Dalbergia sissoo*	Ornamental
higher dicots	Fabaceae	*Desmodium heterophyllum*	Pasture legume
higher dicots	Fabaceae	*Desmodium incanum*	Pasture legume
higher dicots	Fabaceae	*Desmodium intortum*	Pasture legume
higher dicots	Fabaceae	*Desmodium scorpiurus*	Pasture legume
higher dicots	Fabaceae	*Desmodium strigillosum*	Pasture legume
higher dicots	Fabaceae	*Desmodium tortuosum*	Pasture legume
higher dicots	Fabaceae	*Desmodium uncinatum*	Pasture legume
higher dicots	Fabaceae	*Glycine max*	Pasture legume
higher dicots	Fabaceae	*Indigofera spicata*	
higher dicots	Fabaceae	*Indigofera suffruticosa*	
higher dicots	Fabaceae	*Indigofera tinctoria*	
higher dicots	Fabaceae	*Inga* sp.	Fruit tree – recored as invasive by Stanton (pers. comm.)
higher dicots	Fabaceae	*Lablab purpureus*	
higher dicots	Fabaceae	*Lupinus albus*	Pasture legume
higher dicots	Fabaceae	*Macroptilium atropurpureum*	Pasture legume – widespread in region in disturbed localities (pers. obs)
higher dicots	Fabaceae	*Macroptilium lathyroides var. semierectum*	Pasture legume
higher dicots	Fabaceae	*Macrotyloma axillare*	
~~higher dicots~~	~~Fabaceae~~	~~*Macrotyloma axillare var. axillare*~~	
higher dicots	Fabaceae	*Macrotyloma uniflorum*	
~~higher dicots~~	~~Fabaceae~~	~~*Macrotyloma uniflorum var. stenocarpum*~~	
~~higher dicots~~	~~Fabaceae~~	~~*Macrotyloma uniflorum var. uniflorum*~~	

Category	Family	Taxon	Comments
higher dicots	Fabaceae	*Medicago lacinata var. lacinata*	Pasture legume
higher dicots	Fabaceae	*Medicago lupulina*	Pasture legume
higher dicots	Fabaceae	*Medicago polymorpha*	Pasture legume
higher dicots	Fabaceae	*Melilotus indicus*	Pasture legume
higher dicots	Fabaceae	*Neonotonia wightii*	
~~higher dicots~~	~~Fabaceae~~	~~*Neonotonia wightii var. wightii*~~	
higher dicots	Fabaceae	*Pachyrhizus erosus*	
higher dicots	Fabaceae	*Phaseolus lunatus*	Pasture legume (Phasey Bean)
higher dicots	Fabaceae	*Pueraria lobata*	Pasture legume
higher dicots	Fabaceae	*Pueraria phaseoloides*	Pasture legume
~~higher dicots~~	~~Fabaceae~~	~~*Pueraria phaseoloides var. javanica*~~	~~Pasture legume~~
higher dicots	Fabaceae	*Stylosanthes guianensis*	Pasture legume
~~higher dicots~~	~~Fabaceae~~	~~*Stylosanthes guianensis var. guineensis*~~	~~Pasture legume~~
~~higher dicots~~	~~Fabaceae~~	~~*Stylosanthes guianensis var. intermedia*~~	~~Pasture legume~~
higher dicots	Fabaceae	*Stylosanthes hamata*	Pasture legume
higher dicots	Fabaceae	*Stylosanthes humilis*	Pasture legume
higher dicots	Fabaceae	*Stylosanthes scabra*	Passture legume
higher dicots	Fabaceae	*Tephrosia candida*	
higher dicots	Fabaceae	*Tephrosia elegans*	
higher dicots	Fabaceae	*Tephrosia noctiflora*	
higher dicots	Fabaceae	*Tephrosia tinctoria*	
higher dicots	Fabaceae	*Teramnus labialis*	
higher dicots	Fabaceae	*Trifolium glomeratum*	Pasture legume
higher dicots	Fabaceae	*Vigna adenantha*	Pasture legume
higher dicots	Fabaceae	*Vigna hosei*	Pasture legume
higher dicots	Fabaceae	*Vigna mungo*	Pasture legume
higher dicots	Fabaceae	*Vigna parkeri*	Pasture legume
higher dicots	Fabaceae	*Vigna umbellata*	Pasture legume
higher dicots	Fabaceae	*Vigna unguiculata*	Pasture legume
~~higher dicots~~	~~Fabaceae~~	~~*Vigna unguiculata subsp. cylindrica*~~	~~Pasture legume~~
~~higher dicots~~	~~Fabaceae~~	~~*Vigna unguiculata subsp. dekindtiana*~~	~~Pasture legume~~
higher dicots	Fagaceae	*Quercus robur*	Ornamental/timber tree (Oak)
higher dicots	Flacourtiaceae	*Flacourtia jangomas*	
higher dicots	Hydrocharitaceae	*Elodea canadensis*	Ornamental pondweed – recorded only recently from Mazlin Ck (unpub. data)
higher dicots	Lamiaceae	*Clerodendrum heterophyllum forma baueri*	
higher dicots	Lamiaceae	*Clerodendrum paniculatum*	
higher dicots	Lamiaceae	*Clerodendrum thomsoniae*	
higher dicots	Lamiaceae	*Hyptis capitata*	
higher dicots	Lamiaceae	*Hyptis pectinata*	
higher dicots	Lamiaceae	*Hyptis rhomboidea*	
higher dicots	Lamiaceae	*Hyptis suaveolens*	
higher dicots	Lamiaceae	*Leonurus sibiricus*	
higher dicots	Lamiaceae	*Leucas decemdentata*	
higher dicots	Lamiaceae	*Leucas linifolia*	
higher dicots	Lamiaceae	*Leucas zeylanica*	
higher dicots	Lamiaceae	*Ocimum americanum var. americanum*	
higher dicots	Lamiaceae	*Ocimum x citriodorum*	
higher dicots	Lamiaceae	*Salvia coccinea*	Ornamental
higher dicots	Lamiaceae	*Salvia misella*	
higher dicots	Lamiaceae	*Stachys arvensis*	
lower dicots	Lauraceae	*Cinnamomum camphora*	Timber tree
lower dicots	Lauraceae	*Persea americana*	Fruit tree
higher dicots	Lythraceae	*Ammannia auriculata*	
higher dicots	Lythraceae	*Rotala rotundifolia*	
higher dicots	Malpighiaceae	*Hiptage benghalensis*	now includes *H. mandablota*
higher dicots	Malvaceae	*Abelmoschus manihot* ~~*subsp. manihot*~~	Ornamental
~~higher dicots~~	~~Malvaceae~~	~~*Abelmoschus manihot subsp. tetraphyllus*~~	~~Ornamental~~
higher dicots	Malvaceae	*Gossypium barbadense*	Ornamental
higher dicots	Malvaceae	*Hibiscus diversifolius*	Ornamental
higher dicots	Malvaceae	*Hibiscus mutabilis*	Ornamental
higher dicots	Malvaceae	*Hibiscus rosasinensis*	Ornamental
higher dicots	Malvaceae	*Malvastrum coromandelianum*	
higher dicots	Malvaceae	*Sida acuta*	
higher dicots	Malvaceae	*Sida rhombifolia*	
~~higher dicots~~	~~Malvaceae~~	~~*Sida rhombifolia var. incana*~~	
higher dicots	Malvaceae	*Sida spinosa*	
higher dicots	Malvaceae	*Urena lobata*	
higher dicots	Marantaceae	*Thaumatococcus daniellii*	Food plant – noted by Stanton (pers. comm.) as invasive in Whyanbeel area

Category	Family	Taxon	Comments
higher dicots	Melastomataceae	*Miconia calvescens*	Ornamental
higher dicots	Melastomataceae	*Tristemma mauritianum var. mauritianum*	
higher dicots	Meliaceae	*Azadirachta indica*	Imported for a range of uses (especially for insect repellant) – invasive in limited area (Speewah)
higher dicots	Meliaceae	*Chukrasia velutina*	Timber tree – wildings establishing from plantation parents on Atherton Tableland (pers. obs)
higher dicots	Mimosaceae	*Acacia angustissima*	
higher dicots	Mimosaceae	*Acacia farnesiana*	
higher dicots	Mimosaceae	*Acacia sinuata*	
higher dicots	Mimosaceae	*Calliandra surinamensis*	Ornamental
higher dicots	Mimosaceae	*Leucaena leucocephala subsp. leucocephala*	Pasture legume
higher dicots	Mimosaceae	*Mimosa diplotricha var. diplotricha*	now includes *M. invisa*
higher dicots	Mimosaceae	*Mimosa pudica*	
~~higher dicots~~	~~Mimosaceae~~	~~*Mimosa pudica var. hispida*~~	
~~higher dicots~~	~~Mimosaceae~~	~~*Mimosa pudica var. tetrandra*~~	
~~higher dicots~~	~~Mimosaceae~~	~~*Mimosa pudica var. unijuga*~~	
higher dicots	Mimosaceae	*Samanea saman*	Ornamental
higher dicots	Mimoscaeae	*Acacia nilotica*	a WONS – occasionally encountered in drier parts of region
higher dicots	Molluginaceae	*Mollugo verticillata*	
higher dicots	Moraceae	*Artocarpus ?communis*	Jackfruit – noted as invasive in Cairns area by Boorman (pers. comm.)
higher dicots	Moraceae	*Castilla elastica*	Provides rubber substitute
higher dicots	Moringaceae	*Moringa pterygosperma*	
monocots	Musaceae	*Musa acuminata x M.balbisiana*	Fruit-bearing plant
higher dicots	Myrsinaceae	*Ardisia* cf *.humilis*	Ornamental - if *A. humilis* it is a major weed elsewhere – but may be confused with *A. solanacea* (see below – Hyland & Waterhouse pers. comm.)
higher dicots	Myrsinaceae	*Ardisia crenata*	Ornamental
higher dicots	Myrsinaceae	*Ardisia crispa*	Ornamental
higher dicots	Myrsinaceae	*Ardisia solanacea*	Ornamental
higher dicots	Myrtaceae	*Eugenia dombeyi*	Fruit-bearing plant – noted naturalising by Stanton (peres. comm.)
higher dicots	Myrtaceae	*Eugenia uniflora*	Fruit-bearing plant – recorded in intact native vegetation at various locations (eg, Cardwell – see Werren 1998)
higher dicots	Myrtaceae	*Psidium guajava*	Fruit tree
higher dicots	Myrtaceae	*Psidium guineense*	?fruit tree
higher dicots	Myrtaceae	*Syzygium cumini*	Fruit tree (Java Plum)
higher dicots	Oleaceae	*Ligustrum sinense*	Ornamental
higher dicots	Onagraceae	*Ludwigia peploides subsp. montevidensis*	
higher dicots	Onagraceae	*Oenothera speciosa*	
higher dicots	Oxalidaceae	*Oxalis corniculata var. corniculata*	
higher dicots	Oxalidaceae	*Oxalis debilis var. corymbosa*	
higher dicots	Passifloraceae	*Passiflora caerulea*	
higher dicots	Passifloraceae	*Passiflora coccinea*	Ornamental
higher dicots	Passifloraceae	*Passiflora edulis*	Fruit-bearing plant
higher dicots	Passifloraceae	*Passiflora foetida*	
~~higher dicots~~	~~Passifloraceae~~	~~*Passiflora foetida var. foetida*~~	
~~higher dicots~~	~~Passifloraceae~~	~~*Passiflora foetida var. gossypifolia*~~	
~~higher dicots~~	~~Passifloraceae~~	~~*Passiflora foetida var. riparia*~~	
higher dicots	Passifloraceae	*Passiflora laurifolia*	
higher dicots	Passifloraceae	*Passiflora quadrangularis*	
higher dicots	Passifloraceae	*Passiflora suberosa*	
higher dicots	Passifloraceae	*Passiflora subpeltata*	
higher dicots	Phytolaccaceae	*Phytolacca octandra*	
higher dicots	Phytolaccaceae	*Rivina humilis*	?ornamental
?higher dicots	Pinaceae	*Pinus caribaea*	Timber tree – wildings extensively established around numerous plantations (pers. obs)
higher dicots	Piperaceae	*Peperomia pellucida*	
higher dicots	Plantaginaceae	*Plantago lanceolata*	
higher dicots	Plantaginaceae	*Plantago major*	
monocots	Poaceae	*Andropogon gayanus*	Pasture grass (Gamba Grass) known to be naturalising within region (Waterhouse pers. comm.)
monocots	Poaceae	*Arundo donax var. donax*	
monocots	Poaceae	*Axonopus compressus*	

Category	Family	Taxon	Comments
monocots	Poaceae	*Axonopus fissifolius*	
monocots	Poaceae	*Bambusa vulgaris*	
monocots	Poaceae	*Bothriochloa insculpta*	
monocots	Poaceae	*Brachiaria brizantha*	Pasture grass
monocots	Poaceae	*Brachiaria decumbens* Stapf	Pasture grass
~~monocots~~	~~Poaceae~~	~~*Brachiaria decumbens* Stapf cv Basilisk~~	~~Pasture grass~~
monocots	Poaceae	*Brachiaria humidicola*	Pasture grass
monocots	Poaceae	*Brachiaria mutica*	Pasture (ponded) grass (Para Grass)
monocots	Poaceae	*Cenchrus caliculatus*	Pasture grass
monocots	Poaceae	*Cenchrus ciliaris*	Pasture grass (Buffel Grass)
monocots	Poaceae	*Cenchrus echinatus*	
monocots	Poaceae	*Cenchrus setiger*	
monocots	Poaceae	*Chloris gayana*	Pasture grass (Rhodes Grass)
monocots	Poaceae	*Chloris inflata*	
monocots	Poaceae	*Chloris virgata*	Pasture grass
monocots	Poaceae	*Cynodon aethiopicus*	
monocots	Poaceae	*Cynodon nlemfuensis var. nlemfuensis*	
monocots	Poaceae	*Cyrtococcum deltoideum*	
monocots	Poaceae	*Dactyloctenium aegyptium*	
monocots	Poaceae	*Dactyloctenium australe*	
monocots	Poaceae	*Dichanthium annulatum*	
monocots	Poaceae	*Dichanthium aristatum*	
monocots	Poaceae	*Dichanthium caricosum*	
monocots	Poaceae	*Digitaria ciliaris*	
monocots	Poaceae	*Digitaria didactyla*	
monocots	Poaceae	*Digitaria eriantha*	
monocots	Poaceae	*Digitaria violascens*	
monocots	Poaceae	*Echinochloa colona*	
monocots	Poaceae	*Echinochloa crus-galli*	
monocots	Poaceae	*Echinochloa frumentacea*	
monocots	Poaceae	*Echinochloa polystachya*	inclusive of "Amity" cultivar
~~monocots~~	~~Poaceae~~	~~*Echinochloa polystachya cv. Amity*~~	
monocots	Poaceae	*Eleusine indica*	
monocots	Poaceae	*Eragrostis amabilis*	
monocots	Poaceae	*Eragrostis cilianensis*	
monocots	Poaceae	*Eragrostis minor*	
monocots	Poaceae	*Eragrostis pilosa*	
monocots	Poaceae	*Eragrostis subsecunda*	
monocots	Poaceae	*Eragrostis tenuifolia*	
monocots	Poaceae	*Eriochloa meyeriana*	
monocots	Poaceae	*Eustachys distichophylla*	
monocots	Poaceae	*Hordeum vulgare subsp. Vulgare*	
monocots	Poaceae	*Hymenachne amplexicaulis*	Pasture (ponded) grass (Hymenachne) – a WONS - recorded extensively from Babinda to the Herbert floodplain in the east and further to the west from Julatten to Mareeba
monocots	Poaceae	*Hyparrhenia hirta*	
monocots	Poaceae	*Hyparrhenia rufa*	
~~monocots~~	~~Poaceae~~	~~*Hyparrhenia rufa subsp. altissima*~~	
~~monocots~~	~~Poaceae~~	~~*Hyparrhenia rufa subsp. rufa*~~	
monocots	Poaceae	*Lolium perenne*	Pasture grass
monocots	Poaceae	*Lolium x hubbardii*	Pasture grass
monocots	Poaceae	*Lolium x hybridum*	Pasture grass
monocots	Poaceae	*Melinis minutiflora*	Pasture grass
monocots	Poaceae	*Melinis repens*	Pasture grass
monocots	Poaceae	*Panicum coloratum*	Pasture grass
~~monocots~~	~~Poaceae~~	~~*Panicum maximum var. coloratum*~~	~~Pasture grass~~
monocots	Poaceae	*Panicum maximum* ~~*var. maximum*~~	Pasture grass (Guinea Grass)
~~monocots~~	~~Poaceae~~	~~*Panicum maximum var. maximum cv Coloniao*~~	~~Pasture grass~~
~~monocots~~	~~Poaceae~~	~~*Panicum maximum var. maximum cv. Hamil*~~	~~Pasture grass (Hamel Grass)~~
~~monocots~~	~~Poaceae~~	~~*Panicum maximum var. trichoglume*~~	~~Pasture grass~~
monocots	Poaceae	*Paspalum conjugatum*	Pasture grass
monocots	Poaceae	*Paspalum dilatatum*	Pasture grass
monocots	Poaceae	*Paspalum notatum*	Pasture grass
monocots	Poaceae	*Paspalum paniculatum*	Pasture grass
monocots	Poaceae	*Paspalum plicatulum*	Pasture grass
monocots	Poaceae	*Paspalum urvillei*	Pasture grass
monocots	Poaceae	*Paspalum virgatum*	Pasture grass (Clyde River Grass)

Category	Family	Taxon	Comments
monocots	Poaceae	*Paspalum wettsteinii*	Pasture grass
monocots	Poaceae	*Pennisetum alopecuroides*	Pasture grass
monocots	Poaceae	*Pennisetum clandestinum*	Pasture grass
monocots	Poaceae	*Pennisetum glaucum*	Pasture grass
monocots	Poaceae	*Pennisetum pedicellatum subsp. unispiculum*	Pasture grass
monocots	Poaceae	*Pennisetum purpureum*	Pasture grass
monocots	Poaceae	*Phalaris canariensis*	
monocots	Poaceae	*Phalaris minor*	
monocots	Poaceae	*Phyllostachys bambusoides*	Ornamental + other
monocots	Poaceae	*Poa annua*	
monocots	Poaceae	*Saccharum officinarum*	food plant (Sugar Cane)
monocots	Poaceae	*Saccharum spontaneum*	listed as 'doubtfully naturalised' by Qld Herbarium but known locally to be somewhat invasive (pers. obs)
monocots	Poaceae	*Setaria pumila ~~subsp. pallidefusca~~*	Pasture grass
~~monocots~~	~~Poaceae~~	~~*Setaria pumila subsp. pumila*~~	~~Pasture grass~~
monocots	Poaceae	*Setaria sphacelata*	Pasture grass
~~monocots~~	~~Poaceae~~	~~*Setaria sphacelata var. sericea*~~	~~Pasture grass~~
~~monocots~~	~~Poaceae~~	~~*Setaria sphacelata var. splendida*~~	~~Pasture grass~~
monocots	Poaceae	*Sorghum bicolor*	Pasture grass
monocots	Poaceae	*Sorghum halepense*	Pasture grass
monocots	Poaceae	*Sorghum x almum*	Pasture grass
monocots	Poaceae	*Sporobolus africanus*	
monocots	Poaceae	*Sporobolus jacquemontii*	
monocots	Poaceae	*Sporobolus pyramidalis var. natalensis*	Pasture contaminant - Giant Rats-tail Grass recorded by Sullivan on Tablelands (Little, pers. comm.)
monocots	Poaceae	*Themeda quadrivalvis*	Pasture seed contaminant
monocots	Poaceae	*Urochloa mosambicus*	
monocots	Poaceae	*Zea mexicana*	Food plant
higher dicots	Polygalaceae	*Polygala paniculata*	
higher dicots	Polygonaceae	*Acetosella vulgaris*	
higher dicots	Polygonaceae	*Emex australis*	
higher dicots	Polygonaceae	*Fallopia convolvulus*	
higher dicots	Polygonaceae	*Triplaris americana/surinamensis*	Ornamental – featured in Cairns City PMP – invasive about Bramston Beach
monocots	Pontederiaceae	*Eichhornia crassipes*	Ornamental pondweed
higher dicots	Portulacaceae	*Talinum paniculatum*	
higher dicots	Primulaceae	*Anagallis pumila*	
ferns	Pteridaceae	*Pteris semipinnata*	Ornamental
higher dicots	Rhamnaceae	*Ziziphus mauritiana*	Food plant (Chinee Apple)
higher dicots	Rosaceae	*Rubus alceifolius*	
higher dicots	Rubiaceae	*Coffea arabica*	Food plant
higher dicots	Rubiaceae	*Coffea liberica*	Food plant -listed as 'doubtfully naturalised' by Qld Herbarium but recored as naturalising (Stanton, pers. comm, Boorman, Pers. comm.)
higher dicots	Rubiaceae	*Mitracarpus hirtus*	
higher dicots	Rubiaceae	*Musenda frondosa*	shrubby garden escapee along powerline corridor on the approaches to Bramston Beach (Jensen, pers. comm.)
higher dicots	Rubiaceae	*Oldenlandia corymbosa var. corymbosa*	
higher dicots	Rubiaceae	*Richardia brasiliensis*	
higher dicots	Rubiaceae	*Richardia scabra*	
higher dicots	Rubiaceae	*Spermococe assurgens*	
higher dicots	Rubiaceae	*Spermococe mauritiana*	
higher dicots	Rutaceae	*Casimiroa edulis*	Fruiy-bearing tree
higher dicots	Rutaceae	*Citrus x limon*	Fruiy-bearing tree (Lemon)
higher dicots	Rutaceae	*Murraya koenigii*	Food plant (curry leaf)
higher dicots	Rutaceae	*Murraya paniculata*	Ornamental – inclusive of *M.paniculata cv. exotica*
ferns	Salviniaceae	*Salvinia molesta*	Ornamental aquatic
higher dicots	Sapindaceae	*Blighia sapida*	Fruit-bearing tree – naturalising along creek banks and forest edges along footslopes of the McAlister Range west of Palm Cove (Small, pers. comm.)
higher dicots	Sapindaceae	*Cardiospermum halicacabum*	
~~higher dicots~~	~~Sapindaceae~~	~~*Cardiospermum halicacabum var. halicacabum*~~	
higher dicots	Sapotaceae	*Chrysophyllum cainito*	Fruit-bearing tree recorded by Stanton (pers. comm.) as naturalising

Category	Family	Taxon	Comments
higher dicots	Scrophulariaceae	*Angelonia salicariifolia*	
higher dicots	Scrophulariaceae	*Lophospermum erubescens*	Rampant along road verges of Maalan circuit (Jensen, pers. comm.) and along the Beatrice (Small, pers. comm.)
higher dicots	Scrophulariaceae	*Mecardonia procumbens*	
higher dicots	Scrophulariaceae	*Scoparia dulcis*	
spike mosses	Selaginellaceae	*Selaginella plana*	Ornamental
spike mosses	Selaginellaceae	*Selaginella umbrosa*	Ornamental
spike mosses	Selaginellaceae	*Selaginella vogelii*	Ornamental
spike mosses	Selaginellaceae	*Selaginella wildenovii*	Ornamental
higher dicots	Solanaceae	*Brugmansia x candida*	
higher dicots	Solanaceae	*Capsicum annuum var. glabriusculum*	Fruit-bearing plant
higher dicots	Solanaceae	*Capsicum frutescens*	Fruit-bearing plant
higher dicots	Solanaceae	*Datura stramonium*	Ornamental
higher dicots	Solanaceae	*Lycium barbarum*	
higher dicots	Solanaceae	*Lycopersicon esculentum*	Fruit-bearing plant
higher dicots	Solanaceae	*Nicandra physalodes*	
higher dicots	Solanaceae	*Nicotiana glauca*	Drug plant
higher dicots	Solanaceae	*Physalis peruviana*	
higher dicots	Solanaceae	*Solanum capsicoides*	Fruit-bearing plant
higher dicots	Solanaceae	*Solanum erianthum*	
higher dicots	Solanaceae	*Solanum mauritianum*	
higher dicots	Solanaceae	*Solanum nigrum*	
higher dicots	Solanaceae	*Solanum pseudocapsicum*	
higher dicots	Solanaceae	*Solanum seaforthianum*	Ornamental
higher dicots	Solanaceae	*Solanum torvum*	
higher dicots	Theaceae	*Camellia sinensis*	Food (beverage) plant
higher dicots	Tiliaceae	*Muntingia calabura*	Fruit tree
higher dicots	Tiliaceae	*Triumfetta pilosa*	
higher dicots	Tiliaceae	*Triumfetta rhomboidea*	
higher dicots	Urticaceae	*Boehmeria nivea*	
higher dicots	Urticaceae	*Pilea microphylla*	
higher dicots	Verbenaceae	*Duranta erecta*	Ornamental – syn. *D. repens*
higher dicots	Verbenaceae	*Lantana camara var. camara*	Ornamental
higher dicots	Verbenaceae	*Lantana montevidensis*	Ornamental
higher dicots	Verbenaceae	*Stachytarpheta cayennensis*	Ornamental
higher dicots	Verbenaceae	*Stachytarpheta jamaicensis*	Ornamental
higher dicots	Verbenaceae	*Stachytarpheta mutabilis*	Ornamental
higher dicots	Verbenaceae	*Stachytarpheta x adulterina*	Ornamental
higher dicots	Verbenaceae	*Stachytarpheta x trimenii*	Ornamental
higher dicots	Verbenaceae	*Verbena incompta*	Ornamental
higher dicots	Verbenaceae	*Verbena litoralis*	Ornamental
monocots	Zingiberaceae	*Alpinia zerumbet*	?ornamental
monocots	Zingiberaceae	*Costus dubius*	Ornamental
monocots	Zingiberaceae	*Hedychium coronarium*	?ornamental
monocots	Zingiberaceae	*Zingiber officinale*	Food plant