

A risk assessment of the tropical wetland weed *Mimosa pigra* in northern Australia

Dave Walden,¹ Rick van Dam,¹ Max Finlayson,¹ Michael Storrs,² John Lowry¹ and Darren Kriticos³

Abstract

Information on the biology and management of mimosa, *Mimosa pigra* L., has been collated and analysed in a risk assessment in the regional context of northern Australia. The aim was to provide guidance for environmental managers and researchers to collate and assess relevant information to assist management decisions relating to areas at risk of invasion and consequences of invasion. The major wetland categories in northern Australia are briefly described and a summary of the effects of mimosa on native fauna, flora and socio-economic factors is presented. The current and potential distribution of mimosa in northern Australia is discussed, along with factors influencing establishment, density and distribution.

The prediction of the potential distribution compares annual rainfall zones with CLIMEX modelling, overlaid with potentially vulnerable wetlands and land tenure. These are discussed in the context of the current management of mimosa in northern Australia. Uncertainty and information gaps relating to the extent and effects of mimosa are also highlighted. An estimated 4.2 to 4.6 million ha of wetlands in northern Australia are under threat from mimosa, though the actual area of suitability within this range is unclear and dependent on further research. Resolving such uncertainty is seen as a priority task, as it will provide a stronger basis for strategic research and control activities.

Keywords: management, risk assessment, predictive modelling, weed invasion, impacts.

Introduction

Tropical wetlands are renowned for providing many values and benefits for people and for

supporting a diverse and plentiful biota (Finlayson and Moser 1991, Dugan 1993). There is also increasing pressure on such wetlands as human population increase and development impacts both the wetlands themselves and their catchments. Responses to such pressures have varied and as a consequence many wetlands have been lost and degraded.

The extent of invasion of wetlands has been described for some invasive species although often incompletely. Vital information on the ecological changes wrought by these species is often confined to a few isolated studies or to anecdotal evidence.

¹ Environmental Research Institute of the Supervising Scientist (*eriss*) GPO Box 461, Darwin, NT 0801, Australia <dave.walden@ea.gov.au>, <rick.vandam@ea.gov.au>, <max.finlayson@ea.gov.au>, <john.lowry@ea.gov.au>.

² Northern Land Council, PO Box 42921, Casuarina, NT 0811, Australia <michael.storrs@nlc.org.au>.

³ Forest Research, PB 3020, Rotorua, New Zealand <Darren.Kriticos@forestresearch.co.nz>.

Economic analyses of the losses caused by pest species are not common, and studies on the social and cultural impacts of weeds have not been done (Finlayson and Spiers 1999).

Given that weeds are an increasingly serious problem in tropical wetlands, there is a need for management prescriptions to be developed at several levels. Critically, for managers and users of wetlands, practical techniques and options are required that take into account local differences, priorities and resource levels. However, for localised effort to be effective, a strategic framework is required that provides the necessary options and places particular weed infestations and their control into a regional perspective. A means of ensuring that the above aspects are not forgotten is through the adoption of ecological or wetland risk-assessment procedures as the basis for effective weed management.

Within this context, information on the biology, ecology and management of mimosa, *Mimosa pigra* L., has been collated and analysed in a risk assessment of the weed in northern Australia. Much of the information for this assessment has come from northern Australia where mimosa has been seen as a major weed for more than two decades, and has consequently attracted substantial research and management attention (Cook *et al.* 1996, Douglas *et al.* 1998, Finlayson *et al.* 1998).

Project aims

The risk assessment was concerned with answering three main questions.

- What wetlands across northern Australia are at risk of invasion by mimosa?
- What are the likely consequences of mimosa invading these wetlands?
- What management actions are being undertaken or need to be undertaken to minimise the risks of further mimosa invasion across northern Australia?

Approach

Wetland risk-assessment framework. Over the last decade the concept of environmental risk assessment has developed and expanded from a narrow and precise analysis of quantitative ecotoxicological data to more general and qualitative/semi-quantitative analyses of environmental problems (Finlayson *et al.* 1999). This has led to the Ramsar Convention on Wetlands recommending a model for wetland risk assessment (Figure 1) coupled with advice on the deployment of early warning systems for detecting adverse ecological change in wetlands. The model provides guidance for environmental managers and researchers to collate and assess relevant information and to use

this as a basis for management decisions that will not result in adverse change to the ecological character of the wetland. Our objective has been to provide a framework for informed decision-making. Thus, it is not prescriptive.

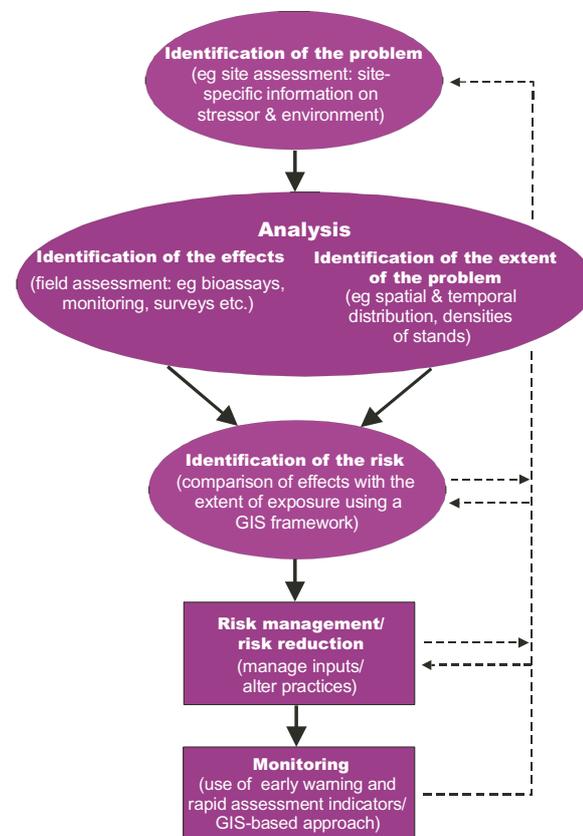


Figure 1. Wetland risk-assessment framework (adapted from van Dam *et al.* (1999)).

Identification of the problem

Advantageous features

Mimosa has many features that are generally considered 'advantageous' to a weed as follows.

1. Mimosa can withstand the anaerobic conditions of inundation and flooded soils by sprouting adventitious roots near the surface where they can take up oxygenated water (Miller *et al.* 1981).
2. If chopped down, mimosa will easily resprout from the stump (Wanichanantakul and Chinawong 1979). If mimosa is burnt, the foliage may become desiccated and fall, but up to 90% of mature plants and up to 50% of seedlings may regrow.
3. The plants mature quickly and can set seed in their first year of growth (Lonsdale *et al.* 1985). The seedpods are covered with bristles that enable them to adhere to animals and clothing, and to float on water for extended periods

(Miller *et al.* 1981). The seeds are also dispersed in soil and mud, adhering to vehicles and other machinery (Lonsdale *et al.* 1985). Livestock and native animals sometimes graze mimosa plants (Miller 1988) and pass the seeds in their dung (Miller and Lonsdale 1987).

4. The lifespan of the seeds in the ground depends greatly on their depth in the soil and the soil type, and may be up to 23 years in sandy soils (S.E. Pickering, pers. comm., in Lonsdale 1992).
5. Seed rate production has been measured between 9,000 and 12,000 m⁻² per year depending on the conditions (Lonsdale *et al.* 1988). The most productive plant observed in the field produced about 220,000 seeds per year (Lonsdale 1992).
6. Under the right conditions, mimosa grows quickly at a rate of about 1 cm per day, and infestations can double in area in one year. It can also withstand droughts (Lonsdale 1993).
7. Mimosa has low nutrient requirements and consequently can grow within a wide range of soil types including nutrient-poor sands, alluvial red and yellow earths, silty loams and heavy black cracking clays (Miller 1983).

Conceptual model

A conceptual model, based on known information on mimosa, and the potential ecological, cultural

and socio-economic impacts is shown in Figure 2. This formed the basis of the risk assessment.

The potential effects of mimosa in northern Australia

Effects on ecosystems

Mimosa poses an enormous problem for conservation. In the Northern Territory (NT), a largely intact natural landscape is being completely altered, with floodplains and swamp forest being covered by dense monospecific stands of mimosa, which have little understorey except for mimosa seedlings and suckers (Braithwaite *et al.* 1989). The severity of the impact of mimosa results from the following: (1) the high dominance by the invading species; (2) the gross change in vegetation structure; and (3) the conversion of a wide range of structural types of vegetation to a homogeneous tall shrubland (Braithwaite *et al.* 1989).

Very few studies have been done to determine the effects of mimosa on native flora and fauna. Unless cited otherwise the following information is summarised from Braithwaite *et al.* (1989).

Effects on native flora

Once established, mimosa is able to out-compete native herbaceous layer vegetation for light, moisture and nutrients, although the rela-

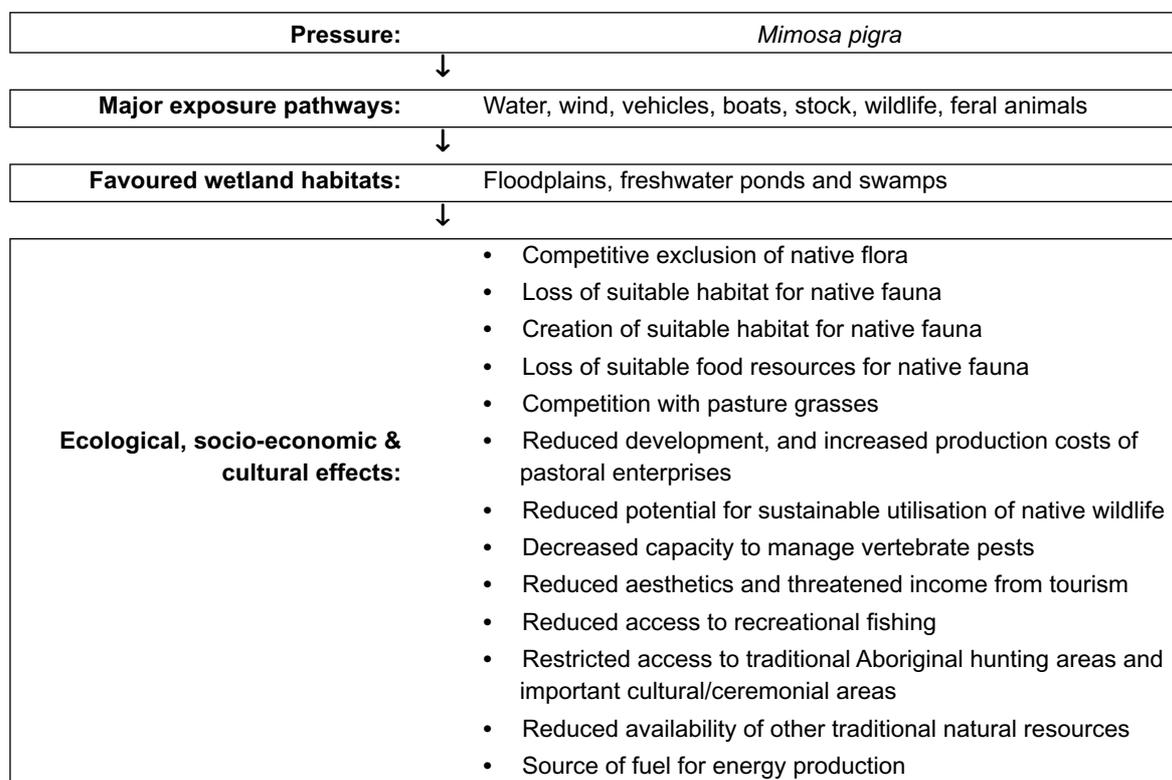


Figure 2. Conceptual model of *Mimosa pigra* in northern Australia.

tive importance of these three factors has not been determined. A comparison of incident light measurements beneath the mimosa canopy at two study areas found that the sedgeland sites received between 62% and 81% of the incident light when mimosa was present.

The *Melaleuca*-dominated swamp forests fringing the floodplains have a rather open canopy, and mimosa has also penetrated this habitat, preventing seedlings of the native forest trees from establishing themselves. Incident light measurements in this environment revealed that only 26% reached the ground flora with the additional presence of a mimosa canopy. Due to the demonstrated exclusion of native tree seedlings, it is proposed that the mature native tree canopy would eventually die out, and these swamp forests, like the sedgelands, would become mimosa-dominated shrubland. The light measurements were taken during the dry season when the weed has a relatively sparse canopy. The impacts could possibly be exacerbated in the wet season, when the denser canopy of a lush mimosa thicket may prevent around 90% of the incident light from reaching the ground.

Effects on native fauna

Effects on native fauna result from the dramatic floristic and hydrological changes brought about by mimosa invasion. Braithwaite *et al.* (1989) identified a number of species that were affected both adversely and favourably by mimosa invasion.

Birds

The abundance and species richness of terrestrial birds was positively related to the presence of mimosa. Waterbird abundance and species richness related negatively to mimosa. Treeless, species-rich, deep-water sedgeland is the prime habitat for waterbird populations, which rely on it for breeding and feeding. Further loss of this habitat through mimosa invasion would see an increasing negative impact on waterbird populations. The main rookery sites for species such as ibis, spoonbills and cormorants, and the main roosting and nesting sites of most of the raptors, are found in the wet forests (paperbark, riparian and monsoon). Destruction of these habitats would impact greatly on these and other similar bird species.

Mammals

Small mammals seemed to favour the dense mimosa canopy. The rodent *Rattus colletti* greatly favoured the Adelaide River mimosa sites, whilst the small insectivorous dasyurid *Sminthopsis virginiae* was particularly abundant in the Finniss River mimosa sites. Analyses showed that

mammal abundance, related positively to mimosa cover/abundance and negatively to woody species diversity. It is thought that these small mammals will probably survive only as long as the mimosa occurs in patches from which they can make forays into the surrounding sedgelands for food (Lonsdale and Braithwaite 1988).

Reptiles and amphibians

Mimosa appeared to provide an unsatisfactory microhabitat for lizards, as few were found in mimosa-dominated areas. Amphibians showed no distinct pattern with respect to mimosa.

Vulnerable species

Fauna

There are a number of species that are rare and/or have a limited distribution that may be threatened via habitat loss as a result of mimosa infestation. Northern Territory species identified by the Northern Territory Parks and Wildlife Commission's (PWCNT) list of threatened species, and the *Environment Protection and Biodiversity Conservation Act (1999)* include:

1. false water-rat, *Xeromys myoides*
2. yellow-rumped Mannikin, *Lonchura flaviprymna*
3. grass owl, *Tyto capensis*
4. red goshawk, *Erythrotriorchis radiatus*
5. a subspecies of yellow chat, *Epthianura crocea tunneyi*, now recognised as endangered (Garnett and Crowley 2000).

Flora

The herbarium of the PWCNT identified nine rare or vulnerable floodplain species (Northern Land Council 1991). Some taxonomic uncertainty and data deficiency still exist with these species, thus only the following species were recommended for inclusion at this stage (I. Cowie, pers. comm. 2002):

1. *Aldrovanda vesiculosa* L.
2. *Lemna tenera* Kurz.
3. *Monochoria hastata* (L.) Solms
4. *Goodenia quadrifida* (Carolin) Carolin.

Socio-economic effects

In addition to adversely affecting native flora and fauna, mimosa can also impact upon the activities of humans. It interferes with stock watering, irrigation projects, tourism, recreational use of waterways and the traditional lifestyles of Indigenous peoples. It can also smother pastures, reduce the available grazing areas and make mustering difficult (Miller *et al.* 1981), thus

reducing the development of pastoral enterprises in addition to increasing the production costs.

The potential extent of mimosa in northern Australia

Current distribution

In the NT, mimosa is found in most major Top End river systems from the Victoria River in the west (approximately 50 km from the Western Australia (WA) border), to the Phelp River in south-eastern Arnhem Land, and the Arafura swamp to the north-east. The size of infestations varies between river systems, with the largest infestations on the Adelaide, Mary and Finnis rivers and in the Daly River/Port Keats Aboriginal Land Trust. In February 2001, a small infestation of 800 to 1,000 plants was discovered at Peter Faust Dam, approximately 25 km west of Proserpine (just below 20°S) in Queensland (Chopping 2004).

Preferred habitats and environmental conditions

Mimosa has been introduced into most tropical regions of the world where it grows in comparatively open, moist sites such as floodplains, coastal plains and riverbanks (Lonsdale *et al.* 1985). In the introduced range, mimosa infests naturally or anthropologically disturbed places such as reservoirs, canal and riverbanks, roadside ditches, agricultural land and floodplains. In its native range, mimosa occupies similar habitats, especially in areas which have been disturbed, but usually occurs as small thickets or individual plants (Harley 1985).

Potential distribution in northern Australia

Mimosa has the potential to expand its area considerably in Australia. Miller (1983) made the conservative prediction that, except around dams and watercourses, mimosa would probably not be a major problem in regions with less than 750 mm annual rainfall (see inset of Figure 3).

Earlier attempts at predicting the potential distribution of mimosa in Australia using CLIMEX (Sutherst and Maywald 1985) have been further refined by Kriticos (Agriculture and Resource Management Council 2001) by incorporating the climate information with growth and stress indices. The current boundaries for the habitat suitability classes are somewhat arbitrary, being based on experience associated with the more subjective descriptions of habitat suitability.

Comparison of the predicted distribution based on the rainfall zone and southern latitudinal limit

(Figure 3 inset) and the 'suitable' category of the predicted distribution based on the CLIMEX model (Figure 3) indicated reasonable concordance. This is not unexpected, as the soil moisture indices, for example, would correlate with the higher rainfall.

Greenhouse effect implications

There are a number of climate change projections for northern Australia, depending on which climate scenarios are used. The greatest uncertainties in projecting climate changes are associated with the politico-economic issues affecting future global emissions of greenhouse gases. It is predicted that temperatures and possibly summer rainfall will increase over northern Australia. It is also predicted that extreme events will change in magnitude and frequency more rapidly than the averages (e.g. more very hot days, fewer frosts, more floods and dry spells) (CSIRO 1998, IPCC 2001).

Under these scenarios, the potential range of mimosa will likely be extended by climate change (Williams *et al.* 1995), with some inland areas becoming more favourable to its establishment. Increased flooding would most likely enhance its rapid spread; however, sea level rises may inundate and destroy some existing infestations in low-lying coastal areas (DASETT 1990).

Identification of the risks

Wetlands at risk of mimosa infestation

Given the broad scale of this assessment (i.e. across northern Australia), information from 1:250,000 digital topographical data (Topo250K data - AUSLIG 1999) were used to identify relevant wetland areas, as it was the only data set which was consistently available across the whole of northern Australia at a standard, useful scale. The wetland habitats represented in the Topo250K data by the classifications 'Land subject to inundation' and 'Swamp land' were considered as representing suitable mimosa habitat. This was supported by the fact that the majority of documented locations of mimosa in the NT occur on the above two wetland habitats.

Using the ArcView desktop Geographic Information System (GIS), the wetland types were overlaid on the potential distribution of mimosa in northern Australia based on (i) the >750 mm rainfall zones and (ii) the CLIMEX model (Figure 3). These represent the wetlands in northern Australia that may be at risk of infestation by mimosa. The area estimates are detailed in Table 1. The rainfall model of potential mimosa distribution provided a slightly more conservative estimate of the wetland

area potentially at risk of mimosa infestation than the 'suitable' category of the CLIMEX model, although the total wetland area using CLIMEX (i.e. wetland in 'suitable' + 'marginal' areas) was greater. However, further work is required to better define the largely arbitrary suitability categories used with the CLIMEX model.

Overall, it appears that approximately 4,000,000 ha of natural wetland habitat in northern Australia is potentially at risk of infestation by mimosa. However, it is acknowledged that actual habitat suitability will vary amongst these wetlands, and there will be areas that are more or less suitable for mimosa due to a range of factors including hydroperiod, soil type, local topography, plant communities and land use.

Nationally and internationally important wetlands

Within the wetland areas identified as being potentially at risk, there exist a number that are of particular ecological importance (Environment Australia 2001).

1. In the NT there are 21 important wetlands within the northernmost bioregions where

mimosa is present and still spreading (i.e. above 16°S). Three of the 21 sites are internationally important Ramsar-listed sites that include Kakadu National Park stages I and II, parts of stage III and the Cobourgh Peninsula. Twelve of the 21 sites already have mimosa infestations varying from minor to extensive.

2. In Queensland there are 121 important wetlands within the potential range of mimosa. Four of the wetlands are Ramsar-listed sites, and although they are listed as coastal areas, all have some freshwater habitat.
3. In WA there are 13 important wetlands within the predicted range of mimosa. Four of these are Ramsar-listed sites.

Land tenure implications

Land tenure may influence the likelihood of mimosa actually arriving at an area, and subsequently on the ease of establishment. It may also determine how the consequences of the threat and impacts of mimosa are perceived. For the purposes of this risk assessment three broad types of land use are identified:

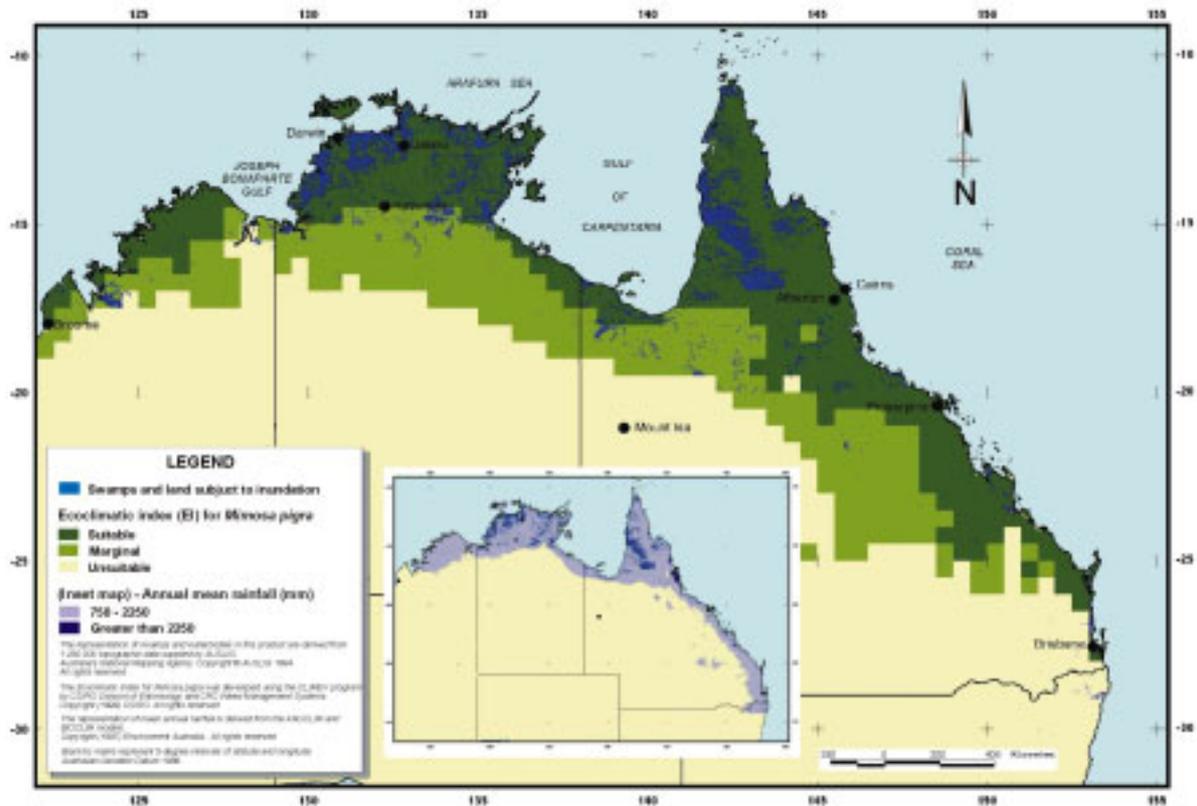


Figure 3. Wetlands across northern Australia potentially at risk of mimosa infestation, based on 1:250K topographical wetland data (see text) and potential distribution using CLIMEX. The inset shows those wetlands within the potential distribution of mimosa based on a mean annual rainfall greater than 750 mm and a southern latitudinal limit of 29°S.

1. cultural – Aboriginal lands and culturally or historically significant areas
2. ecological – heritage, national park and other conservation areas
3. economic – pastoral/agricultural lands and areas of concentrated tourism.

There are obviously overlaps among these broad categories. Culturally significant areas can have both economic value, such as supporting enterprises for Aboriginal economic independence, and gain revenue from tourism. Ecological areas are also often a source of revenue from tourism, and thus have an economic value, while many, including nationally important wetlands, also have considerable pastoral activity. There are also sites of cultural significance within ecological areas, with Kakadu National Park being a prime example.

Mechanisms of seed transport

Within the scope of this risk assessment it is only possible to generalise how different land tenure may influence the likelihood of establishment and colonisation of mimosa. To give some examples: pastoral properties could be considered to be at high risk if there is significant movement of stock, vehicles and machinery to and from the property; areas of concentrated tourism could also be at high risk if there is a large movement of vehicles and in particular fishing boats; Aboriginal lands could be at higher risk if animals were imported for food or for stocking toward an economic enterprise. All of the land-tenure types are at risk from seed importation by vehicles as both the Aboriginal and European populations of

northern Australia are highly mobile and vehicles (in particular four-wheel drives) regularly traverse between river catchments. All areas are also at risk as feral and native animals (including waterbirds) move between catchments.

Factors affecting colonisation

The major factor that affects the colonisation of mimosa is disturbance. Once the native or pasture vegetation is removed, mimosa seedlings can readily establish in the absence of competition. Disturbance could be caused by feral or domesticated animals, fire, agriculture or the type of disturbance associated with areas such as roadsides, quarries, logging areas and high-use recreation. Throughout the NT, mimosa largely infests and continues to colonise areas that are currently, or have been in the past, highly disturbed by feral or domesticated animals. Both Queensland and the NT also have vast pastoral cattle properties, and feral animals including buffalo, pigs, donkeys and horses remain in high numbers throughout much of northern Australia.

Tables 2 and 3 outline the areas of land-use types within the predicted range of mimosa as identified by the two models.

Consequences of the threat and impacts of mimosa

Although mimosa has broad-ranging impacts, the specific consequences of these are perceived in different ways according to the type of land use of a given area. These perceived consequences are listed in Table 4.

Table 1. Estimates of wetlands potentially at risk of mimosa infestation, using two predictive models of mimosa distribution.

Potential distribution model	Category	Wetland area (ha) ^a	Total (ha)
> 750 mm rainfall + southern latitudinal limit of 29°S	750–2,250 mm	4,216,855	4,231,154
	>2,250 mm	14,299	
CLIMEX	Suitable	3,959,800	4,628,000
	Marginal	668,200	

^a Wetlands are represented by ‘land subject to inundation’ and ‘swamp land’ from 1:250K topographical maps (AUSLIG 1999.)

Table 2. Areas of land use types within the predicted range of mimosa based on rainfall.

Land use	Area within lower rainfall zone (ha)	Area within higher rainfall zone (ha)	Total area (ha)
Aboriginal	1,311,214	1,775	1,312,989
Forestry	16,143	96	16,239
Nature conservation	519,806	3,023	522,829
Private lands	2,196,863	8,270	2,205,133
Reserved Crown	28,022	166	28,188
Vacant Crown	51,673	426	52,099

Table 3. Areas of land use types within the predicted range of mimosa based on CLIMEX.

Land use	CLIMEX – suitable category (ha)	CLIMEX – marginal category (ha)	Total area (ha)
Aboriginal	1,316,176	10,476	1,326,652
Forestry	15,165	< 1	15,165
Nature conservation	511,808	7,735	519,543
Private lands	1,963,397	61,1501	2,574,898
Reserved Crown	18,175	21,615	39,790
Vacant Crown	49,744	5,915	55,659

Table 4. Perceived consequences of the impacts of mimosa for different types of land use.

Land use	Consequences
Cultural	<ul style="list-style-type: none"> • Reduction of species and numbers available as traditional foods • Restriction of access to traditional hunting and gathering grounds • Contamination of sacred, historical and other culturally important sites • Reduced capacity for economic independence of Aboriginal people • Reduced status as a nationally important or Ramsar wetland
Ecological	<ul style="list-style-type: none"> • Reduction in biodiversity of flora and fauna • Loss of habitat for feeding, breeding and roosting of birds and bats • Restriction of access to watering holes for native animals • Provides protective habit for feral pigs
Economic	<ul style="list-style-type: none"> • Reduces available grazing land • Restriction of access to watering holes for stock • Interferes with irrigation projects e.g. access and siltation • Restricts recreational use of waterways e.g. fishing and tourism • Provides fuel for energy production

Uncertainty and information gaps

Extent of mimosa

1. The 1:250,000 scale topographic map information used in this assessment represents a broad view of identifying the wetland habitats in question. 1:50,000 data, for example, may define some of the smaller waterbodies.
2. For the purposes of this risk assessment, the classifications of *land subject to inundation* and *swamp land* have been used as suitable mimosa habitat. There may be other suitable areas such as rainforest margins, riparian zones and areas under irrigation that would not be represented by the classifications used. In addition, it cannot be assumed that all areas within these classifications will be suitable mimosa habitat, due to factors including hydroperiod, soil type, local topography, plant communities and land use. Greater understanding of these factors would need to be gained in more detailed, site-specific assessments.
3. There are also assumptions about what land-use practices promote invasion and/or establishment of mimosa, and to what extent. The issue of disturbance is probably the main issue, with natural versus non-natural disturbance further exacerbating the uncertainty.
4. While the current distribution of mimosa in the NT is reasonably well known, the actual area is uncertain and probably misquoted. The majority of mimosa infestations have been recorded, but there is a need for detailed mapping of the distribution and the density of the stands.
5. Another uncertainty is the precise relationship between climate change and the distribution of mimosa. It is possible to hypothesise about the likely influence of climate change based on projected changes in temperature, rainfall, seasonal and interannual variation and extreme events, but the actual effect and extent of these remains unclear. A sensitivity analysis using CLIMEX may be informative.

Effects of mimosa

1. There is a lack of quantitative data on the effects of mimosa on the native flora and fauna. The aspects of severe habitat alteration are acknowledged but the resulting effects on flora and fauna seem to be poorly understood.
2. There is a lack of quantitative data on the economic losses caused by mimosa.
3. The impacts on social and cultural values are recognised, but no studies have been done to determine the effects.

4. The assumptions of land-use practices influencing the extent of mimosa also apply to the effects. Again, due to the overlaps in land use, it is difficult to be certain what the effects and consequences of the impact will be, and how the tenants will perceive them.
5. There is scant information on the impacts of the control methods used for mimosa. The main concern here is for the large volumes of herbicides that have been used for control in the NT.

Management implications

Even before the discovery of mimosa at Peter Faust Dam in Queensland, there had been increasing interest in the mimosa problem by the Queensland and WA governments. Large areas of Queensland and WA are potentially at risk of mimosa invasion and many of these areas are often remote, difficult to access and lowly populated.

The Mimosa Strategic Plan (Agriculture & Resource Management Council 2001) has evolved over many years and represents the planning strategies to prevent further spread of mimosa in northern Australia and reduce the impacts of current mimosa infestations, coordinating government and Aboriginal agencies from the NT, Queensland and WA, as well as the CSIRO. The management programs in the strategic plan formed the basis of the recent funding submission to the National Weeds Program, where the seven components of the submission were developed to address the critical gaps in knowledge and operational capability to fully implement the programs.

The four programs of the mimosa strategic plan aim to:

1. inform and educate stakeholders and the community about mimosa, its adverse impacts and the strategy for its control
2. prevent mimosa from spreading to and impacting on new areas
3. further develop the knowledge base and methods for effective and efficient management of mimosa
4. reduce the current adverse impacts of mimosa infestations.

Information and education

Education and awareness are the most powerful and cost-effective forms of weed management. In the NT, members of the public have reported most of the new infestations. Very few new infestations have been discovered by systematic surveys. Perhaps the most significant information and education program on Aboriginal-owned lands has been the recent develop-

ment of groups of Indigenous rangers across the Top End (northern part) of the Northern Territory. Landholders and land managers have primary responsibility for weed management and they need to be trained in the eradication of new outbreaks and to develop effective weed-management plans. Communicating the best land-management practices that reduce the susceptibility of an area to mimosa invasion is also essential.

Prevention of spread

Perhaps the most important aspect of the prevention of spread is the ability to locate and eradicate satellite outbreaks before they become unmanageable. For areas not currently surveyed, increased surveys are planned for the state/Territory border areas at risk and other high-risk areas at the eastern and western limits of the current mimosa distribution. The risk of seed spread can be greatly reduced by ensuring that transport corridors remain mimosa free and that livestock to be transported are quarantined for several days. Vehicle, boat and machinery wash-down facilities may also be appropriate for some areas. It is important to note that the prevention of spread is largely dependent on the success of information and education programs.

It is also important to decrease the susceptibility of the land to mimosa invasion and establishment. This method of preventative management usually utilises the competitive qualities of wetland plant communities, and of course reiterates the needs for best land-management practices as mentioned earlier.

Research and development

Much of the research and development program focuses on the efficiency, methodology improvement and impact assessment of the control methods. The issues that are more relevant to this risk assessment are those that deal with research into the aspects of mimosa ecology that will ultimately aid in reducing the spread. These include, for example, the factors that limit distribution, causes of invasiveness, modes of dispersal, revegetation and competition species, and vulnerable habitats. As stated earlier, site-specific assessments of vulnerable habitat types involving factors such as plant communities, topography, hydrology, soil type and land use can be used as a valuable predictive tool for land management. Further research into the ecological impacts of mimosa control methods, in particular the use of herbicides, is also needed to assess the risks. Other important areas of proposed research include: 1) how to integrate grazing onto flood-

plains following the control of mimosa; 2) determining the factors that affect successful revegetation; and 3) how the timing of burning affects mimosa management.

Impact reduction

By definition, the impact-reduction program is primarily concerned with the control of mimosa in those catchments where large stands already occur, thus reclaiming the land for its intended use, and as such is largely beyond the scope of this risk assessment. Many thousands of hectares of land have been reclaimed due to the efforts of the various NT Government agencies, Aboriginal land councils/associations and other private land-owners or leaseholders. Although the risk assessment doesn't detail control options, the biological control program should be mentioned in the context of long-term management. The program has been running for over 20 years and, in that time, 13 agents have been released and more are being studied. Although the results have been variable, four of these have become effective herbivores of mimosa and are showing some impact on the population (CSIRO 2003). Apart from potential ecological impacts, traditional control methods are expensive, as continual follow-up control is needed in nearly all circumstances. For a limited amount of investment, biological agents can ultimately maintain mimosa at a level where the impact is lessened or minimal. Spread and growth of infestations can be greatly reduced and the technique is ideal for large and small, remote and inaccessible infestations.

Conclusions

Other than the considerable area of mimosa infestation in the NT (estimated at about 80,000 ha), a great number of other wetlands of northern Australia, including nationally and internationally important wetlands remain under threat from mimosa. The total area at risk is estimated at between 4.2 and 4.6 million ha. The actual area of suitability within this range is unclear and dependent on further research into the characteristics of and land-management practices in the habitats. Climate change due to the greenhouse effect will most likely see an increase in localised spread of mimosa and expansion of the predicted potential range in northern Australia.

Because the current area of mimosa in the NT is uncertain, it cannot be assumed that the available resources and control strategies are keeping pace with mimosa. The expanding human population and advancing climate change will most likely result in an increase in the spread of mimosa.

Without maintaining or increasing resources for mimosa management, it will continue to spread throughout the NT and eventually to parts of WA and Queensland. In addition to the considerable cultural and conservation value impacts, the NT losses include a component of its primary industry, tourism and recreational activity revenue for every year that mimosa is present. Similar infestation in other areas of northern Australia would likely see similar impacts.

The current estimated distribution of mimosa represents only about 1.8% of the estimated potential distribution. Although the control of large infestations is seen as important from a local perspective, the prevention of spread to clean areas must be given the highest priority. The preventative strategies of education and awareness, control of the deliberate or accidental movement of plants and seeds, surveillance and early intervention and the minimisation of ecological disturbance are essential in achieving the prevention of further spread.

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