Adaptive management of the invasive shrub *Mimosa pigra* at Gorongosa National Park

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1. **BACKGROUND ON MIMOSA**

Mimosa pigra, one of the 100 "World's Worst" invasive species (Global Invasive Species Database), is a highly aggressive shrub that poses a serious threat to biodiversity, water resources, and tourism at Gorongosa National Park. Mimosa is native to tropical America, but has invaded ecosystems worldwide including Africa, Asia, Pacific islands, and Australia, favoring a wet-dry tropical climate with at least 750 mm annual rainfall. Mimosa is well-established on the floodplains, pans, and waterways of Gorongosa, and may be poised to expand rapidly in the future if it is not effectively managed.

1. 1 Biological characteristics of *Mimosa pigra*

Taxonomic name: *Mimosa pigra* L.

Common names: *Mimosa* or *Giant Sensitive Plant* (English); *Columbi-da-lagoa* or *Malicia-de-boi* (Portuguese)

As a young plant mimosa grows as a single prickly stem, often as a ground creeper or prostrate form (Photo 1). Mature mimosa tends to be a branched shrub with rose-like thorns (Photo 2). The plant can reach a height of 3-6 m with a branching tap root extending 1−2 m deep. Leaves are green, feathery and fern-like, with the central leaf stalk being prickly and 20−25 cm long. Each leaf contains up to 16 opposite segments, each segment 5 cm long and divided into pairs of leaflets which fold up at nightfall or when touched or injured. The flowers are round, fluffy, pink or mauve balls 1−2 cm across (Photo 3). Each flower head produces a cluster of 1−30 seed pods which are 3−8 cm long and covered with dense hairs (Photo 4). The pods turn brown when mature and break into segments, which fall away from the pod leaving a skeletal outline. Each segment contains an oblong shaped seed 4−5 mm long and 2 mm wide (Walden et al. 1999).

Photo 1. Typical prostrate form of mimosa on Urema floodplain (R. Beilfuss).

Mimosa typically germinates as flood waters recede. Plants mature quickly and can set seed in their first year of growth (Walden et al. 1999). The first flowers tend to appear 6−8 months after germination. Flowers are bee-pollinated or possibly wind-pollinated. Seeding occurs approximately 3−6 weeks after the flower bud is formed.

Photo 2. Mature mimosa shrub (G. Howard).

Photo 3. Mimosa leaves, thorns, and flowers (R. Beilfuss).

Photo 4. Mimosa seed pods (R. Beilfuss).

The one seeded, hairy segment of mimosa pods are easily spread by humans, animals, and water. Segments may become attached to people's hair, shoes, and clothing. The segments stick to the fur of animals and can pass unharmed through their digestive tract. Seeds pods are buoyant, and are readily dispersed by flood waters and water currents.

The seeds have an extremely hard, often impermeable seed coat. Some are able to germinate as soon as conditions permit, while others may remain dormant for 15 years or more depending on the environment. Lonsdale (1983) counted more than 12,000 seeds per meter squared from soil in a mimosa-infested area in northern Australia. Seed production and plant life expectancy are highest on black cracking clays such as those found on the Lake Urema floodplains.

Mimosa's invasiveness is attributed to its aggressive growth. Once seedlings are established growth is rapid; one-year-old plants with a stem diameter of 2.5 cm often attain a diameter of 7 cm in the second year. In experiments in the Northern Territory of Australia, regrowth from young plants severed at ground level reached a height of 2.5 meters and covered an area of 6.3 square meters within 12 weeks (Land Protection 2006).

Mimosa often spreads with changes in land use and general "disturbance," including alterations to the hydrological regime (Mumba and Thompson 2006). However, mimosa's buoyant seed pods can be spread long distances in flood waters and establish on a range of soil types, enabling it to spread quickly from disturbed areas to natural floodplain systems (Photo 5).

Photo 5. Spread of mimosa along the Malinde Channel of the Kafue Flats, Zambia (G. Howard).

1.2 Ecological, social, and economic impacts of *Mimosa pigra*

Mimosa forms dense, monospecific, impenetrable thickets, 3−6 meters high, that establish on waterways, floodplains, and wetlands similar to those found in Gorongosa National Park (Photo 6).

Photo 6. Impenetrable mimosa thicket (Tran Triet).

Mimosa thickets significantly reduce available grazing areas for herbivores and eliminate most other species of grasses and forbs; converting floodplains into unproductive scrubland with reduced levels of biodiversity. Mimosa thickets block access to pans and waterways for wildlife, livestock, irrigation, and recreation purposes. Mimosa colonizes water courses, reducing water flow and increasing silt levels.

Mimosa will also invade agricultural areas, coastland, natural forests, planted forests, range/grasslands, riparian zones, shrublands, and urban areas. When large infestations spread to farmland, mimosa may reduce the area of cropland and grazing land and the overall carrying capacity of the land. Furthermore, it may block access to water sources for livestock. Mimosa may interference with the cultivation of other economically-important plants. For example, mimosa is able to outcompete young palm trees in immature oil palm plantations and cause a decrease in the production of palm oil (Praneetvatakul 2001).

There are numerous examples of the ecological, social, and economic costs of mimosa invasions from around the world. I have personally observed significant mimosa invasions in Thailand, Vietnam, northern Australia, Zambia, and Ethiopia over the past 20 years. In Thailand, mimosa chokes irrigation systems that supply rice fields, reducing crop yield and harming farming livelihoods. It also provides cover for of rats and crabs, which damage crops (Praneetvatakul 2001). In Vietnam, mimosa began invading Tram Chim National Park in the early 1990s, and now threatens the biodiversity of seasonally inundated grasslands in this highly unique and vulnerable remnant of the original Mekong Delta ecosystem. According to Triet et al. (2004), despite warnings from weed experts (including a study-visit of Vietnamese resource managers to mimosa problem areas in Northern Australia that I hosted in 1994), very little has been done in Tram Chim to control mimosa, and now the infestation has gone beyond easy management (Photo 7). At the current rate of spread, and if there is no improvement in weed control effort, mimosa is expected to invade all grassland areas of Tram Chim in less than five years, seriously jeopardizing the life of native plants and animals that depend on the native grassland habitat (Photo 8).

Photo 7. Mimosa thicket invading Tram Chim National Park in the Mekong Delta of Vietnam (Tran Triet)

Photo 8. Mimosa displacing floodplain grassland of Tram Chim National Park (Tran Triet).

In the Northern Territory of Australia, more than 80 000 ha of floodplains have been covered by mimosa, and it threatens Kakadu National Park, a World Heritage Site (Photo 9). River floodplains and swamp forests are threatened by dense thickets of mimosa, resulting in fewer numbers of birds and lizards, less herbaceous plants, and fewer native tree seedlings. Mimosa also prevents traditional food gathering by Aborigines on otherwise resource rich wetlands.

Mimosa has also invaded wetlands, floodplains, and waterways across much of sub-Saharan Africa. It is reported (Global Invasive Species Database) as a problem species in Ghana, Guinea, Kenya, South Africa, Swaziland, and Uganda. Photo 10 shows mimosa invasion to the Boyo Wetlands in Ethiopia, a lake-floodplain system very similar to the Lake Urema floodplain. A similar pattern was recently observed at Lake Chilwa in Malawi (M. Finlayson *pers. com.*)

Photo 9. Mimosa invasion covering 100% of a tropical floodplain in northern Australia (M. Finlayson).

Photo 10. Mimosa invasion in the Boyo Wetlands of Ethiopia. Mimosa invaded on recently deposited sediments along drainage lines, and spread laterally to the floodplain that surrounds Boyo Lake (R. Beilfuss).

The spread of mimosa across the Kafue Flats of Zambia has many important management lessons for Gorongosa National Park. Mimosa has become a dominant species in the Chunga Lagoon of Lochinvar National Park over the last 15 years (Photo 11). Before 1980 there was only one known infestation of approximately 2 ha, at the head of Nampongwe steam which flows from Chunga Lagoon (Mumba and Thompson 2005). By the mid-1980s it was spreading and covered approximately 100 ha (Thompson 1986). Thompson (1986) suggested that control measures were needed, but no steps were taken. A survey undertaken in 2003 indicated that this area had increased to around 2500 ha, with mimosa quickly replacing previous dominant grassland vegetation in the flats such as *Echinochloa stagina* and *Oryza longistaminata* (Photo 12) (Mumba and Thompson 2005). Most recent reports (G. Howard *pers. com.*) indicate the mimosa infestation at Lochinvar now covers more than 3000 ha. G. Howard also reports that mimosa is now spreading far from Chunga lagoon along the main floodplain of the middle Nampongwe stream (an area that was "looking very healthy at the

end of the dry season in 2006') and mimosa is expanding as well in Blue Lagoon National Park on the northern side of the Kafue Flats.

Photo 11. Solid thickets of mimosa on the periphery of Chunga Lagoon in 2003. Mimosa has reduced access to floodplain grazing lands for endemic Kafue lechwe and Vulnerable Wattled Cranes (R. Beilfuss).

Photo 12. Dense mimosa thickets on the border of Chunga Lagoon, which now cover more than 2500 ha (R. Beilfuss).

Although an action plan was drafted to control mimosa at Chunga Lagoon, aimed at employing local laborers to hand cut and remove the shrubs, and donor funding was secured, the Zambian Wildlife Authority (ZAWA) and the Star of Africa Tourism Camp chose not to implement the plan and the invasion continues to expand (Photo 13). Only recently has a serious effort been launched to combat the dense mimosa thickets, which are "a huge problem to control" (G. Howard *pers. com.*)

Photo 13. View of Chunga Lagoon from the 5-star "Star of Africa" lodge in Lochinvar National Park, blocked by mimosa (R. Beilfuss).

2. STATUS OF *MIMOSA PIGRA* AT GORONGOSA

Tinley (1977) makes only brief mention of mimosa in his comprehensive ecological study of Gorongosa. Tinley recorded the presence of mimosa in the ephemeral mudflat annual communities that occur on the edge of receding Lake Urema waters, and noted that "mimosa is a favored browse food and only attains shrub growth form during inundations; the remainder of the time it assumes a prostrate growth form in response to heavy utilization by herbivores."

Tinley monitored 30 m^2 quadrats in each of 18 1-hectare sampling sites (total of 540 m^2 quadrats) covering the *microperennial Cynodon-Digitaria lawn grasslands* south of Lake Urema near the Sungue inflow channel. The prostrate form of mimosa was recorded in only 16 of 540 m^2 quadrats, with a 1% relative frequency. However, the sampling approach used by Tinley (transects along a catenal sequence of increasing moisture) may have under-sampled mimosa in its preferred habitat at the edge of the inundation zone. Among the woody saplings sampled along these transects, mimosa was clearly the dominant species (95% relative density). Mimosa was not recorded in any of the other floodplain grassland associations sampled, which included *saline grassland*; *Setaria floodplain grassland*; *Echinochloa stagnina marsh grassland*; *Vetiveria nigritana tall grassland*.

Tinley's accounts suggest that mimosa has certainly been present around Lake Urema for decades, but was not a problem species due to intense herbivory (and likely corresponding trampling) and perhaps other, unknown factors.

Preliminary field assessments during September to November 2007 suggest that mimosa now occurs throughout the floodplain grasslands that form a ring around Lake Urema. It typically occurs in prostrate form, 10-20 cm in height, with taller growth up to 1.5 m height along drainage lines. It varies in density from a few shrubs to hundreds of shrubs per hectare, and is the dominant non-graminoid ground cover around Lake Urema (Photo 14). Mimosa occurs at highest density in the *Cynodon-Digitaria* short-grass associations, where it appears to be expanding. It also occurs at lower density in the *Echinochloa-Setaria* medium-grass

associations on the floodplain. Mimosa is sparse or absent in floodplain areas where dense stands of *Acacia xanthophloea* fever trees have established.

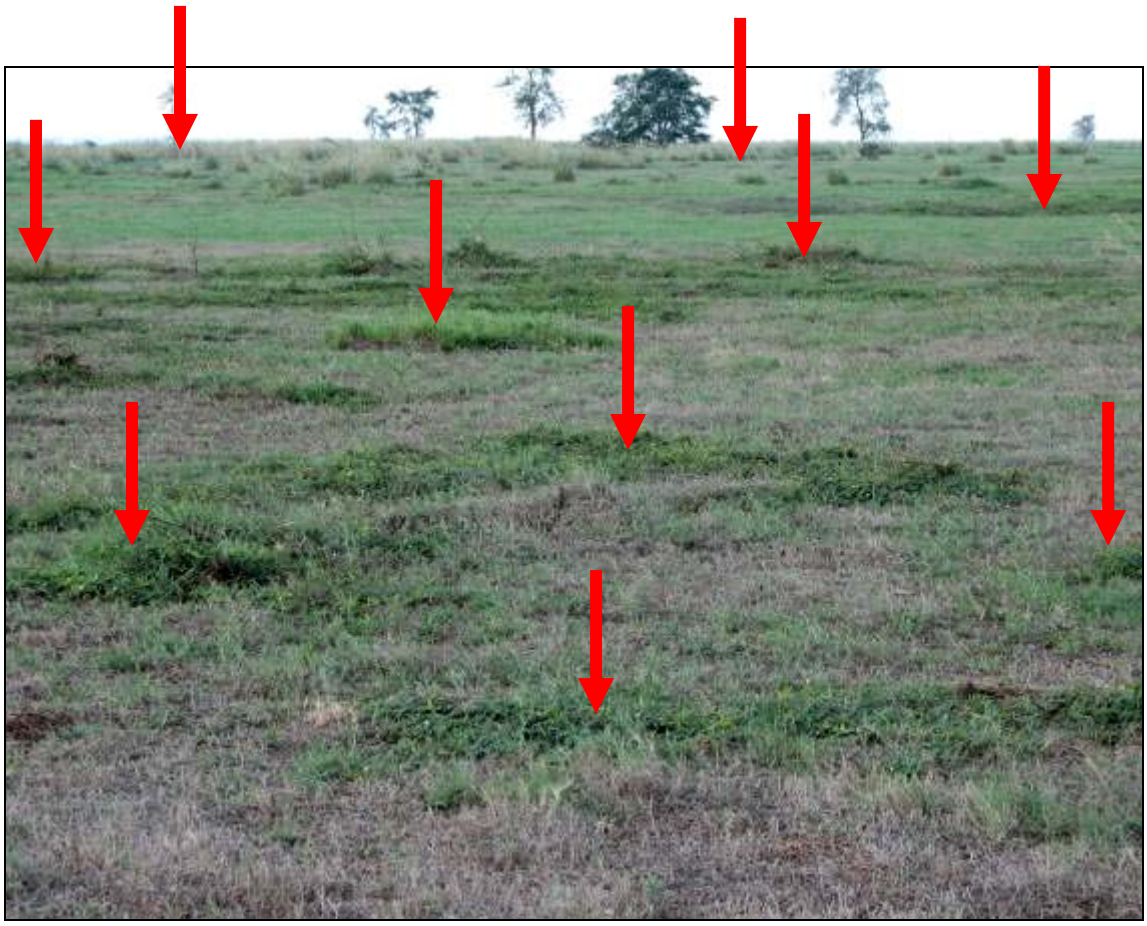
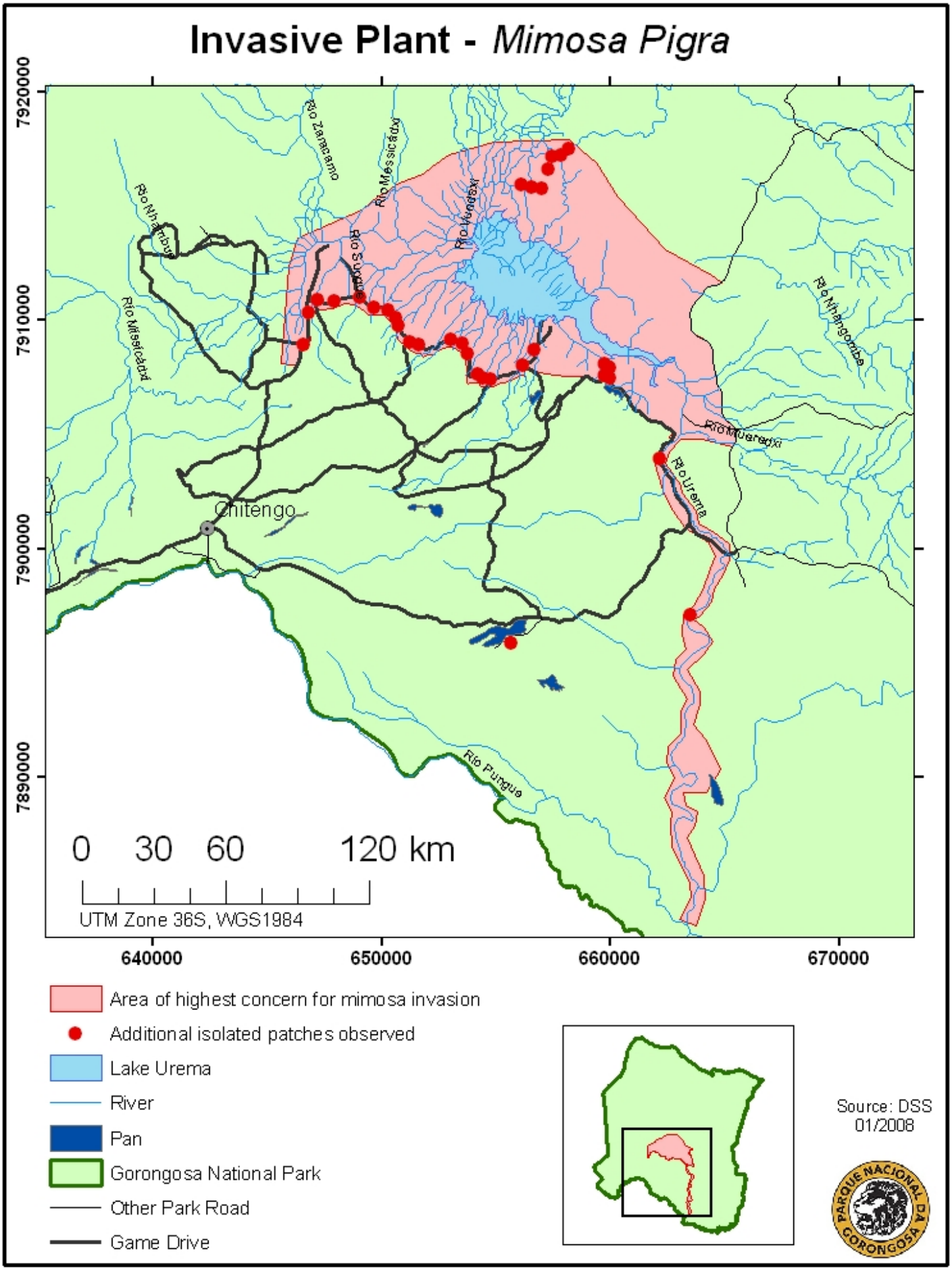


Photo 14. Mimosa prostate clusters along Picada 4, extending 100s of meters onto the floodplain towards Lake Urema. These clusters are capable of forming an impenetrable thicket over vast areas (R. Beilfuss).

Within the Chitengo trails system that can be easily monitored by road, mimosa is found along almost the entire length of Picada 4 that dissects *Cynodon-Digitaria* short-grass associations, on both sides of the road (Photo 15). Mimosa occurs in small isolated patches on the eastern floodplains opposite *Casa dos Leões,* becoming increasingly dense near the intersection of Picadas 4 and 6 and continuing to the interaction of Picadas 4 and 8. The only observed gaps in distribution correspond to dense stands of *Acacia xanthophloea* and *Faidherbia albida*, and some of the tall, unburned patches of *Setaria* floodplain grassland. Mimosa also occurs on *Echinochloa*-dominated floodplains near *Miradouro dos Hipopótamos* and on the edge of the larger pans, including Lago Mareza (Picada 12), *Lago Nhamutengo* (Picada 4), and *Lago do Paraiso* (Picada 11)

Map 1 shows the generalized distribution of mimosa at Gorongosa National Park. Further monitoring is needed to confirm whether mimosa is present in any of the other major pans along the trail system, especially *Lago Inhatite* and *Lago Nhansato*, or the *Rio Mussicadzi* and *Rio Sungue* channels. The species has not been observed in these areas to date.

A permanent plot of 1256m^2 (20m swept radius around a permanent rebar) was sampled to establish a baseline estimate of mimosa cover in an area where the species has recently established. It is an easily observed area at the intersection of Picada 4 and 3 (GPS: S18º


Invasive Plant - Mimosa Pigra
7920000
7910000
7900000
7890000
640000
650000
660000
670000
Rio Zamacamo
Rio Messicádzy
Rio Vungazi
Rio Nhambyi
Rio Sungue
Rio Messicádzi
Rio Nhangombe
Rio Muerradzi
Rio Urema
Chitengo
Rio Pungue
0 30 60 120 km
UTM Zone 36S, WGS1984
Area of highest concern for mimosa invasion
Additional isolated patches observed
Lake Urema
River
Pan
Gorongosa National Park
Other Park Road
Game Drive
Source: DSS 01/2008
PARQUE NACIONAL DA GORONGOSA

54.172'; E034º 26.112'). For each mimosa patch observed, the distance from center rebar and compass direction was recorded and the cover (rectangular area) was estimated. Total cover of mimosa in the sample plot is 1.4% (Table 1).

Photo 15. Mimosa prostrate growth form along Picada 4 in Cynodon-Digitaria grassland (R. Beilfuss).

Table 1. Patch size and location of *Mimosa pigra* in an experimental monitoring plot (1256 m^2) on the Lake Urema floodplain.

Orientation from center (degrees)	Distance from center (m)	Patch dimensions (m)	Patch area (m^2)
80	10	1.7 x 1.4	2.4
84	8.5	2.1 x 1.7	3.6
85	13.5	1.6 x 1.3	2.1
92	16	2.1 x 1.9	4.0
256	15	5 x 1.1	5.5
Total area			17.5

Other plots in this same region range from near absence to >50% cover (Photo 16). Additional sampling quadrats will be established for areas where the species has been established for a longer time period, with repeat measurements to determine to changes in species cover and density over the annual wet and dry cycle

Photo 16. Dense mimosa cover on floodplain at end of dry season (R. Beilfuss).

3. *MIMOSA PIGRA* MONITORING AND CONTROL PROGRAM

3.1 Is *Mimosa pigra* a problem invasive species at Gorongosa?

The evidence is inconclusive, but several factors suggest that Gorongosa National Park Management should take urgent action to learn how to best control mimosa pigra:

1. The species is widespread around Lake Urema and very dense in the *Cynodon-Digitaria* short-grass associations that form important grazing lands for my herbivores.

2. Although historical data are insufficient to quantify the change in density of mimosa over the past 40 years, these data and other anecdotal evidence suggests that mimosa is expanding significantly, especially in the *Cynodon-Digitaria* short-grass associations.

3. The density of herbivores on the Lake Urema floodplain is greatly reduced relative to historical conditions. There is no evidence of significant herbivory on mimosa at present. This reduced grazing pressure has enabled the species to photosynthesize throughout the year, and its mostly prostrate growth form suggests that most of the mimosa energy has been allocated to subsurface growth, establishing dense rooting networks.

4. There is evidence that a recent fire (probably during 2006) top killed many mimosa patches, while stimulating basal regrowth (Photo 17). Although individual fires do not kill the species, repeat annual fires may reduce plant vigor or eliminate some patches, and will slowly deplete the seed bank. However, the floodplain area between Picada 4 and Lake Urema remains fairly green and vigorous during the dry season due to high water table conditions, and will not burn regularly without managed fires (see below).

5. As evidenced throughout the world, mimosa can remain in slow-growing prostrate form for many years before expanding rapidly into dense impenetrable thicket (hence M. Finlayson described mimosa as the “Rip Van Winkle” of the plant world).

Photo 17. Mimosa shrub that was top killed by fire during previous growing season, as evidenced by large number of thick, dead stems. Note vigorous regrowth at the base. (R. Beilfuss).

6. The rapid spread of mimosa after a long quasi-dormant period is often observed in response to changes in hydrological conditions on floodplains. Many scientists suggest that the Lake Urema system is already drying, which could trigger a mimosa response (e.g., Kafue Flats in Zambia). Alternatively, an altered runoff and sediment regime resulting from the land use change and deforestation on Gorongosa Mountain, the Midlands, or Cheringoma escarpment could result in the rapid spread and infestation of mimosa (e.g., Boyo Wetlands in Ethiopia).

7. There are severe negative consequences of a mimosa infestation around Lake Urema for wildlife carrying capacity, access to water resources, and tourism development, and the option of "doing nothing" entails great risk. These negative effects have been recorded repeatedly throughout the world in floodplains similar to the Lake Urema system. Several websites have been established to document these impacts

3.2 Monitoring and control plan

In response to these concerns, a mimosa monitoring and control program is urgently recommended. The program should commence in the *Cynodon-Digitaria* short-grass associations along Picada 4, with emphasis on floodplain areas on Picada 4 between Picada 6 and Picada 2 intersections (10.3 km), where the threat to tourism, wildlife, and the natural structure and function of the floodplain is of greatest concern.

Permanent monitoring plots should be established to evaluate change in density and cover of mimosa over a two-year evaluation period in response to the following management treatments:

1. Fire
2. Herbicide
3. Manual removal
4. No action (monitoring only)

3.2.1 Fire management

Procedure and timetable:

1. Establish four 1-ha burn treatment plots along Picada 4. Mark the corners of each plot with permanent rebar and GPS position. March 2008.
2. Measure baseline density and cover of mimosa in each plot. April 2008.
3. Conduct annual burn during the mid-dry season as soon as conditions are suitable to carry hot fire. August 2008.
4. Measure density and cover of mimosa in each plot at the end of the dry season and compare to other treatments. November 2008.
5. Repeat burn treatment during dry season in second year. August 2009.
6. Repeat measurement and evaluation procedure at end of second year. November 2009.

Justification:

As noted above, there is evidence that mimosa growing along Picada 4 was top-killed by fires during the previous growing season, but in all cases resprouts occurred next to dry burned stems. We will test if repeated annual burning of the same patches causes the mimosa to die-out over time or show signs of significantly reduced vigor. Because there is limited grassy understory in dense thickets of mimosa, it is difficult to destroy infestations with fire once they become well established. Therefore, this prescribed burning program must be implemented urgently while the species remains in its present, prostrate growth form within heavy grass cover that can carry fire. Although mimosa seeds on the soil surface are also destroyed by fire, germination of seeds from the seed bank, within 5 cm of the soil surface, may be enhanced by this control program. It may stimulate seed germination due to the removal of seed coats (Miller and Lonsdale 1992, in Walden *et al*. 1999). Therefore it is important to continue the controlled fire experiment even if all the mimosa shrubs are eliminated, to prevent new resprouts from establishing.

3.2.2 Herbicide application

Procedure and timetable:

1. Establish four 1-ha herbicide treatment plots for along Picada 4. Mark the corners of each plot with permanent rebar and GPS position. March 2008.
2. Measure baseline density and cover of mimosa in each plot, and flag each patch for identification by herbicide team. April 2008.
3. Herbicide all above ground foliage of mimosa. A locally available herbicide suitable to woody species control with foliar spray or stump application will be used (the herbicide "Access" or comparable). April 2008.
4. After two weeks, evaluate results of herbicide treatment and repeat herbicide of any live mimosa foliage. May 2008.
5. Measure density and cover of mimosa in each plot (herbicide top-kill effectiveness and resprouting) at the end of the dry season and compare to other treatments. November 2008.
6. In addition, herbicide all know isolated patches of mimosa, including especially the eastern floodplains opposite *Casa dos Leões* where mimosa has just established at low density, and small pans around Gorongosa NP (including Lago Mareza (Picada 12), *Lago Nhamutengo* (Picada 4), and *Lago do Paraiso* (Picada 11). Record all treatment locations with GPS. Check effectiveness of herbicide treatment after two weeks, and repeat treatment as needed. April-May 2008.
7. Repeat herbicide treatment of plots (including 2-week recheck) and isolated patches of regrowth during second year. April-May 2009.
8. Repeat measurement and evaluation procedure at end of second year. November 2009.

Justification:
Herbicides are widely used to control mimosa, especially in Australia. Herbicide should be applied during the active period of growth of the mimosa and before any seed mature. In Australia, this is during the wet season (Lonsdale 1988, Miller 1988, in Walden *et al*. 1999). Ground-based herbicide application methods include direct injection, foliar/basal bark spraying, and soil application (Walden *et al*. 1999).

3.2.3 Manual removal by cutting

Procedure:
1. Establish four 1-ha manual cutting plots along Picada 4. Mark the corners of each plot with permanent rebar and GPS position. March 2008.
2. Measure baseline density and cover of mimosa in each plot, and flag each patch for identification by manual cutting team. April 2008.
3. Manually remove all above ground foliage of mimosa as soon as access is possible following the wet season. The crew should be provided with thick gloves to avoid thorns, and should attempt to pull out the roots of each patch when soils are still damp. April 2008.
4. After two weeks, evaluate results of manual removal and remove any additional live mimosa foliage that was missed. May 2008.
5. Measure density and cover of mimosa in each plot (resprouting) at the end of the dry season and compare to other treatments. November 2008.
6. Repeat manual cutting of plots (including 2-week recheck) during second year. April-May 2009.
7. Repeat measurement and evaluation procedure at end of second year. November 2009.

Justification:
Manual removal takes advantage of unskilled labor and readily available equipment. However, it provides only temporary control. Hand weeding may be effective for controlling seedlings in crops. Seeds should be collected and burnt before weeding commences. Roots should be removed and destroyed. Long handled cutters, axes and machetes may be used but any stumps left will resprout unless herbicide is applied immediately after removal (Thamasara 1985, in Walden *et al*. 1999). Methods that cut plants off at ground level or above (such as slashing or chaining) result in resprouting and will not control mimosa. Blade ploughing is one method of physical control that cuts the plant off below ground level. It was found to be very effective in preventing mimosa resprouting.

3.2.4 No action (monitoring control plots)

Procedure:
1. Establish four 1-ha no treatment (control) plots along Picada 4. Mark the corners of each plot with permanent rebar and GPS position. March 2008.
2. Measure baseline density and cover of mimosa in each plot. April 2008.
3. Measure density and cover of mimosa in each plot at the end of the dry season and compare to other treatments. November 2008.
4. Measure density and cover of mimosa in each plot at the end of the dry season and compare to other treatments. November 2008.

Justification:
Provides clear baseline information about status and spread of mimosa without any control action. May also provide insights about the impact of herbivory on mimosa, including the possibility of increasing impact of browse over time as wildlife populations further recover in the park.

3.2.5 Other recommended actions

At the end of the second year (November 2009), all the treatments will be evaluated to determine the most effective and feasible course of action to be implemented on a large scale. For all plots, we will record any observations of herbivory or other ecological activity in the plots throughout the year and during the field measurements at the end of the dry season. Ongoing reconnaissance throughout the park is important to ensure that any other isolated infestations are identified and targeted before they expand to uncontrollable levels.

It is recognized that combinations of treatments may be part of the control program---for example, a cutting and burning treatment, or an herbicide and burning treatment. The scope of this first experimental program is to try to understand specifically the growth response following each of these management treatments. The ideal scenario is that the infestation can be controlled with fire until herbivore numbers have recovered adequately to maintain the mimosa with browsing activity. Although fire is ineffective for managing mimosa shrubs once they form dense thickets, it may be effective while they are in the more widespread, prostrate growth form. Herbicide and manual cutting operations are much more labor intensive and costly options, and combination treatments even more so.

This experimental program is based on the assumption that mimosa will continue to spread in its prostrate form but will not undergo rapid transformation into thicket over the study period. If sudden expansion or growth of mimosa is observed during 2008, more drastic measures must be immediately implemented. These should be based in part on results of the experimental treatments, if available, and in part on comparable experience from the region.

Mimosa control efforts recently implemented for the Kafue Flats illustrate a comprehensive program involving a combination of treatments (G. Shanungu *pers. com.)*. Forty field workers from surrounding local communities are employed to physically remove the mimosa. Mimosa is first cleared at the invasion front, aimed at eradicating isolated "founder" populations and preventing further spread, followed by efforts focused on the larger well-established infestations. The workers first remove any mimosa seeds and burn them to prevent entry into the seed bank. For thicker stands of mimosa where hand picking of seeds is difficult, plants (or thickets) are cut to ground level using machetes and the cut stems with foliage are stacked, dried, and burned. Burning exposes the stumps and opens the areas for easier access—the stumps are then uprooted by hand or with the use of mattocks, stacked to dry for a period of 2-3 weeks, and burned. Burning is found to destroy any seeds near the soil surface, and helps to break the dormancy of the seeds in the seed bank, causing seedlings to sprout after a few weeks (on average two weeks after removal and burning). These seedlings are then easily removed from cleared areas during follow-up action, further depleting the seed bank. All areas are checked regularly to clear any regrowth of mimosa in target areas.

Chemical control is also under consideration for the flats, aimed at following-up the physical removal process with the herbicide treatment (i.e., Glyphosate) on resprouts and seedlings after the annual floods recede. The control team is concerned about the ecological sensitivity of the area, however, and has decided not to apply herbicides on a large scale pending the results of an Environmental Impact Assessment (EIA) are reviewed.

Results from the Kafue Flats control program thus far indicate that native vegetation is growing back in cleared areas, most notably the herb *Ambrosia maritima* and grass species such as *Cynadon dactylon.* Kafue lechwe have been observed utilizing areas now cleared of mimosa.

Such an intensive program is not justified for Gorongosa at present, but conditions can change and must be regularly monitored.

Educating local communities about mimosa impacts and spread could be an important tool for identification and control of mimosa in the buffer zone.

Restricting the movement of vehicles, soil, and sand from infested areas is important to prevent the spread of mimosa seeds.

3.2.6 Comments on biological control (possible control method in the future)

Although still under development, biological control is being considered as a long term management option in some areas, including the Kafue Flats (G. Shanungu *pers. com.).*

PIER (2002) reports: "Six natural enemies have been released in Australia following rigorous host-specificity testing, but have not yet had any discernible effect. Four of these have also been released in Thailand. The six include two seed-feeding bruchid beetles, one stem-feeding chrysomelid beetle, two stem-boring moths and, in January 1992, a flower-feeding weevil."

Cronk and Fuller (2001) report: "For long-term control, biological methods are probably the most cost-effective considering the extent and ecology of this species. Palatability to higher animals is low, but in its native range it is attacked by more than 200 species of insect herbivores and fungal pathogens. The first insects introduced to Australia as controlling agents were the seed-feeding beetles *Acanthoscelides quadridentatus* and *A. puniceus* (Bruchidae) from Mexico. They were released in Australia in 19845 and 1985, respectively, but have not attained high population densities and have had little impact on seed production. Two stem-boring moths, *Neurostrota gunniella* (Gracillariidae) and *Carmenta mimosa* (Sesiidae), were released in Australia in 1989; of these, *N. gunniella* established readily. The young larvae mine leaf pinnules and the older larvae tunnel in the stems, causing them to die. *Carmenta mimosa* complements the action of *N. gunniella* by tunneling stems of larger diameter. Other important insects currently being tested for their host specificities in Mexico and Australia are the seed- and flower-feeding weevils *Apion* sp., *Chalcodermus serripes*, *Sibinia fastigiata*, *S. ochreosa*, *S. pervana* and *S. seminicola*.

"Two fungal pathogens, *Phloeosporella* sp. (Coelomycetes), and a rust, *Diabole cubensis* (Uredenales), severely debilitate *Mimosa pigra* in Mexico. *Phloeosporella* sp. attack leaves, branches, main stems and seed pods, causing leaf fall and cankers of the stems and leading to ring barking and die-back. *Diable cubensis* causes chlorosis in stems and leaves resulting in premature leaf fall. Both fungi are attacked by hyperparasitic fungi in their native range and it seems likely that their effect on *Mimosa pigra* could be even more damaging in Australia if they were to be introduced without their natural enemies. These fungi are under investigation in Mexico and Britain."

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How to attack *Mimosa pigra* on a grand scale

The successful *Mimosa pigra* control program on Melaleuca Station in the Northern Territory is the result of a practical, reasoned and planned approach to tackling a large-scale infestation. The lessons learnt over the past five to six years provide valuable insights in the way both large and smaller-scale infestations of mimosa and other damaging weeds can be tackled.

Mimosa pigra growing wild. By 1993 the weed covered 10,000 ha of Melaleuca's floodplain

Tony Searle, Manager, Melaleuca Station, Mary River District, NT.
Richard Fell, Tropical Savannas CRC, Northern Territory University, Darwin.

Melaleuca Station lies in the Mary River catchment approximately 100 km east of Darwin in the Northern Territory. It experiences a monsoonal climate with an average annual rainfall between 1300 and 1600 mm. The station was subdivided from Point Stuart Station in the early 1980s to form a 300 km^2 property used for the purpose of domesticated buffalo production. Three other such 'buffalo blocks' were formed at the same time.

History of the *Mimosa pigra* invasion

In the early 1980s mimosa was already established on the property. It was a very small infestation and control only took two men two days. However, by 1993, the mimosa had spread to cover 10,000 ha of the flood plain. This was a very large infestation and meant that almost 33 per cent of the property was not available for production. At this time, the property changed hands and a mimosa control program began.

The Sampan Project saw the Northern Territory Government take initiatives under the *Noxious Weeds Act* to control mimosa on navigable channels of the lower Mary River. On Melaleuca, 2000 ha in the Red Lily 1 paddock were cleared of mimosa.

The decision to act

In 1995 a new manager was faced with a restricted carrying capacity on the flood plain. Mimosa still covered 8000 ha, and the 2000 ha cleared by the government program were in need of continuing maintenance to keep them mimosa-free. It was decided to tackle the problem in a systematic and planned way, building on the good work already started. A proposed five-year control plan including a detailed budget was put to the directors of the company that owned Melaleuca in 1995. The proposal was accepted and the program started in 1996. As of November 2000, the 2000 ha originally cleared as part of the Sampan Project remains free of mimosa and is back in production. Another 3000 ha are under various stages of treatment, of which 2000 ha are used for dry-season cattle production at a capacity of one beast to every two hectares (1:2 ha).

Mimosa control program

The aim of the mimosa control program is to:

- Maintain the 2000 ha area that has already been cleared of mimosa in Red Lily 1 and return it to production.
- Clear the country closer to the homestead and work downstream along a line in 1000 ha blocks. The line was selected early in the program and stretched from Red Lily 1 to Rumby and Ackerie Plains, and covered a further 3000 ha on top of that already cleared.
- Clean up these areas and have all 5000 ha back into production in five years.

The program is based on a year-by-year approach.

Year 1

A 1000 ha area of old-growth mimosa is selected and in December a 100 metre perimeter around the area is sprayed.

Year 2

The perimeter is chained, stick raked and burnt. In October the whole 1000 ha area is burnt inwards from the perimeter. This has the effect of opening the country

up and saves on one year of spraying. Floodwaters then control the regrowth through the suppression of any seedlings that germinate after burning.

Year 3

The whole area is chained in July, or when the floodwaters recede and machinery can gain access. The first bulk spray over the whole area to control regrowth takes place in December. This is done meticulously using a run-by-run approach from fence line to fence line so that no plants are missed.

Year 4

The area is now classed as 'clean country' and is stick raked and bulk sprayed once again. Grasses are planted in around May. Particular attention is paid to watercourses so that seed can be spread through water movement in the wet. Species planted depends on what is available as seed or runners. Choice of species is a critical factor in ensuring that the area is revegetated, thus becoming productive once more.

Year 5

Treatment is similar to Year 4. Another bulk spray may be done if required and perhaps another stick rake, if the season permits.

Year 6

The area is grazed lightly for a short period and attention is paid to any regrowth areas. The country is now essentially clear of mimosa.

Progress: maintaining the pressure

Some unforeseen problems have been encountered throughout the program. As water runs both ways on the flood plain, mimosa seeds can be moved in two directions. Control of regrowth therefore takes more time than originally envisaged.

As more country is cleared, the effort required to maintain these areas also increases. Time, effort and resources are then not available to clear more old-growth areas.

The fifth year of the program is largely on schedule. The last 1000 ha on Rumby Plain were burnt in late October 1999. The 2000 ha in Red Lily 1 are being grazed and the other 2000 ha on Ackerie and Rumby Plains are now in the maintenance program

The program aimed to have an additional 1000 ha start the process in 1996, however, this did not end up being feasible. 2000 ha went into Year 3 of the program as outlined above, and additional areas were cleared in 1997, 1998 and 1999 to bring up the total to 5000 ha under treatment at the present time. Thus the program has slipped a year or so from the original targets, however, the full importance of maintaining the pressure on the cleared areas has become well reinforced.

Chemical control

Spraying efficiency in the mimosa control program has improved through experience. Application rates, spraying conditions and delivery of chemicals have been modified over time.

Application rates

The following chemicals and application rates are used for the mimosa control program on Melaleuca:

Task	Chemical	Rates
Burning	Napalm	label rate
Bulk spraying	Brush-off	50% label rate (see below)
Spot spraying	Star Rain	label rate

Given that recommended chemical rates are for old-growth mimosa, trials have been run in conjunction with chemical companies to determine the rates needed for mimosa regrowth. These indicated that regrowth can be killed effectively at 50% of the label rate.

Spraying conditions

Air and ground conditions have to be right for an effective kill. Spraying must be done on the right day, at the right time and in the right conditions. In particular:

- the temperature should not be over 35°C; and
- spraying should not be done in the late afternoon when the leaves have curled up.

Delivery

The type and/or location of spraying determine which helicopter is used. Three helicopters are used for spot spraying; spraying within close range of the watering/loading point (that is, within a ten minute reload cycle); and spraying where a higher capacity and range is required.

Revegetation

The type of pasture species used for revegetation after clearing of mimosa depends on the seed and/or runners that are available. Olive hymenachne (*Hymenachne amplexicaulis*), para grass (*Brachiaria mutica*) and aleman (german) grass (*Echinochloa polystachya*) are the preferred species.

Some native species have been used and trials are underway to further investigate their use.

Financial considerations

The mimosa control program is working to a strict budget that was set over five years ago. Slowing of the program occurred as the cost of controlling larger areas of regrowth overtook the cost of the initial kill. Experience and increasing efficiency, however, enabled the last 1000 ha of old-growth on Rumby Plain to be tackled in 1999/2000.

Future of *Mimosa pigra* control

Over the next five years, the mimosa control program will focus on maintaining the control achieved in the

Principles of woody weed control

Principles of *Mimosa pigra* and woody weed control that have emerged from the program at Melaleuca are:

- Don't clear more than you can manage in the subsequent years of the program
- Operate within your budget of finance, labour and resources
- Effective spraying means paying attention to the conditions
- Be set for the long haul and have ways to measure progress
- Use the natural environment to help. Floods can kill regrowth and spread grass seed.
- Time the program to use the season to best effect. December, October and July are critical times.
- Modify the options to suit your local environment.

For more information about land-management issues in northern Australia, go to the Savanna Explorer section of our website at: http://savanna.ntu.edu.au/

For more information about the Centre's extensive research program go to our research section.

first five years and reducing the need to spend time and money on regrowth. Another 5000 ha of old-growth mimosa will then be tackled in the subsequent five years. Step-by-step progress will be measured each year.

Conclusion

A successful mimosa control program at Melaleuca Station is the result of a practical, planned and reasoned approach, which began in 1996. A year-by-year program of spraying, burning, revegetation and thorough follow-up has been used. Over this time a number of principles for large-scale mimosa control were developed and can be applied to the management of other damaging infestations.

Acknowledgments

The NT Department of Primary Industry and Fisheries started mimosa control in the Mary River district in 1993–94 as a result of government policy. This proved to be the basis of a successful program on Melaleuca Station. The Mimosa pigra subsidy scheme provided the resources to keep the program moving forward. Without this, the program would have been much smaller. The directors of Melaleuca have also shown a great deal of faith in the program and allowing it to continue with little in the way of economic return to date.

Also see the information sheet on this CD: *Native species for revegetation*