Invasive-Plant Assessment and Weed Management Plan for the Fijian Crested Iguana Sanctuary Island of Yadua Taba, Bua.

August 2005

July 2003 Survey Team

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The field team on Yadua Taba, 23 July 2003. From left to right (standing) Jenny, Peter, Tamara, Senirusi, Jone and Erica, and (sitting) Wendy, Baravi, Pita and Isaac.

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ABSTRACT

The Fijian Crested Iguana Sanctuary on the island of Yadua Taba is administered by the National Trust of Fiji Islands and contains the only viable wild population of Fijian crested iguanas in the world. This makes it the most important wildlife sanctuary in Fiji and of high international significance. A recent vegetation survey identified several invasive plant species of concern and suggested immediate action is required to eradicate and control these species that have the potential to degrade the natural vegetation on Yadua Taba (Olson *et al.*, 2002).

In July 2003 we investigated the status of invasive plants on Yadua Taba, and identified a small number of exotic species of concern. We initially prioritized five species that require physical methods of management. Early detection and control may prevent the spread of these species and provides the soundest long-term management strategy. Only one species appears to have the ability to dominate undisturbed native plant communities (rain tree, *Samanea saman*). The other species requiring management currently do not appear to actively invade undisturbed sites (vaivai, *Leucaena leucocephala*; *Wedelia*, *Wedelia trilobata*; guava, *Psidium guajava*; and *Lantana*, *Lantana camara).*

Trial control methods of hand removal, cutting and poisoning were used on experimental sites for the above five invasive species in July 2003. Rain trees were ringbarked* and poisoned (with diesel or Glyphosate 360). Vaivai, *Lantana* and guava were cut off at 20-80 cm above the ground and poisoned. Small *Lantana* plants were removed by hand. *Wedelia* was removed by hand and burnt. An assessment of the effectiveness of these techniques was made in May and November 2004, along with further control measures.

Our final recommendations for long-term management of invasive weeds on Yadua Taba identify four species that require continued active removal and/or poisoning (rain tree, *Wedelia*, guava and *Lantana)* until 2010, when a reassessment should be made. We recommend that two other invasive plants should not be disturbed as we feel that natural forest regeneration will eventually displace and minimise the impact of these species (vaivai and mile-a-minute vine, *Mikania micrantha*).

The importance of raising local awareness of the potential for invasive plants to degrade native vegetation was addressed by a series of meetings and lectures in the village of Denimanu on Yadua. The need to prevent future introductions of unwanted plant species to Yadua (and thus Yadua Taba) was stressed. The National Trust of Fiji Islands is fortunate to have all necessary resources already in place (*i.e.*, a full-time ranger and sanctuary boat) to coordinate and carry out a weed management plan at minimal expense.

* There is a glossary of terms and abbreviations at the end of the report.

INTRODUCTION

The Fijian Crested Iguana Sanctuary on the island of Yadua Taba was established in 1980 to ensure the survival of, what was then, the only known population of crested iguanas (*Brachylophus vitiensis*). Other crested iguana populations were subsequently found on islands in the Yasawa-Mamanuca group and on Macuata Island, but Yadua Taba remains the only protected population and the only viable population.

In 1987 Laurie *et al.* estimated that about 25 ha of the 70 ha Yadua Taba Island consisted of beach forest, the most important habitat for the crested iguana. Recent population estimates suggest that almost 200 iguanas per hectare live in the beach forest of Yadua Taba, with the total population estimated at over 6000 iguanas (Harlow & Biciloa, 2001). The most recent estimate (Olson *et al.*, 2002) suggests that around 40-50 % (28-35 ha) of the island is now covered with beach and dry forest.

The beach and dry forests of Yadua Taba are also among the most threatened habitats in the Pacific (Laurie *et al.*, 1987; Olson *et al.*, 2002), having been cleared and burnt on most other leeward islands. Yadua Taba has one of the best examples of this forest type left in Fiji; a recent survey identified 133 vascular plant species (7 ferns, 126 flowering plants: Olson *et al.*, 2002). This same survey identified 28 plant species (19%) introduced to Yadua Taba in historic and recent times. Based on occurrence in relatively undisturbed vegetation and the degree of invasiveness, several of these species are considered to be serious weeds in Fiji and other tropical countries, and a few appear to be increasing in abundance on Yadua Taba.

Many introduced plant species can exist for years or even decades in an area following introduction before undergoing an explosive range expansion and becoming recognised as invasive (Fig. 1; Hobbs & Humphries, 1995; Batianoff & Franks, 1997; Grice & Ainsworth, 2003). The explosive expansion after a long lag phase may result from change in conditions or some episodic event such as a flood, drought or introduction of a pollinator (Hobbs & Humphries, 1995). Different plant species have varied greatly in the time taken to become significant weeds and it is difficult to predict which species will become future problem weeds. In many (if not most) instances introduced species have not been recognised as potentially invasive

until control had become difficult or near impossible. Therefore, early detection and control is an important component of weed management (Fox, 1991; Hobbs & Humphries, 1995). Most weed management projects begin only after there is a major problem, by which time control is very costly and sometimes impossible (Hobbs & Humphries, 1995). Several of the weed species on Yadua Taba are known to have been there for decades (e.g. rain trees and vaivai) and to have expanded the area that they occupy since first recorded (P. Biciloa pers. comm.). For these reasons we consider it essential that action be taken to assess and manage the invasive weeds on Yadua Taba immediately.

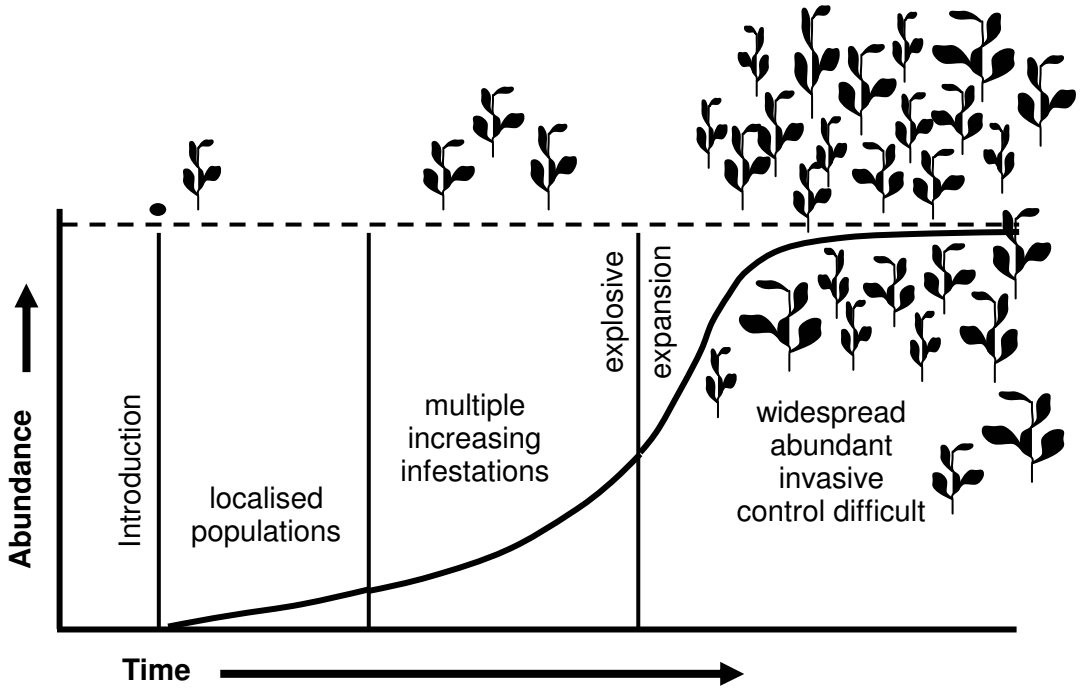

Figure 1. Generalised phases of plant invasion (modified from Hobbs & Humphries, 1995)

For successful weed control or eradication, the cause of invasion and establishment must be addressed (Hobbs & Humphries, 1995). Disturbance is now generally accepted as the major factor affecting the invasibility of natural ecosystems (Fox & Fox, 1986; Rejmánek, 1989; Hobbs, 1991; Hobbs & Huenneke, 1992) and combining different types of disturbance further enhances the chances of invasion (Hobbs, 1991). Disturbance may include grazing by introduced animals, changes in

fire or grazing regimes, clearing of vegetation, construction of tracks or roads, or natural disturbances (*e.g.*, wind, flood, cyclone).

For Yadua Taba the disturbance that initiated the establishment or increased abundance of many of the exotic plants was undoubtedly the combination of goat grazing and frequent forest fires. Goats were introduced to Yadua Taba in 1972 (Gibbons & Watkins, 1982) and numbered over 200 by the late 1970s (Gibbons, 1984). In 1981, after Yadua Taba was proclaimed a sanctuary, most goats were removed. Despite occasional goat captures since then, small numbers of goats continued to survive on Yadua Taba, numbering between about 5 and 10. In December 2001 another goat round-up was held and most were captured, in July 2003 two more goats were removed and the last goat was removed in 2004.

During the period of intensive goat grazing (1972-1980), forest fires were regularly lit on Yadua Taba to clear the forest and encourage the growth of new vegetation at the onset of the wet season. This resulted in large open areas along the ridge lines where the vegetation today is still dominated by grasses and introduced species (Fig. 2). No forest fires have occurred since 1980. Since the cessation of intensive goat grazing and forest fires, the beach forest has been regenerating and expanding into what were previously open grasslands and *Casuarina*-dominated forests. However, several invasive weeds have also been increasing in abundance in these open areas and slowing the regeneration of forest in some areas. Thus the time is right to address the problems created by invasive plants on Yadua Taba.

In July 2003 a team undertook field work on Yadua Taba to:

- assess the status of invasive plant species on Yadua Taba;
- identify those invasive species of most concern;
- measure and map the extent of the most serious invasive species on Yadua Taba;
- trial some control or eradication techniques for these species with a focus on easily implemented techniques requiring minimal resources;
- assist with training of Denimanu community members in appropriate and safe eradication techniques specific to each species;
- carry out an education and awareness program (in Fijian) in Denimanu Village on the effects of invasive plants on native vegetation;

- make recommendations for the long-term management of invasive plants on Yadua Taba.

Follow-up trips were undertaken in May 2004 and November 2004 to continue weed control and to assess the success of control measures implemented in July 2003. See Appendix 1 for more details about each field trip.

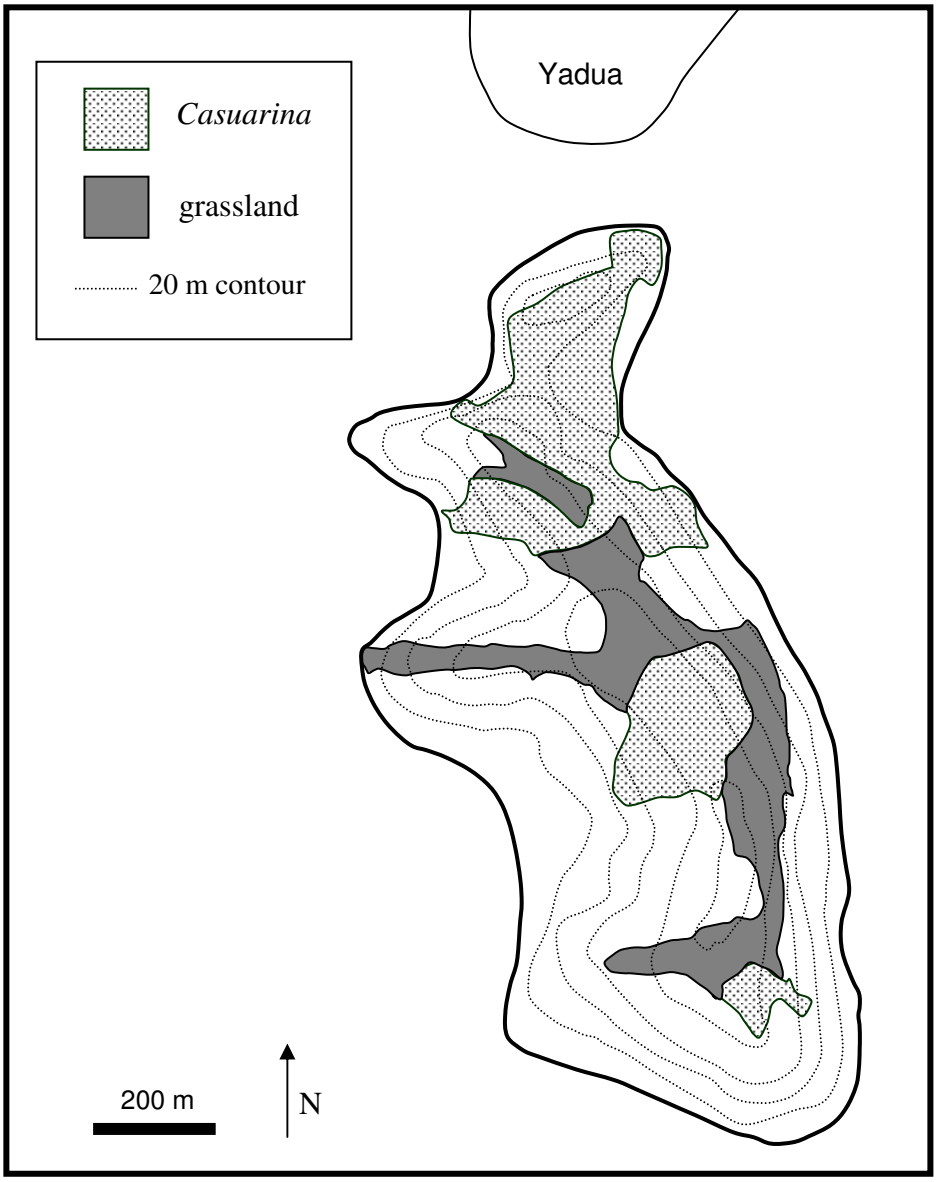

Figure 2. Contour map of Yadua Taba showing approximate distribution of *Casuarina* forest and grassland in early 1980s (based on Gibbons 1984) and proximity of Yadua Taba to Yadua at the closest point. (Scale and vegetation boundaries are approximate).

INVASIVE PLANT SPECIES OF MOST CONCERN

There are at least twenty-eight plant species on Yadua Taba that have been introduced in historic or recent times (Olson *et al.*, 2002), some of which are considered invasive (see Appendix 2). The four invasive plant species of most concern on Yadua Taba are *Samanea saman* (rain tree), *Wedelia trilobata* (*Wedelia* or trailing daisy), *Psidium guajava* (guava), and *Lantana camara* (*Lantana*). All of these species are native to tropical America. All are, or have been, cultivated in Fiji. All are considered to be problem invasive weeds elsewhere in Fiji and elsewhere in the world (Meyer, 2000). *Wedelia* and *Lantana* have been listed among the world's worst 100 invasive weeds by the IUCN (International Union for Conservation of Nature, 2005) and as dominant invaders in Fiji (Meyer, 2000). Rain tree and guava are listed as moderate invaders in Fiji (Meyer, 2000). None of these species appear to provide good habitat for Fijian crested iguanas (Harlow & Biciloa, 2001).

The following sections give a description of each of these species and their occurrence on Yadua Taba. Also in each section is a description of the control measures attempted for these species on Yadua Taba in 2003 and 2004, the initial outcomes of these controls and recommended measures to be undertaken in the future for the control of these weeds.

Rain Tree *(Samanea saman)*

Description and species notes

Samanea saman goes by the Fijian name of 'Vaivai ni vavalagi' (or Vaivai moce moce on Yadua) and is one of several trees given the English name of 'rain tree'. *Samanea saman* is a large to massive tree that grows to 25 m tall with a rounded crown that is usually broader then the tree is tall (Plate 1). Each leaf has 2-8 pairs of primary leaflets each with 2-7 pairs of secondary leaflets 3-6 cm long (Plate 2). The distinctive pods are 20-24 cm long, thick but compressed, black when mature and pulpy and contain 12-20 red-brown seeds (Durr, 2001; Stone, 1970) (Plates 2a & 3). Janzen (1977) recorded a maximum of 70 000 pods produced from a single tree in one year, which represents more than one million seeds. However pod production in this species is highly variable between trees and between years.

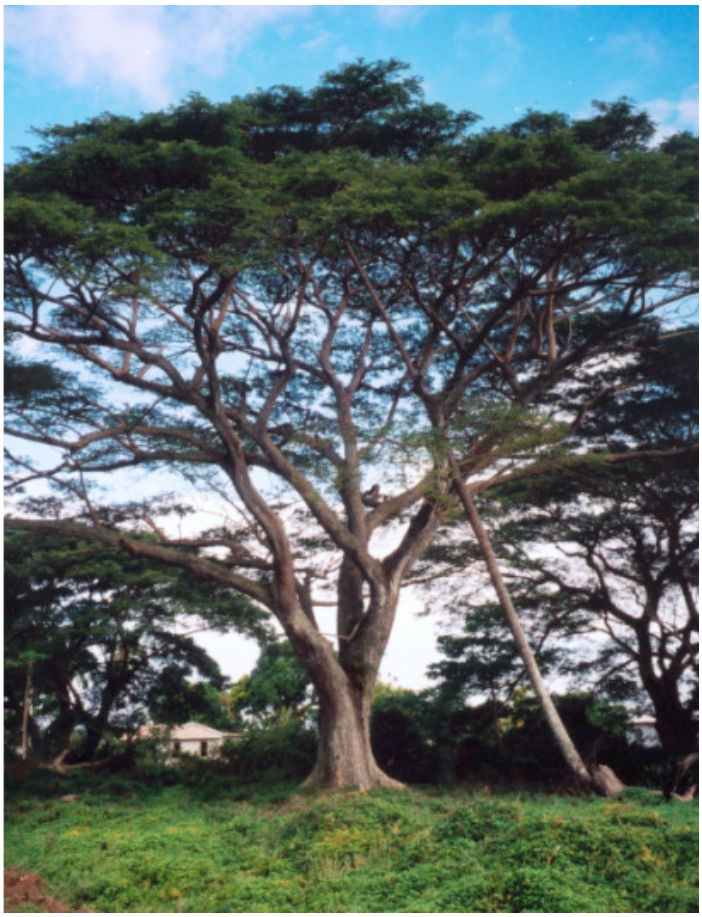

Plate 1. Mature rain tree (*Samanea saman*) at Nabouwalu on Vanua Levu showing the spreading canopy.

In Fiji this species is found from near sea level to an elevation of 700 m, and is cultivated, sometimes naturalised in forest (Smith, 1985) and frequently naturalised along road sides and river banks on Viti Levu and Vanua Levu. Although not noted as a serious problem on most Pacific islands, in Hawaii it has the ability to spread through native forest ecosystems. It is regarded as an invasive species in Fiji and is estimated to contribute 85% of the total volume of woody biomass per hectare in low-lying alluvial sites and river valleys in drier zones of the major islands (PIER web site, 2003; Wilco Liebregts, Ecoconsult Pacific, pers. comm.). Its ability to colonise disturbed dry forest and shade out native vegetation makes it a potential threat to the regeneration of forest on Yadua Taba.

(a)

(b)

Plate 2. **(a)** Leaves and pods of a mature rain tree (*Samanea saman*) on Yadua Taba. **(b)** Leaves on a branch that re-sprouted from the base of a ringbarked rain tree on Yadua Taba (6 months after ringbarking).

Plate 3. A seedling (approximately 10 cm tall) and dried pods of rain tree (*Samanea saman*) on the ground at the edge of a stand of mature rain trees on Yadua Taba.

There is some experimental evidence that rain trees produce chemicals that are capable of inhibiting germination and seedling growth of some crop species (Meher & Khan, 1994) and stimulating growth of other crop species (Channal *et al.*, 2000). This effect (termed allelopathy[†]) may aid the ability of rain trees to invade native vegetation and hinder regeneration of native forest in Fiji.

Occurrence on Yadua Taba

Rain trees may have been on Yadua Taba for 40 years (Olson *et al.*, 2002) and are now widely, but patchily, distributed in the forest. In July 2003, one patch of over 30 trees was located high on the ridge (S1) and another patch of more than 220 trees (S7) was located on the slope leading up to the ridge on the south-eastern side (Fig. 3; Table 1). Both of these were continuous with the forest-grassland ecotone suggesting that the first tree to colonise the patch may have done so when the area was more open due to the effects of fire and goat grazing. In addition there were

[†] There is a glossary of terms and abbreviations at the end of the report.

many groups of 4-8 trees and also single trees in the forest that were hundreds of metres from the nearest conspecific. A very rough estimate is that there were 600 - 800 non-seedling rain trees on Yadua Taba in July 2003.

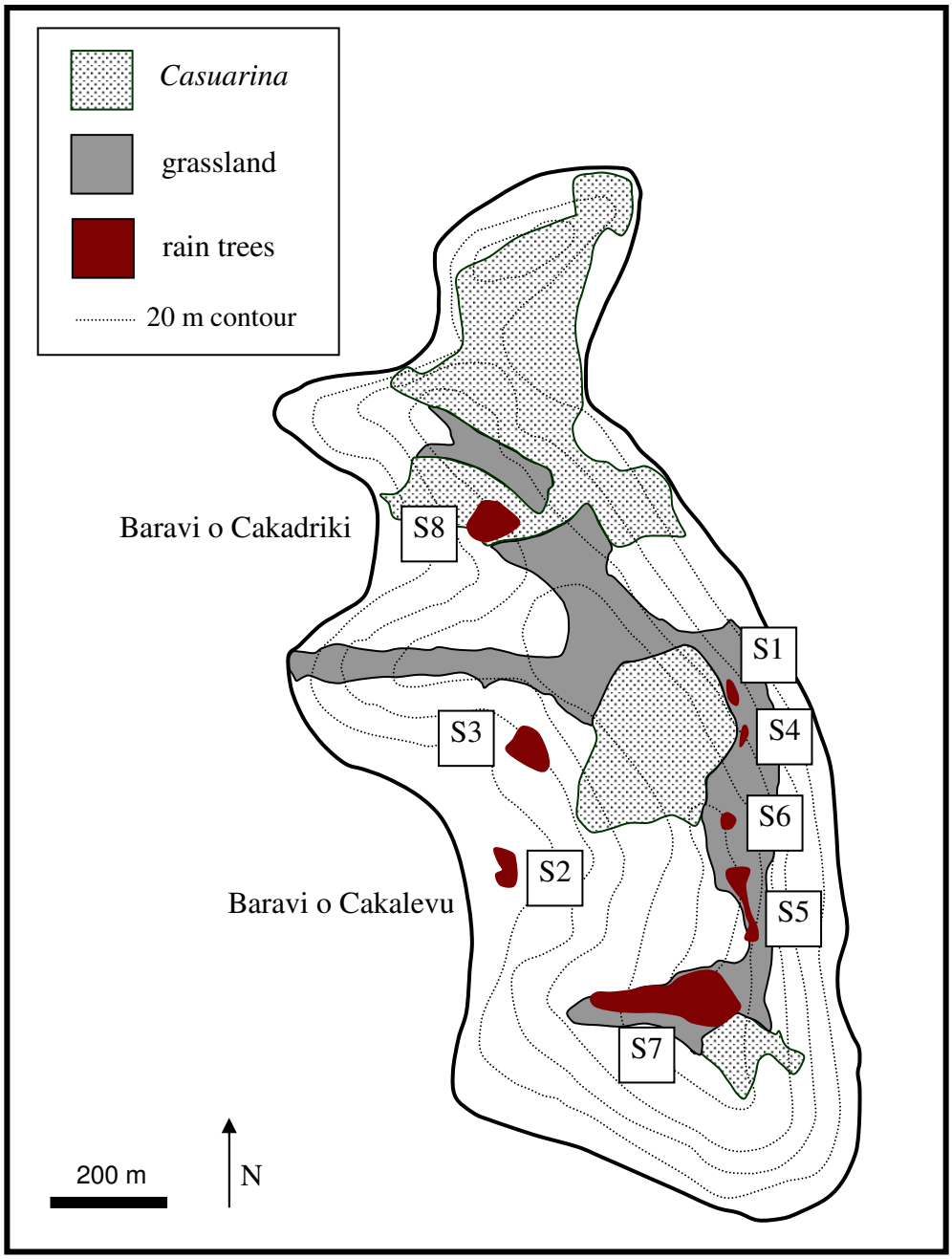

Figure 3. Contour map of Yadua Taba showing approximate location of larger rain-tree (*Samanea saman*) patches in 2003-2004. The distribution of grassland and *Casuarina* forest as it was in early 1980s (Gibbons 1984). (Scale and vegetation boundaries are approximate, see Table 1 for more precise locations).

Table 1. Location, date of treatment, number of trees treated (No. trees), mechanical treatment and poison used for rain trees on Yadua Taba. Glyphosate was undiluted, except where stated otherwise. See Fig. 4 and Plates 5 - 7 for diagrams and photos of mechanical treatments.

Date	Patch No.	Location	No. trees	Mechanical treatment	Poison used
September 2002	--	100m N of camp at Baravi o Cakalevu	1	ringbarked	3% Glyphosate
July 2003	S1	see Fig. 3	30	ringbarked	diesel
July 2003	S2	see Fig. 3	4	ringbarked	diesel
July 2003	S3	see Fig. 3	16	ringbarked	14 diesel 2 Glyphosate
July 2003	S4	16°49.74'S, 178°16.58'E	5	ringbarked	Glyphosate
July 2003	S5	16°50.02'S, 178°16.74'E	7	ringbarked	Glyphosate
July 2003	S6	16°49.97'S, 178°16.70'E	3	ringbarked	Glyphosate
May 2004	S7	16°50.12'S, 178°16.67'E	210	ringbarked	diesel
November 2004	S7	16°50.12'S, 178°16.67'E	212	chiseled *	Glyphosate

* most trees chiseled had been ringbarked in May 2004.

Control measures: Implementation and effects

Trial poisoning of single tree: September 2002

A single mature, fruiting rain tree (88 cm DBH) about 100 m north of the main beach (Baravi o Cakalevu) was treated in September 2002. This tree was ringbarked (as in Fig. 4a) and poisoned by spraying the ringbarked area with 300 ml of 3% 'Glyphosate 360' in water. In September 2002 there were almost no understorey plants (native or introduced) beneath the tree (Plate 4a).

In July 2003 this tree still had about 5% of its outer leaves alive, but the canopy seemed likely to be completely dead within a few months (by late 2003). It had also sprouted 8-10 shoots from the trunk below where it had been ringbarked (Plate 4b). Incisions were cut above each of these shoots in July 2003 (similar to chiseling shown in Fig. 4c) and a few millilitres of undiluted poison (Glyphosate 360) dripped into each incision.

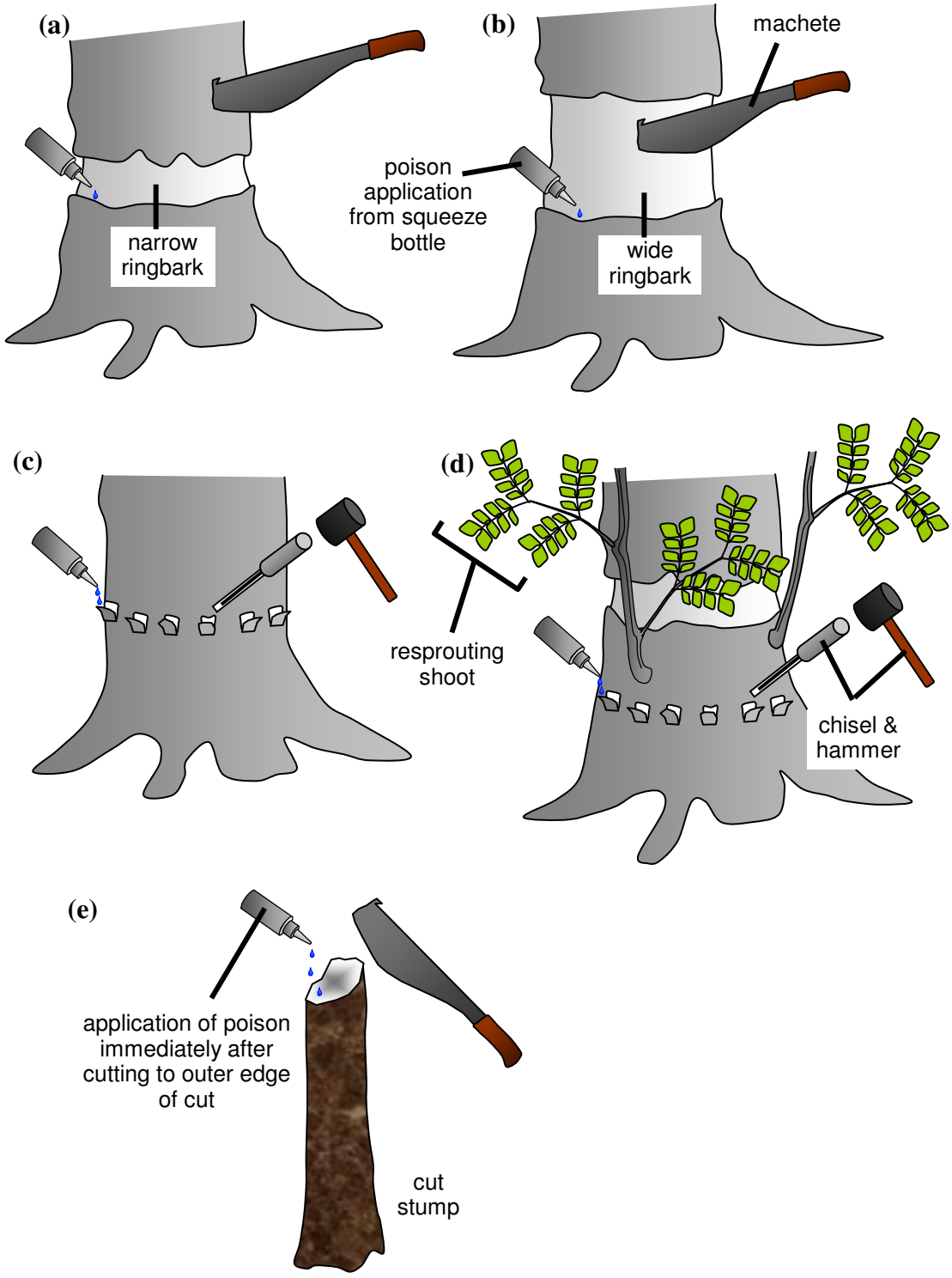

Figure 4. Methods of mechanical and chemical treatment used on weeds on Yadua Taba: **(a)** narrow ringbarking, **(b)** wide ringbarking, **(c)** chiseling, **(d)** chiseling of a rain tree that re-sprouted after ringbarking, and **(e)** cutting and applying poison direct to cut stump.

Plate 4. **(a)** Open understorey in 2002 beneath the rain tree (*Samanea saman*) ringbarked in September 2002 on Yadua Taba. By July 2003 the rain tree ringbarked in September 2002 **(b)** had re-sprouted and **(c)** had substantial regeneration of native plant species underneath. **(d)** By November 2004 the rain tree ringbarked in September 2002 was dead and there was good regeneration of native plant species underneath.

By July 2003 (10 months after ringbarking) large numbers of native seedlings had established under this rain tree (Plate 4c). At least 11 rain-tree seedlings and two *Lantana* seedlings had also germinated in this period. However, the native seedlings were mostly much larger and more established than the rain tree and *Lantana* seedlings. The *Lantana* seedlings were uprooted and the rain-tree seedlings were left to allow a comparison of their growth with that of the native species.

In November 2004 this rain tree was dead; the canopy and all of the re-sprouting shoots observed in July 2003 had died and no new shoots had grown. In November 2004 we found six rain-tree seedlings under the dead tree, all were less than 30 cm tall. Some of these may have been the same seedlings as observed in July 2003, if so then growth had been very slow. All of these seedlings were removed in November 2004. The death of the rain-tree canopy opened a gap approximately 8-m diameter. By November 2004 a dense understorey of native plant species (especially qiqila, *Micromelum minutuum*) had grown under the dead tree (Plate 4d) and the canopy of an adjacent *Hisbiscus tiliaeceus* (vau) had grown to fill part of the gap.

July 2003

On 19 July 2003 the ranger for the Crested Iguana Sanctuary, Pita Biciloa, the other authors and eight men from Denimanu village spent the day on Yadua Taba ringbarking and poisoning rain trees. The majority of ringbarking of rain trees was done by removing a wide strip of bark (Fig. 4b; Plate 5). A total of 30 rain trees were ringbarked and poisoned high on the ridge (patch S1 on Fig. 3), followed by 4 trees close to the camp site (patch S2), and another 16 scattered in dry forest about 150-200 m east of the camp site (patch S3) (Table 1). All of these were poisoned with a liberal application of diesel fuel poured over the ringbarked area, except for two trees in patch S3 that were poisoned with small amounts of undiluted ‘Glyphosate 360’ (approximately 30 - 40 ml per tree).

On 22 July 2003 the authors ringbarked and poisoned more rain trees (patches S4 - S6; Table 1). These rain trees were all 30-60 cm diameter at breast height (DBH), 10-15 m tall and were poisoned with undiluted 'Glyphosate 360' applied from a 250 ml soft plastic squeeze bottle (Fig. 4; Plate 6).

In all we ringbarked and poisoned 65 rain trees (some up to 1m in trunk diameter) on Yadua Taba in July 2003: 48 were treated with diesel fuel and 17 with

undiluted 'Glyphosate 360'. For the 48 diesel-treated rain trees a total of 50 litres of diesel fuel was used. For rain trees poisoned with undiluted 'Glyphosate 360', about 15-30 ml (depending on tree diameter) was applied directly to the freshly cut wood and bark tissue of each tree.

Our original aim for this initial trip was to ringbark and poison one or two mature (fruiting) rain trees in every clump; this was to avoid opening up large forest clearings under the dying rain trees that could be colonised by seedlings of rain tree, *Lantana*, guava and *Mikania*. Our original aim became impossible to manage when the team of village men dispersed into the forest, eager to cut and poison every rain tree in sight. Consequently some entire clumps of 6-10 large rain trees were cut and poisoned.

Plate 5. Ringbarked rain tree (*Samanea saman*) on Yadua Taba with wide ringbark.

May 2004

In May 2004 many of the rain trees that had been ringbarked in July 2003 had sprouted shoots on the trunk from below the ringbarked area. These were cut off and diesel applied.

In May 2004 approximately 210 large rain trees in the forest on the middle and top left side behind Baravi o Cakalevu (i.e. camping beach) were ringbarked (S7). Ringbarking was done with a relatively narrow strip of bark removed (Fig. 4a) and trees were poisoned with diesel.

Plate 6. Application of poison to a chiseled rain tree with plastic squeeze bottle. Gloves are worn to prevent skin contact with the poison.

November 2004

In November 2004 we found eight rain trees in patch S7 that had not previously been treated. These were chiseled and poisoned with Glyphosate (Fig. 4c; Plate 6). We also located 210 trees that had been ringbarked in May 2004. Only 6 of these 210 trees (3%) were dead in November 2004 after a single ringbark and poison treatment. The remaining 204 (97%) ringbarked trees were re-sprouting shoots from the trunk below the ringbark (Fig. 4d; Plate 4b). We left the re-sprouting shoots intact on all of these trees and chiseled and poisoned them with about 15 - 30 ml (depending on tree size) of Glyphosate per tree (Fig. 4d; Plate 7).

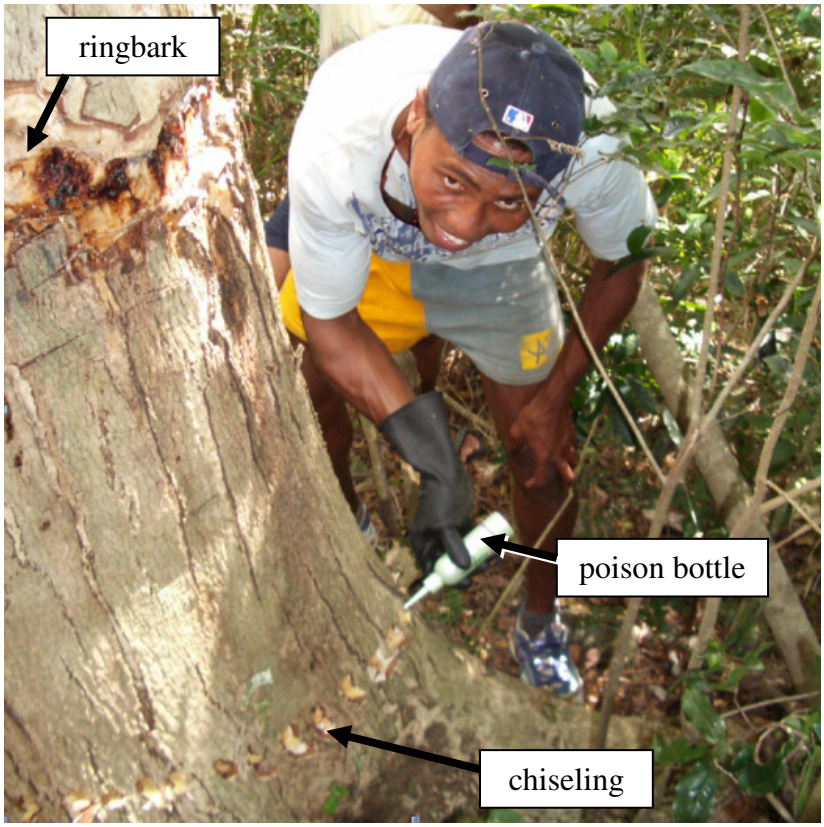

Plate 7. Chiseling and poisoning a rain tree in November 2004 after ringbarking in May 2004 had failed to kill the tree.

Regeneration of rain trees from seed

Many of the rain trees on Yadua Taba showed no evidence of having ever produced seedpods. However, the largest rain trees were laden with thousands of seedpods and there were large numbers of pods on the ground under many of the large trees (Plate 3). As rain-tree seeds have a hard protective coat and are long lived, there are likely to be tens of thousands of rain-tree seeds in the soil on Yadua Taba.

Noticeably there was a total lack of rain-tree seedlings under the largest mature trees, while younger trees formed a complete ring around the outer canopy circumference of many of the largest mature trees. We found only one area where significant numbers of seedlings were present (Plate 3). This area was at the edge of a rain-tree patch (S7) where it joined the grassland at the top of the ridge. In November 2004 we removed approximately 40 seedlings between 5cm and 20cm tall from the uphill side of the rain tree closest to the ridge top.

The general lack of seedlings, saplings and young trees under the mature rain trees, is in keeping with an inhibitory effect of mature rain trees on germination of rain-tree seeds. Inhibition of germination of seeds may result from lack of light under the rain-tree canopy; there was more light at the edge where the seedlings were found. Inhibition may also be due to chemicals being produced from the mature trees; the effects of such chemicals may have been reduced on this steeply sloping site by rainfall runoff washing down hill from the grassland above.

Effects of canopy removal

Control measures undertaken on Yadua Taba in 2002-2003 resulted in a slow death of rain trees and a gradual opening of the canopy over a period of approximately 8–12 months. Effects of opening the canopy are likely to vary across the island depending on seed availability in the soil and canopy and the state of the surrounding forest. Presence of relatively undisturbed native forest around dead trees is likely to aid regeneration of native forest by providing a source of seeds and limiting the light that allows rapid growth of many weed species. This was seen in the rapid regeneration of native colonising species such as qiqila (*Micromelum minutum*) around the rain tree poisoned in September 2002. There were also gaps at the edge of rain-tree patch S7 with high densities of native plant seedlings, especially qiqila (*Micromelum minutum*). In these less open and less disturbed situations, native plant species seem able to out-compete seedlings of rain trees and other weed species. Some monitoring and removing of weed seedlings may aid this process.

In more disturbed areas that were formerly grassland such as patch S1, seeds of rain trees and other weed species are likely to be abundant. There are also likely to be many fewer seeds of native plant species available in more disturbed areas. Therefore, creation of gaps within the grassland may result in growth of many introduced species. Consequently, regrowth of native vegetation in these areas is likely to be much slower than under the single tree poisoned in September 2002. These more disturbed areas will require careful monitoring and a reassessment of control measures 1 to 2 years after poisoning. Follow up removal of rain-tree seedlings and seedlings of other invasive plants may be essential in these areas to allow native forest species to re-establish, especially for patch S1.

Summary of effects of control treatments of rain trees

1. Treatment of over 200 rain trees (*Samanea saman*) indicates that they are extremely vigorous and rarely die in response to one-off ringbarking and poisoning done during the dry season.

2. Although not resulting in tree death, initial ringbarking and poisoning greatly weaken healthy rain trees, even when done in the dry season, and appear to result in death of most of the canopy within 12 months.

3. Nearly all rain trees (97%) sent up vigorous shoots from the trunk below the initial ringbark. These shoots grew 1 - 3 m in a year.

4. Re-sprouting trees are likely to be killed by a second chiseling (without removing the re-sprouting shoots) and poisoning treatment.

5. Loss of the canopy appears to allow rapid regeneration of native plants and weed species that have previously been inhibited by the rain-tree canopy (this may be due to lack of light or chemical inhibition of seed germination).

6. We recommend that future chiseling and poisoning is limited to the wet season (November - April) when trees are most actively growing, and most susceptible to poison.

Discussion and recommended future management practices

To ensure control of rain trees on Yadua Taba and aid the regeneration of the native beach forest by minimising competition from introduced species we recommend:

1. continued eradication of rain trees during the wet season using chiseling and poisoning (Fig. 4c);

2. giving priority to the patch (S8 on Fig. 3) of rain trees behind the central western beach (Baravi o Cakadriki) that has not yet been touched;

3. follow-up checks of rain trees after approximately one year so that any trees that have grown new shoots after the initial poisoning can be chiseled (leaving new shoots intact) and poisoned (Fig. 4d); and

4. monitoring regeneration under rain trees after poisoning and removing all seedlings (including roots) of rain trees and other invasive species of concern especially *Lantana*, guava and *Leucaena*.

Wedelia (*Wedelia trilobata*)

Description and species notes

Wedelia trilobata (or trailing daisy) is a creeping, mat-forming perennial herb with fleshy leaves 4-9 cm long and 2-5 cm wide (Plate 8a). The stems are rounded with pairs of opposite leaves emerging at nodes that are 10-30 cm apart. It reproduces vegetatively, and takes root wherever a node (even on a broken stem) touches the ground (Fig. 5). Whistler (1995) states that *Wedelia trilobata* does not produce seed. However, it has been recorded as producing seed where it is invading sandy beach fronts in Australia (Batianoff & Franks, 1997). Although widely known as *Wedelia trilobata* (the name used in this report), the current accepted scientific name of this species is *Sphagneticola trilobata*.

Introduced and cultivated as an ornamental in many parts of the world, this species is an invasive weed in agricultural areas, along roadsides and trails, in open lots, garbage dumps and other disturbed areas. In Fiji it is naturalised and invasive along streams, canals, along the borders of mangroves and in coastal strand vegetation (Thaman, 1999). *Wedelia* tolerates a wide range of conditions: dry to moist, sun and shade, and high salinity levels (Thaman, 1999).

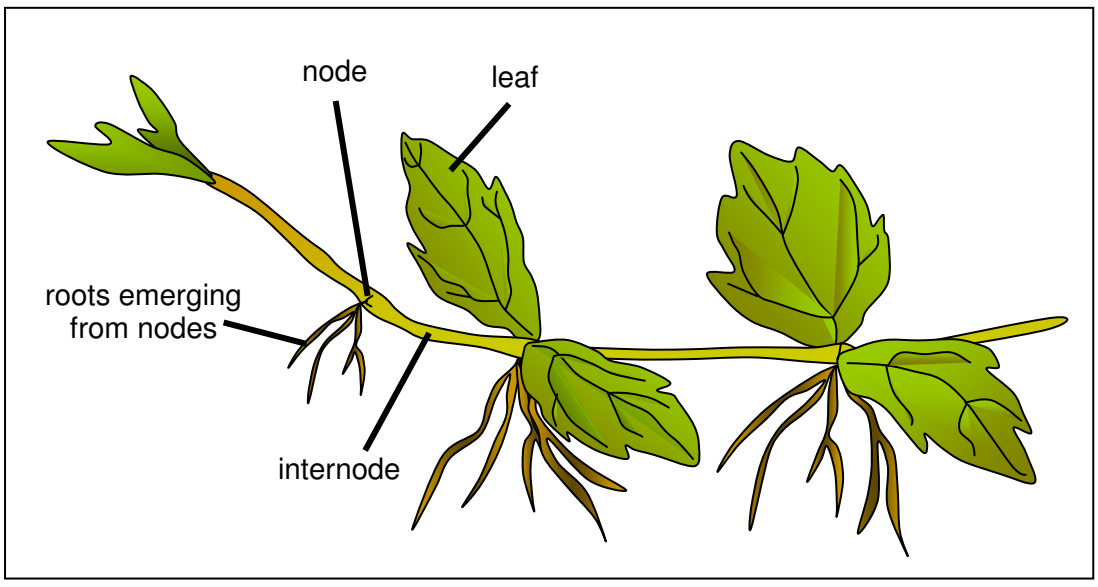

Figure 5. Diagram illustrating vegetative growth of *Wedelia trilobata* with roots emerging from nodes.

(a)

(b)

Plate 8. *Wedelia trilobata*: **(a)** healthy *Wedelia* in Suva and **(b)** part (most already removed) of the 30-cm thick mat of *Wedelia* at site W2 on Yadua Taba that was removed in July 2003.

Occurrence on Yadua Taba

Wedelia was first identified on Yadua Taba during vegetation surveys in May 2002 (Olson *et al.*, 2002). This infestation was located behind the small beach on the north-western side of the island (Baravi o Talice: Patch W1) (Fig. 6). In early 2003

Pita Biciloa located four more patches behind the beach at the north-eastern end of Yadua Taba (Baravi o Devo) and another patch was located nearby in mid-2004; these five patches of *Wedelia* were between 10 and 80 m^2 each (W2-W6; Fig. 6; Table 2).

When and how *Wedelia* was introduced to Yadua Taba is not known. However, the initial introduction may have been from stems washed up attached to floating plant material. All infestations were on the northern end of the island where the prevailing winds deposit most flotsam and jetsam. *Wedelia* is known to tolerate high salinities (Thaman, 1999), and small pieces of *Wedelia* were found growing attached to coconuts and *Barringtonia* seeds that appeared to have washed up relatively recently.

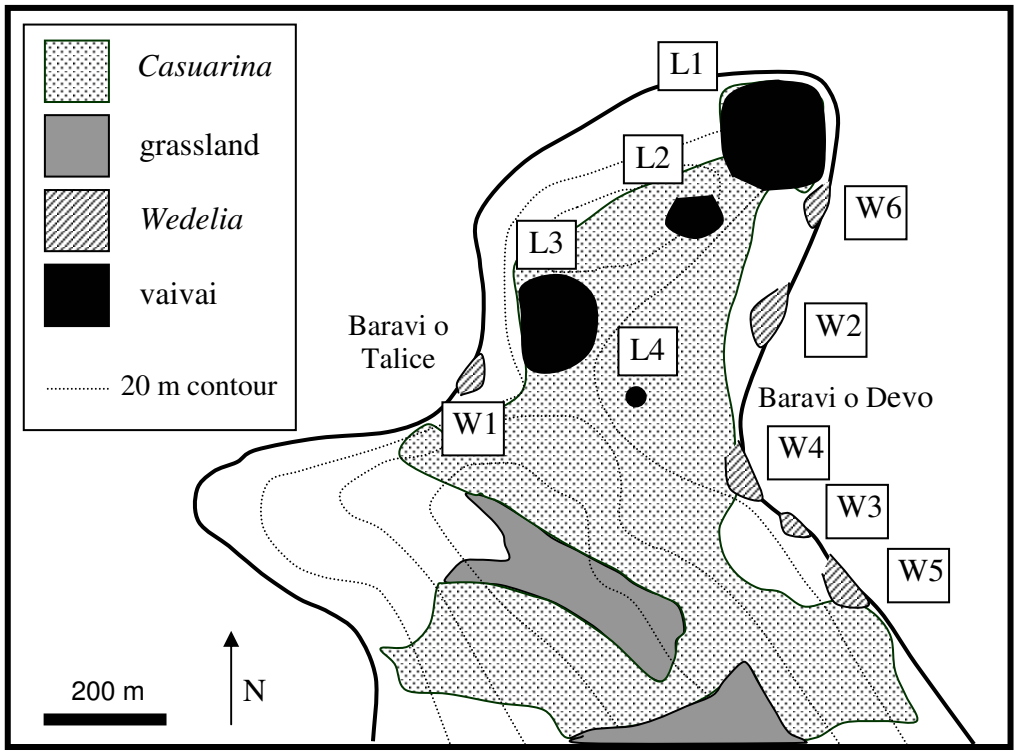

Figure 6. Map of the northern end of Yadua Taba showing the locations of patches of *Wedelia* (*Wedelia trilobata*) and vaivai (*Leucaena leucocephala*). Contours and distribution of *Casuarina* forest and grassland in the early 1980s (Gibbons 1984) are also shown. (Scale and vegetation boundaries are approximate, for more precise locations see Table 2 for *Wedelia* and in the text for vaivai.)

Table 2: Location (beach name and latitude and longitude from a GPS) of the six known patches of *Wedelia* on Yadua Taba.

Wedelia Patch No.	Location	Latitude, longitude
W1	Behind Baravi o Talice	16°49.74'S, 178°16.58'E
W2	Behind Baravi o Devo	16°49.73'S, 178°16.71'E
W3	Behind Baravi o Devo	16°49.82'S, 178°16.70'E
W4	Behind Baravi o Devo	16°49.81'S, 178°16.73'E
W5	south of Baravi o Devo	16°49.85'S, 178°16.77'E
W6	north of Baravi o Devo	16°49.65'S, 178°16.74'E

Implementation and effects of control measures

July 2003

On 21 July 2003 the authors and 27 men from the village of Denimanu removed by hand the single patch of *Wedelia* behind Baravi o Talice (W1) and the four known patches behind Baravi o Devo (W2-W5). The four patches behind Baravi o Devo were discreet, up to 30 cm thick and showed evidence of stress, perhaps due to the combination of it being mid-dry season and the continual salt spray from the prevailing winds (Plate 8b). Large fires of drift-wood were lit on the beach and the *Wedelia* was heaped onto these and burnt. Care was taken to ensure that every stem of *Wedelia* was burnt to ash, as even one small piece of stem left on the beach has the potential to be washed ashore elsewhere and begin a new infestation.

The areas cleared of *Wedelia* in July 2003 were checked by the sanctuary ranger, Pita Biciloa, in early November 2003. Occasional new leaves and stems were found, all of which were removed by hand and burnt.

November 2004

In November 2004, sparse (5–25% diffuse cover) regeneration of *Wedelia* had occurred at four of the original five infestations at Baravi o Devo (W2, W3, W4 and W5) (Plate 9). The regenerating stems appeared healthy but were not flowering. Four large plastic garbage bags of *Wedelia* were removed by hand from these four patches. The bags of *Wedelia* were returned to Denimanu village on Yadua and burnt. At patch W2 which in July 2003 was a dense 30-cm thick mat of *Wedelia*, some regeneration of native species had occurred.

(a)

(b)

Plate 9. (a) *Wedelia* patch W2 in November 2004 with sparse regrowth of *Wedelia* and some regeneration of native species. This was the largest (80 m^2) and thickest (30 cm thick) patch on Yadua Taba in July 2003. **(b)** Regrowth of *Wedelia* was sparse but healthy in November 2004 in patches W2-W5 that were weeded in July 2003.

A single new infestation (W6) at Baravi o Devo was found and removed by Pita Biciloa in mid-2004 and there was no evidence of any regrowth at this patch in November 2004. Careful inspection at the site of the single infestation on Baravi o Talice (W1) showed no trace of *Wedelia* in November 2004. It therefore appears that careful and repeated hand removal (being sure to remove roots and underground stems without breaking the stems) is sufficient to control and eventually eliminate this weed.

Hand removal of *Wedelia* was used here in preference to other methods of control due to the location and nature of the infestation. Poisoning was not seen as a viable option for several reasons: (i) *Wedelia*-specific herbicides are expensive, not readily available and difficult to transport and use on Yadua Taba; (ii) successful poisoning of all of the *Wedelia* infestation with one application was unlikely due to the fact that any small isolated fragments of *Wedelia* stem that were buried would not be poisoned and are capable of forming new plants, (iii) the stressed condition of *Wedelia* during the initial work in the July 2003 dry season would have made effective transport of poison to all parts of the plant unlikely.

Summary of effects of control treatments of *Wedelia* on Yadua Taba

1. *Wedelia trilobata* grows rapidly, shoots from nodes, and on Yadua Taba was seen to have sent shoots up from more than 30 cm below the soil surface.

2. Because it breaks readily at nodes and was buried deeply in the sand at the sites where it was removed, there may be many small pieces of *Wedelia* remaining in the soil at each of the removal sites. As a consequence of this, regrowth of *Wedelia* is expected at each of these sites after the onset of each wet season.

3. However, repeated hand removal seems to be an effective control method for *Wedelia* on Yadua Taba.

Recommended future management practices:

Although *Wedelia* seems to be currently under control on Yadua Taba, reinvasion may occur from unchecked growth of small fragments of stem remaining in the soil. There is also a possibility of reinvasion from pieces washed assure with floating plant material to which it can attach such as coconuts. We therefore recommend:

1. Regular monitoring of all *Wedelia* sites identified here with hand removal of any *Wedelia*.

2. All *Wedelia* removed should be placed in bags and taken from Yadua Taba to Yadua and burnt so that no fragments remain.

3. Regular inspections for potential new infestations on Yadua Taba.

Regular monitoring and hand removal of all remaining *Wedelia* infestations on Yadua Taba by the ranger is recommended, as this has been shown to be an effective eradication method. In addition, regular inspections for potential new *Wedelia* colonisation sites should be made before they become established and difficult to eradicate.

Guava (*Psidium guajava*)

Description and species notes

Psidium guajava is a shrub or tree to 10 m high with thin, smooth patchy, peeling bark. Leaves are opposite, elliptic to oblong and strongly veined on the lower surface. It produces numerous flowers with showy white stamens and yellow fleshy fruit (Whistler, 1995) and is widely planted as a fruit tree (Plate 10a,b). It has become naturalised and is an invasive weed of disturbed forest in many tropical areas (*e.g.*, Hawaii, Wagner *et al.*, 1999; northern Australia, Batianoff & Butler, 2002). Shrubs form dense thickets in disturbed areas that have been cleared for pastures or plantation production (Plate 10c). Evidence from Christmas Island suggests that this species is largely confined to disturbed areas with growth being limited by competition with native rainforest species (Swarbrick & Hart, 2000). Fruit is dispersed by frugivorous birds, fruit bats and rats (PIER web site, 2003), all of which are present on Yadua Taba.

Occurrence on Yadua Taba

Olson *et al.* (2002) reported seeing only one guava during their visit to Yadua Taba in May 2002. However, in July 2003 guava was found to be common in the grassland

and along forest-grassland edges. Occasional individuals and small clumps were found on the higher slopes of the beach forest on the western side of the island but guava was rare or absent in the undisturbed sections of the forest. Most guava on Yadua Taba are small (< 3m tall) and few large trees were seen in 2003 and 2004 and are presumed to be very uncommon. We estimate the numbers of guava plants on Yadua Taba to have been >500 in July 2003.

Control measures: implementation and effects

July 2003

Guava plants are able to regrow from cut stumps and from buds along damaged roots (Swarbrick, 1997, as cited by PIER web site, 2003). Therefore, poison must always be applied immediately to the cut stem to ensure plants are killed.

On the 19 July 2003 the authors and nine Denimanu village men cut and poisoned guava thickets in the grassland and adjacent forest edges in the vicinity of rain-tree patch S1. Approximately 80-100 guava stems were cut with machetes and poisoned in patch S1. On 22 July 2003 the authors poisoned another 8-10 clumps of guava that were located opportunistically as they walked through the beach forest from the campsite to the northern end of Yadua Taba.

Guava trees were cut down at about 20-40 cm above ground level and poisoned (Fig. 4e). 'Glyphosate 360' was applied to cut stems using 250 ml soft plastic squeeze bottles. Half were poisoned with undiluted 'Glyphosate 360' and half with 'Glyphosate 360' diluted 50:50 with diesel fuel. To ensure maximum effect we tried to apply the systemic herbicide to the surface within 30 seconds of cutting.

November 2004

In November 2004 we relocated two groups of guava plants that had been treated in July 2003. In one group one plant had re-sprouted and nine were dead. In the other group five plants had re-sprouted and three were dead. So an average of 36% of plants were killed by the treatment applied in July 2003. These re-sprouting guava plants were chiseled and poisoned (as in Fig. 4d; Plate 10d). In November 2004 an additional 5 (previously untreated) guava plants were also chiseled and poisoned, all were between 1 and 3 m tall.

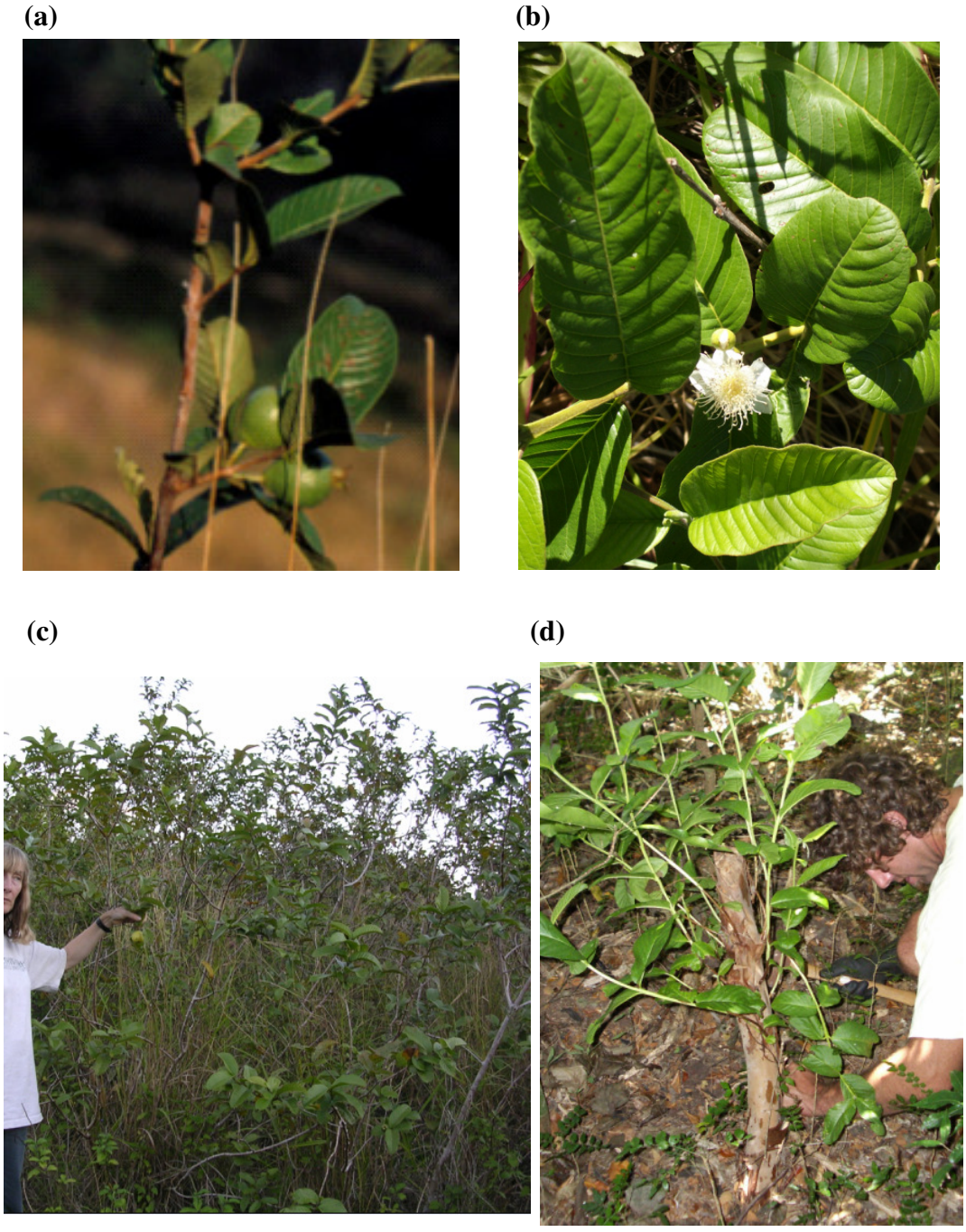

Plate 10. Guava (*Psidium guajava*) **(a)** fruit, **(b)** flower, **(c)** forming a dense thicket in a cleared area, and **(d)** in November 2004 on Yadua Taba with new shoots that re-sprouted after the tree was cut and poisoned in July 2003.

Recommended future management practices:

Evidence from Christmas Island (Swarbrick & Hart, 2000) and the current situation on Yadua Taba suggest, in the absence of disturbance, progressive regeneration of the native forest vegetation may act to limit the spread of guava by preventing establishment of new seedlings. We therefore recommend:

1. Avoiding disturbance of the vegetation where ever possible.

2. Control of guava on Yadua Taba continue using cutting and immediate poisoning (for seedlings and small trees) or chiseling and immediate poisoning (for large trees). This should be part of any future vegetation management plan.

3. That cutting and poisoning be concentrated in the grassland and along the forest-grassland edges on the ridges of Yadua Taba where the largest numbers of guava appear to grow and where the most open habitat is available for establishment of new seedlings.

Lantana (*Lantana camara*)

Description and species notes

Lantana is one of the most invasive weeds in tropical, subtropical, and warm temperate regions of the world (Batianoff & Butler, 2002). It is a rambling shrub up to 4 m high with prickly stems that are square in cross-section. Sometimes stems are vine like, climbing to over 10 m. The leaves are finely haired, opposite with a strong pungent odour when crushed. Flowering occurs throughout the year, with inflorescences of multi-coloured flowers maturing to produce shiny black fruits (Whistler, 1995) (Plate 11). The plant originated from horticultural hybrids and varieties from Central and South American parent stock.

Plants physically crowd or shade out native vegetation and prevent most regeneration occurring. *Lantana* infestations alter soil chemistry and nutrient cycling affecting the health and vigour of remaining over-storey plants. It also releases chemical exudates, inhibiting and suppressing the growth of other species.

Lantana has been widespread in Fiji as a naturalised species since the early 1900's (Thaman, 1974). It has become a weed of economic importance in parts of Fiji (Waterhouse & Norris, 1987; Anon., 1993, as cited in Swarbrick *et al.*, 1995) and

was declared a noxious weed in Fiji in 1985. *Lantana* spreads readily by seed and vegetatively by layering of branches that come in contact with the ground (Swarbrick *et al.*, 1995). After cutting back *Lantana* regrows vigorously from dormant buds at the bases of the stems (Swarbrick *et al.*, 1995). It burns readily and recovers quickly after fire unless drought stressed. Spread of *Lantana* is correlated with removal of vegetation and is facilitated by disturbance of native vegetation. It is known to rapidly invade and dominate more open areas (Thaman, 1974; Swarbrick *et al.*, 1995) but is less able to invade dense tropical forests where it tends to persist only at edges and where there are gaps in the canopy (Swarbrick *et al.*, 1995).

Plate 11. Dense thicket of *Lantana camara*. *Lantana* was common on Yadua Taba in 2003-2004 but such dense thickets as this were uncommon.

The species is well adapted to short-range dispersal as its major dispersal seems to be by birds that eat the ripe fruit (Thaman, 1974; Parsons & Cuthbertson, 1992; Swarbrick *et al.*, 1995). The common Mynah (*Acridotheres tristis*) especially is well known as a disperser of *Lantana* seeds (Swarbrick *et al.*, 1995; Thaman, 1974). In Australia, the Silvereye (*Zosterops lateralis*) is an important disperser of *Lantana* seeds (Liddy, 1985); this species is the commonest bird seen on Yadua Taba (Laurie *et al.*, 1987). In Australia two species of fruit dove (genus *Ptilinopus*) are

recorded as likely dispersers of *Lantana* (Loyn & French, 1991*),* so the common crimson-crowned fruit dove of Yadua Taba *(Ptilinopus porphyraceus*) as well as the white-throated pigeon (*Columba vitiensis*) are also potential *Lantana* seed dispersers. Thus, seeds of *Lantana* are likely to be widespread through the forest of Yadua Taba and available in the soil seed bank if gaps in the forest canopy occur.

Occurrence on Yadua Taba

Olson *et al.* (2002) reported *Lantana* in extensive patches within the dry forest of Yadua Taba, forming thick mats that grew up and over the canopy in several cases. In July 2003 *Lantana* was found to be common but was patchily distributed. Most patches were sparse and not the dense infestations for which *Lantana* is renowned. The largest patches were in the grass lands and forest edges along the central ridge line. Its occurrence in the forest seemed to coincide with canopy gaps, especially where there had been a treefall (mostly of *Casuarina equisetifolia* trees).

Lantana is common on Yadua and is likely to have been brought to Yadua Taba by birds. *Lantana* spread 100 m into rainforest in Queensland (Willson & Crome, 1989 as cited in Loyn & French, 1991) and Thaman (1974) suggests dispersal by birds may be up to 1 km. As Yadua is only 120 m from Yadua Taba at the closest point, Yadua will continue to provide a source of *Lantana* seeds.

Control measures: implementation and effects

Most patches of *Lantana* encountered on Yadua Taba in July 2003 were relatively small, consisting of approximately 1-10 scattered plants in a single clump.

Complete removal of plants is recommended as a means of control where possible and was used in July 2003 for smaller plants. Where plants were too large to remove by hand we cut and poisoned them. Plants were cut as close as practical to the ground and below any branches. The cut was made as horizontal as possible so the herbicide would not run off. Undiluted 'Glyphosate 360' was applied from a 250 ml soft plastic squeeze bottle to the outer rim of the cut stump. There is no need to cover the central heartwood with herbicide.

All cut branches and stems of *Lantana* were carefully hung in low tree branches or bundled onto large, open rock piles so that they were not in contact with

any soil. Under these conditions cut *Lantana* stems will eventually desiccate and die, although this will take some months even in the dry season. *Lantana* will readily root from nodes where it touches any damp soil. An important part of the village awareness program was to stress to the ranger and village men that slashing or burning *Lantana* without follow-up poisoning and without care to avoid cut branches taking root, will only result in an increase in the density of *Lantana* on Yadua Taba.

In November 2004 the *Lantana* that had been removed by the roots and hung upside down in trees or placed on rocks had dried out and appeared dead.

Chemical and biological control methods for *Lantana*

Potential biological and chemical controls of *Lantana* have been reviewed in a number of places (*e.g*., Julian, 1992, as cited in Swarbrick *et al.*, 1995; Swarbrick *et al.*, 1995). Only some chemical controls have proved effective and effectiveness varies among plants, with plant size, and with season of application (Motooka, 2000). In Queensland, Australia, applications of some herbicides were found to be largely ineffective during cool or dry times (Swarbrick *et al.*, 1995). The results of biological controls have frequently been unsuccessful although it may slow the spread of *Lantana*, and significant control has been achieved in some instances (Swarbrick *et al.*, 1995). Success of biological control seems to vary with the habitat and with the variation in the plant across its range (Julian, 1992, as cited in Swarbrick *et al.*, 1995). It should be noted that biological controls rarely prove to be a viable control alternative due to the low rate of success (1 in 6), risk posed to non-target species, and the large amount of research and development time and resources that are required (Hobbs & Humphries, 1995). Existing biological controls seem unlikely to be effective on the sparse coverage of *Lantana* on Yadua Taba and would not be recommended at this point in time.

Recommended future management practices

1. Currently, the small amount of *Lantana* present on Yadua Taba is most easily and effectively controlled by hand removal or cutting and poisoning with herbicide.

2. Pieces of cut *Lantana* stem must not be left on the ground as they may shoot and grow into a new plant.

3. Any cut stems not uprooted must be treated with herbicide to prevent them regrowing, and need to be checked in case new shoots grow from underground rootstock.

4. All areas where *Lantana* is removed will need follow-up inspections to remove any seedlings.

Regular monitoring and control is important for this species as once established there is evidence that few native seedlings will germinate underneath the *Lantana* (Swarbrick *et al.*, 1995 and references cited therein). As with the other invasive species discussed here, *Lantana* control should be part of the ranger's regular Sanctuary Management plan, as detailed in the Discussion.

The spread of *Lantana* in the Pacific is largely correlated with open habitats that result from disturbance, and both fire and grazing are thought to have been important in its spread (Thaman, 1974). With cessation of goat grazing and forest fires on Yadua Taba, the rate of spread of *Lantana* is likely to slow as the amount of open habitat available for invasion lessens. As with the other most invasive species identified on Yadua Taba, the abundance of *Lantana* needs to be regularly monitored. Even with minimal disturbance from human activities, tree falls will continue to provide gaps in the forest that may be colonised by *Lantana*. This seems especially likely higher up on the island where there are many old *Casuarina equisetifolia* trees that seem to account for many of the fallen trees. Birds will continue to disperse seeds of *Lantana* from Yadua into such gaps. Thus it is unlikely that *Lantana* will be eradicated from Yadua Taba. However, with regular control measures in place and by limiting human disturbance on the island, a significant reduction in abundance of *Lantana* should be achieved.

INVASIVE PLANT SPECIES OF LESS CONCERN

As well as the four invasive species described above, there are a number of introduced plant species which are difficult (perhaps ‘impossible’?) to control but which are common in the forest of Yadua Taba. Two of these species are listed among the world’s worst 100 invasive species by the IUCN (IUCN Global Invasive Species Database, 2003) and considered to be significant invasive plants in Fiji (Meyer, 2000): vaivai (*Leucaena*

leucocephala) and mile-a-minute vine (*Mikania micrantha*). Both species are native to tropical America and both are common on Yadua Taba. Although these species are highly invasive, we believe that in the absence of forest disturbance they do not require active control on Yadua Taba. Indeed, the disturbance required to physically control *Leucaena* and *Mikania* may in fact increase the spread of these and other weeds.

Vaivai (*Leucaena leucocephala*)

Description and species notes

Vaivai (*Leucaena leucocephala*) forms almost pure stands of small to medium-sized thornless trees 3-15 m tall and 5-50 cm in trunk diameter. Of the three subspecies, the one introduced into Fiji is presumably the smaller *Leucaena leucocephala* subsp. *leucocephala*, also called the Common or Hawaiian type, which is significantly smaller than the maximum sizes listed above. Trees are generally short lived (20-40 years), however the hard seed coat means that seeds can remain viable in the soil for at least 20 years. Flowering and seeding may occur throughout the year as long as moisture permits. Pods occur in crowded clusters of 5-20 per flower head, are 11-19 cm long, 15-21 mm wide, pendulous, flattened and papery with 8-18 seeds per pod (IUCN Global Invasive Species Database, 2005; Plate 12).

Vaivai is a weed of open, disturbed and degraded habitats, but is not known to invade undisturbed closed forests (*e.g.*, Christmas Island: Swarbrick & Hart, 2000). It can flourish in tropical and subtropical areas with strongly seasonal rainfall, and survives in areas with 500-3500 mm rainfall per year. Once established it is difficult to eradicate, and it re-sprouts vigorously after cutting.

Vaivai is readily dispersed to at least 35 m from the parent tree in agricultural areas (Patil & Kumar, 1990). Trials in South Africa found a low germination rate of *Leucaena leucocephala* seed and that germination rate was reduced by about 80% after passing through the gut of goats (Smit & Rethman, 1996). However, this shows that goats are potential dispersers of vaivai seeds, and where goats are present the dispersal distance of vaivai is likely to be much greater than 35 m.

Plate 12. Vaivai (*Leucaena leucocephala*) with seed pods.

Occurrence on Yadua Taba

Vaivai is common on Yadua, including on Nukubalavu Peninsula only 120 m across the water from Yadua Taba. On Yadua Taba it is restricted to three major patches on the northern end of the island across the water from Nukubalavu Peninsula (L1: 16°49.60'S, 178°16.69'E; L2: 16°49.62'S, 178°16.67'E; L3: 16°49.66'S, 178°16.61'E; Fig. 6). Occasional scattered seedlings were found between these discreet patches and two outlying mature tree were found about 150 m south of the larger patches (16°49.76'S, 178°16.63'E; L4 on Fig. 6). These two trees were in the understorey of apparently undisturbed dry forest but may have colonised a gap in the forest that was no longer visible. Within the main patches of vaivai, trees are at very high density and occur as almost pure stands towards the centre of the patches (Plate 13).

A bruchid beetle (*Acanthoscelides macrophthalmus*) seed predator of *Leucaena leucocephala* has been introduced into South Africa and Australia as a biological control (IUCN Global Invasive Species Database, 2003). In September 2002 a species of bruchid beetle devastated vaivai seeds on Yadua Taba (Charan,

2002), but this beetle has not to our knowledge been identified. The vaivai on Yadua Taba was also severely defoliated in September 2002 and this has been attributed to the psyllid insect defoliator, *Heteropsylla cubana* (Charan, 2002). The combination of these two insects will not kill the trees, however they can seriously debilitate trees which may slow its spread to adjacent areas.

The vaivai patches on Yadua Taba are largely composed of mature trees and the dense cover of dry seed pods on the ground is evidence of abundant seed production by these trees. As seeds may remain viable for at least 20 years, there are likely to be large quantities of viable vaivai seed within the soil seed bank of the four patches of vaivai on Yadua Taba. The vaivai patches are also located on the ridge top. This means that vaivai seeds are likely to have been dispersed many metres into the adjacent native forest by the prevailing winds and by washing down hill. Seeds are likely to have been spread even further afield in the droppings of the goats that were previously on the island.

Plate 13. Vaivai (*Leucaena leucocephala*) on Yadua Taba showing the high density of vaivai plants and lack of understorey plants.

Control measures: implementation and effects

July 2003

In July 2003 two potential control measures were trialed on vaivai plants on Yadua Taba. On 21 July 2003 the authors and 27 men from Denimanu village on Yadua chopped and poisoned (with diesel fuel) an estimated 350 vaivai stems in patches L1 (16°49.60'S, 178°16.69'E) and L3 (16°49.66'S, 178°16.61'E; Fig. 4e). On 22 July the authors chopped and poisoned (with undiluted Glyphosate 360) an estimated further 150 stems in patch L2 (16°49.62'S, 178°16.67'E). In all cases trees were cut down at about 20-80 cm above ground level. The two mature, seeding vaivai trees that were located 150 m south of the nearest patch (16°49.76'S, 178°16.63'E; Fig. 6) were cut and poisoned with undiluted Glyphosate 360 as above (Fig. 4e). All seedlings found around these two trees (about 20 individuals between 5 cm and 1 m tall) were uprooted by hand.

November 2004

By November 2004, neither of the two control measures implemented in July 2003 had succeeded in reducing the density of vaivai trees. In patch L2 (Fig. 6) we examined a sub-sample of 23 of the *Leucaena* trees cut and poisoned with glyphosate in July 2003. All of these trees had stems of between 2 and 10 cm (average about 5 cm) diameter that had been cut off between 20 and 80 cm (average about 50 cm) above ground. Only one of the 23 plants (4.3%) was dead in November 2004, the remaining plants had sprouted new growth from the base or along the trunk. Most of the re-sprouting plants had multiple new shoots, although a few had single very vigorous stems sprouting from the trunk (Plate 14). Results for treatment with diesel were not quantified but were similar.

Summary of effects of controls

Based on the extremely low success rate of control measures implemented in July 2003, we concluded that cutting and poisoning would not control the vaivai on Yadua Taba. In fact, the vigorous regrowth of treated vaivai plants indicated that the type of cutting and poisoning used in July 2003 was highly likely to result in the vaivai

patches increasing in density due to production of multiple stems by most cut stems. This would be likely to further hinder regeneration of native forest.

In July 2003 the vaivai patches did not appear to be advancing into the adjacent native forest. In November 2004 we established two transects with permanent markers from the native forest across the edge into vaivai patches L1 & L2 (Fig. 6) to quantify changes in abundances of species at the junction of the vaivai and the native forest. Each transect was 30 m long with approximately 5 m in native forest and 25 m in a vaivai patch. Each transect was divided into quadrats 2 m X 2 m within which we identified all plant species and counted the number of individuals of each species. There were relatively few native seedlings within the centre of the patches of vaivai and very few vaivai seedlings in the adjacent forest (Fig. 7). However, along the boundary between the native forest and the vaivai patches, both native and vaivai seedlings appeared to be common (Fig.7).

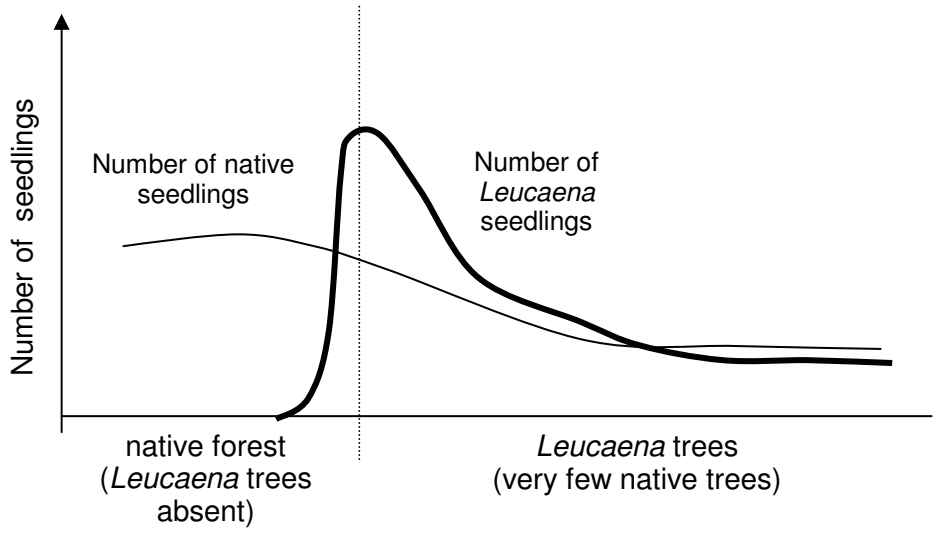

Figure 7. Stylised diagram showing abundance of vaivai (*Leucaena leucocephala*) seedlings relative to the number of native seedlings in relation to the boundary of the native forest and the vaivai patch. Based on data from two transects.

(a)

(c)

(b)

Plate 14. Vaivai (*Leucaena leucocephala*) that were cut and poisoned in July 2003 had, by November 2004 sprouted multiple new shoots from the base [**(a)** and **(b)**] or single new vigorous shoots from the trunk as in **(c)**.

Discussion and recommended future management practices

In the absence of disturbance from fire and goat grazing, we predict that seedlings of the native forest species will gradually out-compete the vaivai seedlings over the next few years. Some active management may aid this process:

1. Although there is no advantage in cutting vaivai trees, hand removal of vaivai seedlings may aid establishment of native seedlings found in the vaivai patches by reducing competition.

2. Vaivai seedlings may need to be removed by hand if they manage to out-grow the native seedlings.

There is likely to be a large store of vaivai seed in the soil in and around the vaivai patches. It is thus recommended that:

3. the canopy of the surrounding forest should not be disturbed to minimise opportunities for vaivai seedlings germinating and establishing.

4. any gaps that occur in the forest due to falling trees be checked for emerging vaivai seedlings.

Leucaena leucocephala trees are recorded as relatively short lived. If the above control measures are followed, adult trees may have mostly disappeared from the island in 10-20 years having reached their lifespan and died. However, the large store of seeds in the soil means that on-going monitoring beyond this time may be necessary to remove occasional seedlings that become established in forest gaps.

Mile-a-minute vine (*Mikania micrantha*)

Description and species notes

Mikania micrantha is a perennial climbing vine with distinctive white-cream flowers borne in many large, loose heads. *Mikania* was first recorded in Fiji in 1906 (Whistler, 1995) and today is a common weed in pastures, along roadsides and forest edges in many parts of Fiji. It is considered unlikely to germinate under dense vegetation and it grows best on forest margins and disturbed areas that are well lit (Swarbrick & Hart, 2000).

Occurrence on Yadua Taba

On Yadua Taba *Mikania* is mostly an opportunistic invasive of forest gaps. It occurs in extensive patches in only a few large clearings in the dry forest on Yadua Taba, where it forms thick mats that grow up and into the canopy. Its seeds are wind dispersed (Swarbrick & Hart, 2000) and are likely to be widespread through the forest of Yadua Taba.

On Yadua Taba it would be virtually impossible to remove *Mikania* except by intensive hand removal, a pointless exercise as it would rapidly re-invade. In addition, *Mikania* does not appear to significantly retard the regeneration of forest tree seedlings, and retreats once these native seedlings grow to fill the forest gap. Thus, rather than attempting to remove *Mikania*, it is far better to let normal forest regeneration occur. This is then likely to result in a natural suppression of the *Mikania*.

OTHER PLANT SPECIES OF LESS CONCERN

Passion fruit vines (*Passiflora suberosa* and *P. foetida* var. *hispida)*

Two species of New World *Passiflora* are naturalised and common on Yadua Taba: *Passiflora suberosa* and *Passiflora foetida* var. *hispida* (Smith, 1981). Both are vigorous climbing, twining or scrambling vines that are most obvious during the wet season, but die back and are barely visible by the end of the dry season. In July 2003 (mid dry season) these two species had very low biomass on Yadua Taba and were difficult to find. In November 2004 (beginning of wet season) after recent rains they were much more common. Although regarded as invasive in many parts of their non-native range (*e.g.*, south-east Queensland, Australia: Batianoff & Butler, 2002), there is no feasible way to remove these species except by intensive hand removal. Due to the die back of these two species in the dry season, it is possible that they do not displace native plants on Yadua Taba. However, a detailed study of these species on Yadua Taba would be required to determine if this is actually the case.

In addition, the fruit (and probably the leaves) of both species are eaten by crested iguanas, which may actually contribute to maintenance of the high population of iguanas on the island. Analyses of the droppings obtained from 56 iguanas in April - May 1999 found that 44 (77%) contained the seeds of *P. suberosa* fruit and two contained the seeds of *P. foetida* fruit (Harlow & Biciloa, unpublished data). As a consequence, the seeds are likely to be widely dispersed by the iguanas, making it impossible to control or eradicate the species.

Mission grass (*Pennisetum polystachion*)

Mission grass (*Pennisetum polystachion*) is a perennial grass native to Africa and India but widely naturalised in tropical areas around the world (IUCN Invasive Species Specialist Group Database 2005). It forms large tussocks 50-200 cm tall and its light fluffy seeds are readily dispersed on fur or clothing or by water (Parsons & Cuthbertson, 1992). It is especially abundant in Fiji where it dominates many dry hillsides (Whistler, 1995) and is listed as one of the dominant invasive plants of Fiji (Meyer, 2000).

Mission grass is primarily a weed of cultivated or other disturbed areas (Parsons & Cuthbertson 1992; IUCN ISSG Database 2005). On Yadua Taba it is one of the dominant species of grassland areas (Olson *et al.,* 2002). It also occurs in gaps in the forest, for example mission grass and another introduced grass, *Paspalum conjugatum*, were growing in the gap in the forest on the seaward side of the rain tree the was killed in September 2002. However, mission grass does not occur in the undisturbed native forest on Yadua Taba, although the easily dispersed seeds may be present.

We do not recommend any control measures for this grass at present as there is evidence that the native forest is capable of regenerating over grassland areas where the mission grass is abundant (Olson *et al.*, 2002). The edge between the forest and grassland should be monitored to determine if the native forest is still advancing into the grassland. Areas of other weed control efforts should be monitored for invasion by mission grass. Disturbance to native forest should be avoided so as to minimise the potential for invasion by mission grass. A

reassessment of its status and its effects on regeneration of native forest should be made in about 5 years time.

Kudzu vine (*Pueraria lobata*)

Description and species notes

Pueraria lobata is a semi-woody climbing vine from 10–30 m long that can form large tuberous roots. The leaves are alternate, with 3 leaflets each 8-18 cm long and 6-20 cm wide. Its flowers are in a reddish-purple inflorescence and the fruit is a flattened legume that is brown and hairy and splits to release a few hard-coated seeds. This native of Asia can form dense infestations covering ground and trees. The species is recorded as very invasive in several parts of the world and difficult to eradicate. (IUCN Global Invasive Species Database, 2005)

Occurrence on Yadua Taba

Kudzu vine was listed by Meyer (2000) in his review of invasive plants of the Pacific as a potential invader in French Polynesia and a moderate invader in Hawaii. It is also known from Fiji (Swarbrick, 1997). Kudzu vine was recorded as an uncommon plant in the dry forest of Yadua Taba by Olson *et al.* (2002) but was not sighted in July 2003 or November 2004. In Fiji this species is common on disused agricultural land and other highly disturbed sites (G. Keppel pers. comm.), so it seems likely that it will not become a problem species on Yadua Taba.

Paw paw or weleti (*Carica papaya*)

The paw paw is native to Central America and is widely cultivated throughout the South Pacific and other tropical areas for its delicious, edible fruit. Generally, paw paw is not considered to be a problematic weed of any region of the world (OECD, 2003). Nevertheless, *C. papaya* has naturalised in many tropical and subtropical countries (Randall, 2002). Space *et al.* (2000) have suggested that in Rota, in the

Mariana Islands, paw paw may be invasive in highly disturbed habitats. Similarly, Kwit *et al.* (2000) observed the establishment of exotic *C. papaya* seedlings following disturbance of forest canopies by a hurricane.

Occasional paw paw trees are found in the dry forest of Yadua Taba, but do not appear to be very common. Birds and fruit bats undoubtedly disperse the seeds, and crested iguanas have been seen feeding on the over-ripe fruit (P. Biciloa pers. obs.). Paw paw does not appear to be an invasive species or a threat to the undisturbed forest of Yadua Taba.

NATIVE PLANT SPECIES OF INTEREST

Vao (*Neisosperma oppositifolium*)

Neisosperma oppositifolium (vao) is a native tree that is widely distributed on islands in the Indian and Pacific Oceans (Parham, 1972). It is a natural component of the dry and beach forest of Fiji but normally only moderately common in these forests. However on islands that are severely disturbed by intensive goat grazing and regular forest fires vao has the potential to dominate (Harlow & Biciloa, 2001) as it is not eaten by goats.

On Yadua Taba it is an uncommon forest species, but is abundant at one site (< 0.5 ha in area) behind the small beach on the north-western end of the island (Baravi o Talice; 16°49.74'S, 178°16.58'E). This site is immediately inland of the first patch of *Wedelia* (W1) successfully removed from Yadua Taba. On 21 July 2003 a team of men from the village of Denimanu cut or ringbarked (but did not poison) about 30 mature and sapling vao trees, plus many sprouting coconut trees, at this site. Vao was not one of the species that we had previously discussed as in need of control on Yadua Taba although it may be a species requiring control on other islands targeted for beach forest restoration (see below). We do not recommend any control measures for vao (*Neisosperma oppositifolium*) on Yadua Taba due to the fact that:

1. it is a natural component of the forest and is not invasive except in response to severe forest disturbance;

2. it is very uncommon on the island except in a very small area at just one site; and

3. any control measures would create large gaps in the canopy. There is good evidence that such gaps in the canopy elsewhere on Yadua Taba have provided invasion points for weeds such as *Lantana*, rain tree, vaivai and guava. Gaps in the canopy at the current patch of vao would provide a potential invasion point for these weeds and the introduced weed *Wedelia* removed from the area adjacent to this site in July 2003.

The response of these vao trees on Yadua Taba to ringbarking may provide useful information for future restoration of disturbed beach forest on islands in other parts of Fiji. The cutting and ringbarking in July 2003 seems largely to have failed to kill the vao plants. By November 2004 most of the plants had sprouted vigorous new growth from the base (Plate 15) and many of the ringbarked trees also had vigorous new growth in the canopy. We recommend monitoring the recovery of these trees.

Plate 15. Vao (*Neisosperma oppositifolium*) trees that were ringbarked in July 2003 had all sprouted vigorous new shoots by November 2004.

Nokonoko (*Casuarina equisetifolia*)

Casuarina equisetifolia is a fast-growing colonising species that is abundant on Yadua Taba. Its abundance may have resulted from the opening of the vegetation by frequent fires and goat grazing providing suitable sites for *Casuarina* to grow. There are large numbers of *Casuarina* trees towards the top of the ridge in forest that has probably regenerated from grassland over the last 25 years. *Casuarina equisetifolia* in southern USA (where it is an introduced invasive species) reaches maximum size in 20 years and has a maximum life span of 40-50 years.

In 2003 and 2004 most of the *Casuarina equisetifolia* trees on Yadua Taba were large and many of the largest trees may be reaching the end of their life span. Most of the fallen trees towards the top of the ridge were *Casuarina* trees. These fallen trees have produced gaps in the forest that have often been colonised by weeds, especially *Lantana*. These gaps therefore represent particular areas that should be monitored for invasion by *Lantana*.

POTENTIAL THREATS TO NATIVE FOREST AND CRESTED IGUANAS ON YADUA TABA

The greatest potential threats to the crested iguanas on Yadua Taba are loss of habitat, introduction of predators (eg. mongooses, cats, ship rat) or the introduction of an exotic reptile disease to which the iguanas have no natural immunity.

The possibility of disease introduction can be minimised by limiting the number of people visiting the island, avoiding transfer of iguanas or other reptiles onto the island and preventing movement of other biological material onto the island.

Introduced predators have caused the rapid extinction of iguana species on islands elsewhere in the world. Feral cats and dogs eliminated the entire population (estimated at 15 000) of West Indian rock iguana (*Cyclura carinata*) on the island of Pine Cay in less than five years (Iverson, 1978). Feral animals (mostly mongoose and cats) caused the near extinction of the Jamaican iguana, *Cyclura collei* (Vogel

1994). None of these predators are currently on Yadua Taba, but all occur elsewhere in Fiji. The chance of introduction of predators to Yadua Taba can be minimised by limiting visitation to the island.

The habitat that provides food, shelter and breeding resources for crested iguanas on Yadua Taba are the beach and dry forests. Therefore threats to these forests constitute threats to the survival of the iguanas on Yadua Taba. The main threats to this habitat are likely to come from introduction of other invasive plant species, expansion of existing invasive species, repeated burning or crazy ant 'supercolonies' developing.

Direct human disturbance and invasive species

We recommend that every effort be made to avoid disturbance to the existing vegetation. This includes not allowing any permanent structures to be built on the island, minimising visitation, not clearing vegetation and minimising disturbance when weeds are removed.

Buildings inevitably encourage more visitors to stay overnight, as well as providing openings in the vegetation that encourage invasion by weeds. Transport of building materials to the island provides a great risk of introducing new invasive plant and animal species. Invasive species are frequently moved around with such materials.

Visitation to the island should be kept to a minimum to reduce the risk of introducing new invasive plant or animal species or potential pathogens to the island. It will also minimise disturbance to the vegetation. Limiting disturbance to the vegetation will also help limit the expansion of existing invasive plant species as these are more likely to be able to germinate and spread in the presence of disturbance.

Other disturbance: fire and cyclones

Two other disturbances that are likely to affect the island are fire and cyclones. Evidence from the past indicates that repeated burning is devastating to beach and dry forest and gradually converts it to grassland. This process is apparently exacerbated by grazing from goats. We therefore recommend that fire continue to be

excluded from Yadua Taba. However, once forest has regenerated over Yadua Taba there is every indication that the island is at relatively low risk of being devastated by fire. In fact, the native forest in good condition is likely to be fairly resilient to a single fire for the following reasons.

1. Most of the fuel for fires on Yadua Taba comes from dried grasses and other weeds in grassland areas.

2. Forest in good condition has low fuel loads with relatively little leaf litter on the ground. This probably results from a rapid turnover of leaf litter during the wet season. Rapid decomposition rates are likely to be assisted by the large population of land crabs on Yadua Taba.

3. Low fuel levels and relatively high humidity in the forest for much of the year will tend to result in low intensity and very patchy fire if a fire does enter the forest. There is evidence for this from single fires on other dry-forest islands in Fiji where fires in grassland have been observed to burn only a small distance into neighbouring forest (order of 5-10 m, Waya Island: P. Harlow pers. obs.).

4. There is also evidence from seasonally dry rainforests in other tropical areas suggesting that these forests may recover from a single, occasional fire but repeated fires will destroy and convert forest to grassland.

The above would suggest that a one-off fire is unlikely to be devastating to iguanas on Yadua Taba. In addition, on Yadua Taba a fire is most likely to occur in the late dry season of September to December, when there are large numbers of iguana eggs still in the ground. So in the extremely unlikely event that the adult population was devastated by fire, large numbers of hatchlings are likely to appear after the fire and at the onset of the wet season.

Cyclones occur in the wet season when Fijian crested iguanas are mating and laying eggs. A severe cyclone hit Yadua Taba in January 1993 (Cyclone Kina) when there was less forest on the island and the iguanas appear to have recovered rapidly. It seems unlikely that any cyclone is likely to be completely devastating to such a large iguana population.

Crazy ants (*Anopolepis gracilipes*)

The yellow or long-legged crazy ant, *Anopolepis gracilipes*, was identified by Olson *et al.* (2002) on Yadua Taba. This species is native to Africa or tropical Asia and has been introduced to many other countries (Australia, Pacific islands, SE Asia, Indian Ocean islands, Caribbean islands, South America, Madagascar and Hawaii). It is listed as one of the top 100 world's worst invasive species (Global invasive species data base, IUCN 2005). In 2003 and 2004 this species of ant was extremely commonly seen feeding on sap-sucking scale insects living on *Planchonella grayana* plants.

On Christmas Island, Australia, the species existed without being a problem for many years but was observed to form 'super colonies' in the early 1990's. In the time since then, the yellow crazy ant has had devastating effects on the land crabs, native forest and other fauna of Christmas Island (Green *et al*., 2004).

It is unclear what triggered the explosion in the population size of this ant on Christmas Island. We recommend that a close watch be kept on the abundance of this ant on Yadua Taba. Perhaps the only insurance for possible effects of this species, if it should explode in abundance, is to establish iguana colonies on Fijian islands free of crazy ants.

VILLAGE AWARENESS PROGRAM
written by Jone Niukula

The village awareness presentations were conducted in Denimanu Village, Yadua Island, on Saturday 19 July 2003 and were sponsored by the Wildlife Conservation Society, South Pacific Program.

Location - Village Spokesman's bure

Duration - 1 hour

Attendance - 11 people attended, including the Matanivanua (Village Spokesman), Turaga ni Koro, Pita Biciloa (ranger) and Senirusi Sevutia (volunteer ranger). Their presence was greatly appreciated as they are among the most respected persons in the community and have a lot of influence in village decision making, as well as

influence on others members of the community. It was recommended that the participants pass on the information that they learnt at this session to the others members of the community, so as to increase their understanding of the project that they had participated in.

Talks given (in Fijian) by three team members and topics covered

Baravi Thaman

- biology of plants [photosynthesis in the leaves]
- intake of water by the roots
- xylem and phloem and their importance
- why the invasive-plant eradication on Yadua Taba has been done by ringbarking and poisoning (*i.e.*, why the stems were cut only on the outer layer, and why were the cut stems painted with diesel or 'Glyphosate 360' ?)

Issac Rounds

- distribution of specific plants in the region and their origins
- seed dispersal agents for different types of plants (eg. wind, flotation, birds, bats and iguanas)
- weeds (why they are weeds and how major weed species in Fiji are dispersed)
- other herpetofauna species found in Fiji and what constitutes an 'endemic' species (examples given were the Fiji ground and tree frogs).
- recommendations on controlling or eradicating probable invasive species which are already present on Yadua Island but not Yadua Taba (an example given was African tulip trees in the school compound).

Jone Niukula

- introductions
- preventing the introduction of new weeds (its importance and how to prevent new species establishing on Yadua)
- iguanas in Fiji, their lives, food and predators
- conclusions - the importance of future monitoring of the current project's results to find out the successes and failures, proposed future visits from the National Trust of Fiji Islands to the Iguana Sanctuary Island of Yadua Taba.

DISCUSSION AND RECOMMENDATIONS

A realistic assessment of Yadua Taba is that the plant community will always include a mix of native and introduced species. This is similar to other islands in Fiji (Ghazanfar, 2001). Given the longevity of some seed banks of the invasive species and the mobility of some of their seed dispersers, it is unlikely that complete removal of more than a few targeted introduced species will ever occur. The risk of reinvasion is high.

Long-term control or removal of an invasive weed requires treatment of the cause of the weed invasions (Fox, 1991; Hobbs & Humphries, 1995). Removal of goats and fire from Yadua Taba have been very important steps in this. It seems likely that in the absence of goats and other disturbances, native plant species may be able to out-compete many of the invasive species. However, consideration of future sources of propagules of weed species, and limiting the chances of reinvasion are also essential. The long-term management plan for Yadua Taba should aim to:

- increase the area covered by forest dominated by native species,
- decrease the area covered by grassland or dominated by invasive species, and
- minimise the amount of disturbance occurring on the island.

An increase in native forest will increase the resistance of the island vegetation to further weed invasion. It will also increase the available forest habitat for crested iguanas providing for a larger iguana population. A larger iguana population is likely to be more resilient to stochastic events such as cyclones or one-off fires.

Work done in 2003 and 2004 on Yadua Taba indicate that resources available to the National Trust are sufficient to achieve the above aims. The ranger, Pita Biciloa, is fully trained and experienced in all the techniques referred to in this report. Table 3 outlines an approximate five-year work plan for control of the four major invasive plant species identified on Yadua Taba. All work should be completed during the wet season when plants are most susceptible to poisoning. Full details of all work (date, site, species and numbers poisoned) should be recorded in the ranger's diary to allow for tracking of the outcomes of invasive-plant control. In 2010 another invasive-plant assessment of Yadua Taba will be necessary, most

importantly to reassess our recommendation not to attempt control of vaivai (*Leucaena leucocephala*) and mile-a-minute vine (*Mikania micrantha*), and to assess regeneration of native forest where rain trees have been killed.

The conservation value conferred on Yadua Taba by the Fijian crested iguana and the beach forest habitat make it the most important area for habitat management in Fiji.

Summary of immediate management priorities

- On-going control of invasive plants as part of the ranger's regular sanctuary management duties (see details below).
- Avoid unnecessary vegetation disturbance and opening additional gaps in the forest. This is best achieved by taking care when removing weeds, and minimising the number of people on island and their activities.
- Avoid introduction of new exotic plant species, by implementing stricter quarantine on people, dogs and equipment brought to Yadua Taba, including an on-going village awareness program. Dogs should be banned from landing on Yadua Taba (because of the potential for carrying weed seeds in their fur).
- Increase awareness of the invasive weeds on Yadua that are not yet on Yadua Taba (e.g., African tulip tree, *Spathodea campanulata*; prickly pear cactus, *Opuntia sp.*), and early intervention should they be found on Yadua Taba.
- Increase awareness of vertebrates on Yadua that pose a potential threat to iguanas and beach forest if introduced to Yadua Taba (eg. feral cats and pigs, goats, domestic dogs). Currently there is no evidence of any rodent species on Yadua (or Yadua Taba) except for the Pacific rat, *Rattus exulans*.

Specific priorities for the invasive species of most concern

On-going control of the invasive plants on Yadua Taba will be part of the regular duties of the ranger, Pita Biciloa. At least one day per week during the wet season should be devoted to hand removal or cutting and poisoning of the four invasive species (rain tree, *Wedelia*, *Lantana* and guava). The ranger needs to record in his work diary the full details of all invasive-plant eradication work to

allow quantification of the success of control measures. Diary records need to include details of date, site, species and numbers removed or poisoned. Additional notes about regeneration of native plants in areas of invasive-plant control aid the assessment of success of the weed eradication. Photocopies of all diary entries should be kept at the National Trust office in Suva. Below is a list of the main actions required for each of the invasive species of most concern and Table 3 below shows an approximate five-year work plan.

Rain tree (*Samanea saman*)

- Long-term 'chisel and poison' program is needed
  - (i) start with the large patch of seeding rain trees behind Baravi o Cakadriki;
  - (ii) then poison all remaining seeding rain trees on Yadua Taba;
  - (iii) then all medium-large rain trees on Yadua Taba;
  - (iv) finally all small rain trees on Yadua Taba;
  - (v) revisit rain trees one year after poisoning to check that trees are dead, chisel (but do not remove) and poison any new shoots on trees; and
  - (vi) two years after poisoning, revisit sites of poisoned rain trees to remove any weed seedlings (especially seedlings of rain trees, lantana, guava and vaivai).

***Wedelia* (*Wedelia trilobata*)**

- Monthly checks on all *Wedelia* sites by the ranger,
  - (i) continue hand removal of new shoots at known sites
  - (ii) regular checks for new sites of invasion by *Wedelia*.

Guava (*Psidium guajava*) & *Lantana* (*Lantana camara*)

- continue to cut and poison these species when seen,
  - (i) give priority to mature guava trees and large *Lantana* clumps growing along the forest-grassland ecotone;
  - (ii) remove seedlings of both species by hand whenever encountered; and
  - (iii) one year after poisoning, revisit poisoned plants to check that they are dead, chisel and poison any new sprouts on plants.

Table 3: Five-year work plan for control of the four major invasive plant species on Yadua Taba showing number of days work required per month and per year. All work should be done during the wet season, and full details recorded in the ranger's work diary.

Weed species	November to April (wet season)	**Action required**	Number days per month *	Minimum days work per year *
Rain Tree	2005 - 2006	▪ Chisel & poison seeding trees, ▪ start behind Baravi o Cakadriki	2 to 3	12 - 18
	2006 - 2007	▪ Chisel & poison all remaining seeding trees, ▪ Check & poison any trees not yet dead after poisoning in 2005-06	2 to 3	12 - 18
	2007 - 2008	▪ Chisel & poison all medium-large trees ▪ Check & poison any trees not yet dead after poisoning in 2006-07 ▪ Hand remove any weed seedlings beneath dead rain trees	2 to 3	12 - 18
	2008 - 2009	▪ Chisel & poison all remaining medium-large trees ▪ Check & poison any trees not yet dead after poisoning in 2007-08 ▪ Hand remove any weed seedlings beneath dead rain trees	2 to 3	12 - 18
	2009 - 2010	▪ Chisel & poison all remaining trees ▪ Hand remove any weed seedlings beneath dead rain trees	2 to 3	12 - 18
Wedelia	2005 - 2010	▪ Hand remove & return to Yadua for burning, ▪ search for new invasions	1 to 2	6 - 12
Guava	2005 - 2010	▪ Cut & poison trees as encountered, ▪ Check & poison any trees not dead from first poisoning ▪ Hand remove seedlings	1 to 2	6 - 12
Lantana	2005 - 2010	▪ Cut & poison medium & large plants when seen, ▪ Check & poison any trees not dead from first poisoning ▪ Hand remove seedlings	1 to 2	6 - 12

* Number of days assumes one person, fewer days may be needed if ranger has several people assisting.

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APPENDICES

Appendix 1: Field work on Yadua Taba

July 2003: The initial trip to assess the status of invasive weeds on Yadua Taba and implement experimental control measures was made by all authors from 18 - 23 July 2003. Twenty-seven men from Denimanu village on Yadua joined the authors on Yadua Taba to assist in weed control.

May 2004: On 26 & 27 May 2004 Jone Niukula, Pita Biciloa, Senirusi Sevutia and Clare Morrison, with assistance from 34 men and boys from Denimanu Village, continued weed control on Yadua Taba. *Wedelia* patches were re-weeded by hand and approximately 210 large rain trees growing behind and to the north of Baravi o Cakalevu (i.e. camping beach) were ringbarked and poisoned with diesel.

November 2004: From 15 to 20 November 2004 Pita Biciloa, Senirusi Sevutia, Jennifer Taylor, Peter Harlow, Wendy Kinsella, Rick Van Veen and Sara Hicks assessed the success of previous weed control measures implemented and continued rain tree, *Wedelia*, Guava and *Lantana* eradication work on Yadua Taba.

Appendix 2: Introduced plant species on Yadua Taba

Plant species recorded on Yadua Taba that are not native to Fiji. Source of the record (Source) and information about potential invasiveness (Invasion) is also given (see key below table).

Family	Scientific name	English common name	Source	Invasion
Asclepiaceae	*Asclepias curassavica*	milkweed	1	
Asteraceae	*Mikania micrantha*	mile-a-minute	1, 2, 3	a, c
Asteraceae	*Synedrella nodiflora*	nodeweed	1	
Asteraceae	*Tridax procumbens*	wild daisy	1	
Asteraceae	*Vernonia cinerea*	iron weed	1	
Asteraceae	*Wedelia trilobata*	trailing daisy	1, 3	a, c, d
Caricaceae	*Carica papaya*	pawpaw	1, 2, 3	
Cyperaceae	*Elaeocharis geniculata*		1	
Cyperaceae	*Fimbrystylis dichotoma*	tall fringe rush	1	
Fabaceae	*Leucaena leucacephala*	vaivai	1, 2, 3	a, c, d
Fabaceae	*Pueraria lobata*	kudzu bean	1	b, c
Fabaceae	*Samanea saman*	rain tree	1, 2, 3	a, d
Malvaceae	*Urena lobata*	hibiscus bur	1	
Myrtaceae	*Psidium guajava*	guava	1, 2, 3	a, d
Orchidaeceae	*Eulophia sp.?*		1	
Oxalidaceae	*Oxalis corniculata*	yellow wood sorrel	1	
Passifloraceae	*Passiflora foetida*	stinking passion flower	1, 2, 3	a
Passifloraceae	*Passiflora suberosa*		1, 2, 3	
Poaceae	*Bothriochloa bladhii*	Lautoka grass	1	
Poaceae	*Cenchrus echinatus*	sand bur	1	
Poaceae	*Cymbopogon refractus*	barbed wire grass	1	
Poaceae	*Eragrostis tenella*		1	
Poaceae	*Panicum maximum*	Guinea grass	1	a
Poaceae	*Pennisetum polystachion*	mission grass	1, 3	a
Rubiaceae	*Speracoce assurgens*	buttonweed	1	
Solanaceae	*Capsicum frutescens*	bird chilli	1, 2	
Solanaceae	*Solanum americanum*	black nightshade	1, 3	
Verbenaceae	*Lantana camara*	*Lantana*	1, 2, 3	a, c, d

Key:

Source: 1 = listed by Olson *et al.* (2002); 2 = recorded by Harlow & Biciloa, unpublished data; 3 = recorded by the authors in July 2003 or November 2004.

Invasion: a = listed as significant invader in Pacific and found on most Pacific islands by Meyer (2000); b = listed as potential invader in French Polynesia and Hawaii by Meyer (2000); c = in IUCN top 100 worst invasive species; d = considered invasive and of concern on Yadua Taba

* *Bothriochloa bladhii* is also known as *Andropogon bladhii, Andropogon intermedius* or *Bothriochloa intermedius*

Glossary of terms and abbreviations

allelopathy	inhibitory or stimulatory affect of one plant on another through production of chemical compounds that escape into the environment (allelopathic)
chisel	used here as a verb ('to chisel'), to describe the way this tool is used to cut into the outer bark of a tree prior to applying herbicide (see Figure 4)
conspecific	individuals of the same species
DBH	diameter at breast height (used to measure tree diameter)
ecotone	The transition area between two different ecological communities. Used here to describe the point where different vegetation types meet.
Glyphosate 360	herbicide or plant poison (common brand is 'Roundup') [Nufarm. Agchem Limited, Subsidiary Co. Lane (Fiji) I.T.D.]
GPS	geographical positioning system, for finding exact latitude and longitude (a hand held unit was used here)
internode	the part of the stem between the nodes
node	the point on a plant stem at which leaves are connected
ringbark	remove the bark in a complete ring around the stem to kill a tree as illustrated in Figure 4. Ringbarking is also termed ‘girdling’.
weed	used here to refer to plant species introduced to Fiji either accidentally or deliberately by people either recently or in historic times and that have then become naturalized in self-sustaining populations.