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Conservation, Management and Ethnobotany of Sago (*Metroxylon vitiense*)

in South-East Viti Levu, Fiji Islands

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M.Sc. thesis submitted to the
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2007
DECLARATION

I hereby certify that this thesis is my own work. Assistance and work by other people has been properly acknowledged and cited.

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I, as supervisor of the above mentioned student declare that this thesis to be the original production of the above mentioned student.

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ABSTRACT

*Metroxylon vitiense* is an endemic palm currently listed as Vulnerable by IUCN (International Union for the Conservation of Nature and Natural Resources). Once widespread throughout the main island of Viti Levu, Fiji, it is now restricted to seven populations on the southeastern part of Viti Levu. The aims of this study were to determine the current distribution of *M. vitiense*, determine the harvesting impacts on population structure, conduct ethnobotanical studies on the use of *M. vitiense* by local communities, and develop a conservation management plan for the sustainable use of *M. vitiense*.

A detailed literature survey was used to determine the location of all the historical populations of *M. vitiense* on SE Viti Levu. All these sites were surveyed and current distribution maps were drawn using COREL DRAW 12 mapping software. Four populations were identified: Galoa, Culanuku, Pacific Harbor & Wainiyabia. Areas with varying harvesting intensities (high and low) were located in each population. A total of 14 subplots were placed in each population (seven each in high and low harvesting regimes). Heights of all palms found in a 10x10 m sub-plot were classified into three categories: seedling, juvenile or adult. A detailed questionnaire was conducted on the resource owners about their use of *M. vitiense*.

Significantly more seedlings and juveniles were observed in areas with high harvesting intensities. More palms/10 m$^2$ were found in low harvesting regime than in high harvesting regimes.

In addition, the harvesting of leaves for thatching and the felling of adult trees for palm heart, opens up gaps which facilitates the introduction of weeds such as *Mikania*...
macrantha, Annona glabra and Merremia peltata which obstruct growth of *M vitiense* by smothering, competing for space and nutrients and disrupting the microclimate.

The current harvesting rates of *M. vitiense* are unsustainable as there is no replanting. The harvesting of *M. vitiense* for thatching and palm heart in SE Viti Levu has both direct and indirect negative effects on the population structure.

Re-assessment of the conservation status of the sago palm proposed that species should be listed as **Endangered (EN A4+B2b)** based on a reduction of the natural population distribution and size by almost 50% by unsustainable harvesting for thatches and palm-heart.

Citation

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CHAPTER 1
INTRODUCTION

1.1 NATURE OF STUDY

This study focuses on the biogeography, ecology, conservation status and ethnobotany of Fiji's endemic species of sago palm *Metroxylon vitiense* (H. Wendl.) H. Wendl ex Hook f. in southeastern Viti Levu, the main island of the Fiji Islands. *Metroxylon vitiense* was first formally described as *Coelococcus vitiensis* H. Wendl. in early 1862 by H. Wendland based on Seemann's collections from 1860 during his trip to document Fiji's flora. Later in 1862, it was transferred to another genus, *Sagus*, by H. Wendland, and the name became *Sagus vitiensis* (H. Wendl.) H. Wedl. Then in 1884 the name was again transferred to another genus, *Metroxylon* by J.D. Hooker, and it became *Metroxylon vitiense* (H. Wendl.) Hook.f.

Fiji has two native palm species of genus *Metroxylon*, *Metroxylon vitiense* and *Metroxylon warburgii* (Heimerl) Becc. *Metroxylon warburgii* is widely distributed in the Pacific (ranging from Vanuatu to Samoa) but is much less abundant in Fiji than the endemic *M. vitiense*, which dominates the sago palm swamps (Smith, 1979; Ehara and Mishima, 2003). *Metroxylon vitiense* is currently listed as vulnerable by the International Union for the Conservation of Nature (IUCN, 2001) (Fuller, 1997; Watling, 2005). Apart from taxonomic work by Moore (1979) and Fuller (1997) and the detailed ethnobotanical study by McClatchey and Cox (1992) on *Metroxylon warburgii* in Rotuma, there has been very little work on the biogeography, ecology or conservation status of *Metroxylon* palms in Fiji. Recently, some basic ecological and agronomic
studies of the Fijian *Metroxylon* have been initiated by Japanese scientists in collaboration with the South Pacific Regional Herbarium (SPRH) and Biology Department of The University of the South Pacific (Ehara and Mishima, 2003).

1.2 AIMS, OBJECTIVES AND RATIONALE

This study aims to:

1) Determine the current distribution of *M. vitiense* in southeastern Viti Levu

2) Assess harvesting impacts on population structure and viability

3) Conduct ethnobotanical studies on the use of *M. vitiense* by local communities

4) Assess the current conservation status of sago palm

5) To develop, in consultation with local communities and government agencies, a management plan for the conservation and sustainable use of the species.
Figure 1: The geographical focus area of southeastern Viti Levu, Fiji Islands.
1.3 HYPOTHESIS

The exploitation of *Metroxylon vitiense* in Southeastern Viti Levu, Fiji Islands for commercial thatching and the palm heart trade is occurring at an unsustainable level. This has severely threatened some populations of *M. vitiense* and other culturally important plants and animals.

1.4 METHODOLOGY

For this study four methods were used to achieve the overall objectives of the study: 1) in-depth literature survey, 2) aerial photo interpretation, mapping and field surveys and observation, 3) targeted field surveys, 4) community-based questionnaire surveys; and, 5) in-depth interviews.

1.4.1 In-depth Literature Survey

All known information about the species was collected from herbarium records, the published literature, previous surveys and local knowledge. Information collected from these sources, included information on phenology, biogeography, habitat requirements, phytosociological relationships, land-use, vernacular names and the ethnobotany of *M. vitiense*. Scientists who have worked on or are currently working on the same species or similar species were also consulted to gather relevant up-to-date information on sago palms.
1.4.2 Aerial Photo Interpretation, Mapping, and Field Surveys and Observation

Most of the more extensive *Metroxylon vitiense* populations are found in southeastern Viti Levu and two small populations on Vanua Levu. As the study focused only on southeastern Viti Levu all known populations/individuals of *M. vitiense* were located to verify their status (Fig. 1). This was done using 1:50,000 topographical maps of Navua and Namosi areas and a low-level (1:5000) aerial photograph (1994), and a preliminary mapping of existing *M. vitiense* populations was completed. This map was subsequently modified and corrected based on ground-truthing. The use of aerial photographs made it possible to map what are normally clearly defined boundaries of the relatively homogenous populations of sago palms (Chapman, 1976; Elzinga et. al., 2001).

1.4.3 In-depth Field Survey

Four populations were chosen for in-depth field survey. These were the Culanuku, Galoa, Wainiyabia 2 and Pacific Harbor populations. The basis for choosing these populations for survey included accessibility and the size of population. The size was important to conduct a comparative study between the harvesting regimes. The boundaries of each population were delineated using a combination of maps, aerial photos and ground truthing. Seven 10m x 10m subplots were then randomly placed into each delineated area of different harvesting intensities. High harvesting regimes were defined as areas with harvesting occurring and low harvesting regime as areas with no harvesting occurring. 10m$^2$ subplots were selected because they were easy to manage and work within and researchers have the ability to see the whole area being assessed (Mueller-Dombois & Ellenberg, 1974; Thompson et. al., 1992). A
Figure 2: Culanuku population, located along the Galoa Coast next to Culanuku Village, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31–Government of Fiji, 1993).
Figure 3: Galoa population, located along east of Sigasiganilaca Creek, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31—Government of Fiji, 1993).
Figure 4: Wainiyabia 2 population, located along the east of Taunovo Creek, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31-Government of Fiji, 1993).
Figure 5: Pacific Harbour population, located above Pacific Harbor, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31-Government of Fiji, 1993).
total of 14 sub-plots (7 high harvesting and 7 low harvesting) were placed within the four populations. This total number of sub-plots was based on how many sub-plots could fit into the smallest population.

All palms found in each 10x10m sub-plot were recorded, their heights were measured and those palms with distinct stems (stems clearly visible) had their diameter at breast height (dbh), crown height and width measured. Plant height and whether the palm was flowering and fruiting were also recorded. The heights of the palms were measured using the geometric method where one person stands adjacent or against the tree stem with a long pole marked into 1m intervals. The second person stands from a distance where they can see the top and bottom of the tree and the poles with the clearly marked intervals. The same person using the pole as a guide reads the height of the tree by converting the known 1m intervals against the tree as an estimate (Cunningham, 2001).

Based on the height and size structure of *M. vitiense*, the palms were divided into three height-classes. These height classes were: 1) seedlings (0-2 m), 2) juvenile (2-6 m), and 3) adults (>6 m) (Plate 1).

A small germination study was conducted and the Galoa site was chosen for this pilot study because of easy access. Germination rate was recorded under 3 different treatments for 30 seeds (ten-husks removed by bats; ten-husk manually removed; ten-husks not removed) in four replica, each located under a closed canopy. Within each replica site seeds were marked with spray paint in different colours and placed in 10cm intervals on the ground. The seeds were monitored fortnightly to determine the germination rate for the three treatments.
Plate 1: left-right- seedlings, juveniles (note the absence of distinct trunk) and adult trees with fruits in the foreground (trunk clearly visible)
1.4.4 Analysis

All data were analyzed using SPSS version 12.0 for Windows. Two factor ANOVAs were used to compare population size and height between the different populations and harvesting intensities. All data were log_{10} transformed prior to analysis. A Chi-square analysis was used to compare percentage proportions of seedlings, juveniles and adults within populations and between populations.

1.4.5 Questionnaires

A detailed questionnaire was prepared to gather information on current location of *Metroxylon vitiense* populations, land owners, current threats, major exploiters of *M. vitiense*, uses (apart from thatching and palm heart) and any folk stories associated with sago palms. A total of 40 people were interviewed, ten each from three villages (Galoa, Wainiyabia and Dranikula) and five each from two settlements (Sigasiganilaca and Tai). Opportunistic interviews were also conducted with some elders to gauge the duration and intensity of harvesting regimes for different populations. Information was also obtained through direct field observations while accompanying harvesters wherever possible.

1.4.6 Conservation Analysis

The re-assessment of the conservation status of *Metroxylon vitiense* is based on a conservation evaluation using the IUCN Red List Categories and Criteria (2001). The five main evaluation categories using adequate data are extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), data deficient (DD) and not evaluated (NE).
When placing a taxon in the threatened category an A-E criterion is followed: A-decline in population, B-declining in geographic range, and decline or extreme fluctuations, C-continued decline in population size, D- decline in mature individuals and E-quantitative analysis (form of analysis which estimates the extinction probability of a taxon based on known life history, habitat requirements and threats).

1.5 ORGANIZATION OF THESIS

The balance of the thesis is divided into three chapters. Chapter 2 is a literature review on sago palm and its conservation status in the Indo-Pacific, with particular emphasis on Fiji. Chapter 3 includes a detailed description of the study sites including geology, biogeography, vegetation association and cultural significance. Chapter 4 focuses on the results of the study on the conservation status and importance of sago palm in South-east Viti Levu, while the last chapter, Chapter 5, includes the conclusions, recommendations and a \textit{M. vitiense} management plan.
Table 1: G.P.S locations of study sites in South East Viti Levu, Fiji Islands.

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<td>E 177° 59' 38.11&quot;</td>
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<tr>
<td>Galoa</td>
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<td>E 178° 00' 44.60&quot;</td>
</tr>
<tr>
<td>Wainiyabia 2</td>
<td>S 18° 14' 45.38&quot;</td>
<td>E 178° 02' 50.74</td>
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<tr>
<td>Pacific Harbour</td>
<td>S 18° 13' 26.65&quot;</td>
<td>E 178° 04' 46.48&quot;</td>
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CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is a review of literature on sago palm (*Metroxylon spp.*) in the Indo-Pacific region. It includes information on taxonomic diversity, origin, range and distribution, physical description, habitat requirements, phenology, ethnobiology and conservation status of *Metroxylon spp.*.

2.2 TAXONOMIC DIVERSITY, RANGE AND DISTRIBUTION

There are six species of the genus *Metroxylon*, which is divided into two sections, sections *Eumetroxylon* and *Coelococcus* based on morphological and phylogenetic analysis (McClatchey 1996, 1999). Five of the six species, *M. amicarum* (H. Wendl), *M. salomonense* (Warb.) Becc, *M. paulcoxii* (McClatchey), *M. vitiense* and *M. warburgii*, are placed in the section *Coelococcus*, whereas the single widespread species *M. sagu* Rottb. is the only representative species of the section *Metroxylon* (Rauerdink 1986; Schuiling 1996; Ehara and Naito 2002) (Fig. 6). There are four recognized varieties of *Metroxylon sagu*, forma *sagu*, forma *tuberosum*, forma *micracanthum* and forma *longispinum* (McClatchey, 1996; Flach, 1997; Kjaer et al., 2002).

*Metroxylon sagu* is the most widespread of all the species. It is found in Papua New Guinea (PNG), Moluccan Islands in Indonesia, Malaysia, Thailand and Philippines where they are naturally distributed (McClatchey, 1996; Ehara et al., 2000). *Metroxylon amicarum* is endemic to the Micronesian islands of Pohnpei and Chuuk in the Federated States of Micronesia and the Marshall Islands (McClatchey, 1996).
*salomonense* is found in the Solomon Islands, Bougainville (PNG), eastern parts of New Guinea and Vanuatu (Jones, 1995; McClatchey, 1996). In Vanuatu *M. salomonense* is found in Gaua, Vanua Lava and Ureparepare Islands-Banks Island Group and Malakula (Ehara *et al.*, 2003). *Metroxylon warburgii* is found in Vanuatu and Solomon Islands where they are naturally distributed. It is also found in Rotuma where it was probably introduced by the first settlers, and possibly from there to Samoa, where it is known as niu Lotuma (“coconut or palm from Rotuma”) (Whistler, 2000). It is also found in Fiji where it was probably introduced (Fuller, 1997; Watling, 2005). *Metroxylon paulcoxii* is endemic to Samoa on Upolu and Savai’i Islands (McClatchey, 1996, 1998).

*Metroxylon vitiense*, the focus of this thesis, is endemic to Fiji on the Islands of Viti Levu and Vanua Levu (Seemann, 1862; Moore, 1979). It is also found on Ovalau and Beqa Islands where it is probably a recent introduction (Watling *pers. com.*, 2006).
Figure 6: Distribution of *Metroxylon* palms (Adapted from Ehara & Mishima, 2003)
*Metroxylon amicarum* is the tallest of the six species with average heights of up to thirty-three meters with rounded to pyriform shaped fruits. It also flowers for a number of years (pleonanthic) instead of flowering once and dying (McClatchey *et al.*, 2004). *Metroxylon sagu* is a tall and large palm which attains a height of about fifteen meters. *M. sagu* produces both pollinated (seeded) and parthenocarpic (non-pollinated) fruits. Seeded *M. sagu* fruits are depressed-globose to obconical in shape with 18 rows of scales on the fruit, which contain a white endosperm (McClatchey *et al.*, 2004).

*Metroxylon paulcoxii* is a small to medium sized palm with pear shaped fruits (McClatchey, 1998). *Metroxylon salomonense* is a tall palm with heights of up to 20 m with rounded to globular fruits covered with 25-38 regular ordered yellowish scales (McClatchey *et al.*, 2004). *Metroxylon warburgii* is the smallest of all the sago palms attaining a height of less than nine meters, pear shaped fruits lined with 23-31 rows of green to yellow brown scales.

*Metroxylon vitiense* is a large, solitary, monocarpic, up to 16 m tall, DBH (diameter at breast height) to 1 m. Leaves are 5 m long, erect, pinnate, with spines along the rachis and petioles and crownshaft lacking. Pinnae are numerous to 40 cm long by 7 cm wide. The terminal inflorescence is 4 m long, branched to 2 orders, the second order branching with catkin like rachilla to 10 cm long. Flowers are spirally arranged in pairs; staminate and hermaphroditic flower with 6 stamens. Fruit globose to globose-ovoid (pear shaped), covered in scales, 7 cm long by 6 cm in diameter, brown when ripe (Moore, 1979; Fuller, 1997).


2.2.1 Propagation

Sago palms can be propagated by both seed, and suckers for the species that produce suckers such as *M. sagu*. Matured or ripe fruits have the best germination results, although on sago plantations in Indonesia, where it is difficult to harvest seeds of *M. sagu* because trees are harvested before they fruit, suckers are utilized as planting material (Jong and Flach, 1995). *Metroxylon amicarum, M. paulcoxi, M. salomonense, M. vitiense* and *M. warburgii* can only be propagated from seeds. In Vanuatu, sago palm seeds germinate easily. The removal of husks loosens up the operculum and speeds up germination by up to forty percent (Schuiling and Flach, 1985; Ehara *et al.*, 1998).

2.2.2 Sago in Agroforestry

Sago palms have been suggested as particularly being suitable for cultivation in agroforestry throughout its range and have been listed among Pacific Islands one hundred most important agroforestry trees (Thaman 1993b). In Sarawak Indonesia, unspinned varieties of *M sagu* are planted along boundaries of spinned sago palm plantation to mark different plantation boundaries (Schuiling *et al.*, 1993; Diemont & Schuiling, 1995).

In Nendo, Solomon Islands *M. salomonense* is cultivated in wetlands by people of the Duff group. It is also the main species found planted along as intercropping (planting of sago amongst other crops) in coastal and inland food gardens. Seeds of sago palm are also planted along rock-walls or property boundaries, where the young trees with their numerous spines act as effective deterrents to pigs and trespassers (Williams, 1969). Sago palms have also been used as coastal protection, used to improve fallow land and home gardens.
The Keraki people of the Morehead District in P.N.G also plant sago locally called as “bi” but not in large quantities for starch (Williams, 1930). In Manus Island and Krisa area, Sandaun Province *M. sago* are often planted with fruit trees such as bananas (*Musa AAB*), breadfruit (*Artocarpus altilis*), *Canarium decumanum*, *Gnetum gnemon* and *Syzygium spp*. *Piper methysticum* are often planted under the shade of sago palm in the Western Province of PNG (Dwyer and Minnegal, 1994; Juillerat, 1996). In the lowlands of New Guinea *M. sago* are often planted in secondary forest amongst fruit trees such as *Spondias sp*, *Terminalia sp*, *Syzygium malaccense*, *Pometia sp.* and breadfruit trees (Hubber, 1977; Rhoads, 1982; Lebot, 1991).

People from the island of Rotuma northeast of Fiji and from other Polynesian outliers, where it is known as *ota*, plant *M. warburgii* for starch (McClatchey & Cox, 1992). In Fiji it has been recorded from Namosi and Matainasau, Naitasiri as an important agroforestry plant and has been planted along rivers, villages and gardens (Thaman, 1993a).

### 2.3 HABITAT AND ECOLOGY

*Metroxylon sago* is found in humid tropical lowlands from sea level to elevations of up to 700 m above sea level (a.s.l). *M. sago* tolerates temperatures of around 17 °C but temperatures above 25 °C are more preferable. *M. sago* is found in areas with a rainfall above 2000 mm per year with no long dry periods as water shortage affects growth (McClatchey *et al.*, 2004).

In Vanuatu, *M. warburgii* is found in swamps bordering watercourses, seepage areas to well drained slopes and coral terraces to 500 m a.s.l, in areas that receive an
annual rainfall of over 2300 mm per year (Dowe, 1989; Dowe and Cabalion, 1996). The eastern-most islands in the Vanuatu Group where *M. warburgii* is found, receives more than 4000 mm of rain per year (O’Byrne and Harcombe, 1999). *M. warburgii* in Vanuatu is found in soils ranging from heavy texture derived from Quaternary volcanics to soils with gravely surface from uplifted coral limestone (Ehara et al., 2003).

*Metroxylon amicarum* stands in the Federated States of Micronesia are found on uplifted, flat terraces consisting of coral limestone and at the base of lava flows near running water up to 40 m a.s.l (Ehara and Naito, 2002). The soil types for most areas are mostly inseptisols (young soils), soils that develop under moist water regimes as most of the areas have high annual rainfall amounting to 5000 mm and the palm’s preferable habitat are low-lying, poorly-drained areas (Ehara and Naito, 2002).

*Metroxylon salomonense* is found in predominantly swampy areas both in Solomon Island and on Bougainville, PNG. In Vanuatu, it occurs in well-drained coral terraces just above the shoreline at 1-5 m a.s.l (Dowe and Cabalion, 1996). Jones (1995) reported that *M. salomonense* does not grow in swamps but are components of the forest growing in fertile well-drained soils. *Metroxylon paulcoxii* is considered endemic to Samoa and is found in plantations and gardens (McClatchey, 1998).

*Metroxylon vitiense* is found in dense stands on colluvium and alluvium in valleys upstream of coastal swamps with the most extensive remaining natural populations located on Navua River Delta (Ash and Ash, 1984) and in the coastal lowlands in the Pacific Harbour area. The Pacific Harbour population is large and relatively intact and is located on a swamp/slope boundary 10 m-30 m a.s.l (Fig. 5) (Ehara & Mishima, 2003). The nearby Galoa population is located on a flat coastal strip in the vicinity of Galoa.
village, Serua Province to the west of Pacific Harbour (Fig. 3). It is bordered by mangroves at the coastal end and secondary forest on the northern end, village with an elevational range of less than 5 m. The Culanuku population is situated along the coastal strip at Galoa next to Culanuku village bordered by mangrove (Fig. 3). The Wainiyabia 2 population is located to the north of Leplanoni settlement near Pacific Harbour along Taunovo Creek (Fig. 5) (Scott, 1993; Smith, 1979).

2.4 FLORA AND VEGETATION ASSOCIATIONS

*Metroxylon amicarum* is a component of upland rainforest in Pohnpei (Federated States of Micronesia) where it cohabits with the native *Clinostigma* palm and other widespread Indo-Pacific tree species, such as *Glochidion*, *Myrsine*, *Elaeocarpus*, *Syzygium*, *Psychotria*, *Timonius* and *Astroniidium* spp, and tree ferns and lianas. *M. amicarum* can also be found growing with freshwater swamp species such as *Terminalia*, *Campnosperma*, *Barringtonia*, *Erythrina*, *Ficus*, *Hibiscus*, *Phragmites*, *Acrostichum*, and *Scirpodendron* (Mueller-Dombois and Forsberg, 1998). In Papua New Guinea *Metroxylon sugu* is often associated with *Campnosperma brevipetiolata*, *Terminalia brassii*, *Pandanus*, *Nypa fruticans* and other associated freshwater swamp species (Paijmans, 1976; Mueller-Dombois and Forsberg, 1998).

*Metroxylon salomonense* forms a dense freshwater forest type in Solomon Islands and, when found on riverine habitats, is often associated with *Campnosperma breviopetiolata*, *Inocarpus fagifer*, *Eugenia tierneyana*, *Barringtonia* spp., *Calophyllum vexans*, and *Pterocarpus indicus* (Mueller-Dombois and Forsberg, 1998).
In Fiji, sedges, such as *Eleocharis ochrostachys, E. dulcis, Scleria polycarpa, Cyperus haspan, Cyperus polystachyos*, dominate the vegetation of the *M. vitiense* swamps in lowland peaty areas. Also present are the native moss, *Sphagnum cuspidatum*; club moss, *Lycopodium cernuum*; ferns, including *Dicranopteris linearis, Nephrolepis biserrata*; and the native pandanus *Pandanus tectorius* (Mueller- Dombois & Forsberg, 1998).

In non-peaty localities near the coast, the swamps on brackish water soils support many introduced grasses (e.g., *Brachiaria mutica, Paspalum conjugatum, Paspalum orbiculare*), sedges (*Eleocharis ochrostachys, E. dulcis, Scleria polycarpa, Kyllinga polyphylla, Fimbristylis dichotoma, Rhynchospora corymbosa*) and a different species of pandanus (*Pandanus whitmeaenus*). In places where there is mixture of peat and gley soils the swamp tends to support large trees and shrubs, such as the introduced species, *Psidium guajava* (guava) and *Psidium cattleyanum* (cherry guava). Other large native trees found there include *Inocarpus fagifer, Barringtonia racemosa, Glochidion cordatum, Annona glabra, Fagraea berteroana* and *Hibiscus tiliaceus* (Mueller-Dombois & Forsberg, 1998; Scott, 1993).

2.5 PHENOLOGY

The life cycle of sago palms is divided into three stages: the trunkless rosette stage, trunk stage and flowering and fruiting stage. The trunkless rosette stage is the stage after germination, during which there is crown development and the growth of an extensive root system, but no development of a trunk. The second stage of development is the trunk stage, which happens when the crown and root system are fully developed and the plant
begins to grow vertically with the formation of a distinct trunk. The last stage of the sago palm life cycle is flowering and fruiting (Schuiling and Flach, 1985; McClatchey et al., 2004).

*Metroxylon sago* have been found to reach the second stage of development at about eight years and reaches the maximum age of about 12 years (McClatchey, 1999). Semelparous *Metroxylon* species have a short lifespan and a short reproductive phase unlike the iteroparous species (Henderson, 2002).

### 2.5.1 Pollinators

There has been very little work done to determine the principle pollinators of *Metroxylon* palms. Mogea (1978) found that weevils pollinate the elongated *Metroxylon* inflorescence. Jong and Flach (1995) found that bees and wasps (*Trigona* spp., *Apis dorsata* and *Vespa tropica*) were the principal pollinators of the semelparous *Metroxylon sago* in Sarawak, Malaysia.

### 2.5.2 Seed Dispersal and Predators

Sago palm seeds drop short distances away from the parent tree. As sago trees are located close to water bodies, the buoyant fruits float on water, which is another important method for dispersal (Johns and Hay, 1984). There has been no record of animals such as bats or rats predating or dispersing sago fruits (Ehara and Naito, 2002; McClatchey, 2002).
2.5.3 Pest and Diseases

There are no known serious pests or diseases that affect sago palms. Some pests that do predate sago palms include hispid beetles (*Botronyopa grandis*), the larvae of which feed on young tissues of the unopened spears at the central base of the crown. Termites (*Coptotermes spp.*), tunnel through trunks of sago palm that grow on peat soils. The red stripped weevil (*Rhynchophorus schach*) attacks living palm and the rhinoceros beetle (*Oryctes centaurus*) feeds on the plant juices freed by gnawing through the heart of the crown (Schuiling and Flach 1985; McClatchey, 1996).

2.6 ETHNOBOTANY

This section reviews the traditional and commercial uses of sago. The main uses are as a staple and supplementary or emergency food source and for thatching. It also has a number of other minor uses, such as its use in handicrafts, and is associated with traditional trade, is used in rituals, ceremonies and myths, and features in legends.

2.6.1 Food

Throughout its range, sago palms have been harvested to produce edible sago starch and in some cases the meristem is cooked as a vegetable (Rutherford, 1974). Before the emergence of rice, sago was a main staple food source for many people living in the Malay Archipelago, where desiccated products made from sago starch could be stored for long periods (Terrel, 2002). Raw chunks or baked pieces of pith may also be eaten with whole logs baked and taken as sea provisions on long canoe voyages (Chew *et al.*, 2000).
Sago flour which is extracted from sago starch production is currently an important commercial activity in Sarawak (Indonesia), which is the world's largest exporter of sago products, exporting roughly 25,000 to 40,000 tonnes of sago products annually to Malaysia, Japan, Taiwan, Singapore and other countries. Sago starches in Sarawak are mostly processed into sago flour, which is very high in carbohydrate and has a multitude of uses, including the production of monosodium glutamate, syrups for the soft drink industry, glues used for plywood manufacture, production of biodegradable plastics, alcohol, ethanol and citric acid (Oliver, 1955; Chew et al., 2000; Charoenlap et al., 2004).

Sago Palms were formerly grown in large quantities in parts of the Solomon as a primary source of carbohydrates and starch, although its use has declined recently (Laycock, 1975). The use of traditional sago starch has declined significantly much throughout its range because of the relatively large amount of labour used to extract the starch for such a small return (McClatchey & Cox, 1992; Baker, 1997). In most cases sago starch is only harvested for ceremonial purposes such as large communal feast (Organ, 1972).

There has been considerable debate about the exploitation of sago as food in Fiji. Southern (1986), using data from coring work in the Rewa delta suggested that *M. vitiense* was present before human habitation about 4000 BP, but as humans began to arrive *M. vitiense* began to decrease from the pollen record until it disappeared which led to the conclusion that humans exploited sago as food. But this statement was contradicted by lack of cultural record and recent analyses by Ehara & Mishima (2003) in which *M. vitiense* were found to be more fibrous than other similar species rendering it an
unsuitable food source. In Fiji only people from the Polynesian Island of Rotuma exploit sago palm for sago starch (Seemann, 1862; McClatchey and Cox, 1992; McClatchey, 1996).

Throughout its range native people have used sago (\textit{M. sagu}) as an emergency source of food when major food crops such as taro or yam have been damaged by cyclones, drought or other hazards (Saville, 1926). In 1972 after an unusually long wet season, the people of Buin, south Bouganville resumed sago production as most of the plantations were flooded. At Mailu Island, along the coast of Table Bay, P.N.G, people occasionally use sago palm when their crops fail or may shift to it for ceremonial feasts. The people of Orokaiva, P.N.G turn to making sago flour as the North-West season approaches as this brings dry season, and it is during this time that many crops fail so provides an unfailing resource in times of scarcity (Saville, 1926; Ehara \textit{et al.}, 2003). In Siuai, Solomon Islands, people sell sago flour when they are temporarily without taro or sweet potatoes (Cabalion, 1989).

Sago leaf vegetable or the apical meristem or palm heart which is large and soft is also harvested and eaten as vegetable or cooked with other food (McClatchey \textit{et al.}, 2004). Harvesting of \textit{M. vitiense} palm heart is done commercially in Fiji and it is a major ingredient in curry among the Fiji Indian community (Fuller, 1997; Ehara and Naito, 2002).

2.6.2 Thatching

Thatching from sago palm is an important building material throughout its range. \textit{Metroxylon} thatch lasts much longer (c.a. 10-20 years) than many alternatives such as
leaves from coconut, pandanus, sugarcane, or nipa, which must be replaced every one to four years (Zuniga, 2000).

In West Java and East Point, New Guinea, sago thatched roofs are preferred as it is cool and there is very little noise when it rains compared to its corrugated iron counterpart (Dowe, 1989; Flach, 1997; Dowe and Banka, 2002). In Vanuatu thatching, called atap, is soaked in seawater and sewn in the form of a “shingle” over a Miscanthus stem before it is used (Dowe and Cabalion, 1996). On the Island of Rotuma sago leaves are used both as roof thatching and wall coverings (McClatchey and Cox, 1992). The Samoans also use sago leaves as thatching and prefer leaves of M. warburgii rather than that of M. paulcoxii. They prefer sago thatching because of the quality and because it is easier to grow and maintain than sugarcane (Whistler, 2000).

There is no cultural record of people using sago thatching in Fiji prior to the 19th century. The earliest written record came from William Geddes from his account during his stay at Deuba village, Serua Province close to study area from 1942 to 1943. An extract from Geddes (2000) related that “. . . the use of the leaf itself is comparatively recent, having been learnt from indentured Solomon islanders . . .. This account provides the first evidence that the use of sago thatching is relatively a recent practice. Before sago thatching people reportedly used the native sedge Cyperus haspan or local asparagus Saccharum edule (Geddes, 2000). Currently, leaflets of M. vitiense are still used for thatching materials for houses, although this practice gradually declined because it is very labour intensive and because of the increased use of corrugated iron as a roofing material.
However, in the past 2-3 decades the practice of using thatching from sago palm leaves has regained popularity, especially within the tourism sector where hotels that use it to thatch their tourist “bures” (traditional Fijian thatched houses) (Smith, 1979). As a result, sago thatching has now been commercialized in many areas. In Johot, West Malaysia *M. sagu* shingles are sold with sago palms now grown for leaf production (Flach, 1997). In Moen, Truk Islands, (FSM) thatches made from *M. amicarum* are sold to hotels at around US$2 per shingle (Ehara and Naito, 2002). In Vanuatu leaves of both *M. warburgii* and *M. salomonense* are sold as thatches for 50 Vatu (US$1.43-2003 exchange rate) (Ehara *et al.*, 2003). On the island of Guadalcanal, Solomon Islands, thatching made from *M. salomonense* are sold for SI$1.50 per shingle (Ehara *et al.*, 2003).

In Fiji, *M. vitiense* has been heavily utilized for commercial thatching especially for those people living close to the remaining natural sago populations. In Fiji houses that use *Metroxylon*, thatches often last 30 years without repair (McClatchey, 1996; Smith, 1979). Sago thatchings are sold to hotels and resorts from all over Fiji with prices ranging from F$1.00-$2.00 per shingle (Ehara and Mishima, 2003).

2.6.3 Use in Handicrafts

The attractive seeds of sago palms are also used in handicrafts. These include carving jewellery from endosperm of sago palm seeds, buttons, brooms, cricket bats and balls. In Vanuatu the *Natangura* (local name for endosperm of sago palm seed) industry is a cottage industry creating income and employment from selling palm ivory jewellery.

A small industry set to help the underprivileged youths to increase employment
opportunities and to protect the sago palm species found in Vanuatu, *Metroxylon warburgii* involves carving jewellery from the endosperm of *M. warburgii* seeds (Ehara *et al.*, 2003). The endosperm of sago palms seeds is very hard and is carved into jewelry, sometimes referred by people of Vanuatu as “palm ivory”. Seeds are removed from trees when they are still green as they are easy to carve when still green. All *natangura* jewelry are exclusively marketed overseas and all local handicraft stores (Ehara and Naito, 2002; Ehara *et al.*, 2003).

In the Caroline Islands the endosperm is used in button making and other handicrafts. Sago leaves are also used as brooms, and their bases may be used to make cricket bats and balls (Ehara *et al.*, 2003). In Orokaiva Society in PNG sago thorns are usually made into fish hooks (Williams, 1930).

### 2.6.4 Other Uses of Sago palms

In many parts of Papua New Guinea shredded sago leaves are used to produce twine and general lashing materials (McClatchey *et al.*, 2004). The leaf midribs are used in the construction of walls for dwellings, and hollowed-out stems are used in the production of canoes where other suitable timbers are lacking (Paijmans, 1976). Extracts from the spathe are used for bow bracer and stem sap is used in headache remedies (Hughes, 1970). In areas west and south of Mt. Karimui in New Guinea sago palms are planted in steep and limestone areas to keep domesticated pigs from human habitation (McClatchey, 1996).

There have been reported cases by people from Espritu Santo, Vanuatu extracting salt from pith of sago palm (Ehara *et al.*, 2003). The Sani-Hiowe people of the Wogamus
River, Papua New Guinea perfected the technique of extracting salt ash from sago palm midrib (Townsend, 1974). Other uses of sago palms include living fences, boundary markers, windbreaks, animal fodder, wildlife habitats and coastal protection (Flach, 1997). Recent studies have shown that the waste from sago flour processing is the best absorbent of lead pollution from water systems (Quck et al., 1998).

2.6.5 Sago in Trade Networks

Sago starch and other sago products were also the focus of important trade networks, mainly in Melanesia. This included the well known Hiri trade which was taken by Motu-speaking people of what is now the Port Moresby region. The trade was not only confined to the Port Moresby region but extended to other parts of New Guinea.

The most well known is the Hiri trade that took place between the Motu in the area around Port Moresby and the Kerema people of the Gulf of Papua, Papua New Guinea. The Motuan people traded clay pots, tools and other food for sago products with people who lived along the gulf coastline. The trip begins in September through till the end of the year where large Motuan canoes called lagatoi take advantage of the south-east trade winds taking them to villages bordering the Gulf of Papua. Once they reach their destination clay pots and arms-hells are exchanged for sago and canoe hulls. They return home between the beginnings of the year till March to coincide with the north-west monsoon (Oram, 1982).

The South Coast people of Manus Island northeast of New Guinea are also dependent upon bartered material from sago and were known to be the richest and proudest people. They have few natural resources but they have most material things
such as best diet of fish and shellfish complemented with large quantities of bartered coconut oil, sago and taro.

2.6.6 Sago in Traditional Rituals and Ceremonies

Sago palm is an important tree, revered in some places and thus is part of traditional rituals and ceremonies. These includes sago grub festivals, feast accorded to pregnant women and the birth of a new child.

Asmat People, Papua New Guinea

In Papua New Guinea, the Asmat people take part in the infrequent sago grub festivals. The festival is planned before special occasions such pig as hunting expeditions (National Geographic Magazine, 1996). During the festival day a sago palm is carefully selected preferably a matured palm about to bear fruit. The trunk is carefully cleaned and dressed up with a woman’s skirt of leaves (Whitten and Whitten, 1996). Then past pig hunting exploits by the men are recited and the tree attacked just like an enemy and felled with holes bored into the trunks. After six weeks sago grubs which were left by sago palm beetle (*Rynchophorus ferrugineous* and *R. bilineatus*) are collected from the hole bored into the sago trunks and carried to the village on a tray of sago leaves like a slain enemy and consumed (Whitten and Whitten, 1996). The Asmat eat sago sometimes mixed with fish, meat or vegetables, wrapped in palm leaves roasted in the open fire and their favorite, long sausage about 20cm long, made of sago mixed with sago grubs (McClatchey *et al.*, 2004)
In Korowai a neighbor of Asmats they also have a similar sago grub festival and planned months in advance according to moon phases. When the festival day approaches a patch of forest is cleared and a longhouse built preferably around a scared pole. Sago palms are then felled, split, tied and left to rot where the sago beetles lay their eggs. Sago grubs (sago beetle egg) are then harvested after two months with a big feast organized (Whitten and Whitten, 1996). After the chanting, dancing and feasting a ritual of fertility and growth is invoked for the young boys and sago trees, the next morning by the host clan. When different stages of the ritual are complete, alliance made and past problems are reconciled (National Geographic Magazine, 1996; Balick and Cox, 1997).

During the warring days when men returned alive, usually with gifts, they were given title to sago lands along the shore. On Manus Island pregnant women are often accorded feasts, kinekin, in which sago packs are stacked in three and another feast after birth called pinpuaro, at which sago packs are stood upright. When a pregnant woman gives birth, mother and child are often isolated and the father is not allowed to see either the new born child or the mother. He can only see both mother and child after the wife’s brother validates the birth with a large payment of sago (Mead, 1956).

In Tangu traditions, PNG when a young man builds himself a shelter in the fronds of sago palm it is a sign that he has reached manhood. The use of sago fronds evokes the garamb meaning protection from the storm, the divine and unobliged (Burridge, 1969).

2.6.7 Sago Myths and Legends

Sago palms are feature of traditional folklore being part of myths and legends associated with chiefly status, gods and man, and triumph in wars.
In Pohnpei a child born of chiefly status whose maternal blood is known as Neinneinioahs Soupeidi which refers to three of the tallest palms in Pohnpei for which one is *Metroxylon amicarum* (Merlin and Juvik, 1996). There is also an old legend that refers to an old lady with magical powers that felt sorry for the people of Pohnpei before the island was vegetated. As a result, she sent them the sago palm to use for thatching and other uses (McClatchey *et al.*, 2004).

At Table Point south of Papua New Guinea there are two big rocks representing two gods, Boniva and Baniva standing at the foot of the hill. These two gods are said to be returning from Lea making sago when their poles broke because of the heavy load. All the sago they made was broken up and thrown over the ground which grew immediately. That is why the people of Mailu and Dalava and all other villages call upon the help of these two men for help and guidance when cutting down sago trees (Saville, 1926).

The Dogi people, of the Orokaiwa Society, P.N.G, have a legend about the eel and the flood. Two children who survived the flood were saved by very large woman who resembled an island with sago palms growing on her back (Williams, 1930).

Bangu people of the Trans-Fly region, P.N.G tell of a legend of Kambel, a god on his way to raising the sky, and took with him some roasted sago. He broke the roasted sago and crumbled it in his hands and throwing it in the air creating the real cloud. The secret vocabulary for clouds in the Bangu language is called javaraarigani which means sago clouds (Williams, 1969).
2.7 HARVESTING IMPACTS

There is no literature available on the harvesting impacts of thatching or palm heart on growth and structure *Metroxylon spp.* However there is literature available on other palm species such as *Dypsis fibrosa* where constant pruning of leaves for commercial thatching, prevents the palms from growing and keeps them at a quasi-juvenile state (Dransfield and Beentje, 1995). Palm species where entire plant is removed, age structure is skewed depending on which age class is harvested (Runk, 1998; Byg and Balslev, 2001).

2.8 CONSERVATION

In Indonesia and Malaysia, the harvesting of *Metroxylon sagu* for sago flour was originally from natural populations. But as the natural populations decrease, it has been difficult to access and reduce pressure on the natural populations, and extensive *M. sagu* plantations were created and almost all sago is now from plantations (Flach, 1997). In PNG, the harvesting of sago for its starch is mostly done from natural populations (ACIAR, 2001). Conservation of the genetic diversity of *M. sagu* is mostly through field gene-banks but only limited collections have been made. Representative varieties of *M. sagu* from areas such as Papua New Guinea, Indonesia and Malaysia are kept at various field gene-banks at the University of Malaysia, Sarawak and the Ministry of Agriculture, Lae, Papua New Guinea (Flach, 1997). Most other species of sago palm collections are at Bogor University Garden, Lyon Arboretum, and Fairchild Botanical Garden and at the University of the South Pacific, Laucala Campus. There is ex-situ conservation of *M. vitiense* at population level (McCltachey *et al.*, 2004).
CHAPTER 3

CONSERVATION STATUS OF SAGO PALM IN SOUTH-EAST VITI LEVU

3.1 INTRODUCTION

This chapter discusses the results of the study of the conservation status of the Fiji sago palm (*Metroxylon vitiense*) conducted in southeast Viti Levu, Fiji Islands. It includes information on the current distribution, new population records, populations most commonly visited and exploited, those populations that are threatened with extirpation, population health related to human impact and new ecological data. Also included is information on the cultural uses.

The natural populations remaining in SE Viti Levu, from what was once a large, continuous population covering most of the Navua and Rewa Delta, persist only in six small pockets at swamp/slope boundaries. These include the Wainiyabia, Culanuku, Galoa, Pacific Harbor, Lobau and Nabukeluvu populations. There is also a population located on the island of Ovalau. The island of Ovalau was once connected to the main island of Viti Levu during the last inter-glacial thus providing a land bridge for *Metroxylon* (Gibbons & Clunie, 1986).

3.2 NEW AND THREATENED POPULATION RECORDS

During the study only two new populations were discovered (Table 2), both of which are located along the Navua River or its tributaries, the Wainikevu (Fig. 7) and the Maratu populations (Fig. 8). Three populations were found to be threatened with extirpation.
These were the Toguru (Fig. 9), Wainiyabia (Fig. 10) and Naduruloulou (Fig. 11) populations.

### 3.2.1 New Populations

The new populations are the Wanikevu and the Maratu populations. The Wanikevu population is located to the east of Nukusere village, near Wanikevu River a small tributary that feeds into the Navua River, in the Namosi Province (Fig. 7). This a small population used by the nearby village of Nukusere only to harvest leaves for traditional thatching. The Wanikevu population is very difficult to access and according to villagers is not commercially exploited for the thatching trade.

The Maratu is the largest of the new populations and is located along Savudugudugu Creek in Serua Province, within the Galoa mahogany plantation (Fig. 8). According to forestry officers and villagers who worked during the mahogany planting, it is the most extensive population of *M. vitiense* they have seen. According to an old story, a person was lost in Maratu sago forest never to be found again. The Maratu population is very difficult to access as it is bordered by the steep Navua gorge on its northern end and on the southern end mahogany plantations which are located two and half hours from the nearest tar sealed road.
Table 2: G.P.S locations of newly located populations of *Metroxylon vitiense*, southeastern Viti Levu, Fiji Islands.

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<th>SITES</th>
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<tr>
<td>Wainikevu</td>
<td>S 18° 06' 30.71&quot;</td>
<td>E 178° 05' 25.56&quot;</td>
</tr>
<tr>
<td>Maratu</td>
<td>S 18° 07' 56.83&quot;</td>
<td>E 177° 53' 56.63&quot;</td>
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Figure 7: Wainikevu *Metroxylon vitiense* population, located on the Wainikovu River to the east of Nukusere and Sabata Villages, Namosis Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31—Government of Fiji, 1993).
Figure 8: Maratu *Metroxylon vitiense* population, located along the Savudugudugu Creek drainage, a tributary of the Navua River, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31–Government of Fiji, 1993).
3.2.2 Threatened Populations

A number of *Metroxylon vitiense* populations were found to be seriously threatened and near extirpation. These are the Toguru, Naduruloulou and Wainiyabia 1 populations.

The Toguru population is located on the floodplains of the Navua River catchment behind mangrove forest on the eastern side of the Navua River (Fig. 9). The population was described in 1862, as follows, by Berthold Seemann during his trip along Toguru Creek a tributary of the Navua River, during his work in Fiji between 1860-1862:

"... fine groves, several miles in extent were seen by us on various branches and deltas of the Navua River." Only a few scattered trees remain at this site as there have been extensive developments in the area (Fig. 9) for irrigated paddy rice fields during the 1970s. Most of the remaining *M. vitiense* trees are found on the back of mangrove swamps.

The Naduruloulou population is a small population located behind the Naduruloulou Fisheries Research Station near the Rewa River five minutes from Nausori town. Only a small patch of trees remains at this site. About 90% of the original swamp has been drained and reclaimed by the Fisheries Department for the fish ponds at the research station (Fig. 10). The remaining patch can be found towards the north-eastern end of site. This population was first visited by P.B. Tomlinson and Isikeli Kuruvoli in 1969, who collected voucher specimens and made several herbarium specimens (DA 16551) kept at the South Pacific Regional Herbarium (SPRH-SUVA).

The Wainiyabia 1 population is a small population located at the back of Wainiyabia Village in the Serua Province. Only a few patches of trees remain. The population was first described, as follows, by Degener (1949) during his trip there in
1940: "Before us lay salt marshes densely studded with tall stiff erect sago palms." The population is located close to Wainiyabia village and the Indo-Fijian settlement of Wainiverau (Fig. 11). The close proximity of this population to human habitation has made it a target for use in house thatching and for sale in the palm heart trade. This population is severely fragmented.

The Lobau population is located along Lobau Creek adjacent to Lobau village (Fig. 12). It has been severely affected by harvesting of sago palm heart and commercial thatching, which have been occurring there over the last 25 years (Fuller, 1997). Recent resurgence in the commercial thatching industry has placed further strain in this population.
Table 3: G.P.S. locations of threatened populations in South East Viti Levu, Fiji Islands.

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<th>SITES</th>
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</thead>
<tbody>
<tr>
<td>Toguru</td>
<td>S 18° 12' 38.13&quot;</td>
<td>E 178° 11' 41.00&quot;</td>
</tr>
<tr>
<td>Naduruloulou</td>
<td>S 17° 58' 07.01&quot;</td>
<td>E 178° 31' 07.01&quot;</td>
</tr>
<tr>
<td>Wainiyabia 1</td>
<td>S 18° 14' 59.61&quot;</td>
<td>E 178° 02' 59.02&quot;</td>
</tr>
<tr>
<td>Lobau</td>
<td>S 18° 09' 49.70&quot;</td>
<td>E 178° 11' 38.20&quot;</td>
</tr>
</tbody>
</table>
Figure 9: Toguru *Metroxylon vitiense* population, located on the floodplains of the Navua River, Namosi Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31–Government of Fiji, 1993).
Figure 10: Naduruloulou *Metroxylon vitiense* population, located along the floodplain of the Rewa River, Tailevu Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31–Government of Fiji, 1993).
Figure 11: Wainiyabia 1 *Metroxylon vitiense* population, located along Waisese Creek, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31-Government of Fiji, 1993).

*M. vitiense* population
Settlement
Mangroves
River/Creek
Road
20m contour lines

Figure 11: Wainiyabia 1 *Metroxylon vitiense* population, located along Waisese Creek, Serua Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31-Government of Fiji, 1993).
Figure 12: Lobau *Metroxylon vitiense* population, located along Lobau Creek, Namosi Province, Viti Levu, Fiji Islands (Adapted from Fiji Map Series 31–Government of Fiji, 1993).
3.3 HARVESTING IMPACTS

3.3.1 Harvesting Impacts on Population Structure

This section discusses human impacts on the population health of sago palms, in terms of age, size structure and size classes due to different harvesting intensities in four populations (Galoa, Culanuku, Wainiyabia and Pacific Harbour).

3.3.1.1 Size Structure

Trees were smaller in areas of high harvesting regimes compared to those in low harvesting regimes respectively (F = 10.9, P < 0.002, d.f = 3, 45 (Fig. 13). No significant interaction between site and harvesting intensity was observed.
Figure 13: Mean height of palms of four *Metroxylon vitiense* populations in two different harvesting regimes (low harvesting regimes-dark grey, high harvesting regime-light grey).
More palms were found in subplots with high harvesting regime than in those with low harvesting regimes (F= 20.2, P< 0.001, d.f. = 3, 45 Fig. 14) at all sites.

The four populations of Metroxylon vitiense were studied in detail. The population structure of low harvesting regime had an average ratio of seedlings: juveniles: adult being 5.5: 1: 1.3 while the ratio in the high harvesting regime was 26.2: 6.9: 1. These ratios are consistent with species that have entire plant removed, age structure are skewed depending on which age class is harvested (Runk, 1998; Byg and Balslev, 2001).
Figure 14: Mean number of palms/10 m² in the four Metroxylon vitiense populations with two different harvesting regimes (low harvesting regimes-dark grey, high harvesting regime-light grey).
3.3.1.2 Age structure

Age structure varied significantly between high and low harvesting intensities ($\chi^2 = 278.68$, $p<0.001$, d.f = 6) for all population combined. Adults account for about 2-3% of all sago palms in low harvesting regimes, but less than 1% in high harvesting regimes (Fig. 15). Conversely, there were more juveniles in high harvesting regimes than in low harvesting regime areas. There was no significant difference in the percentage of seedlings, which account for about 80% of the population in each of the harvesting regime.

In each of the four populations the trend similar to the overall trend with adults more common on low harvesting regime subplots and seedlings more abundant in the high harvest regime subplot was; Galoa ($\chi^2 = 66.09$, d.f = 2, $p<0.001$), Culanuku ($\chi^2 = 50.87$, d.f = 2, $p<0.001$), Wainiyabia 2 ($\chi^2 = 50.35$, d.f = 2, $p<0.001$) and Pacific Harbor ($\chi^2 = 66.9827.12$, d.f = 2, $p<0.001$) (Fig. 16).
Figure 15: Proportions of adults (closed triangle), juveniles (open square), and seedlings (closed circle) in the different harvesting regimes for all four populations combined.
Figure 16: Percentage of each age class (adults-closed triangle, juveniles-open square, seedlings-closed circle) at the four populations with varying harvesting intensities.
3.4 ECOLOGY

This section discusses findings of a pilot ecological study that was conducted to determine some ecological aspects of sago palms such as seed dispersal and predation on *M. vitiense* by the masked shining parrot, fruit bats and rats respectively. We will also discussing seed germination and leaf production of *M. vitiense*.

3.4.1 Seed dispersal and seed predation

The masked shining parrot (*Prosopeia tabuensis*) and fruit bats (*Pteropus spp.*) have been observed feeding on the *Metroxylon vitiense* fruits. This has been corroborated by local people. Fruit bats especially have been observed at all sites usually taking *M. vitiense* fruits back to their roost trees for the night with large seed piles seen under overnight roosting sites (Plate 2). Informants often told how they would go to sago forest to hunt for fruits bats feeding on sago infructescenes. These can be easily identified with piles of fruits with distinctive fruit-bat bite marks with large scattered food pellets. The other predator observed during the study were the introduced rats (*Rattus spp.*) feeding on endosperm and shoots of young *M. vitiense*. Rats leave small food pellets compared to fruit bats and pellet distributions tend to be localized within a couple centimeters of the seed. Rats feeding on young shoots usually kill the seedlings.

*Metroxylon vitiense* seeds are buoyant and easily float in water for extended periods of time. Their seeds can be found on beaches with riverine materials. *Metroxylon vitiense* have been observed growing in floodplains several kilometers downstream and at the back of mangrove forest especially at populations adjacent to mangrove forest. At the Galoa population *M. vitiense* can be observed growing within
mahogany plantation (Plate 2). Smith (1990) found *M. vitriense* seeds at the Deuba and Taunovo beaches, but these were found to be not viable through germination experiments, possibly due to excessive emersion in sea-water.
Plate 2: Left, seed pile left by fruit bats under the mahogany forest; middle, *Metroxylon vitiense* seedlings as understory plants in the mahogany plantation; right, very large and scattered seed pellets of fruit bats.
3.4.2 Seed Germination

This section discusses a small pilot germination study which was conducted to determine if fruits bats aid in the germination of *M. vitiense* seeds. I have personally observed that bats feeding on the mesocarp, though playing no part in dispersal, may aid or hasten germination.

Seeds with husks removed manually and those with husks removed by bats at the proximal end germinated much faster than the controls seeds. But within five to seven days of germinating the young shoots were chewed upon by rats. The control seeds with husks not removed germinated much later but survived the rat predation as the husk protected the young shoots. This could be an evolutionary survival mechanism whereby *M. vitiense* predations by bats and rats both have advantages and disadvantages (bet-hedging).

This is very critical especially for re-introduction efforts of *M. vitiense*. When deciding which age class of sago palm to introduce it would be better if based on a pilot study to plant some seeds with husked removed and some with husks not removed if there are no seedlings available. If seedlings are available then they can be re-introduced as it greatly reduces the predation pressure by rats.

3.4.3 Leaf Production

This sections discusses a three year collaborative work with Agricultural Scientist from Mie University, Japan and University of the South Pacific which involves counting leaf scars on *M. vitiense* trees planted at the university gardens and Thurston Gardens at the Fiji Museum, it was found that they only produce about 8-9 leaves per year. However
with harvesting of leaves for thatching occurring all throughout the year at the study sites. Harvesting too many leaves may lead to the depletion of palm populations and constant pruning of leaves prevents palm from growing and keeps them at a quasi-juvenile state.

Determining the number of leaves sago palm produce annually is very important especially in setting up conservation management plans for *M. vitiense*. Failure to do this will jeopardise the commercial thatching industry.

3.5 ETHNOBOTANY

This section discusses the ethnobiological aspects of the study with information obtained through in-depth interviews on the main uses of *M. vitiense* such as thatching and palm-heart trade. It also discusses how they are extracted and sold, the resultant income, which sites they frequent the most, division of labor related to exploitation, harvesting and management regimes, and other important cultural important plant or animal species found in sago forest.

3.5.1 Thatching

All the study sites in southeastern Viti Levu are used for harvesting of sago thatching. This section discusses methods used for the harvesting of thatches both traditionally and commercially, method of constructing sago shingles, how an average person or family earns from selling sago thatching, those who are people involved and where they are sold to. Most of the informants stated that *M. vitiense* leaves are the superior roof material compared to grass and coconut.
Thatching made from matured leaves is called "soga revo" by locals. For the roof of an average sized "bure" or hut about 600 shingles of sago palm thatching is needed. There are two methods used for the harvesting of leaves for thatching. The first method involves felling of large trees using axes and chainsaws which are now often used. Trees selected to be harvested are based on number of leaves per tree, condition of leaves; whether they are attacked by insects and length and width of leaflets are not too small. Harvesters prefer more leaves per tree and leaflets that are wide and long as this would reduce the amount of leaflets used per shingle. Once the tree is felled a cane knife is used to remove at least nine to ten leaves and again using the cane-knife, leaflets are removed sorted and placed into a pile (see Plate 3). For a reasonable bundle which could make 25-30 shingles of about one meter long, at least three to four adult trees are felled.

The second method is the easiest but the amount of quality leaves per tree obtained is often less. Leaves are removed from standing juvenile trees, about two to three leaves are rejected and thus about ten to fifteen trees are needed to make a reasonable size bundle (see Plate 3). Depending on quality of leaves and craftsmanship thatch often lasts for 30 years without repair. A fireplace is lit under the roof one or two weeks prior to use as smoke removes or kills the insects in the thatching while the black shoot from the fire acts like preservative.
Plate 3; left- felled adult tree with leaves removed, top middle-leaves removed from juvenile tree, top right- leaflets removed from rachis, bottom left-bundle of sago palm leaves, middle bottom-sorting of leaflets, bottom right- *M. vitieuse* shingles.
3.5.1.1 Commercial exploitation of sago thatching

Recently four villages and two settlements around the study sites began selling thatches to hotels, resorts and to private residences. Thatch shingles or panels, which consist of a thin rib about one and half meters long usually bamboo and about two to three centimeters wide, with sago palm leaves sewn over a rib (usually bamboo) about one and a half meters long using twines, are sold.

Orders from hotels and private developers for thatching are placed in villages and are collected after one month and are taken to a kiln (large oven) where they are treated with chemicals to kill insects and to preserve the thatches.

Twenty of the forty informants stated that they harvest leaves for commercial purpose from the Pacific Harbor site while another ten stated they harvest from Galoa population and the other ten from the Culanuku population. Seven informants stated that they also harvest from both Galoa and Culanuku sites while five stated that they used to harvest from Wainiyabia 1 site.

Orders for sago thatching are not often placed with a single person, family or village but often divided up amongst the villages and if orders are given to a single person he divides it up between people as it is often hard doing it alone. Prices of sago thatching per shingle vary from $0.80c-F$2.00. Most customers are resort and private construction companies. Last year alone Vatulele Island Resort bought 5000 shingles and Taunovo Bay Resort 3000 shingles at a cost of $1.50/shingles and $2.00/shingles respectively. It may end up with at least 150-1000 shingles/family with the current price each family may receive between $200.00 and $1500.00 every one and a half or two months.
Most of the physical work involved in palm-heart harvesting and thatch harvesting involves men and includes the actual harvesting from the forest to transportation home. Thirty-five out of the forty informants stated that women are normally involved in thatching, that is stitching or sewing the leaflets an activity which tends to be the more time consuming than harvesting itself. Ten of the forty informants were women, seven were women from Wainiyabia village, and one each from Sigasiganilaca Settlement, Dranikula and Galoa Village. These ten women informants stated that they now do all the physical work from harvesting to completing the final product. Of these ten women informants, three are widows and the other seven are married but their husbands and sons are working mainly in the hotel construction industry. According to these women they do not want to rely on their husbands and sons to give them money but want to earn money for themselves and be more independent.

3.5.1.2 Description of thatch production
Thatches are manufactured using the following procedure: 1) leaflets are removed from the rachis using a cane-knife. 2) each leaflet is folded onto a thin rib usually of bamboo, *bitu ni viti* (*Schizostachyum glaucifolium*) with predetermined lengths to form the sago “shingle”. The leaflets are sewn onto the bamboo rib using thin strips of the inner bark or bast fibre of *vau* (*Hibiscus tiliaceus*). 3) once completed the singles are applied in layers, each directly tied to the rafters with a vine-like fern, *wa midri*, *Stenochlaena palustris* (Plate 4).
Plate 4: top left, sorting of leaflets removed from rachis middle, sewing of leaflets onto a thin rib of Bitu ni Viti (*Schizostachyum glaucifolium*); top right, finished panels of thatch; bottom left, panels of thatch shingles tied to rafters-sorting of leaflets; bottom right, a finished house with *M. vitieuse* thatching.
3.5.2 Palm heart

The harvesting of palm heart is recent and is quite popular with Indo-Fijians, who have developed a taste for sago palm-heart curry and are the majority consumers. The local name for sago palm heart is ‘seko’ derived from the word sago. At present only five families from the Indian settlement at Wainiverau next to Wainiyabia village sell sago palm heart. Of the five people from the settlement that were interviewed all of them stated that they harvest sago palm heart from the Pacific Harbor site. They also stated that they used to harvest sago palm heart from the Wainiyabia 1 population but have moved to the Pacific Harbor site due to the reduction in palm numbers at the Wainiyabia 1 site. According to the five respondents they harvest palm heart once or twice a month depending on demand and in a single trip may harvest twenty to twenty-five palm hearts of various sizes.

The harvesting method for palm heart is very destructive. According to the five respondents, harvesting involves, firstly, selection of palms, with a preference for juvenile trees, which are easier to access than adult trees; Once the palm tree is selected, the leaf bases are removed until the heart of the palm is exposed; The palm heart is then removed from the base using an axe or sharp cane-knife. Adult trees are felled using a chainsaw and the crown-shaft chopped off. Leaf bases are then removed until the palm heart is reached (see Plate 5). Five respondents stated that they prefer to harvest adult palm tree as it brings them a higher return.

Since *M. vitiense* are single stemmed palms the extraction of palm heart is very destructive as it involves cutting down of palm trunks. The harvesting of palm heart is very wasteful as only the palm heart is removed and not the leaves.
The five respondents stated that they sell palm heart regularly along the roadside at Wainiverau Settlement near Wainiyabia and, the majority of their customers are Indo-Fijians and vegetarian restaurant owners. According to the five respondents, on an average day they sell five to six palm hearts ranging from F$2.00 to F$15.00 depending on the sizes of palm heart but on a good day they can sell up to eight or nine palm hearts. These respondents stated that men do the physical work of harvesting the palm hearts while women are only involved in selling the palm heart.
Plate 5: left – a recently harvested area with only fruiting individuals remaining, second left – felled adult tree with crown-shaft chopped off, second right – peeling of leaf bases to reach palm heart, right – sago palm heart.
3.5.3 Culturally important plant, animal or fish species found in *M. vitiense* forest

Cultural important plant species found in *Metroxylon vitiense* forest include *Eleocharis ochroostachys* and *Eleocharis dulcis*, the latter which is used for making traditional mats called kuta. *Cyperus haspan* and *Cyperus polystachyos*, both known locally as misimisi, are used for the decking of traditional *bures*. These, like sago, have recently have also been harvested commercially at a cost of F$15.00/ bundle for the construction of tourist *bures*.

Thirteen of the forty respondents stated that they harvest *Diplazium esculentum* (saulaki) from swamps behind sago forest (Plate 6). At some sites there are relatively good stands of Tahitian chestnut, *ivi* (*Inocarpus fagifer*), a local delicacy (ivi). Extensive stands of *Barringtonia racemosa* (vutu wai or vutu vala) can also be found at the back swamps, and they are used in the area as an excellent living fence post, especially for grazing lands in poorly-drained areas.

Culturally important animal or fish species found in sago forest include at least two species of gudgen, known locally as mija (*Giruris margaritacea*) and kedromo (*Bunaka gyrinoides*), and the invasive tilapia, mala (*Oreochromis mossambicus*), which is of African origin. Freshwater prawns, *Macrobrachium spp.* can also be found in small rivers and creeks that drain into the swamp.
Plate 6: Left, *Diplazium esculentum* growing at the swamp behind sago forest and *Barringtonia racemosa* growing on the foreground; right – person collecting *D. esculentum*. 
3.6 Conservation Analysis

This section combines all information obtained from ethnobotanical questionnaires, data from detailed harvesting impact assessment and ecology. Using the IUCN Red List Categories and Criteria - version 3.1 (2001) it is proposed that *Metroxylon vitiense* be classified as – **Endangered (EN A4+B2b)**.

This is due to the populations reduction of greater than 50% in the last 10 years (A4) and having an area of occupancy <500 km$^2$ with continuing, observed and projected decline (B2b). However, it is currently known from 11 locations from which only six viable populations remain. Commercial exploitation of the leaves for the thatching trade and sago-palm heart trade have decimated four populations and another population threatened from a combination of commercial thatching, palm heart extraction and land clearance. The populations that are severely fragmented and have a high probability of extirpation within the next 10-20 years include, Wainiyabia 1, Naduruloulou, Togoru, Lobau and Pacific Harbour populations. Thirty out of the forty informants stated that there is no replanting or any management regime in place but they unknowingly do not harvest those palms that are either flowering or fruiting as they have no leaves at all as the plants stop producing leaves at this stage. Exploitation of *Metroxylon vitiense* for commercial thatching and sago palm heart is entirely from wild populations.
CHAPTER 4

CONCLUSION AND CONSERVATION MANAGEMENT PLAN

4.1 CONCLUSION

The results of this study clearly indicate the importance of commercial sago thatching and sago palm heart to communities who depend on it and how this species of palm, *Metroxylon vitiense*, and its populations are threatened by unsustainable harvesting. Almost three quarters of the people interviewed stated that money earned from selling thatching and palm heart is an important source of income.

The harvesting of sago palm heart and leaves for thatching is an activity for which men are primarily involved while women are mostly involved in the construction of the thatches and selling of the palm heart. The role of women, especially in the work relating to sago thatch harvesting, has changed significantly during the last year (2005). As more resorts are being built (e.g., the Taunovo Bay Resort), an increasing number of men have obtained salaried employment in the construction industry, leaving women and older men in the village. This situation has driven the women of three villages (Galoa, Wainiyabia and Qarasarau) to take over duties normally reserved for men. This change has had an impact on sago population dynamics, according to men from other villages who harvest from the same populations, because women typically harvest from the juvenile trees, which are easier to access, rather than adult trees.

Current harvesting method for both thatching and sago palm heart is unsustainable especially when 40 of the people interviewed stated that there are no replanting or conservation initiatives in place. Detailed study of four of the 11 remaining populations confirms this argument. As expected, there was a significant difference
between alternative harvesting regimes. The significantly larger numbers of tall trees found in low-harvesting intensity subplots are due to the larger number of adults and juveniles present, dominating the stand structure. In high-harvesting regimes, seedlings and a few juveniles dominate the stand structure (as measured by total height) because most adults have been removed. The total number of palms was also greater in low harvesting regimes because the increased number of adults translates into greater capacity to produce seeds and seedlings. In high-harvesting regimes, the smaller number of adults reduces the total reproductive output, resulting in fewer seedlings. A similar study by O'Brien & Kinnaird (1996) found that leaf harvesting of Livistona rotundifolia in North Suluwesi, Indonesia, had adverse effects on the number of reproductively-sized palms in areas of high harvesting intensity compared to those of low intensity. In the present study, the structures of the Galoa and Culanuku populations of Metroxylon vitiense exhibit a pattern similar to Livistona in Indonesia, and both of these populations have experienced a longer history of harvesting than the Wainiyabia and Pacific Harbor populations.

Examining age classes within and among individual populations, there was a significant difference in the percentage of adults, juveniles, and seedlings in areas of low-harvesting versus high-harvesting regimes. The most significant difference was observed for adults. Under low-harvesting intensity, adults account for <4% of the total number of individuals, whereas in high harvesting regimes, it accounts for <2% of the entire population. Adults always account for the smallest proportion of individuals in the populations and they are also the most vulnerable age class because they are targeted for harvesting. Adults also have the best quality leaves for thatching and the most well-developed palm hearts.
Juveniles accounted for the second highest proportion of individuals. Juveniles were more numerous in high-harvesting regimes than in low harvesting regimes due to the removal of adults, which allows juveniles to exploit canopy gaps. In some populations (e.g., the Galoa and Culanuku populations); there was a significantly larger proportion of juveniles in both low and high harvesting regimes. These significantly larger proportions of juveniles are probably due to the particular history of harvesting that has occurred at these two populations over the last decade (both located close to villages and are subjected to intense harvesting).

The highest percentage of individuals is always represented by seedlings. There were no significant differences between the low- and high-harvesting intensity regimes, and because *M. vitiense* is semelparous, a large number of seedlings were expected. Monocarpic plants direct most of their energy towards seed production. These seeds have high survival rates (Type-I or Type-J curves; Kitajima & Augspurger, 1989 typically as much as 80-90%), and only 10% of seedlings will persist to the adult stage. After flowers and seed production, the plant dies and then the top of the tree snaps off, allowing the seedlings and juveniles to compete in the resulting canopy gap.

The harvesting of *M. vitiense* does not appear to affect regeneration because harvesters, especially those harvesting for thatch, fell only those trees that have the best quality leaves. Because flowering and fruiting adults stop producing new leaves, harvesters typically do not harvest these trees, thus unintentionally helping the regeneration process. Seedlings in low-harvesting regime areas undergo a natural thinning process, and only the fittest individuals reach the juvenile and adult stages (Kitajima & Augspurger, 1989). Under low-harvesting regimes, only those gaps left by
dying trees are available, leading to intense competition among seedlings and juveniles. The additional gap left in high-harvesting areas relaxes competition and thus allows survival of less fit individuals into the next age class. The present study, however, was conducted over a one year period, and thus cannot fully test these hypotheses. Longer-term studies are needed to compare the fate of seedlings and juveniles under low- and high-harvesting regimes.

Other indirect effects of harvesting include the introduction of weeds and invasive animals. The intensive harvesting of leaves for thatch has disrupted the structure and microclimate in one of the *Metroxylon* populations. Because of their size, thatch harvesting from adults requires felling the trees to access the upper, higher-quality leaves, whereas high-quality leaves can be more easily harvested from the smaller juvenile plants while they are still standing. Gaps created by removal of adult trees allow the introduction of weeds, particularly in over-harvested areas. Since the transition from seedling to juvenile stages takes roughly two to four years (Schuiling & Flach, 1985), noxious weeds such as *Mikania micrantha*, *Annona glabra*, *Clidemia hirta*, and *Merremia peltata* may exploit these gaps. Once established, these weeds can completely overtake an area, competing with sago palms for space and nutrients, and often smothering the sago palms (at all stages, seedlings, juveniles, and adult), leading to reduced growth or death of the plant. The present study tends to support work by Flach (1997) and Schuiling et al., (1993), which demonstrated that sago palms do not compete well with fast growing, weedy plants.

By contrast, closed, un-harvested stands that are dominated by *Metroxylon* trees provide a suitable microclimate under which juveniles and seedlings can survive until
smaller gaps are created. *Metroxylon* palms need wet soils for survival, but opening up
the canopy to sunlight leads to over-drying of the soils, and this may adversely affect the
growth of seedlings. During the present study, seedlings growing under closed canopies
were observed to exhibit good growth, whereas those exposed to excessive sunlight
exhibited very poor growth.

Past human activities have severely reduced the distribution of *M. vitiense*. It was
once common around the Navua and Rewa River Delta 4300BP (Southern, 1986) but is
now found in only 11 localities. This was due to both anthropogenic and natural factors.
When the current sea level was achieved around 4300BP, a beach was formed and
freshwater drainage was impeded, allowing *M. vitiense* to become established. This also
coincided with rapid expansion of human alteration of the swamps, including a complex
series of drainages, local increases in the use of fire, build-up of sediments and increases
in peaty areas that became unfavourable for growth of *M. vitiense* (Southern, 1986).

Of the 11 remaining populations, four (Waniyabia 1, Toguru, Lobau and
Naduruloulou) were and are highly threatened by past and present human activities. All
four populations are now almost extirpated mainly due to unsustainable exploitation for
the thatching and palm heart trade. This is especially evident for the Waniyabia 1 and
Lobau populations. The Toguru and Naduruloulou populations are mainly affected by
clearing of swamps for housing developments and plantations.

The largest remaining population in the Navua Delta is at Pacific Harbour. This
population and its associated swamps will likely disappear over the next five years due to
subdivision of the entire population and drainage of the swamps for housing.
development. This property has been sub-divided and sold very cheaply, at a cost of approximately US$1,000 per acre (McGoon pers com, 2003).

The Culanuku population is also threatened by human alteration of the swamp. The population is lodged between the village of Culanuku on the south (Figure 2) and a hilly terrain and mangroves to the north. The inhabitants are villagers from nearby Serua Island who do not own any other land in this area. Faced with little arable land for farming, they started draining small parts of the swamp to farm. Other threat to this population, include those posed by logging the mahogany forest that is adjacent to the small on the nearby Galoa population, which is due to start in early 2007. This activity will create changes to the swamp microclimate and siltation of the swamp, which may have a cascading effect through increased incidence of flooding. A recent study conducted by Korovulavula (2005) on behalf of Fiji Hardwood Cooperation recommended that they minimize logging impacts on sago swamps as proposed logging tracks for the removal of cut logs crosses the northern end of the population. The same recommendation was made for the Wainiyabia-1 population, which is threatened by a proposed highway diversion for the development of the Taunovo Resort.

The current distribution of *Metroxylon vitiense* is mostly on the southeastern part of Fiji’s main island of Viti Levu, on the Navua Delta at the boundary between coastal swamps and adjacent slopes. The persistence of sago-palm populations in these small areas can be attributed to several factors, principally little human interference through drainage, fire and resource exploitation. Parry (1981) suggested that Rewa Delta supported higher human population densities than the Navua Delta, and that exploitation of *M. vitiense* for human consumption may have led to its extirpation. The Bonatoa site is
located on the windward side of the main island, with an annual rainfall (ca. 3000-6000 mm per year) favourable to *M. vitiense*. Threats, mostly from anthropogenic factors, place all the *Metroxylon* population in great danger. Future prospects look bleak, especially for the large Pacific Harbour population. The natural range of *M. vitiense* populations continues to decrease from a wide variety of threats, mainly from development and overexploitation of sago leaves and palm hearts and solutions must be implemented to curb further decline. Fortunately, the demise of four populations (Wainiyabia 1, Toguru, Wanikevu and Naduruloulou) and the imminent loss of the Pacific Harbour population have been offset by the discovery of two new populations. Compared to other populations, threats to these newly discovered populations at Maratu (a large population, similar in size to Pacific Harbour) and at Wanikevu are much reduced.

Populations located close to human settlements, such the Galoa and Culanuku populations, are easily accessed and therefore show the greatest impact. Both of these populations are within walking distance to the villages of Galoa and Culanuku, respectively, and the access to these populations has been intensified by their close proximity to roads. The Wainyabia population, however, has not been exploited by indigenous landowners, but has been exploited to the point of extirpation by Indo-Fijian harvesters of sago palm. The largest population, at Pacific Harbor, has recently been the target of harvesters for both sago palm thatch and palm hearts because roads cross the population. This population was relatively untouched until as recently as 5-10 years ago, but the land has since been sold and developed. Despite its remote location, harvesters now prefer to pay the cost of getting there by truck since, once there, it is very easy to
access abundant and good quality thatching and palm heart materials compared to the other two populations. According to some private landowners they do not mind harvesters harvesting sago palms since it helps clear their property.

It is also important to note the other important species of plants and animals found in the sago forest. Two introduced sedges (Cyperaceae) are commonly found in sago-palm swamps and are now harvested in large quantities because both are useful in constructing traditional bures. At the Culanuku, Pacific Harbour and the Galoa population, vast fields of the fern Diplazium esculentum (ground fern) have disappeared due to unsustainable human exploitation, grazing by cows, and clearing of the forest for plantations. Destructive logging practices and feral cows trampling and grazing the understory have caused siltation of small rivers, creeks and sago swamps, resulting in the loss of gudgeon and prawn species.

The impact of harvesting and other human related activities may upset unique population structures, reduced palm abundance, consequently reducing population sizes and eventually lead to extirpation of local populations. Therefore it is important to incorporate management strategies in harvesting regimes to address conservation and resource management issues.
4.2 FIJI SAGO PALM – A CONSERVATION MANAGEMENT PLAN

Goal

To manage the Fiji sago palm, *Metroxylon vitiense* and promote an interest in its conservation so that viable populations of the species and its habitat are restored in a self-sustaining manner so that it is protected in the wild throughout the natural range of the species.

Biodiversity Significance

The Fijian endemic *Metroxylon vitiense* is native to Viti Levu, and those populations found in Vanua Levu are probably recent introductions. Sago Palm is also found in Ovalau, an island that was once attached to Viti Levu during the last ice age. The species was once widespread throughout the Navua and Rewa River Deltas, but now it is only found in six localities. Sago palms are found in wetlands where they play a vital role in local ecosystems, including groundwater replenishment, sediment and nutrient retention and export, water purification and flood control.

Species Biology & Ecology

*Metroxylon vitiense* is a large emergent, semelparous palm. The seeds of *M. vitiense* are dispersed by fruit bats (*Pteropus spp.*) and water and the main seed predators appear to be rats (*Rattus spp.*). *M. vitiense* produces eight to nine leaves per year which is not enough to sustain the current thatching trade. The constant pruning of leaves for the thatching leaves slows growth of the tree, keeping it in a quasi-juvenile state and at the same time it opens up the canopy causing a drying effect of the under-story disrupting the micro-
climate which affects the growth of seedlings. Seedlings do no compete well with many weedy dicotyledons as they obstruct their growth, eventually killing them.

**Status: Former and Current status**

The first critical analysis of this species using the IUCN criterion was done by Fuller (1997) and the sago palm was listed as Vulnerable (VU). A recent publication by Watling, (2005) stated that this species should remain as Vulnerable (VU).

**Causes of decline and threats**

There are many causes for the decline of *M. vitiense* and the major cause is exploitation of leaves for commercial thatching and the sago palm-heart trade. This is further exacerbated by subdivision of sago forest for development and plantation by property developers.

**Exploitation**

**Heart**

The current harvesting of sago palm heart is very destructive (entire plant is removed) and is occurring at an unsustainable rate as there is no replanting. This has resulted in the destruction of the Wainiyabia 1 population and threatened others.
Thatch

The harvesting of sago leaves for commercial thatching for the hotels and resorts have increased dramatically in recent times and will continue to increase as more new hotels continue to be built.

Subdivision

The most threatened populations are those located on freehold land and is currently being sub-divided into plots and sold. The Pacific Harbour population which is one of the largest remaining populations is currently been subdivided into small blocks. It is now dissected with roads and drains with about 30% of the population already removed and the entire swamp has now been drained.

Past Conservation Efforts

There has been little conservation work done on *M. vitiense* except several palms planted at the University of the South Pacific and Thurston Gardens as a Germplasam resource and the endorsement of Fiji's first wetland in Upper Navua Gorge which contains the last relatively undisturbed natural population of *M. vitiense* under the RAMSAR convention on wetlands. The upper Navua population is the only natural population found 100m a.s.l compared to the populations found along the coast.
Lack of action on existing Recommendation

The National Environment Strategy for Fiji prepared by Watling and Chappe (1993) recommended that a complete trade ban to be enforced as soon as possible on threatened and endangered species, including *Metroxylon vitiense*, with the only exemptions for traditional and cultural uses. This recommendation was endorsed by cabinet, but as yet no action has been taken.

Lack of awareness – international, national, institutional

There has been a lack or no awareness done by the Government of Fiji through relevant departments such as Department of Forestry and Environment, and Non-governmental organizations, on the importance of *Metroxylon vitiense*.

Conservation Status

*Metroxylon vitiense* mabe locally abundant in SE Viti Levu and is reproducing in large numbers, but the remaining populations are being severely impacted upon by commercial harvesters for thatching and palm heart as they are being harvested at an unsustainable level. Of the 11 populations initially documented by Scott (1993), Fuller (1997), only six populations remains, corresponding to an almost 50% decline.

It is proposed that *M. vitiense* be changed on the IUCN Red List threatened category to – Endangered (EN A4+B2b).
Options for Conservation Management

Six options for both in-situ and ex-situ conservation of *Metroxylon vitiense* are identified which range from a confrontational approach of a complete ban, partial ban to a compromise approach which include moratorium replanting and using sago forest as wetland attraction. Protection of existing wild populations where there is potential; supplementary planting or restoration/rehabilitation where there is potential, insurance planting and distribution of planting to eliminate or reduce threats – heart palm substitution; thatch sustainable management are some options to protect this palm species.

Complete Ban

A complete ban on commercial extraction (with exception for traditional and cultural extraction) would be a desired option for most conservationists and for the government, but would be difficult to implement because villages depend on exploitation of this species to generate income especially in the Wainiyabia, Galoa, and Culanuku villages. A complete ban could be imposed on populations that are already protected, are inaccessible, and have very little or no human impact at all, notably for the Nabukelevu and Maratu populations.

Possible populations for protection

In deciding which populations to protect, it is very important to note that sago palm grows in fresh- and brackish-water environments. Therefore, is imperative to select populations that are found in both environments to maintain genetic
diversity. But this can only be done once the level of genetic diversity is determined.

**Brackish-water populations**

Brackish-water populations include those at Galoa, Culanuku, Lobau and Pacific Harbour. Two populations that could be rehabilitated and protected are the Galoa and Culanuku populations, but these are the most accessible sites by the harvesters because of the proximity to villages. Negotiations with the relevant stakeholders are needed to decide which of these population(s) should be protected.

**Freshwater population**

The Nabukelevu, Maratu and Waikevu populations are all in freshwater swamps. The Nabukelevu population is in the Upper Navua Conservation Area (NCA), which is a RAMSAR Wetland protected area site and the Maratu also has good chances of being protected as it is adjacent to the Nabukelevu but not within the 200m protection area from the Navua River. This will involve liaising with government agencies in extending the current boundary of NCA, to include the Maratu population. Both populations are difficult to access, which means they receive little human interference.
Partial Ban on Harvesting

A partial ban involves allowing part of the population to be harvested for traditional and cultural reasons but setting aside other parts for no harvesting. This could be achieved through one of the following cyclic harvesting regimes:

1. Within a population, a plan can be developed to rotate harvesting for palm hearts (on a small scale) in combination with a schedule for replanting.

2. Amongst populations, a harvesting rotation could be implemented that would allow for each population to recover naturally i.e., without replanting. Germplasm materials should be collected at all populations with the help of the Secretariat of the Pacific Community (SPC) Plant Protection Unit to conserve the diversity of gene pool.

Moratorium

A temporary moratorium (4-5 years) could be placed on the harvesting of *M. vitiense*. This approach is similar to the moratorium that was recently placed on sea turtles in Fiji, and is currently in place for the harvesting of Maori wrasse in Fiji.

Quota System

A national quota system could be introduced whereby a harvesting quota is allocated for each population depending on its size. A licensing system could be introduced to force the harvesters to pay a fee to landowners, (similar to a fisheries license), and adhere to strict conditions.
Re-planting

Germplasm material stored at germplasm facility could be used to set up *ex-situ* population conservation programme whereby *M. vitiense* could then be planted in wetland systems which have been already identified. This would greatly reduce the pressure on natural populations.

Palm Certification

Certification of sago-palm products through a “fair trade” protocol that includes stringent harvesting and monitoring guidelines would ensure that the palm-hearts sold and thatching used in hotels and resorts are harvested from sustainable through resources.

Wetland Attraction

Populations that are close to major roads or hotels could be rehabilitated in a way that would provide an eco-tourist attraction, either by constructing a walkway through the sago forest or a channel where tourists could travel by boat to visit sago forest. This could generate income for local landowners and educate tourist about the importance of sago palm wetlands.
Conservation Plan

Objectives

1. Initial meetings need to involve the stakeholders including landowners, government, thatch users, palm heart producers/consumers and conservation organizations in the conservation of *Metroxylon vitiense*.

2. Protect existing populations, ensuring that there are at least three viable populations that are securely/legally protected.

3. Establish alternatives for source of heart of palm and sustainable "thatch" production by liaising closely with relevant government departments on possible introduction of similar species.

4. Set up a restoration project for an existing population or former population which has been extirpated.

5. Identify new legally protected sites suitable for the propagation of the protection of the species and reduce pressure on natural populations. This would provide some insurance if natural populations are not fully protected.

6. Identify priorities for research such as detailed ecological study and population and conservation genetics.
<table>
<thead>
<tr>
<th>OBJECTIVES</th>
<th>ACTIVITIES</th>
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<tr>
<td>Initial meetings involve stakeholders including landowners, government,</td>
<td>Identify priority stakeholders including government, conservation</td>
</tr>
<tr>
<td>thatch users, palm heart producers/consumers and conservation organizations</td>
<td>organizations, landowners, palm-heart producers/consumers, thatch users</td>
</tr>
<tr>
<td>in the conservation of <em>Metroxylon vitiense</em>.</td>
<td>and funding organizations.</td>
</tr>
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<td></td>
<td>Initiate consultations with relevant stakeholders to discuss the project</td>
</tr>
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<td></td>
<td>intentions and aims</td>
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<tr>
<td></td>
<td>Produce a brochure, posters for advocacy awareness purposes at villages</td>
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<tr>
<td></td>
<td>in Fijian.</td>
</tr>
<tr>
<td></td>
<td>Undertake public awareness initiatives, television and radio interviews.</td>
</tr>
<tr>
<td></td>
<td>Arrange briefings with resource owners, relevant government departments</td>
</tr>
<tr>
<td></td>
<td>on the progress and future plan of the management of sago-palm.</td>
</tr>
<tr>
<td></td>
<td>Determine timeline and costs.</td>
</tr>
</tbody>
</table>
| Establishing a legal protection for the protection of *Metroxylon vitiense* | Determine traditional and legal protection possibilities and liaise closely with resource owners and users, relevant government departments and legislators.  
Prepare draft legislation/regulations for consultations with relevant stakeholders.  
Prepare final legislation for Department of Environment (DOE) approval.  
Awareness amongst relevant stakeholders on new legislation/regulations. |
| Protect existing populations, ensuring that there are at least three populations securely/legally protected | Identify three populations at least with good protection possibilities such as those located close to reserves and include representatives of some brackish and freshwater populations.  
Prepare implementation plan.  
Consult with landowners and determine protection possibilities. |
| Establish alternatives for source of heart of palm and sustainable “thatch” production | Consult with landowners and resource users on reasons for introducing alternative sources for ‘thatch production’.

Identifying alternative species of palms for heart of palm and thatch production.

Identifying suitable places where trial planting could be done.

Liaising closely with SPC, Department of Agriculture and possibly Quarantine Services for the importation of the identified species of palms.

Establishment of nursery for trial and distribution of seedlings.

Prepare and write up report for funding agency |
|---|---|
| Guidelines for sustainable harvest | Mapping of multiple-use/ harvesting/ conservation zones.

Socio-economic survey (demographics, livelihood strategies).

To assess the demand for sago palm-heart and thatching

Monitoring the current use of sago palm. |
<table>
<thead>
<tr>
<th>Identify new sites suitable for establishment of insurance population for protection of the species and reduce pressure on natural population.</th>
<th>Develop timeline and costs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conduct a study to determine suitable sites for establishment (physical parameters) of insurance population.</td>
<td></td>
</tr>
<tr>
<td>Suitable site is determined and relevant landowners consulted to seek permission.</td>
<td></td>
</tr>
<tr>
<td>Consultation with landowners on plans for replanting</td>
<td></td>
</tr>
<tr>
<td>Begin site preparation for replanting and start replanting</td>
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Research Priorities

Most studies conducted on *Metroxylon vitiense* have been mostly taxonomic. Apart from this study there has been no extensive study done on *M. vitiense*. Currently there is an agronomic study by scientists from Mie University, Japan in collaboration with the South Pacific Regional Herbarium, USP.

Future studies should focus firstly on the detailed study of the ecology and phenology of the palm. During the course of this study a small germination study was conducted. The results were promising but more work needs to done. More work is needed especially on nutrient requirements, growth, dispersal, seed predators, flowering and pollen studies and life cycle. This information is critical if we are looking at rehabilitating a populations or setting up new populations.

Genetic studies a critical component for the conservation of endangered species. If individuals are needed to form new genetically diverse population long-term genetic integrity is important in *ex-situ* or *in-situ* conservation programmes especially for endangered palms.
Bibliography


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Runk, J.V. 1998. Productivity and Sustainability of a Vegetable Ivory Palm
(Phytelephas aequatorialis, Arecaceae) Under Three Management Regimes in

Rutherford, J. 1974. Mobile Agriculturalists: land and population exchanges in the
social organization of the Bougainville Aita, University of Hawaii, MSc
Dissertation.

Saville, W.J.V. 1926. In Unknown New Guinea: a record of twenty-five years of
personal observation and experience amongst the interesting people of an almost
unknown part of this vast island and a description of their manners and customs,
occupation in peace and methods of warfare, their secret rites and public
ceremonies. J.B. Lippincott Company, Philadelphia, USA.

Yielding Non-Seed Carbohydrates, Backhuys, Leiden. Pp 116-120.

University, Wageningen University, Netherlands.

Sago Palm (Metroxylon sagu). Department of Agronomy, Section Tropical Crop
Science, Wageningen Agriculture University, Netherlands.


**APPENDIX 1: SUMMARY OF THE NUMBER OF INDIVIDUALS IN THREE SIZE CLASSES OF *METROXYLON VITENSE* ON SOUTH-EASTERN VITI LEVU.**

**GALOA**

Low harvesting intensity

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High harvesting intensity

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**TOTAL**

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**CULANUKU**

Low harvesting intensity

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**TOTAL**

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High harvesting intensity

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**TOTAL**

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**WAINIYABA**

Low harvesting intensity

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High harvesting intensity

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**TOTAL**

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### PACIFIC HARBOUR

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**TOTAL**

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**High harvesting intensity**

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230
APPENDIX 2: ETHNOBOTANY QUESTIONNAIRE

SAGO PALM CONSERVATION AND BIODIVERSITY SURVEY 2004-05
COMMUNITY-BASED BIODIVERSITY USE AND CONSERVATION QUESTIONNAIRE

Name: ___________________ Male/Female: ___________ Date: ____ Village/Place: _______________________

CULTURAL/TRADITIONAL

1. List 6 different area(s)/populations of sago palm in your area.
   1. ___________________ Location(s) ________________________________
      Owner(s)_________________________ Use(s)________________________

   2. ___________________ Location_______________________________
      Owner(s)_________________________ Use(s)________________________

   3. ___________________ Location_______________________________
      Owner(s)_________________________ Use(s)________________________

   4. ___________________ Location_______________________________
      Owner(s)_________________________ Use(s)________________________

   5. ___________________ Location_______________________________
      Owner(s)_________________________ Use(s)________________________

   6. ___________________ Location_______________________________
      Owner(s)_________________________ Use(s)________________________

(2) List (3) areas of sago palms population(s) that have been reduced through overexploitation over last 10-30 years.

   1. ___________________ Provide details______________________________

   2. ___________________ Provide details______________________________

   3. ___________________ Provide details______________________________
(3) List 4 problems associated with over-harvesting of sago.
1. Explain
2. Explain
3. Explain
4. Explain

(4) List 3 major users of sago palm in your area.
1. 2. 3.

(5) Explain 4 major subsistence uses of sago in your area.
1. Explain
2. Explain
3. Explain
4. Explain

(6) Do you use any other parts of the sago apart from the leaves and palm heart? Y/N If yes provide details.

(7) List 6 important cultural plant species found in the sago forest.
1. Uses
2. Uses
3. Uses
4. Uses
5. Uses
6. Uses

(8) List 6 important cultural animal or fish species found in the sago forest.
1. Uses
2. Uses
3. Uses

4. Uses

5. Uses

6. Uses

(9) List at least 5 people who sell sago palm products in the area, with their uses and estimated income.

1. Products

2. Products

3. Products

4. Products

(10) Are there any myths or ancient folklore related to the sago/sago forest? Yes/No If yes provide details.

(11) Do any of the clan in your area have sago as their totem? Yes/No If yes explain?

CONSERVATION

(12) Are there alternatives to using sago as roofing materials? (Y/N)

(13) If (Yes) what are the other alternatives?
(14) List at least 6 advantages of using sago as thatching materials.
1. ______________________ 2. ______________________ 3. ______________________
4. ______________________ 5. ______________________ 6. ______________________

(15) List at least 6 disadvantages of using sago as thatching materials.
1. ______________________ 2. ______________________ 3. ______________________
4. ______________________ 5. ______________________ 6. ______________________

(16) Are the sago replanted after a harvest? (Y/N) If yes, how long after and using what method?
__________________________________________________________________________
__________________________________________________________________________

(17) During sago harvesting are there any mature plants left for natural regeneration? (Y/N)
Please explain.
__________________________________________________________________________
__________________________________________________________________________

(18) What can be done to protect/re-establish or increases the abundance of these sago populations?
__________________________________________________________________________
__________________________________________________________________________

(19) Which palm size class (juvenile/adult) is chosen to be sold as commercial thatches and those for private use in the village.
Commercial__________________________Reason(s)______________________________
__________________________________________________________________________

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(20) List at least 3 harvesting methods and equipments used in harvesting of sago leaves/palm heart. Give advantages and disadvantages of each.

1. | Advantages | Disadvantages |
---|---|---|
2. | Advantages | Disadvantages |
3. | Advantages | Disadvantages |

(21) Do you cut down the entire tree or only remove the leaves? Please explain. Why?

(22) Does the harvesting of sago palm leaves for thatching and sago palm heart occur weekly, monthly, annually or varies? Please explain.

ECOLOGICAL

Soga (*Metroxylon vitiense*)

a) Preferred habitat of the tree

- Elevation
- Aspect/Slope
- Climate/Microclimate
- Soil or Substrate
- Vegetation type
- Landuse type
- Other habitat information

b) Abundance and endangered status

- Tree abundant
- Tree common/uncommon
- Tree rare or endangered
- Tree extinct
- In what areas or habitat is it above?
e) **Times/months and frequency of flowering and seed production.**

f) **Pollinators (insects/birds/bats etc/don’t know)**

e) **Dispersal of seeds (birds/bats etc/don’t know)**

f) **Availability and types of seeds.** Whether the seeds establish easily naturally?

g) **Husbandry and cultivation:**
   Is tree planted from seed? Yes/No Explain.
   By transplanting seedling? Yes/No Explain.

h) **Are there plants or animals species that grow or live with or on this species in the same habitat or which serve as host species?**

i) **Growth characteristics**
   Fast growing.
   Grows straight/crooked etc.

j) **Environmental threats to species:**
   Resistance/Susceptibility to cyclone damage?
   Drought.
   Water logging.
   Fire.
   Other threats.

k) **Susceptibility to pests and disease**
   If so what pests & diseases.
   How often.
   How are they spread.
   How do they affect the tree.

l) **Quality, character and advantages of the leaf.**

m) **Genetic variation:**
   Are there different named or unnamed varieties of the palm?
   If so what are they.
   Do they have local names.
   Do they vary from one another in growth characteristics in wood type or leaf quality, fruit characteristics, propagation, utility, etc?

List 6 ecological benefits of sago/sago forest.

1. 
2. 
3. 
4. 
5. 
6.
Any other information about sago palm.