RMAP WORKING PAPERS

Resource Management in Asia-Pacific

Working Paper No. 51

Eaglewood in Papua New Guinea

B. Gunn and P. Stevens

CSIRO Forestry and Forest Products, Canberra, Australia

M. Singadan

Papua New Guinea Forest Authority, Lae, Papua New Guinea

L. Sunari and P. Chatterton

WWF South Pacific Programme, Madang, Papua New Guinea

Submitted to the First International Agarwood Conference
for publication as part of the conference proceedings.
November 1—15, 2003
Tropical Rainforest Project, Vietnam

The correct citation for this publication is:

Author: B.V. Gunn, P. Stevens, M. Singadan, L. Sunari and P. Chatterton
Year of Publication: 2004
Title: Eaglewood in Papua New Guinea
Series: Resource Management in Asia-Pacific Working Paper No. 51
Publisher: Resource Management in Asia-Pacific Program
Research School of Pacific and Asian Studies
The Australian National University
Place of Publication: Canberra
ISSN – 1444-187X

Resource Management in Asia-Pacific

Working Papers

The Resource Management in Asia-Pacific Working Paper series seeks to provide readers with access to current research on environmental and resource issues in the Asia-Pacific. Working Papers produced by the Program aim to facilitate discussion and debate on critical resource management issues in the area, and to link scholars working in different disciplines and regions.

Publication as a 'Working Paper' does not preclude subsequent publication in scholarly journals or books, indeed it may facilitate publication by providing feedback from readers to authors.

Unless otherwise stated, publications of the Resource Management in Asia-Pacific Program are presented without endorsement as contributions to the public record debate. Authors are responsible for their own analysis and conclusions.

Resource Management in Asia-Pacific Program
Research School of Pacific and Asian Studies
The Australian National University
Canberra ACT 0200
Tel: +61 2 6125 9978
Fax: +61 2 6125 4896
Email: rmap@coombs.anu.edu.au

Eaglewood in Papua New Guinea

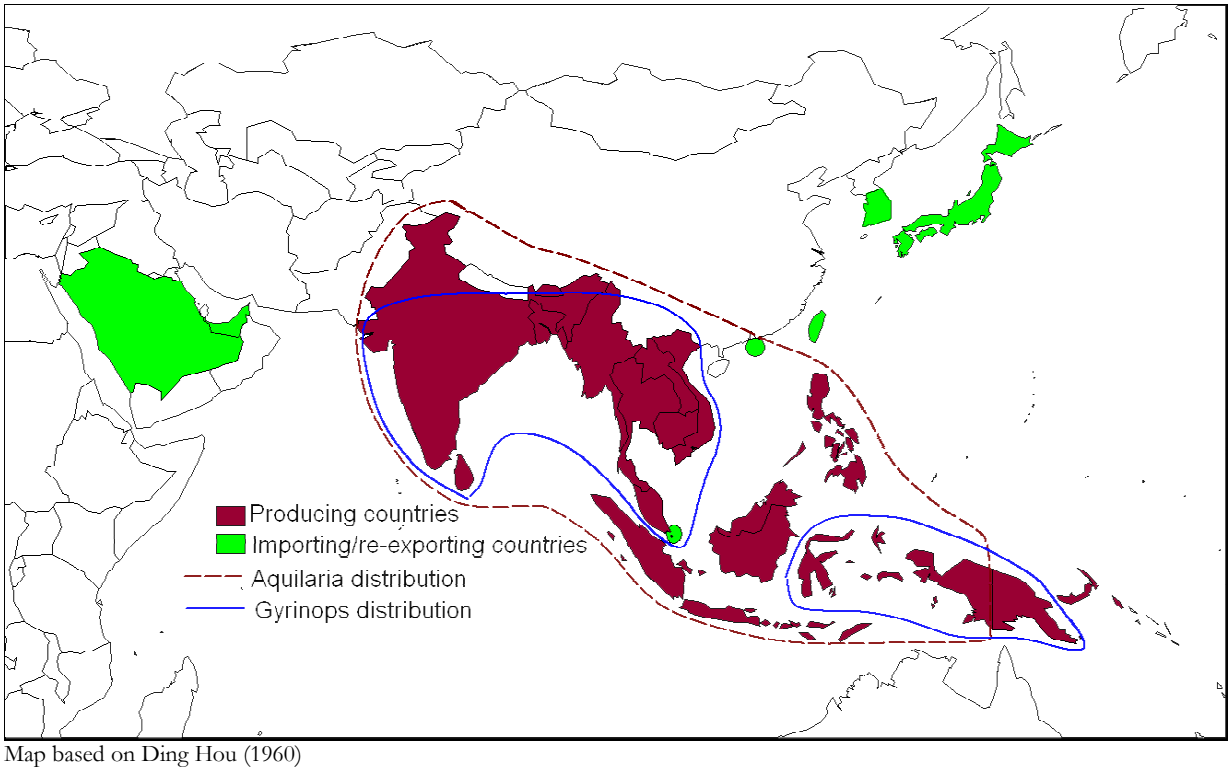
Abstract

Papua New Guinea is arguably one of the last frontiers in the world where the exploitation of natural stands of eaglewood is possible. The trade in eaglewood first commenced in the late 1990s. Prior to the demand for export of eaglewood, the tree species had not been regarded as having any cultural or commercial importance. To date, only one species of eaglewood, Gyrinops ledermannii, is known to occur in Papua New Guinea. The lack of information and awareness of eaglewood is creating major problems exacerbated by the remoteness of producers and landowners who harvest the resin wood. There is an urgent need to develop a practical plan for scientifically-based biological conservation and management of eaglewood. This paper provides a general overview of eaglewood with specific reference to Papua New Guinea. Summary information on the recommendation contained in the strategy document on biological conservation and management of eaglewood is also presented.

Background

Internationally, eaglewood, otherwise known as agarwood, aloeswood or gaharu (the Indonesian name frequently used by villagers in Papua New Guinea), is known for its fragrant resinous wood. For the purpose of this paper, eaglewood refers to the tree and gaharu to product derived from the tree. Eaglewood refers to species within four genera; *Gyrinops, Aetoxylon, Gongystylis* and more commonly, *Aquilaria* within the family Thymelaeaceae. The value of the tree is in the resin found in a small percentage of trees mainly harvested from certain species in the Genus *Aquilaria*. The process of olio-resin production is the tree's response to injury if its first line of defence, formation of phloem callus tissue, is inhibited from forming over the injury (R. Blanchette 2003). The resin derived from the eaglewood tree is highly sought after for religious, medical, ceremonial and domestic activities by Asian Buddhists and Moslems. Middle Eastern countries and Japan are major users. The product is also gaining demand from users in Europe and North America for perfumery and medicinal uses as reported at the First International Agarwood Conference in Vietnam (J. Katz *pers. comm.* 2003).

Species of *Aquilaria* and *Gyrinops*, the two important gaharu producing genera are naturally distributed in at least 12 countries: Bangladesh, Bhutan, Cambodia, India, Indonesia, Lao PRD, Malaysia, Myanmar, Philippines, Thailand, Vietnam and Papua New Guinea (Barden *et al.* 2001) (**Figure 1**). The range is from approximately latitude 27°N to 10° 30'S and longitude 75°E to 149°E. Elevation ranges from just above sea level to over 850 m a.s.l.



Map based on Ding Hou (1960)

Figure 1. Map showing distribution of eaglewood (red/ dark shading) and importing/ re-exporting countries (green, light shading) associated with the product (gaharu).

Demand for gaharu increased very significantly at the end of the 1970s, when the supply of high-quality resin wood from Vietnam and Cambodia diminished because of the political situation. At the same time, Saudi Arabia and the Gulf Emirates experienced the oil boom, which generated high incomes, and an increase in the demand for eaglewood. Immigrant workers from neighbouring Middle Eastern countries also benefited from the oil boom, and started spending more money on luxury products such as gaharu (WWF 1999).

In Papua New Guinea (PNG), eaglewood was first discovered and harvested for resin production in about 1998 in the Yapsiei, May River and Ama villages in West Sepik. At that stage information on the species was unknown. It was only in 2001 that taxonomic work was undertaken which determined the species as *Gyrinops ledermannii*. This was the first official recording of this species being harvested for the resin wood. Since the initial findings, there has been a dramatic escalation in the rates of harvesting and export of gaharu. Most of the natural distribution of eaglewood is associated with some of the poorest communities in the country. This makes eaglewood trade very important particularly to those remote communities who have very little opportunities for earning.

There is very limited information on the harvesting of gaharu and there are no regulations governing the exploitation of the resource. Trade figures on exports are kept by the PNG Forest Authority (PNGFA), but it is well known that there is a substantial unrecorded trade making it difficult to obtain reliable figures on gaharu production and sale. At the same time villagers are frequently unaware of the value of the wood and are at the mercy of the buyers until they become better informed about the true worth of gaharu.

In 2000, a management and conservation project titled 'Domestication of Papua New Guinea's Indigenous Forest Species' was implemented involving the PNG Forest Research Institute (PNGFRI) through the PNGFA with technical support from CSIRO Forestry and Forest Products.

The project agreed to develop a conservation and management strategy for eaglewood in PNG in conjunction with other parties.

Early Development of Eaglewood in Papua New Guinea

Between the 1980s and early 1990s there was major harvesting of eaglewood locally referred to as `*damam gaharu*' (gaharu fever) in East Kalimantan. This was largely caused by the significant increase in demand for gaharu coupled with diminishing supplies from Vietnam and Cambodia (Barden *et al.* 2001). Expeditions of professional collectors, sometimes dropped by helicopters and sponsored by ethnic Chinese and bogus traders, were organised to hunt for gaharu. At that time, about 70 per cent was exported to the Middle East, and 30 per cent to China, Hong Kong, Taiwan and Japan, with a slight decrease following the Gulf War. By 1995, traders stopped funding high-cost expeditions in Kalimantan and turned instead to Indonesian West Papua (WWF 1999).

In 1997 traders established eaglewood harvesting operations in Sandaun and East Sepik Provinces of PNG (Singadan 2003.). This coincides with observations made by R. Kiapranis (pers. comm. 2001) that while Forest Research Institute herbarium staff were working in the Green River area of West Sepik in 1998 they heard reports that people were 'collecting valuable wood' It is assumed that it must have been eaglewood. At this time, staff at the FRI herbarium in Lae were receiving frequent enquiries from SE Asians asking whether eaglewood occurred in PNG. . Harvesting then extended to the Yellow River and Ama areas. From there harvesting expanded to the Hunstein Ranges, Ambunti, Chambri Lakes area and Mt Garamambu followed by the Middle Sepik along the Karawari River, Yuat River and Amboin area, where the main collection is now occurring. Harvesting may soon commence near Bogia along the Keram River in Madang Province, as the presence of eaglewood has been confirmed.

People who are keen to obtain gaharu, usually encouraged by buyers, often fell trees indiscriminately in the vain hope of finding the resin wood even if the trees show no external signs of having resin. This is especially the case with outsiders and non-resource owners who have no long term stake in the species. This led to severe depletion of trees in particular areas. The most crucial element of any sustainable conservation and management strategy for eaglewood in PNG will be to educate traditional landowners on sustainable utilisation practices, especially how to identify those trees containing gaharu so that only those trees are harvested. To date, harvesting has been going on in the Sepik basin including Sandaun and East Sepik Provinces and more recently the Keram and Biwat River areas in Madang Province. Small quantities of wood are being traded in other parts of the country associated with the natural distribution.

Biological Description of Eaglewood in PNG

Taxonomy and nomenclature

The word 'eaglewood' refers essentially to two genera, *Aquilaria* and *Gyrinops*, within the Family Thymelaeaceae. Ding Hou (1960) refers to 12 species of *Aquilaria* and eight species of *Gyrinops*. Mabberley (1997) refers to 15 tree species of *Aquilaria*. The distribution of these two genera is illustrated in **Figure 1** based on Ding Hou (1960). Of the eight *Gyrinops* species, five are found on the island of New Guinea (incorporating Indonesian West Papua and Papua New Guinea): *Gyrinops ledermannii, G. caudata, G. podocarpus, G. salicifolia* and *G. versteegii.* It is interesting to note that with the exception of the reported occurrence of *G. walla* in Sri Lanka (Ding Hou 1966), the occurrence of the other seven *Gyrinops* species are distributed east of the Wallace Line. This artificial line is significant in that it marks the edge of the two biogeographical zones, the Asian zone to the west and the Australian zone to the east.

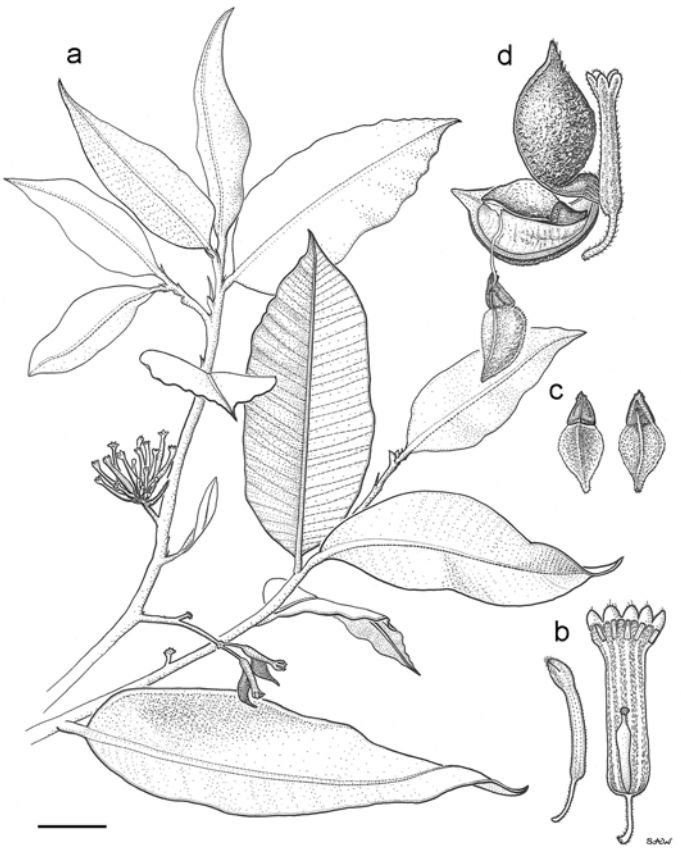
At the time of submitting this paper, only *Gyrinops ledermannii* has been confirmed to occur in PNG. However, there is every possibility that other species including those found in West Papua may also occur. K. Damas (*pers. comm.* 2003) has suggested that specimens collected from Central, Gulf and Western Province are likely to be different species of *Gyrinops* and one specimen has affiliations with *Aquilaria,* based on the floral taxonomy.

The survey undertaken in 2000 by the TRAFFIC (international non government organisation responsible for wildlife trade monitoring program of IUCN and WWF) (Zich and Compton 2001) in the Hunstein Ranges area of the Sepik District determined that the species found in that region is *Gyrinops ledermannii* Domke, on the basis of flowering and fruiting material. This species was first described and published by Domke (1932) from a single specimen collected at Station Mt. Pfingst, Sepik River. Ding Hou (1960) acknowledged the similarities between the two genera *Aquilaria* and *Gyrinops*, which differ only in the number of stamens. In *Aquilaria* the number of stamens (10) is twice the number of petals while in *Gyrinops* there are equal numbers (5) of stamens and petals (Zich and Compton 2001). There are surprisingly few botanical collections in the PNG FRI herbarium, and the more complete flowering and fruiting specimens are all of recent origin. These specimens were collected by employees of the World Wide Fund for Nature from the region of the Hunstein Range of PNG. **Figure 2** provides a botanical illustration of *G. ledermannii* foliage, flowers and fruit drawn from a herbarium specimen collected as part of the expedition to the Hunstein Range (Zich and Compton 2001). Resource owners refer to two distinct varieties of eaglewood based on leaf size.

Zich and Compton (2001) provide the following description for *Gyrinops ledermannii*[1]:

> "*Habit:* A tree, often crooked and of poor form, usually 10-15 (-32) m tall with a 10-30 (60 – 95) cm dbh. *Bark:* pale white to cream. *Wood:* light brown or white with fibrous rays, soft and light with pleasant smell when fresh. *Leaves:* adult leaves, alternate, spirally arranged, simple, variable shape and size from oblong to ovate and obovate-lanceolate, (5.5-) 15-22 cm long, (2.5-) 5-8 cm wide, dark green glossy above and light green shiny underneath, margins entire, sharp pointed tip with rounded base:. *Inflorescences*: 6-10 flowers form at the tips of branchlets and each flower is trumpet-like in appearance, 3-6 mm long, white at the tips of the flower and green towards the middle and base of the flower. *Fruits:* small, green, ovoid, splits open when ripe into two halves from the tip to reveal two black seeds. S*eeds:* 2 or 1 by abortion, seeds ovoid, *ca* 11.5 long by 5 mm wide hanging from capsule by very fine funicle".

[1] Numbers in parentheses refer to extremes in a specific character



a- branchlet habit
b- flower bud (left), opened flower (right)
c- seed dorsal view (left), ventral view (right)
d- dehisced fruit emerging from lateral slit of floral tube with one seed hanging out on funicle
Herbarium specimen Zich 315, CANB Accession Number 531408
Botanical illustration : Sharyn Wragg.
(Zich and Compton 2001).

Figure 2. Illustration of *Gyrinops ledermannii*

Another scented species in Thymelaeaceae is *Phaleria macrocarpa*, commonly known as 'puk puk gaharu'. This species has no commercial value as it does not give off a desirable aroma when burnt. It appears to occur fairly commonly from the Sepik down to Morobe Province and South Coast. It has very thick bark whereas eaglewood has thin bark. In the upper Sepik *bilums* (traditional woven carrying bags) are made from the bark. The same species was also identified by Zich and Compton (2001) from near Gahom, Bugapuki and Wagu. It is also suggested that *Wikstroemia* another species within Thymeliaceae, also occurs in New Guinea (Ding Hou 1960).

The demand from villagers for accurate plant identification is considerable, but few forestry officers are able to provide reliable advice on taxonomy. Taxonomic clarification is further limited as people are unaware of the importance of providing complete botanical specimens containing flowers and fruit and invariably only bring in leaves, bark or wood for identification.

A better understanding of the taxonomy of eaglewood in PNG will require studies of its genetic variation and relationships with other closely related species in Asia. A comprehensive inventory is also required to determine the distribution of the species within the country and characteristics of the trees and stands.

Natural distribution

The island of New Guinea, incorporating Indonesian West Papua and the state of Papua New Guinea, is the eastern extreme of eaglewood. At present there are three gaharu producing species known from New Guinea: *Aquilaria filaria*, *Gyrinops versteegii* and *G. ledermannii*. All are endemic to New Guinea.

The distribution of eaglewood (*G. ledermannii*) in PNG is currently not well documented, with on-going reports of new locations. **Figure 3** shows the known natural distribution in PNG, indicating locations of herbarium and official recordings of trade. It also indicates the potential distribution of eaglewood, using GIS modelling based on current known ecological parameters relating to elevation, forest type, rainfall and inundation prepared by WWF. The current confirmed occurrence of eaglewood extends from latitude 3°30'S to 10° 30'S and from the West Papuan border at longitude 141°E to 149°E. At least seven Provinces are recorded as having eaglewood: Sandaun or West Sepik, East Sepik, Madang, Gulf, Central, Southern Highlands and Western. There are anecdotal reports that eaglewood occurs in other parts of the country including Wabag, Milne Bay, Oro and Northern Provinces. The most recent confirmed siting is in the vicinity of Cape Rodney, Central Province (O. Gideon *pers. comm.* 2003).

Papua New Guinea eaglewood is associated with humid tropics at elevations between 70 and 600 m a.s.l., but it has been reported over 1000 m, mainly associated with hill slopes. The mean annual rainfall is 1700 - 5200 mm, falling throughout the year and with no dry season. **Table 1** provides rainfall figures for representative meteorological stations associated with the natural occurrence of eaglewood. Temperatures are hot with mean monthly maximum temperature in the range of 31-33°C and mean monthly temperature of 26-27°C. The absolute minimum temperature is about 12-17°C.

Ecology and population structure

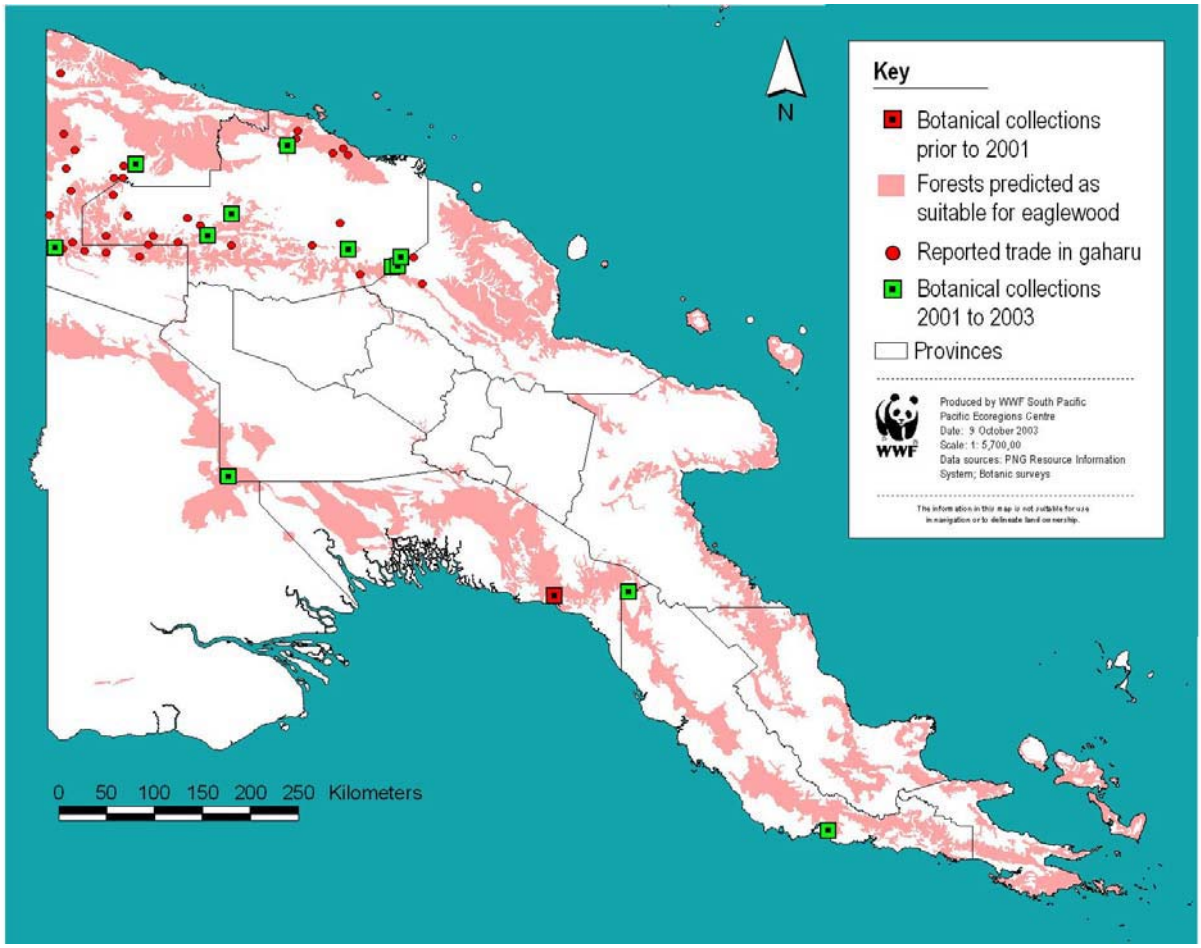
Papua New Guinea eaglewood is associated with mid-canopy tree species in rainforest. Associated species include: *Agathis, Astronia, Barringtonia, Buchanania, Campnosperma, Canarium, Cryptocarya, Diospyros, Dysoxylum*, *Endiandra, Ficus, Garcinia, Gnetum, Horsfieldia, Intsia bijuga, Lithocarpus, Litsea, Myristica, Pandanus, Phaleria macrocarpa, Pometia, Pouteria, Prunus, Terminalia, Syzygium, Xylopia* and various palms such as *Licuala* and rattans (Singadan *et al.* 2002, Zich and Compton 2001). It occurs on steep slopes to flat areas with a seasonally high watertable or possibly inundated for short periods (Zich and Compton 2001). It is clearly intolerant of long periods of inundation and tends to be absent from flood prone areas.

Soil types include sticky yellow to red clays, typically acid (pH 4.8-5.6), with a thin humus layer and often a dense humus root mat. In the seasonal swamp soils the most common soil type is sandy clay over clay.

Based on their findings in the Hunstein region, Zich and Compton (2001) found that the distribution of *G. ledermannii* appears to be strongly clumped, with high local concentrations in some areas. This has been confirmed with eaglewood sighted in the Kokoro area of Gulf Province (Gunn and Singadan obs. 2003). Mapping of eaglewood stands by forest owners during training for sustainable harvest planning in the Hunstein Range in 2002 reinforced this impression (Sunari 2002). Young (2001) also reported this characteristic for *Aquilaria crassna* in Khao Yai National Park in Thailand.

Table 1. Rainfall figures for representative meteorological stations associated with eaglewood

Station Name	Latitude (degrees and minutes S)	Longitude (degrees and minutes E)	Altitude (m a.s.l.)	Mean Annual Rainfall (mm)
Amanab, West Sepik	3 36	141 13	305	2,504
Amboin, East Sepik	4 37	143 29	141	5,214
Ambunti, East Sepik	4 12	142 48	2	2,554
Annanberg, Madang	4 54	144 39	28	3,828
Angoram	4 04	144 04	5	2,101
Kokoro, Gulf Province	7 50	146 31	65	
Kerema, Gulf	7 58	145 45	0	3,612
May River, East Sepik	4 17	141 52	245	4,671
Musula, Western Province	6 50	142 55		
Yangoru, East Sepik	3 39	143 18	255	1,757
Yellow River, West Sepik	3 53	141 47		2,994
Green R, Sandaun	3 53	141 10	161	3,440
Abau (Cape Rodney)	10 10	148 43	(50)	2,211



(Predicted distribution of eaglewood using GIS modelling based on presence of forest cover, absence of water inundation and altitude below 600 m).

Figure 3. Distribution of eaglewood (*G. ledermannii*) in Papua New Guinea.

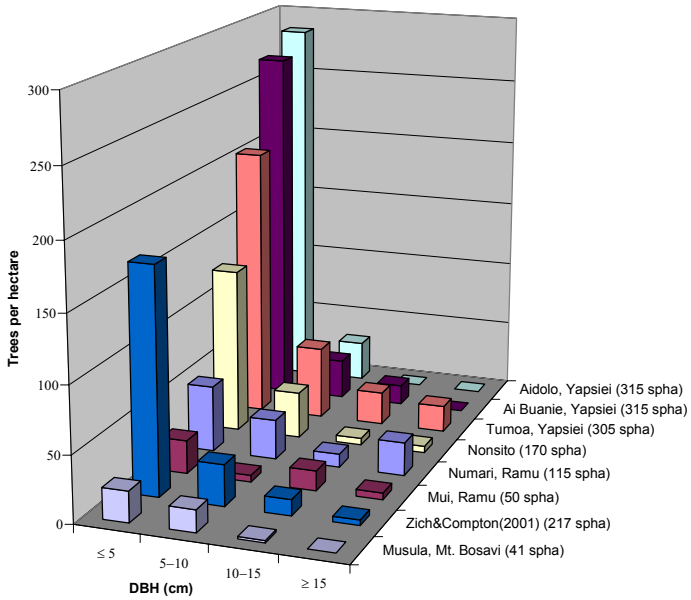


Figure 4 Comparison between spatial distribution and diameter range classes for eight inventory survey locations in Papua New Guinea.

A series of inventory surveys of the eaglewood resource were carried out as part of a Participatory Rural Appraisal (PRA) in 2002 and 2003, results of which are presented in **Figure 4**. Sample plots were mostly 0.2 ha (20 x 100 m) and located within stands of eaglewood. The stocking rate of eaglewood ranged from 41 to 315 stems/ha. Most trees measured were saplings with dbh less than 10 cm. This largely reflects that the surveys were carried out in harvested areas. Soehartono and Newton (2001) reported population density values of less than 1.2 individuals/ha in studies of the distribution of *Aquilaria* species in Indonesia. It is not clear whether sampling related to density across the whole forest area or specifically to areas associated with *Aquilaria,* as was done in PNG. Under the PNG inventories, stems less than 2 cm dbh were classed as saplings. It is of note that a large number of these saplings were recorded in inventory sites associated with harvesting in the late 1990s and 2000 (e.g. Yapsiei). Areas where harvesting had not taken place or only just started in the last year had a much lower incidence of saplings (e.g. Ramu). This would indicate that regeneration is taking place following harvesting.

Felled trees were observed to produce coppice shoot growth about 30 cm below the stump. However, it is not known whether the coppice growth has the ability to grow into a mature tree under management or whether the young coppice growth will die without developing into a tree. If eaglewood is able to successfully regenerate from coppice, then this will greatly increase the ability of the species to withstand harvesting pressure. An independent report also reported a high incidence of sapling regeneration in *A. crassna* in Thailand following felling of eaglewood trees (Pinyopusarerk pers. comm. 2003). More research work is required to understand the species' coppicing ability and how best to manage it for resin production.

The product

Formation of resin

Gaharu formation is caused by the trees response to mechanical injury associated with the wood (Blanchette *pers. comm.* 2003). The Tropical Rainforest Project (TRP) in Vietnam has found that *Aquilaria malaccensis* can be artificially induced to yield gaharu at a rate ten times faster than in nature (Barden *et al.* 2001) (http://www.agarwood.org.vn/). At the first International Agarwood Conference held in Vietnam in 2003, Dr Blanchette presented his research findings on how the species forms the resinous gaharu (http://forestpathology.coafes.umn.edu/). In brief, the tree has two response mechanisms to injury. The first line of defence is for the phloem cells to produce callus growth over the injury. Should the formation of callus be prevented then the tree will produce resin as a chemical defence to the injury. Development of a successful and reliable commercial technique for producing resin would be extremely valuable with application as a sustainable agroforestry enterprise in villages.

Limited information is available on the production of resin from eaglewood. As with *Eucalyptus*, other factors probably govern the level of tree response to damage; e.g. tree age. Differences in the tree caused by seasonal, environmental and genetic variations may play a role but are poorly understood (Mohammed 2003). There have been numerous failed attempts to induce resin production through the application of a range of fungi and other agents.

As with communities and researchers in other parts of the world, harvesters in PNG have deliberately wounded trees in an attempt to stimulate agarwood production. For example, people from Imnai village (Yapsiei) have reported that they were able to harvest B and C grades of gaharu from wounds caused during the first harvest three years previously. They believe that muddy water entering through wounds or branch stubs are responsible for causing gaharu formation. Similar techniques are used in West Papua and in other parts of the world in an effort to promote resin production.

Harvesting and grading

Harvesting

Harvesting requires the removal of the resin wood, gaharu, from the rest of the tree. Only a very small percentage (3-8%) of naturally occurring trees produce the gaharu. Within those trees that do produce gaharu, production is often associated with tree injury such as broken branches or damaged roots which provide for openings into the tree stem or roots. Most pockets of resin wood comprise between 50 - 1000g per tree.

The first step in harvesting is identifying trees containing gaharu. Villagers have developed visual indicators to determine whether an eaglewood tree may contain resin. These are:

- leaf canopy a more yellow colour than the average eaglewood tree together with leaf shed (a sign of an aging tree or tree under stress)
- holes in the bole or branches of the tree
- termites or other mounding insects nesting on or near the tree
- lightning strike
- burls or knots on trunks or large branches
- naturally broken branches

Once a tree has been identified, the decision has then to be made whether to fell the whole tree before identifying where the gaharu is or identify the location of the gaharu and cut out the resin infected section. The decision rests with the collector and depends on ease of gaharu removal, confidence of the operator in ensuring that all the gaharu has been removed and the level of importance placed on retaining the living tree and its potential to produce gaharu in the future. Education and community pressure have an influence on the degree to which trees are felled.

Almost all eaglewood occurs on community land. Land owners are normally responsible for harvesting their own gaharu although there are frequent reports of illegal harvesting by other communities. Traditionally, men have the task of searching and harvesting the wood which is frequently done as part of a hunting party. Harvesting is usually hard work. It can take 2-3 months for one person to collect 1 kg of marketable product.

Grading

In preparation for grading, it is important for producers to prepare the wood in order to optimise financial returns. The process of preparing gaharu for sale is the removal of undesirable wood from the marketable wood (gaharu). This normally involves removing light sap wood using sharp knives, pieces of broken glass or special company-issued hooked knives. This process is very laborious and time consuming. Each piece of wood should be of uniform colour in order to obtain the best grading. Scraping the wood is a slow process.

Grading gaharu is a subjective and complicated process based on size, colour, odour, shape, weight, density and flammability. The allocation of grades varies from country to country and from buyer to buyer. Irregular shapes with angled features fetch more than regular shaped pieces because of the greater ease of lighting them to burn. Chips a few centimetres long are likely to fetch a higher price per kg compared with larger pieces, even though their colour and odour may indicate a lower grade.

Burning gaharu chips is one indication of resin content. Brown chips burn with a strong flame, while the more desirable black gaharu burns for a shorter time before the flame dies and incense from the smoke is produced for an extended period of time. Burning can be used to identify

Phaleria as the smoke smells bitter and unpleasant. Another way of separating high grade from low grade is to place the wood in water to determine whether it floats or sinks. High grade gaharu will sink and low grade gaharu floats.

In PNG grading of gaharu is based on colour, shape and density of the wood. At present there are five grades: Super A, A, B, C and D as presented in **Table 2**.

Table 2. Guidelines for grading gaharu based on size, shape and weight of wood

Grading on colour	**Heavy irregular shape**	**Heavy regular shape**	**Light large pieces**	**Heavy thick chips (Kacang)**
Black shiny	Super A*	A	B	C
Mixture of dark black & chocolate brown	B	B	C	C
Mixed colour (pale black/ chocolate brown)	C	C	C	C
Brown	D	D	D	D
Pale yellow or tan brown	D mostly rejected	D mostly rejected	D mostly rejected	D mostly rejected
White	reject	reject	reject	reject

* Scraping of wood must follow natural grain

Gaharu trade

Most buyers are forced to visit the sellers in their remote communities, requiring travel by chartered plane or by boat. In order to justify such trips financially, they must have an assured large supply. In areas where there is only very limited production or where the supply is unknown, villagers must travel to major centres to sell their wood.

Official records show two main buyer/ exporting companies. The exporters collectively engage about 24 agents who trade with several hundred households which are harvesting gaharu. Companies wishing to trade in gaharu are required to obtain a licence issued by the government. The annual licence fee is K1000. In addition to the annual licence, PNG registered companies are required to pay a registration fee of K10 000 while foreign companies pay K50 000. There is also a 10% export levy on the value of the shipment. The legal buyers and traders often fly into collection sites in order to buy gaharu directly from local collectors. The gaharu is exported primarily to Singapore with smaller shipments to Malaysia and Indonesia via Vanimo and Port Moresby or through West Papua. Official trade statistics indicate that 1011, 2670, 10508, 9479 and 11708 kg of gaharu were exported in the last five years from 1999 to September 2003. Illegal trade in gaharu is estimated to be much larger than the legal trade.

Initially, people of Asian descent were reportedly the main buyers in PNG. Trade was often through a system of bartering where villagers were paid in the form of food and clothing. There was little understanding by the producers of the value of the gaharu. Gradually, as the villagers became more aware of the true value of the wood, coupled with greater competition, there was stronger demand for cash payment and fairer prices. In February 2001, the PNGFA introduced pricing guidelines (**Table 3**).

Table 3. PNGFA guideline on the minimum prices

paid to resource owners for gaharu wood.

Grade of gaharu	Value USD/kg
Super A grade	560
A grade	420
B grade	280
C grade	140
D grade (very wet)	14

Gaharu products

As discussed above, the PNG eaglewood industry has only focused on solid wood exports. There is therefore an opportunity to assess the potential for adding value. It is important first to understand the market for 'non-wood products' and whether PNG would be able to meet the needs of such a market. In the case of oil, there are also the logistical problems associated with linking the resource to the processing. The technology for distillation of oil is fairly straightforward. As mentioned earlier, eaglewood generally occurs in very remote areas with poor access, requiring villagers to transport wood over a considerable distance.

A few samples of eaglewood from PNG were steam distilled at the University of New South Wales (J. Brophy *pers. comm*. 2003). The oil obtained by steam distillation of gaharu (*Gyrinops ledermannii*) from PNG presented a complex mixture of mainly mono-oxygenated sesquiterpenes. Several compounds, of formula C^{15} H^{26} O, predominated, with one compound accounting for 14-25% of the oil. Small amounts of benzaldehyde (0.1-0.5%), humulene (0.3-0.5%), elemol (0.5-2%) and 4-phenylbutan-2-one (1-18%) were determined in the oil, but the remainder of the oil presented a complex mixture of at least 30 compounds, with formulae of C^{15} H^{26} O, C^{15} H^{24} O, C^{15} H^{22} O, as well as suspected di-oxygenated sesquiterpenes. The oil yield was 0.2-0.7%, the higher oil yields being from the higher grade samples. These results need to be compared with commercially available gaharu oil for comparison.

Propagation and Establishment

Gyrinops ledermannii appears to flower and seed sporadically at different times of the year with no evidence of a distinct pattern. There have been reports of seeding between September - October at Edwaki and around May River in the Yangoru area. At Mt Turu, East Sepik Province, both flowering and fruiting were reported to be occurring in mid June and towards the end of July. It would appear that flowering and fruiting extend for some time (months) with only a small portion of seed maturing at any one time. Further phenological studies are required to gather more accurate information on flowering and fruiting times and whether there are cyclical patterns including the size of phenological activity. Ripe fruit look dark green to brown in colour and should show signs of opening. Once mature the fruit rapidly opens shedding the seed. After

collection the fruit are dried out in the shade for a few days allowing the capsule to open releasing the seed (Beniwal 1989).

A small number of *G. ledermannii* seeds were taken from herbarium specimens collected from Ambunti and were sown in the nursery at PNG FRI without any pre-treatment in July 2000. Germination started after two months from sowing. After 12 months the seedlings had reached a height of 30 cm. One hundred and seven fruit were collected from 11 trees found in the Mount Turu area by FRI staff between 23-25th August 2003. The collections were made from trees with heights less than 7 m and 15 cm dbh. Collected seed was placed in moist kapok inside a plastic bag to minimise desiccation. Four days later the fruit was sown in a mixture of 1:1 sterile soil: sand under a mist house. First signs of germination occurred 22 days later with only 7 germinants recorded after six weeks. Given the difficulty of collecting sufficient quantities of seed, remote location of trees, high cost associated with the collection and very poor viability, alternative methods of acquiring germplasm need to be found. This includes looking at options for establishing seed production areas and use of vegetative propagation techniques.

Soft tip short cuttings from 12 month old seedlings referred to above, were taken and almost 90% developed roots after 2.5 months. Dr Hoang Thanh Loc (pers. comm. 2003) reported that cuttings of *A. crassna* gave 90% strike using vegetative material from young trees treated with a Chinese rooting powder ABT1.

Villagers are known to have transplanted wildings to locations nearer to their villages where it is easier to manage and maintain them. The establishment of plantations has the potential to provide an on-going source of income for resource owners and the government, and at the same time might take pressure off the natural resource.

The PNGFA is planning to establish an eaglewood plantation at Barira in Sandaun Province, with an eaglewood nursery planned for a site near Yambi in Sepik Province (Bakat pers. comm. 2001). This planting is being modelled on an area of 100 ha established from seed in West Papua at Nimbontang Besa Berek south of Jayapura. The trees in this plantation are about 4 m high after two years.

Management, Conservation and Sustainability

The PNGFA, other Government institutions, Non Government Organisations such as TRAFFIC and WWF, Australian Centre for International Agricultural Research (ACIAR) (aid donor), CSIRO (research support) and PNG citizens have effectively collaborated to develop the industry since it started in the late 1990s. The ability to reach out to hundreds of remote village communities associated with eaglewood has been very challenging. Logistical problems associated with lack of education, language, distance from towns, lack of transportation and communications (telephones, postal services and radios) have all contributed to the challenge.

WWF has been actively involved in developing management strategies for stakeholder groups. These have been done in close consultation with landowners, traders, government officials and other commercial operations to ensure people are fully informed about sustainable harvest guidelines, protection of seedlings and young trees, grading, local and national conservation issues and legal obligations. A strong focus has been placed on promoting less destructive harvesting techniques. In order to assist stakeholders in preparing a management strategy, a set of guidelines have been compiled by WWF for use in developing sustainable management of eaglewood (**Table 4**). Consideration should be given to including steps for sustainable management of earnings by resource owners to improve their long-term livelihood.

The scope, size and rapid expansion of the trade has revealed considerable gaps in our knowledge of eaglewood and gaharu. Basic information about the taxonomy, available resources and location of species is incomplete. Effective techniques on least destructive methods for harvesting of the resin, the size and value of the trade and many other aspects require further development. There is a serious lack of knowledge about the best ways of managing the natural stands for safe and

sustainable yields of tradeable product. This situation has led to concern about the sustainability of the resource.

Several recent publications (Barden *et al.* 2001, Gerber unpubl., Zich and Compton 2001, Singadan et al. 2001), have provided valuable and accurate information on eaglewood, the production and sale of gaharu and conservation issues. The management and conservation strategy is the latest in a list of information provided to the industry. The key objectives of the strategy are to outline:

1. activities necessary to provide a sound scientific basis for biological conservation;

2. plan the activities necessary for better management of the remaining stands, and for plantation establishment and management;

3. activities necessary to provide a marketing structure for the eaglewood trade; and

4. the need for a management strategy to assist resource owners in managing their earnings

Table 4. "14 steps for sustainable gaharu harvest"

(Mondai and Chatterton 2001, with adaptations based on field trials and recommendations from Gerber (2003 *in prep.*)

Step	Title	Explanation
Community Entry		
1	Community Interest	Community sends a letter to NFA/DEC/NGOs agreeing to develop and harvest gaharu resources sustainably under a management plan.
2	Clan Group Meeting and Awareness	Meeting of clans in the community to discuss their interest. Awareness undertaken on the steps in gaharu management planning.
Resource Inventory		
3	Community Survey	Use PRA tools to map: clans; ownership; areas of gaharu; disputes; harvest history; flowering and fruiting times.
4	Scientific Survey	Gaharu inventory conducted including distribution, species and other biodiversity values with technical support from NGOs/Government. Review the results of the two surveys and discuss options for best gaharu management.
5	Boundary Mapping	Map the boundaries of coupes for gaharu harvest and other land uses excluding areas of conflict.
Market Analysis		
6	Marketing	Assess the market potential (availability and quality) of the resource in the community to determine the viability of the trade. Identify registered buyers, fair prices and the best ways to sell gaharu.

Rules Development		
7	Rules and Guidelines	Develop specific rules for the conservation, sustainable harvest and marketing of gaharu including penalties and methods of enforcement.
Management Group		
8	Training and Education	Harvesting techniques, grading, record keeping and trading skills have to be promoted amongst rural communities.
9	Gaharu Management Group	Community/clan to decide on a group to ensure that the rules are followed.
Eaglewood Management Plan		
10	Gaharu Management Plan	Compile the results of the steps above into a Gaharu Management Plan.
11	Declare a Gaharu Harvest Area	Declare the area under the WMA, CA, TA, Community Gaharu Management Agreement and/or custom law.
Harvest and Monitoring		
12	Gaharu Harvest Based on Management Plan	Harvest gaharu based on the management plan.
13	Rehabilitation and Maintenance	Reforest old harvest sites and enrichment plants. Establish gaharu nurseries in the forest.
14	Monitoring and Review	Inspection/assessment of the gaharu cut-over to determine impact and quality harvest. Use the monitoring results to update and improve the management rules and plan as necessary.

Ten broad recommendations have been identified under the strategy as briefly discussed below.

1. Revision of the international taxonomy of eaglewood to include the relationship between *Aquilaria* and *Gyrinops* and other closely related genera. Conduct further work in PNG on the ecology and distribution of eaglewood across the country and links with West Papua. Studies should include gathering information on environmental factors associated with natural distribution, tree habit, regeneration resulting from felled trees of different sizes and from seedling regeneration. The relationship between the various ecological parameters (habitat, tree size, elevation, soil) and formation of gaharu should be assessed.

2. Expand the work on conservation and management of existing stands of eaglewood. Determine the extent to which eaglewood is under threat through assessing rate of harvesting and evidence of natural regeneration. Develop an approach for the conservation of eaglewood linked to management giving consideration to *in situ* and *ex situ* conservation.

The application of resin induction techniques should have positive consequences for conservation and management of natural stands of eaglewood. Once villagers become aware that they can apply the technique to their trees, then there will be an incentive not to indiscriminately fell trees in the vain hope of finding gaharu. By controlling the supply of 'induction kits' and educating the resource owners, much greater sustainable management of eaglewood can be attained.

3. With specific reference to Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), it is recommended that the analysis of whether additional species in the genus Aquilaria should be included in CITES Appendix II be widened to include at least the two species of *Gyrinops* (*G. versteegii* and *G. ledermannii*) known to be harvested for gaharu.

4. The techniques to induce eaglewood trees to produce gaharu developed by the TRP project in Vietnam must be introduced into PNG. The technique should be applied to both natural populations and to planted stands. The techniques should be applied at the village level through extension training of the technique and support in providing material 'induction kits' to undertake the technique.

5. Village-based nurseries need to be established with the support of resource providers (Government agencies and NGO groups). Villagers should to be trained in seed collection and handling of seed together with nursery techniques, planting and tending. Once the trees reach sufficient size (15 cm dbh, 5 years), then the skills learned to promote resin production in the natural stands could then be applied to the planted trees. Carry out research into silvicultural practices for managing the trees associated with maximising gaharu production.

6. Explore techniques to further improve skills associated with identifying eaglewood trees in the field. Research and develop non-destructive techniques for identifying and harvesting eaglewood/gaharu, including the development of a simple drill/ wood borer which villagers could purchase to remove a wood core from sections of trees suspected of having gaharu.

7. Continue to develop methods and gather information on techniques for processing and grading gaharu which can be applied by villagers. Grading standards must be addressed both nationally and internationally with more tangible guidelines developed.

8. Explore options for producing value-added products of gaharu in PNG. Such options should take into account the findings from any marketing strategy on the financial merits of selling whole wood compared with other products. This study should also take into account information gained from any national or international marketing strategy findings.

9. Develop legislative mechanisms and enforcement/management capacity in PNG. As part of a National Management Strategy, more comprehensive regulatory mechanisms to control and monitor harvesting and trade of gaharu are required. This should include implementation of appropriate legislation, policing, resources and prioritisation by relevant PNG authorities. An economic assessment of the value of gaharu as a component of rural livelihoods and as a potential revenue resource for National Government should also be conducted. Address issues such as licensing and regulating harvesters and traders based on annual quotas of weight and/or value. Establish a national mechanism for regulating and tracking the trade of gaharu.

10. Undertake ongoing awareness campaigns and extension work in order to inform and resource owners of new developments. A major problem for resource owners is the lack of information on management and conservation of eaglewood. Continuing, well-developed awareness campaigns must be implemented, focusing on areas where harvesting is being undertaken and also on potential areas where eaglewood occurs but where villagers have not as yet started to harvest and trade.

Develop a management strategy to assist villagers in managing their earnings which includes opportunities for investment in long-term livelihood as opposed to the current short term consumption of earnings. These strategies would then be linked to the "14 Steps for Sustainable Gaharu Harvest".

Implementation of recommendations

The implementation of these recommendations will require a well co-ordinated approach involving all key players associated with the eaglewood industry in PNG. With such a long list of recommendations, all key players must work together in order to prioritise the activities. To date

there has been strong support from the PNGFA and the Forest Research Institute, TRAFFIC Oceania, WWF and CSIRO through the Domestication project with FRI and the PNG community. The Inter Agency Committee (IAC) has played a coordinating role involving government agencies to include PNGFA, FRI, Department of Environment and Conservation (DEC), Internal Revenue, Customs and NGOs WWF, TRAFFIC and Foundation for People & Community Development (FPCD).

WWF has developed a plan to assist villagers in managing their eaglewood resource through what is know as '14 steps to Sustainable Harvest'. This process has already been implemented with a number of communities. This work must be on-going to ensure it is implemented and fully understood if it is to be sustainable.

The PNGFA has been successful in acquiring project funding from the FAO Technical Cooperation Programme. The project titled 'Eaglewood Management Project' is planned to commence in October 2003 and be completed by May 2005. The project will focus on a range of activities associated with the eaglewood industry in PNG.

These and other planned activities provide a strong and much needed support to the eaglewood industry and will have positive flow-on to the international industry. However, we must not lose sight of the fact that the industry must be developed to assist the resource owners and those associated with the industry.

Acknowledgements

The Australian Centre for International Agricultural Research (ACIAR) provided funding for the development of the eaglewood conservation and management strategy from which this paper is based. The Papua New Guinea Forest Authority supported the work carried out with respect to the Participatory Rural Appraisals. Khongsak Pinyopusarek, David Bush and Paul Macdonell from CSIRO Forestry and Forest Products together with the review committee provided valuable comment on the draft. Kron Aken and Paul Macdonell assisted in the preparation of a number of the figures.

References

Barden, A., Noorainie Awang Anak, Muliken, T., and Song, M. 2001. Heart of the Matter: Gaharu and Trade and CITES Implementation for *Aquilaria malaccensis*. TRAFFIC.

Beniwal, B.S. 1989. Silvical characteristics of *Aquilaria agallocha* Roxb. .The Indian Forester. Vol. 115, No. 1; 17-21.

Chung, R.C.K. and Purwaningsih 1999. *Aquilaria malaccensis*. in Oyen L.P.A., Dung N.X., eds. Plant Resources of South-East Asia No. 19. Essential-oil plants. Prosea Foundation, Bogor, Indonesia. Leiden, Netherlands. Backhuys Publishers; 64-67.

Ding Hou, 1960. Thymelaeaceae. pp.1-15 in Van Steenis C.G.G.J., ed. Flora Malesiana, Vol. 6. The Netherlands: Sijthoff & Noordhoff International Publishers.

Domke, W. 1932. Zur Kenntnis einiger Thymelaeaceen. Notizblatt des Botanischen Gartens und Museums zu Berlin – Dahlem 11: 348-363.

Fink, S. 1999. *Pathological and regenerative plant anatomy*. Gebruder Borntraeger, Berlin, Stuggart. 1095pp.

Gerber, N. 2003. (*in prep.*) Capturing the Resource Rent. An economic assessment of the gaharu (gaharu/eaglewood) trade in Papua New Guinea. A TRAFFIC Report in conjunction with WWF South Pacific Program.

Mabberley, D.J. 1997. *The Plant Book*. The Press Syndicate of the University of Cambridge, UK. 858pp.

Mohammed, C. 2003. The artificial stimulation of resin formation in the stems or branches of gaharu producing trees: *Aquilaria, Aetocylon, Gonystylus* and *Gyrinops*. Proposal submitted to Australian Centre for International Agricultural Research by CSIRO Forestry and Forest Products.

Mondai, K. and Chatterton, P. 2001. 14 steps for sustainable gaharu harvest. Unpublished material presented to the 2nd Papua New Guinea Gaharu Inter Agency Committee Meeting, 2001 .Port Moresby. WWF, Madang.

Oldfield, S. 1998. *The world list of threatened trees*. Edited by Oldfield, S., Lusty C. and MacKinven, A. World Conservation Press, Cambridge, UK; 650 pp.

Sunari, M 2002 Workshop Report - Planning for Sustainable Gaharu Harvest, Pukapuki Village, Hunstein Range, East Sepik Province 16-21 July 2002 Internal report by WWF South Pacific Programme, Madang PNG.

Singadan, M., Yelu, W., Beko, J., Bosimbi, D. and Boland, D.J. 2001. Some aspects of the eaglewood trade in Papua New Guinea. FAO Forest Genetic Resources in "Non-Wood News" number 9, pages 49-51.

Singadan, M., Sunari, L., and Fazang, K. 2002. Gaharu trade on the Keram River area of Madang Province, Papua New Guinea. Part of the 'Domestication of Papua New Guinea's Indigenous Forest Species' Project managed by CSIRO, Forestry and Forest Products, Canberra, Australia in conjunction with WWF South Pacific Programme, Madang, PNG and PNG Forest Research Institute, Lae, PNG.

Singadan, M. 2003. Personal perspective of the eaglewood trade in Papua New Guinea. Paper presented to the 'First International Agarwood Conference', Ho Chi Minh City, Viet Nam, 10-15 November, 2003.

Soehartono, T., and Newton, A. 2001. Conservation and sustainable use of tropical trees in the genus Aquilaria II. The impact of gaharu harvesting on Indonesia. Elsevier Science Ltd.. Biological Conservation 97, 29-41.

Sunari, L. B. and Singadan, M. 2002. Report of a survey trip to examine gaharu trade in the Yapsiei area, Sandaun Province, Papua New Guinea. 11-22 March 2002. Internal report by WWF South Pacific Programme, Madang PNG in conjunction with PNG Forest Research Institute, Lae, PNG.

WWF, 1999. Eaglewood-background information. Unpublished paper prepared by the World Wide Fund for Nature.

Young, C.M. 2001. The extraction of the non-timber forest product mai hom (*Aquilaria crassna*) in northeast Thailand. Tropical Resources Institute Newsletter, Spring 2001.

Zich, F.A. and Compton J. 2001. The Final Frontier: Towards Sustainable Management of Papua New Guinea's Gaharu Resource. TRAFFIC Oceania-WWF South Pacific Programme.