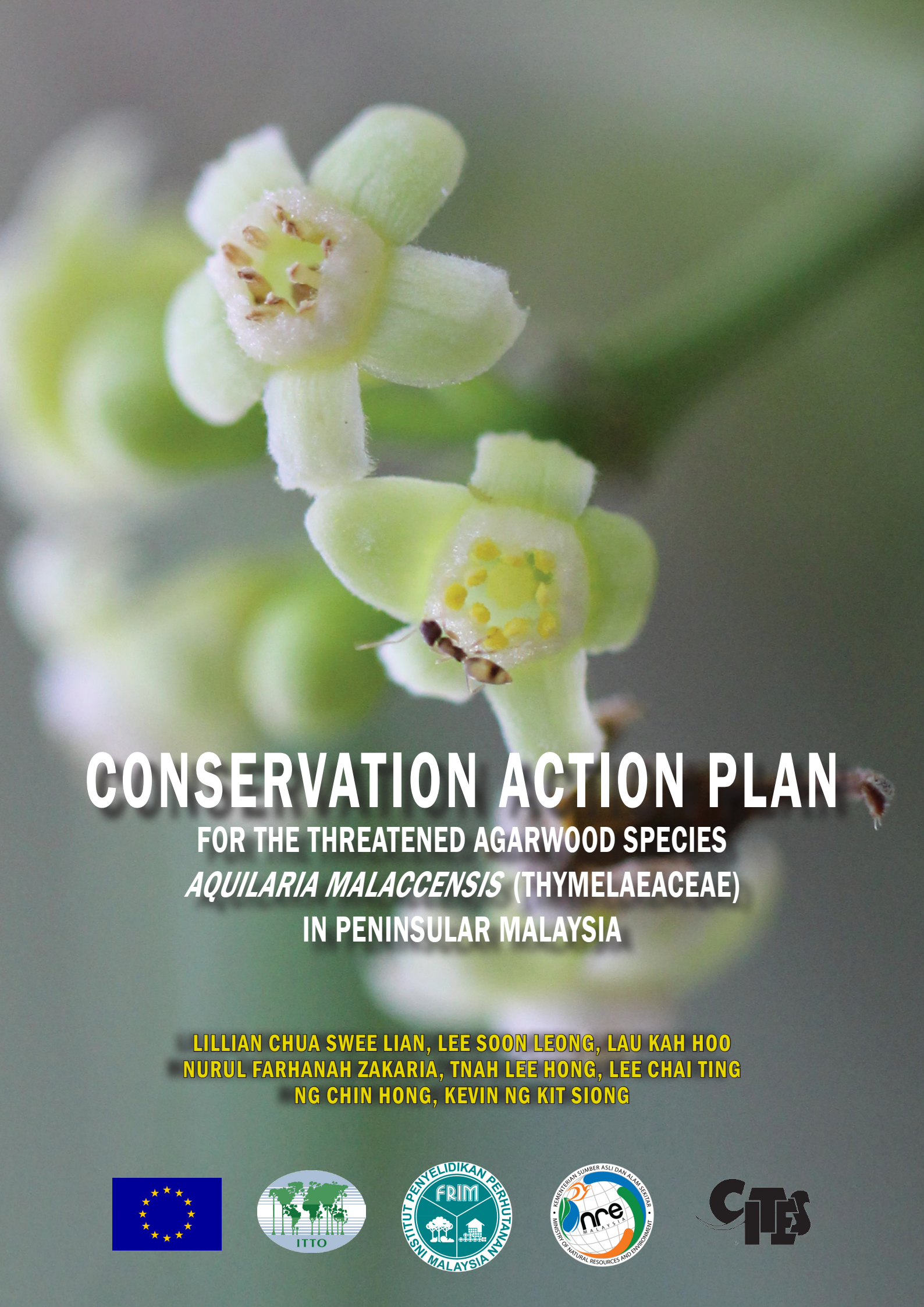

CONSERVATION ACTION PLAN

FOR THE THREATENED AGARWOOD SPECIES *AQUILARIA MALACCENSIS* (THYMELAEACEAE) IN PENINSULAR MALAYSIA

LILLIAN CHUA SWEE LIAN, LEE SOON LEONG, LAU KAH HOO
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NG CHIN HONG, KEVIN NG KIT SIONG

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2016

Date of Publication: September 2016

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Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Chua, Lillian Swee Lian
Conservation Action Plan for the Threatened Agarwood Species *Aquilaria malaccensis* (Thymelaeaceae) in Peninsular Malaysia / Lillian Chua Swee Lian, Lee Soon Leong, Lau Kah Hoo, Nurul Farhanah Zakaria, Tnah Lee Hong, Lee Chai Ting, Ng Chin Hong, Kevin Ng Kit Siong.
Bibiliography: page 63
ISBN 978-967-0622-59-0
1. Agarwood (Wood)--Conservation--Malaysia
2. Agarwood (Wood)--Planting--Malaysia
I. Lee, Soon Leong. II. Lau, Kah Hoo. III. Nurul Farhanah Zakaria.
IV. Tnah, Lee Hong. V. Lee, Chai Ting. VI. Ng, Chin Hong.
VII. Ng, Kevin Kit Siong. VII. Title
634.9709595

MS ISO 9001:2008 Certified

Design and typesetting: Siti Fariezza Khairi Thaw

Front cover: An insect visitor on a newly opened and older flowers of *Aquilaria malaccensis.* Photo: Lau Kah Hoo
Back cover: A large *Aquilaria malaccensis* tree in the forested area of Universiti Teknologi PETRONAS, Perak. Photo: Lee Soon Leong

Printed by Forest Research Institute Malaysia, Kepong

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Foreword

The 'Conservation Action Plan for the threatened agarwood species *Aquilaria malaccensis* (Thymelaeaceae) in Peninsular Malaysia' is a timely production by researchers from Forest Research Institute Malaysia (FRIM), their counterparts, and stakeholders that were involved. As one of the range states for *Aquilaria* and an important trading hub for agarwood species, Malaysia has the obligation to deliver a Non-detriment Findings.

Since its inclusion in the Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 2005, the entire genus of *Aquilaria* has gone through substantial regulatory stages in its chain-of-custody in order to prevent unsustainable harvesting in its range states and trading worldwide. The Management Authority (MA) from these range states are empowered to manage the trade of the listed species, and to enforce the regulations. They collaborate with the Scientific Authority (SA) and local enforcement agencies to undertake the management of the resource.

Knowing its biological behavior and genetic diversity is the first step towards addressing the problems faced by the species with regards to conservation and management. In the attempt to save *A. malaccensis*, FRIM has undertaken several research projects funded by Government of Malaysia and international agencies to carry out reproductive and genetic studies in Peninsular Malaysia.

I thank the research team in taking the initiative to tackle this challenging issue. It is my hope that all relevant parties would study and refine the Action Plan and take the necessary steps in ensuring that the wild populations of *A. malaccensis* will continue to be sustained in the future.

Dato' Dr. Abd. Latif bin Mohmod
Director-General, FRIM

Preface

The Conservation Action Plan for the species *Aquilaria malaccensis* is produced after seven years of data accumulation and analysis over three phases of projects. The project included two phases which were funded by the Government of Malaysia and one from the ITTO-CITES program.

Over the years, one of the major threats to its populations, i.e., illegal harvesting has been on the increase. While much effort and enforcement activities have been carried out to curb these activities, the rate of loss resulting from harvesting is much higher than its ability to regenerate. In addition, the biological behaviour of the species as well as other threats such as land use change and climatic factors contribute to the population decline in the country.

The Action Plan has targeted six main objectives to be achieved in a period of five years. Various implementing agencies and landowners are key players in engaging the activities outlined in the Action Plan. In each activity, an indicator or milestone is suggested for the purpose of monitoring the progress of the activity. The success of the implementation, and the conservation of *A. malaccensis*, is very dependent on the involvement of all stakeholders.

Dr. Lillian Chua Swee Lian
Director, Forest Biodiversity Division, FRIM

Acknowledgements

This work was made possible by a grant from ITTO under the collaborative program with CITES “Support to ITTO: CITES Implementation for Tree Species and Trade/Market Transparency (TMT)”. Donors to this collaborative program include the EU (primary donor), the USA, Germany, the Netherlands, Norway and China. The project commenced from 2013 until 2015.

The project was also partially funded by the Ministry of Natural Resources and Environment (NRE) and Ministry of Science, Technology and Innovation (MOSTI) of Malaysia between 2011–2012 and 2007–2008 respectively.

The Action Plan would not be materialized without the excellent team of supporting staff from the Conservation and Biodiversity Informatics Branch (Damahuri Sabari, Ayau Kanir, Hamidi Abu Bakar, Alang Mahayu, Mohd. Zian Salehin, Norzamli Amli, Norazmi Amli, Ahmad Raffizi Othman and Zarul Zurhaidy Tahir) and three former staff Hazlina Ali, Amir Nurdin Abdul Rahman and Azril Alias. The late Chan Yee Chong is also recognized for his work during the earlier stage of the project to determine populations and study sites. Batches of interns from various universities helped in the field and samples processing; Ng Choi Ling, Sam Wai Kit, Nur Ashiqin Abdul Hamid, Sam Pui Kwan, Nurlina Ridwan, Siti Nor Hidayati Kamaruddin and Heng Pooi San of whom their attachment in FRIM were timely. Over in the Genetics Laboratory, Sharifah Talib, Ramli Ponyoh, Yasri Baya, Suryani Che Seman, Ghazali Jaafar, Yahya Marhani, the late Zakaria Yusoff, Hamiliar Hamid and Nur Azizi Abdul Rafae are acknowledged for their assistance in the laboratory and field.

Mohamad Shahfiz Azman helped to identify the small mammal and Ong Su Ping with the insect predators. Phon Chooi-Khim, Nur Zati Akma Mustafa, Seiki Yamane, Muhammad Dzulhelmi Muhammad Nasir, John S. Ascher, Chey Vun Khen and Roger Kendrick are entomologists who identified the insect visitors.

Sincere thanks are also due to the Centre for Tropical Forest Science and Forest Research Institute Malaysia (FRIM) for the permission to use the ecological data from a research plot. The data are invaluable to support the findings in this report.

The Forest Department of Peninsular Malaysia, State Forest Departments (Kedah, Pulau Pinang, Perak, Selangor, Negeri Sembilan, Melaka, Johor, Pahang, Terengganu, and Kelantan), Universiti Teknologi PETRONAS, Penang Botanic Gardens, Department of Wildlife and National Parks (DWNP) and National Landscape Department are acknowledged for granting permission to work in the forest under their jurisdiction. We also gratefully thank the District Forest Officers and staff of the Rangers’ Office who provided assistance and logistic support during the field trips.

Input, feedback and ideas from the participants of the Stakeholder Dialogue held in Putrajaya in September 2015 are most appreciated and much valued in our attempts to save the remaining *karas* populations in Peninsular Malaysia.

Summary

Agarwood products exported from Malaysia are mainly derived from wild populations of *Aquilaria* spp. where harvesting pressures have been intense as a result of a lucrative market. Previous qualitative-based projects have speculated on a decline in the resource. This Activity was undertaken to determine the extent of harvesting impact on the survival of extant populations. The results collectively show that the species is not resilient to current harvesting activities. The declining trend in its population change and nation-wide abundance observed since the late 1980s, in addition to higher mortality rates in small and largest diameter classes, supra-annual flowering behaviour and substantial abortion of its flowers and fruits indicate that the populations cannot withstand the continued onslaught of harvesting. The species shows extensive gene flow which arises from an efficient seed dispersal mechanism and high outcrossing rates. There is high genetic diversity and low population differentiation. Two distinct clusters have been detected and these are geographically defined. Drawing from the results of this Activity and other related projects, a partial Non-detriment finding is presented and a conservation action plan (CAP) developed as a measure to prevent a catastrophic decline. The objectives and actions related to *in situ* and *ex situ* conservation, management of the resource, artificial propagation, enforcement, research and development and strengthening cross-sectoral enabling factors are presented here.

1 Introduction

Aquilaria, of the family Thymelaeaceae and known worldwide as agarwood and in Malaysia as *karas*, is a genus of 15 species and is confined to the Indo-Malayan region of the Asia-Pacific. It is distributed from the Assam district in India, Myanmar and south-eastern China (Hong Kong and Hainan) to south-east Asia (Indochina, Borneo, Philippines, Malay Peninsula, Sumatra, Moluccas and New Guinea (Ding Hou 1960) (Fig. 1.1).

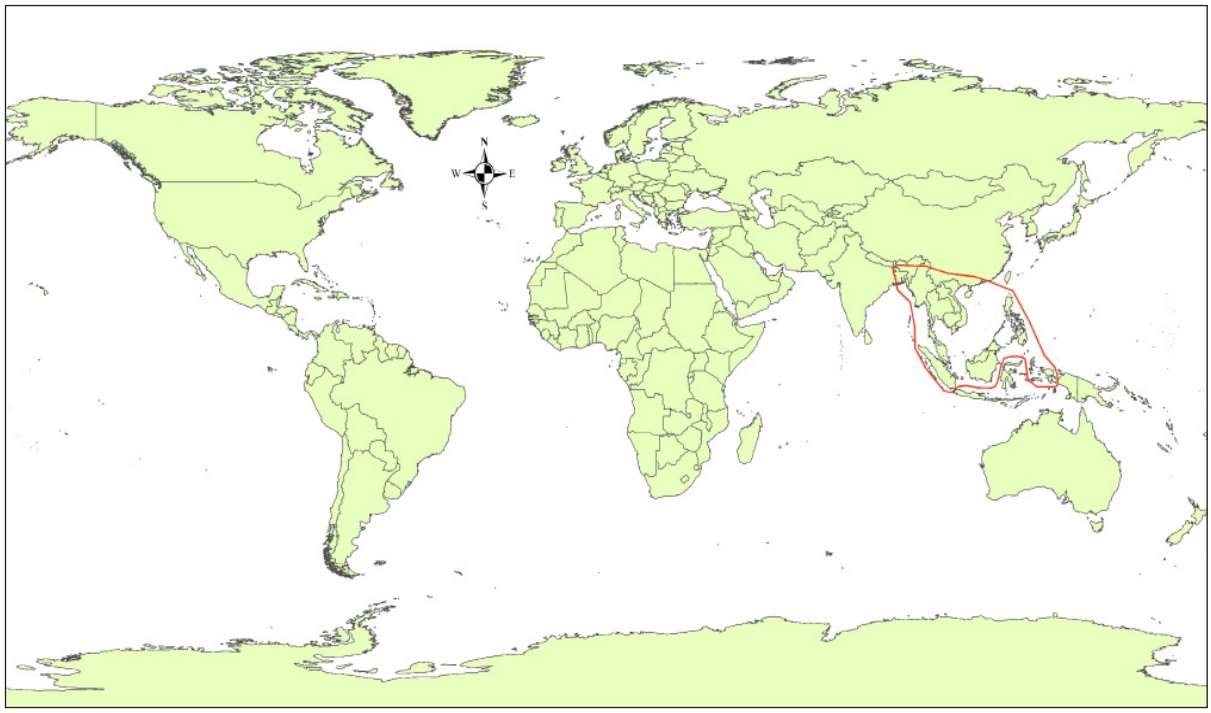


Fig.1.1. Global distribution of the genus *Aquilaria* (Ding Hou 1960).

In Malaysia, five species of *Aquilaria* (*A. beccariana*, *A. hirta, A. malaccensis*, *A. microcarpa* and *A. rostrata*) are known and in the peninsula, four species with the exception of *A. microcarpa* are present. *Aquilaria beccariana* occurs in the lowland and swamp forests of Johor (Ding Hou 1960); *A. rostrata* is confined to Mt. Tahan in the Taman Negara National Park and Besut, Terengganu while *A. hirta* is mainly found on the east coast. *Aquilaria malaccensis* is by far the most widespread and common, until recently, in many states (Whitmore 1972). This species is absent in Sarawak but reappears in Sabah and Kalimantan on the island of Borneo (Tawan 2004). Fig. 1.2 shows the range distribution of the genus in Malaysia.

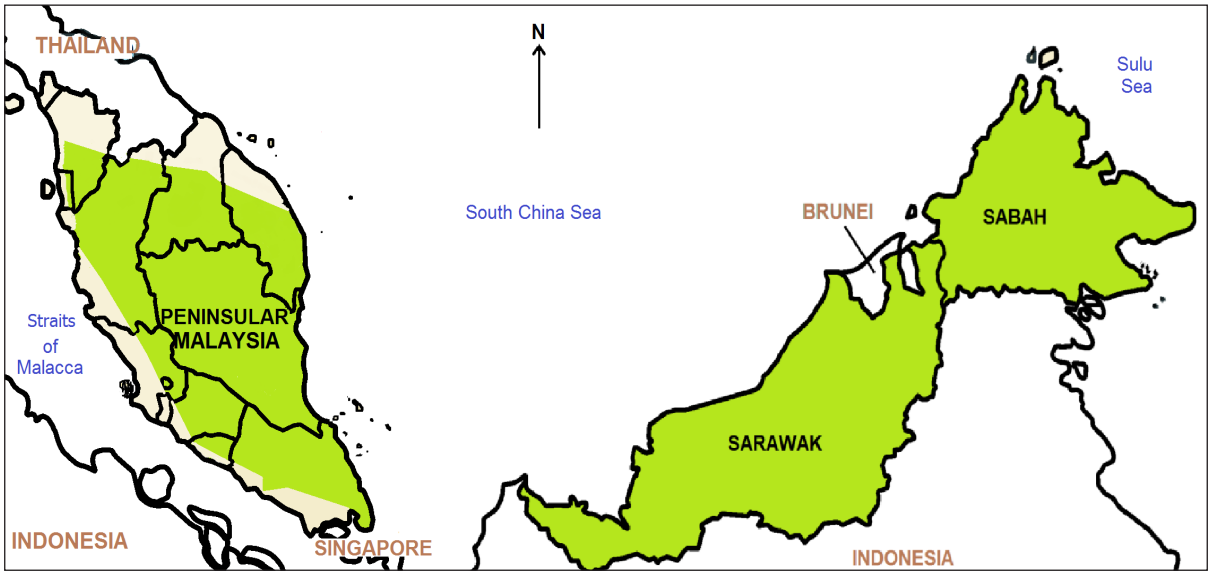


Fig.1.2. Distribution of the genus *Aquilaria* in Malaysia (shaded areas) (not drawn to scale).

Members of the genus *Aquilaria* in Malaysia are trees often taller than 20 m. *Aquilaria malaccensis* may reach 40 m tall although in reality, no trees of such stature have been observed in the recent past. It has smooth bark and glabrous leaves with many lateral veins (up to 16 pairs) and these are distinct on the leaf undersurface. The plant may bear terminal and/or axillary inflorescences which are often branched with 2−3 umbels, of which each bears up to 10 flowers. The flowers are tiny (up to 6 mm) while the fruits are pear-shaped, 3−4 cm in length with no distinct stalk. It generally has one seed which is densely covered with red hairs. In Malaysia, *A. malaccensis* is found on both well-drained soils and water-logged areas in the lowland and hill forests dominated by dipterocarps. Its altitudinal range is up to 750 m above sea level (Ding Hou 1960). Although the species appears to be common in both primary and regenerated logged-over forests, trees are essentially scattered (Whitmore 1972, Manokaran *et al.* 1992, Jutta *et al*. 2009) (see also results of this study). It is neither gregarious nor forms dominant stands in the habitats it occupies. Being an intermittent food source for some animals (see results of this study), it is unlikely to be a keystone or guild species. Lacking dominance and because of the complex interaction of many biotic and abiotic factors in the tropical rain forest, its role in its habitat is not clearly understood. Thus the effects of its removal through over-harvesting on ecosystem processes are not yet known.

According to the IUCN Red List version 2015.2, globally, *A. beccariana*, *A. hirta* and *A. microcarpa* are Vulnerable (VUA1d). *Aquilaria malaccensis* is also Vulnerable (VUA1cd) while *A. rostrata* is Critically Endangered (CRB1ab(v)). Refer to World List of Threatened Trees (Oldfield *et al*. 1998) and IUCN (2001) for details of the categories and criteria. In Malaysia, *A. beccariana, A. microcarpa* and *A. rostrata* are Data Deficient (DD) while *A. hirta* and *A. malaccensis* are Vulnerable (VUA4cd) (Malaysia Biological Diversity Clearing House Mechanism (http://www.chm.gov.my)). There is no data on the global population size for each of these species. The main threat to the wild populations of *A. malaccensis* in Malaysia is over-harvesting while *A. beccariana* suffered from habitat loss. *Aquilaria rostrata* is legally protected by virtue of it occuring in the national park.

Aquilaria species is the principal source of agarwood, a highly valuable fragrant wood used for incense, traditional medicines and in the perfumery industry. Its use as incense in ceremonies, rituals and meditation practices in Buddhism, Confucianism and Hinduism is widespread. In the Middle East, *oud* which is Arabic for agarwood, is considered a symbol of wealth, status and hospitality (Chang *et al*. 2001). As medicine, the incense is used to treat thyroid cancer, asthma, colic, diarrhoea and abdominal complaints, among others (Chung & Purwaningsih 1999). All parts and derivatives of the plant including the roots, fruits, seeds and seedlings are traded either as raw, semi-finished or finished products (see PC22 17.5.3 Glossary of Agarwood Products). The method of harvesting wild trees has been described by Soehartono & Newton (2001c).

Other genera in the family Thymelaeaceae also produce oleoresins in the heartwood as a wound reaction. In international trade, apart from *Aquilaria*, agarwood may comprise species of *Gyrinops* but this genus is absent in Malaysia. Similar resin impregnated heartwood is also found in *Gonystylus* (Ramin) and it is reported to be similarly used in small quantities (Soerianegara *et al*. 1993). Ramin is however more highly prized for its fine-grained timber. The resin impregnated heartwood of *Aetoxylon sympetalum*, a monotypic genus endemic to Borneo (Sarawak and Kalimantan) but not listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices, is also an important source of *gaharu* oil and incense. Some members of the genus *Enkleia*, *Phaleria* and *Wikstroemia* also produce these in small quantities. Of Peninsular Malaysia's *Aquilaria* species, all four are believed to produce the aromatic resin when injured (Chang *et al*. 2001). However, *A. beccariana* and *A. rostrata* are extremely rare and because of this, they most likely do not get into the trade.

Since 2010, Malaysia has capped an export quota of 200,000 kg per annum of *A. malaccensis* blocks, chips, sawdust and its derivatives. The harvesting intensity for *karas* can be gleaned from its past export records. The export trend from Malaysia fluctuated between the years 1995 and 2006 after which it stabilised (Fig. 1.3) (CITES 2015 Trade database extracted for Malaysia (originating and/or exported) for the period 1995 to 2013). The rather abrupt increment before the end of the 20th century is most likely a response to soaring demand and high pricing of agarwood products—this rapid rise in demand has also been reported elsewhere (Barden *et al*. 2000). However, the export volume plummeted in the years immediately preceding 2004, that is the year when both genera of *Aquilaria* and *Gyrinops* were listed in Appendix II. The dramatic increase in 2005 may be due to reporting error, in particular the transaction of 12,564.5 kg of oil. According to the United Arab Emirates (UAE) standard, one litre of agarwood oil requires 144 kg of chips and one litre of oil is equivalent to 1 kg. This meant that close to 1,800 tonnes of chips were used to produce the reported volume of oil. During that year, Malaysia imported only 195 tonnes of chips. Whether or not such an amount of *Aquilaria* biomass was present in Malaysia is uncertain. Regardless, it is apparent that trade is singularly the most important contributor to the rapid decline of the resource because during this period, the other potential threat to wild populations, i.e., forest conversion had already stabilised in the peninsula. Minor fluctuations seen after 2006 may be the result of a persistently low availability of the resource and the regulatory mechanism that was created to address this decline. Now trade in *Aquilaria* from Malaysia is highly regulated and closely monitored by national and international stakeholders. Low export volumes reported before 1997 were possibly due to a combination of factors such as less rigorous reporting by range states and monitoring by

CITES, and low demand for agarwood products. Note that in generating the export trend, two approaches were used: (1) to avoid double counting, the weight of chips used to produce the oil is removed from the calculation although in real terms the residual powder is often exported in other forms; and (2) all imports are considered as re-exports. Harvest data is not available so the export figures, as reported in the CITES trade database, were used as proxy data. There had been efforts to gather harvest information from people involved in the production of parts and derivatives but their answers were often vague and indefinite. Soehartono & Newton (2001c) reported a highly volatile nature of the Indonesian agarwood trade but acknowledged that several factors, including inadequate and manipulated reporting and occurrence of illegal trade, had constrained the analysis of the trade trend.

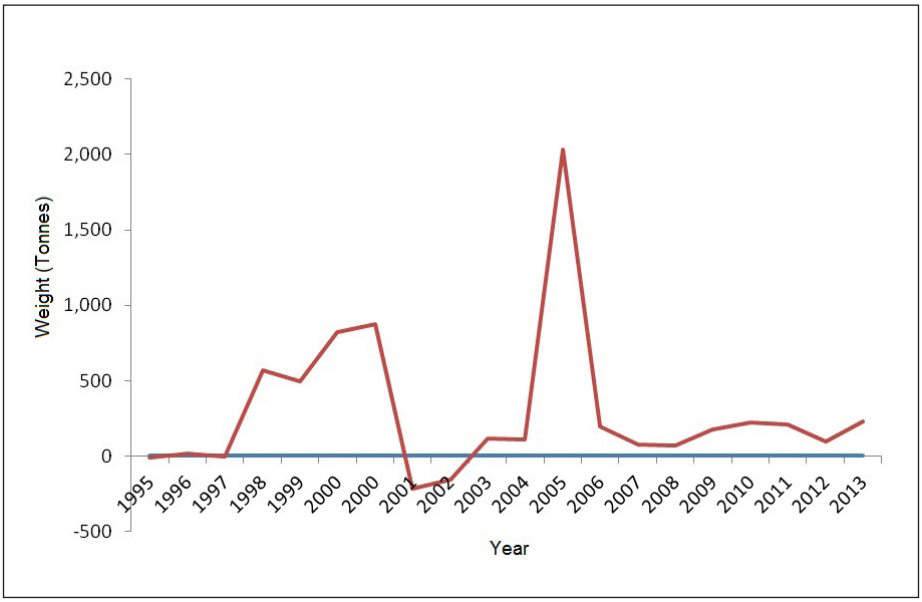


Fig.1.3. Summary of *Aquilaria* spp. exported from Malaysia for the period 1995 to 2013. The extreme spike in 2005 could be due to reporting error. The terms and units reported were in oil and kg respectively. One kg or litre of oil requires approximately 144 kg of wood chips.

Under the National Forestry Act (1984, amended 1993; Act 313), *karas* is considered a minor forest produce. In the peninsula, although indigenous and local communities are permitted to roam the forests freely, the land and its resources belong to the State government and a license is required to harvest forest resources from the Permanent Reserved Forests (PRFs) and Stateland. Where local villagers and *Orang Asli* (indigenous) communities are concerned, *karas* is considered a minor produce harvested in small quantities which formed part of their livelihood. With regards to the licence holder, any timber, blocks or chips of *karas* that leave the PRF or stateland must be accompanied by a removal pass. This pass is mandatory and contains information that is subsequently used by the state authorities to calculate royalties, premium, cess and other charges. This entire process is a form of monitoring as the pass is required when applying for other permits such as the CITES export permit, and the state authorities get to keep records of harvest. Since 2004, control has been applied through the national export quota. To date, we are not aware of any harvest or management plans that are applied by the state authorities on the harvesting of wild *karas* populations in the PRFs and Stateland. The standard forest management prescriptions such as the application of an

annual allowable coupe, minimum cutting limit of 45 cm dbh, retention of mother trees and other silvicultural practices are not employed on *karas*. In protected areas such as national parks, state parks and protection forests in the PRFs, no form of harvesting is permitted. In reality however, this is not adhered to as the lure of a lucrative income is too tempting to be ignored. Since any form of management and/or monitoring of the resources is undertaken by the state authorities and such data is confidential, we have no knowledge of the proportion of legally harvested *karas* that enters into the process chain.

These are some adaptive management measures that Malaysia practises to make harvesting of its natural resources more sustainable. These include more significantly, the greater spirit of cooperation and collaboration between primary stakeholders (such as the state authorities) and other enforcement agencies such as the police and armed forces, customs, maritime and immigration authorities. Concurrently, Act 313 is being revised to take into account the changing patterns in the forestry sector and the need for a greater emphasis on forest enforcement, integrity, and conservation of the ecosystem roles it provides to environmental and public health.

Trees in the study sites have not been spared from illegal harvest. From the period beginning March 2011, 25.2% of trees in the observed populations were lost, with 85.8% of the loss caused by illegal harvest while the remaining died naturally. From this loss, trees of diameter at breast height (dbh) greater than 30 cm comprised 57.1% while a further 25.7% was in the 20−29.9 cm dbh range. Large trees are prime targets as they have a higher potential for resin development. Fig. 1.4 shows the increasing tree loss in the study sites due to illegal harvesting activities. Illegal harvesting was most rampant at Site 2 (see section 2.1 for site description) possibly because of its accessibility and inadequate enforcement. Despite attempts by the state authorities to curb the illegal harvests mass media reports of such activity occurring in different states in the peninsula have regularly appeared in the past few years (Table 1.1). There is evidence to show that many of these activities were conducted by foreigners (Annex 1). It is not known how significant the illegal harvest is because it is virtually impossible to enumerate population sizes in its distribution range. Market and supply chain information do not distinguish parts that are obtained legally or illegally and traders basically are not aware of or concerned about the harvesting implications. CITES export permit data do not differentiate between the legally versus illegally obtained products. The substantial penalties imposed by the International Trade in Endangered Species Act 2008 (Act 686) and National Forestry Act 1984 (Amended 1993) do not have any impact unless such harvesters are apprehended. There had been several reports of prosecution, e.g., in its 14 August 2004 edition, The Star newspaper reported that between 2001−2002, 19 Thai nationals had been caught for illegal extraction of *karas* in protected areas (Annex 1). However, this did not include cases that had been reported by Malaysia in its biennial reports to CITES (Table 1.2).

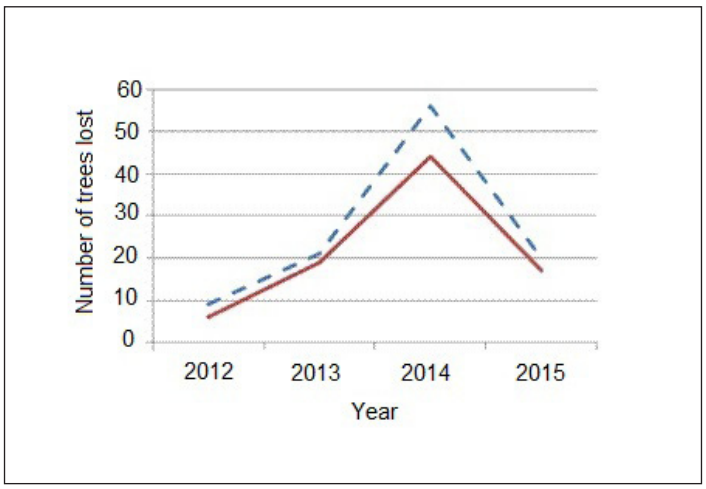


Fig.1.4. Number of *Aquilaria* trees lost in the study sites during the period March 2012 to September 2015. The apparent drop in 2015 could be due to enhanced enforcement activities. Solid and dashed lines indicate S2 and all sites respectively.

Table 1.1. Compilation of news reports on the illegal harvest of *Aquilaria* in the peninsula.

State	Year	Date of report	Location	No. trees/kg of chips, blocks
Penang	2014	Feb-19	Mt. Erskine	NA
Penang	2014	Feb-19	Batu Ferringhi	NA
Perak	2014	Feb-27	Grik	90 kg
Johor	2014	Apr-16	Endau Rompin National Park, Panti FR	NA
Penang	2014	Jul-09	Penang National Park	NA
Penang	2013	Oct-11	Near Penang Botanic Gardens	NA
Penang	2012	Feb-23	Gambier Hills	NA
Penang	2012	Feb-28	Several sites near Butterworth	NA
Penang	2012	Mar-05	Mar Vista Resort and Chee Seng Garden in Tanjung Bungah	NA
Penang	2012	Mar-17	Fettes Park in Tanjung Bungah	NA
Penang	2012	Mar-30	Simpang Empat in Nibong Tebal	51 kg
Penang	2012	Apr-02	Batu Ferringhi	3
Penang	2012	Nov-12	Taman Permai in Tanjung Bungah	NA
Penang	2012	Nov-12	Mt. Erskine	NA
Penang	2011	Oct-11	Bukit Panchor in Nibong Tebal	NA
Penang	2011	Oct-12	Cherok Tokun Hill in Bukit Mertajam	NA
Sabah	2010	Apr-13	Kalabakan FR	NA
Perak	2004	Aug-14	Belum Forest Reserve (FR)	NA

Table 1.2. Legal action taken by the Malaysian authorities against illegal *karas* harvesters since 2005 (extracted from Malaysia's biennial reports to CITES).

Year	Details	Amount	Value of fine (RM)	Jail term (months)
2005	In possession	7.4	NA	20
2006	Illegal entry	0	0	8
2006	Illegal entry	0	0	3
2006	Illegal activity	0	2000	0
2006	Illegal entry	0	1600	0
2008	Seizure of chips, blocks (kg)	15	NA	NA
2009	Seizure of chips, blocks (kg)	50	NA	NA
2010	Seizure of chips, blocks (kg)	5819	NA	NA
2010	Seizure of oil (litres)	4	NA	NA
2010	Seizure of wood (pieces)	3	3000	4
2011	Chips, blocks import without CITES export permit (kg)	17.4	NA	NA
2012	Import of saplings without CITES export permit (number)	3400	NA	NA

Currently harvest of agarwood from wild populations only occurs in the range states of Malaysia and Indonesia—the harvest is regulated through a quota system and is enforced through a legal framework at the national level and monitored by CITES. Malaysia, like other range states, has resorted to establishing plantations to take advantage of the profitable revenue and as a means to address the decline in wild populations. As required by Act 686 and Resolution Conf. 16.10 of CITES, some 53 companies and individuals in Peninsular Malaysia have registered their nurseries and plantations (including smallholdings) with the Malaysian Timber Industry Board (MTIB) which is the Management Authority (MA) in charge. Currently there are about 984 ha of plantations with c. 959,500 standing trees, mainly of *A. malaccensis, A. crassna* and *A. subintegra* (http://cites.org/eng/2015_india_agarwood_workshop). These are planted either as a mono-crop or intercropped with fruit trees and in village/community gardens. There is a report on financial subsidies being available for such plantation activities (Annex 2) but we were unable to verify it. The challenges faced by the *karas* plantation industry in Malaysia includes the lack of quality planting stock, processing chain not being readily available, lack of an international grading standard and high input costs that reduce the competitiveness of Malaysian agarwood products.

In order to reduce harvesting pressures on and decline of the wild *A. malaccensis* populations, a conservation action plan (CAP) is clearly required. To ensure the applicability of the CAP, management prescriptions that are formulated should be based on an understanding of the critical functional components that affect population regeneration and viability. Such components include reproductive ecology, fecundity (flowering phenology and floral biology) and genetic diversity. Thus, the objectives of the Activity were to: (i) document its flowering phenology and reproductive behaviour; (ii) develop DNA profiling databases for the species in Peninsular Malaysia; and finally (iii) prepare a CAP. Note that while this Activity did not aim

to reduce the rate of illegal harvesting nor address issues associated with it, it is anticipated that in the incorporation of the measures recommended in the CAP, the rate of decline in the populations may be sufficiently arrested. The information contained in this report forms part of the Non-detriment findings (NDF) required by Resolution Conference 16.10 for agarwood-producing species with particular emphasis on biological characteristics and population status.

In this report we bring attention to the following: (1) although the Malay name *karas* refers collectively to the genus *Aquilaria*, in the context of this report/article, it refers to *A. malaccensis* only; (2) site names and coordinates are purposefully withheld to maintain anonymity and reduce harvesting pressures; (3) mature individuals are individuals that exceed the reproductive dbh threshold of 145 mm; (4) the data used in this report have been sourced from other projects, mainly the Centre for Tropical Forest Science and Forest Global Earth Observatory (CTFS-ForestGEO; see methodology for details). In the preparation of the CAP, information is also drawn from previous studies that were funded solely by the Malaysian Government such as "*In vitro* technology for mass propagation and phytochemical analysis of *Aquilaria malaccensis* and *Aquilaria hirta* (endangered gaharu producing species)" (undertaken 2007−2008) and "*Kajian pemuliharaan dan pembangunan penanda mikrosatelit DNA ke atas* Aquilaria malaccensis *(karas) di Semenanjung Malaysia*" (undertaken 2011−2012).

2.1 Location of sites

Site 1 (S1) is located in the state of Perak and is covered by periodically inundated freshwater swamp forest on Telemong-Akob-Local Alluvium soil, surrounded by urban and tin tailing landscapes. Mean annual rainfall is approximately 2150 mm—monthly rainfall means exceed 167 mm but annually there are two weak dry seasons occurring in the months of February and June, respectively. The lowest minimum temperature recorded during the period of January 2011–August 2015 was 18.7ºC and this occurred on 4 February 2014. The following day, the minimum temperature was also low at 19.3ºC.

Sites 2, 3, 4 and 5 (S2, S3, S4, S5) are located on Penang Island. S2 is situated in the northeast, in a recreational forest that is semi-wild and not managed but maintained as part of the recreational area while S3 is in a hill dipterocarp forest with an elevation of up to 320 m a.s.l.; both sites are surrounded by urban and built-up landscapes and categorised as steepland. S4, located in the northwest of the island, is also a recreational forest with an elevation of 90 m a.s.l. It is not managed but maintained as a part of the recreational area, while S5 is in a coastal lowland dipterocarp forest. For these sites, the mean annual rainfall is approximately 2448 mm—monthly rainfall means exceed 187 mm and annually there are two dry seasons occurring in the months of December−February and June. The lowest minimum temperature recorded for these sites was similar to that in S1.

Site 6 (S6) is located in the state of Negeri Sembilan. It comprises lowland dipterocarp forests—the southwest area is part of a river delta while the central and northeast areas are undulating up to 24 m elevation (Manokaran *et al*. 1992). Soils are of ultisol/entisol type (Adzmi *et al.* 2010, Baldeck *et al*. 2012). Mean annual rainfall is approximately 2000 mm—monthly rainfall means exceed 100 mm but annually there are two weak dry seasons (July and January) (Numata *et al*. 2003). Other site factors such as light intensity, below ground and nutrient fluxes have been reported respectively by Yoda (1978), Yamashita *et al*. (2003) and Yamashita and Takeda (2003). S6, established in 1985, is censused every five years following a standard protocol (Manokaran *et al*. 1990, Condit 1998) where all woody plants ≥1 cm dbh are identified, tagged, measured and mapped. To date six censuses have been conducted with the last one conducted in 2010–2011. Although no legal harvesting of *karas* is allowed, there were assumptions (LaFrankie 1994) and unofficial reports of illegal harvest since 1987. The growth, mortality, recruitment and abundance data used in this report is obtained from CTFS-ForestGEO.

Meteorological data (daily maximum and minimum temperature, mean relative humidity and rainfall) from the nearest government meteorological stations (Titi Gantong Agricultural Station for S1, direct distance of 13 km, March 2011–June 2015; Butterworth for S2 and S3, direct distance of 12 km, April 2011–June 2015; Muka Head for S4 and S5, direct distance of 3 km, April 2011–June 2015) were obtained from the Malaysian Meteorological Department. All analyses were conducted in R 3.2.0 (http://www.R-project.org) using available functions from its various packages.

2.2 Demography

2.2.1 Spatial pattern

S6 data from Census 6 (2010–2011) was used. Visually, most trees seem to be scattered randomly throughout the plot. To see whether the observed pattern is consistent with complete spatial randomness, the pattern was tested using Ripley's K(t) function (Ripley 1976). This function tests whether the distribution of trees is aggregated, regular or random and further tests how the observed pattern changes with the distance scale. The spatial pattern of the populations in S1−S5 was not run because plots were not placed in these sites.

2.2.2 Growth, recruitment, mortality and abundance

Using the S6 data, we compared the mean and confidence limits for the dbh distribution of the population between censuses from census 1 (1987) to census 6 (2011). As shown by Condit *et al*. (1998) and Kohyama *et al*. (2015), demographic growth is a predictor of future population trends. Therefore, we also compared the means for different dbh categories (10–50 mm, 50.1–100 mm, 100.1–200 mm and >200.1 mm). These means were compared to those of *Gonystylus maingayi*, the only other member of the Thymelaeaceae family that is present in S6. Growth, recruitment and mortality data was analysed using functions in the CTFS R Package (http://ctfs.arnarb.harvard.edu/Public/CTFSRPackage/).

The rate of change in the abundance of stems (P) between censuses was calculated as

$$P = \log(n_2) - \log(n_1)/t$$

where n_2 and n_1 are numbers of stems recorded at the final and initial census, respectively, and t is the mean time expressed in the number of years between censuses (Condit *et al*. 1998).

2.2.3 Abundance at the national level

The National Forest Inventory (IHN), conducted in the years 1991–1993 (IHN3, Chin *et al*. (1997)), 2002–2004 (IHN4, Anon. (2007)) and 2010–2013 (IHN5, Anon. (2014)), provide abundance data that spanned 20 years for both *A. malaccensis* and *A. hirta* (>15 cm dbh) in the production and protection forests under PRF and Stateland in Peninsular Malaysia. Forests covered in the IHN included both primary and logged-over forests of various ages. Chin *et al*. (1997), Anon. (2007) and Anon. (2014) provide details with respect to definition, map scale, sampling design, number of sampling plots, calculations and analysis of data. Detailed comparison of the IHN abundance data is not reported here as the sampling method used in IHN3 varied markedly from other IHNs. Although plot location was randomised in all three IHNs, the final selection of the sampling plot was based on whether the plot had the appropriate representation of the pre-determined strata. In using and presenting the results, we have made the following assumptions: (1) on the basis of rarity, *A. beccariana* and *A. rostrata*

were most likely absent in the sampling plots; (2) in IHN5, only 1.1% of the sampling plots contained *karas*. The geographic distribution of *karas* is known to be widespread while its sister species *A. hirta* is more restricted, hence the IHN5 data likely underestimates the density of both species; (3) we used the area of occupancy (AOO) as defined by the World Conservation Union (IUCN 2014). The AOO is obtained from herbarium and voucher collections and written field notes from present and past projects; (4) the spatial pattern discerned from S6 was used as a guide; and (5) because we have no information on the location of the sampling plots, we did not attempt to segregate the data by species.

2.3 Flowering phenology and floral biology

2.3.1 Flowering phenology

A total of 423 trees ≥1 cm dbh were enumerated in S1−S5 following the method of Manokaran *et al.* (1990). Tree coordinates were acquired with Garmin 60CSX. Populations that are larger having individuals with a range of dbh size classes were selected for observation. S1 and S2 populations were visited bi-monthly while S3, S4 and S5 populations were visited once in 3–4 months, whenever possible.

Phenological observations of all 423 trees took place between 1 April 2011 and 31 August 2015. Fortnightly observations were changed to weekly and monthly when necessary for trees in S1 and S2. Leaf flush, floral budding, flowering, fruiting and fruit dehiscence were observed from the ground using a 12 × 42 5º angular field view Nikon binoculars. Leaf flushes which are formed at terminal and axillary branches were especially checked for flower buds as these are known to emerge together in several other tropical species. A tree is considered flowering when a small amount of flowers was visible. As its flowers are small, the flowering episode in some trees may be missed but the presence of fruits confirmed that flowering had taken place. Masting is deemed to occur when trees produced large seed crops and this event is synchronized within a population (Kelly 1994).

2.3.2 Floral and fruit biology

In 2013 observation towers of about 5 m height were erected at tree AM186 in S1 and tree AM27 in S2. Tree AM186 was 47 cm in dbh and 41 inflorescences bearing approximately 140 flowers and 430 flower buds were tagged in 2013. The tree was observed daily from 9−13 September 2013 between 15:00 on the first day until 12:00 the following day. Observations were made from 10:00 until 17:00 on 17−19 September and 23−25 September 2013. Tree AM27 has a dbh of 24 cm and was chosen because its low drooping canopy allowed detailed observation and examination. Initially, a total of 30 inflorescences bearing approximately 150 flowers and 270 flower buds were tagged in the same year. An additional 16 inflorescences bearing approximately 60 flowers and 90 flower buds were added later in that year. The tree was observed from 25−29 March, 1−5 April and 8−12 April 2013 from the tower. Daily observations began at 15:00 on the first day and ended at 12:00 the following day for the period 25-29 March and 1-5 April whereas from 8−12 April, observations were made between

09:00 and 12:00 daily. This duration covered the period from flower opening to early fruit formation; subsequent observations were conducted every two weeks.

Time of flower opening, anthesis and stigma receptivity were recorded for flowers in the tagged inflorescences. Anthesis and stigma receptivity tests were conducted on a total of 20 flowers of tree AM186 and 65 flowers of tree AM27. The tests were performed hourly on freshly opened flowers for 19 hours. Stigma receptivity was tested with Nile blue 1% (Owens *et al*. 1991) and hydrogen peroxide 3% (Valdiani *et al*. 2012). Because of the small flower size, both tests required that the female reproductive organ be isolated. In the Nile blue 1% test, the whole pistil was dipped into the solution and receptivity was confirmed when the stigmatic surface turned bluish. In the latter test, a single drop of diluted hydrogen peroxide was placed on the stigmatic surface. Presence of stigmatic activity was confirmed when bubbles were produced inside the droplet. The fruit dimension was measured from early formation until abortion or dehiscence. Developing fruits were observed for any abnormalities including signs of damage. Number of seeds per fruit was recorded where possible and the dimensions of 20 fruits were measured for tree AM27 and 7 for tree AM186.

2.3.3 Flower, fruit and seed production

Ten 1 × 1 m traps were positioned under tree AM186 in S1 and 20 under tree AM267 in S2 at the beginning of September and April 2013 respectively. The traps were set up 1 m above the ground and randomly placed under the tree canopy. Flowers and seeds were collected weekly, air-dried in an air-conditioned room at temperatures around 26ºC for at least 7 days and weighed using A&D FX-2000i Digital Weighing Scale. Where counting of flowers was not feasible, the mean weight of 30 replicates for 50 flowers in each trap was used to estimate the number of flowers from that trap on that particular day. The number of fruits and seeds from each trap was counted on a particular day. In cases where no seeds were available, the number was inferred from the number of mature capsules present (*A. malaccensis* usually has one seed per capsule although two may occur). Traps were visited until no more flowers, fruits, capsules and seeds were found. The production of flowers, fruits and seeds of a tree (floral load) was estimated using the formula ($r/t \times n$), where r is the canopy area projection, t is the trap area and n is the number of flowers, fruits and seeds trapped. Abortion rate is calculated by subtracting the total production of mature fruits from the floral load.

2.3.4 Pollinator and predator observations

Table 2.3.4.1 shows the date and time of pollinator observations which coincided with the flowering period. Insect visitors were observed and caught using a modified fish net. Only insects which lingered on the flowers were sampled. Samples were obtained from the tower and for tree AM27 samples were also obtained from the ground level. The insects were preserved in 70% ethanol. All specimens were sent to the Entomology Unit in FRIM for identification.

Table 2.3.4.1. Schedule for pollinator sampling at sites S2 and S1.

S2		S1	
Date	**Time**	**Date**	**Time**
26 March 2013	07:00 – 21:00	10 September 2013	21:00 – 11:00
27 March 2013	17:00 – 03:20	11 September 2013	21:00 – 11:00
28 March 2013	17:00 – 02:30	12 September 2013	21:00 – 11:00
1 April 2013	09:00 – 12:00	13 September 2013	09:30 – 17:00
2 April 2013	09:00 – 12:00, 17:00 – 23:00	18 September 2013	09:30 – 18:00
3 April 2013	17:00 – 20:00	19 September 2013	09:30 – 18:00
4 April 2013	02:00 – 06:00	24 September 2013	10:00 – 17:00
5 April 2013	09:30 – 13:00	25 September 2013	10:00 – 13:00
12 April 2013	09:30 – 12:30		

Fruit predation was observed using binoculars, digital camera and standard dissecting tools. Extracted insects from the fruits (if any) were sent to the FRIM Entomology Unit for identification. Seeds collected from the traps were sown in a river sand and soil mixture in the FRIM nursery (23–34ºC, 77–100% humidity). Watering was done using a misting system that operates every 30 minutes. Germination was recorded when the radicle emerged through the seed coat (ISTA 2004).

2.4 Population genetics

2.4.1 Population survey and sample collection

Population survey and sample collection of *A. malaccensis* was conducted (Fig. 2.4.1.1) throughout Peninsular Malaysia. From the 31 forest reserves/forested areas surveyed, samples were collected from 23 forest reserves/forested areas (with sample sizes ≥ 7). Together with samples collected during phase 1 (March 2011 to November 2012; funded by Government of Malaysia), a total of 35 populations consisting of 963 samples were used for microsatellite analysis (Table 2.4.1.1; Fig. 2.4.1.2). However, after carefully checking through the microsatellite data, the total number of samples was reduced from 963 to 942 (averaging 27 samples per population) due to dubious genotypes of certain individuals from Machincang (3), Lubuk Semilang (3), Bukit Malut (9), Gunung Jerai (1), Gunung Inas (1), Solok Duku (1) and Chabang Tongkat (3).

Fig. 2.4.1.1. Population survey and sample collection throughout Peninsular Malaysia. (A) A large *Aquilaria malaccensis* tree in Berkelah, Pahang being measured for dbh and tagged; (B) A large *A. malaccensis* (dbh 77 cm) tree in the forested area of Universiti Teknologi PETRONAS, Perak; (C) Wildings of *A. malaccensis* in the forested area of Mont Kiara, Selangor; (D) Team members during a field trip to Panti, Johor; (E) Harvesting of *gaharu* by *Orang Asli* in Lenggor, Johor; and (F) Extensive damage of an adult tree at Panti due to the slashing of its trunk.

Table 2.4.1.1. Population codes, sample sizes (*N*) and state of origin of 35 populations of *Aquilaria malaccensis* included in the study. *Values in parentheses are the final sample size used for microsatellite analysis.

Population	Code	*N*	State of origin
1. Machincang	MAC	23 (20)*	Kedah
2. Lubuk Semilang	LSE	20 (17)*	Kedah
3. Bukit Malut	BMA	30 (21)*	Kedah
4. Bukit Perangin	BPE	34	Kedah
5. Gunung Jerai	GJE	17 (16)*	Kedah
6. Gunung Inas	GIN	12 (11)*	Kedah
7. Gunung Bongsu	GBO	16	Kedah
8. Penang National Park	PEN	25	Pulau Pinang
9. Bukit Kerajaan	BKE	54	Pulau Pinang
10. Gunung Semanggol	GSE	32	Perak
11. Bubu	BUB	23	Perak
12. Kledang Saiong	KSA	7	Perak
13. Universiti Teknologi Petronas	UTP	34	Perak
14. Bukit Tapah	BTA	37	Perak
15. Bukit Lagong	BLA	35	Selangor
16. Mont Kiara	MKI	40	Selangor
17. Pelangai	PEL	9	Negeri Sembilan
18. Pasir Panjang	PPA	20	Negeri Sembilan
19. Solok Duku	SDU	40 (39)*	Melaka
20. Sungai Udang	SUD	59	Melaka
21. Paya Rumput	PRU	36	Melaka
22. Maokil	MAO	28	Johor
23. Panti	PAN	61	Johor
24. Lenggor	LEG	12	Johor
25. Lentang	LEN	7	Pahang
26. Som	SOM	16	Pahang
27. Tekai-Tembeling	TTE	20	Pahang
28. Berkelah	BEK	24	Pahang
29. Beserah	BES	25	Pahang
30. Merchang	MER	34	Terengganu
31. Gunung Tebu	GTE	31	Terengganu
32. Chabang Tongkat	CTO	53 (50)*	Kelantan
33. Jeli	JEL	11	Kelantan
34. Nenggiri	NEN	17	Kelantan
35. Batu Papan	BPA	21	Kelantan

The samples were collected in the form of inner bark or leaf tissues. For inner bark sampling, a small piece of inner bark measuring 10 × 10 cm was cut from each identified tree and the wound then sprayed with paint to prevent infection. As for leaf sampling, the 'shaking-catch' method described by Ng (2005) was employed for large trees. In this method, a fishing weight attached to nylon fishing string was shot up using a catapult and looped over a small branch. A bigger and stronger rope was then hauled up to replace the fishing string. The two ends of

the rope were then pulled vigorously together to break a small branch. The collected samples were immediately processed in the field and kept in silica gel, or wrapped with aluminum foil, and kept in liquid nitrogen.

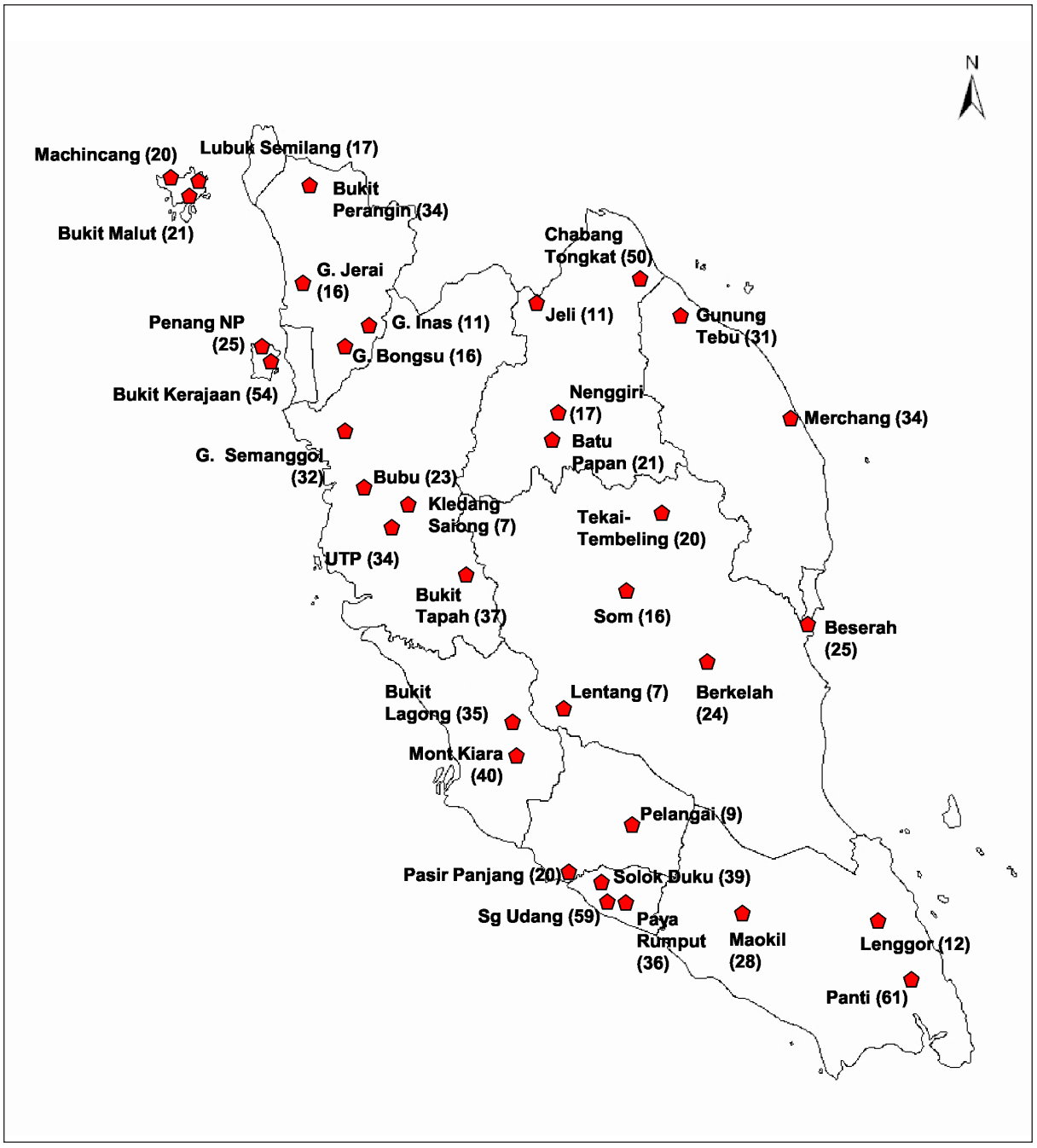


Fig. 2.4.1.2. Locations of the 35 populations of *Aquilaria malaccensis* in Peninsular Malaysia included in the study. Values in parentheses are the final sample size used in the study.

2.4.2 DNA extraction and purification

Genomic DNA was extracted using the CTAB method described by Murray and Thompson (1980) with modification. The method was slightly modified by 2X CTAB extraction buffer to accommodate the tissue to buffer ratios. Approximately 3–5 g of fresh leaf or inner bark tissue was placed in a mixer-cup with liquid nitrogen and homogenized into fine powder using Miller IFM-150 homogenizer (Iwatani). The fine power was then transferred into a 50-ml tube and mixed with 20 ml pre-heated (65ºC) 2X CTAB extraction buffer (2% [w/v] CTAB, 20 mM EDTA, 100 mM Tris-HCl [pH8.0], 1.4 M NaCl, 1.5% [v/v] mercaptoethanol and 1% [w/v] PVP-40, with final pH 8.0) to form a homogenous slurry. The slurry was incubated at 65ºC for 30 min with occasional mixing and then left to cool to ambient temperature. Subsequently, an equal volume of chloroform-isoamyl alcohol (24:1) was added and mixed gently for 15 min and then centrifuged at 2700 rpm for 10 min to remove proteins and carbohydrates. The supernatant (top phase) was transferred to a new 50-ml tube and the DNA was precipitated with two-third volume of cold isopropanol (-20ºC).

The CTAB-nucleic acid complex was spooled out with a glass rod (for particulate precipitates, the tubes were spun at 2700 rpm for 10 min), transferred into a 1.5-ml tube containing 1 ml of wash buffer (76% ethanol and 10 mM NH_4OAc) and left for at least 1 h at 4ºC in order to dissolve the CTAB from CTAB-nucleic acid complex. The tubes were subsequently centrifuged at 12000 rpm for 10 min (4ºC). Then the supernatant was carefully discarded and the pellet was vacuum-dried for 20 min. After drying, the pellet was dissolved in 0.5–1.0 ml of TE buffer (10 mM Tris-HCl pH 8.0 and 1 mM EDTA). The final solution should contain a combination of RNA, nuclear DNA, chloroplast DNA and mitochondrial DNA.

The DNA quality and quantity were determined on a 0.85% agarose gel containing 0.5 µg/ml of ethidium bromide (Fig. 2.4.2.1). Electrophoresis was carried out with 1X TAE buffer (40 mM Tris-acetate pH 8.0, 1 mM EDTA) and calf thymus concentration markers (Boehringer Mannheim) were used as standard for comparison. Purification of the genomic DNA was carried out using the High Pure PCR Template Preparation Kit (Roche Diagnostics GmbH) following the manufacturer's instructions. Finally, the quantity and purity of the DNA were further quantified using NanoDrop 2000 Spectrophotometer (Thermo Scientific).

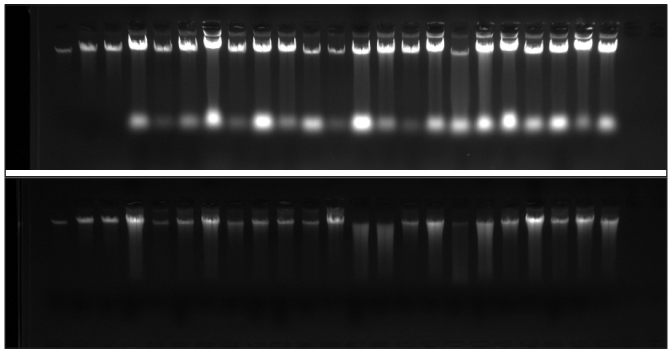


Fig. 2.4.2.1. Gel result obtained before (above) and after (below) purification of the genomic DNA. The first three lanes from the left indicate calf thymus marker of concentration 10, 25 and 50 ng/µl.

2.4.3 Multiplex-polymerase chain reaction amplification

Multiplex–PCR amplification was used to verify the suitability of the 17 pairs of microsatellite primers *Ama*025*, Ama*040*, Ama*053*, Ama*057*, Ama*067*, Ama*101*, Ama*114*, Ama*115, *Ama*131*, Ama*144*, Ama*177*, Ama*211*, Ama*233*, Ama*263*, Ama*264*, Ama*331*, Ama*338 (Tnah *et al*. 2012) developed for *A. malaccensis.* The multiplex PCR amplification was carried out using TYPE-IT MICROSATELLITE-PCR KIT (Qiagen) following the manufacturer's protocol with modification. The multiplex-PCR amplifications were performed in 8 µl reaction mixture, with 5 ng template DNA, 1X TYPE-IT MULTIPLEX PCR MASTER MIX, and 0.05 µM of each primer. Optimal amplification conditions were 1 cycle of 3 min at 94ºC, followed by 35 cycles of 94ºC (30 s), 50ºC–57ºC (30 s), and 72ºC (30 s), and final step of 30 min at 72ºC using 2720 THERMAL CYCLER (Applied Biosystems). For genotyping, the PCR products were subjected to fragment analysis using ABI 3130*xl* GENETIC ANALYZER (Applied Biosystems) with ROX 400 as internal size standard. Individuals were genotyped using GENE MAPPER v4.0 (Applied Biosystems).

After the multiplex-PCR screening, out of the 17 loci, five were dropped from further analysis, due to stuttering (*Ama*067 and *Ama*211) and non-specific amplification (*Ama233, Ama263* and *Ama264*). The remaining 12 loci were assigned to three sets of primer combinations for multiplex-PCR amplification, based on the product size range and the type of fluorescently labelled dye (Tables 2.4.3.1 & 2.4.3.2). The fluorescently labelled and unlabelled forward primers were optimized in ratios of 1:1 to 1:9 depending on allele peak intensity.

2.4.4 Statistical analyses

2.4.4.1 Genetic diversity within and among populations

The allele frequency, allelic richness (R_s), private alleles, average number of alleles per locus (A_a), observed (H_o) and expected heterozygosity (H_e) (Nei 1987) were computed using the program FSTAT V2.9.3.2 (Goudet 2002) and GDA V1.1 (Lewis & Zaykin 2002). Allelic richness was measured by the method of El Mousadik and Petit (1996) using rare-fraction approach whereby the allelic richness was standardized to that of the smallest sample size over populations and over loci. The number of rare alleles (frequency of less than 5% in the population; Marshall & Brown 1975) per individual in each population was also calculated.

Fisher exact test for Hardy-Weinberg and linkage disequilibrium were performed using GDA V1.1. A Bonferroni correction was then used to compensate for multiple comparisons between loci (Rice 1989). Wright's (1951) *F*-statistics was calculated to measure the deviation of Hardy-Weinberg equilibrium at each locus in each population. Weir and Cockerham's (1984) estimates of the inbreeding coefficient or fixation indices ($F_{IS} = 1 - H_o/H_e$) for each population across each locus were computed using FSTAT V2.9.3.2 and the average value for each locus determined. The significance of the F_{IS} values ($F_{IS} \neq 0$) was determined based on 1000 randomizations with standard Bonferroni correction.

Genetic structure was assessed using the infinite allele model (IAM; Kimura & Crow 1964). The population differentiation coefficients, Weir and Cockerham's (1984) estimates of Wright's F_{ST} (θ, Wright 1951, 1977) were calculated using FSTAT V2.9.3.2.

Table 2.4.3.1. Characteristics of 12 polymorphic microsatellite markers of *Aquilaria malaccensis* developed by Tnah *et al*. (2012). Annealing temperatures (T_a) and expected numbers of alleles (*A*).

No.	Locus	GenBank accession	Repeat	Primer sequence (5' - 3')	T_a (°C)	Allele size range (bp)
1.	*Ama*025	JQ845077	$(CT)_{20}$	F: ATGAATGAAACCCAATGAA R: ATTTCCTTTATTGCTGGTTC	45	85-128
2.	*Ama*040	JQ845078	$(GA)_{22}$	F: CACGACAAAGAAAACATACA R: AACCTCATCCCGTCCTCGCA	45	96-122
3.	*Ama*053	JQ845079	$(GT)_8(GA)_{15}$	F: GGGAGAGAGAGAGAAAAG R: CTGCTGTTCAACGAGTTCT	45	147-178
4.	*Ama*057	JQ845080	$(AC)_6$-$(AC)_9$	F: CACATACATAGACACGC R: GCAATACAATACAATGAAG	45	98-113
5.	*Ama*101	JQ845082	$(AC)_6$	F: GCTTAGACAGGCAATATCCAT R: GAGAAAACGGCAAAAG	45	157-159
6.	*Ama*114	JQ845083	$(AC)_{13}$	F: TGCCCTCTCTCAAGTTATT R: AAGCATATAATAAGAATCC	45	178-192
7.	*Ama*115	JQ845084	$(GT)_9$	F: TCCCATCAGAAGCCCTC R: ACAACCATAAATGCTAC	45	92-101
8.	*Ama*131	JQ845085	$(AC)_{12}$	F: GGTCTTGAGCTGGAATGAG R: TCGATGACGGATAGCAG	45	169-187
9.	*Ama*144	JQ845086	$(AC)_{13}$	F: GAACGCAATGCAATATCT R: GGTGATGATATGTCGCTTC	45	205-220
10.	*Ama*177	JQ845087	$(CT)_{18}$	F: GGACCACTGCTGCATTTAA R: TGGCAAGATGGACAAGCAG	45	256-294
11.	*Ama*331	JQ845092	$(AC)_{10}$	F: TGTGATGACTGTGAGAAG R: CATCTGTTGTTCCTTTTG	62	108-118
12.	*Ama*338	JQ845093	$(AC)_6$	F: ATATATGCCACCTACCTA R: CCACGACGTAGACTCAA	50	128-141

Table 2.4.3.2. Three sets of primer combinations assigned for multiplex-PCR amplification, based on the product size ranges and types of fluorescently labelled dye with expected numbers of alleles (*A*) and annealing temperatures (T_a). The fluorescently labelled and unlabelled forward primers were optimized in a ratio of 1:1 or 1:9.

Set	Locus	Fluorescent dye	F-Primer ratio	Size range (bp)	*A*	T_a (°C)
Set1	*Ama*025	HEX	1:1	81-137	27	50
	*Ama*131	6-FAM	1:10	171-189	10	50
	*Ama*144	HEX	1:2	207-233	7	50
	*Ama*177	6-FAM	1:9	270-308	19	50
	*Ama*338	6-FAM	1:10	132-140	4	50
Set2	*Ama*040	HEX	1:9	94-136	21	50
	*Ama*114	6-FAM	1:2	176-202	12	50
	*Ama*331	6-FAM	1:9	106-120	9	50
Set3	*Ama*053	HEX	1:9	146-184	21	50
	*Ama*057	6-FAM	1:9	101-115	8	50
	*Ama*101	6-FAM	1:3	155-159	3	50
	*Ama*115	HEX	1:9	93-103	4	50

For the analysis of isolation-by-distance, Mantel tests (Mantel 1967) were carried out between the matrices of genetic differentiation (F_{ST}) and geographical distances using GENALEX 6.1 (Peakall & Smouse 2007). The geographical distances between populations were calculated from the respective latitudes and longitudes using the same software. The association between the two types of distances was tested for significance by 999 permutations.

2.4.4.2 Relationship among populations

Three approaches were used to determine the relationship among the populations: (1) cluster analysis based on D_A genetic distances; (2) principal component analysis (PCA); and (3) Bayesian approach to deduce population structure.

Cluster analysis based on D_A genetic distances (Nei *et al*. 1983) was used because of its independence of the mutation models (Nei 1987) and superior to other distance measures in correct tree topology construction using microsatellites (Takezaki & Nei 1996). D_A between all pairs of populations was estimated using POWERMARKER V3.25 (Liu & Muse 2005) and the average distance was estimated across all loci. Consequently, a dendrogram was constructed by Neighbour-Joining (NJ) method (Saitou & Nei 1987) using the same software, viewed under MEGA V4.0 (Tamura *et al*. 2007). Branch node support was estimated by resampling over loci with 1000 bootstraps.

PCAs were computed to view pairwise differentiation among populations (F_{ST}) using the programme PCAGEN v1.2.1 (Goudet 1999). Estimations were based on the correlation matrix of population allele frequency where three different analyses were performed:

PCA1: On all the 35 *A. malaccensis* populations.
PCA2: On the 14 populations from Cluster Kedah-Perak.
PCA3: On the 21 populations from Cluster Kelantan-Johor.

For each analysis, two-dimensional standard plots were produced representing the first three principal components. The significance of axes for each PCA was estimated by 1000 randomizations.

Unlike the preceding analyses which are based on predefined populations, the Bayesian-clustering method of Pritchard *et al*. (2000) detects genetic structure without prior information on the number of locations from which the populations were sampled. The software STRUCTURE v2.3.3 (Pritchard *et al*. 2000, Falush *et al*. 2003) and STRUCTURE HARVESTER v0.6 (Earl & VonHoldt 2011) were used to evaluate the optimal number of clusters (K), and assign each of the 942 individuals of *A. malaccensis* to a population without the predefined population information. In the analysis, loci were assumed to be independent with complete Hardy-Weinberg equilibrium within the population. A Markov Chain Monte Carlo (MCMC) algorithm was used to compute the allele frequencies in each of the K regions. Initially, 35 independent runs were performed for all populations with simulations of 50,000 burn-in periods, 20 iterations and 100,000 MCMC. Similar parameters were used for K = 1–14 for the populations on Cluster Kedah-Perak and K = 1–21 for the populations on Cluster Kelantan-Johor. After the STRUCTURE analyses, the 942 individuals of *A. malaccensis* were subsequently assigned to their respective populations when the best K value was elucidated and individual admixture proportions were sorted.

2.4.4.3 Optimum population size

The optimum population size to maintain the current level of genetic diversity was estimated according to Lee *et al*. (2002). The genotype data from all studied populations were pooled (total number of samples was 942) for simulation analysis. To determine the optimum population size required for maintaining the total number of alleles (A_t), 930 out of 942 samples were sampled without replacement 1000 times using a computerized algorithm. The A_t was calculated. The A_t was also estimated for sample sizes of 930 to 10, with a 10-sample reduction interval. The percentage means A_t with standard errors were plotted against sample sizes to reveal trends.

2.5 Non-detriment findings (NDF)

From the data on demography, reproductive ecology and genetic components, the partial NDF for *A. malaccensis* was developed.

3.1 Spatial pattern

The population at S6 shows no specific association with topography or soils (Fig. 3.1.1A). It is spatially random up to a distance of 20 m, beyond which it becomes regularly spaced as evidenced by a weak but statistically significant deviation. At distances greater than 45 m, the pattern returns to randomness. There is no evidence of clustering (Fig. 3.1.1B). The pattern for mature individuals is random for all distances up to 100 m (Figs. 3.1.1C & 3.1.1D). There appears to be no shift in the spatial pattern since 1987 (Manokaran *et al*. 1992, LaFrankie 1994). The absence of aggregation at all distances suggests that density-dependent mortality continued steadily to alter the spatial pattern towards a regular distribution.

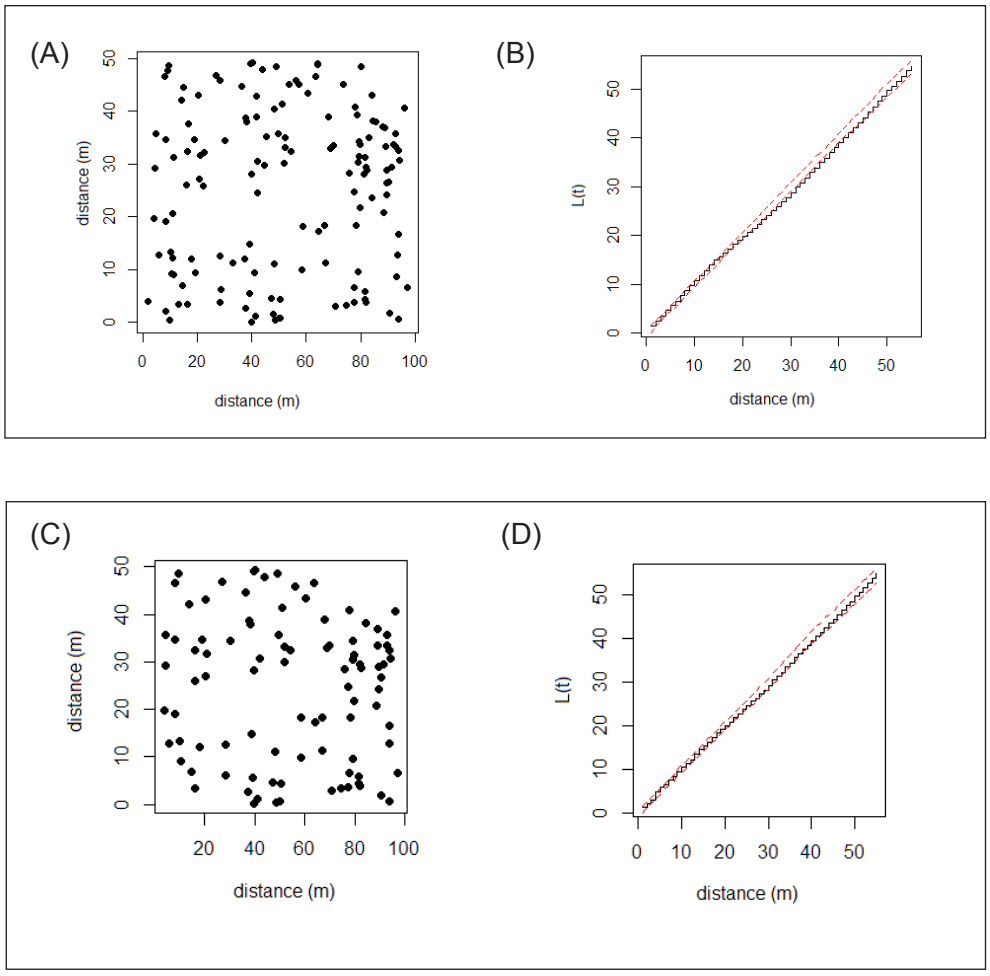


Fig. 3.1.1. Spatial distribution and L(t) plots for *Aquilaria malaccensis* at S6 Census6. (A) Distribution for all 142 trees. (B) Plot of L(t) vs. distance up to 100 m for all trees. Dashed lines are 0.025 and 0.975 quantiles of L(t) estimated from 100 simulations. (C) Distribution for 95 mature trees with dbh>145 mm. (D) Plot of L(t) vs. distance up to 100 m for mature trees. Line description is the same as in (B).

3.2 Demography

3.2.1 Growth, recruitment and mortality

The mean annual dbh growth rate for the S6 population over the 23-year period was 3.3 ± 2.49 mm/year. Table 3.2.1.1 and Fig. 3.2.1.1 provide the mean annual dbh increment between two consecutive censuses for the same period. The rate of diameter growth showed an almost linear increment across all categories with the smallest dbh category consistently having the lowest rates while the largest category had the highest rates (Fig. 3.2.1.2). The mean annual dbh growth rate generally (with a single exception) decreased with time in all dbh categories - the growth of smaller juveniles (10−100 mm) continues to fall as years passed by; this trend is however somewhat reversed in the 100−200 mm dbh category. *Aquilaria malaccensis*, across all dbh sizes, had a consistently higher growth rate when compared to *Gonystylus maingayi*, a member of the same family (Fig. 3.2.1.2). Increment rates between dbh categories are also higher in *A. malaccensis*.

Table 3.2.1.1. Mean annual rate of diameter growth, mortality, recruitment and change in abundance of *Aquilaria malaccensis* between consecutive censuses in S6.

Btw census	Abundance		Growth		Mortality		Recruitment		Population change	
	N1	N2	N	Rate	Died	Rate	Recruits	Rate	interval	Little r
C12	125	124	117	3.732251	5	0.01431782	4	0.01143128	2.868376	-0.00280025
C23	124	122	110	2.97556	11	0.01670426	9	0.01385057	5.570168	-0.002919216
C34	122	118	107	3.092607	4	0.006969114	3	0.00538864	4.783452	-0.006969114
C45	118	114	103	3.212163	5	0.009273046	4	0.007785603	4.665735	-0.007391371
C56	114	104	91	3.479425	13	0.02261291	5	0.009335401	5.355447	-0.01714284

Note: C12: denotes years between census1 and census2, the same applies to other notations. Census 1 took place in 1987; N1: abundance in the first census; N2: abundance in the subsequent census; interval: time interval in years; little r: the rate of population change given by (log(N2)-log(N1))/time.

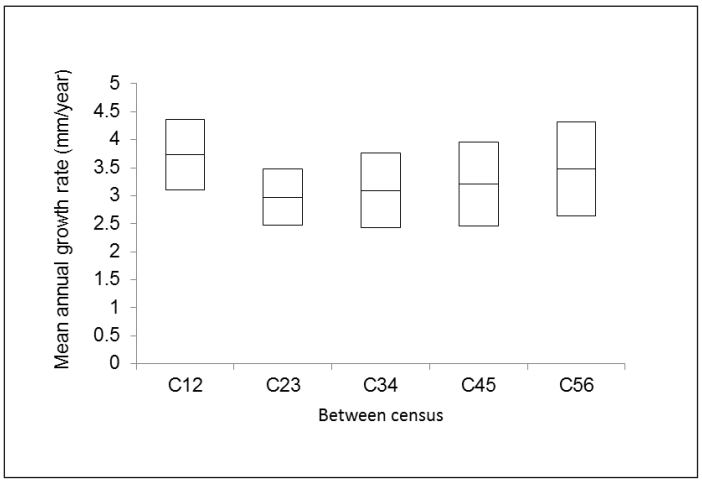


Fig. 3.2.1.1. Mean annual dbh increment rates for *Aquilaria malaccensis* population in S6. In each bar, the mid line is the mean while the upper and lower lines reflect the 95% confidence interval.

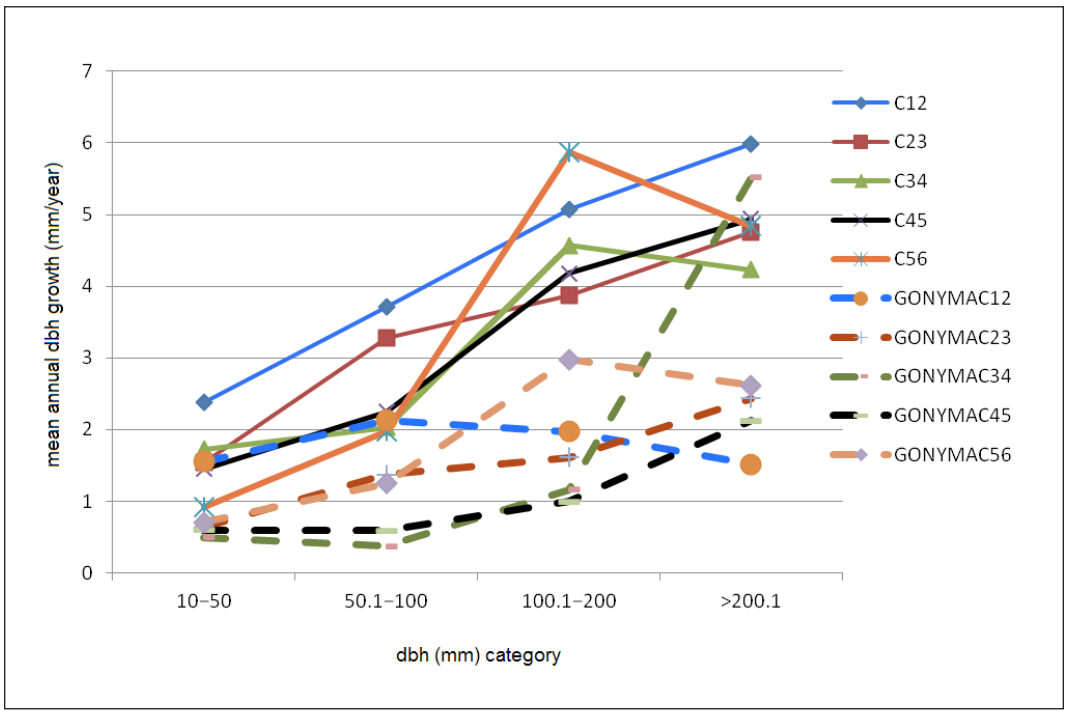


Fig. 3.2.1.2. Mean annual dbh growth (mm/year) between dbh categories for *Aquilaria malaccensis* and *Gonystylus maingayi*. Note that the large increase seen in GONYMAC34 could be partly due to the very large statistical error in that dataframe. GONYMA in all censuses has less than 6 individuals in the largest dbh category available for analysis.

The rate of population change, calculated on the basis of abundance, has been on a decline since 1987 (Fig. 3.2.1.3). The lowest rate was seen between Census 5 (2005) and 6 (2010) and this was due to a mortality rate that had more than doubled from the previous census (Table 3.2.1.1, Fig. 3.2.1.4). Since 1987, the mean annual mortality rate has been consistently higher than the recruitment rate in the population. Rates for mortality and recruitment fluctuated during the 23-year period but generally both appeared to show a similar trend (Fig. 3.2.1.5). Mortality was highest in the small-sized class (Fig. 3.2.1.6) while remaining stable in the mid-sized class but decreased in the largest size class. This explains why the abundance of smaller dbh trees had dropped since 1987 (Fig. 3.2.1.7). These combined factors have led to a decline in the rate of population change. Soehartono & Newton (2001a) indicated that populations under study in West and East Kalimantan were likely to increase in the future in the absence of disturbance but results here show otherwise. This may be due to the short period of assessment and limited sample sizes used in their assessment.

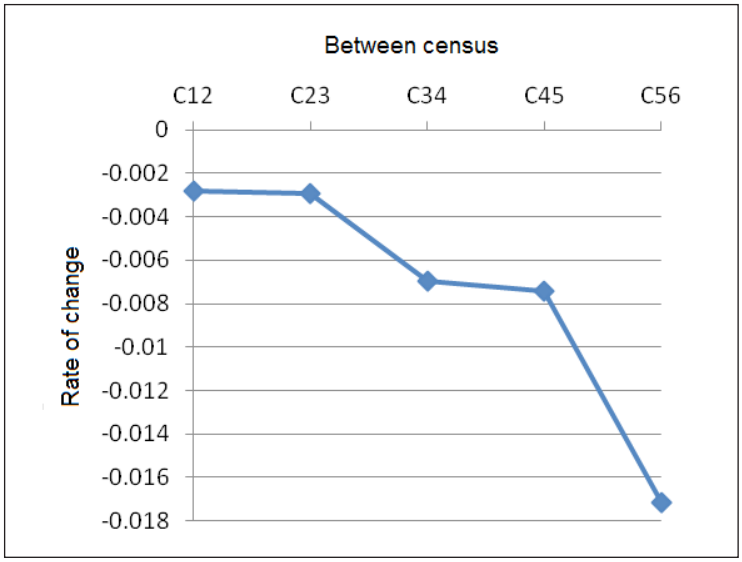


Fig.3.2.1.3. Rate of *Aquilaria malaccensis* population change between censuses at S6.

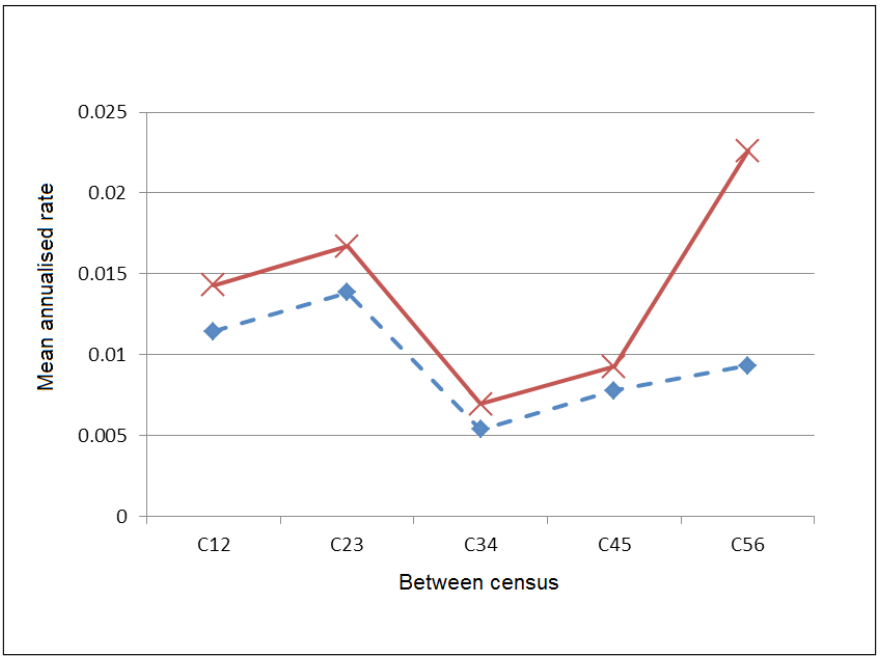


Fig. 3.2.1.4. Mean annual recruitment and mortality rates of *Aquilaria malaccensis* in S6. Solid and dashed lines indicate mortality and recruitment respectively.

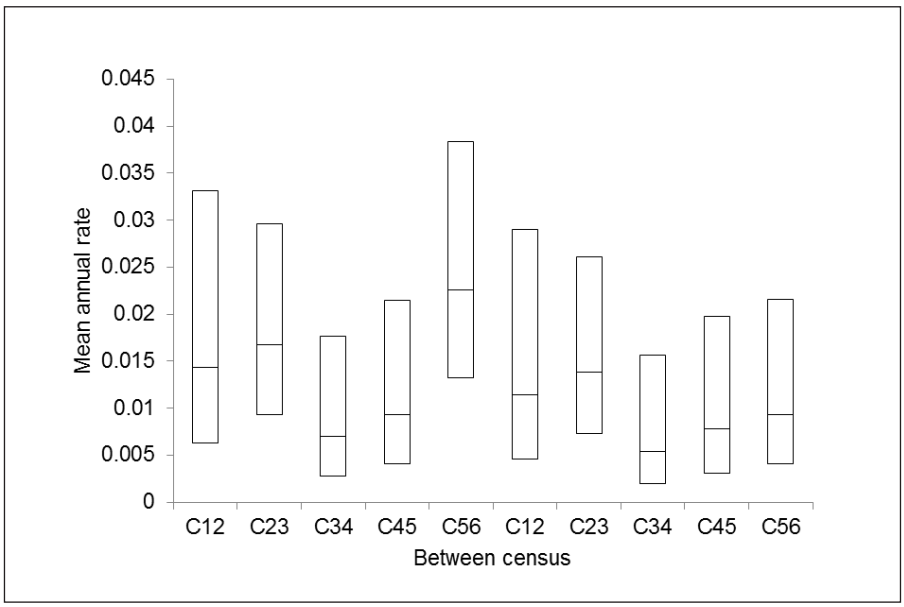


Fig. 3.2.1.5. Mean annual mortality and recruitment rates for *Aquilaria malaccensis* population in S6. The line in the bar is the mean. The left 5 bars indicate mortality, the remaining 5 are for recruitment. Y axis applies to both mortality rate (number of dead stems/year) and recruitment rate (no. of recruits/ year).

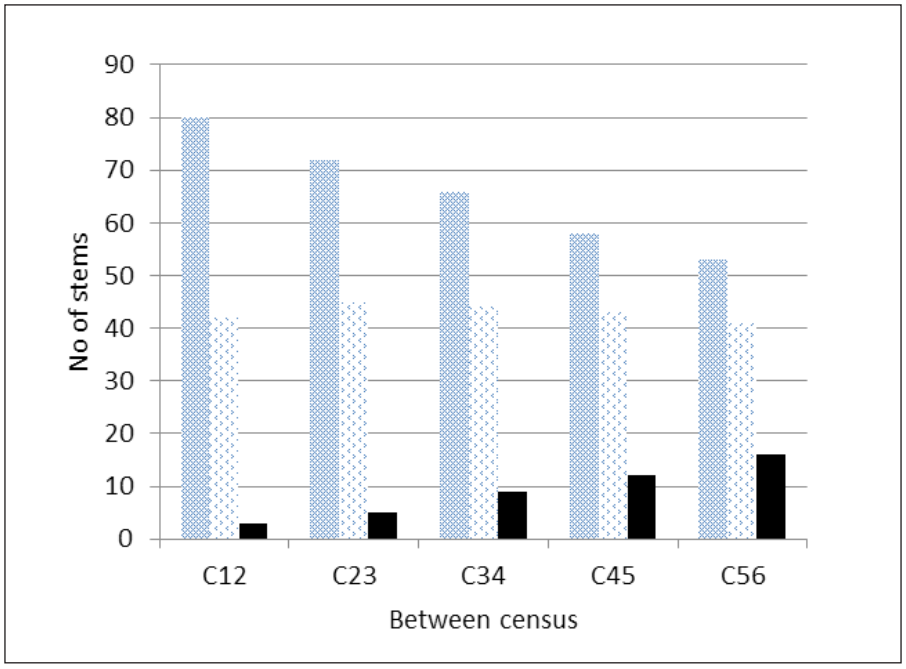


Fig. 3.2.1.6. Change in the abundance of *Aquilaria malaccensis* trees by dbh category in S6 from 1987 to 2010. Closed bars, well-spaced dotted bars and solid bars indicate 10–99 mm, 100–299 mm and greater than 300 mm dbh category.

Fig. 3.2.1.7. shows the frequency of the dbh distribution of the S6 population in 1987 (A, B) and 2010 (C, D). Both distributions have the inverse-J curve and the distribution in 2010 has become flatter compared to that in 1987.

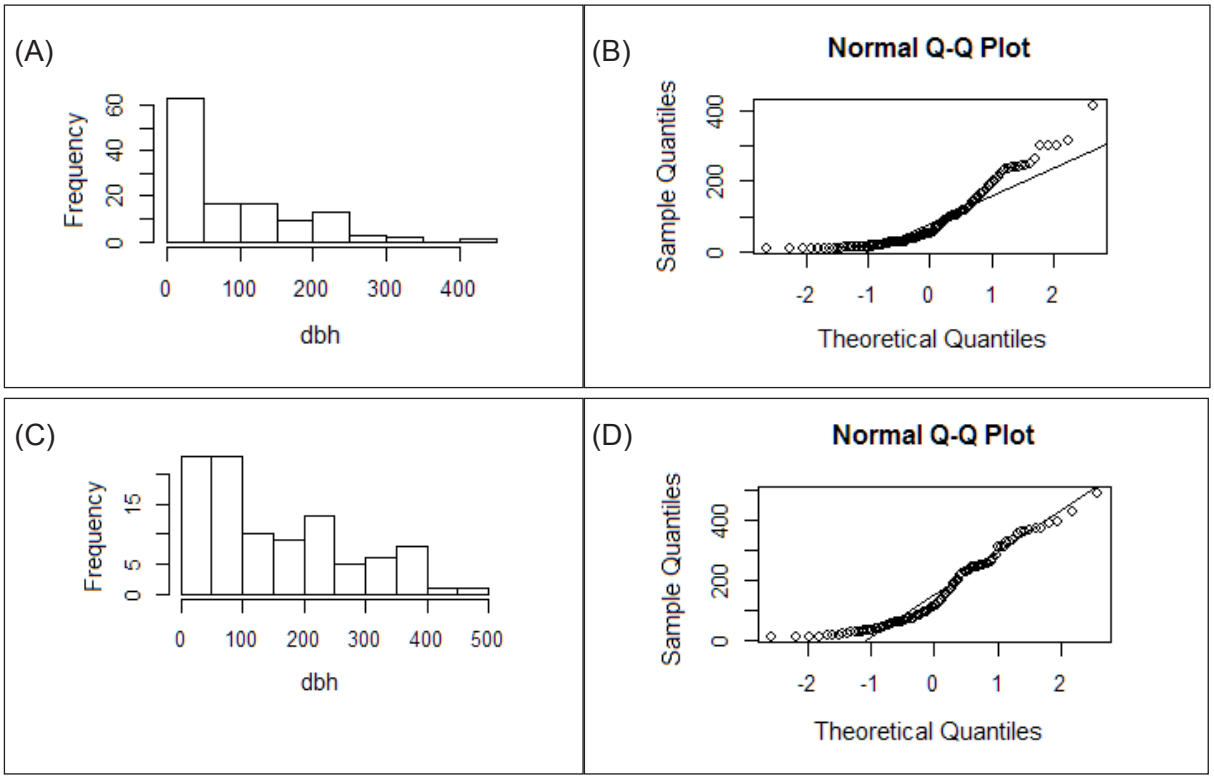


Fig. 3.2.1.7. Frequency distribution and departure from normality for S6 *Aquilaria malaccensis* population in 1987 (A, B) and 2010 (C, D).

Demographic information from growth, recruitment and mortality in S6 projects that the future population change of *A. malaccensis* will continue to decline. The lower recruitment rate and the higher growth rate exhibited by larger individuals partly explain the shift to a flatter distribution curve between 1987 and 2010. Also, future population change would be influenced more by the growth rate of larger trees compared to smaller juveniles and therefore harvest of larger trees could potentially result in a steeper decline. The inter-annual variability in recruitment and mortality rates is also expected to persist, following predictions by Metz *et al*. (2008) as the species is supra-annual (see section 3.3). Condit *et al*. (1998) speculated that juvenile growth would be the strongest predictor of size distribution but this is not reflected in the S6 population. This non-conformity is not unexpected given the large inter-specific variations in life history traits and strategies of the species covered in their study, and the interaction with the highly heterogenous physical environment (see also King *et al*. 2006).

The low growth rate in the smallest dbh category implies that juveniles are likely to stay in this category for a longer period of time. Because of this longer period, their survival strategies remain limited and they become more vulnerable to predation and environmental stochastic processes (Green *et al*. 2015).

3.2.2 Abundance

Fig. 3.2.2.1 shows the stocking of *A. malaccensis* and *A. hirta* in the natural forests based on their AOO. The greatest loss took place between the years 1993 and 2004; in 2004 the genus was listed in the CITES Appendix II. Using the reproductive threshold dbh of 145 mm established by this study, there was a potential loss of 89% of mature individuals in its geographical range in the peninsula between those years. This partly explains the drastic decline in recruitment into the higher size classes and hence the sharp drop in all size classes registered in the intervening years between 1993−2004. There is no significant change in the frequency of the 2013 size class distribution; in this inventory, no trees above 55 cm dbh were recorded in the sample plots. Additionally, the characteristic decreasing exponential curve associated with a thriving tropical plant population that was present in 1993 had become linear. This result corroborates the result from S6. A point of caution to be noted here is that bearing in mind that *karas* has a regular distribution, this apparent decline could have been influenced by the size and location of the plots that did not capture an adequate representation of the existing *karas* populations.

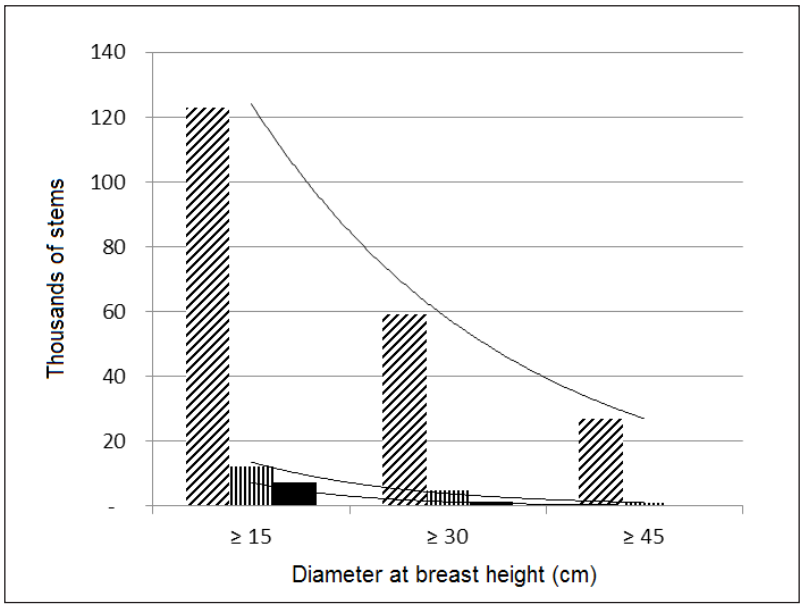


Fig. 3.2.2.1. Stocking of *Aquilaria malaccensis* and *A. hirta* in 1993, 2004 and 2013 in Permanent Reserved Forests in Peninsular Malaysia based on AOO. Slash, vertical and solid bars indicate 1993, 2004 and 2013 stocking respectively.

The IHN5 results suggest that the distribution of mature trees must now be more scattered than previously recorded. Many merchantable trees may already have been injured if not lost by now. Although harvesters traditionally do not target smaller diameter trees as they perceive that the amount of impregnated wood would be too small, the lucrative demand has begun to push this self-imposed threshold size even lower. In fact, this has been reported as far back as 2000 by Barden *et al*. (2000) and at the local scale, there has been abundant evidence of harvest of smaller trees (foresters and rangers from various state Forest Departments, Jutta, M. & Lee, S.L., pers. comm.). The notion that low density and scattered distribution

are a hindrance to collection efforts (LaFrankie 1994) was dispelled during communication exchanges with collectors (Mohd. Noor, pers. comm.). Indiscriminate harvesting is aided by forest fragmentation which increases accessibility and opportunities for harvesting. The ability of younger individuals to reproduce early and to produce more seeds (Soehartono & Newton 2001b) is insufficient to offset the negative impacts of indiscriminate harvesting. In face of harvesting pressure, every tree is likely to have a very short reproductive lifecycle.

3.3 Flowering phenology

Aquilaria malaccensis populations in Perak and Penang Island flowered annually during the period 2011 to 2015. The flowering intensity however varied between years and sites. During this period, masting in these states occurred once, in 2014 (Fig. 3.3.1) (Lau 2015). Generally, flowering and fruiting episodes occurred earlier in the Penang populations, i.e., between February/March to June/July while flowering took place later in August/September to December/January in Perak. In the 2014 masting year however, populations in both states flowered simultaneously. *Aquilaria malaccensis* clearly exhibits a supra-annual flowering behaviour.

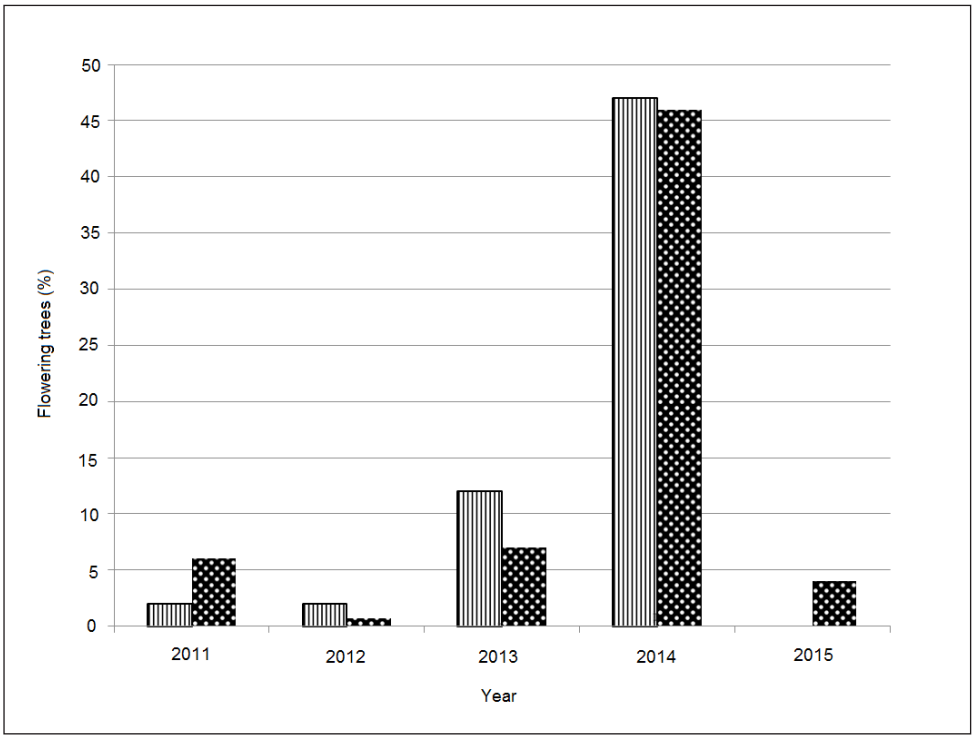
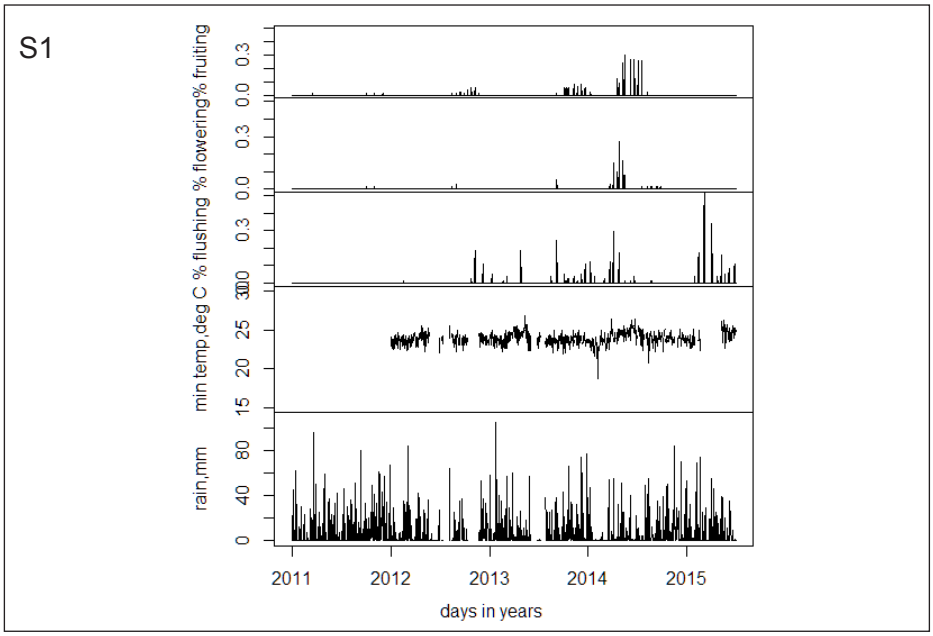
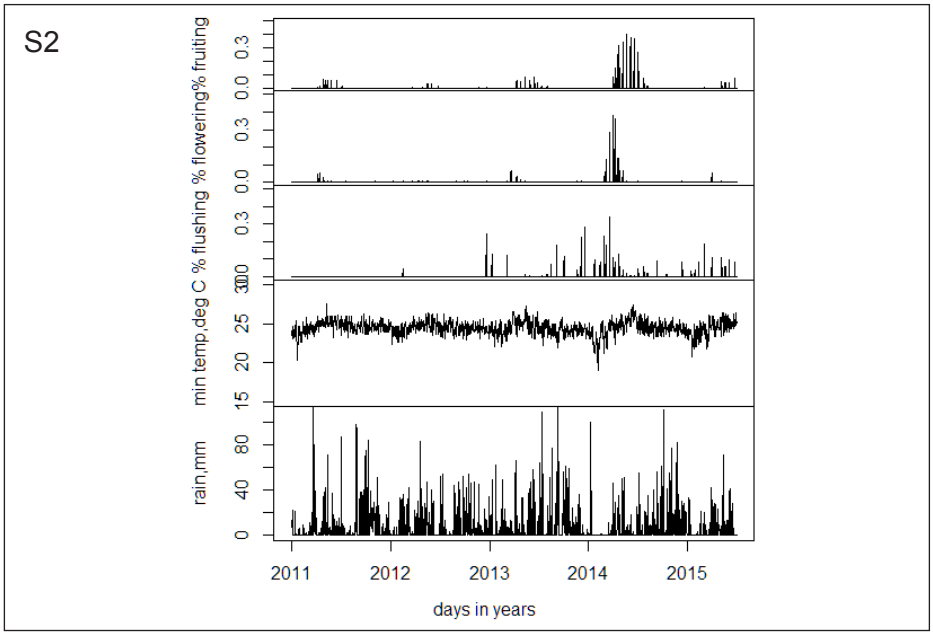


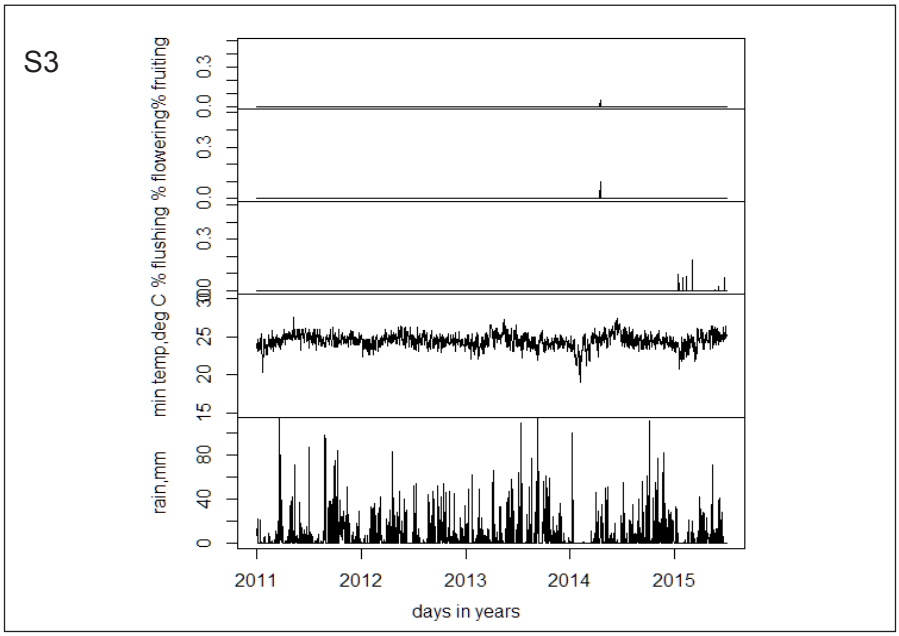
Fig. 3.3.1. Flowering intensity in the observed *Aquilaria malaccensis* populations during the period 2011 to 2015. Vertical and dotted bars indicate Perak and Penang Island respectively

The masting event in the S1 population (beginning 21 March 2014) occurred after a distinct drop in minimum temperature two months before (23 January) and in S2 populations (25 February 2014) after a similar distinct drop one month before (21 January); both temperature

drops occurred during a short spell of drought (Fig. 3.3.2). Populations in S3, S4 and S5 however did not respond similarly and this may be due to the smaller number of samples observed. Not all occurrences of a distinct drop in minimum temperature during a drought produced masting, for example, such an event that happened in S2 in early 2011 did not produce a masting event there. Beginning 2013 flushing occurred regularly in S1 and S2. The masting event of 2014, as well as other sporadic flowering events also coincided with the flushing events at these sites (Fig. 3.3.2). It appears that flowering may coincide with leaf flush, hence leaf flushing may be used as an indicator of flowering. Flushes may occur with or without senescence of the older foliage.






S3
rain,mm
min temp,deg C
% flushing
% flowering
% fruiting
0
40
80
15
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0.0
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2011
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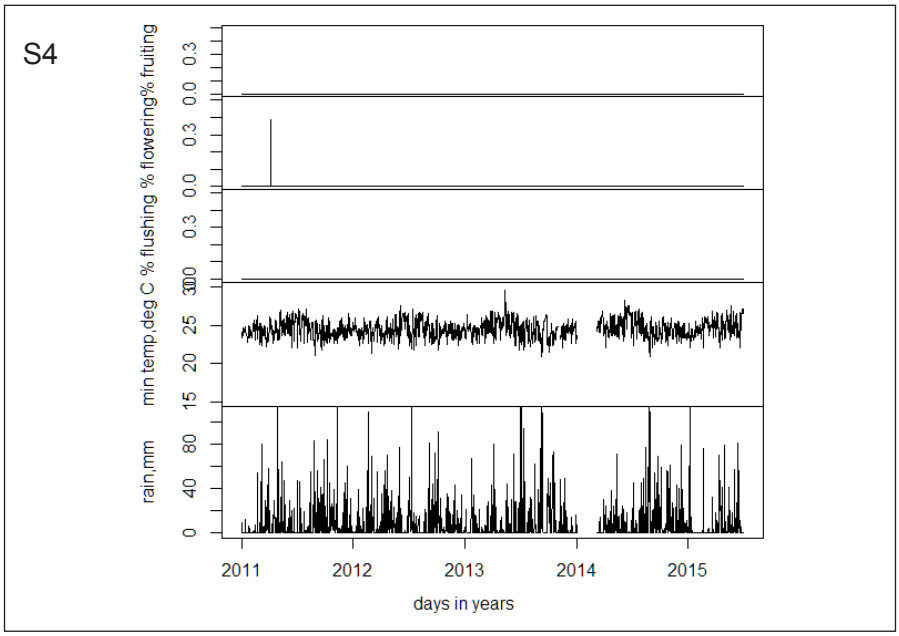
2013
2014
2015
days in years


S4
rain,mm
min temp,deg C
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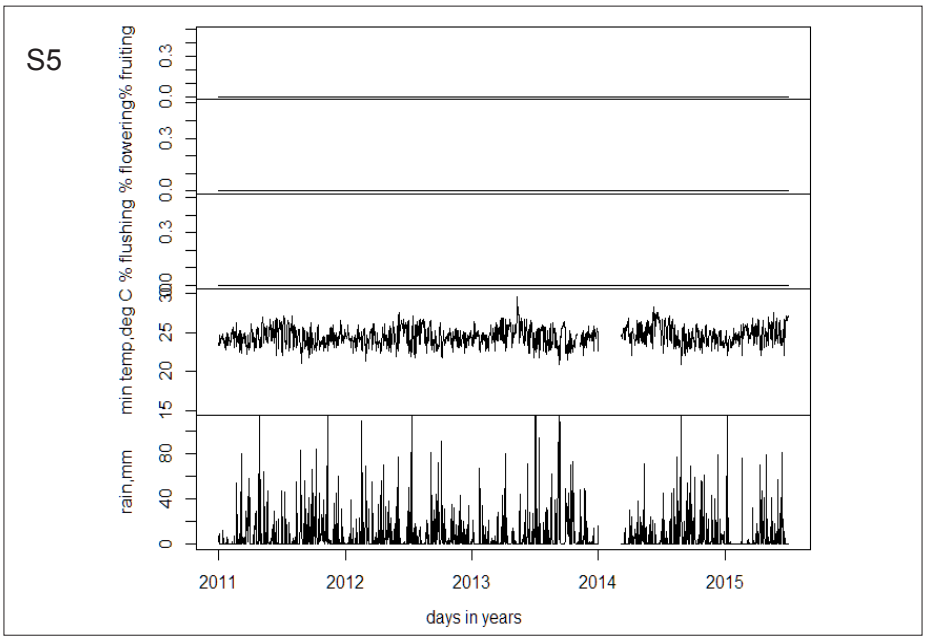

Fig. 3.3.2. Flushing, flowering and fruiting phenology of the *Aquilaria malaccensis* populations in relation to daily rainfall and minimum temperature at the five sites, S1–S5.

3.4 Floral and fruit biology

The complete reproductive cycle from flower initiation to mature fruit fall usually lasts up to four months with flowering lasting about two months. In an inflorescence, the duration from budding to first flower opening is between one to two weeks. The complete reproductive cycle from flower initiation to mature fruit fall usually lasts up to four months with flowering lasting about two months. In an inflorescence, the duration from budding to first flower opening is between one to two weeks. The inflorescences of *A. malaccensis* are axillary, supra-axillary or terminal, sometimes borne at internodes and can be sessile or short-peduncled (Fig. 3.4.1A, B). Each inflorescence bears between 10 and 20 flowers. Flowers are campanulate, green to dirty yellow, 5-6 mm long, hermaphroditic, pedicelled, filaments short or filiform, stigma distinct, globose, capitate, pyramidal or oblong (Fig. 3.4.1C). Bud development takes about one week. The flower usually opens in the late evening between 3.00–7.00 pm. On average, a flower takes about 40 minutes to fully open (Fig. 3.4.1D). The anther is already at anthesis upon opening (Fig. 3.4.1E). Approximately two hours later, the stigma becomes receptive and this lasts for about 16 hours providing plenty of opportunity for pollen arrival. Anthers turn dark, indicating end of viability, approximately 24 hours later (Fig. 3.4.1E). These observations suggest that the flower of *A. malaccensis* is protandrous but because of the long overlap in anther dehiscence and stigma receptivity periods, there is a potential for selfing and this possibility is supported by isoenzyme results (Norwati 2000). Successful pollination is exhibited by the formation of young fruits (Fig. 3.4.1F) and a fully matured fruit can grow to a size of 3-4 x 2.5 cm (Fig. 3.4.1G).

Fig. 3.4.1. Floral and fruit biology of *Aquilaria malaccensis*. (A) The beginning of flowering usually coincides with leaf flush; (B) Young floral buds at the terminal shoot; (C) An inflorescence bears between 10 to 20 individual flowers; (D) A flower beginning to open; (E) Yellow anthers from a newly opened flower (left) and dark anthers in one that has reached senescence (right); (F) Very young fruits; (G) An almost fully developed fruit.

Twenty five and 29 insect specimens were collected from S1 and S2, respectively. Flowers in S1 and S2 were each visited by insects from at least four families (Annex 3). Table 3.4.1 lists specimens that had been identified to genus and species levels. The peak insect visitation periods for flowers in S1 and S2 were almost similar—in S1, these was between 21:00−01:00 and 11:00−15:00 and in S2, between 20:00−0.00 and 08:00−12:00. The night time peak period coincided with stigma receptivity and therefore insects visiting during that period may be considered as potential pollinators. There is apparently no overlap in species between S1 and S2 but further work is required to support this observation.

Table 3.4.1. The species and number of insects visiting *Aquilaria malaccensis* flowers in S1 and S2.

Order/Family	Species	Site	No. specimen(s)
Erebidae: Erebinae	*Oxyodes scrobiculata*	1	1
Hymenoptera: Vespidae	*Provespa* sp.	1	2
Diptera: Tabanidae	*Chrysops* sp.	1	5
Hymenoptera: Halictidae	*Patellapis* (*Pachyhalictus*) sp.	1	1
Hymenoptera: Apidae	*Trigona* (*Lepidotrigona*) *terminata*	2	4
Hymenoptera: Apidae	*Trigona* (*Heterotrigona*) *itama*	2	2
Hymenoptera: Formicidae	*Gesomyrmex chaperi*	2	1
Hymenoptera: Crabronidae	*Trypoxylon* sp.	2	1
Thomisidae: Thomisinae	*Thomisus guangxicus*	2	3

Fruits began to develop before the flowering phase ended and a single fruit could take up to 1.5 months to mature. The whole fruiting period may last for 3 months. The fruits are 1−2 loculed, mostly one-seeded, globose-obovoid or oblanceolate, rugose or smooth, puberulous to glabrous, to 3−4 x 2.5 cm (Fig. 3.4.1G). The fruits split loculicidally on the tree upon maturity and seeds are dispersed by gravity. The seeds are recalcitrant and germinate almost immediately but at low percentages (<19.4%).

During the 2014 masting event, abortion of both flowers and fruits occurred with flowers aborted before being fertilized and fruits aborted either due to damage or failure to develop (Table 3.4.2 and Fig. 3.4.2). Flower abortion rates were very high at 98.4% for tree AM267 and 97.2% for tree AM186. However, mature fruit production was significantly higher in tree AM267 compared to tree AM186. Based on the estimated floral load, the abortion rate for tree AM267 is 99% and tree AM186 is 99.5% (Table 3.4.2). More samples from different mother trees will be collected in the future to verify these data.

Table 3.4.2. Estimated number of aborted flowers, aborted and mature fruits and abortion rate for tree AM267 and tree AM186 during the 2014 masting event.

Tree	Floral load (%)	No. aborted flowers (%)	No. aborted fruits[1] (%)	No. mature fruits[2] (%)	No. mature seeds[3]	Abortion rate (%)
AM267 (S2)	11,182,977 (100)	11,009,364 (98.4)	66,943 (0.6)	106,669 (0.95)	90,155	11,076,308 (99)
AM186 (S1)	4,850,673 (100)	4,715,901 (97.2)	108,292 (2.2)	26,479 (0.55)	21,298	4,824,194 (99.5)

1: aborted fruits are immature whole fruits with or without signs of damage and dehisced capsules with signs of damage; 2: mature fruits successfully dehisced without signs of damage; and 3: actual number collected. We assumed that all non-aborted flowers developed into fruits.

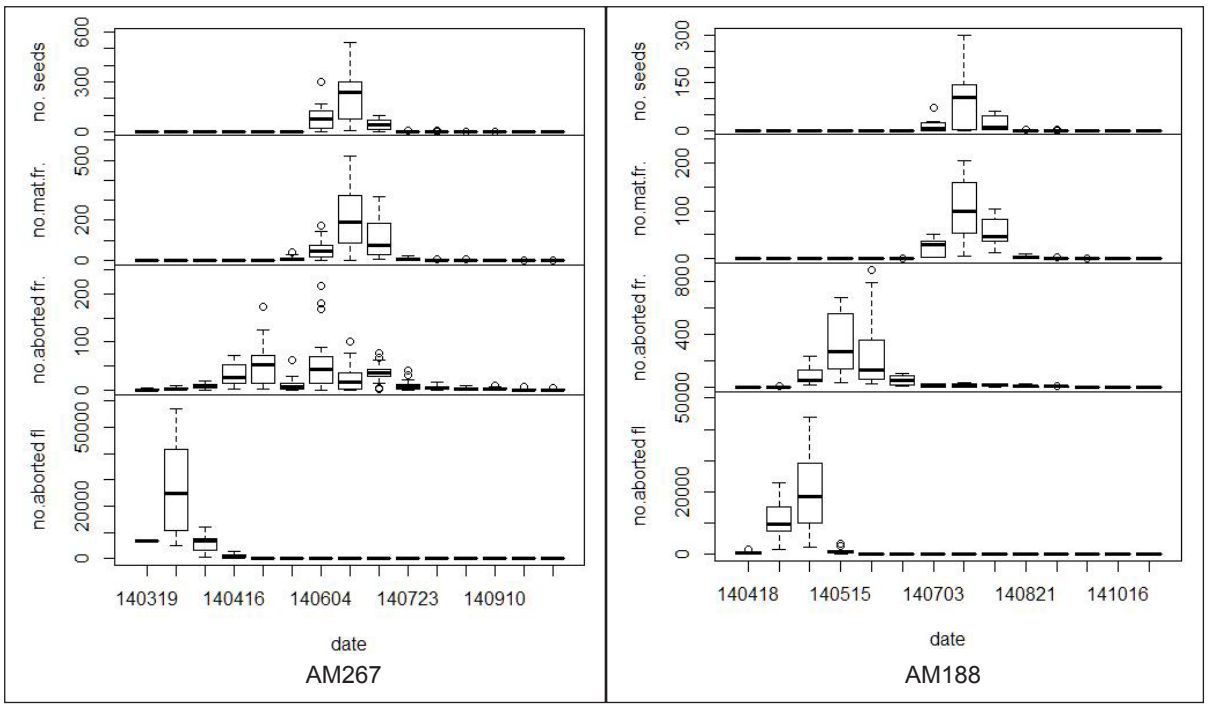

Fig. 3.4.2. Estimated numbers of aborted and mature flowers, fruits and seeds produced by tree AM267 and tree AM186 during the 2014 masting season.

Small mammals, mainly *Macaca fascicularis* (Cercopithecidae), *Ratufa bicolor* (Sciuridae) and *Callosciurus prevostii* (Sciuridae) predated the inflorescences and infructescences while insects such as *Heortia vitessoides* (Crambidae), *Pitama hermesalis* (Crambidae), *Zeuzera* sp. (Cossidae), scale insects of the family Diaspididae and whiteflies (Aleyrodidae) predated leaves, stems and also young fruits (Annex 3).

No reproductive ecology observations were conducted on the S6 population but based on the behaviour shown by the S1 and S2 populations, we speculate that the downward trend seen in the rate of population change was most likely influenced by traits associated with fecundity. The high floral abortion rate during a masting event and the supra-annual flowering behaviour also indicate low resilience of the species to harvesting impacts.

3.5 Genetic diversity

3.5.1 Genetic diversity within and among populations

Based on the 942 samples collected throughout Peninsular Malaysia and 12 microsatellite loci, a total of 159 alleles were detected. At the population level, the study revealed high levels of genetic diversity in *A. malaccensis* (Table 3.5.1.1). The mean number of alleles (A_a) was 5.414, ranging from 3.333 (Batu Papan) to 8.000 (Sungai Udang) whereas the mean expected heterozygosity (H_e) was 0.537, ranging from 0.447 (Batu Papan) to 0.642 (Lenggor). Based on microsatellite analysis, the H_e was high and comparable with other tropical trees such as its restricted congeners *Gonystylus bancanus* (0.691, Nurul-Farhanah 2014), *Swietenia macrophylla* (0.657, Novick *et al.* 2003) and *Santalum austrocaledonicum* (0.660, Bottin *et al.* 2005), and various dipterocarps such as *Shorea lumutensis* (0.648, Lee *et al.* 2006) and *S. ovalis* (0.640, Ng *et al.* 2004). However, the H_e was lower when compared with *Koompassia malaccensis* (0.798, Lee *et al.* 2008) and *Shorea curtisii* (0.790, Ng *et al.* 2006).

Rare alleles were detected in most of the *A. malaccensis* populations except in Kledang Saiong, Pelangai and Lentang. The highest number of rare alleles was found in Bukit Lagong and Panti (0.506 respectively). A total of 15 private alleles were detected across all loci (Table 3.5.1.1). Out of the 35 populations sampled, private alleles were detected only in 11 populations. The highest number of private alleles was found in Lenggor (4) followed by Nenggiri (2). This might indicate that these four populations harbour some unique genetic characteristics and should receive additional attention for conservation purposes.

The study also showed that Lenggor exhibited significant positive value of fixation index ($F$is = 0.183, $p < 0.05$; Table 3.5.1.1), an indication of excess of homozygotes, which might indicate depression due to inbreeding. Inbreeding causes the loss of heterozygosity with no change in allele frequencies, because continuous selfing will purge the deleterious recessive alleles and expose them as homozygotes to the environment. It is generally agreed that inbreeding is associated with increased seed abortion, low germination rates, high seedling mortality, and poor growth and flowering of the offspring. Thus, the priority management prescriptions should try to enlarge the Lenggor population to minimize inbreeding depression due to small population size.

Table 3.5.1.1. Gene diversity parameters of *Aquilaria malaccensis* throughout Malaysia, including mean number of alleles per locus (A_a), allelic richness (R_s), observed (H_o) and expected heterozyosity (H_e; Nei 1987), fixation index (F_{is}), number of rare alleles per individual and private alleles. Values in parentheses denote standard deviation.

Population	A_a	R_s	H_o	H_e	F_{IS}	Rare allele	Private allele
1. Machincang	5.083 (2.353)	3.822	0.614 (0.032)	0.596 (0.075)	-0.030	0.131	0
2. Lubuk Semilang	4.167 (2.290)	3.333	0.500 (0.035)	0.534 (0.078)	0.066	0.140	0
3. Bukit Malut	4.333 (2.640)	3.230	0.459 (0.031)	0.509 (0.078)	0.102	0.269	0
4. Bukit Perangin	5.667 (3.393)	3.818	0.548 (0.025)	0.554 (0.092)	0.010	0.294	1
5. Gunung Jerai	4.750 (2.701)	3.725	0.625 (0.035)	0.580 (0.080)	-0.081	0.158	0
6. Gunung Inas	4.417 (2.429)	3.666	0.568 (0.043)	0.549 (0.087)	-0.037	0.302	0
7. Gunung Bongsu	4.417 (2.275)	3.508	0.536 (0.036)	0.532 (0.085)	-0.009	0.189	1
8. Penang National Park	5.167 (2.691)	3.611	0.576 (0.029)	0.575 (0.070)	-0.002	0.306	0
9. Bukit Kerajaan	6.333 (4.163)	3.679	0.575 (0.019)	0.554 (0.079)	-0.039	0.447	1
10. Gunung Semanggol	4.750 (2.896)	3.263	0.523 (0.025)	0.516 (0.079)	-0.015	0.316	0
11. Bubu	5.167 (3.129)	3.551	0.514 (0.030)	0.526 (0.083)	0.022	0.355	0
12. Kledang Saiong	3.667 (2.348)	3.479	0.536 (0.054)	0.492 (0.085)	-0.098	0.000	0
13. UTP	6.833 (5.391)	4.099	0.585 (0.025)	0.571 (0.091)	-0.025	0.415	0
14. Bukit Tapah	5.167 (3.512)	2.972	0.505 (0.024)	0.467 (0.088)	-0.081	0.484	0
15. Bukit Lagong	7.083 (5.435)	3.865	0.531 (0.024)	0.534 (0.089)	0.005	0.506	0
16. Mont Kiara	6.667 (4.942)	3.929	0.560 (0.023)	0.565 (0.091)	0.009	0.375	0
17. Pelangai	3.750 (2.633)	3.248	0.461 (0.049)	0.458 (0.096)	-0.006	0.000	0
18. Pasir Panjang	5.583 (3.801)	3.732	0.554 (0.032)	0.531 (0.092)	-0.044	0.284	0
19. Solok Duku	6.833 (5.306)	3.888	0.525 (0.023)	0.538 (0.091)	0.025	0.378	1
20. Sungai Udang	8.000 (5.752)	3.987	0.528 (0.019)	0.537 (0.090)	0.017	0.490	1
21. Paya Rumput	5.417 (3.753)	3.705	0.586 (0.024)	0.543 (0.085)	-0.079	0.277	1
22. Maokil	6.417 (5.178)	3.890	0.514 (0.027)	0.529 (0.092)	0.029	0.338	1
23. Panti	6.750 (5.396)	3.627	0.544 (0.018)	0.538 (0.083)	-0.011	0.506	1
24. Lenggor	5.417 (3.175)	4.508	0.530 (0.044)	0.642 (0.083)	0.183*	0.108	4
25. Lentang	3.750 (2.221)	3.621	0.548 (0.055)	0.516 (0.102)	-0.066	0.000	0
26. Som	5.417 (3.605)	3.847	0.560 (0.036)	0.542 (0.087)	-0.034	0.292	1
27. Tekai-Tembeling	5.250 (3.415)	3.399	0.542 (0.032)	0.492 (0.090)	-0.105	0.349	0
28. Berkelah	6.167 (4.174)	3.753	0.561 (0.030)	0.535 (0.089)	-0.049	0.459	0
29. Beserah	5.500 (3.477)	3.798	0.600 (0.028)	0.590 (0.075)	-0.016	0.333	0
30. Merchang	6.083 (3.777)	3.577	0.494 (0.025)	0.527 (0.082)	0.065	0.452	0
31. Gunung Tebu	6.250 (3.934)	3.856	0.567 (0.026)	0.550 (0.091)	-0.031	0.440	0
32. Chabang Tongkat	6.167 (3.786)	3.724	0.547 (0.021)	0.541 (0.085)	-0.011	0.365	0
33. Jeli	4.500 (2.393)	3.744	0.520 (0.044)	0.553 (0.091)	0.063	0.259	0
34. Nenggiri	5.250 (3.841)	3.701	0.539 (0.035)	0.545 (0.092)	0.010	0.222	2
35. Batu Papan	3.333 (2.015)	2.643	0.508 (0.031)	0.447 (0.087)	-0.140	0.275	0
Mean	5.414 (3.549)	3.651	0.542 (0.031)	0.537 (0.086)	-0.012	0.300	-

*p = 0.05

The levels of genetic diversity of a plant species can be attributed to the species' life history traits, in particularly its reproductive system. However, comprehensive studies on the breeding process of *A. malaccensis* are still lacking. Investigations of its reproductive biology revealed that *Aquilaria* species are insect-pollinated and obligate outcrossers with generally high seed production but limited seed dispersal (Soehartono & Newton 2001b). The *A. malaccensis* flower structure is characterized as hermaphroditic. However, from the mating system study conducted by Norwati (2000) and as also shown here by its being insect-pollinated, we can conclude that *A. malaccensis* is predominantly an outcrosser. Thus, the high levels of genetic diversity observed in *A. malaccensis* might be attributed to the species' life history and ecological traits such as its longevity and its mixed-mating system.

The coefficient of population differentiation quantified using *F*-statistics showed that most of the total genetic diversity was partitioned within the population. The proportion of genetic diversity distributed among populations was estimated at 0.081, thus only 8.1% of the genetic variability was distributed among populations. In comparison with other tropical tree species (Hamrick *et al.* 1992), these values are comparable with the means for regionally distributed long-lived tree species (0.119), long-lived outcrossing animal pollinated tree species (0.099), long-lived tree species with seed dispersed by gravity (0.131), and long-lived tree species that reproduce sexually (0.086). Isolation-by-distance via Mantel's test showed that the pairwise F_{ST} values were significantly correlated with geographic distance ($r = 0.204$; $p < 0.01$). This may indicate that populations that live near each other are genetically more similar than the populations that live further apart.

Moderate levels of population differentiation and significant isolation-by-distance in *A. malaccensis* can be attributed to restricted gene flow due to inefficient pollen and seed dispersal. *Aquilaria malaccensis* is pollinated by low-energy insects (see results of this study). The species produces seed that hangs by a thread-like appendage from the fruit capsule after dehiscence and is dispersed mainly by gravity. However, recently, Manohara (2013) reported that the wasp, *Vespa affinis* L. could disperse *A. malaccensis* seeds up to 500 m from the parent tree. Even though the wasp mediated seed dispersal mechanism contributed only one-third to overall seed dispersal (Manohara 2013), it may probably still contribute to gene flow over longer distances. As *A. malaccensis* is widespread; it is likely that in the past the species was more widely distributed than it is today. Therefore, the gene flow between plants via seeds and/or pollen was probably more extensive and unhindered in the past before the populations become isolated. High genetic diversity and moderate population differentiation of *A. malaccensis* in Peninsular Malaysia can be attributed to limited gene flow due to inefficient pollen and seed dispersal or insufficient length of time for further differentiation of genetic diversity following a recent fragmentation of a once continuous genetic system.

3.5.2 Relatedness among populations

The relatedness among the populations was determined by using three approaches, i.e. cluster analysis based on D_A genetic distance, Principal Component Analysis (PCA) and STRUCTURE analysis. A dendrogram of D_A genetic distances derived by the neighbour-joining algorithm is shown in Fig. 3.5.2.1. In general, weak bootstrap support (< 60%) could be seen in most nodes except in two clusters, i.e., Lubuk Semilang/Bukit Malut/Machincang (99%) and Merchang/Gunung Tebu (62%). Nonetheless, the groupings separated Peninsular Malaysia into two geographic sub-regions: Cluster 1–Kedah, Penang and Perak; and Cluster 2–Kelantan, Terengganu, Pahang, Selangor Negeri Sembilan, Melaka and Johor.

In PCA 1, the first two axes (both axes were significant, $p < 0.01$) explained 35.14% of the total variation. As observed, populations from Cluster Kelantan-Johor were showed to be genetically distinctive from the Cluster Kedah-Perak, with Machincang, Lubuk Semilang and Bukit Malut shown to be further apart from the rest of the populations (Fig. 3.5.2.1). The PCA 2 generated two significant axes ($p < 0.01$) with 48.07% total variation and Machincang, Lubuk Semilang and Bukit Malut appeared to group into one island population, whereas Bukit Tapah was isolated from the rest of the populations (Fig. 3.5.2.2). In PCA 3, two significant axes ($p < 0.01$) with 30.80% total variation nevertheless could not reveal a clear separation among populations in Cluster Kelantan-Johor.

The STRUCTURE analysis together with STRUCTURE HARVESTER estimated the most likely number of clusters [LnP(D) or Ln(K)] based on Bayesian approach (Figs. 3.5.2.1 & 3.5.2.3). The highest likelihood was found when $K = 2$ was detected by the mean difference between successive likelihood values of K, L(K) plotted for each K. The maximum value of ΔK also revealed the real value of $K = 2$ (Fig. 3.5.2.3), further supporting that the most probable number of populations was two (Evanno *et al*. 2005).

As the cluster analysis partitioned the populations into two genetic clusters, corresponding to two geographical regions in Peninsular Malaysia (Fig. 3.5.4.1), these two regions should be considered independently for the selections of *in situ* conservation areas. *Aquilaria malaccensis* has 8.1% of the total genetic diversity residing among populations. Therefore, five strategically placed populations in each of the two regions should capture the majority of their total genetic diversity and *in situ* conservation of these populations is likely to be sufficient to prevent the species from becoming an endangered species.

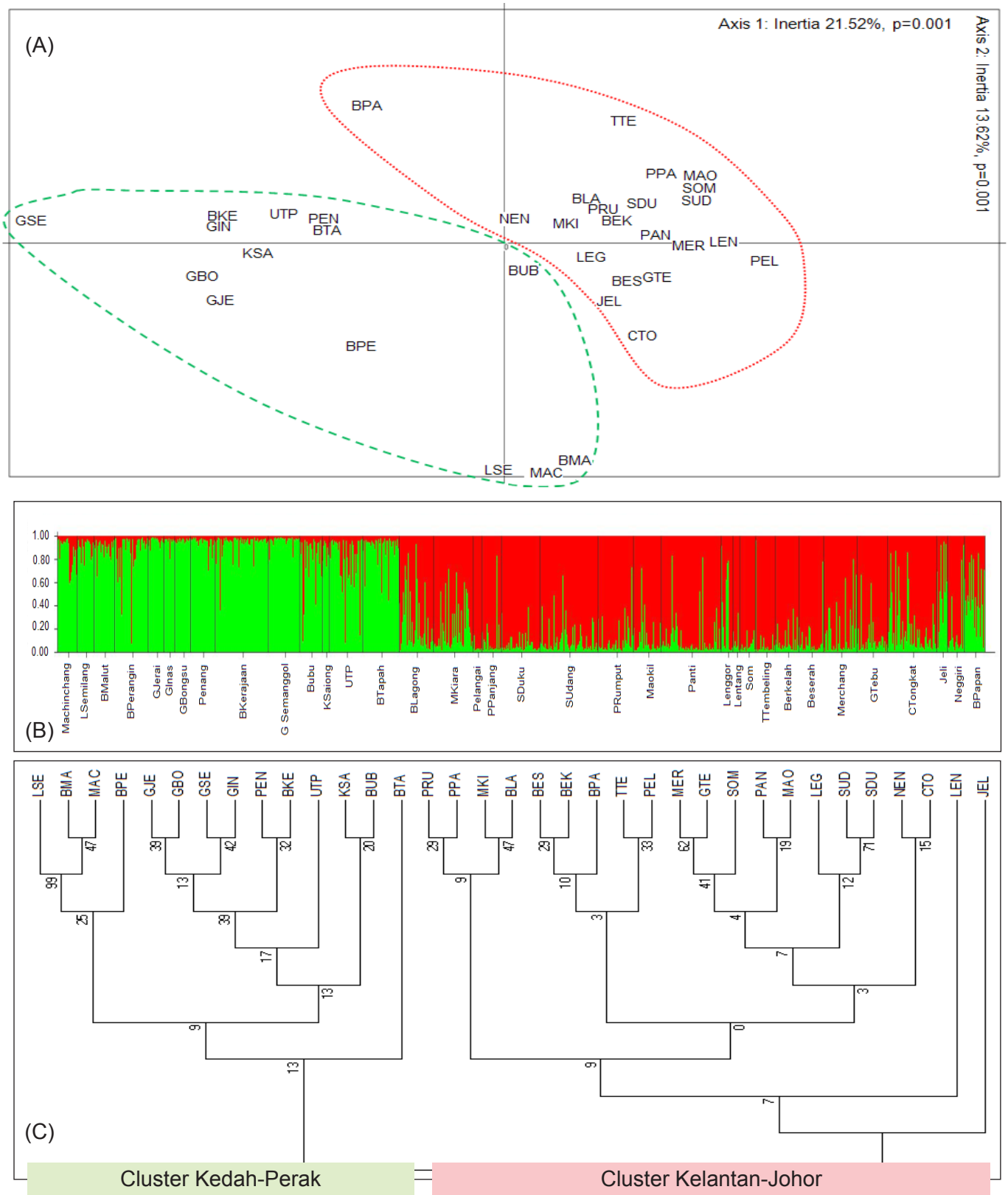

Fig. 3.5.2.1. Relationship among populations determined using (A) Principal Component Analysis; (B) Bayesian analysis via STRUCTURE; and (C) Dendogram based on genetic distance (D_A) derived using neighbour-joining algorithm. Nodes with 3000 replication bootstrap support.

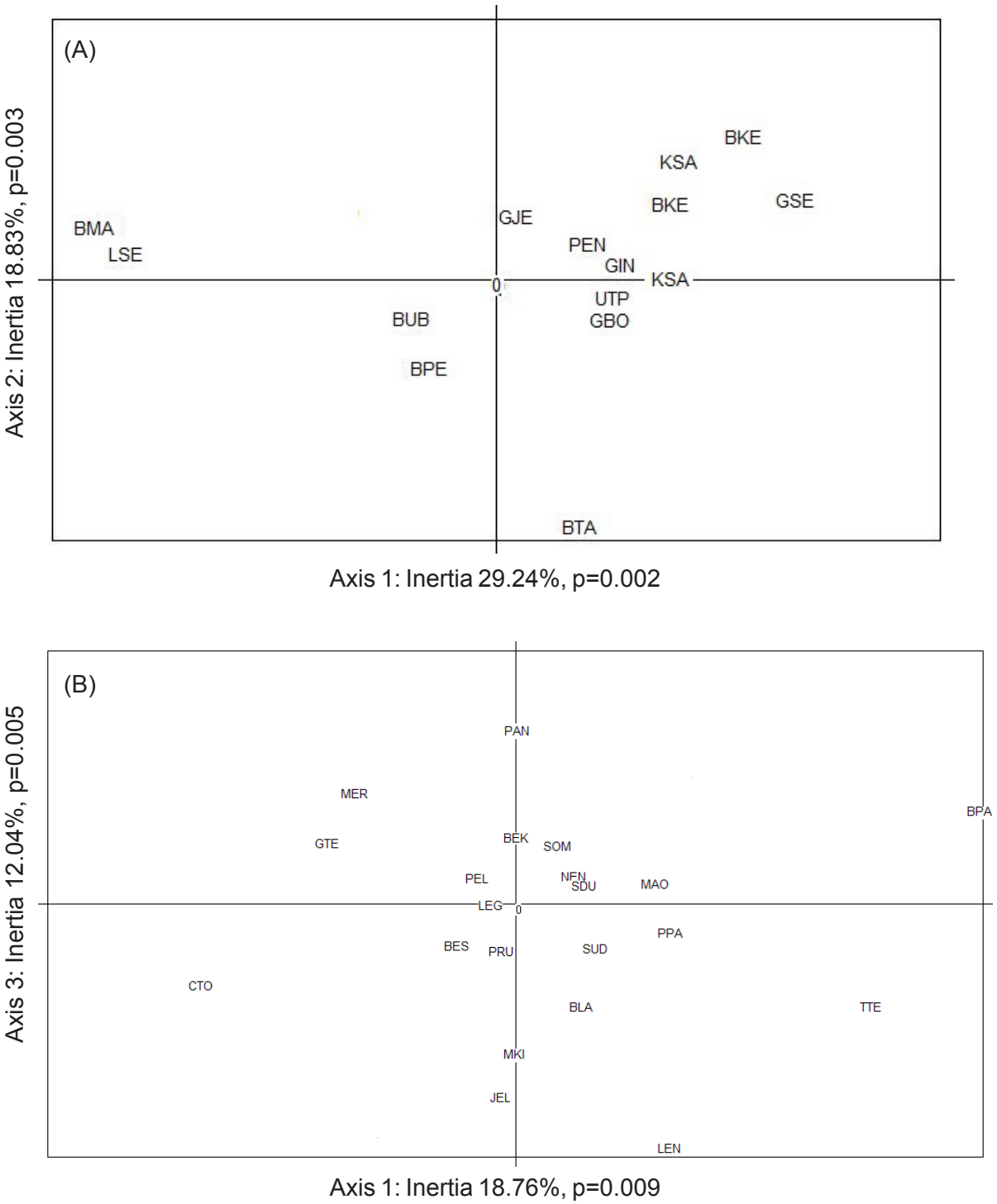

Fig. 3.5.2.2. Principal Component Analysis performed for (A) Cluster Kedah-Perak; and (B) Cluster Kelantan-Johor.

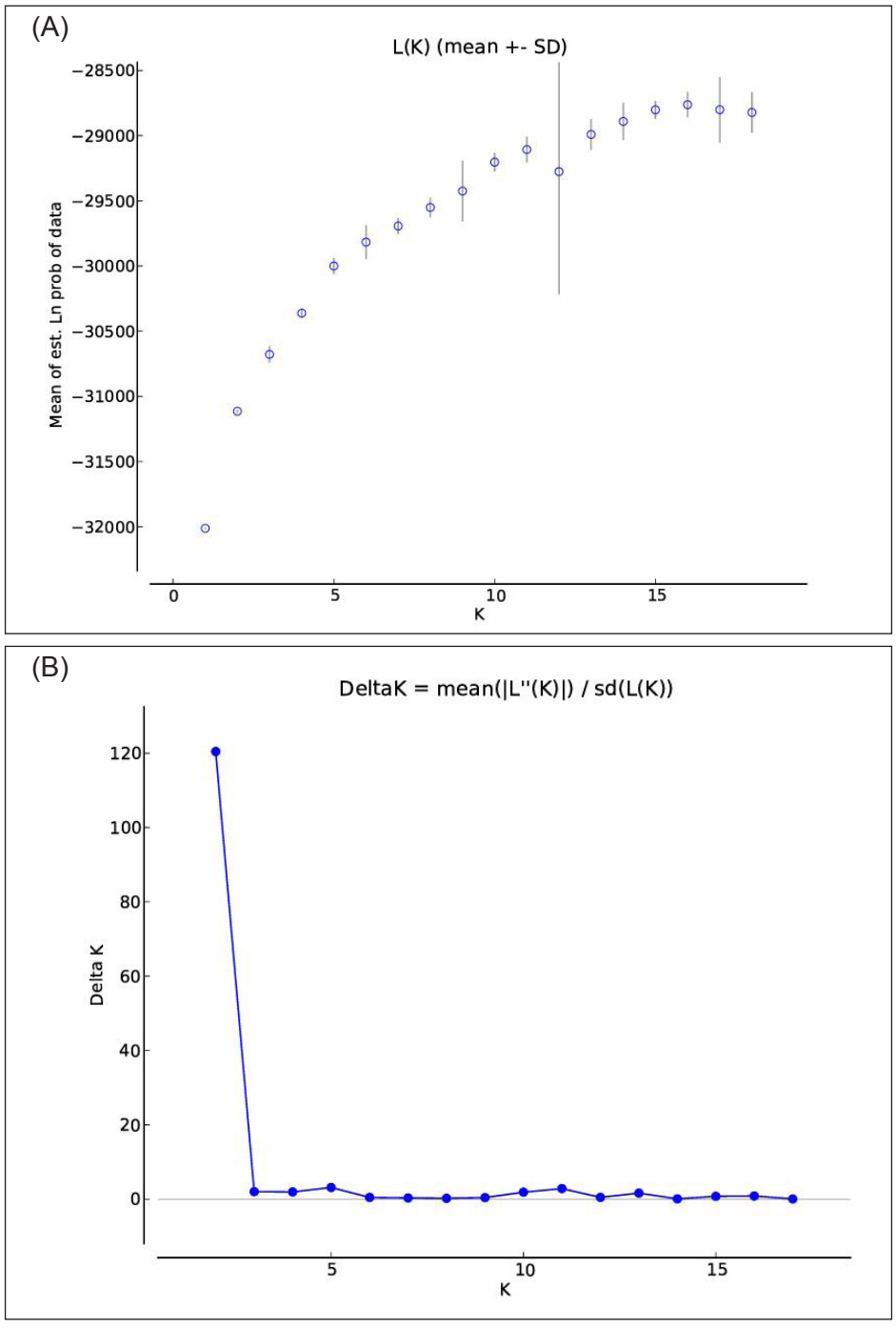

Fig. 3.5.2.3. Graphical plot of detection method for the true number of clusters *K* over 20 runs, 50 000 length of the burn-in and 100 000 MCMC respectively for each *K* value: (A) Mean L(K) (± SD) and (B) ΔK calculated as $\Delta K = m\left|L''(K)\right|/s[L(K)]$. The true number of *K* is 2.

3.5.3 Optimum population size

Fig. 3.5.3.1 shows the sample sizes plotted against percentage number of alleles with standard errors. Based on the simulation analysis using a computerized algorithm (in accordance with Lee *et al*. 2002), in order to maintain 95% of its genetic diversity, the optimum population size of *A. malaccensis* is postulated at 390 individuals with standard errors ranging from 250−550. This data is an important contribution to the species' conservation strategy.

3.5.4 Implications for conservation

Genetic information is essential to generate conservation guidelines and management of a species. The genetic data enable identification of prioritized populations for conservation (Petit *et al.* 1998; Melville & Burchett 2002), given that not all populations have equal adaptive capacities. There are three main objectives for preserving genetic resources; these are (i) to protect the potential adaptation of a species (Young & Boyle 2000; Krauss *et al*. 2002), (ii) to preserve current genetic structure as reference material for future comparison, and (iii) to save populations that are endangered from anthropogenic activities, directly or indirectly (Eriksson & Ekberg 2001; Finkeldey & Hattemer 2007). Hence, the establishment of *in situ* and *ex situ* conservation areas are as important as the sustainable utilization of natural forests (Cossalter 1989; Finkeldey & Hattemer 2007). In this study, the genetic information generated will be used to construct three main conservation and management guidelines for *A. malaccensis* in Peninsular Malaysia.

Guideline 1: *In situ* conservation of *A. malaccensis*

One of the criteria set for *in situ* conservation is the number of populations known to be sufficient to cover the maximum preservation of the species' gene pool and which populations to select (Prance 2006). Suitable representation and viability of important populations influence the effectiveness of genetic conservation (Thomson *et al.* 2001). For instance, selection of only a few populations of *Pinus palustris* would be needed to maintain most of its genetic diversity since it is a widespread and wind-dispersed species with high gene flow (Duba 1985). In contrast, all the populations of *Sarracenia leucophylla* might have to be conserved as it has a narrow distribution with restricted gene flow (Wang *et al.* 2004).

In the present study, since the cluster analyses partitioned the populations into two genetic clusters (Fig. 3.5.4.1) corresponding to two geographical regions in Malaysia, these two regions should be considered independently for the selection of *in situ* conservation areas. Hamrick (1993) proposed that for tropical tree species, if 80% of the genetic diversity is partitioned within populations, then five strategically placed populations should be able to capture 99% of their total diversity. Graudal *et al.* (1995) proposed that one to three gene conservation areas would be likely to be sufficient for widespread and highly outcrossing species. They opined that many more and perhaps smaller conservation areas would be needed for species with mixed-mating systems and high percentage of selfing, or outcrossing species with scattered and disjunct distribution patterns. *Aquilaria malaccensis* has 8.1% of its total genetic diversity residing among populations, i.e. 91.9% of its genetic diversity is partitioned within populations. Therefore, five strategically placed populations in each of the two regions should capture

the majority of their total genetic diversity. This in addition to *in situ* conservation of these populations is likely to be sufficient to prevent the species from becoming an endangered species. With the consideration of underlying genetic diversity (A_a >5, H_e >0.5) and the current status of population health (population should possess >10 large trees) in each of the 35 populations, the following 16 populations were identified as potential *in situ* conservation areas for *A. malaccensis* in Malaysia (Fig. 3.5.4.1): Machinchang, Penang NP, Bukit Kerajaan, Gunung Jerai, Bubu and UTP from Cluster Kedah-Perak; and Chabang Tongkat, Gunung Tebu, Merchang, Berkelah, Panti, Paya Rumput, Sg. Udang, Pasir Panjang, Mont Kiara and Bukit Lagong from Cluster Kelantan-Johor.

Another important criterion set to best determine the success of the *in situ* conservation programmes was to estimate the minimum population size that was large enough to avoid effects of inbreeding depression and counter balance the loss of genetic diversity by genetic drift. Based on a simulation analysis, in order to maintain 95% of its genetic diversity, the minimum population size of *A. malaccensis* was calculated as 390, ranging from 250 to 550 large trees (Fig. 3.5.3.1). Previous studies using a similar approach on *Intsia palembanica* (Lee *et al*. 2002), *Koompassia malaccensis* (Lee *et al.* 2003), *Shorea lumutensis* (Lee *et al*. 2006) and *Gonystylus bancanus* (Nurul-Farhanah 2014) reported minimum population sizes of 200, 190, 270 and 420 individuals, respectively.

When planning a conservation area, a minimal population size should only be regarded as a last resort and an extreme compromise. For added safety, much larger populations should constitute units of *in situ* conservation (Hawkes *et al*. 1997). Thus, for *A. malaccensis*, conserving >300 trees per population will be sufficient to maintain maximum levels of genetic diversity to withstand loss of genetic variability due to genetic drift. This should also be enough to contain the minimum number of reproductive individuals to prevent inbreeding. For *A. malaccensis* the minimum number of reproductive individuals needed to prevent inbreeding would be 65 mature trees >20 cm dbh. The *in situ* conservation areas to be established should have a central core area, surrounded by a buffer zone and on its periphery, a transition zone. The presence of a buffer zone will protect the population of *A. malaccensis* present in the core from edge effects and other factors that might threaten its viability. The transition zone, however, may be made available for sustainable harvesting activities.

The establishment of *in situ* conservation areas is not decided solely on the basis of biological expedience or scientific principles; political determination will play a part. Malaysia has a federal system of government. Under the Malaysian constitution, land (including forested land) is defined as a state responsibility and each state is empowered to enact laws and to formulate policies independently (Lee & Krishnapillay 2004); the reservation of conservation areas is therefore affected by state legislation. Hence, to ensure effective conservation of *A. malaccensis*, the state governments need to urgently designate these aforementioned areas as strictly protected areas. The establishment of *in situ* conservation areas will not only conserve *A. malaccensis* but also help to conserve the forest ecosystem and other important but non-targeted species found within these areas.

Guideline 2: Plant material transfer guideline for *A. malaccensis*

In this study, the genetic structure analyses divided the populations into two genetic clusters, corresponding to two main regions: region Kedah-Perak and region Kelantan-Johor. By preserving the genetic structure and its resources, the species has a higher chance to adapt to environmental changes and survive in the event of disaster. Therefore, transfer of plant materials from a population in region Kedah-Perak should be restricted to locations within that region. For example, the transfer of *A. malaccensis* wildlings from Bukit Kerajaan (Penang) to Bukit Tapah (Perak) is acceptable as it is within the region Kedah-Perak. On the other hand, planting of *A. malaccensis* from the region of Kedah-Perak in the region of Kelantan-Johor should be avoided and vice versa.

Guideline 3: *Ex situ* conservation of *A. malaccensis*

For *ex situ* conservation, similar to the selection of *in situ* conservation areas, the two geographical regions should be considered independently for the selection of mother trees for seed collection. As the species is an outcrosser, and about 91.9% of its genetic diversity is partitioned within the population, a minimum of 25 mother trees per region should be used to establish a field gene bank. Using 40 progenies per mother tree would provide a stand of 2000 individuals. If the individuals are line-planted at a spacing of 5 x 5 m, a minimum area of 5 ha is required.

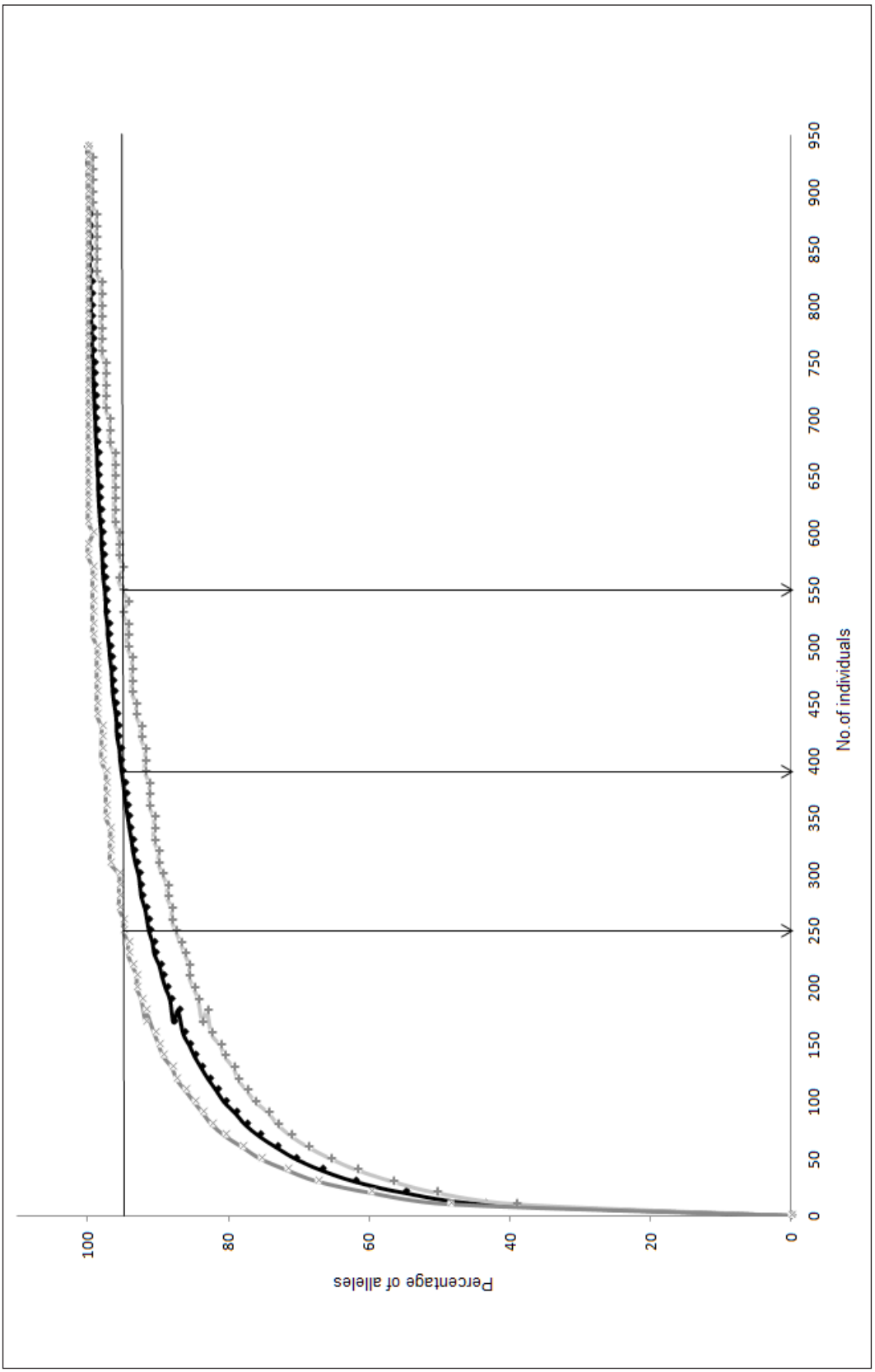

Fig. 3.5.3.1. Relationship between percentage of alleles against sample size. All values were based on 1000 resamplings from 930 of the 942 individuals with standard errors (SE). Grey lines represent standard errors.

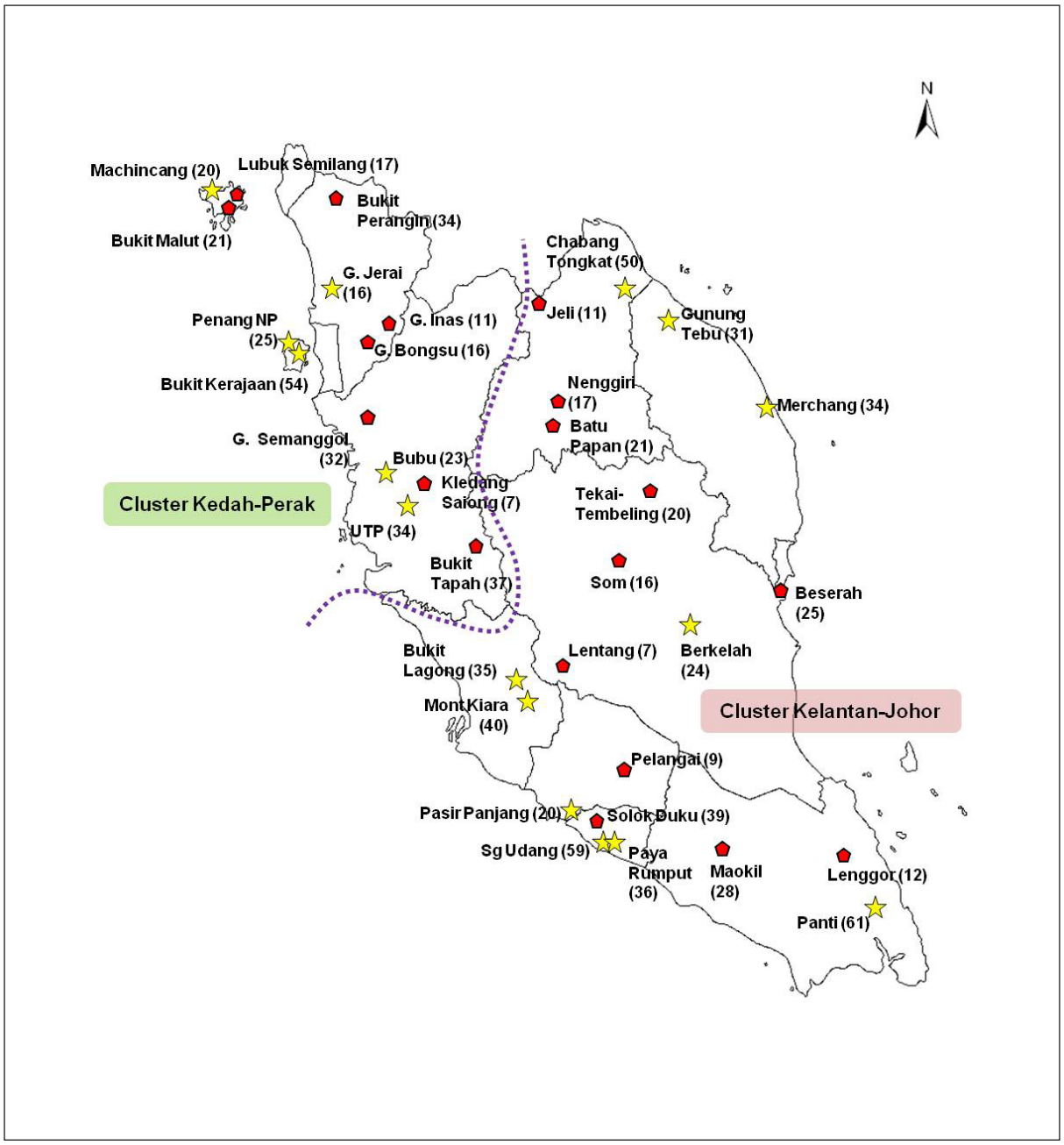

Fig. 3.5.4.1. Distribution of *Aquilaria malaccensis* populations partitioned into two unique genetic clusters. Yellow stars denote the priority areas for *A. malaccensis* conservation.

3.6 Non-Detriment Finding (NDF)

Tables 3.6.1 and 3.6.2 outline the partial NDF for *Aquilaria malaccensis* in Malaysia. A summary of the assessment indicates that the species has a generally low resilience and its wild populations are likely to be strongly impacted by harvesting.

Table 3.6.1. Assessment of the resilience of wild populations of *Aquilaria malaccensis* to harvesting.

Resilience factor	Information	Higher Resilience	Lower Resilience	Ref No.
Biological characteristics				
Life form vs. harvested plant part	• Perennial tree between 21−40 m tall; • Lethal harvest of bark, stem, roots; • Harvest of leaves.		√	14, 76, 86
Distribution	Wide in the Indo-Malayan region from the Assam district in India, through Burma and south-eastern China (Hong Kong, Hainan) to south-east Asia (Indochina, Borneo, Philippines, Malay Peninsula, Sumatra, Moluccas (Morotai, Ceram, Ambon, Halmahera) and New Guinea)	√		14, 86
Habitat	• No habitat preference, highly adaptable to various habitat types; • Representative habitats well conserved and stable.	√		14, 86
National abundance	• Observed population sizes: small; • Spatial distribution: scattered in natural forests.		√	51
National population trend	Rate of population change decreasing.		√	This report
Threats	Harvesting: multiple and severe; Habitat loss: minor.		√	This report
Reproduction	• Hemaphrodite; • Flowering phenology: supra-annual; • Potential pollinators: mainly Hymenoptera.		√	This report
Regeneration	• Mortality is consistently higher than recruitment and the rate of population change is decreasing; • Sprouting capability of stumps has been observed; • Regeneration guild: primary.		√	This report

Dispersal	• Seed type: recalcitrant • Seed dispersal strategy: most likely small mammals • Dispersal efficiency: unknown • Disperser abundance: unknown • Germination: ranged from 0−19%		√	This report
Harvest characteristics				
Harvest specificity	Target species easy to identify, no close look-alikes	√		9
Demographic segment of population	Both mature and juvenile (excluding saplings and seedlings) plants harvested		√	9
Multiple use	Multiple, non-conflicting uses	√		9
Yield per plant	Uncertain		√	
Scale of trade	Domestic and international trade fluctuate but the trend is declining due to the decline in supply (Fig. 1.3)		√	10
Utilization trend	Increasing fast		√	10

Table 3.6.2. Assessment of factors affecting the management of *Aquilaria malaccensis*

<table>
<tr><th>Factors of sustainability</th><th>Information</th><th>Ref No.</th></tr>
<tr><td colspan="3">Biological characteristics</td></tr>
<tr><td>Role of the species in its ecosystem</td><td>Characteristics outlined in Table 3.6.1 indicate that as a species, it is unlikely to have a significant role in the ecosystem. It is neither a keystone or guild species. As a supra-annual species, its contribution as a food source is likely to be intermittent. Hence, ecosystem processes are unlikely to be interrupted or changed by its removal.</td><td>This report</td></tr>
<tr><td colspan="3">Population status</td></tr>
<tr><td>Global and national distribution</td><td>Table 3.6.1. and Fig. 1.1</td><td>This report</td></tr>
<tr><td>National and global conservation status</td><td><table><tr><th>Species</th><th>Malaysia Plant Red List</th><th>IUCN</th></tr><tr><td>Aquilaria beccariana</td><td>DD</td><td>VUA1d</td></tr><tr><td>A. hirta</td><td>VUA4cd</td><td>VUA1d</td></tr><tr><td>A. malaccensis</td><td>VUA4cd</td><td>VUA1cd</td></tr><tr><td>A. microcarpa</td><td>DD</td><td>VUA1d</td></tr><tr><td>A. rostrata</td><td>DD</td><td>CRB1ab(v)</td></tr></table></td><td>32, 48</td></tr>
<tr><td>National population trend</td><td>Population trend is decreasing</td><td>This report</td></tr>
<tr><td>Global population size and trend</td><td>Unknown but likely to be decreasing based on personal communications with range states.</td><td></td></tr>
<tr><td colspan="3">Harvest management</td></tr>
<tr><td>Regulated / unregulated</td><td>Regulated through the:
• implementation of a national export quota of 200,000 kg; and
• mandatory issuance of removal pass at the point of first exit.</td><td></td></tr>
<tr><td>Management history</td><td>For many decades, harvesting is conducted at low densities by local communities as part of their source of livelihood. No additional management history known.</td><td></td></tr>
<tr><td>Illegal harvest or trade</td><td>A significant national problem (see Table 1.1, Fig. 1.3 and Annex 1)</td><td></td></tr>
<tr><td>Management plan</td><td>• No on-site management plan;
• Conservation measures are available but generic in approach;
• National legislation and international framework that assist the conservation of the species ;
• No specific restoration measures because of its lack of habitat specificity;
• Records of collection through the issuance of removal passes;
• Size of tree that is to be harvested is no longer self-imposed, fear of loss of potential income is the primary factor that lowers size threshold;
• Collection takes place all year round.</td><td></td></tr>
</table>

Control of harvest		
Percent of harvest in Protected Areas	Unknown, but present as indicated in Table 1.1 and Annex 1	
Percent of harvest in areas of strong tenure	Unknown	
Percent of harvest in open access areas	Unknown	
Proportion of range or population protected from harvest	14% of the species' natural range or population is legally excluded from harvest	
Confidence in effectiveness of strict protection measures	Confidence fluctuates with the changes in annual operational budget funds. The fund determines the frequency and intensity of enforcement activities.	
Effectiveness of regulation of harvest effort	Unknown	
Confidence in harvest management	None	
Monitoring of harvest		
Monitoring of collection impact and management practices	There is baseline information on the population size, distribution and frequency of dbh categories of selected populations based on direct observations and surveys. Data on the quantity of annual national exports and records on quantities collected from the PRFs are not readily available.	
Confidence in monitoring	Low but may be improved when enabling factors that enhance enforcement capacities and activities have improved substantially.	
Other factors that may affect whether or not to allow trade	None	

The proposed action plan presented in Table 4.1 draws upon the results from this Activity, stakeholders' dialogue as well as existing and past projects as mentioned above.

The goal of the action plan is to ensure that future harvesting does not continue to threaten the survival of this species as well as other *Aquilaria* species in Malaysia. This goal is in line with the National Policy on Biological Diversity (2016−2025) Goal 3: We have safeguarded all key ecosystems, species and genetic diversiy, Target 8: By 2025 the extinction of known threatened species has been prevented and their conservation status has been improved and sustained, and the Convention of Biological Diversity Strategic Plan for Biodiversity (2011−2020) Aichi Biodiversity Target 12: Reducing risk of extinction. This goal also reflects the aim of CITES that seeks to ensure that international trade in specimens of wild animals and plants does not threaten their survival.

To achieve this goal, a holistic approach is required that looks beyond the research efforts that had been undertaken. For this purpose, six elements need to be considered. These are (1) conservation and monitoring; (2) resource management and monitoring; (3) establishment of plantations; (4) research and development; (5) enforcement; and (6) enabling factors. Many of these elements are already in place but requires enhancement. In addition, these elements are not mutually exclusive but this division is necessary for the ease of planning, implementation and monitoring. The main objectives and outcomes are identified for each element.

To make this plan practical, it is developed within the government's existing framework for environmental and biodiversity conservation. Addressing these elements will require the support and involvement of all sectors in the industry and from the government, including enhanced financial support and enabling mechanisms that have been established. These enabling factors are implicit in each objective. It is necessary to note that this plan is not exhaustive in that not all outcomes necessary to achieve the objectives are included here; only those considered as priorities are listed. Hence this plan should be viewed as part of adaptive management and should be reviewed and revised accordingly.

The first objective relates to the conservation of *Aquilaria* species in Malaysia. Results from our studies have shown that unregulated harvesting activities had contributed to the decline in population change. This change is exacerbated by its infrequent reproductive frequency, high flower and fruit abortion rates, poor recruitment and high mortality. This functional behaviour is expected to persist throughout its life period. Together with the threat from unsustainable harvesting, these will negatively impact the survival of natural populations. The first objective therefore, is to ensure that sufficient numbers of representative wild populations are conserved throughout the range of the species. The protocol for the selection of representative populations is to know how many populations are sufficient to cover the maximum preservation of the species' gene pool and which populations to select (Annex 4 and Fig. 3.5.4.1) and is based on the presently known levels of genetic and population diversity of *A. malaccensis* in the peninsula. These populations should be monitored periodically to determine the status of its individuals.

The second objective is to enhance the manner in which the resource is being managed and monitored. Gaps in the current management of PRFs have been identified and the immediate associated activities to address these are listed in Table 4.1. Periodic monitoring is again essential and should be conducted more frequently than the current practice of once in ten years but this is subject to the availability of funds. This monitoring should also include populations in the protected areas. The results from such activities would enable adaptive management. Where information is severely lacking, the use of the precautionary principle approach on whether to approve licences and permits for harvesting should be applied.

The third objective is to enhance the production of artificially propagated *A. malaccensis* using the plantation approach. This will prevent the above-mentioned problems associated with harvesting of wild materials, thus allowing better control of harvesting and trading activities. Malaysia is implementing the guidelines that have been established under CITES and these mechanisms need only to be enhanced by the respective Management and Scientific Authorities.

The fourth objective is to further enhance research and development in aspects related to *in situ* and *ex situ* conservation and the plantation sector, in particular, the quality of planting materials. One of the biggest problems faced by Malaysia when using this approach is the mixed and often inferior quality of planting materials. An unregulated planting stock industry and insufficient scientific data on the potential quantity and quality of resin put farmers at risk in the venture. Breeding is a key R&D activity which can only be facilitated by the presence of field and seed genebanks. In addition, looking beyond *A. malaccensis*, the R&D programme should also include *A. hirta*, the lesser known relative of *karas*.

The fifth objective is to enhance enforcement at national and state levels. This essentially requires enhanced networking and sharing of information between enforcement agencies to increase stakeholders' engagement, the use of DNA profiling technologies to assist in the identification and origin of seized specimens and improvement in institutional governance.

The sixth objective is to enhance the enabling factors to improve the resilience of extant populations to harvesting pressures. These factors are mainly cross-cutting and may include some which are covered under any one of the above five objectives including the necessary Communications, education and public awareness (CEPA) programmes.

Table 4.1 outlines the objectives and desired outcomes and translates these into tangible activities to be implemented by the relevant stakeholders. It presents the actions which must be taken, and by which leading agency and when, in order to achieve the outcome. In addition, each action lists a measurable indicator against which progress will be monitored. The first agency named is the leading agency—it will collaborate with other agencies but will be ultimately responsible for the implementation of the action and reporting of progress to the Lead Management Authority. Some outcomes are achievable within the next five years. Others may take longer, and any additional time required for these is dependent on the performance of the related agencies over the next five years. Additionally, an adaptive style of management is preferred and hence, a review and enhancement of this action plan is necessary. Where possible, actions are listed in a logical order but this does not apply to the last objective which has a cross cutting approach.

Table 4.1. Proposed outline of the objectives, outcomes, actions, implementing agencies, indicators and timelines to achieve the goal of the action plan.

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Objective 1	**Ensure that sufficient numbers of representative wild populations are conserved throughout its range**								
Outcome 1.1	Sufficient numbers of wild populations are conserved in its natural habitats and range								
Action 1.1.1	Identify at least five populations in each of the geographical regions of Kedah-Perak and Kelantan-Johor	FRIM, State Forest and Wildlife Departments, private and public landowners	Five populations each in the Kedah-Perak and Kelantan-Johor regions are identified and the operational/ administrative mechanisms to conserve these populations are established	Minutes of discussions, consultations and meetings					
Action 1.1.2	Demarcate a buffer zone of at least 200 m width for each target population	State Forest and Wildlife Departments, private and public landowners		Buffer zones demarcated					
Action 1.1.3	Provide legal protection for these populations if not already provided for	State Forest and Wildlife Departments, private and public landowners	These populations are legally protected	Minutes of meetings that deliberate legal aspects of species and habitat protection					
Action 1.1.4	Develop monitoring protocol guidelines to determine trend in population change	FRIM	Stakeholders are trained to conduct monitoring	Number of capacity building workshops conducted					

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Objective 2	**Enhance resource management and monitoring in the Permanent Reserved Forests (PRFs)**								
Outcome 2.1	Resource management of *Aquilaria* in the PRFs is enhanced								
Action 2.1.1	Conduct detailed inventory of karas populations at periodic intervals at state level	FDPM	Inventory data from PRFs is available for use by relevant stakeholders	Size class distribution of karas populations, reports from inventory activities					
Action 2.1.2	Determine, from the inventory, maximum harvest quantity allowed at the state level	NRE, FDPM	Maximum harvest quota is in place for each state	Director-General's notifications/circulars, minutes of meetings					
Action 2.1.3	Assess regularly whether the harvest quota reflects sustainability of the resource	FDPM, State Forest Departments	Annual export quota revised according to the results of the assessment	Assessment reports, discussion notes					
Action 2.1.4	Analyse, assess and review regularly harvest data in removal passes	FDPM, State Forest Departments	Sharing of analysed and assessed harvest data between state and federal agencies	CITES export permits					
Action 2.1.5	Determine the period for the collection of planting stocks	FRIM	A collection plan is available	Records of past flowering and fruiting trends, drought trends					
Outcome 2.2	Monitoring of *Aquilaria* in the PRFs is enhanced								
Action 2.2.1	Develop monitoring protocol guidelines to assess harvest impacts	FRIM	Application of the guidelines at the state level	Data sheets					

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Action 2.2.2	Promote use of karas in enrichment planting and rehabilitation of degraded sites	FRIM, FDPM, State Forest Departments	The use of *karas* trees in enrichment planting and rehabilitation of degraded sites is increased	Purchase records, transfer records					
Action 2.2.3	Conduct stakeholders' dialogues to improve adaptive management	FDPM, State Forest Departments	Increased commitment by stakeholders to collectively address threats	Dialogue reports, finance records					
Objective 3	**Enhance the production of artificially propagated *Aquilaria malaccensis***								
Outcome 3.1	The harvesting pressure on wild populations is significantly reduced								
Action 3.1.1	Promote the cultivation of parental stocks by increasing the areas dedicated to such cultivation in state or private land. Designate these areas as seed production areas and genebanks	State Forest Departments, MTIB	Seed production areas and genebanks established	Road shows, number of areas designated for such purpose in private land or village gardens					
Action 3.1.2	Encourage local communities to designate trees in their villages/farms as genebanks	MTIB	Village genebanks established	Road shows					
Action 3.1.3	Develop effective and cheap propagation techniques, including a protocol to record the origin of stocks, to increase availability of planting stocks	FRIM	Propagation and agronomic protocols are available for use	Workshop notes, draft protocols					
Action 3.1.4	Develop appropriate agronomic practices at plantation/farm level	FRIM, MTIB							

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Action 3.1.5	Certify the quality of planting stocks through registration or certification mechansim	MTIB	Registration/certification mechanism is in place	Minutes of meetings, draft regulations					
Objective 4	**Enhance research and development related to *in situ* and *ex situ* conservation and selection for superior stocks**								
Outcome 4.1	Sufficient germplasm material from representative populations is conserved and utilised for R&D and CEPA programmes								
Action 4.1.1	Identify and designate seed provenance areas in the natural forests as genebanks	State Forest and Wildlife Departments	Genebanks and seed provenance areas established in PRFs, wildlife sanctuaries and state parks	Minutes of meetings					
Action 4.1.2	Designate and establish suitable areas in relevant states as karas arboretum to support genebanks	State Forest Department	At least two arboreta established, one for each region	Minutes of meetings					
Action 4.1.3	Investigate demographic patterns for *Aquilaria hirta*	FRIM	Proposals to conduct such studies are approved and funded	Draft proposals, reports of field work					
Outcome 4.2	The problem of unpredictable quality and quantity of harvest in the plantation/agro-industry is reduced								
Action 4.2.1	Conduct selection and breeding programmes using the above genebanks to enhance the quality of planting materials	FRIM	Proposals to conduct such studies are approved and funded	Draft proposals, reports of field work					
Action 4.2.2	Investigate the potential production of gaharu at plantation scale and related costs and benefits	FRIM, MTIB	Proposals to conduct such studies are approved and funded	Draft proposals, reports of field work					

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Objective 5	**Enhance enforcement at national and state levels**								
Outcome 5.1	The frequency of illegal harvesting is reduced significantly								
Action 5.1.1	Monitor regularly representative populations including those in genebanks and protected areas	State Forest and Wildlife Departments, public and private owners	Monitoring reports are available	Monitoring reports, field work claims					
Action 5.1.2	Apply DNA profiling technologies for identification of species, population and individuals	FRIM, State Forest and Wildlife Departments, private and public landowners	Staff of State Forest and Wildlife Departments are trained to use these technologies	Workshop modules comprising lecture and practical sessions					
Action 5.1.3	Enhance enforcement capabilities, assets and manpower resources in respective agencies	Enforcement agencies at federal and state levels	Respective agencies are better equipped with trained manpower and assets when conducting raids	Number of successful raids					
Action 5.1.4	Increase patrolling frequency and intensity in sensitive areas	Enforcement agencies at federal and state levels	More frequent patrolling in sensitive areas	Field reports					
Action 5.1.5	Enhance cooperation between state authorities and federal enforcement agencies such as Customs, Immigration, Maritime, Police and Army Units	Enforcement agencies at federal and state levels	Intelligence networking is improved significantly	Regular uptake of intelligence data					
Action 5.1.6	Improve governance along harvest process and chain of custody	State Forest Departments, private and public landowners	Harvest process and chain of custody complies with existing regulations	Compliance reports					

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Objective 6	**Enhance the enabling factors to improve the resilience of extant populations to harvesting**								
Outcome 6.1	Enhanced facilitation of enabling factors increases the resilience of extant populations to harvesting impacts								
Action 6.1.1	Support R&D activities that aim to improve understanding of the impacts of harvesting on wild populations	NRE, MPIC	Proposals to conduct additional studies are approved and funded	Draft proposals, reports of field work					
Action 6.1.2	Monitor the chain-of-custody through a registration mechanism	MTIB, NRE	Monitoring mechanism established	Monitoring reports, field work claims					
Action 6.1.3	Analyse and review regularly the export data for market and harvesting trends	MTIB, NRE	Regular analysis of export volume, trend etc is available	Analyses reports					
Action 6.1.4	Consider *karas* as the country's third major plantation commodity to enable more concerted efforts to be channeled into species conservation and development of the industry	MPIC, MTIB	Karas is regarded as the country's third major commodity	Minutes of meetings/ discussions					
Action 6.1.5	Enhance financial incentives and enabling procedures for the setting up of plantations	MoF, MPIC, MTIB	Increased financial incentives\ to small holders and plantations is declared by GoM	Minutes of meetings/ discussions					
Action 6.1.6	Consider collection of cess and royalties from plantations	MTIB, NRE	Initial discussion on the possibility of charging cess and royalties are initiated	Minutes of meetings/ discussions					

Objectives and Outcomes		Implementing agencies	Indicators	Means of verification	Timeline				
					2016	2017	2018	2019	2020
Action 6.1.7	Encourage further use of the reward system for information at state level	Enforcement agencies at federal and state levels	The number of reward cases in each state surpasses five	Reports					
Action 6.1.8	Strengthen networking between relevant states and federal agencies, including the sharing of data	FRIM, State Forest and Wildlife Departments, private and public landowners	Data analyses are available	Minutes of meetings/ discussions					
Action 6.1.9	Conduct CEPA programs particularly for local communities	State Forest and Wildlife Departments, private and public landowners	More village genebanks are established	Number of village genebanks and number of road shows					

Abbreviations

CEPA	-	Communication, Education and Public Awareness
CITES	-	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DNA	-	Deoxyribonucleic acid
FDPM	-	Forest Department Peninsular Malaysia
FRIM	-	Forest Research Institute Malaysia
GoM	-	Government of Malaysia
MoF	-	Ministry of Finance
MPIC	-	Ministry of Plantation Industries and Commodities
MTIB	-	Malaysian Timber Industry Board
NRE	-	Ministry of Natural Resources and Environment
PRFs	-	Permanent Reserved Forests

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Annex 1. Media reports on the illegal harvest of *Aquilaria malaccensis* referred here as *gaharu*.

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Updated: Wednesday April 16, 2014 MYT 8:25:52 AM

Illegal foreigners scour forest in search of agarwood

BY ZAZALI MUSA

FACEBOOK TWITTER GOOGLE+ LINKEDIN

JOHOR BARU: Illegal harvesting activities of agarwood (gaharu) by foreigners are rampant in Johor forests especially in the Endau-Rompin National Park and Panti Forest Reserve.

Malaysia Nature Society (MNS) Johor chairman Vincent Chow claimed that the

http://www.thestar.com.my/News/Community/2014/04/16/Rampant-harvesting-Illegal-foreigners-scour-forest-in-search-of-agarwood/

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Published: Friday December 12, 2014 MYT 12:00:00 AM

Updated: Friday December 12, 2014 MYT 8:58:03 AM

Illegal poachers coming for the trees cultivated in Johor forests

BY ZAZALI MUSA

FACEBOOK TWITTER GOOGLE+ LINKEDIN

JOHOR BARU: Illegal poachers from neighbouring countries are encroaching into Johor forests for years harvesting agarwood (gaharu) as demand for the product is good.

Gaharu thefts in Johor forests

By Sim Bak Heng
news@nst.com.my

JOHOR BARU, Tues. — Johor's forest reserves are drawing Thai poachers looking for the prized Gaharu incense wood trees from which a resin is extracted for making perfume.

Several have been caught chopping down the trees.

However, to date only two have been charged for the offence.

They operate in groups of three or four and are usually armed with axes and machetes.

Mohd Azhari Hashim, a nature guide, spotted two Thais chopping a Gaharu when he was scaling Gunung Panti in Kota Tinggi last month.

"The two Thais spoke broken English and panicked when they saw us. They claimed they were from nearby Kampung Lukut at the foothills," he said.

"Their slang and their body tattoos clearly showed they were Thais. They were armed with an axe each and bags for collecting the resin.

Gaharu trees (Aquilaria agallochum) are mostly found in China, Thailand and northern India and grow to a height of 120 feet.

Besides Gunung Panti, the Endau Rompin National Park and Gunung Ledang National Park are also the target of people looking for Gaharu.

Johor Forestry Department director Che Hashim Hassan believed the Thai poachers were members of a syndicate supplying the resin to perfume manufacturers in Singapore or Thailand.

He said the smuggling of Gaharu had been going on for years due to the huge demand for the resin.

"We need members of the public to tip us off about their activities so that we can take action immediately," he said.

Those caught stealing Gaharu from national parks could face a fine of up to RM500,000 or 20 years' jail or both.

theSundaily

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Perhilitan nab 2 Vietnamese men for enroachment

Posted on 9 July 2014 - 09.43am
Last updated on 9 July 2014 - 11:14am

KUALA LUMPUR: The Department of Wildlife and National Parks of Malaysia (Perhilitan) in Penang have arrested two Vietnamese men for encroaching on Pantai Teluk Ketapang Kecil, Penang National Park.

The Natural Resources and Environment Ministry said in a statement here yesterday, that the duo aged 26 and 20 had been remanded at the Bayan Baru police station for 14 days to facilitate investigations.

"Penang national park enforcement teams found recent encroachment signs such as a camp site and new tracks.

"They also seized some Bukit Baring shells, wire nets and at least one kilogram of gaharu," said the statement.

The case is being investigated under the National Parks Act 1980 (Act 226) and Wildlife Conservation Act 2010 (Act 716), which carries a fine of not more than RM100,000 or a maximum jail term of three years, or both, upon conviction. – Bernama

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ar SATURDAY 14 August 2004

'Gaharu' poachers held

Adenan: Thais caught in protected areas

MALACCA: Several Thais illegally collecting *gaharu* in protected areas in the country have been caught as authorities stepped up measures to flush out more of the poachers.

Natural Resources and Environment Minister Datuk Seri Adenan Satem said both the Wildlife and National Parks and Forestry Departments were working with the army to nab the poachers.

"Just two weeks ago, our officers caught two Thais collecting *gaharu* in Belum.

"Earlier this year, we caught a few Thais in the same area," he said after an official visit to the state on Thursday.

Adenan said enforcement officers were constantly vigilant to curb illegal activities.

He was commenting on a report by *The Star* last Tuesday that uncovered the presence of a syndicate with links to Thailand which was involved in the illegal collection of *gaharu* in the Endau-Rompin National Park last month.

He said several cases were pending in court and that the Thais would be charged under the National Forestry Act for illegal extraction of the precious *gaharu* wood.

"From 2001 to 2002, 19 Thais were caught carrying out such activities in protected areas," he said.

The price of *gaharu* has reportedly soared from RM500 to RM8,000 per kilo over the last few years and there had been reports of frenzied collection by orang asli communities as well as others throughout the peninsula.

Under the National Forestry Act, an individual could be charged for taking forest produce without a licence.

The maximum fine is RM50,000 or five years' jail or both.

Adenan: 'Just two weeks ago, our officers caught two Thais collecting gaharu in Belum'

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Nation

Gaharu trees felled illegally

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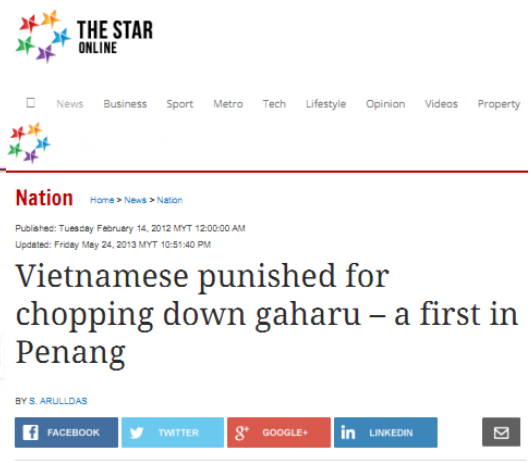
GEORGE TOWN: Local syndicates with foreign connections are allegedly felling the highly-valued gaharu (agarwood) trees illegally in the rainforest near the Penang Botanic Gardens here and in other areas.

Believed to be armed with dangerous weapons, these syndicates with links in Thailand, Myanmar and Vietnam, which also operates in Seberang Prai, are illegally felling the trees rampantly in various areas on Penang island.



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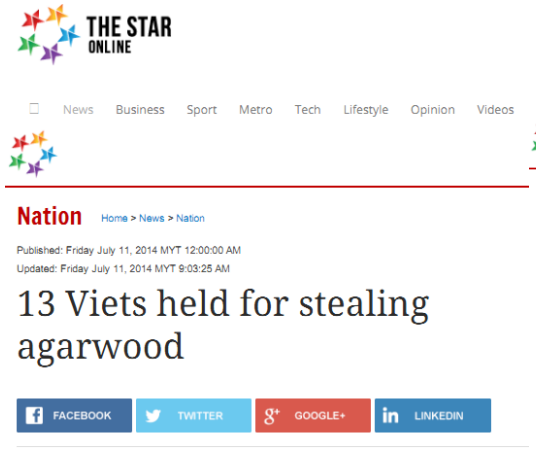
Published: Tuesday February 14, 2012 MYT 12:00:00 AM
Updated: Friday May 24, 2013 MYT 10:51:40 PM

Vietnamese punished for chopping down gaharu – a first in Penang

BY S. ARULLDAS

FACEBOOK TWITTER GOOGLE+ LINKEDIN



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Published: Friday July 11, 2014 MYT 12:00:00 AM
Updated: Friday July 11, 2014 MYT 9:03:25 AM

13 Viets held for stealing agarwood

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Published: Saturday March 17, 2012 MYT 12:00:00 AM
Updated: Saturday May 25, 2013 MYT 5:46:14 PM

Runners come across men cutting down trees in Penang park

BY SIMREN KAUR

GEORGE TOWN: A group of Penang Hash House Harriers (PHHH) runners was climbing the hill at Fettes Park in Tanjung Bungah like it would on any normal day when the group stumbled upon some men chopping down some trees.

Gurdial Singh, 52, a veteran runner with the PHHH, said that during the run last

www.thestar.com.my/News/Nation/2012/03/17/Runners-come-across-men-cutting-down-trees-in-Penang-park/

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Published: Friday March 30, 2012 MYT 12:00:00 AM
Updated: Saturday May 25, 2013 MYT 8:46:56 PM

Viets held over agarwood theft

FACEBOOK TWITTER GOOGLE+ LINKEDIN

NIBONG TEBAL: Six Vietnamese men were detained in connection with the theft of 51kg of agarwood (gaharu) in Taman Merak Jaya, Simpang Ampat here.

The men, aged between 22 and 37, were picked up inside an apartment at 8.30pm on Wednesday by an Anti-Smuggling Unit (UPP) team acting on a tip-off.

The suspects were then handed over to the state Forestry Department, pending further questioning, and were remanded by a Jawi magistrate's court yesterday.

Forestry Department investigating officer Ramlee Ahmad said the case was being

www.thestar.com.my/News/Nation/2012/03/30/Viets-held-over-agarwood-theft/

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Tuesday April 13, 2010

Foreigners illegally harvesting trees from Sabah forest reserves

FACEBOOK TWITTER GOOGLE+ LINKEDIN

KOTA KINABALU: Foreigners are making a beeline to Sabah to illegally harvest the valuable agarwood or *gaharu* from forest reserves here.

Over the past year, Sabah Forest Department officials nabbed several Thai nationals who were found to be illegally harvesting agarwood at the Kalabakan forest reserve near the southwest Sabah district of Tawau.

Department deputy director Rahim Sulaiman said the incidence of illegal harvesting of the wood was not at a "serious level" yet.

http://www.thestar.com.my/story/?sec=nation&file=%2F2010%2F4%2F13%2Fnation%2F6044492

Gaharu thieves' mini village was the 'perfect hideout'

iSnap me for more photos http://thestar.com.my/isnap

By ROYCE TAN
roycetan@thestar.com.my

GEORGE TOWN: A group of agarwood tree (gaharu) thieves set up four large camps deep inside a jungle near Mount Erskine to cleverly hide their location from view.

Their "mini village" had a kitchen, a storage place and a workshop to process the agarwood.

It was a perfect hideout until the state Forestry Department officers busted it on Monday.

A stockpile of food comprising some 10kg of rice, cooking oil, canned food and vegetables enough to last several people for at least two weeks was confiscated.

Department officers visited the site again yesterday and recovered several pieces of low quality agarwood.

"We believe the higher quality ones were sold earlier," said state Forestry Department director Abdul Wahab Deraman.

Two Cambodians were arrested during the ambush on Monday while two others managed to flee the scene.

Two large pieces of agarwood, believed to be worth between RM50,000 and RM100,000, were also seized in Monday's raid.

According to veteran hiker Gurdial Singh, even regular hikers and mountain bikers had not stumbled upon the "hideout".

"Access to their 'mini village' is via an undiscovered path and you would have to go in from Point 8 on the hill behind the Mount Erskine wet market," he said.

Gurdial tipped off the department on Sunday after coming across five felled trees while running near Taman Lembah Permai in Tanjung Bungah.

The oil from gaharu resin is highly prized in the Middle East and can fetch up to RM20,000 per kilo.

The oil is used as a base for perfumes due to its fresh and woody scent.

It is also used as a key ingredient in traditional Chinese medicine for various ailments.

Gathering evidence: State Forestry Department officers investigating the 'mini village' where two Cambodians (inset) were detained in Taman Lembah Permai, Tanjung Bungah.

Annex 2. Mass media report of financial subsidies being available for *karas* plantation schemes.

Headline	RM3 juta buka ladang kayu gaharu		
MediaTitle	Sinar Harian		
Date	02 Apr 2012	Color	Full Color
Section	Nasional	Circulation	60,000
Page No	I-55	Readership	180,000
Language	Malay	ArticleSize	204 cm²
Journalist	N/A	AdValue	RM 1,122
Frequency	Daily	PR Value	RM 3,366

RM3 juta buka ladang kayu gaharu

GUA MUSANG - Ahli Parlimen Gua Musang, Tengku Razaleigh Hamzah mengumumkan peruntukan RM3 juta yang sudah diluluskan Kerajaan Pusat untuk membuka ladang kayu gaharu di kawasan perkampungan Orang Asli daerah ini dalam masa terdekat ini.

Beliau berkata, peruntukan permulaan sebanyak itu diluluskan Perdana Menteri, Datuk Seri Mohd Najib Razak ketika beliau mengunjungjnya di Pejabat Perdana Menteri di Putrajaya Ahad lalu.

Menurutnya, beliau terpaksa berkunjung sendiri ke pejabat perdana menteri bagi mendapat peruntukan untuk merlaksanakan projek itu sebagaimana yang dicadangkan sebelum ini untuk meningkatkan pendapatan penduduk Orang Asli di Hulu Kelantan.

"Saya terpaksa menemui perdana menteri sebelum saya datang ke majlis ini supaya apa menjadi kenyataan," katanya kepada pemberita selepas majlis Perasmian Pusat Gerakan Rakyat Dewan Undangan Negeri (DUN) Galas 2012, di Pedang Awam Pos Brooke, dekat sini, petang kelmarin.

Sempena majlisita, Tengku Razaleigh turut menyampaikan Bantuan Rakyat 1Malaysia (BR1M) dan bantuan pakaian seragam sekolah kepada pelajar

Tengku Razaleigh memakaikan beg sekolah kepada seorang pelajar anak Orang Asli pada majlis tersebut.

Pengarah Jabatan Kemajuan Orang Asli (Jakoa), Datuk Mohd Sani Mattam, Ahli Dewan Undangan Negeri (Adun) Galas, Ab Aziz Yusof serta Pegawai Pembangunan Jabatan Pembangunan Persekutuan Kelantan (JPPK) Cawangan Gua Musang, Muhamad Shukri Ab Aziz.

Tengku Razaleigh yang juga Ketua Umno Bahagian

an projek berkenaan dan memerlukan perkara itu kepada Jakoa untuk mengadakan perbincangan dengan jabatan serta agensi berkaitan.

Beliau berkata, Jakoa juga perlu mengadakan perbincangan dengan Kerajaan Negeri bagi mendapatkan kelulusan tanah untuk tujuan berkenaan sementara berbincang dengan institut

Annex 3. Predators of *Aquilaria malaccensis*.

Macaca fascicularis (Cercopithecidae)

Ratufa bicolor (Sciuridae)

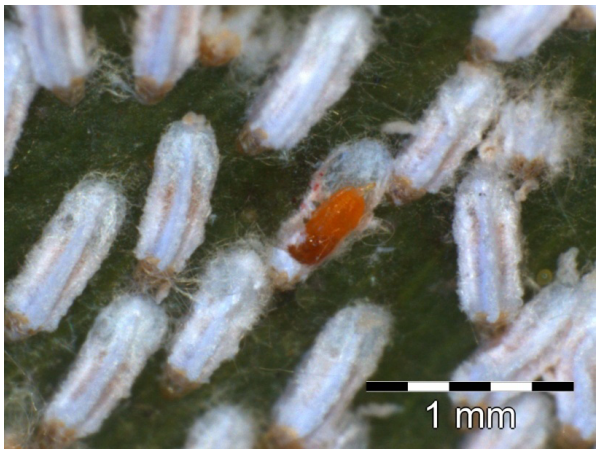
Callosciurus prevostii (Sciuridae)

Heortia vitessoides (Crambidae)
(Photo credit: Ong Su Ping)

Exuvia of *Zuezera sp*. (Cossidae) on a tree trunk (Photo credit: Ong Su Ping)

Whitefly of the family Aleyrodidae
(Photo credit: Ong Su Ping)

Pitama hermesalis (Crambidae)
(Photo credit: Ong Su Ping)



Scale insects of the family Diaspididae
(Photo credit: Ong Su Ping)

Annex 4. The protocol for the selection of representative populations of *Aquilaria malaccensis* in the peninsula for the purpose of conservation.