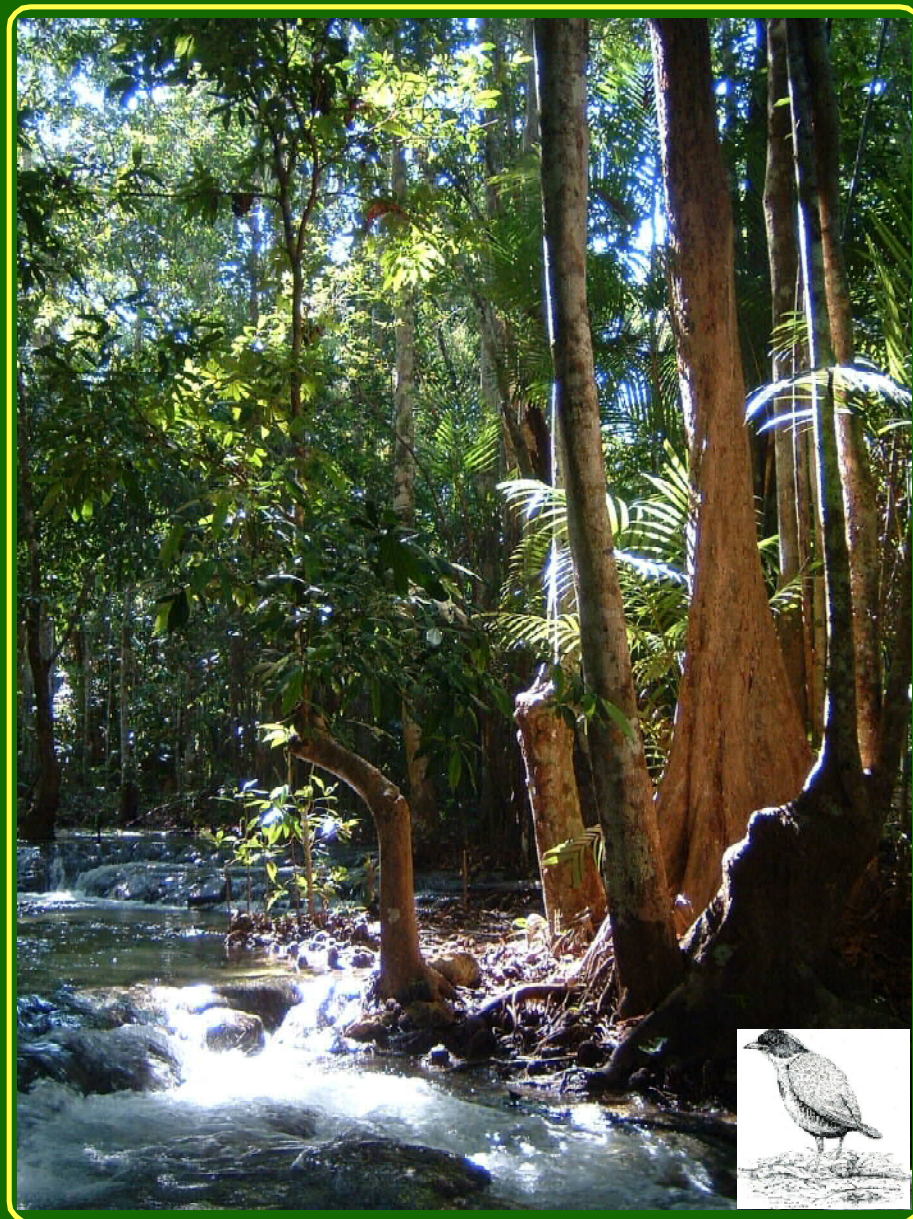


A Technical Strategy for Restoring Krabi's Lowland Tropical Forest

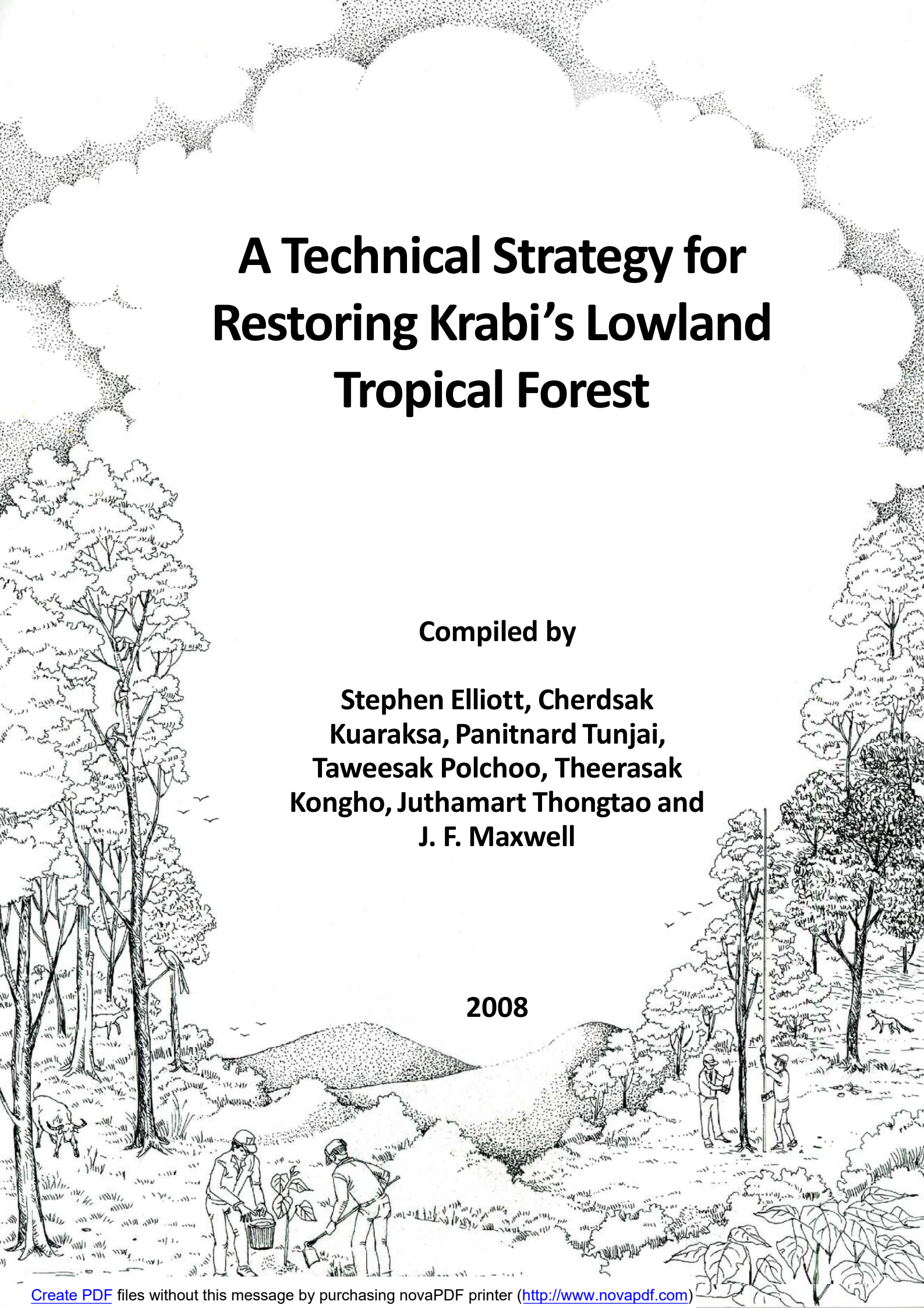


THE FOREST RESTORATION RESEARCH UNIT
BIOLOGY DEPARTMENT, SCIENCE FACULTY
CHIANG MAI UNIVERSITY





Is it possible to reverse destruction of the unique lowland tropical evergreen forest ecosystems of Krabi Province, S. Thailand?



A Technical Strategy for Restoring Krabi's Lowland Tropical Forest

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2008

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This report was compiled by Stephen Elliott with scientific inputs from Cherdasak Kuaraksa and Panitnart Tunjai, as well as substantial indigenous knowledge and experimental results provided by the current FORRU-Krabi nursery staff: Taweesak Polchu, Theerasak Kungho and Jutamart Thongkhao and previous staff Mr. Iss Sawadepahp and Mr. Pichaet Chantawangso. David Moore helped to collate information for the tree species descriptions. This project would not have been possible without the valuable input of plant taxonomist, J. F. Maxwell, who was responsible for providing all plant names in this report. Photographs are by Stephen Elliott.



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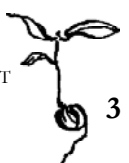
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This project addresses the problem of loss of one of Thailand's rarest and most unique forest ecosystems i.e. lowland tropical evergreen forest, the habitat of one of Thailand's rarest bird species, Gurney's Pitta. The project provides hope that the process is technically reversible.



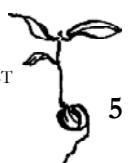
Introduction

Lowland tropical evergreen forest is one of Thailand's rarest and most endangered wildlife habitats. Formerly widespread over most of Thailand's southern provinces, this forest type has now been reduced to a few tiny, isolated fragments. The small patches that remain around Khao Nor Chuchi in Khao Pra Bang Kram Wildlife Sanctuary and in the adjacent reserved forest and non-hunting area of Khlong Tom District, Krabi Province, are probably the most significant remnants of lowland tropical evergreen forest still surviving in the Kingdom. Not only do they support the high biodiversity that is characteristic of most tropical forest ecosystems, but they are also home to Thailand's rarest bird species, Gurney's Pitta (*Pitta Gurneyi*), now reduced to about 40 birds (in 2006) (Donald, et al, 2006).

The importance of the area was first recognised in 1985, when satellite imagery was used to identify the last remnants of lowland rainforest and southern Thailand. An important outcome of this research was the rediscovery of Gurney's Pitta in June 1986. This prompted the Royal Forest Department (RFD) to designate parts of the area as Khao Pra Bang Kram Non-Hunting Area in October 1987 and to upgrade a core area to the status of a wildlife sanctuary (with the same name) in 1993. The area is particularly noted for supporting one of the most diverse forest bird communities in peninsular Thailand, which attracts large numbers of bird watchers and eco-tourists. In addition, the Emerald Pool (Sa Morakot) is a popular recreational attraction for both local people and overseas tourists. The forest and its birds, therefore, contribute substantially to the local economy.

The small patches of primary forest, within the wildlife sanctuary and adjacent reserved forest, are extremely vulnerable to disturbance, rendering the whole habitat highly endangered. This situation has arisen as a result of human occupation of the area, coupled with inadequate management. Unregulated tourism development is also becoming a problem. Khao Pra Bang Kram Wildlife Sanctuary covers an area of 156 km², but only about 25 km² remains covered by primary forest. Primary forest in the surrounding Reserved Forest Area, which is less well protected under Thai law, is now reduced to several tiny, scattered fragments.

Human occupation of the area began to have a significant impact on forest cover during the period of communist insurgency from the mid-1960s to the early 1980s, when logging was rampant. The area became a stronghold of communist insurgents and was the site of several battles. Following defeat of the communists, from about 1980, there was an influx of people from other



provinces (Nakorn Sri Thammarat, Surat Thani and Patalung), which penetrated into the interior of the area to plant rubber trees and oil palms and also to grow coffee on the plateau of Pen Din Samur. During this period, large mammals such as elephant, gaur and tiger were extirpated, probably due to hunting, as well as habitat shrinkage. Many larger birds such as Lesser Adjutant (*Leptoptilos javanicus*) and White-winged duck (*Carina scutulata*) also disappeared (Round and Treesucon, 1996). Logging continued until 1989, when disastrous floods in Nakorn Sri Thammarat, attributed to deforestation, prompted the government of Gen. Chatichai Choonhaven to implement a nation-wide ban on logging in reserved forests.

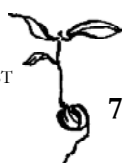
Today the most serious threat remains the clearing of forest to establish rubber tree and oil palm plantations, now driven by the skyrocketing prices of rubber and palm oil on international markets. This provides an irresistible economic incentive for replacement of forest with plantations. Steep increases in the palm oil price are the result of promotion of biodiesel, as a replacement for fossil fuels, both in Thailand and abroad; a misguided attempt to mitigate global climate change. In addition to destruction of wildlife habitat, hunting and trapping of birds and mammals, both for food and for the illegal wildlife trade, remains a serious problem. Having eliminated most large vertebrates, hunters now turn their attention towards the small mammals and birds, including of course the highly valuable Gurney's Pitta.



Wildlife conservation in the area has involved the creation of protected areas of various status (non-hunting area, wildlife sanctuary and reserved forest), the stationing of forest officers to carry out protective duties, ecological research and the education of local people and their involvement in eco-tourism.

One of the first educational projects in the area was initiated by the Children's Tropical Forests Foundation (U.K.), founded by British conservationist Tina Jolliffe. This project established the 2.7-km-long Tina Jolliffe Nature Trail around Emerald Pool in 1992 and carried out various educational events for school children. Unfortunately, the trail and its information boards have not been well-maintained. More recently, the Bird Conservation Society of Thailand (BCST) initiated several educational projects for schools and villagers in the area, to raise awareness of the importance of Gurney's Pitta and the need to conserve its habitat. These have been largely successful, since Gurney's Pitta is now very well known in the area and has become a major source of income for local people, through the development of eco-tourism. Last year, a small exhibition centre was established, near the entrance to the Emerald Pool, to educate visitors and the project, reported here, funded a display about forest restoration.

High profits from rubber cultivation (left) and oil palm for biodiesel (below) are the main economic incentives for illegal clearance of lowland tropical forest in Krabi Province and its conversion to plantations.



Research For Restoring Gurney's Pitta Habitat



Top - The research tree nursery at Ban Bang Tiew, with enthusiastic volunteers. Mid left - collecting seeds. Mid right - germination trials. Below left - training FORRU-Krabi staff to monitor seedling growth. Below right - establishing the first experimental plot.



RESTORING LOWLAND TROPICAL FOREST

Research on Gurney's Pitta and other birds was started in the late 1980's by ornithologists from Mahidol University's Centre for Conservation Biology (CCB-MU) and Bird life International (1987-89). This led to the "Khao Nor Chuchi Lowland Forest Project", which commenced in March 1990. This was a joint project of Bird life Denmark, Bird life International and CCB-MU, implemented in collaboration with the Bird Conservation Society of Thailand (BCST), and funded by DANCED (Danish Cooperation for the Environment and Development). The project aimed to secure participation of local villagers in conservation management of the area to prevent further forest. Forest restoration was included as one of the project activities, but the project failed to prevent further destruction of Gurney's Pitta habitat, largely due to lack of support, amongst local people, for the wildlife sanctuary and the reserved forest status of adjacent areas (Round and Treesucon, 1996). The project's research component focussed almost entirely on birds, but research to develop effective habitat restoration techniques was lacking. However, this project helped to raise awareness of the need for effective methods to restore deforested sites in protected areas, where those responsible for encroachment have been evicted and control of the land returned to the Department of National Parks and Wildlife (DNP), the government agency now responsible for the area.

"An important part of future protection must be not only to protect remaining forest but to enhance the regeneration of forest and secondary growth" - (Round and Treesucon, 1996). Forest restoration was also recommended as one of the cornerstones of a Gurney's Pitta rescue plan by Donald, et al (2006): "reforestation in (areas of) illegal encroachment, as well as unsuitable forest habitat in lowland areas, where the birds were formerly sighted, to re-connect fragmented forest patches, by creating forest corridors."

The aim of the report presented here is to respond to the lack of technical information available to effectively restore lowland tropical evergreen forest to deforested areas in peninsular Thailand, not only to re-establish habitat for Gurney's Pitta, but also to promote recovery of many other species that are restricted to this unique and highly endangered forest type.



The recommendations presented in this report are based on the principles and techniques of forest restoration, developed by the Forest Restoration Research Unit of Chiang Mai University (FORRU-CMU) in northern Thailand since 1994 and subsequently modified to suit the ecological conditions of lowland tropical evergreen forest in peninsula southern Thailand, under the project “Gurney’s Pitta Research and Conservation in Thailand and Myanmar”, implemented by the U.K.’s Royal Society for the Protection of Birds and sponsored by the Darwin Initiative for the Survival of Species, a U.K. government organization established to promote implementation of the international Convention on Biodiversity (CBD).

Many of the concepts and methodologies of forest restoration, developed in northern Thailand (such as ANR, the framework species method and tree propagation techniques) can be applied equally well to restoring southern forests. So, some of the material presented in this report is reworked from FORRU-CMU’s previous publications, which were also sponsored by the Darwin Initiative (“How to Plant a Forest” and “Research for Restoring Tropical Forest Ecosystems”, FORRU, 2006 & 2008). However, it was also necessary to carry out original research on-site, to select those indigenous tree species, most likely to promote biodiversity recovery in general, and provide habitat for Gurney’s Pitta in particular. To that end, we established a new forest restoration research unit at the entrance to Khao Pra Bang Kram Wildlife Sanctuary HQ (FORRU-Krabi), to carry out the required research including: i) a survey of indigenous forest tree species and voucher specimen collection, ii) a phenology study of flowering and fruiting of selected trees, iii) seed collection and experiments on seed germination and seedling growth in a nursery, and v) field trials to compare performance among species. In this report, we present recommended tree species that we feel are

most likely to accelerate forest restoration and promote biodiversity recovery, based on the best scientific data available at this time, as well as indigenous local knowledge. However, the research is still ongoing, so the list of recommended species will doubtless change, as the long-term results from field trials become available.



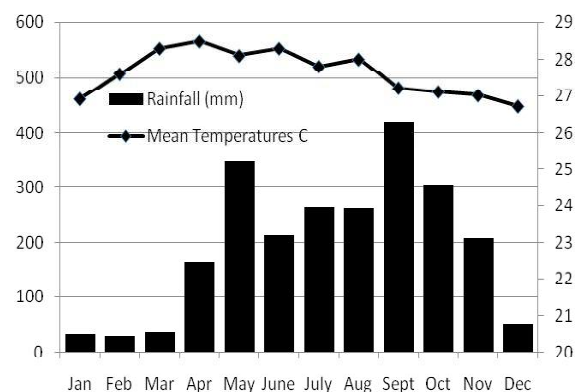
Climate

The climate of Krabi Province is monsoonal and hot and humid all year round, with two seasons: the rainy season from May to November and the dry season from December to April. Humidity levels are high throughout the year, from 75% to 100%. Temperatures range from a minimum of 16.9°C to a maximum of 37.3°C, but mean monthly temperatures vary little from 26.9°C in January to 28.5°C in April. Annual rainfall averages 2,568 mm, with monthly peaks in May (348 mm) and September (419 mm).

The seasons are dictated by tropical monsoon winds, which blow from the northeast for half the year, then reverse and blow from the southwest, producing a dry season and a wet season respectively. The dry season begins in December and usually lasts until March. The northeast monsoon draws cool, dry air from the Asian continent, resulting in a slight drop in temperature. The dry season climate is characterized by gentle breezes and clear blue skies, with monthly rainfall falling to about 30-50 mm from December to March. It is also the coolest time of year. The south-west monsoon brings moist air in from the Indian Ocean, causing the rainy season from June until October. However rainfall is not evenly spread over the months. A peak in May (350 mm) is followed by a slight decline in June to August (c. 200-260 mm), followed by a sharper peak in September (c. 420 mm).

There are two transitional periods, each lasting 4-6 weeks, during which the weather is highly unpredictable. The period before the rainy season, around April - May, is the hottest time of year. There may be prolonged periods of either dry weather with clear skies or overcast skies with rain. The October - November transition is cooler with erratic rainfall events.

This has implications for the timing of tree planting. Ideally, trees should be planted at the beginning of the rainy season, to allow maximum time for development of a root system before onset of the dry season. However, even though monthly rainfall in April averages an acceptable 160 mm, the timing of rainfall events is unreliable and there is the possibility of dry periods lasting several days or weeks. Planting earlier than mid-May, therefore, is risky, since even 2-3 days without rain immediately after planting (with temperatures reaching the mid-30's°C during the daytime) can result in very high mortality of planted trees.



Palms (right), gingers (opposite) and epiphytic ferns (inset, below) are all characteristic features of primary evergreen seasonal forest (main picture).



The Target Forest Type

The main forest types in the area are i) primary evergreen seasonal forest (with bamboo), and ii) fresh water peat swamp forest, which grows along streams, each with generally different floras. Both forest types provide habitat for Gurney's Pitta.

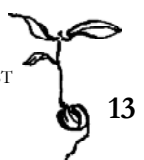
Although the vegetation is often referred to as "tropical rain forest", this is misleading, because the term is usually reserved for forests growing in non-seasonal climates. Whitmore (1991) states that rain forest occurs where mean monthly rainfall remains above 100 mm in every month of the year. The climate of Krabi, therefore, does not support rain forest, since mean monthly rainfall declines to 30-50 mm for 4 consecutive months (December to March). Using the classification system of Walter (1985), the lowland forest of Krabi conforms closely, but not exactly, with his definition of "evergreen seasonal forest" (annual rainfall > 1,800 mm, 3 months when rainfall declines to 50-100 mm and mean annual temperature of 24-28°C).

As part of the project "Gurney's Pitta Research and Conservation in Thailand and Myanmar", J. F. Maxwell, Curator of CMU Herbarium, was engaged to carry out a vegetation survey of the area. The description of the two forest types, below, is adapted from his paper (Maxwell, in press). He recorded a total of 412 vascular plant species during his work in the area.

Primary Evergreen Seasonal Forest (with bamboo)

This kind of forest is found slightly above the swamp forest, mostly on sandstone bedrock above about 25 m elevation, where the drainage is better than in swamp forest areas. The forest is dense, with complete canopy closure, and evergreen, with large canopy trees growing up to 40 m tall. Buttresses and pneumatophores, structural features which characterize swamp forest, are largely absent.

Typical canopy trees include: *Enicosanthum fuscum* (King) A.S. (Annonaceae), *Schima wallichii* (DC.) Korth. (Theaceae), *Irvingia malayana* Oliv. ex Benn. (Irvingiaceae), *Callerya atropurpurea* (Wall.) Schot (Leguminosae, Papilionoideae), *Tetrameles nudiflora* R. Br. ex Benn. (Datiscaceae, which is deciduous), *Cinnamomum iners* Reinw. ex Bl. and *Litsea grandis* (Wall. ex Nees) Hk. f. (both Lauraceae), *Chaetocarpus castanocarpus* (Roxb.) Thw. (Euphorbiaceae), *Castanopsis schefferiana* Hance and *Lithocarpus falconeri* (Kurz) Rehd. (both Fagaceae).



Massive buttresses on some trees (right) and pneumatophores (knee roots) for gaseous exchange help trees survive in the waterlogged conditions of swamp forest (below).



The dense understorey and shrub layers are formed of numerous treelets and shrubs. Typical species include *Clausnea excavata* Burm. f. var. *excavata* (Rutaceae), *Leea indica* (Burm. f.) Merr. (Leeaceae), *Psychotria curviflora* Wall. (Rubiaceae), *Breynia vitis-idaea* (Burm. f.) C.E.C. Fisch. (Euphorbiaceae) (all dicots) and *Pandanus ovatus* (Gaud.) Kurz (Pandanaceae) (a monocot). Bamboos (Gramineae, Bambusoideae) are well-represented, with some species also found in the swamp forest. *Dinochloa scandens* (Bl.) O.K., a sprawling species, *Gigantochloa nigrociliata* (Buse) Kurz and *Thyrsostachys oliveri* Gamb. are common in this forest type. *Orania sylvicola* (Griff.) H.E. Moore (Palmae), a conspicuous palm tree up to 20 m tall with pinnate leaves and a smooth trunk, grows commonly on slopes.

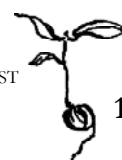
Woody climbers are numerous and include: *Tectaria loureiri* (Fin. & Gagnep.) Pierre ex Craib (Dilleniaceae), *Uvaria cordata* (Dun.) Alst. (Annonaceae), *Entada rheedei* Spreng. (Leguminosae, Mimosoideae), *Aganope thyrsiflora* (Bth.) Polh. (Leguminosae, Papilionoideae) and *Urceola rosea* (Hk. & Arn.) Midd. (Apocynaceae).

The ground flora is generally dense and evergreen. Herbs are plentiful with *Hedyotis pachycarpa* Ridl. (Rubiaceae), *Staurogyne merguensis* O.K. (Acanthaceae) (both dicots); *Etlingera littoralis* (Kon.) Gise. and *Zingiber zerumbet* (L.) J.E. Sm. (both Zingiberaceae, monocots). Ferns are represented by *Taenitis blechnoides* (Willd.) Sw. (Parkeriaceae), *Tectatia angulata* (Willd.) C. Chr. (Dryopteridaceae) and *Lygodium flexuosum* (L.) Sw. (Schizaeaceae, a vine). Tree seedlings and saplings are abundant, indicating a strong regenerative potential.

Fresh Water Swamp Forest

Fresh water swamp forest covers a flat area of barely 2½ km², at 25-75 m elevation, around the Emerald Pool and along adjoining streams. The canopy is complete, dense and up to 40 m high. Canopy trees are typically massive and many have buttresses and pneumatophores (branches that grow upright from tree roots to enable gas exchange); structural features that distinguish this forest type.

Representative upper canopy and emergent trees include *Dipterocarpus kerrii* King (Dipterocarpaceae), *Canarium patentinervium* Miq. (Burseraceae), *Toona ciliata* M. Roem. (Meliaceae), *Pometia pinnata* J.R. & G. Forst. (Sapindaceae), *Parkia timoriana* (DC.) Merr. (Leguminosae, Mimosoideae), *Duabanga grandiflora* (Roxb. ex DC.) Walp. (Sonneratiaceae), *Eugenia operculata* Roxb. (Myrtaceae), *Horsfieldia brachiata* (King) Warb. (Myristicaceae), and *Ficus variegata* Bl. (Moraceae).



Smaller trees make up a dense understorey, including *Garcinia merguensis* Wight (Guttiferae), *Sterculia guttata* Roxb. (Sterculiaceae), *Stemonurus malaccensis* (Mast.) Sleum. (Icacinaeae), *Saraca indica* L. (Leguminosae, Caesalpinioideae), *Carallia brachiata* (Lour.) Merr. (Rhizophoraceae), *Eugenia muelleri* Miq. and *E. oleina* Wight (Myrtaceae), *Madhuca malaccensis* (Cl.) Lam and *M. motleyana* (de Vr.) Baeh. (Sapotaceae), *Diospyros undulata* Wall. ex G. Don var. *cratericalyx* (Craib) Bakh. and *D. venosa* Wall. ex A. DC. var. *venosa* (Ebenaceae), and *Triadica cochinchinensis* Lour. (Euphorbiaceae).

The shrub layer is composed of many shrubs and treelets, as well as palms and bamboos, with woody climbers, including rattans, adding structural diversity. Typical species include *Ixora diversifolia* Wall. ex Kurz and *Saprosma longicalyx* Craib (both Rubiaceae), *Trevesia valida* Craib (Araliaceae), *Galeria fulva* (Tul.) Miq., *Phyllanthus albidiscus* (Ridl.) A.S., and *P. oxyphyllus* Miq. (the latter three Euphorbiaceae). Rattan palms provide a striking structural component of this forest type, including *Calamus axillaris* Becc., *C. exilis* Griff., *C. javensis* Bl., *C. palustris* Griff. var. *cochinchinensis* Becc., *Daemonorops sabut* Becc., and *Korthalsia laciniosa* (Griff.). Other palms grow as treelets, such as the common species *Licuala kunstleri* Becc., *Pinanga malaiana* (Mart.) Scheff., and *Salacca wallichiana* Mart. The latter is an important nesting tree of Gurney's Pitta. Bamboos (Gramineae, Bambusoideae) are diverse and abundant. The commoner species include *Gigantochloa apus* (Schult.) Kurz, *G. wrayi* Gamb., and *Cephalostachyum virgatum* (Munro) Kurz.

The ground flora consists of many evergreen herbs, dominated by *Dracena curtisii* Ridl. (Agavaceae), *Aglaonema oblongifolium* (Roxb.) Schott (Araceae), *Donax cannaeformis* (G. Forst.) K. Sch. (Marantaceae), *Tacca chantrieri* Andre (Taccaceae), *Globba fasciata* Ridl. (Zingiberaceae), *Freycinetia sumatrana* Hemsl. var. *sumatrana* (Pandanaeae), a creeping vine (all monocots). Dicots are relatively sparse with



Acrotrema costatum Jack (Dilleniaceae), *Sericocalyx glaucescens* (Nees) Brem. (Acanthaceae), *Adenosoma indiana* (Lour.) Merr. (Scrophulariaceae), and *Thottea tomentosa* (Bl.) Hou (Aristolochiaceae). The ground flora is also replete with seedlings and saplings of woody species.

Apart from the vascular flora, bird species is the only other group to have been surveyed in the area. Round and Treesucon (1996) list 318 species present; an extraordinarily high number for such a small area.

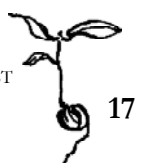


Characteristics of Gurney's Pitta Habitat

When considering the restoration of these forest types, specifically to provide habitat for Gurney's Pitta, it is important to take into consideration the habitat requirements of the bird when designing the restoration techniques. These were described in detail by Donald et al. (2006). Gurney's Pitta requires forest with dense undergrowth and no human disturbance. The species lives in both primary and secondary forest, and therefore should be able to colonize restored forest sites fairly rapidly (within a few years) after planting, provided that essential habitat needs are met. Forest restoration should aim to create dense ground cover (>65% cover).

Forest restoration should provide adequate nesting sites. The birds build their nests most commonly on rattan palms (*Calamus* spp.) and also on the spiny palm *Salacca wallichiana* Mart. and *Licuala kunstleri* Becc. (both treelets). Nests have also been recorded rarely on lianas and standing trees. Tree species (including seedlings and saplings), associated with nesting areas, include *Saraca indica* L. (Leguminosae, Caesalpinioideae), *Alstonia macrophylla* Wall.ex G.Don (Apocynaceae), *Elaeocarpus stipularis* Bl. (Elaeocarpaceae) and *Garcinia merguensis* Wight (Guttiferae). So, in addition to the nesting palms, these tree species should be included in forest restoration plantings.

An old Gurney's Pitta nest, from which 3 chicks successfully hatched in 2008, typically placed amongst the spines of a rattan palm in primary evergreen forest in a valley bottom.





An abandoned rubber tree plantation (above) on the boundary of the wildlife sanctuary supports dense regrowth of many primary evergreen forest tree species. The site below is undergoing rapid natural regeneration from tree stumps, as well as saplings which survived the loggers' chainsaws. Application of ANR techniques can rapidly achieve canopy closure on such sites with little or no additional tree planting.



Characteristics of deforested sites

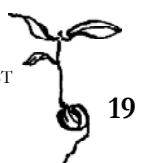
Deforested sites in the area can be classified into three types, according to the dominant vegetation, which is dependent on the length, type and severity of disturbances:-

- i) Abandoned rubber plantations – dominated by mature rubber trees, but supporting a very diverse under-storey community of forest tree seedlings and saplings. A few such sites are privately owned on the periphery of the wildlife sanctuary. Recommended restoration strategy: protect from disturbance and gradually thin out the mature rubber trees, to liberate the understory forest tree community.
- ii) Open sites, undergoing natural regeneration, which retain fairly dense populations of tree seedlings and saplings, often including coppicing tree stumps, but few or no mature trees. These areas are often those recently cleared for planting with rubber trees, but where the authorities have evicted the encroachers, before rubber trees could grow, and regained control of the land. Top soil remains rich in organic matter. Recommended restoration strategy: protection plus accelerated natural regeneration (ANR).
- iii) Sites dominated by grasses, with few trees present (as seedlings, saplings or adults), where natural regeneration is severely retarded – usually sites which have a history of complete clearance, followed by some kind of cultivation, abandonment and fire. Soil is usually very sandy and the top soil is degraded, with little organic matter. Recommended restoration strategy: protection and ANR plus planting framework tree species.

Sites undergoing natural regeneration

Such sites often support >300 tree saplings (>50 cm tall) per rai (>1,875/ha), as well as dense populations of small tree seedlings and they may retain many tree stumps, capable of re-sprouting (coppices). This means that saplings need only grow to a mean crown width of about 2½ m in order to bring about canopy closure. This can usually be achieved within 2-3 years by applying treatments to accelerate growth, provided there is no further disturbance to the vegetation.

The fast-growing pioneer trees, *Macaranga denticulata* (Bl.) M.A. and *Mallotus peltatus* (Geisel.) M. A. (both Euphorbiaceae), *Anthocephalus chinensis* (Lmk.) A. Rich. ex Walp. (Rubiaceae), *Dillenia obovata* (Dilleniaceae) and *Trema orientalis*





On grassy sites, such as along the trail to Tone Tiew Waterfall (above) and at Chong Yom (below), natural regeneration is severely retarded. Such sites require intensive planting with framework tree species to re-establish the natural mechanisms of forest regeneration.



(L.) Bl. (Ulmaceae), are abundant on such sites. *T. orientalis* can grow so densely that thinning may be necessary to reduce its dominance and allow other tree species, present in the under-storey as seedlings, to grow up. Two common fig species in regenerating sites, *Ficus hispida* L.f. var. *hispida* and *Ficus callosa* Willd. (both Moraceae), can produce a food source to attract seed-dispersing animals after 3-4 years of growth. A few climax tree species also commonly invade such sites, such as *Diospyros malabarica* (Desr.) Kostel. var. *siamensis* (Ebenaceae) and *Cinnamomum iners* (Lauraceae), both with fleshy fruits that attract wildlife, whereas the legumes, *Callerya atropurpurea* (Wall.) Schot (Leguminosae, Papilionoideae) and *Peltophorum pterocarpum* (Leguminosae, Caesalpinioideae) may help to increase soil nitrogen levels.

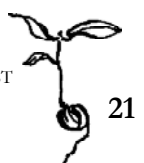
The ground flora consists mainly of herbs (particularly of the families Zingiberaceae and Compositae), tree seedlings, shrubs and bananas, usually with a relatively sparse cover of grasses. *Eupatorium odoratum* Linn. (Compositae) is very common and can approach dominance in some sites. Other common representative species include *Ageratum conyzoides* L. (Compositae), *Etlingera littoralis* Kon. (Zingiberaceae), *Leea indica* Merr. (Leeaceae) and *Melastoma malabathricum* Linn. (Melastomataceae) (both shrubs or treelets) and the wild banana *Musa acuminata* Colla (Musaceae).

Natural regeneration on such sites leads to the formation of secondary forest, dominated by a few species of pioneer tree species (listed above). Enrichment planting can be carried out to increase tree species richness and return the forest to its primary condition more rapidly than would occur naturally. Species added to the system, after canopy closure has been achieved, should be climax forest tree species, including the palms favoured by Gurney's Pitta as nest tree species (listed above).

Grassy Sites

Grassy sites support up to 120 tree saplings (>50 cm tall) per rai (equivalent to about 730/ha), but of very few species. This is not enough to achieve canopy closure, even with ANR treatments. Therefore, tree planting with framework tree species to increase tree density and attract seed-dispersing animals is necessary to ensure rapid site recapture.

Only one tree species can be regarded as typically common in such sites: *Cratoxylum formosum* (Jack) Dyer (Guttiferae, Hypericaceae) (small tree) (about 20/rai, 120/ha). This is rare or absent from sites with more prolific natural regeneration. Other species, present but sparse, include the fast-growing



pioneers, *Trema orientalis* (L.) Bl. (Ulmaceae), *Macaranga denticulata* (Bl.) M.A. (Euphorbiaceae), *Vitex pinnata* L. and *Callicarpa arborea* Roxb. var *arborea* (both Verbenaceae) and the fig, *Ficus hispida* L.f. var. *hispida*, (Moraceae). Obviously, where common, these species need not be included amongst those planted.

Such sites are usually dominated by the grass *Imperata cylindrica* Beauv., with *Phragmites vallatoria* (Pluk. ex L.) Veldk. (both Gramineae) also very common. These grasses constitute a considerable fire risk to planted trees. Other herbs, frequent but rarely dominant, include *Costus speciosus* Smith (Zingiberaceae) and *Cheilanthes belangeri* C.Chr. (Parkeriaceae) as well as the ubiquitous, exotic, *Eupatorium odoratum* Linn. (Compositae) (sometimes as a shrub). Such areas also support several species of aggressive vines, which can rapidly smother young trees and are very difficult to remove without damaging the trees. Common species include *Dioscorea oryzetorum* Prain & Burk. (Dioscoreaceae), *Pueraria phaseoloides* Benth. (Papilionaceae), *Streptocaulon juvenas* Merr. (Asclepiadaceae) and *Lygodium flexuosum* Sw. (Schizaeaceae). The first woody species to gain a foothold in such areas are usually the common shrub or treelet, *Melastoma malabathricum* Linn. (Melastomataceae) and the shrub *Kopsia fruticosa* (Ker) A. DC. (Aponcynaceae), both of which are fairly common.

Due to intense competition from the grasses and herbs, as well as the high fire risk, establishing planted trees on such sites is challenging. Frequent weeding and fire prevention measures are essential for success.

Soil conditions

Soils of deforested sites are highly acidic and this may inhibit establishment of planted trees. Grassy sites have the most challenging soil conditions, with sandy, acidic soils with low organic matter content (and therefore low water retaining capability) and lower nutrient levels compared with sites undergoing natural

Table 1 - Soil conditions of deforested sites

regeneration, suitable for ANR.

	Grass Dominated Plot		Regenerating Plot	
	Mean	SD	Mean	SD
pH	4.0	0.1	3.4	0.1
Organic Matter (g/100g)	1.4	0.1	2.0	0.4
Total N (g/100g)	0.1	0.0	0.1	0.0
P (mg/kg)	3.5	0.3	9.6	7.0
K (mg/kg)	72.4	8.0	105.7	37.1
Sand (%)	73.7	1.4	40.7	1.3
Silt (%)	15.2	1.2	45.3	4.4
Clay (%)	11.2	0.4	14.0	3.6
Texture	Sandy Loam		Loam	



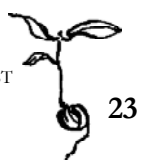
Accelerated Natural Regeneration (ANR) Techniques

ANR covers any set of activities that enhance the natural processes of forest regeneration. These include promoting the natural establishment and subsequent growth of indigenous forest trees, whilst preventing any factors that might harm them e.g. competition from weeds, browsing by cattle, fire etc. Because ANR relies on existing natural processes, it requires less labour input than tree planting and is therefore a very cheap way to restore forest ecosystems. ANR and tree planting should not be regarded as two exclusive alternatives to forest restoration. Successful restoration usually depends on combining elements of both techniques.

ANR is appropriate wherever natural regeneration is already underway i.e. type ii) sites, as defined above. To determine if a site is suitable for restoration by ANR, carry out a rapid and simple site survey. Randomly select one corner of the site and use a compass to fix a bearing for a line, passing through the middle of the site towards the opposite corner. Walk at least 10 m into the site along the line. Estimate the number of tree saplings taller than 50 cm and coppicing tree stumps within a radius of 5 m of that point. A rough estimation is usually sufficient but, for added accuracy, attach a 5-m-long piece of string to a bamboo pole and walk round in a circle to more accurately define the sample area. Repeat for 10 points, evenly spaced across the site. If the average number of saplings + stumps per circle is >20, ANR should bring about rapidly canopy closure within 2-3 years after treatments are applied.

Start to apply ANR treatments in mid-May. Mark all tree stumps, saplings and tree seedlings with coloured bamboo poles. Then carefully expose them, by pulling out surrounding weeds (including roots), by hand, to a radius of 50-100 cm. Avoid disturbing the roots of tree seedlings/saplings when pulling out weeds. Areas in between the exposed trees can be weeded by using hand-held, powered, weed-cutters or by machete, but make sure all sources of natural regeneration are clearly visible, before allowing blades of any kind on site.

After weeding has been completed, apply fertilizer in a ring about 20 cm away from the base of tree saplings and seedlings. Since standard chemical fertilizers (NPK 15:15:15) have now become so expensive (due to the oil price), we recommend using locally available, organic fertilizer in doses of 100-200 gm. The one, which we have used successfully in ANR trials, is Food and Green Super Organic ("*Sam Dauk Jig*"). It is made from bat dung, rock phosphate and dolomite and contains (unspecified) amounts of N, P, K, as well as trace elements (Mg, Ca, S, Mn, Cu, Fe, Zn, B, Mo).





ANR techniques can be very effective. Naturally established seedlings and saplings on the site above were treated with fertilizer application, mulching and weeding in May 2007. By March 2008 (below) canopy closure had been achieved. Taweesak is holding two stems of *Callerya atropurpurea* (Wall.) Schot, a climax tree species, thriving in the newly created shade.



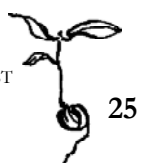
Next, apply a circle of corrugated cardboard around the bases of saplings and seedlings. The circle should be 20-30 cm radius with a 5-cm radius hole in the centre and slit from the perimeter to the centre to facilitate positioning the circle without harming the seedling/sapling. Make sure that the stem of the seedling/sapling lies in the centre of the hole, to prevent the cardboard from abrading the stem and providing an entry point for diseases; then anchor the cardboard in position by pushing the bamboo pole through it. The main purpose of the cardboard mulch is to prevent weed growth in the immediate vicinity of seedlings/saplings and maintain competition-free conditions for 2-3 months after beginning treatments. The cardboard breaks down rapidly adding organic matter to the soil. Mulching also helps to reduce acid splash onto the foliage of planted trees, when rain drops hit the acidic soil. If cardboard is not available, apply a dense layer of cut weeds, generated from the mechanical weeding.

Repeat weeding and fertilizer application every 4-6 weeks during the rainy season (depending on weed growth rates), trying not to disturb the cardboard mulch mat and continue the following rainy season, until canopy closure is achieved. Do not weed during the dry season (Dec-Mar). Allow weeds to grow up, during this period, to protect young tree seedlings from exposure to the hot, dry and sunny conditions of the dry season.

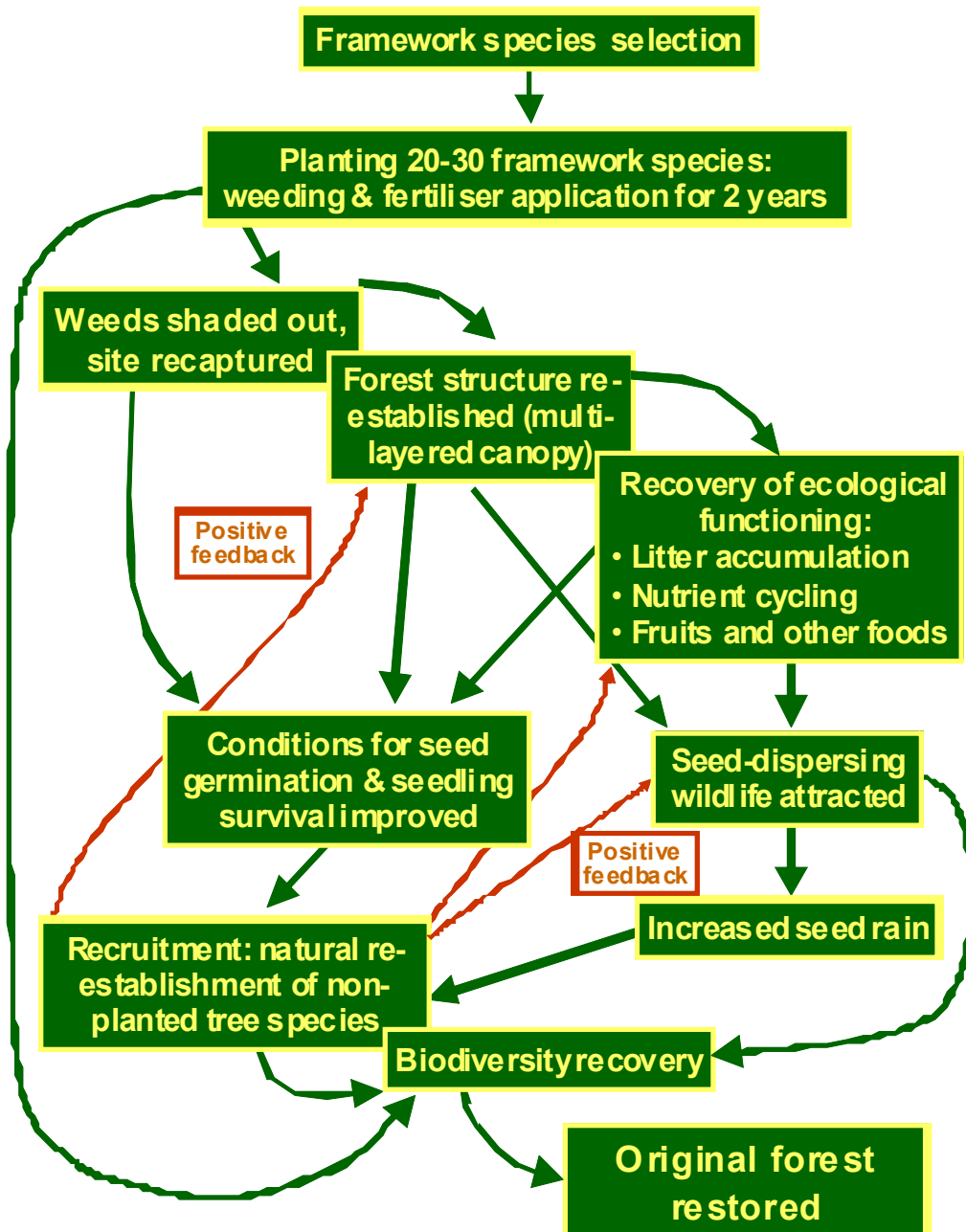
For tree stumps with multiple shoots, cut back all shoots except the tallest. Mulching and fertilizer application are unlikely to have much effect on regeneration from tree stumps.

Ensure that cattle are excluded from the site. Prevent fire by cutting a fire break around the site in January and engage local people to maintain a lookout for approaching fires and fight fires that threaten the restoration sites.

Once canopy closure has been achieved, carry out a second survey to assess the extent to which primary forest trees are colonizing the site (usually in the 3rd rainy season after starting treatments). Most of the canopy trees will be fast-growing pioneer species (e.g. *Trema orientalis* (L.) Bl. (Ulmaceae), *Macaranga denticulata* (Bl.) M.A., *Mallotus peltatus* (Geisel.) M. A. (both Euphorbiaceae), *Ficus hispida* L.f. var. *hispida* (Moraceae), *Anthocephalus chinensis* (Lmk.) A. Rich. ex Walp. (Rubiaceae) etc.), representing a small fraction of the tree species community that is characteristic of mature forest. Colonization by primary forest trees depends mostly on the occurrence primary forest with fruiting trees close to the restoration site.



How the Framework Species Method Works



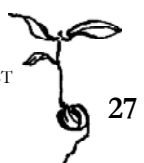
Use the circular sample technique, described above, to count saplings of **primary** forest trees growing taller than 50 cm in the under-storey. If the density of such trees is >10-15 per circle, representing more than 20 species (including some of the palms favoured by Gurney's Pitta as nest sites), there is no need for enrichment planting. If these conditions are not met, then consider enriching the tree community by under-planting with shade-tolerant climax tree species, to bring the total average tree density across the site to about 500/rai. Species known to perform well under these conditions include *Eugenia syzygioides* (Miq.) Hend. and *E. grandis* Wight var. *grandis* (both Myrtaceae), *Pometia pinnata* J.R. Forst. & G. Forst. (Sapindaceae), *Hopea avellanea* Heim (Dipterocarpaceae), *Sandoricum kaotjape* (Meliaceae) and the Gurney's Pitta nesting palm, *Salacca wallichiana* Mart. (Palmae).

Direct seeding could be another useful technique to rapidly increase tree species richness on ANR sites, without the need to maintain a nursery to produce tree saplings. This technique works well for some pioneer tree species in N. Thailand (Tunjai, 2007) and experiments are currently underway to determine the effectiveness of this technique and its potential role in restoring Krabi's lowland evergreen forests.

The Framework Species Method

This technique is suitable for grass-dominated sites, where primary forest trees remain in the vicinity (within a few kilometres). It involves planting indigenous tree species, specially selected to promote rapid re-establishment of forest structure and ecological function, as well as biodiversity recovery. It represents a compromise between ANR alone (which usually does not involve tree planting) and the expensive "maximum diversity" method (which involves planting all tree species, which formerly compromised the original forest habitat). The framework species method combines the planting of a moderate number of key tree species with the ANR techniques, already described above, to enhance natural regeneration, creating a self-sustaining forest ecosystem from a single planting event. The concept was originally pioneered in Queensland, Australia to repair damaged tropical rain forest (Goosem and Tucker, 1995), and has been successfully modified to restore seasonally dry tropical forests in northern Thailand (FORRU, 2006)

Framework trees are indigenous, non-domesticated, forest tree species, which, when planted on deforested land, help to re-establish the natural mechanisms of forest regeneration and accelerate biodiversity recovery. The framework species method involves planting 20-30 such tree species and caring for them for two or





The grassy plot above was planted with candidate framework tree species in August 2006. By October 2008 (below), several tree species were showing high field performance, whilst others could reliably be removed from the list of candidate framework tree species.

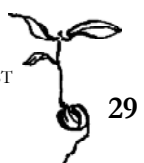


more years (e.g. weeding, applying fertilizer etc.). The planted trees “re-capture” the site, by shading out herbaceous weeds. They also re-establish forest structure, by developing a multilayered canopy. Furthermore, they restore ecosystem processes, such as nutrient cycles, and improve conditions for seed germination and seedling establishment of additional (non-planted) tree species (termed “recruits”), by creating a cooler, more humid microclimate on the forest floor. Moist, nutrient-rich leaf litter, free of weed competition, creates the perfect conditions for germination of in-coming tree seeds and survival of tree seedlings.

Biodiversity recovery relies on birds, bats and other small mammals being attracted to the planted trees. The 20-30 tree species planted represent only a fraction of the total number of tree species that grow in tropical forest ecosystems. To restore the forest’s original tree species composition, wildlife must be employed as seed-dispersers. Once planted trees have created conditions conducive to tree seedling recruitment, they must produce resources (e.g. nectar-rich flowers, fruits or bird nest sites etc.), which attract seed-dispersing animals. These animals transport seeds of many additional tree species from nearby surviving forest into the planted sites. It is this next generation of naturally established trees, germinating from the seeds brought in by animals, which ultimately restores the forest to its original condition.

The essential ecological characteristics of framework tree species are therefore i) high survival when planted out in deforested sites, ii) rapid growth, iii) dense, spreading crowns that shade out herbaceous weeds and flowering and fruiting, or provision of other resources, at a young age, to attract seed-dispersing wildlife. In addition, framework species must be easy to propagate in nurseries, using simple techniques. Trees cannot be planted if they cannot be grown. Therefore, desirable nursery characteristics of framework tree species include reliable seed availability; rapid and synchronous seed germination and, most importantly, production of vigorous seedlings of a plantable size in less than 1 year. In the seasonally dry tropics, where wild fires in the dry season are an annual hazard, an additional essential characteristic of framework species is resilience after burning. When fire prevention measures fail, the success of forest restoration plantings can depend on the ability of the planted trees to re-sprout from their rootstock after fire has burnt their above-ground parts (i.e. coppicing).

Mixtures of framework tree species planted should include both pioneer and climax species. By planting both pioneer and climax trees in a single step, forest succession can be short-circuited. Many climax forest tree species perform well in the open, sunny conditions of deforested areas, but they fail to colonize such areas due to lack of seed dispersal. Many climax tree species have large, animal-





The same individual *Alstonia macrophyla* tree, planted in August 2006, 4 months (top left), 9 months (top right), 17 months (lower left) and 26 months (lower right) after planting. Right - flowering and fruiting 26 months after planting. High survival, rapid growth, a dense canopy and early flowering and fruiting makes this an ideal framework tree species. It is also associated with Gurney's Pitta nest sites.

dispersed seeds. The decline of large mammals, over wide areas now prevents dispersal of large-seeded, climax trees into deforested sites. By including some climax forest tree species amongst those planted, it is possible to overcome this limitation and accelerate recovery of climax forest. Fast-growing, pioneer trees rapidly close canopy and shade out weeds, whilst slower growing climax species form an under-storey beneath the pioneer tree crowns, adding structural diversity to the forest and increasing the variety of wildlife resources available. Pioneer trees begin dying 15-20 years after planting. However, by this time, a rising under-storey of climax forest trees is ready to replace them, along with a dense layer of naturally established trees, derived from seeds brought in by wildlife.

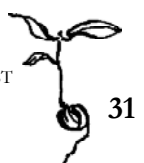
Research, under this project, focussed on identifying such framework tree species, suitable for restoring the forest habitat of Gurney's Pitta. It involved surveying the tree species composition of the forest, carrying out phenology studies (to determining when seeds could be collected), germinating more than 100 tree species in a nursery and establishing 2 field trials. Because data from the field trials is just coming in (first data sets are compiled 18 months after planting) and the project was not long enough to assess attractiveness of the trees to wildlife or biodiversity recovery, it is not possible to present a definitive list of framework tree species for Krabi. However, we have accumulated sufficient data to compile a shortlist of "candidate" species. Below, we present useful notes on the indigenous tree species most likely to act as framework species (on the basis of currently available data), which are recommended for long-term field trials.

Selected Candidate Framework Species

DBH = diameter at breast height; GP = typical germination percentage; MLD = median length of seed dormancy (days); TNT = total nursery time (from collection of seeds or wildlings to planting out).

***Alstonia macrophylla* (Wall.) ex G. Don (APOCYNACEAE) "Tung Fa"**

A medium-sized, evergreen tree of secondary forests. Fruits: thin, elongate pods, 20-40 cm long, green turning brown when ripe, July-November. Seeds: many per pod, reddish brown, 6 x 1.5 mm, with dense, golden-brown hairs 7-10 mm on the tips and one side. This species is very hardy in the harsh conditions of deforested sites. It had the highest survival and growth rates of all species tested in field trials. Flowering and fruiting occurred 2½ years after planting and birds nest in the young trees. The species is strongly associated with GP nesting sites. Dig up wildlings <20 cm tall in September. and grow them on in containers in the nursery. Saplings are ready to planting out by May-June.





Top left - *Antidesma montanum*, growing in the nursery, 12 months old. Top right - *Carallia brachiata*, planted in August 2006, 26 months old. Above left - *Cinnamomum iners*, also 26 months after planting and (bottom right) two natural saplings, 12 months after receive ANR treatments. Above right - a wildling of *Diospyros venosa* grown on in the nursery.



***Antidesma montanum* Bl. var. *montanum* (EUPHOBACEAE) “Maw”**

Common, understorey, pioneer, tree species, 10-20 m tall, often in gaps in disturbed evergreen forests. Fruit: fleshy drupe, elliptic, oblique, red, March to October. Seeds: 1-2 per fruit. This species attracts many birds when fruiting. Collect fruits in September. Remove flesh and sow seeds in baskets. Transfer seedlings into containers after the first two pairs of leaves have fully expanded. GP typically 50%, MLD 40 days, TNT 10 months. This species is popular with local people because the fruits are used to make a high-priced wine.

***Carallia brachiata* (Lour.) Merr. (RHIZOPHORACEAE) “Kor Haeng”**

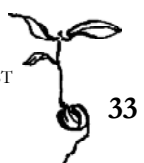
A rare, small, understory, evergreen tree, up to 20 m tall, occasionally with buttresses, in deciduous or evergreen forest types, and freshwater peat swamps. Fruits: fleshy, glabrous, globose, berries, purple-red to black, when ripe, 6-7 x 6-7 mm, with persistent calyx lobes, January to April. Seeds: usually 1 seed per fruit, reddish brown, kidney-shape, approximately 5-6 x 5-6 mm. Attracts many birds when fruiting, easy to propagate in nurseries, with high survival and growth rates when planted out in deforested areas. Collect ripe fruits in March. Remove fruit flesh and sow seeds into baskets. Prick out into plastic bags, when first true leaf pair has expanded. GP >90%, MLD 41 days, TNT 14 months. Alternatively, dig up wildlings in June. Pot into 9" x 2.5" plastic bags and grow on for 11 months.

***Cinnamomum iners* Reinw. ex Bl. (LAURACEAE) “Op Cheuy”**

A rare, medium-sized to large (15- 30 m tall), evergreen tree in the understory of evergreen forests (often found along the forest edge and streams) and in disturbed areas. Fruits: elliptic to ovoid berries, green turning dark purple-black when ripe, 17 x 8 mm, February to May. Seeds: 1 per fruit, ellipsoide, tan to brown, with smooth testa, 9 x 6 mm. Fruits are very attractive to seed-dispersing birds. A dense crown effectively shades out weeds. Germination trials in the nursery failed. Therefore, propagate from wildlings, which are plentiful in the area. Dig up wildlings < 20 cm tall in June. Transfer them to containers and grow them on in the nursery. Saplings are ready for planting the following May.

***Diospyros venosa* Wall. ex A. DC. (EBENACEAE) “Kumin Reusi”**

An evergreen tree or treelet, up to 20 m tall with straight stem and buttresses, in lowland evergreen forests. Fruits: berries, green, turning black brown when ripe; smooth skin with scarce brown spots and thin fleshy mesocarp, 17 x 15 mm, July to February. Seeds: 6-7 per fruit, light brown, 3 x 14 mm. The fruits of





Top left - *Eugenia cerasiformis* in the nursery and (bottom right) mature seed tree along the trail to Sa Morakot. Top right - *Eugenia grandis*, planted to enrich an ANR experiment (9 months old). Lower left - *E. grandis*, 9 months after planting in a grassy site. Lower right - the same tree 26 months after planting.



this species are highly attractive to seed-dispersing animals. The species is easy to propagate from seeds in the nursery with reasonable seedling growth rates. Collect ripe fruits in February. Remove fruit flesh and sow seeds in baskets. Pot up seedlings, once the first pair of true leaves has fully expanded. GP >50%, MLD 41 days, TNT 13 months. Alternatively, dig up wildlings <20 cm tall in June. Pot into 9 x 2.5" plastic bags and grow on for 11 months. Saplings are ready for planting out the following May.

The Genus, *Eugenia*

Eugenia is represented by at least 11 species in the area. All are probably suitable as framework species, due to their reasonable high survival and growth rates after planting out, dense crowns and fleshy fruits (usually single-seeded berries), which attract seed dispersing animals into planted sites. They are all relatively easy to grow in nurseries, either from seeds or wildlings (which are abundant in remnant forest throughout the site). Species showing particular promise as framework species (on the basis of research data and indigenous knowledge) are detailed below.

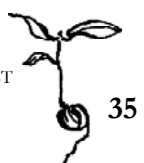
***Eugenia cerasiformis* (Bl.) DC. (Myrtaceae) "Kia Dai"**

A rare, small, understory, evergreen treelet or tree up to 8 m tall (DBH up to 10 cm), only known from along streams in primary evergreen forest remnants. Fruits: fleshy, globose, glabrous, green, berries, turning blackish-purple when ripe, 12-15 x 15-20 mm, edible. Seeds: 1-2 per fruit, sub-globose, brown, 10 x 8 mm. Fruits are attractive to many seed-dispersing animals, including birds and squirrels, during the day time and civets at night. Collect ripe fruits in February. Remove fruit fleshy and sow seeds directly into plastic bags. GP>70%, MLD 34 days, TNT 15 months.

***Eugenia grandis* Wight var. *grandis* (MYRTACEAE) "Mau"**

Synonyms: *Syzygium grande* (Wight) Wight ex Walp.

Evergreen tree, up to 25 m tall (DBH up to 1.5 m), with dense spreading crown, often branching near the base, in open places usually in secondary forest. Fruits: subglobose to globose, green, berries with smooth skins and fibrous pulp, 2-3 cm diameter, January to May, attractive to squirrels and frugivorous bats. Seeds: 1 per fruit, globose, 19 x 17 mm, cream to light green. Collect fruits in May, remove pulp and sow seeds directly into plastic bags. GP>60%, MLD 15 days, TNT 12 months.





Top left - *Eugenia muelleri* in the nursery, ready for planting after 12 months and (top right) 5 months after planting into a grassy site. Above left - *Eugenia oleina* undergoing a seedling growth experiment in the nursery and (bottom right) 6 months after germination. Above right - *Eugenia syzygioides*, 6 months after planting into a grassy site.



***Eugenia muelleri* Miq. (MYRTACEAE) “Mau Bai Lek”**

Large, evergreen, canopy tree, up to 30 m tall, sometimes with small buttresses, in lowland evergreen forest, often near streams. Fruits: green, fleshy berries, round, ellipsoid, 2-2.5 x 2.5-3 cm, December to January. Seeds: 1 per fruit, 16 x 16 mm. Fruits are attractive to squirrels and bats. Collect ripe fruits in January. Remove flesh and sow seeds directly into plastic bags. GP >50%, MLD 40, TNT 16 months.

***Eugenia oleina* Wight (Myrtaceae) “Wah” (high tone)**

A rare evergreen, medium-sized, lower-canopy tree, up to 15 m tall, with a broad crown and sometimes with buttresses. It grows in lowland evergreen forest, often near streams and in peat forests. Fruits: fleshy berries, turning dark red to black when ripe, 7-10 x 5-7 mm, February to June. Seeds: 1 per fruit. Fruits are highly attractive to many bird species. Collect ripe fruits in May. Remove fruit flesh and sow seeds into baskets. Transfer seedlings to plastic bags as soon as the first leaf pair has fully expanded. GP up to 45%, MLD 21 days, TNT 12 months.

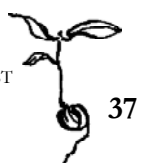
***Eugenia syzygioides* (Miq.) Hend, (MYRTACEAE) “Daeng Kuan”**

Synonyms: *Syzygium syzygioides* (Miq.) Merr. & L. M. Perr

An evergreen canopy tree, of medium crown width, up to 40 m tall (DBH 95 cm) in secondary forest, in both open and shaded places. Fruit: fleshy berry, black when ripe, 6-10 x 6-13 mm, January to April; very attractive to many bird species. *E. syzygioides* is easy to grow in the nursery from seed. Seedlings have high growth rates in the nursery and saplings had high survival and growth rates in field trials, particularly those planted in moderate shade. Collect ripe fruits in March. Remove the fruit flesh; drop seeds into water and discard the non-viable ones which float. Sow seeds in trays in full sunlight. Then move trays into shade, immediately after germination. GP typically >60%, MLD 45 days, TNT 12-14 months.

The Genus, *Ficus*, Fig Tree Species (MORACEAE) “Sai” or “Madeua”

The area supports at least 11 *Ficus* spp. All (except *F. globosa* Bl, which grows as a woody climber) can be planted as framework tree species. Some smaller *Ficus* species (e.g. *Ficus hispida* L.f. var. *hispida* and *Ficus callosa* Willd.) naturally colonize deforested areas. If present in sufficient numbers, they need not be planted, but where absent, they are recommended for planting. Fruits: figs are actually the swollen, fleshy stalks of inflorescences (receptacles), which have become





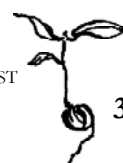
Top left - Naturally established *Ficus hispida* sapling, 6 months after receiving ANR treatments. Top right - developing figs of *Ficus variegata*. Above left - *Garcinia hombroniana* sapling, established naturally beneath the developing canopy of an ANR experimental plot. Above right - young *G. hombroniana* seed tree, along the Sa Morokot trail, showing typical branching pattern and (right) the bark of a more mature tree.



inverted to enclose many tiny flowers or fruits within. The whole structure is termed a “syconium”. Seeds: 1 per fruit, small, brown. Two main characteristics make most *Ficus* tree species excellent framework tree species. Firstly, their very dense root systems enable them to survive and grow well under the harshest of conditions and to grow back rapidly after burning or slashing. Such root systems allow most species to retain their leaves throughout the dry season, by tapping into soil moisture deep underground. This makes *Ficus* trees excellent for preventing soil erosion and stabilizing stream banks. Secondly, figs are an essential food for a wide range of seed-dispersing animals, including many species of birds and bats, as well as primates, civets, squirrels, bears, deer and wild pig. Most species produce figs within 6 years after planting. *Ficus* species are well-known as “keystone species” *i.e.* their figs sustain populations of fruit-eating animals, when other foods are scarce. Thus, they help to maintain viable populations of seed-dispersers, which are vital for recovery of tree species richness in regenerating forest. Cut figs from *Ficus* spp trees when they are fully ripe (*i.e.* when birds or squirrels begin to feed on them). Break open figs and scrape out the tiny, light brown, fruits (achenes), each of which contains a single seed. Drop achenes into water and select the viable ones, which sink. Spread them out on paper and leave them to dry in the sun for 1-2 days; then sow them sparsely into germination trays, containing a mix of forest soil and sand (50:50). Fig seedlings are tiny and prone to damping-off. Forest soil provides microbes that may help seedlings to resist damping-off. Apply a fungicide (Captan) to the soil surface when seeds are sown and again 1 month afterwards. Place germination trays in light shade. GPs typically high (often >80%); MLDs usually short (15-60 days, depending on species). Seedlings of most species must be grown for 5-10 months before they are robust enough for pricking-out. After potting, saplings of most *Ficus* species grow rapidly, but most are not ready for planting until the 2nd planting season after germination (TNT 18-22 months). Consequently, propagation by cuttings is now being investigated.

***Garcinia hombroniana* Pierre (GUTTIFERAE) “Wah” (mid tone)**

An evergreen tree or treelet up to 8 m tall (DBH up to 15 cm), with a relatively broad, dense crown, in climax forest or secondary growth. Dioecious, flowering from January to February. Fruits: fleshy, globose, with tough, fibrous mesocarp, 50 mm in diameter, yellow to pink, May to June. Seeds: 7-8 seeds per fruit, 23 x 7 mm. This species is tolerant of adverse soil and climatic conditions, growing in sandy and rocky soils in its native habitat. It also grows well in acidic soils and tolerates drought, as well as high rainfall. It produces a dense crown, capable of rapidly shading out weeds. Monkeys like to eat the aril of the fruit. Collect fruits in March, extract seeds and remove the sticky aril from the seeds. Sow seeds





Top left - Fruits and seeds of *Hydocarpus anthelminthica* with young seedlings (above left). Top right - *Irvingia malayana* sapling, 9 months after planting into a grassy site. Above right - young *Lepisanthes rubiginosa* seedlings 3 months after sowing and right saplings, 9 months after planting.



immediately, without drying, directly into plastic bags. GP 45%; MLD 32 days; TNT 12-14 months. May be suitable for direct seeding.

***Hydnocarpus anthelminthica* Pierre ex. Lanes. (FLACOURTIACEAE) “Krabau”**

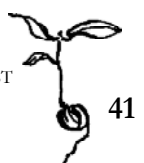
Medium-sized evergreen tree, 10-20 m tall, with straight stem and broad, dense crown in lowland evergreen forests. Fruits: globose, light brown, capsules, 8-9 x 8-9 cm, with hard exocarp and gelatinous endocarp, January to February. Seeds: 4-10 per fruit, hard, black and fused together, 7 x 15 mm. Fruits are highly attractive to seed-dispersing animals, most notably porcupines. Collect ripe fruits in February. Open the fruit, clean off the gelatinous pulp, from the seed clumps, separate the seeds (if possible) and sow them directly into plastic bags. GP about 50%, MLD 36 days, TNT 15 months. Famous as providing a cure for leprosy.

***Irvingia malayana* Oliv. ex Benn. (IRVINGIACEAE) “Bok duak”**

A common, evergreen or briefly deciduous, canopy tree, up to 40 m tall, in deciduous and evergreen forest. Fruits: drupes, 5 x 3-4 cm, with thick pulpy-fibrous mesocarp, thick stony endocarp and smooth green exocarp, December to July. Seeds: large, 1 per pyrene, which retains brown endocarp. Fruits are eaten by medium sized to large mammals; wild cattle, wild pigs, deer, civets etc. Collect fruits in December to January. Strip away the fibrous mesocarp and sow the large pyrenes directly into containers. Seedlings can be ready for late planting by August. Otherwise, saplings must be kept in the nursery until following planting season. Accelerate seedling growth by applying Osmocote. GP >50%, MLD 61 days, TNT 8 months.

***Lepisanthes rubiginosa* (Roxb.) Leenh. (SAPINDACEAE) “Kumchum”**

A medium-sized, evergreen tree, up to 10 m tall (DBH up to 20 cm), with a dense crown, branching low down, in shaded places in secondary forest. Fruits: ellipsoid drupes, 12-15 x 10-13 mm, with thin exocarp, fleshy, juicy mesocarp and thin, tough endocarp. Immature fruits are yellow, turning orange, red and purple and finally black when ripe, February to March. Fruits have 2-3 lobes, each lobe with 1 ellipsoid, 1-seeded pyrene, 8-10 x 7-9 mm. This species is very attractive to seed-dispersing birds and squirrels. Fast growth, along with broad crown and high survival rates after planting out make *L. rubiginosa* an ideal framework species. Collect seeds February to March, extract and clean the pyrenes and sow immediately in baskets in full sunlight. GP >90%; MLD 11-24 days; TNT 12-14 months.





Top left - A naturally established *Macaranga denticulata* sapling, 9 months after receiving ANR treatments and - top right - a mature tree flowering. Above left - nursery-raised saplings of *Oroxylon indicum*, ready for planting after 5 months. Above right - nursery-raised *Pajanelia longifolia* saplings, ready for planting after 15 months and (right) the species' extraordinary capule fruits.



***Macaranga denticulata* (Bl.) M. –A. (Euphorbiaceae) “Tawng Taep”**

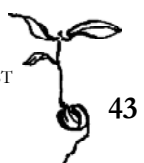
A medium-sized, pioneer, evergreen, tree, growing up to 20 m tall (DBH 40 cm). Fruits: capsules, septicidal, smooth, light brown to blackish brown on ripening, 3-5 x 5-6 mm, April. Seeds: 1 per locule, globose, black, 3-4 x 3-4 mm. An excellent framework species, *M. denticulata* establishes well on degraded land. On average, it grows taller than 2.5 m, by the end of the 2nd growing season after planting. Its large leaves form a dense crown which shades out weeds very effectively and deposits large quantities of leaf litter into the soil. It can flower by the 2nd year after planting and its fruits attract seed-dispersing birds. Collect fruits in October, when they start to split. Sun-dry them, clean off sticky coating from seeds, then sun-dry the seeds for a further 1-2 days. After that, place seeds in concentrated sulphuric acid for 2 minutes, wash off acid and sow seeds shallowly in trays in sunlight. Germination is rapid and synchronous; GP 90%; MLD 19 days. Prick out seedlings when the first true leaf pairs expand. Saplings can be planted when 30 cm tall *i.e.* by the 1st planting season after seed collection (TNT 7 months). This species has delicate saplings, which must be handled carefully to prevent high post-planting mortality. It responds well to cardboard mulching, but is not particularly fire-resilient.

***Oroxylon indicum* (L.) Kurz (BIGNONIACEAE) “Paegah Pah”**

Deciduous tree, growing to about 12 m tall in secondary forest. Fruits: curved, elongate, dehiscent capsules (scimitar-like), about a metre long, January to February. Seeds: many per fruit, with papery white wings about 11 x 9 mm, wind-dispersed. Bats pollinate the flowers, which are rich in nectar and thus attract many birds and insects. Fast growth rate and high survival after planting out. Collect capsules, in early February, just before they begin opening. Leave them in sunlight to dry out and split open. Extract the seeds and sow them directly into plastic bags. Apply Osmocote fertilizer. GP >90%, MLD 18 days, TNT 5 months.

***Pajanelia longifolia* (Willd.) K. Sch. (BIGNONIACEAE) “Ebong”**

An evergreen or briefly deciduous, medium-sized tree, up to 36 m tall (DBH up to 115 cm) with few branches and no buttresses. Locally common in primary but more often in secondary lowland evergreen forest. Fruits: elongate, dehiscent capsules, 390 x 85 mm, brown, January to February. Seeds: many per pod in several rows, with white papery wings, very thin, 11 x 9 mm, wind-dispersed. *P. longifolia* is a very fast growing tree, sun-loving pioneer tree species, which effectively and rapidly suppresses weed growth. It is also a favoured perching





Top left - Bat-pollinated, nectar-rich flowers of *Parkia timoriana*. Top right - 2-month-old seedlings, ready for potting. Above left - *P. timoriana* trees are massive, with large buttresses. Above right - *Pometia pinnata* sapling, 9 months after planting to enrich an ANR plot. Right - 18-month-old *P. pinnata* saplings in the nursery, nearly ready for planting out and - below - fruits.



site for birds. Collect pods just before they open in February. Leave on a bench to dry and split open naturally. Extract the seeds and sow into baskets. Transfer seedlings to containers once the first leaf pair has expanded. Leaves of saplings are often eaten by caterpillars, which must be controlled. Germination data: not available. TNT 15 months (may be reduced to 5 months with use of Osmocote fertilizer).

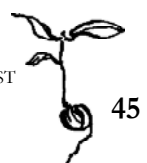
***Parkia timoriana* (DC.) Merr. (LEGUMINOSAE) “Riang”**

A very large, buttressed, briefly deciduous, emergent, climax tree species, up to 50 m tall, in primary forest, often surviving as isolated remnant trees. Fruits: pods, up to 50 cm long (including the stalk) by 4-5.5 cm broad, October to March. Valves, woody, rarely twisted. Seeds: 12-19 per pod, black with brown edges, 6 x 13 mm, edible. The edible seeds of this tree are very attractive to seed dispersing mammals, and the nectar-rich flowers attract bats (which pollinate them). *P. timoriana* can survive and grow well in the hot, dry, sunny conditions of deforested sites. Collect pods, just before they open, in late March. Leave them to dry and extract the seeds when the pods split open. Use a knife or secateurs to chip away the seed coat (at the end opposite to the embryo). Then sow seeds directly into plastic bags. GP c.90%, MLD 6 days, TNT 13 months.



***Pometia pinnata* J. R. Forst. & G. Forst. (SAPINDACEAE) “Sai Nam”**

A very large evergreen, canopy or emergent tree, up to 50 m tall, in lowland evergreen primary or secondary forest. Fruits: indehiscent drupes, round to elliptical, 3-4 x 2-3 cm, black, August to October. Seeds: 1-3 per fruit, black with tough outer coat, with fleshy, gelatinous, white or cream coloured aril, which is sweet and edible, dispersed by bats and birds. The fruits attract squirrels, birds and bats. *P. pinnata* is fast growing in the nursery and in the field, rapidly developing a dense crown. The species grows on a wide range of different soil types. Cut ripe fruits from trees in September. Clean off fruit pulp and remove the aril, then sow seeds into baskets immediately. Seed viability falls rapidly, if sowing is delayed. Transfer seedlings into pots after c. 35 days. Compensate for low germination rate by collecting many fruits. GP about 10%, MLD 10 days, TNT 20 months.





Top left - A sapling of *Salacca wallichiana*, thriving in the shade of an ANR plot, 9 months after planting and - top right - thorny stems of a mature specimen, potentially a nesting site for Gurney's Pitta. Above left - a *Sandoricum koetjape* sapling, 9 months after planting and - right - wildlings growing on in the nursery. Above right - a *Spondias pinnata* wildling, 5 months after being dug up, with fruits in the foreground.



***Salacca wallichiana* Mart. (PALMAE) Ragum**

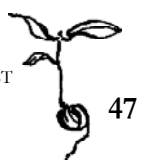
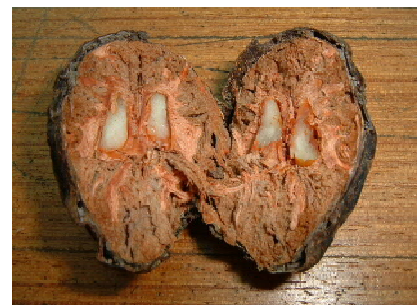
A small, dioecious, creeping and tillering palm, up to 4 m tall, growing in clumps with very spiny leaves in lowland evergreen forest and seasonally dry areas. A favoured nesting tree of Gurney's Pitta. Fruits: red, spiny, oval, drupes, about 2.5 cm long, occurring in dense heads, May. The exocarp consists of red-orange-brown scales. Seeds: 1-3 seeds per fruit. The edible fruits are attractive to seed dispersing animals, and birds like to nest in this tree. It can withstand drought very well. Fresh seed germinates readily. Collect ripe fruits in May. Remove seeds and sow them directly into plastic bags. GP >80%, MLD 56 days, TNT 12 months. Standard vegetative propagation methods have also been published. Cut stem sections of 1-2 m length from old palms. Bury them in mulch (e.g. rice straw) and keep moist. Cut away plantlets, growing from buds on the stem sections, and transfer them to plastic bags for growing on for 12-14 months, before planting out. In the plots, this species performed best in shaded sites.

***Sandoricum koetjape* (Burm. f.) Merr. (MELIACEAE) "Kraton Pah"**

Large, evergreen, canopy tree, up 45 m tall (DBH 50 cm), having buttresses and a broad crown when older, usually growing in secondary forests. Fruits: fleshy drupes, 3 x 4 cm, green turning to yellow when ripe, with thick, tough, leathery exocarp, thin, edible pulpy sweet-sour mesocarp and thin stony endocarp, June to July. Seeds: 4-5 per pyrene, brown, 2 x 1 cm. This species is relatively fast-growing, with a dense crown and with fruits that are highly attractive to mammalian seed dispersers, particularly squirrels and wild pigs. Dig up wildlings (<20 cm tall) in November and pot them directly into 9" x 2.5" plastic bags. Trim the roots to fit the container. Trees are ready for planting by the following May-June.

***Spondias pinnata* (L. f.) Kurz (ANACARDIACEAE) "Ma Gok Pah"**

Common, briefly deciduous tree, growing up to 20 m tall, in both secondary and primary forest. Fruits: fleshy drupes, up to 4.5 cm in diameter, green, turning yellow when ripe January to February. Fruits enclose one large, woody pyrene, with 5 locules (commonly 1 to 3 seeds). This species flowers and fruits at an early age and wild pigs and deer are attracted to the fruits. Dig up wildlings (< 20 cm tall) in November and grow them on in plastic bags in the nursery. Saplings are ready for planting by the following May.



Growing trees from seed

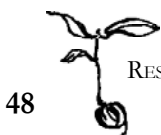
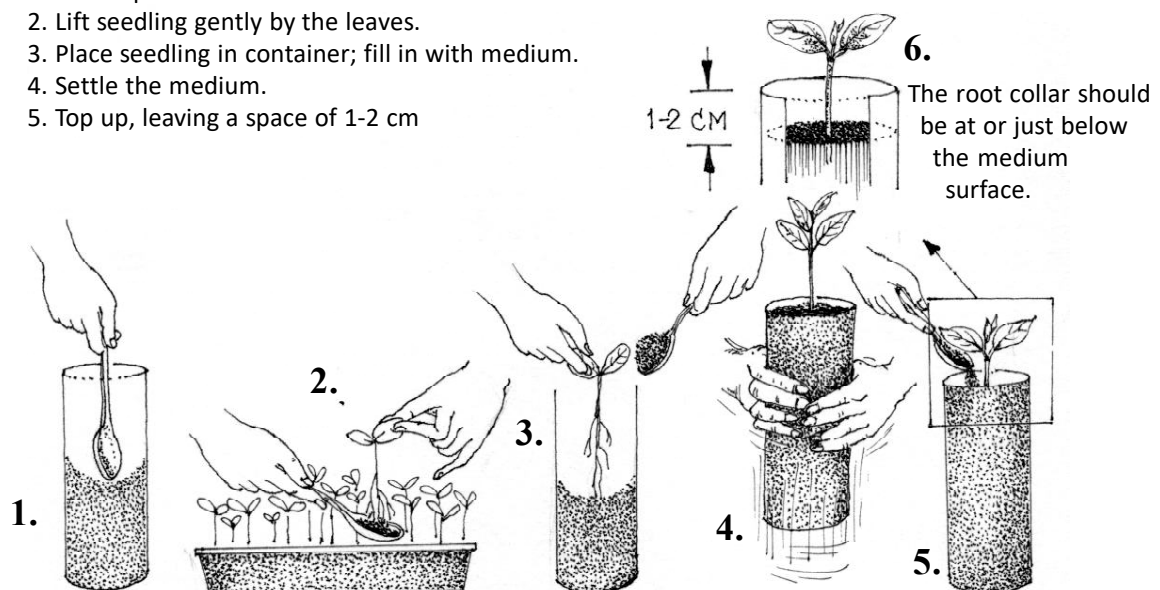
Detailed techniques for growing framework tree species in nurseries are provided in Part 6 of FORRU, 2006. A summary of the main point is extracted below.

Collect ripe fruits from healthy, vigorous trees with dense, spreading crowns, when fruits are just beginning to disperse naturally. Collect fruits from as many different individual trees (of each species) as possible to maximize genetic diversity. Seeds of most of the tree species tested during this project germinated easily with short dormancy periods and without the need of pre-sowing treatments. This is typical of lowland tropical evergreen forest tree species. Instructions for pre-sowing treatments for the few species that require them are included in the descriptions above. In general, clean off fleshy fruit parts and remove seeds. Leave pods or dry capsules to dry out and split open naturally. Remove wings from winged seeds.

Sow most seeds in germination baskets, 6-10 cm deep with plenty of drainage holes, filled with a mixture of two thirds forest soil with one third coconut husk. Do not add fertilizer to the germination mix. Place seeds just below the surface; a general rule is twice their diameter below the surface. Place trays in the shade beneath a roof. Do not expose them to rain. Water the trays lightly after sowing the seeds and daily thereafter, with a watering can or spray bottle, to avoid disturbing the surface of the germination mix. Larger seeds with high germination rates can be sown directly into individual containers, filled with potting mix.

Pricking-out

1. Make space for the roots.
2. Lift seedling gently by the leaves.
3. Place seedling in container; fill in with medium.
4. Settle the medium.
5. Top up, leaving a space of 1-2 cm



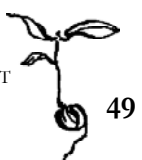
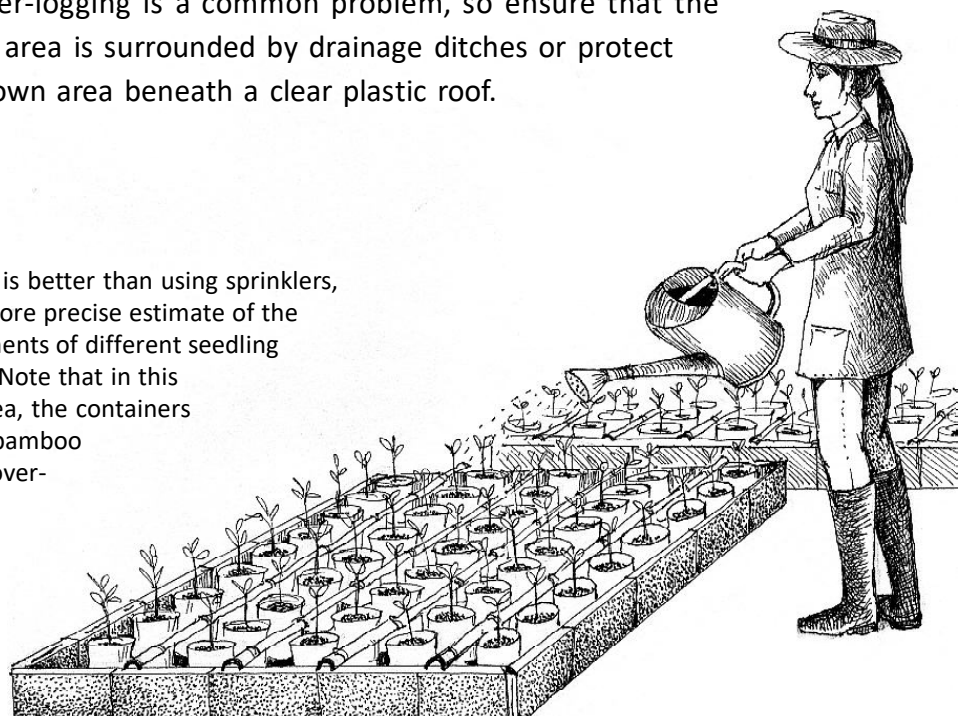
Monitor the seedlings for 'damping off' - fungal diseases which make the seedlings look like they have been pinched at the base of the stem. Once a seedling becomes infected, immediately remove it to prevent spread of the disease to neighboring seedlings. If damping off becomes a serious problem, the seedlings can be sprayed with a fungicide such as Captan.

Transfer seedlings into plastic bags, filled with potting mix, when the first pair of true leaves has fully opened. Prepare the potting medium, by mixing forest soil with peanut husk and coconut husk in the ratio of 2:1:1. Other forms of fibrous organic matter can be substituted for the coconut and peanut husks. Black plastic bags 2 ½ x 9" (8 x 25 cm) are cost effective and have been used successfully with a wide range of species. Taller plastic bags, used locally to propagate rubber tree seedlings, can also be modified, by cutting them down to about 25 cm tall and by punching drainage holes in the bottom.

Fill containers with potting mix. Then make a hole in the mix, deep and wide enough to accept the seedling without bending the roots. Hold a seedling by a true leaf, between the thumb and fore-finger and gently prize it out of the germination tray with a spoon. Place the seedling in the hole in the potting mix and close the hole, if necessary by adding a little more potting mix. After potting, water the seedlings and stand them in shade.

At Krabi, seedlings exposed to rain are watered naturally nearly every day. Watering by hand is only necessary during dry spells, particularly October to March. Water-logging is a common problem, so ensure that the standing down area is surrounded by drainage ditches or protect the standing down area beneath a clear plastic roof.

Watering by hand is better than using sprinklers, since it allows a more precise estimate of the different requirements of different seedling species for water. Note that in this standing-down area, the containers are separated by bamboo strips to prevent over-crowding.



Most species respond well to application of 10 granules of slow-release Osmocote fertilizer NPK 15:15:15 to the medium surface per container every 3 months. Lift containers regularly and prune back any protruding roots with secateurs.

To control pests and diseases:

1. check the nursery regularly, looking for health and hygiene problems;
2. treat affected seedlings immediately with the most appropriate action (remove insects by hand, destroy affected plants or plant parts, or apply chemicals, as appropriate).
3. remove weeds from containers and from around the nursery and
4. ensure adequate air movement.

At least 3 months before planting, gradually reduce shade until the seedlings are in full sunlight. Reduce the frequency of watering. Watch seedlings closely and wait until they begin to wilt before watering them. Most seedling species are ready for planting out when they are about 40-50 cm tall, provided they look healthy and are growing vigorously. Some fast-growing pioneer species can be planted out when only about 30 cm tall.

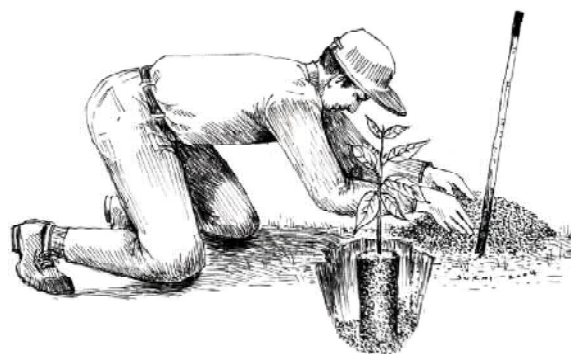
Growing Trees from Wildlings

Producing planting stock from wildlings (seedlings growing wild in the forest) can usually be done more rapidly than from seed. Dig up healthy seedlings, no taller than 20 cm (larger ones have high mortality due to severe transplantation shock), within a 5-m radius of the parent tree (those seedlings would die anyway from competition with the parent tree). To minimize damage to the root system, do this during the rainy season, when the soil is soft. Protect the root system by retaining plenty of soil around the roots to make a “root ball”. Pack the plants carefully between layers of wet cloth or tissue paper, carefully transport them to the nursery. Prune the shoots to compensate for lost or damaged roots during lifting to prevent wilting. Cut back the stem by one third to one half. Make a 45° cut about 5 mm above an axillary bud and cut back remaining leaves by about 50%. Trim secondary roots until seedlings can be potted easily into 9 x 2½-inch plastic bags, filled with the standard potting mix described above, without bending the tap root. Keep the potted wildlings under deep shade (20% of normal sunlight) for about 6 weeks. Then, follow the same procedures described above for care and hardening-off saplings grown from seed. Compared with producing planting stock from seed, these techniques can shorten the time needed to grow trees to a plantable size by several months to a year.

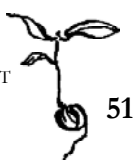
Planting Trees

The optimum time for planting at Krabi is May. This allows maximize time for root system growth before onset of the subsequent dry season in November. Planting and maintenance procedures are described in detail in Part 7 of FORRU, 2006. A summary is extracted below:

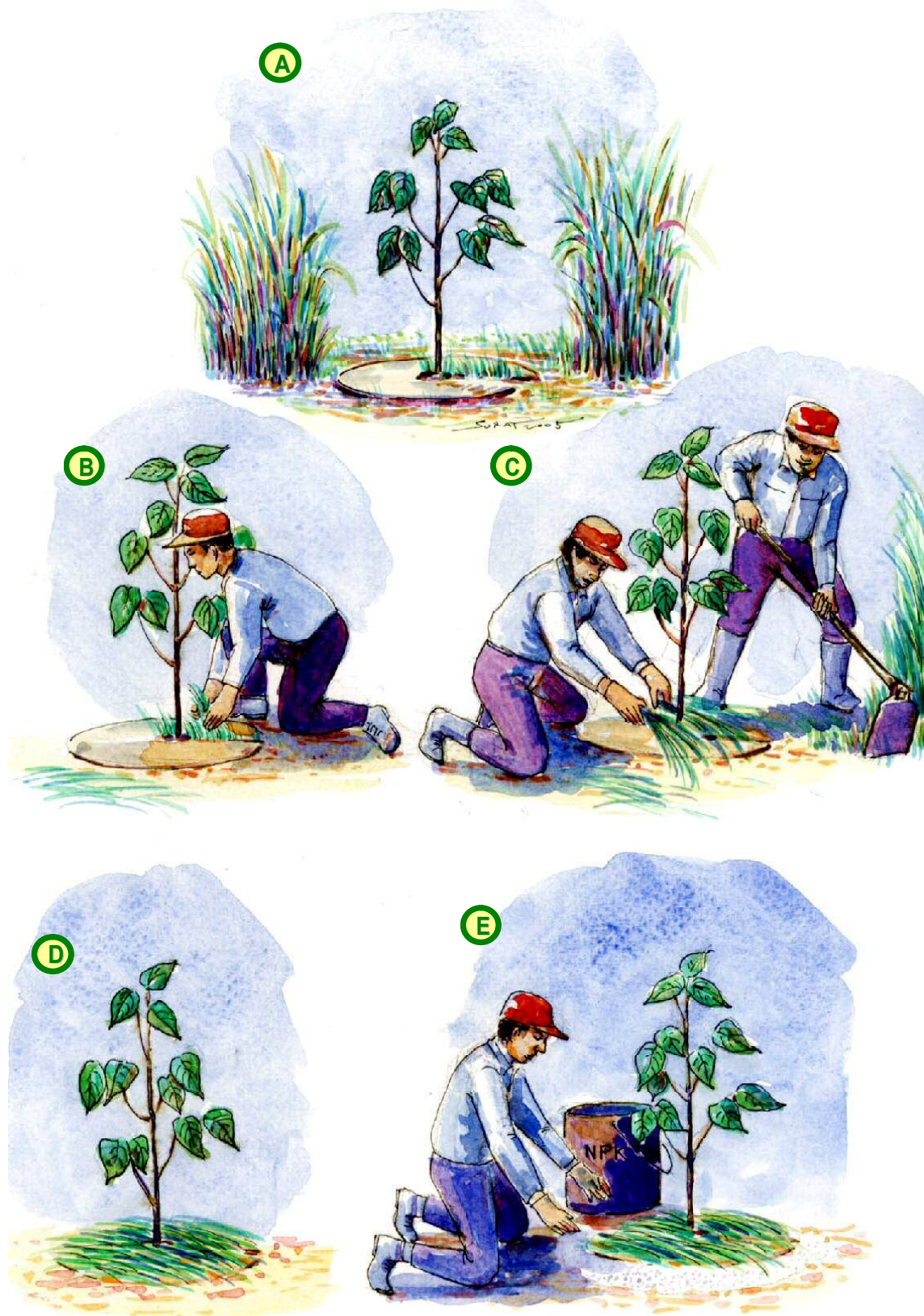
1. Six to eight weeks before planting, measure out the plots.
2. Then slash weeds down to ground level (except in non-planted control plots), but avoid cutting any naturally established tree seedlings and saplings and coppicing shoots (mark them beforehand with coloured poles or flags).
3. One month before planting, apply a non-residual herbicide (e.g. glyphosate) to kill sprouting weeds.
4. Plant trees about 6-8 weeks after the first rains.
5. Plant about 20-30 of the species listed above, spaced on average 1.8 m apart. Randomly mix the species across each plot.
6. Lay a corrugated cardboard mulch mat around each planted tree.
7. Apply 50-100 g of NPK 15:15:15 fertilizer in a ring, about 20 cm away from the stems of planted trees at planting time.
8. During the first rainy season, repeat the fertilizer treatment and weed around the trees (using hand tools) at least 3 times, 6-8 weeks apart (adjust according to the rainfall and rate of weed regrowth).
9. At the start of the first dry season after planting, cut fire breaks around the plots and implement a fire prevention and suppression program.
10. Repeat weeding and fertilizer application during the second rainy season after planting.
11. At the beginning of the 3rd rainy season, assess the need for further maintenance operations.
12. Monitor the planted trees for survival, growth and health, 2 weeks after planting and at the end of each rainy season for 3-5 years.



Slash open plastic bag and remove saplings, keeping root ball intact. Place the sapling in the hole (about twice as big as the container), without bending the roots, and fill in with loose soil.



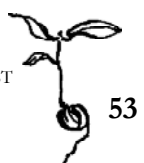
WEEDING AND FERTILIZER APPLICATION ARE ESSENTIAL



Weeding is essential during the first two rainy seasons after planting. A cardboard mulch mat can help keep weeds down to a minimum immediately around the tree stem (A). Pull out any weeds growing near the tree base by hand (wear gloves) to avoid damaging the tree roots (B). Try to keep the mulch mat intact. Next, use a hoe to root out weeds in a circle around the mulch mat (C) and lay the uprooted weeds on top of the mulch mat (D). Finally, apply fertilizer (50-100 gm) in a circle around the mulch mat (E).

Recommendations

1. This document presents “best practices” for forest restoration, based on data currently available from research carried out under the project “Gurney’s Pitta Research and Conservation in Thailand and Myanmar”, in 2005-08. Many more tree species remain to be tested and data from field trials are still at an early stage. Therefore, we recommend continuance of this research program and modification of this working document as results are accumulated.
2. We believe that the information in this document represents a good starting point, on which to base current actions to restore GP habitat in the near future. Therefore, the tree species recommended in this document should be grown in larger numbers for planting in appropriate mixtures as soon as possible and an “adaptive management” approach adopted to gradually improve practices.
3. Existing restored plots and those to be restored over the next few years should be closely monitored, so that we can learn from mistakes.
4. Initially, restoration activities should focus on establishing forest corridors to rejoin fragments of forest habitats, which have become isolated. Riparian strips along streams where GP formerly nested are particularly recommended.
5. The DNP should identify such areas suitable for restoration, in collaboration with local people, as soon as possible, taking into consideration GIS information and location of critical sites for GP nesting.
6. The nursery, established under the original Darwin project, should be expanded to grow more trees, particularly of the species listed above, for i) GP habitat restoration, carried out by the DNP and ii) distribution to the local community.
7. Facilities, established under the project, should be used for education and demonstration purposes, to build support for habitat restoration among local communities and to provide an example for other forest restoration projects in S. Thailand to follow.



References

Donald, P. F., S. Aratrakorn, S. Thunhikorn, K. Sribua-rod, and P. Tinun, 2006. Population, distribution and ecology of Gurney's Pitta in Southern Thailand. 1st Report, Gurney's Pitta Recovery Plan Project (in Thai).

Forest Restoration Research Unit, 2006. How to Plant a Forest: The Principles and Practice of Restoring Tropical Forests. Chiang Mai University, Forest Restoration Research Unit, compiled by Elliott, S., D. Blakesley, J.F. Maxwell, S. Doust, and S. Suwanarattana, 200 pp.

Forest Restoration Research Unit, 2008. Research for Restoring Tropical Forest Ecosystems: A Practical Guide. Chiang Mai University, Forest Restoration Research Unit, Thailand, compiled by Elliott, S, D. Blakesley and S. Chairuangsi, 144 pp.

Goosem, S. P. and N. I. J. Tucker, 1995. Repairing the rainforest – theory and practice of rainforest re-establishment in North Queensland's wet tropics. Wet Tropics Management Authority, Cairns, 71 pp.

Maxwell, J. F., in press, Vascular Flora of the Emerald Pool Area, Krabi Province, Southern Thailand. J. Maejo Uni.

Round, P. and U. Treesucon, 1996. Birds of Khao Nor Chuchi; Check list and bird finding. Bird Conservation Society of Thailand, Bangkok. 85 pp.

Tunjai, P., 2007. Direct seeding as an alternative to tree planting for restoring degraded forest ecosystems: a comparison between deciduous and evergreen forest types. MSc thesis, Chiang Mai University Graduate School.

Walter, H., 1985. Vegetation of the Earth. Springer-Verlag, Berlin.

Whitmore, T.C., 1991. An Introduction to Tropical Rainforests. Clarendon Press, Oxford



How to PLANT a FOREST:

THE PRINCIPLES AND PRACTICE OF RESTORING TROPICAL FORESTS

It is possible to transform largely deforested landscapes into lush tropical forests, supporting rich biodiversity, in just a few years. Based on the work of Chiang Mai University's Forest Restoration Research Unit (FORRU-CMU) since 1994, "How to Plant a Forest" shows how the framework species method of forest restoration has been successfully adapted to re-establish natural forest ecosystems in northern Thailand. It presents background information that enables readers to understand the natural mechanisms of forest regeneration, as well as practical techniques to harness and accelerate them. Richly illustrated with easy-to-follow diagrams, this book provides scientifically tested advice on how to select appropriate tree species; how to grow them in nurseries and how to plant and take care of them in deforested areas. In addition, the logistics of implementing forest restoration projects are explained and, most importantly, how to motivate and involve local people. This book is not just about northern Thailand. The concepts and techniques described in it could be applied equally well to a wide range of different forest types in other areas, so anyone interested in restoring forest ecosystems for wildlife conservation and environmental protection will find it useful. Available in English, Thai, Chinese, Khmer, Lao, Indonesian and Vietnamese. Contact FORRU-CMU for further details.



