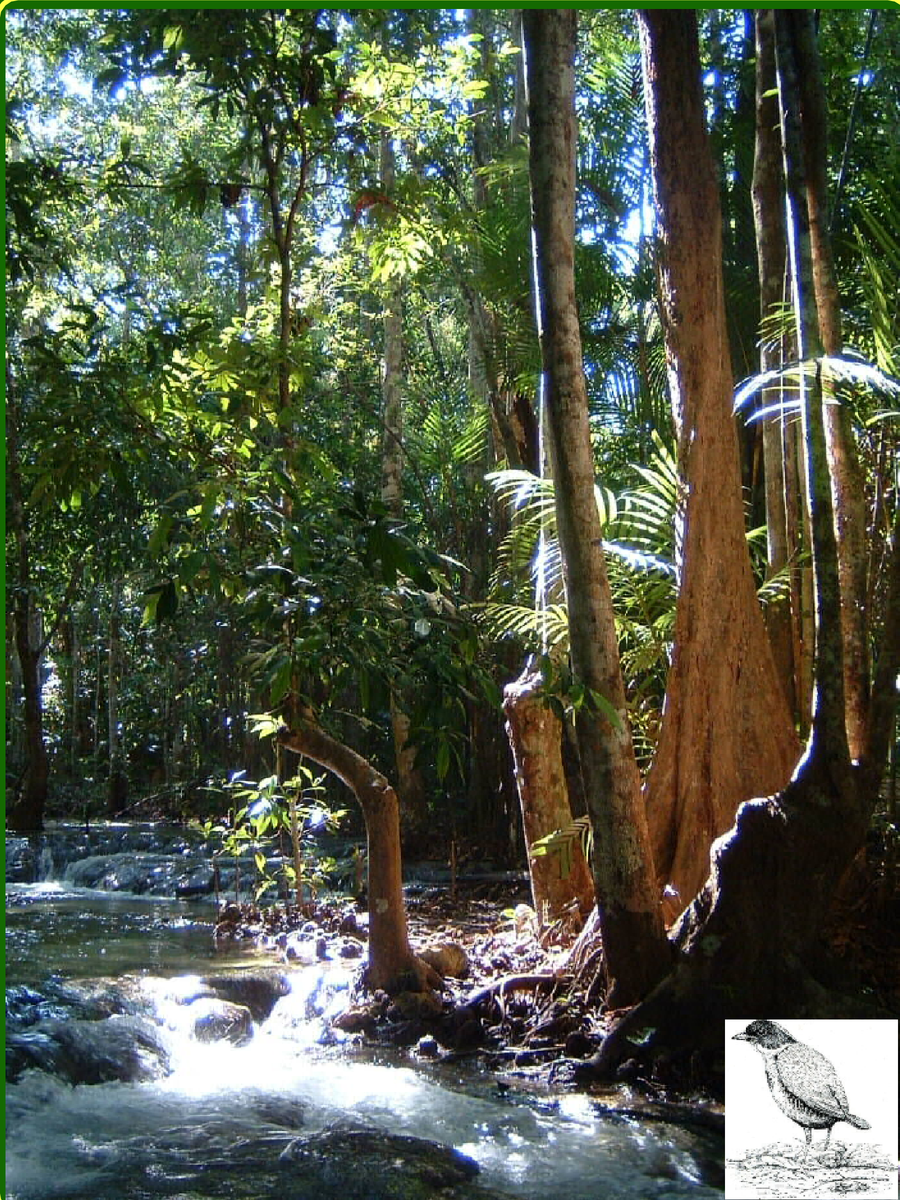
A Technical Strategy for Restoring Krabi's Lowland Tropical Forest



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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

Compiled by

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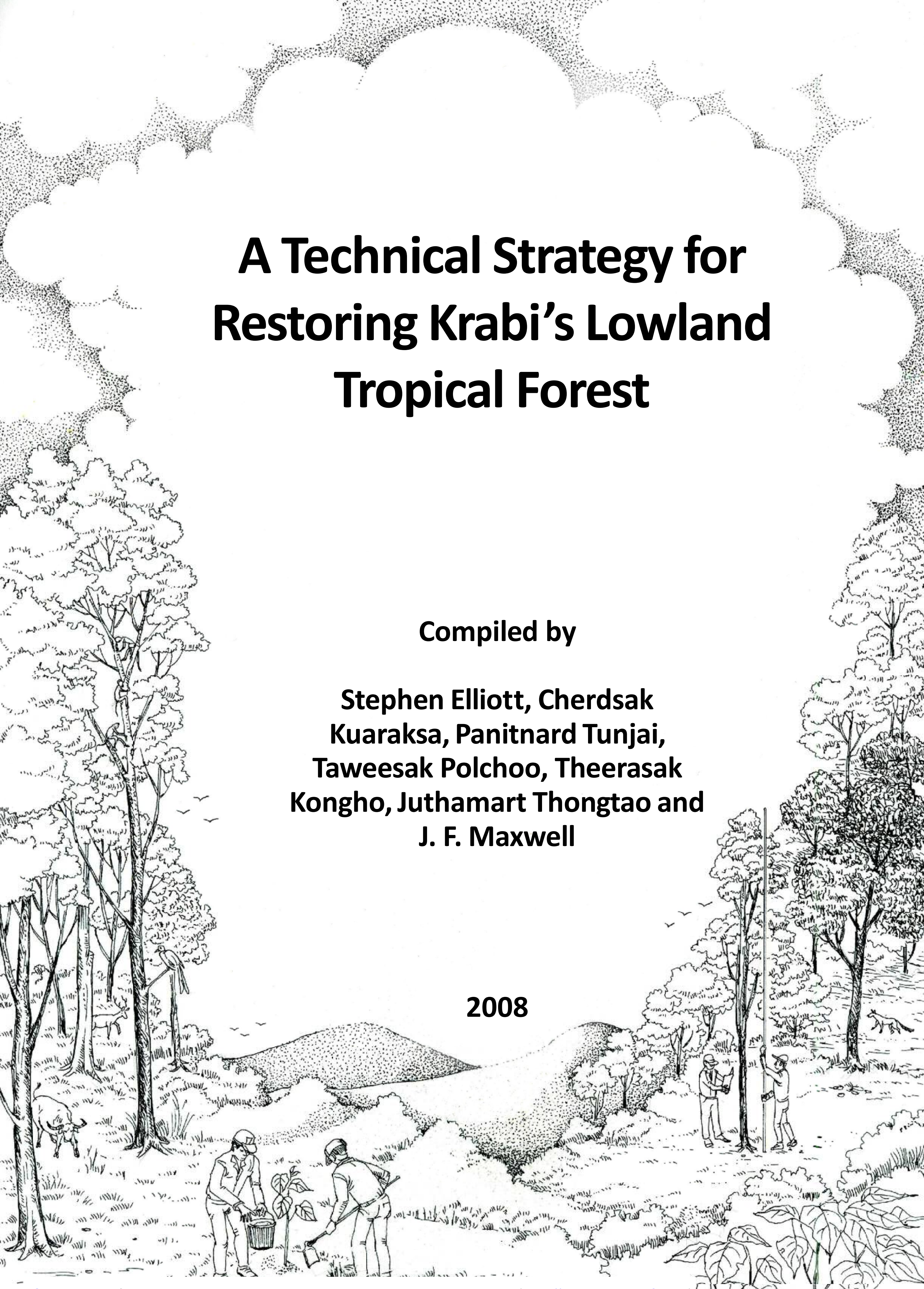

Acknowledgements

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This report was compiled by Stephen Elliott with scientific inputs from Cherdsak Kuaraksa and Panitnard 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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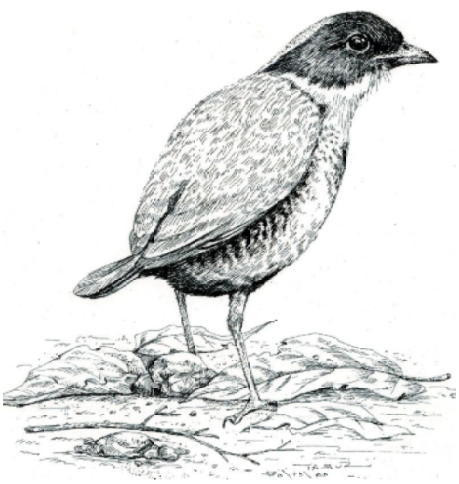


This project addresses the problem of loss of one of Thailand's rarest and most unique forest ecosystems i.e. lowland tropical evergeen forest, the habitat of one of Thailand's rarest bird species, Gurney's Pitta. The project provides hope that the process is technically reversable.

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 km^2, but only about 25 km^2 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.

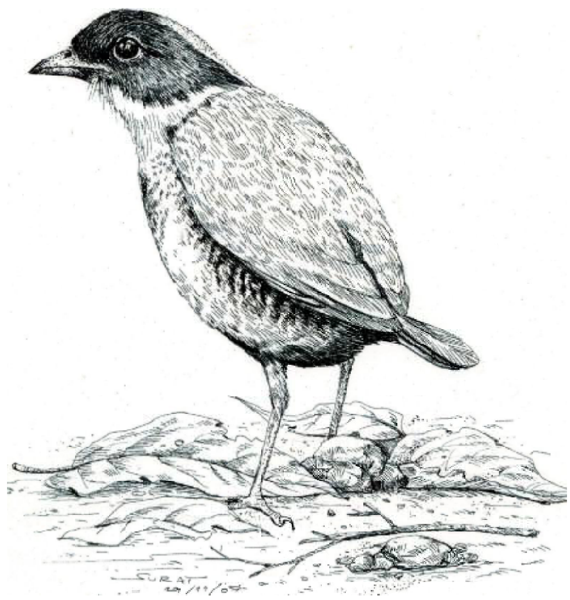
Research For Restoring Gurney's Pitta Habitat

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 monitori seedling growth. Below right - establishing the first experimental plot.

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, develop 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 avail-able at this time, as well as indigenous local knowledge. However, the research is still ongoing, so the list of recomm-ended species will doubtless change, as the long-term results from field trials become available.

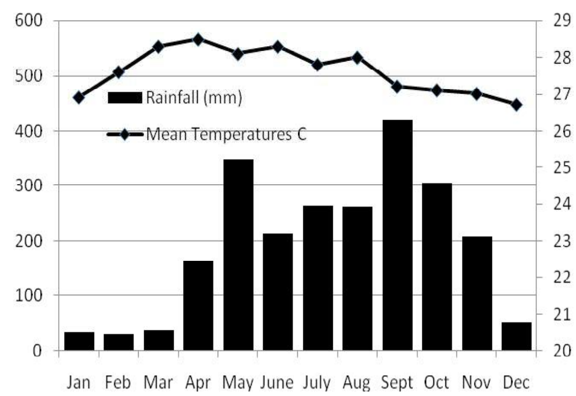
Climate

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 charac-teristic features of primary evergreen seas-onal 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-ideae* (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 pachycarp*a 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 km^2, 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. (Icacinaceae), *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, Bambusoidese) 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* (Pandanaceae), 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 (Apocynacese), *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 lottle 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 juventas* Merr. (Asclepiadaceae) and *Lygodium flexuosum* Sw. (Schizaeaceae). The first woody species to gain a roothold 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 regeneration, suitable for ANR.

Table 1 - Soil conditions of deforested sites

	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.

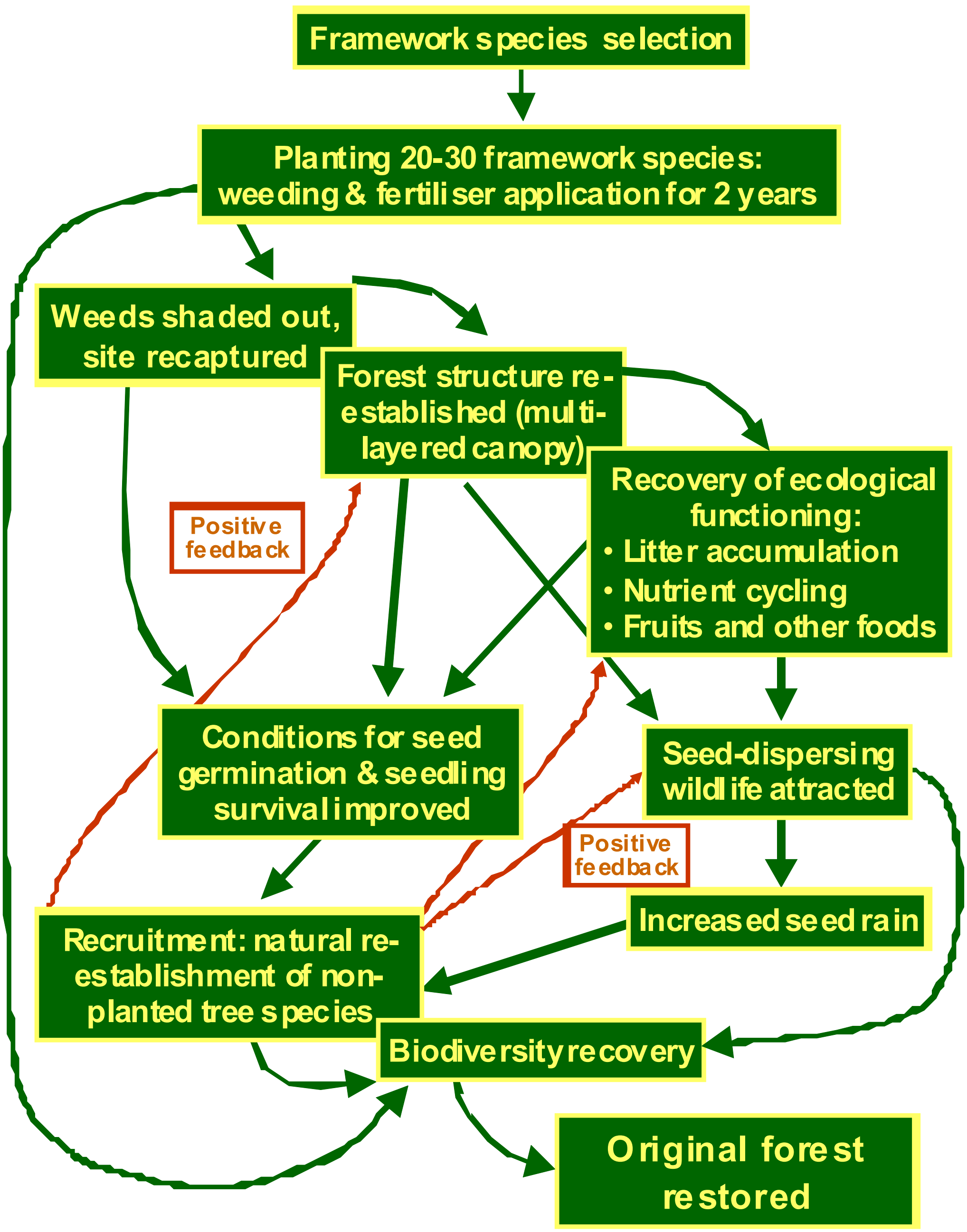
Repeat weeding and fertilizer application every 4-6 weeks during the rainy season (depending on weed growth rates), trying not to disturb the cardboard mulch mat and continue the following rainy season, until canopy closure is achieved. Do not weed during the dry season (Dec-Mar). Allow weeds to grow 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 shorts, 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 candiate 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 stongly 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.