New Forests **24:** 165–174, 2002.

Research needs for restoring tropical forests in Southeast Asia for wildlife conservation: framework species selection and seed propagation

DAVID BLAKESLEY[1], KATE HARDWICK[2] and STEPHEN ELLIOTT[3]
[1]*Horticulture Research International, East Malling, West Malling, Kent ME19 6BJ, UK;* [2]*School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd LL57 2UW, UK;* [3]*Forest Restoration Research Unit, Biology Department, Science Faculty, Chiang Mai University, 50200, Thailand*

Received 7 May 2001; accepted in revised form 31 December 2001

Key words: Biodiversity conservation, Forest restoration, Genetic diversity, Seed, Trees

Abstract. Some governments in Southeast Asia, such as those of Thailand and Vietnam have clear policies to restore large areas of degraded land to native forest. However, knowledge needed for the success of these ambitious programmes is still inadequate, and considerable further research is required. Furthermore, very little literature is available to conservation practitioners about the restoration of tropical forests for biodiversity conservation. This paper introduces the framework species method of forest restoration, which is being developed to restore forests in Thailand. The paper examines the potential for adoption of this technique in different forest types across the Southeast Asia region, and identifies priorities for future research needed before the method can be widely implemented. These include the identification of forest types, the selection of candidate framework species, maintenance of genetic diversity, and development of methods of seed collection and germination.

Introduction

Tropical forests and their associated biodiversity continue to be threatened or destroyed throughout Southeast Asia. Whilst complete protection of all remaining primary forest, and important areas of secondary forest is highly desirable, social, economic and legal constraints make such a lofty aim impossible to achieve. Therefore, even to maintain the current level of forest cover, and certainly to increase it, deforested areas must be converted back into native forest. The Forest Restoration Research Unit (FORRU) is based in northern Thailand, and is developing methods to restore forest in protected areas, large parts of which comprise secondary forests and degraded grass and shrublands.

Usually, reforestation programmes are concerned with utilisation of forest resources, such as timber, biomass or browse, using commercial or plantation species. Forestry for such economic purposes is supported by a wealth of literature on species selection through to genetic improvement and management of seed stands. However, very little research has been carried out on forest restoration using native species, primarily for biodiversity conservation. This was highlighted in a recent international meeting in Thailand devoted to forest restoration for wildlife conservation. During this meeting, 'The Chiang Mai Research Agenda for the restoration of degraded forest lands for wildlife conservation in Southeast Asia' (Elliott et al. 2000) was drawn up.

Within national parks and wildlife sanctuaries, where the primary objectives are conservation of wildlife and protection of watersheds, restoration of natural forest ecosystems in degraded areas is an attainable goal. Indeed, ecosystem rehabilitation and restoration are recognised as important components of *in situ* conservation in the Convention on Biodiversity (UNCBD, Articles 7, 8, 10) (World Conservation Monitoring Centre 1996). However, research on biological aspects of forest restoration has been neglected. Large-scale restoration of forest ecosystems requires close co-operation between government agencies and local people: development of new, technically sound, economically viable and socially acceptable methods of tree propagation and planting, and the availability of resources and expertise to all participating organisations.

Attempts to recreate natural forest ecosystems are hindered by their complexity. Any individual forest type may contain several hundred tree species, each of which may have evolved intricate relationships with hundreds of other organisms, such as herbivores, pollinators and seed dispersers. Managed restoration of 'complete' natural forest ecosystems, therefore, requires a vast amount of ecological information, only a small fraction of which is currently known. We need to understand how forests regenerate naturally, identify the factors limiting regeneration and develop effective methods to counteract them and thus accelerate regeneration (Hardwick et al. 1997). Where natural regeneration is very poor, planting nursery produced seedlings is just one of the options; others include cultivation and husbandry of seeds, seedlings and saplings which are already present, direct seeding and prevention of fire by maintaining a network of fire breaks.

The paper presented here draws upon the authors' collective experience of forest restoration in Thailand, and discusses research requirements related specifically to tree species selection, and techniques of seed collection and seedling propagation.

Selection of framework tree species

Forest rehabilitation programmes designed to catalyse recruitment of natural vegetation have been undertaken by several groups in different parts of the world. In the upland moist forests of Amazonia, Knowles and Parrotta (1995) developed a numerical scoring system to rank species according to their potential suitability for rehabilitation of forest on open cast mines. They screened 160 Brazilian tree species, evaluating their fruiting phenology, ease of propagation and seedling performance following planting in the harsh environments of rehabilitation plots.

In Australia in the late 1980s, the Framework Species Method was developed as a practical method for restoring degraded forest within the Queensland Wet Tropics World Heritage Site (Goosem and Tucker 1995; Lamb et al. 1997). Native tree species, which can survive the harsh conditions of degraded sites, and compete successfully with herbaceous weeds are planted to 'capture the site'. Most species selected have fleshy fruits that are attractive to frugivores. Once such trees reach maturity, their fruits attract bird and mammals from neighbouring forest areas, and they provide perches for birds. This wildlife disperses seed into the plots, thus helping to accelerate recruitment of non-planted tree species and other plants, leading to rapid accumulation of biodiversity in planted areas. The Framework Species method involves a single planting of a mixture of both pioneer and climax tree species, and after 1–2 years maintenance is then self sustaining, relying on the local gene pool to increase biodiversity. Recent reports from the research programme in Queensland have been very promising (Tucker and Murphy 1997). Seven-year-old rehabilitation plots contiguous with forest recruited up to seventy two plant species across all growth forms and successional phases.

The Framework Species Method is also being adapted by FORRU in northern Thailand, to test its suitability for the re-establishment of seasonally dry natural forest ecosystems on degraded upland watershed sites (>1000 m elevation) within conservation areas. A detailed study has been carried out of tree flowering and fruiting phenology, involving some 90 tree species, and descriptions, drawings and photographs have been made of fruits and seedlings of potential framework species (Kerby et al. 2000). An herbarium collection of dried seedling specimens was established, along with computer databases of seed, fruit and seedling morphology. Germination was tested and seedling performance was monitored in the nursery and after planting out in degraded areas. Without such basic background information, it would have been impossible to make sensible choices as to which tree species to use in forest restoration projects. Criteria were compiled to define framework species in the seasonally dry tropical forests of northern Thailand. These were:

- ease of propagation by seed in the nursery
- sapling survival and growth following planting in degraded areas
- crown architecture to shade out weeds
- attractiveness to frugivores and other wildlife (provision of fruit, nectar, insects, perches, cover from predators)
- resistance to fire

Ease of propagation is an important selection criterion for framework species. In most forest restoration programmes almost all species are propagated from seed. This avoids two main problems; the difficulty of rooting cuttings taken from mature trees, and the risk of narrowing the genetic base by using a clonal propagation technique. Successful seed germination must be achieved before a species can be selected for forest restoration programmes. For species-rich tropical forests, a community-wide investigation of seed germination and nursery production is a seemingly daunting task. However, FORRU designed a simple, but effective strategy for screening large numbers of species relatively quickly, to identify those which germinated easily, without any special treatments (Elliott et al. 1995). Replicated germination trials were carried out in a nursery under partial shade. Seventy-two seeds were sown in replicated batches of 24 in each germination trial. In just under 3 years, more than 250 species were screened, many of which were tested on more than one occasion. Although the experiments on any given species were not extensive, the data collected enabled initially candidate framework species to be identified, based on successful propagation by seed.

Lists of framework species now exist for the seasonally dry forests in northern Thailand (Elliott et al. 1998; Kerby et al. 2000), and various forest types in the Wet Tropics of Queensland (Goosem and Tucker 1995). Although the species suitable for each part of the region will vary, the selection criteria are applicable anywhere. For future forest restoration projects in Southeast Asia, further research is needed to select appropriate species to suit the specific ecological conditions that prevail in various parts of the region. This will necessitate the definition of eco-regions and forest types, by reviewing climate, topography and vegetation data. For most native forest types, it is unlikely that sufficient published information exists to select candidate framework species for further investigation. Indigenous knowledge collected by interviews with local people, could prove very important. The current list of recommended framework species for hill evergreen forests in northern Thailand includes 36 species, from 19 different families (Blakesley et al. (in press)), including pioneers such as *Melia toosendan* and climax species such as *Hovenia dulcis*. Important families include the Moraceae (4 species), Meliaceae (2 species), Leguminosae (2 species) and Fagaceae (6 species). It is possible that the provisional selection of species from 'key' families, such as these will allow more rapid progress to be made in other areas. Nevertheless, basic nursery screening programmes must be undertaken to select potential framework species for each forest type in each part of the Southeast Asia region. In addition to germination trials, observations of flowering and fruiting phenology should, also be made.

Attractiveness to frugivores is also an important criterion for the selection of framework species. There is very little information in the literature on the attractiveness of the vast majority of native tree species in Southeast Asia to frugivorous birds, bats and other mammals. This is an important area warranting further research, but any project should be clearly focussed on trees which have already been identified as candidate framework species. Birds are an important group of frugivores. Corlett (1998) identifies 17 families containing species that rely on fruit for a large part of their diet. In undisturbed forest, the most important of these families are hornbills, barbets, broadbills, fruit pigeons, muscapids, bulbuls, white-eyes, laughing thrushes, babblers and flowerpeckers. However, in degraded forest, or 'young' restoration plots with a relatively low tree species diversity, many of these frugivores are likely to be absent. Species such as hornbills and fruit pigeons are unlikely to venture into young planted areas. Furthermore, in many degraded forests, large frugivore species may have become extirpated. Consequently, it may be necessary to consider framework species which are attractive to smaller fruit-eating species, tolerant of degraded areas to disperse seed. These include primarily bulbuls and mynahs, but also jays and magpies; thrushes, robins and chats; white-eyes; laughing thrushes and flowerpeckers. Many of these are insectivores, which also take fruit as part of their diet. In degraded areas near intact forest, which have been replanted for some time and where the canopy has closed, one might expect to see green pigeons, Oriental Pied Hornbill (*Anthracoceros albirostris*) where they still exist, and possibly wood pigeons at higher elevations. Corlett (1998) has also highlighted the lack of published information on the fruit bats (Pteropodidae) of the Oriental Region, which are taxonomically diverse, and highly varied ecologically (Flannery 1995). These could potentially be especially important to the recruitment of non-planted tree species to restoration plots, due to their habits of defecating, and even dropping seeds in flight (Phua and Corlett 1989; Micleburgh and Carroll 1994). However, further research needs to be carried out to assess the extent of this behaviour, in addition to the identification of species present in a given area, and their conservation status.

Source of seed: genetic diversity

One problem for any forest restoration programme, is selection of trees from which to obtain seed. The Convention on Biological Biodiversity (Rio de Janeiro, Brazil, 1992) emphasised the importance of maintaining intraspecific genetic diversity and evolutionary potential. Consequently, adaptability and maintenance of a broad genetic base must be considered. Genetic variation in a founding population is essential, particularly if restored areas are far from pollen sources, or if the restored area is likely to become a seed source itself. Collection of seeds from few individual seed trees can result in low effective population size, by narrowing the genetic base, inbreeding depression and a decrease in the adaptive evolutionary potential of the population (Barrett and Kohn 1991). Trees grown from a restricted seed source may respond in a uniform manner to environmental pressures such as disease or climate, and have less flexibility to adapt to site variability. If planted trees originate from genetically diverse parental material, they should constitute a good seed source, and there will be less concern about seed collection from adjacent trees in such restored areas.

Because framework species are planted with the immediate objective of site capture, it is important that trees with the desired phenotype are selected. Selection of such phenotypes may not immediately accord with conservation of genetic diversity, as it may narrow the genetic base and amounts to 'genetic selection'. However, it is essential that planted framework trees perform well, to ensure site capture and accelerated recovery of biodiversity. Selection of seed from a healthy, vigorous trees may result in planted trees that perform better in the hostile environment of a restoration plot than trees with a poor phenotype. It should however be possible to select phenotypically superior trees as seed sources without genetic erosion.

General guidelines for seed collection which consider the capture of biodiversity have been published in a number of texts (eg Guarino et al. 1995; Schmidt 2000). For provenance or progeny trials, it has been recommended that 10–20 individuals are sampled, which may be increased to 25–50 individuals per population for *ex situ* conservation purposes (Guarino et al. 1995). However, there is relatively little published advice to help seed collectors select seed trees from tracts of intact forest for use in forest restoration programmes for biodiversity conservation. Sampling is critical: the main consideration is maintenance of maximum intraspecific allelic variation. However, no collection system is likely to conserve all such variation, but it should be possible to save as much as possible. Basic guidelines, which can be applied in the absence of other information on population structure, performance of seed progeny or molecular data on genetic diversity are essential. Trees which naturally grow closely together are potentially siblings. This would be especially likely if the species has limited pollen distribution, although this would not take account of more wide ranging seed dispersal. As this may not be known for most species, it may be safer to select seed trees with a minimum distance of, for example, 100 – 300 m. With individual trees which are isolated from the main population, or which flower at a different time of the year to the rest of the population, there is a risk of inbreeding, unless there is a strong incompatibility mechanism preventing self-fertilisation. Such trees are clearly unsuitable as seed trees.

Molecular techniques can provide a valuable tool for measuring the genetic diversity of trees, and contribute to decisions to enable better genetic management for forest restoration. Microsatellite markers, for example, have been used in several studies to assess genetic diversity of tropical trees in threatened forests and forest fragments (Aldrich et al. 1998). However, aside from work currently being carried out by FORRU, the authors are not aware of any studies where the technology has been used specifically to identify parent trees with a 'collective' broad genetic base from which to collect seed for replanting to restore natural forest. Use of microsatellites can be costly due to library generation and sequencing, even before primers can be identified, optimised and tested for polymorphism. Consequently heterologous amplification (application of microsatellites developed from one species, for study with another) could be very useful, particularly for programmes where precise, practical answers such as those posed above are sought, as part of much larger, non-molecular programmes. Discussion of other techniques, and more detail on microsatellites is outside of the scope of this review; reference may be made to Young et al. (2000).

Propagation

Propagation techniques for the production of woody perennial species are quite advanced in the region, both by seed and by cuttings. However, development of this technology has been largely focused on exotic and commercial plantation species, often associated with selection and breeding programmes. Much research has been carried out at local institutes such as the Forest Research Institute Malaysia, and at the ASEAN-Canada Forest Tree Seed Centre, Muak Lek, in Thailand, particularly on dipterocarps, eucalypts and acacias (Kijkar 1991a, 1991b). Very little work has been carried out on the vast majority of native forest tree species in the region, which in Thailand alone number some 3,600. Furthermore, nursery production of native species for forest restoration is constrained by a general paucity of knowledge about most species, the requirement for low-tech input, maintenance of genetic diversity and the handling of relatively small numbers of many different species. The requirements of this technology are clearly quite different from those of a nursery producing plant material for some form of 'harvest' for timber or biomass, where the emphasis may focus on clonal propagation or, seed harvested from 'plus' trees, and involve far fewer species. Many of the conventional techniques developed for these species would be inappropriate for isolated small-scale 'forest conservation' nurseries, and could not be directly transferred to such operations.

Short-term seed storage for up to a year would be useful in the production of native species, both for managing the nursery production schedule, and for supplying seed to nurseries where local seed is unavailable due to forest clearance. In other cases, it may be desirable to store seed for several years when a species' fruit production follows a 'masting' pattern, i.e. fruit is only produced at intervals of several years (Janzen 1978). For such species, seed will be abundantly available one year, far exceeding the nursery's capacity to utilise it all, but will be scarce or unavailable in the following years. It would clearly be useful to be able to store such seed and stagger the production of seedlings over several years until the following masting year.

Successful storage must maintain viability whilst preventing germination, and this is usually achieved by drying seeds to a low moisture content and/or cooling to about 4 °C (Krishnapillay et al. 1993). Seeds that are tolerant of drying and cooling are classed as 'orthodox' and are easiest to store. Unfortunately, many tropical forest species have 'recalcitrant' seeds that do not tolerate desiccation or low temperature storage. Recent research suggests the existence of a third, intermediate category; these seeds can be dried but not cooled, and quickly deteriorate in storage (Krishnapillay et al. 1993). The long-term storage of recalcitrant seeds is a difficult problem, which remains unsolved despite considerable amounts of research. An important first step is to identify the species which can tolerate storage, and this is still not known for the majority of forest tree species in Southeast Asia. In the case of FORRU for example, this might involve experiments with a small number of framework species such as *Prunus cerasoides*, whose production would immediately benefit from short term storage, due to the timing of seed dispersal and its growth rate under nursery conditions (Elliott et al. (in press)).

Nursery production

A basic tool of any nursery manager is a 'production schedule' which coordinates all nursery activities to produce high quality seedlings, which are strong, healthy, and able to withstand the stress of transplantation into degraded forest lands. For some species such as *Melia toosendan* and *Spondias axillaris* (Elliott et al. (in press)) it is likely that such a schedule will be straightforward, as a high percentage of collected seed will germinate and the seedlings will adapt well to container conditions, being ready for weaning at the required planting time. However, for other species such as *Lithocarpus craibianus* and *Castanopsis acuminatissima* (Elliott et al. (in press)), this may not be the case, necessitating further research to improve the efficiency and quality of production. In the case of seasonally dry tropical forests, the combination of seasonal germination/dormancy patterns (Garwood 1983), variable growth rates between species and the narrow window for planting at the start of the rainy season can create logistical problems for nursery management (Blakesley et al. 2000). In this case, the actual nursery practices applied to individual framework species should be examined to identify areas which may require further research. The process involving appraisal of nursery research requirements should apply to any nursery operation which is part of a forest restoration programme. Some nursery practices have been extensively documented elsewhere, and can be considered as standard 'good practice', for example; grading and quality control, watering and weed control. Whilst these factors deserve careful consideration in any nursery operation, they are unlikely to require a major research effort when introducing new species from the forest into the nursery operation. In contrast, other practices such as fertiliser application, the manipulation of root and shoot growth, mycorrhizal inoculation and container type will almost certainly require research (Blakesley et al. 2000). All could have a major influence on the production of healthy, high quality, vigorous seedlings in the nursery which have a good chance of survival after planting out. Furthermore, with a range of native tree species flowering at different times of the year, it will almost certainly be necessary to control seed germination and seedling growth rates in order to prepare propagules for weaning and planting at the right time of year.

Conclusion

In this paper we have tried to emphasise the areas of research related to species selection and seed germination which will need close attention in the future, if large scale tropical forest restoration projects with native species are to be undertaken successfully in Southeast Asia. We believe that the protocol being developed at FORRU can be applied to many different forest types, if certain research requirements are met, which include identification of framework species, and studies of fruiting phenology, seed germination and seedling propagation. However, in any research programme, including current FORRU programmes, more attention must be given to the maintenance of genetic diversity, in order to develop clear guidelines for conservation practitioners.

Ultimately, application of the framework species approach should lead to more successful forest restoration programmes in neighboring countries such as Myanmar, Cambodia, Vietnam, and throughout the Asia-Pacific region. In forests with relatively low tree-species diversity, such as deciduous dipterocarp forests, it may not always be possible to select sufficient numbers of candidate framework tree species based on ease of seed propagation. In these forests, more detailed research might be necessary with species that are difficult to germinate, including issues related to dormancy and recalcitrant seed.

Acknowledgements

FORRU was founded with financial support from Riche Monde (Bangkok) Ltd. and

United Distillers PLC, Shell Forestry Limited, the Biodiversity Research and Training Programme and the Science Faculty of Chiang Mai University sponsored the research described in this paper. Other donors have included The Fagus Anstruther Memorial Trust, The Peter Nathan Trust, The Robert Kiln Charitable Trust, The Barbara Everard Trust for Orchid Conservation, Mr. Alan and Mrs. Thelma Kindred, Mr. Nostha Chartikavanij, Mr. R. Butterworth and Mr. James C. Boudreau. The authors thank J. F. Maxwell for the identification of tree species. Voucher specimens are stored at the Chiang Mai University Herbarium, Biology Department. The authors are grateful to all research assistants and volunteers who assisted with data collection and processing and care of the plants in the nursery including: Jumpee Bunyadit, Thonglaw Seethong, Tim Rayden, Kevin Woods, Rungtiwa Bunyayod and Janice Kerby. The Head and staff of Doi Suthep-Pui National Park Headquarters provide essential collaboration for FORRU's research. We are especially grateful to the Head of the National Park, Mr. Paiboon Sawetmelanon, Mr. Amporn Panmongkol (Deputy Head) and Mr. Prasert Saentaam.

References

Aldrich P.R., Hamrick J.L., Chavarriaga P. and Kochert G. 1998. Microsatellite analysis of demographic genetic structure in fragmented populations of the tropical tree *Symphonia globulifera*. Molecular Ecol. 7: 933–944.

Barrett S.C.H. and Kohn J.R. 1991. Genetic and evolutionary consequences of small population sizes in plants: implications for conservation. In: Falk D.A. and Holsinger K.E. (eds), Genetics and Conservation of Rare Plants. Oxford University Press, New York, pp. 3–30.

Blakesley D., Anusarnsunthorn V., Kerby J., Navakitbumrung P., Kuarak C., Zangkum S. et al. 2000. Nursery technology and tree species selection for restoring forest biodiversity in northern Thailand. In: Elliott S., Kerby J., Blakesley D., Hardwick K., Woods K. and Anusarnsunthorn V. (eds), Forest Restoration for Wildlife Conservation. International Tropical Timber Organisation and The Forest Restoration Research Unit, Chiang Mai University, Thailand, pp. 207–220.

Blakesley D., Elliott S., Kuarak C., Navakitbumrung P., Zangkum S. and Anusarnsunthorn V. Propagating native framework tree species to restore seasonally dry tropical forest: implications of seasonal seed dispersal and dormancy. Forest Ecol. Manage. (in press).

Corlett R.T. 1998. Frugivory and seed dispersal by vertebrates in the Oriental (Indomalayan) Region. Biol. Rev. 73: 413–448.

Elliott S. (ed.) 2000. The Chiang Mai Research Agenda for the restoration of degraded forest lands for wildlife conservation in Southeast Asia. In: Elliott S., Kerby J., Blakesley D., Hardwick K., Woods K. and Anusarnsunthorn V. (eds), Forest Restoration for Wildlife Conservation. International Tropical Timber Organisation and The Forest Restoration Research Unit, Chiang Mai University, Thailand, pp. 383–411.

Elliott S., Anusarnsunthorn V., Garwood N. and Blakesley D. 1995. Research needs for restoring the forests of Thailand. Nat. Hist. Bull. Siam. Soc. 43: 179–184.

Elliott S., Kuarak C., Navakitbumrung P., Zangkum S., Anusarnsunthorn V. and Blakesley D. Propagating framework trees to restore seasonally dry tropical forest in northern Thailand. New Forests (in press).

FAO Forest Resources Division 1995. Collecting woody perennials. In: Guarino L., Ramanath Rao V. and Reid R. (eds), Collecting Plant Genetic Diversity. Technical Guidelines. CAB International, pp. 467–484.

Flannery T. 1995. Mammals of the South-west Pacific & Moluccan Islands. Cornell University Press, Ithaca, N.Y., USA.

Forest Restoration Research Unit, Elliott S., Anusarnsunthorn V., Blakesley D. (eds) 1998. Forests for the Future: Growing and Planting Native Trees for Restoring Forest Ecosystems. 60 p.

Forest Restoration Research Unit, Kerby J., Elliott S., Maxwell J.F., Blakesley D., and AnusarnsunthornV. 2000. Tree seeds and seedlings for restoring forests in northern Thailand. 152 p.

Garwood N.C. 1983. Seed germination in a seasonal tropical forest in Panama: a community study. Ecol. Monog. 53: 159–181.

Goosem S.P. and Tucker N.I.J. 1995. Repairing the Rainforest – Theory and Practice of Rainforest Re-establishment in North Queensland's Wet Topics. Wet Tropics Management Authority, Cairns. 71 p.

Guarino L., Ramanath Rao V. and Reid R. (eds) 1995. Collecting Plant Genetic Diversity. Technical Guidelines. CAB International, 748 p.

Hardwick K., Healey J., Elliott S., Garwood N.C. and Anusarnsunthorn V. 1997. Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in northern Thailand. Forest Ecol. Manage. 99: 203–214.

Janzen D.H. 1978. Seeding patterns of tropical trees. In: omlinson P.B. and Zimmermann M.H. (eds). Tropical trees as Living Systems. Cambridge University Press. pp. 83–128.

Kijkar S. 1991a. Handbook: Coconut husk as a potting medium. ASEAN-Canada Forest Tree Seed Centre, Muak Lek, Thailand.

Kijkar S. 1991b. Handbook: Producing rooted cuttings of *Eucalyptus camaldulensis*. ASEAN-Canada Forest Tree Seed Centre, Muak Lek, Thailand.

Knowles O.H. and Parrotta J.A. 1995. Amazonian forest restoration: an innovative system for native species selection based on phenological data and field performance indices. Commonwealth Forestry Review 74: 230–243.

Krishnapillay B., Mansorm M. and Mohd K. 1993. FRIM suggests seeds not necessarily orthodox or recalcitrant. Seed Centre News (ASEAN-Canada Forest Tree Centre Project) 10: 3.

Lamb D., Parrotta J., Keenan R. and Tucker N. 1997. Rejoining habitat fragments: restoring degraded rainforest lands. In: Laurance W.F. and Bierregaard R.O. (eds). Tropical Forest Remnants: Ecology, Management and Conservation of Fragmented Communities. University of Chicago Press. pp. 366–385.

Micleburgh S.P. and Carroll J.B. 1994. The role of captive breeding in the conservation of Old World Fruit Bats. In: Olney P.J.S., Mace G.M. and Feistner A.T.C. (eds). Creative Conservation: Interactive Management of Wild and Captive Animals. Chapman and Hall, London, UK. pp. 352–364.

Phua P.B. and Corlett R.T. 1989. Seed dispersal by the Lesser Short-nosed Fruit Bat (*Cynnopterus brachyotis*, Pteropodidae, Megachiroptera). Malayan Nature Journal 42: 251–256.

Schmidt L. 2000. Guide to handling of tropical and subtropical forest seed. Danida Forest Tree Centre, Denmark.

Tucker N. and Murphy T. 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the Wet Tropics of North Queensland. Forest Ecol. Manage. 99: 133–152.

World Conservation Monitoring Centre 1996. Guide to Information Management in the context of the Convention on Biological Diversity. United Nations Environment Programme, Nairobi, Kenya.

Young A.G., Boshier D. and Boyle T.J. 2000. Forest Conservation Genetics: Principles and Practice. CSIRO Publishing, Australia.