WILDLIFE COLONISATION ON RESTORED TROPICAL LANDS: WHAT CAN IT DO, HOW CAN WE HASTEN IT AND WHAT CAN WE EXPECT?

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ABSTRACT

With many tropical species facing an uncertain future because of habitat loss and fragmentation, restoration will likely become an increasingly important facet of wildlife management and conservation. Colonisation and utilisation of formerly degraded tropical lands, by a range of local life forms / species, is the acid test of successful restoration. Understanding the dynamics of these processes will assist in more informed strategies for management and a more positive future for tropical biodiversity. This paper briefly describes some of the roles played by wildlife in newly restored tropical areas, the benefits that may accrue from this interaction and suggests ways to hasten and sustain this interaction. Colonisation of one restored area by insects, birds and small mammals is outlined. This shows that colonisation can be quite rapid once threatening processes are removed and restoration works are self-maintaining.

Key words: wildlife, ecological restoration, rain forest, colonisation

WILDLIFE AND RESTORATION

Australia has the dubious honour of recording over twenty mammal extinctions over the past two hundred years and many more species face an uncertain future. Having recognised the need to counter the effects of fragmentation and habitat loss, the removal of threatening processes and the re-building of new habitats offers one means to secure the future of the national store of biodiversity. Whilst increasing habitat will be beneficial for wildlife, benefits can also flow to restored areas as organisms play increasingly complex roles in these developing systems. Several positive benefits accrue from the colonisation of restored areas by native wildlife. Recognition and manipulation of these benefits should be considered an essential part of the restoration process (TUCKER and MURPHY 1997; HARDWICK et al 1997).

In this paper I describe some of the roles played by wildlife in the restoration of degraded lands, suggesting ways to hasten and sustain this interaction, based on work within the humid wet tropics of north-eastern Queensland, Australia. To demonstrate the

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colonisation process, I provide examples from a restored habitat linkage in the same area. Data relating to four species of small mammals, bird communities and one ecological group from one insect order are presented. Colonisation by other groups is also under study and the reader is referred to TUCKER (2000a/b) for further detail on this linkage.

1. Wildlife colonisation: What can it do?

Seed and spore dispersal

Effective dispersal will be essential in promoting a greater diversity of life forms and species. Dispersal adds important resource and structural complexity as recruits grow and develop. By encouraging wildlife visitation and habitation the process of dispersal can be enhanced and increased diversity of many life forms can be expected (TUCKER and MURPHY 1997, Parrotta *et al* 1997).

Pollination

Many tropical plants have very irregular flowering and fruiting cycles and their reproductive ability may be linked to the availability of specialised pollination mechanisms. Many of the insects involved in these mechanisms are relatively slow moving and their ability to re-colonise quickly may be limited (HILL 1995). Because of their size and relative ease of collection, these organisms are good candidates for translocation providing autecological needs have been met. Limited studies indicate bird visitation to restored areas can be rapid, and their contribution to successful pollination is likely to be important.

Regulating pest populations

Birds can also play important roles in regulating populations of herbivorous insects and the damage they cause to planted seedlings. This benefit can also assist in adjacent agricultural crops and commercial forestry plantations. Restoration can also play a key role in regulating populations of vertebrate pests. In north Queensland, restoration of weed infested stream banks has been shown to reduce damaging populations of Canefield Rats (*Rattus sordidus*) in sugar cane (author *unpubl. data*), and potentially other species in other agricultural crops.

Nutrient cycling and soil conditioning

Colonisation by invertebrates and megapodes such as Scrub Turkey (*Alectura lathami*) and Scrub Fowl (*Megapodius reinwardt*) accelerates litter decomposition and nutrient cycling, potentially improving soil porosity, aeration, soil organic matter and moisture retention. This is particularly important in formerly degraded areas where soil structure, nutrient status and stability have often been significantly altered. Tree cover substantially improves soil stability and guards against splash erosion.

2. How can we hasten it?

In designing restoration for wildlife several potential problems must be recognised and managed in order to maximise the value of these areas for wildlife conservation. Ecological restoration is about more than just tree planting, it is just as much about creating complex physical niches for the animals which will perform key roles in the long term development of these areas into self sustaining communities. Factors influencing this development and strategies to enhance (or mitigate) these factors, may include:

Species matrix

All plants established should be local species of local provenance as these are likely to be the most attractive to local wildlife and perform best in local conditions. As well as selecting many life forms, from many individuals to maximise genetic variety, other considerations may include:

***Keystone food plants e.g.* Ficus**

Keystone food plants are those that provide a critical supply of wildlife resources at times when there are few or no other plants to sustain local wildlife populations, and in this way are crucial or keystone species on which much of the ecosystem depends in some way or another. Figs provide a year round source of wildlife resources and can be focal points for natural recruitment and regeneration (GUEVARA and LABORDE 1993). Growing these plants from cuttings can overcome delays in provision of food resources, as cuttings may produce fruits at only six months old. By collecting from many individuals, whether they are fruiting or not, increased genetic variety can be easier to achieve. In plantings undertaken by the Centre for Tropical Restoration in north Queensland, figs represent between ten and twenty percent of all species established. Other plant families will also be important in providing a consistent supply of food resources. In north Queensland the laurel (Lauraceae) family is one of these families; a diverse range of species producing highly nutritious fruits through most of the year.

Framework species (GOOSEM and TUCKER 1995, LAMB et al 1997)

The primary purpose of this group is to rapidly capture a site and accelerate natural regeneration at that site through the dispersal process. However, an equally important task is to establish nodes of framework species that are able to colonise surrounding degraded areas and promote establishment of new habitat nodes. The value of most habitat types, whether restored areas or intact reserves, is likely to be in their degree and quality of connectivity. Framework species are able to enhance habitat heterogeneity at the local landscape scale because of their reliable germination in degraded areas, and attractiveness to dispersal vectors at local sites.

Favoured food plants of target wildlife species

Many restoration projects are driven by the need to preserve a particular species or group of species. Focusing on a target such as this requires a greater understanding of species autecology. However, this will be of great benefit as it forces us to examine much more closely the most desirable biotic and abiotic attributes, and to plan for their installation. For most wildlife this means a wide range of their favoured food plants whether it is the foliage, fruit or nectar which attracts them, or in the case of predators, the organisms feeding on these resources. In north Queensland, larger bodied species, such as arboreal folivores, are often the targets in restoration works, and known food plants of this group are always included.

Large fruited species

Dispersers of these fruits are often the larger bodied wildlife, species themselves most often at risk from forest fragmentation. Studies have shown the lack of regeneration of large fruited tree species (TUCKER and MURPHY 1997, PARROTTA *et al* 1997), often attributed to the loss of key dispersal vectors and a reduction in available habitat (THEBAUD and STRASBERG 1997). For frugivores such as Madagascar's lemurs (HOLLOWAY 1999) and Australia's cassowary (CROME and BENTRUPPERBAUMER 1993), the inclusion of large fruited species in restoration plantings benefits both the plant and its dispersal vectors.

Nitrogen fixers

In severely degraded areas these plants may be required to enhance soil physical and chemical properties prior to, or as an adjunct to, establishing other species.

Rare / threatened species

Restoration permits the immediate re-establishment of endangered plants into areas of their former range. The conservation status of these plants can be dramatically improved if concerted efforts are made to include them in all restoration works. This also adds significantly to our understanding of the propagation and cultivation requirements of these plants.

Cultural plants

The incorporation of plants with medicinal, spiritual or other traditional uses brings into sharp focus the need to recognise and value the place of people in the restoration process. The success or failure of restoration works depends largely on its relevance to and acceptance by, the local human population (JAFFEE 1997, FORRU 1998). By encouraging participation in the restoration process, local communities are far more likely to feel a sense of ownership and responsibility (MURPHY and TUCKER *in press*), perhaps adopting a more sympathetic attitude.

Once a suitable species matrix has been prepared and propagated, several features must be considered to maximise the value of these areas for wildlife habitat.

Niche provisioning

Restored areas in the wet tropics of north-eastern Queensland have similar structural complexity and resource availability to early successional forest and for this reason, niche features such as hollow and decaying logs, nesting hollows / dens and rock piles are installed prior to planting, and as trees grow and develop. Similarly, vines are included in the initial planting phase to guarantee the creation of vine tangles and thickets for wildlife species requiring this habitat feature (GOOSEM and TUCKER 1995, TUCKER 2000*a*).

Edge effects

Many wildlife species avoid forest margins and these are most often the plants and animals at risk. Reducing edge effects in restorations can be achieved by planting wide belts (x hundreds of metres), 'sealing' the new margin with a specially selected range of taxa that are able to dominate a forest margin and be more or less resistant to weed invasion (GOOSEM and TUCKER 1995), or by planting buffer zones / strips of agro-forestry species adjacent to restored vegetation (TUCKER 2000*a*). Other edge exacerbated phenomena such as predation and parasitism may be partially overcome by provision of niche cover features and use of buffer zones. Plantings, especially wildlife stepping-stones, should minimise edge to area ratios by establishing circular plots, rather than linear strips.

Weed and pathogen management

The establishment of restored vegetation can sometimes facilitate spread of weeds (in particular vines), rendering areas unsuitable as wildlife habitat. Surveys should be undertaken to identify potentially invasive weeds and a strategy developed to deal with infestations on a regular basis. Nursery facilities should be maintained in a hygienic condition at all times to ensure weeds, feral worms and pathogens are not introduced into areas where they are not already present (GOOSEM and TUCKER, 1998).

Generalists vs. specialists

Ecological specialists are often the target species for restoration efforts because of their susceptibility to the effects of fragmentation (LAURANCE 1990, TUCKER 2000*a*). These species will be difficult to attract in the short to medium term because of the biological and structural complexity of tropical forests, and the long recovery time before this complexity is achieved in a restoration planting. However, closer attention should be paid to the feeding and nesting requirements of the specialists to at least limit this problem. Generalists appear to colonise restored habitats very quickly, particularly if the extra resources installed for specialists are already in place.

3. What can we expect?

Wildlife colonisation of restored areas in the Wet Tropics of north Queensland

The humid wet tropics of north Queensland contains a number of plant communities classified as either endangered or vulnerable (GOOSEM *et al* 1999) and many of the well-studied vertebrates occurring in these assemblages are equally at risk. Forest types on the most productive agricultural lands have been especially prone to non-random deforestation, some reduced to as little as 2.5% of their original extent, and a number of vertebrate species playing key ecological roles are no longer present in even the largest remnants (>500 ha). Restoration works have commenced to reverse this biodiversity decline, and the monitoring of these restoration works is now beginning to provide some insight into the colonisation process (TUCKER and MURPHY 1997). As functional groups begin to establish and simple food webs become ever more complex, restored systems may function as stepping stones or as habitat per se. The provision of stepping-stones greatly increases the value of the landscape to small and sedentary species as well as migratory species during travel seasons.

Providing new habitat areas or restoring habitat connectivity to isolated reserves is likely to be an increasingly important component of sound regional conservation strategy.

How are we to know whether wildlife uses restored areas unless we monitor and evaluate the response to our work? Monitoring is a badly neglected facet of restoration but is crucial to the survival of target species and the long-term development of the science of tropical restoration for wildlife habitat (TUCKER 2000*b*). Whilst a target species may be the obvious choice it may be decades or hundreds of years before these species naturally re-colonise, depending on their niche requirements. In such instances, it may be possible to re-locate captive-bred animals into restorations to hasten this re-colonisation, providing the area contains sufficient quality habitat.

Several bio-indicators can be used to provide feedback on the dynamics of restored tropical areas. Some studies have examined invertebrates (JANSEN, 1997), though there are an increasing number of studies examining colonisation by other life forms including plants and vertebrates (TUCKER and MURPHY 1997, PARROTTA *et al* 1997). Monitoring plant colonisation can reveal the likely dispersal vectors visiting the site and an assessment of the microclimatic and physical changes that permit plants of different successional stages to establish and grow. Plants are also easy to sample and measure and if identification is not possible at juvenile stage, it can usually be made as the plant grows and identification characters are more recognisable. A combination of these bio-indicators may produce a more comprehensive picture of early trends that can then be interpreted to provide long-term management prescriptions.

Very limited data is available on colonisation of restored tropical areas by wildlife, though corridor restoration projects in the Wet Tropics of north Queensland are now beginning to provide land managers with some insight. One such project is the Donaghy's habitat linkage, established to link the isolated Lake Barrine reserve (491 ha) with the 1.5 kilometre distant Gadgarra State Forest (80,000 ha). Over 20,000 plants were used to replant the linkage, which was severed by land clearing over sixty years ago. Commenced in 1995, the linkage was established over four years, establishing blocks of 5,000 trees annually, and a three row windbreak has been established either side of the linkage. The linkage averages 100 metres in width, excluding the adjacent windbreak (TUCKER 2000*a*).

Small mammal colonisation

Trapping commenced in January 1998 with the completion of the linkage. Since this time, quarterly surveys have been undertaken at 11 sites throughout the linkage (see map), in intact and edge affected forests at either end; in the adjacent open paddocks and in each of the 4 yearly plantings. In each quarter, 20 Elliott box traps and four wire cage traps are set over three nights, baited with a rolled oats / peanut butter / vanilla mixture, in a 30m x 30m grid design. All captures are weighed, sexed with an evaluation of breeding condition, ear-tagged with an identifying number, and released. Captures described here represent a total of 5,544 trap nights.

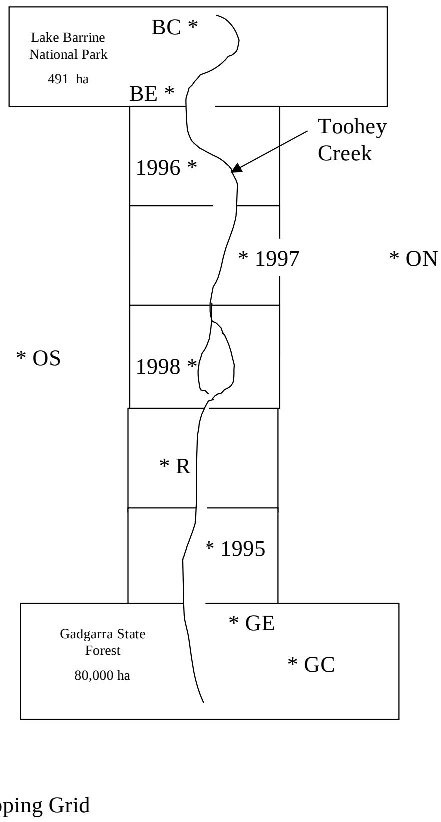
Trees planted in 1997 to form the Donaghy's Corridor at 3 years of age.

Donaghy's Corridor, January 1998.


DONAGHY's CORRIDOR
Donaghy's Corridor
Lake Barrine
Toohey
Creek
Gadgarra State Forest
Scale 1 : 10 000
0.1 0 0.1 0.2 0.3 0.4 Kilometers
WET TROPICS
WORLD HERITAGE AREA

The grassland Melomys, *Melomys burtoni*, is a common grassland / pasture rodent, which is also found in grassy clearings in rain forest habitats (STRAHAN 1995). This preference for grassland and disturbed habitats, similar to early regrowth vegetation, is reflected in Figure 1, where the species is absent from the forest sites at either end of the linkage, but abundant at most other sites. Conversely the Fawn-footed Melomys (*Melomys cervinipes*) is primarily a forest dweller and, whilst it occasionally ventures into disturbed areas with a woody weed / grass component, it is not found in grassland habitats. This is evidenced by the species' distribution in Figure 2., where it is absent from the grassland habitats adjacent to the linkage.

Figures 1 and 2 show sympatry occurring in what are generally considered allopatric species. This is especially the case in the 1997 block where high densities of both species have been consistently recorded. In this case the two species have access to resources common to both grassland and forest habitats, though *M. burtoni* is likely to be displaced as its grass / weed habitat becomes increasingly shaded out, and *M. cervinipes* will probably dominate as a more complex forest structure begins to develop.



Schematic diagram for trapping grids for Small Mammal Monitoring in Donaghy's Corridor.

Figure 1. Cumulative number of *Melomys burtoni* trapped at Donaghy's Corridor, January 1998 to January 2000.

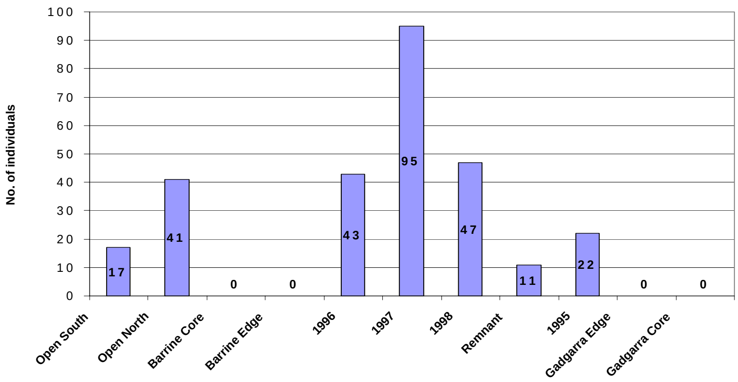


Figure 2. Cumulative number of *Melomys cervinipes* trapped at Donaghy's Corridor January 1998 to January 2000.

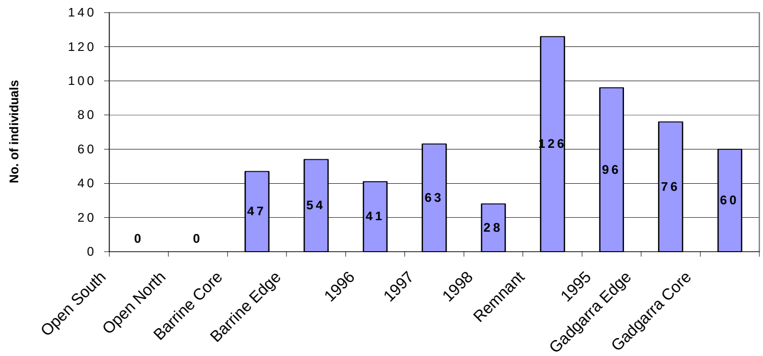
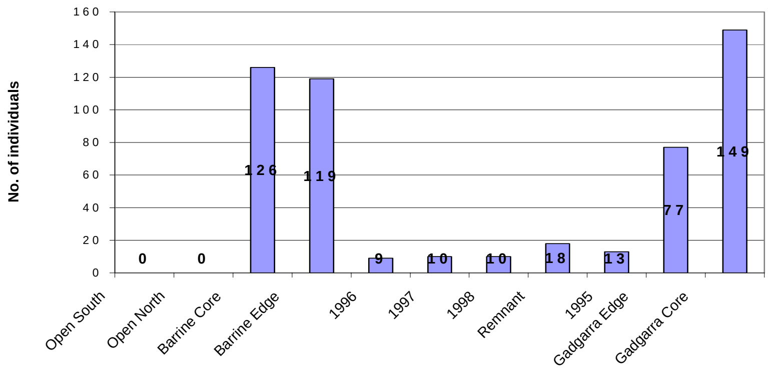


Figure 3. Cumulative numbers of *Rattus fuscipes/leucopus* trapped at Donaghy's Corridor January 1998 to January, 2000.



This structural development also introduces forest dwelling species such as Cape York rats (*Rattus leucopus*) and Bush rats (*R. fuscipes*), which appear to move into planted areas when plots are around 18 months old. Figure 3 shows the abundance of these two rodents in all trapping grids, also demonstrating avoidance of non-forest habitats; relatively high densities in forest habitats and establishing populations in the linkage proper.

Table 1 shows the total number of species captured at all sites, and shows the prevalence of generalists over the ecological specialists. Species such as the Musky Rat Kangaroo (*Hysiprimnodon moschatus*) are not even present in edge-affected forests adjacent to the restoration, and their appearance in restored areas may take many decades. For arboreal mammals, such as the Lemuroid Ringtail Possum (*Hemibelidius lemuroides*), which rely on nest hollows in mature trees, colonisation may take significantly longer, perhaps 100 years or more. There is also an obvious lack of diversity in the open paddocks adjacent to the restored areas and a sharp contrast between the faunas of these two habitats. Only *Mus musculus, Melomys burtoni, Rattus sordidus* and the feral Cane Toad *Bufo marinus*, have been trapped in these structurally simple pasture habitats.

Table 1. Species present in grids at Donaghy's Corridor

Species	OS	ON	BC	BE	1996	1997	1998	R	1995	GE	GC
Mus musculus House mouse	●	●			●	●	●	●			
Melomys burtoni Grassland Melomys	●	●			●	●	●	●			
Rattus sordidus Canefield Rat	●	●				●	●	●			
Melomys cervinipes Fawn-footed Melomys			●	●	●	●	●	●	●	●	●
Rattus fuscipes Bush Rat			●	●	●	●	●	●	●	●	●
Rattus leucopus Cape York Rat			●	●	●	●	●	●	●	●	●
Isoodon macrourus Brown Bandicoot				●		●		●		●	
Perameles nasuta Long-nosed Bandicoot			●		●	●	●		●	●	●
Uromys caudimaculatus White-tailed Rat			●	●	●	●	●	●	●	●	●
Antechinus flavipes Yellow footed Antechinus			●	●	●		●			●	
Antechinus stewartii										●	●
Hypsiprimnodon moschatus Musky-rat Kangaroo											●

Location Key: OS – Open South, ON – Open North, BC – Barrine Core, BE – Barrine Edge, R – Remnant, GE – Gadgarra Edge, GC – Gadgarra Core.

Species diversity is greatest in developing restorations, reflecting the diversity of resources available for a range of habitat generalists, common to both highly disturbed forest fragments and adjacent pastures.

Insects

There is limited data available on invertebrate re-colonisation in tropical restorations and limited studies in north Queensland have shown variable results. JANSEN (1997) showed a return of some orders in a restoration plot near Lake Barrine though there was a clear differentiation between wet and dry seasons. It is interesting that this study detected very few wood-boring beetles (Coleoptera). The inclusion of dead wood is now seen as an important structural element in restoring habitat linkages, and logs of various sizes were put in place prior to re-planting the Donaghy's linkage (GROVE and TUCKER 2000).

Table 2. Wood boring beetles (Coleoptera) present in logs placed in restoration plots aged 1-4 years at Donaghy's Corridor. (Source: From GROVE and TUCKER – *unpubl data*)

Species / Year of transplant	1995	1996	1997	1998
Staphylinidae sp. 1		+		
Staphylinidae sp. 2	+	+	+	
Staphylinidae sp. 3			+	
Staphylinidae sp. 4		+		
Staphylinidae sp. 5		+		
Leidodidae sp. 1	+	+		
Throscidae sp. 1	+			
Corylophidae sp. 1	+	+		
Corylophidae sp. 2		+		
Corylophidae sp. 3	+			
Lathridiidae sp. 1				+
Lathridiidae sp. 2			+	
Monotomidae sp. 1	+			
Ciidae sp. 1	+			+
Ciidae sp. 2		+		
Tenebrionidae sp. 1				+
Tenebrionidae sp. 2		+		
Anthribidae sp. 1		+		
Total **18**	7	10	3	3

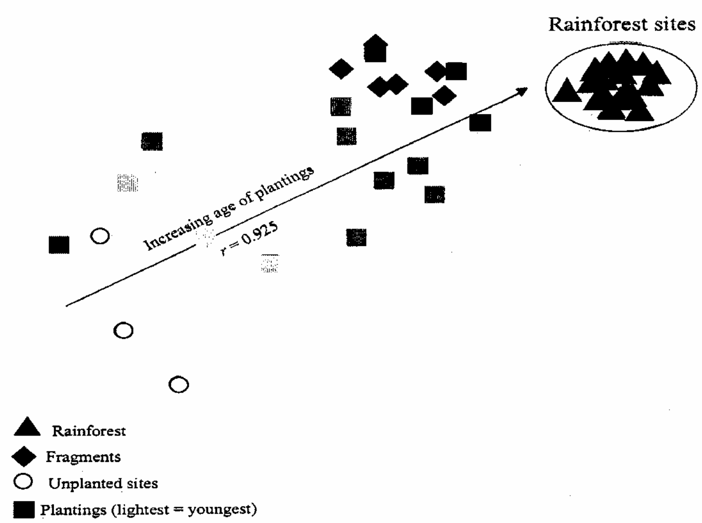
The effect of this placement on 'morpho-species' of wood-boring Coleoptera, recorded in a one-off survey in September 1999, is shown in Table 2. A full description of the methods used in this survey can be found in GROVE and TUCKER (2000). Table 2 indicates eighteen morpho-species of Coleoptera typically associated with dead wood habitat, though once again there are no families such as *Passalidae,* more typically associated with mature forest dead wood habitats. This is a one-off study and results should be interpreted with caution. However, the insects are a likely target to evaluate the efficacy of transplanting, or re-locating, organisms into restored areas and these early signs of colonisation are encouraging.

Birds

JANSEN'S studies in the Donaghy's linkage show a much more rapid return of many birds more typically associated with mature forest, assemblages in older plantings being very similar to adjacent rain forest communities (Figure 4). Likely factors implicated in this return include the inherent mobility of birds, the proximity of forest at either end of the linkage, and the relative paucity of forest specialists in Australia's tropical avifauna (CROME 1990). This study is consistent with other observations in the local area. Considering the demonstrated importance of birds as dispersal vectors in these forests, this is highly desirable.

Nevertheless, species such as Chowchilla's (*Orthonyx spaldingii*), a ground storey insectivore generally only associated with larger forest blocks, have not yet been recorded within the plantings. This is hardly surprising considering the specialised niche of species such as Chowchilla's, which require significant leaf litter depth and moisture, as well as the ground storey cover afforded by structurally diverse habitat.

Figure 4. Non-metric multi-dimensional scaling plot of sites according to their bird communities in the dry seasons of 1996 to 1998 (Stress - 0.11) at Donaghy's Corridor, North Queensland. (Source: JANSEN unpubl.)



CONCLUSION

Though not replicated, the early results from this project are generally consistent with other local studies, for example small mammal studies by CROME *et al* (1994) and LAURANCE and LAURANCE (1996), and plant colonisation surveys by TUCKER and MURPHY (1997). Not surprisingly, there is a general trend toward increasing species diversity and abundance in older plots, and in sites close to existing forest at the Donaghy's site. This trend is consistent for both plants and animals and reflects increasing structural complexity and resource availability within developing plantings, though it is too early to tell whether these patterns will be sustained. Results should be interpreted with caution, although results are encouraging with the oldest plot at the Donaghy's site only five years old, and colonisation by some species is clearly quite rapid.

Wildlife are often the targets for ecological restoration efforts, but they are moving targets in more ways than one. However, only by focusing on targets are we likely to hit the mark. If we are serious about reversing habitat loss, then we must concern ourselves with re-building complex habitats, not just planting trees or controlling weeds. Once these factors are considered, on-going monitoring programs will be essential to assess the community dynamics of restored areas, and their suitability for the organisms our efforts are directed toward.

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QUESTIONS AND COMMENTS

Yadi Setiadi

When establishing a corridor do you conduct screening to decide which tree species to plant or will any species do?

Nigel Tucker

We look closely at target wildlife species, especially patchily distributed arboreal folivores e.g. musky kangaroos and possums. We look at their diets and include the tree species they feed on. Many of the tree species that we plant have multiple uses; e.g. figs are eaten by arboreal animals and have utilitarian values.

Yadi Setiadi

How did you decide upon 100 m for the width of the corridor? Is it wide enough?

Nigel Tucker

A very good question; corridor width is a controversial question. For large carnivores, such as the Florida panther, corridors need to be several kilometres wide, but for us it is not practical to establish such wide corridors on privately owned land. A general rule proposed by Lawrence is that corridors should be 10% of their length. I see it as being twice as wide as the potential height of the forest. Our corridor width is approximately 10% of its length i.e. 1.2 km long and 100-130 m wide. There are no hard and fast rules.

Somsak Sukwong

I believe that in the Southeast Asian landscape the corridor idea is difficult to implement because it is difficult to find enough land. The idea could be adapted to include forest gardens, like in southern Thailand, with fruit trees e.g. durian. In Southern Thailand when landslides and fire destroyed plantations, the forest gardens survived. The same thing happened in Malaysia and Indonesia. Many forest gardens exist between wildlife sanctuaries and national parks and they may also increase movement of wildlife between conservation areas, although they may not be as corridors.

George Gale

Given the controversy concerning the effectiveness of corridors, I think this is the best paper yet, providing proof that they work. Do you have any data that indicate any negative effects of corridors?

Nigel Tucker

No negative data; these corridors are established on private land with a nature conservation agreement that goes with the land. If the land is sold, the new owners cannot clear or alter the forest. I am working on several corridor projects to try to replicate the results reported here. The problem is that we don't yet have other corridors to show that this is not a one off thing.