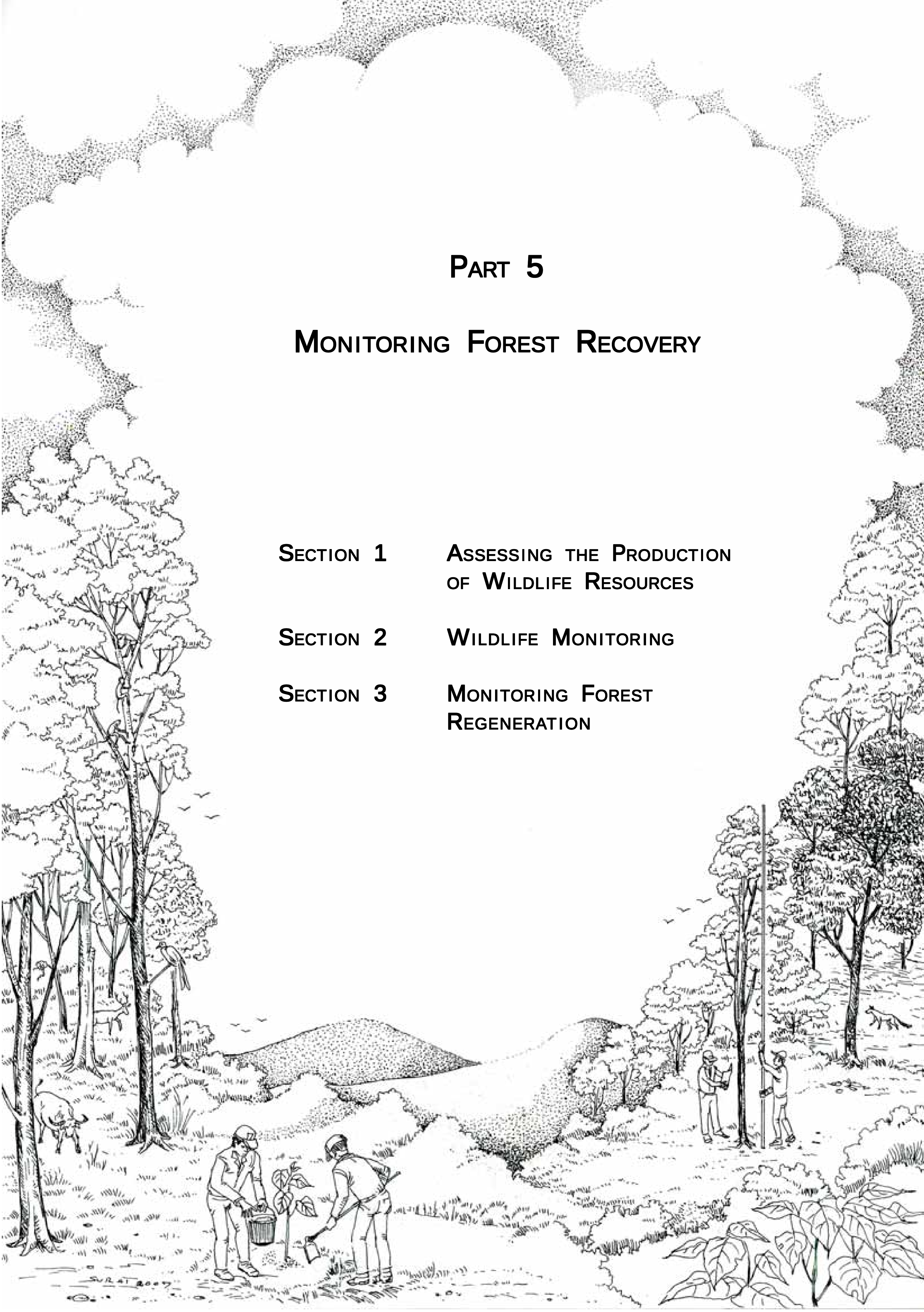
Part 5

Monitoring Forest Recovery

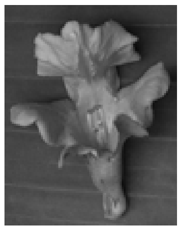
Section 1	Assessing the Production of Wildlife Resources
Section 2	Wildlife Monitoring
Section 3	Monitoring Forest Regeneration



Natural regeneration occuring in a 9 year old plot with well established leaf litter cover (above). Binoculars are essential for bird survey work (right), though the presence of birds can be detected in other ways (below).

Regular phenology walks will yield much of the biodiversity recovery data needed (right).

Identifying natural regeneration and monitoring its survival and growth is important (left), as is the first flowering and fruit set of planted trees (right and below).



Monitoring Forest Recovery

The ultimate aim of forest restoration is to re-establish original levels of biodiversity in forest ecosystems, from fungi to elephants. The purpose of biodiversity monitoring is therefore to determine to what extent and how fast this occurs, ultimately to assess the success of the forest restoration techniques tested. However, monitoring *all* biodiversity is not practical, so for forest restoration, biodiversity monitoring should concentrate on those components that relate directly to the re-establishment of natural forest regeneration mechanisms, particularly seed dispersal and seedling establishment of recruit tree species (i.e. in-coming tree species, not including those planted). Four critical questions are:

- Do planted trees (and/or ANR techniques) produce resources at an early age (e.g. flowers, fruits etc.) likely to attract seed-dispersing animals?
- Are seed-dispersing animals present in the area, and if so, are they actually attracted by those resources?
- Do seeds, brought in by those animals, actually germinate, increasing the species richness of tree seedlings/saplings naturally establishing beneath the planted trees?
- Do wind-dispersed seeds also establish naturally?

Here we present a few key techniques which can be used to answer the above questions. Whilst monitoring the performance of planted trees yields clear results within 2-3 years, biodiversity recovery takes much longer. Therefore, biodiversity monitoring must be undertaken over periods of 5-10 years, but at less frequent intervals.

As already mentioned in Part 4, the requirement for biodiversity monitoring must be considered from the beginning of field experiments, during the design of FTPS's. Non-planted control plots must be included in a FTPS, and a biodiversity survey carried out over the controls and the plots to be planted, before site preparation is carried out. This provides the essential baseline data, against which subsequent changes in biodiversity can be compared. Biodiversity is then surveyed in both control and planted plots and compared with nearby, remnant, intact forest (i.e. the target forest community).

After each data collection session, two types of comparisons are performed i) before vs. after comparisons between current data and baseline (pre-planting) data and ii) control vs. planted plot comparisons. In this way, the enhanced biodiversity recovery, brought about by the planted trees, can be distinguished from that due to natural ecological succession. Relative biodiversity recovery can then be calculated as a percentage of that recorded with the same methods in target forest.

A bird's nest in a *Betula alnoides* tree just 2 years after planting. Frequent phenology montioring can reveal which planted tree species provide habitat for wildlife.

Section 1 - Assessing the Production of Wildlife Resources

Phenology studies

Simply walking through the planted plots frequently and noting which trees are flowering and fruiting can yield most of the data needed to answer the first question on the previous page. Establish a trail system through the centre of all plots. Walk the trails monthly, recording the following information for trees within 10 m on both sides of the trail:-

Date of observation: **Block/plot** identification number:
Tree number (including species number):
Flowers/fruits: use the 0-4 scoring system from Part 3.
Wildlife signs: nests, tracks, faeces etc. on or near tree
Direct observations of animals using the tree: feeding, bird perching etc.

Enter each observation, as a single row, into a speadsheet to allow easy compilation of the data by species or date. Determine the youngest age (time since planting), at which the first individuals of a species commence flowering and fruit set. The frequency of observations (within a species) can be used as a general indication of the prevalence of flowering/fruiting at the species level. For additional detail, measure the girth at breast height (or RCD), and the height of flowering/fruiting trees, to establish correlations between tree size and age at maturity. The flowering of some species may be inhibited if the trees are heavily shaded by adjacent tree crowns. If there is some variation in the incidence of flowering within a species, a shade score for each flowering tree observed can also be recorded.

In addition to assessing the production of wildlife resources by planted tree species, monthly surveys can yield much additional information about the planted trees species, such as outbreaks of pests and diseases and provide early warning of disturbances to the plots by human activities. This kind of simple qualitative monitoring activity is an excellent way to involve local people in monitoring forest restoration sites, since it is easily learned and requires no special skills.

Planted *Bauhinia purpurea* starts flowering and fruit set within 6 months after planting, providing food for birds and insects, making it an excellent framework tree species for restoring lowland deciduous forest ecosystems.

SECTION 2 – WILDLIFE MONITORING

All returning wildlife species (both plants and animals) contribute to biodiversity, but seed-dispersing animals can accelerate biodiversity recovery more than other species. Birds, fruit bats and medium sized mammals are the major groups of interest, but of these, the bird community is the most easily studied.

Why monitor bird communities?

Birds provide a convenient indicator group for the evaluation of biodiversity because:-

- They are relatively easy to see and most are easy to identify.
- Many excellent identification books and audio guides are available.
- Most species are active by day.
- Birds occupy most trophic levels in forest ecosystems – herbivores, insectivores, carnivores etc. and therefore a high diversity of birds usually indicates a high diversity of plants and prey species, especially insects.

What questions should be addressed?

- What bird species occurred in the area before planting?
- Which bird species disappeared as a result of forest restoration activities and when?
- Which bird species visited forest restoration plots and how soon after tree planting?
- What species breed in the plots?
- Which bird species visiting the plots are most likely to disperse seeds of forest trees into planted plots?
- How does the bird species diversity in the plots compare with nearby remnant forest?

When and where should bird surveys be carried out?

Survey the entire area of the FTPS, once it has been demarcated, but before any activities likely to alter bird habitats (i.e. site preparation for planting) have been implemented. This provides the baseline data, against which changes are compared. Thereafter, carry out bird surveys with the same intensity in both planted and non-planted control plots and also in the nearest area of remnant forest (the latter, to provide data on the richness and composition of the "target" bird community).

Annual bird surveys are usually sufficient to detect changes in bird communities. Carry them out at the same time each year, since bird species richness fluctuates according to seasonal migration patterns. Observe birds during the first 3 hours after dawn and the last 3 hours before sunset. Timetable 1 hour observation periods in each plot, alternating around the plots at hourly intervals, but ensure that, over the entire survey period, all plots are studied for the same number of hours, spread evenly among morning and evening observational periods.

Bird Survey Record Sheet

File Name: *Restoration Plot 6 years old*

Date: *17.12.05* Weather: *sunny, cool* Recorder/s: *LM, MT, CT*

Block Number: *G1* Plot Number: *EG-05*

Start time: *7.47am* Finish time: *10.30 am*

TIME	SPECIES(COMMON NAME)	SONG OR SIGHT	NO. OF INDIVIDUALS	DISTANCE FROM POINT (M)	TREE (SPECIES/ LABEL)	POSITION (CROWN/ TRUNK ETC.)	ACTIVITY (FEEDING, PERCHING, DISPLAYING ETC.)
7.47	Black-crested Bulbul	sight	1	20	Eyrthrina stricta	crown	feeding and flying
7.52	Bar-winged Flycatcher-shrike	sight	5	30	Ficus altissima	crown	feeding and flying
8.06	Hill Blue Flycatcher	song	1	50	Betula alnoides	tree trunk	flying
8.08	Sooty-headed Bulbul	song	1	25	Gmelina arborea	crown	flying
8.15	Puff-throated Babbler	sight	2	15	Spondias axillaris	tree trunk	flying
8.23	White-rumped Shama (male)	sight	1	10	near Prunus cerasoides	ground	perching
8.31	Yellow-browed Warbler	song	1	25	Erythrina stricta	crown	flying
8.35	Oriental White-Eye	song	1	40	Lithocarpus elegans	crown	flying
8.43	Golden-fronted Leafbird	song	1	20	Gmelina arborea	crown	flying
8.43	Bar-winged Flycatcher-shrike	song	7	30	Hovenia dulcis	crown	flying
8.46	Lesser Necklaced Laughing thrush	sight	10	10	Spondias axillaris	tree trunk	flying
9.01	Long-tailed Minivet (male & female)	sight	2	15	Erythrina stricta	crown & tree trunk	feeding and flying
9.01	Golden-fronted Leafbird	song	1	30	Gmelina arborea	crown & tree trunk	flying
9.02	Oriental White-Eye	song	2	30	Lithocarpus elegans	crown & tree trunk	flying
9.05	Bronzed Drongo	sight	1	20	Betula alnoides	crown	feeding and flying
9.05	Velvet-fronted Nuthatch	sight	1	20	Macaranga denticulata	crown	feeding and flying
9.06	Dusky Warbler	song	1	15	Spondias axillaris	crown	flying
9.08	Asian House Martin	sight	1	15	Spondias axillaris	tree trunk	feeding and flying
9.12	Arctic Warlber	sight	2	20	Macaranga denticulata	crown	flying
9.13	Silver-breasted Broadbill	song	1	20	Betula alnoides	crown	flying
9	g-tail... et	s	[illegible]	[illegible]	Eryth... ta	... &	feedin... ing

Data collection

Use the "point count" method to count birds from the centre of each plot. This method can be used to both count species and estimate bird population density (Gibbons et al., 1997 and Bibby et al., 1998). Stand in the centre of each plot and record all bird contacts for 1 hour by both sight and song. Record the species and numbers of birds and estimated distance from the observer when birds first appear in the plot. To reduce the risk of recording the same individual birds, several times, do not record the same bird species entering the plot for five minutes after first recording that species. Record the tree species (and tree number if labeled), in which birds have any activity (particularly feeding) and their position (trunk, lower canopy, upper canopy etc.).

Bulbuls are the "work-horses" of forest restoration. They feed on fruit in remnant forest and drop seeds of many tree species in forest restoration plots.

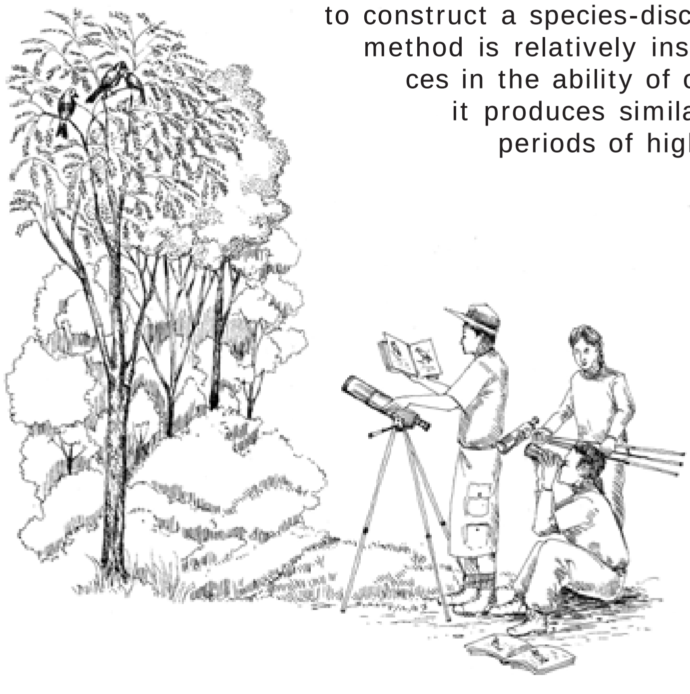
Data analysis

Answer most of the questions listed on the previous page, by simply scanning the species lists and counting the number of bird species that recolonize the plots and those that disappear as a result of forest restoration activities.

To calculate the extent of recovery in the bird community, compare the species lists for remnant target forest and planted plots. Calculate the percentage of the species found in forest that are also found in the restored plots and look at how this percentage changes over successive survey times.

Next, determine which of those species are frugivorous. These are the critical species most likely to disperse seeds from forest into planted plots.

For quantitative analysis of the species richness of bird communities we recommend the "MacKinnon list method". This uses the "list" as the unit of effort to construct a species-discovery curve. The method is relatively insensitive to differences in the ability of observers. Moreover, it produces similar results during periods of high or low activity.



Use binoculars, telescopes and ears, to detect birds within 20 m of a single point in the centre of forest restoration trial plots.

McKinnon Bird Species List - 6 year old Restoration Plot

	Species	List Number 1	2	3	4	5	6	7	8	9	10	No. of lists on which the species occurs
1	Black-crested Bulbul	√			√	√	√		√	√		6
2	Bar-winged Flycatcher-shrike	√	√						√			3
3	Hill Blue Flycatcher	√		√	√	√		√		√	√	7
4	Sooty-headed Bulbul	√				√	√					3
5	Puff-throated Babbler	√	√	√								3
6	White-rumped Shama	√							√	√	√	4
7	Yellow-browed Warbler	√			√		√	√	√			5
8	Golden Spectacled Warbler	√	√	√	√		√	√		√	√	8
9	Golden-fronted Leafbird	√										1
10	Verditer Flycatcher	√				√					√	3
11	Lesser Necklaced Laughing thrush		√									1
12	Long-tailed Minivet		√	√		√		√		√		5
13	Green-billed Malkoha		√						√			2
14	Oriental White-Eye		√		√		√				√	4
15	Bronzed Drongo		√	√					√			3
16	Velvet-fronted Nuthatch		√			√					√	3
17	Dusky Warbler		√				√					2
18	Asian House Martin			√				√		√	√	3
38	Grey-headed Flycatcher							√			√	2
39	Scarlet Minivet								√			1
40	Sulphur-breasted Warbler								√			1
41	Buff-throated Warbler								√			1
42	Pin-tailed Pigeon									√		1
43	Eastern Crowned Warbler									√		1
44	Brown-breasted Bulbul									√		1
45	Flavescent Bulbul										√	1
46	Lanceolated Warbler										√	1
	Number of New Species	10	7	5	5	4	4	3	3	3	2	
	Cummulative Species	10	17	22	27	31	35	38	41	44	46	

6 year old Restoration Plot

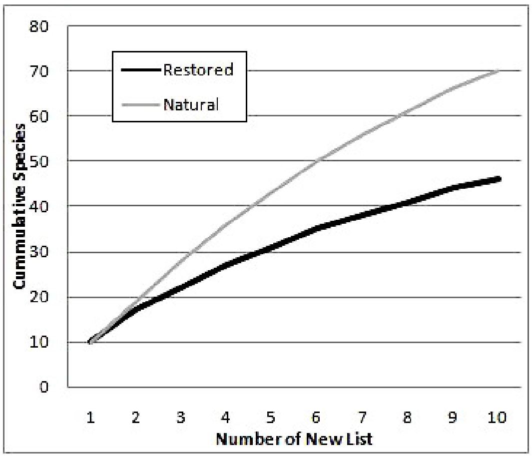
Number of lists on which the species occurs	1	2	3	4	5	6	7	8	9	10
Number of species occuring on above number, of lists (frequency)	14	13	9	4	2	2	1	1	0	0
Log (base 10) frequency	1.15	1.11	0.95	0.60	0.30	0.30	0	0	.	.

Make a new spreadsheet (facing page). Scan the data sheets and make a list of the first 10 different bird species recorded in the first column. Tick off the species in the next column. Then list the *next* 10 different bird species recorded, starting from zero (as if no species had been previously recorded). For species already in the first list, place a tick in the third column against its name. For new species, not recorded on the first list, add the species name to the bottom of the species list and tick it off in the third column. Repeat this process until you have at least 10 lists. Each species can be recorded only once in each list, but the same species may appear on several lists (Bibby et al., 1998).

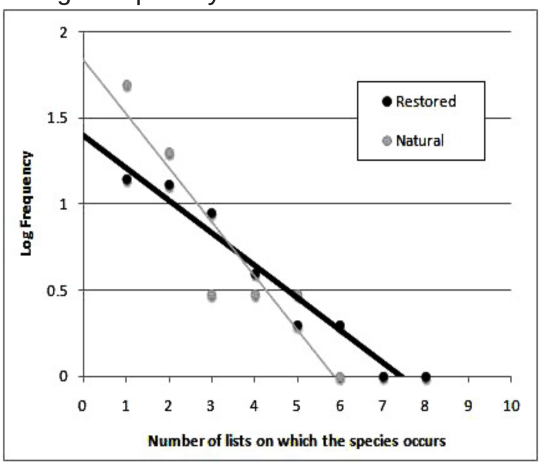
1. Count the number of new species found in each list and fill in the row marked "NO. OF NEW SPECIES" near the bottom.
2. Accumulate the no. of new species in the bottom row of the table
3. Plot a graph of cumulative no. of new species along the vertical axis and no. of lists along the horizontal.
4. Fill in the column on the data sheet, "NO. OF LISTS ON WHICH SPECIES OCCURS" and fill in the table as shown opposite below.
5. Plot a graph of log frequency along the vertical axis and no. of lists on which species occur along the horizontal axis.
6. Draw a straight line-of-best-fit and extrapolate it back to zero. Where the line crosses the vertical axis gives an estimate of the log of the number of species *not* seen during the survey (i.e. the number of species that occur on *zero* lists).
7. Convert this log value into the number of unseen species using antilogs (use the INV LOG function on a scientific calculator) and add the result, to the number of observed species to obtain an estimate of the total number of birds in the community.

Expect to see a decline in bird species richness for the first few years after tree planting. Site preparation and weeding reduces the habitat of open-area birds. After 3-4 years, bird species richness should increase, as some of the planted tree species flower and fruit and attract bird species characteristic of closed forest.

Cumulative species-effort curves



Log Frequency



Extract the numbers of observed species from the species-effort curves (70 and 46 for natural "target" and restored forest respectively, above left). Plot the log frequency graph (right). Extrapolate the line-of-best-fit back to zero and read off the log values for the no. of species *not* observed. Convert the logs into numbers (1.84 and 1.40 = 69 and 25 species respectively). Add that number to the number of observed species, to arrive at an estimate of the total number of bird species in the community (139 and 71 species respectively).

Mammals

Mammals can be divided into two groups of interest: i) fruit-eating species, capable of dispersing seeds from intact forest into restored sites (e.g. large ungulates, civets, fruit bats and so on) and ii) seed predators, which may limit establishment of recruit tree seedling species in restored sites (particularly small rodents).

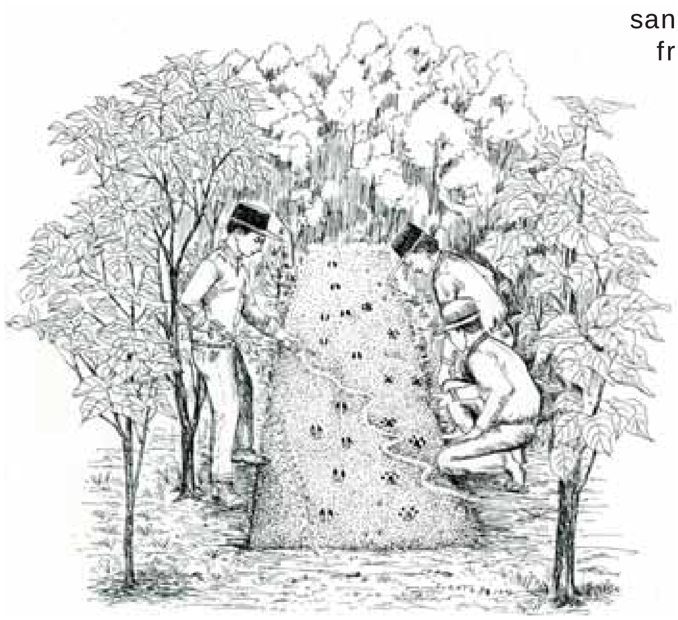
They are far more difficult to survey than birds, since most species are nocturnal and very shy, so direct observations of mammals are usually few and far between. Opportunistic, anecdotal data, are more commonly used to determine recovery of mammal communities after forest restoration (rather than systematic, quantitative data).

For larger, non-bat, species camera trapping is a very effective way of determining the presence of mammal species in an area, but the equipment is expensive, easily damaged and vulnerable to theft. Search the internet for equipment suppliers.

Live trapping, using locally available rat traps, is another useful technique, particularly for small mammals such as rodents. Lay out the traps 10-15 m apart, using a grid pattern. Expect capture rates of below 5%, so a great deal of effort is required for relatively few data. Expect to record a sharp decline in populations of rodent seed predators in planted plots by 3-4 years after planting, as dense, herbaceous vegetation (which provides cover for such small mammals) is shaded out by the developing forest canopy (Thaiying, 2003).

Most records of mammals in forest restoration plots must come from indirect observations of their tracks, feeding remains and other signs. These can be recorded during regular phenology monitoring of planted plots and control (non-planted) plots. The frequency of observations can be used as an index of abundance and to determine whether individual mammal species are increasing or declining in numbers. Carry out a similar survey, with the same degree of sampling effort, in the nearest remnant of intact forest to determine what percentage of the original mammalian fauna re-colonizes restored plots.

Sand traps make foot prints clearer and easier to identify.



For a more quantitative assessment, use sand traps to record the density and frequency of mammal tracks. Clear away leaf litter from sample plots and sprinkle the soil surface with flour or sand. Mammals walking over the sample plots leave very clear foot prints which can be measured and identified.

Lastly, anecdotal information can be collected from local people by interviews. Use pictures in mammal identification hand books (rather than local names) to ask local people which mammal species they see frequently in the FTPS and remnant forest nearby and whether such species appear to be increasing or declining in abundance.

Section 3 – Monitoring Forest Regeneration

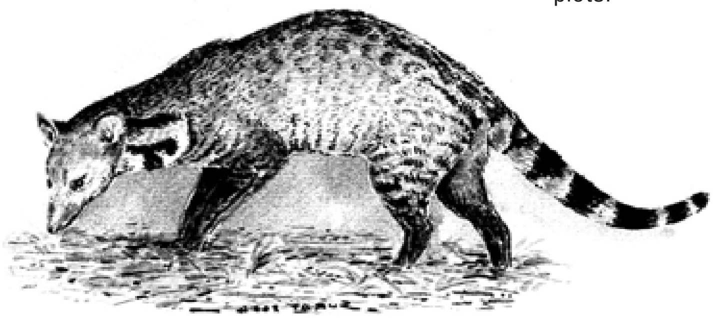
The framework species method of forest restoration relies on planting a low number of tree species to catalyse the re-establishment of most of the other plant species that formerly comprised the original forest ecosystem. Tree planting changes the local micro-climate, converting an open, dry, hot and sunny ecosystem into a cooler, shadier and more humid one. Shade-tolerant plants, characteristic of woodlands, should gradually replace sun-loving, mainly herbaceous, weeds of open areas. Leaf litter produced by the planted trees changes the conditions for seed germination and seedling establishment on the surface of the soil, by adding organic matter and nutrients to the soil and by changing soil structure. In addition, planted framework tree species should attract seed-dispersing animals into planted areas. With increased seed input from such animals, both ground flora species and a wide range of non-planted (recruit) tree species should germinate and establish in planted plots.

However, tree planting might also have some negative effects on natural tree establishment and on the botanical diversity of the ground flora. If trees are planted too close together, they might compete with naturally establishing, non-planted trees. During weeding with hand tools, naturally establishing trees can be accidentally cut. The creation of a shady forest canopy, together with weeding, immediately reduces the biomass of the ground flora. Sun-loving species will disappear rapidly, but the dispersal of shade-tolerant species into planted plots may take some time. This might lead to an overall reduction in the diversity of the ground flora for the first few years after planting. On the other hand, the shading out of smothering, dominant, sun-loving species (e.g. grasses, bracken fern and Compositae herbs) creates opportunities for colonisation by a wide range of other herbs, resulting in increased ground flora diversity.

The overall effects of tree planting on the diversity of naturally establishing trees and ground flora are, therefore, determined by complex interactions among several dynamic processes. Surveys of naturally established trees and ground flora should therefore be designed to determine the overall balance between these various processes.

Why monitor tree species recovery?

In forest ecosystems, the tree community is a good indicator of overall community biodiversity. Trees are the "skeleton" of the ecosystem, providing various habitats or niches for other organisms, such as birds and epiphytes. They are the base of the food web and account for most of the nutrients and energy in the ecosystem. A healthy, diverse tree community, therefore, indicates a healthy diverse forest ecosystem. Trees are easy to study. They are immobile, easy to find and easy to identify.



Civets can disperse quite large seeds over several kilometres and deposit them in clumps in restored forest plots.

What questions should be addressed?

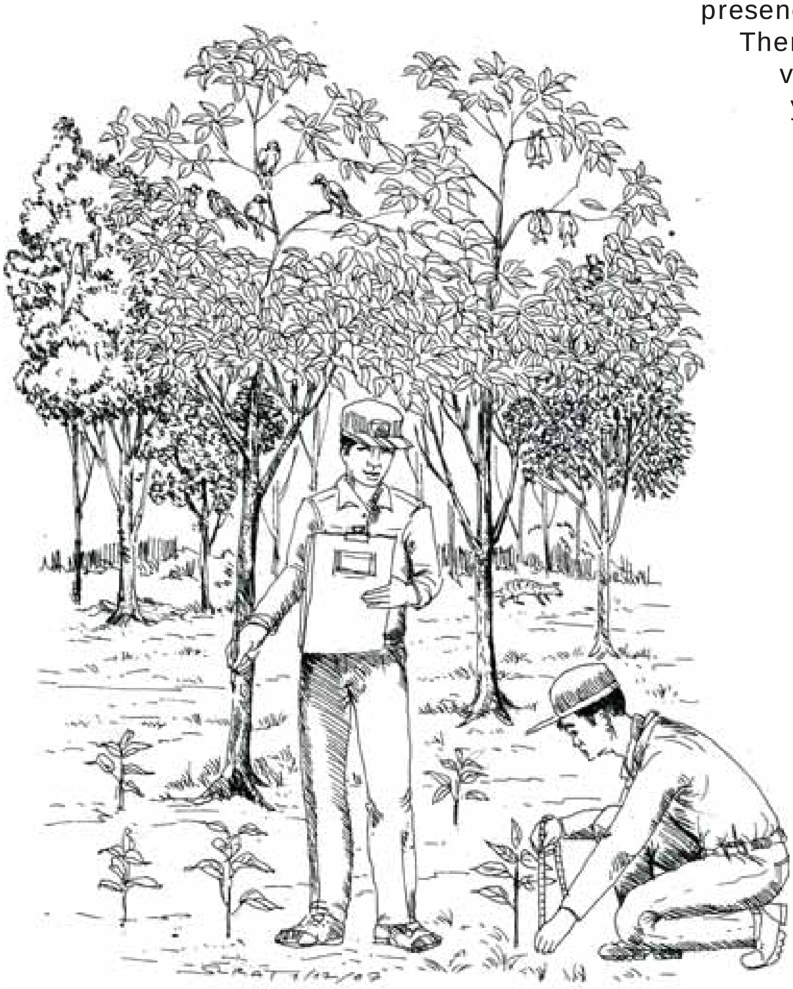
- What is the condition of the vegetation community on the FTPS site before forest restoration activities?
- Which climax forest tree species recolonize forest restoration plots and how soon after tree planting?
- Which pioneer tree species disappear as a result of forest restoration activities and when?
- What percentage of tree species, in nearby intact forest, eventually recolonize the planted plots?
- Which forest herb species recolonize the forest restoration plots and how soon after tree planting?

When and where should vegetation surveys be carried out?

Survey the entire area of the FTPS, once it has been demarcated, but before any activities likely to alter the vegetation (i.e. site preparation for planting) have been implemented. This provides the baseline data against which changes are compared. Thereafter, carry out vegetation surveys with the same sampling effort in both planted and non-planted control plots and also in the nearest area of intact forest to determine how many species from the "target" forest tree community are capable of dispersing into the restoration plots.

In seasonally dry climates, the character of the vegetation varies dramatically with the seasons, particularly the presence or absence of annual herbs. Therefore, carry out subsequent vegetation surveys 2-3 times per year to capture this variability in the first few years after planting and subsequently at longer intervals. If you only have resources to carry out annual vegetation surveys, make sure they are always carried out at the same time of the year.

Weeding in the first few years will of course disturb the vegetation. Therefore, carry out vegetation surveys just before weeding is scheduled.



Planted framework tree species are really just "bait" to facilitate establishment of recruit tree species. The latter are the future forest. To monitor them is to witness the true rebirth of a forest ecosystem.

How should the vegetation be sampled?

Establish permanent circular sampling units (SU's), across the entire study site (with equal numbers of SU's in planted plots, controls and remnant target forest). Mark the centre of each sample unit with a metal or concrete (non-burnable) pole and delineate the perimeter of each SU using a 5 m long piece of string as the radius. Position at least 4 SU's randomly in each 40x40 m (one rai) plot. Species present outside SUs can be recorded as well as 'present in the environs'. Although not contributing to the diversity indices for the SUs described below, they will provide added qualitative evidence of biodiversity recovery.

What data should be collected?

Within each SU, label every tree taller than 1 m. For each labeled tree, record i) the label number, ii) whether it is planted or naturally established, iii) the species name, iv) height, v) RCD (or GBH if large enough), vi) health score (see Part 4, Section 3), vii) crown width and viii) number of coppicing stems. Any tree seedlings or saplings, shorter than 1 m, can be considered as part of the ground flora. For the ground flora survey, record the species names of all species recognized in each SU, including all herbs and vines and all woody trees, shrubs and climbers (shorter than 1 m). Assign an abundance score to each species (e.g. use the Braun-Blanquet scale or Domin scale).

For species identifications, it is easier to work directly with an expert taxonomic botanist in the field, rather than to collect voucher specimens of all species encountered and have them identified later at an herbarium.

How should the data be analysed?

Analyse the data for trees taller than 1 m and the rest of the ground flora separately.

Prepare a spreadsheet with species listed in the first column (all species encountered during the entire survey in all SU's) and SU numbers in the top row. In each cell, enter the number of trees of each species in each SU (or the abundance score). Since the species list for the entire survey will be long and the number of species in each SU will be relatively low, most values entered into the data matrix will be zero. However, the zero values must still be entered to allow calculation of indices of similarity and/or difference. Add data from each subsequent survey to the right of the current data, so that the data can be sorted into chronological order easily by column.

When starting vegetation surveys, work with a professional botanist in the field

After each survey, construct species area curves or calculate species diversity indices to determine to what extent tree planting increases the diversity of naturally establishing trees or the ground flora in general (compared with the non-planted control plots) and to what extent tree planting results in similar levels of diversity as in intact forest.

The following equation can be used to construct smooth species area curves:-

$$s(a) = S - \sum_{i=1}^{S} (1-a)^{n(i)}$$

...where s(a) is the expected number of species in a fraction (a) of the total area surveyed (i.e. a=0-1), S is the total number of species encountered and n(i) is the number of individuals of each species (i.e. i=1 to S). The equation is solved for different values of 'a' and the resulting curve of s(a) vs. 'a' is plotted. This equation assumes random distribution of all species. Clumped distribution results in the curve plotted from raw data rising less steeply than that derived from the equation (Hubbell and Foster, 1983).

Species diversity indices can also be used to assess changes in vegetation diversity over time. Many species diversity indices have been devised, but because they combine two variables (species richness and evenness), it can be difficult to interpret their meaning. Simpson's index of diversity (D) is one of the simplest:

$$D = 1/\sum_{i=1}^{S} (p_i)^2$$

...where p_i is the proportional abundance of the ith species (the number of individuals of the i^{th} species seen, divided by the total number of individuals of all species seen). When all species are represented in the community by an equal number of individuals, the value of D is the same as the value of S (total number of species). For a wider range of diversity indices and a concise and clear discussion of their use, see Ludwig and Reynolds (1988).

Although species-area curves and diversity indices can be useful to show changes in overall diversity, they obscure changes in species composition, which can be determined by simply comparing species lists for planted plots, control plots and intact forest. Which sun-tolerant pioneer species are the first ones to be shaded out by planted trees? Which species typical of intact forest are the first to become established in planted plots? Are they wind dispersed or animal-dispersed? If the latter, which animal species are most likely to have brought their seeds into the planted plots? Which of the planted tree species are most likely to have attracted these important seed-dispersing animals? Which tree seedling species, recorded in the ground flora, eventually grow up to be included in the "trees taller than 1 m" data set?

Answers to these questions do not require complex statistical analaysis and they will help you decide how to improve the species mixtures and plantation design of future field trials to maximise biodiversity recovery rates.