Effects of fragmentation on a keystone tree species in the rainforest of Kalakad-Mundanthurai Tiger Reserve, India.

Project report

Submitted to Rufford

(2006)

M.Soubadra Devy

Ashoka Trust for Research in Ecology and the Environment,
659,5th A Main,Hebbal
Bangalore 560024
India

Team

Dr.M.Soubadra Devy	Scientist and Principal investigator
Dr.T.Ganesh	Scientist
Mr. Ramesh Kumar	Technical assistant
Mr. Anbazhagan	Field assistant

Contents

Acknowledgements

First and foremost we are grateful to Rufford Foundation, UK for showing interest in this work and financially supporting M.S.Devy with an extension of the small grant. We thank Dr.Sukhdev, Chief Wildlife Warden of Tamil Nadu Forest Department for giving us the necessary permission to conduct the study. We are also grateful to the staff of Tamil Nadu Electricity Board for necessary logistic support at Upper Kodayar with out which we would not have been able to accomplish this work. We wish to express our sincere thanks to the Bombay Burma Tea company which has allowed us to work in their estate fragments and the numerous field assistants from Nalmukh who have helped us with the work in the field.

Summary

We encountered 5 mammal species visiting the flowers of *Cullenia exarillata* in the undisturbed forests,8 in disturbed forests and only 2 in fragments. There were more visits during day time in the undisturbed sites compared to more at night time in disturbed sites. Disturbed sites did not attract as much Lion –tailed macaque (LTM) as the undisturbed sites. Fragments did not have any LTMs. Disturbed sites and fragments had high number of visits by Spiny dormouse while the dormouse was not recorded in any undisturbed sites. Seed predation intensity was marginally lower in undisturbed sites than in fragments and disturbed sites. Though fragmentation recorded fewer species it does not appear to affect the fruit production in the keystone species. However in terms of sustaining biodiversity *Cullenia* appears to harbour fewer epiphytes in smaller fragments.

Introduction

One of significant plant-animal interactions in tropical forests that has consequence to conservation and maintenance of biodiversity pertain to keystone tree species and its associated fauna. Many arboreal mammals in tropical forests are frugivores and depend on the keystone species for survival during certain times of the year (Terborgh 1986, Jason *et al* 1981). Removal of these key species is predicted to have a cascading affect on species loss (Cox et al. 1991). Some keystone species also depend on the non-volant mammals for pollination in both old and new world tropics (Momose et. al 1999, Bawa 1990, Kress 1993. Jason *et al* 1981, Devy and Davidar in press). The loss of pollinating non-volant mammals on keystone species survival is however poorly understood. Given the scenario of 'empty forests' almost all over tropics, understanding the consequence of such loss on plant survival is very important for the conservation and long term management of forests.

Western Ghats of India has been identified as a global hotspot of biodiversity (Myers et al. 2000). However, mammal – flower interactions in the evergreen forests are not common in the Western Ghats (Devy and Davidar 2003). *Cullenia exarillata,* an abundant canopy tree in the mid-elevation evergreen forests of Western Ghats, is dependent on a variety of arboreal mammals including endangered primates and bats for its survival (Ganesh and Devy 2000). This tree acts as a hot bed of activity when in flower and functions as a keystone resource for several species of arboreal mammals

including the endangered primate Lion tailed macaque (*Macaca silenus*) (Nayar et al 1999, Ganesh and Davidar 1997, Menon 1993). In many areas the arboreal mammals that visit *Cullenia exarillata* are in low density because of severe hunting and forest degradation and fragmentation but nothing is known on how this affects survival of *Cullenia exarillata*. Seed predation could restrict recruitment of the species especially when there are few fruits in the forest. The seeds of *Cullenia* are eaten by a variety of mammals both in the canopy and in the ground (Ganesh 1996). The loss of *Cullenia exarillata* could substantially reduce biodiversity in the forest as it not only sustains arboreal mammals but other taxa like plants and insects are also dependent on it. The structure and nature of branches, bark and trunk sustains several niches that are not present in other species in the forest.

Much of the forests in Western Ghats are in various levels of disturbance, degradation and fragmentation (Marcot 1992). Therefore, a study on faunal loss on plant survival will help formulate strategies that are pragmatic and substantial to restore the forest areas as viable and functioning ecosystems. First requisite for this is to measure the ability of species to survive in such forests and second is how this ability could be enhanced by correct management and conservation strategies. In the case of *Cullenia exarillata* if fruit production is affected by mammal loss then the best option would be to reintroduce lost fauna where possible. If loss is does not affect the tree and some other species is compensating for the lost mammals, identifying such fauna and understanding how it is benefiting the tree will help in restoring degraded forests where other mammals are absent. This can consequently be used to reintroduce the lost mammals at a future date.

This becomes important in the context of forest land being reclaimed by the local forest department in the south Western Ghats. Much of the area where the present study was carried out is under private ownership that is likely to be handed over to the forest department (Ali 1999). This private land comprises forests that is degraded and cannot sustain a viable population of arboreal mammals. This study can give inputs to the forest department on how these forests can be made viable based on the plant-animal interactions.

Objectives

The overall objective is to determine how human disturbance of forests in terms of animal loss could affect pollination and seed dispersal of tree species. Specifically the focus is on *Cullenia exarillata* an important keystone species and a dominant member of the evergreen forests of southern Western Ghats. The present study aims to answer the following questions.

1. Estimating mammal abundance in continuous forest and in fragments during *Cullenia exarillata* flowering season.
2. Document visitors to flowers of *Cullenia exarillata* in continuous forests and in fragments.
3. Does the reproductive efficacy of *Cullenia exarillata* vary between the fragments and undisturbed sites?
4. How does the seed predation levels in *Cullenia exarillata* vary between fragments and undisturbed sites?
5. What proportion of biodiversity is supported by *Cullenia exarillata* in the forest?

Methods

Study site

The proposed study was conducted in and around Kakachi in the Kalakad-Mundanthurai Tiger Reserve in the southern Western Ghats, India. Kakachi is at 1250 m elevation and receives an annual rainfall of over 3500mm spread across two monsoons the Southwest and the north east monsoon. Dense mid-elevation wet evergreen forests dominated by *Cullenia exarillata* characterize the site. Adjacent to the primary forest, there are selectively felled sites, which have remnant population of *Cullenia exarillata*. This allows for comparison between undisturbed and disturbed sites. This study started in Jan 2005 and is expected to go till end of 2007.

Phenology

Fifteen trees each in 3 fragments surrounded by tea fields and 3 each in undisturbed sites was marked and their phenology in terms of flowering, fruiting, flower and fruit production was monitored on a monthly basis.

Mammal abundance

Relative abundance of arboreal mammals was estimated by transect methods in undisturbed sites. Transects were done during day and night. In fragments the whole area was criss-crossed and mammals or signs present were recorded. Bat activity was possible to recorded only from fallen flowers based on bat bite marks (Ganesh and Devy 2000).

Visitation

Automated photography using thermal sensors were used to document visitors to the flowers of *Cullenia exarillata* (Carthew and Slater 1991). The portable unit was firmly placed on an appropriate branch of the tree facing the flowering branch. A heat pulse from animals visiting the flowering branch is intercepted by the sensor, which triggers the camera to advance the film. Target branches with known number of flowers were observed through these traps during the day and night in both primary and secondary forests. Observations were done on a continuous basis for 5 consecutive days. Five trees each in undisturbed forests and one each in the fragments.

Access to forest canopy

Canopy was accessed by non destructive single rope technique. These were both safe for the researchers and also did not harm the trees nor did it disturb the fauna. Ascending the canopy was also important to estimate flower to fruit ratios and mark flowers for this.

Measure of pollination success

Ten trees in undisturbed forest and fragments were permanently marked. The number of flowers was counted after climbing the tree using binoculars. Fruits were similarly

counted after 4 weeks had elapsed since flowering. Pollination success was measured by fruit/flower ratio (fruit set). This was done on all ten trees in each site.

Measure of Seed predation rates

Ten trees in the fragments and in undisturbed forests were chosen for documenting seed predation levels in the ground. Under each tree 5 seeds were kept and monitored at regular intervals. Removal rates were then calculated for each site.

Epiphytic diversity on *Cullenia*

Ten trees of *Cullenia exarillata* trees were selected randomly in the undisturbed site and 4 fragments. A complete enumeration of species and individuals were carried out. Specimens were collected which were later identified.

Results

Visitors to *Cullenia* flowers in fragments and undisturbed forests

Our earlier study showed that *Cullenia exarillata* attracted *a* total of 2 primates viz Lion tailed macaque (*Macaca silenus*) and Nilgiri langur (*Semnopithecus johnii*) and the Malabar Giant squirrel (R*atufa indica*) to the flowers during day time apart from several species of birds. During night bats *Cynopteres sphinx and C. brachyotis,* Flying squirrel (*Petaurista petaurista)*, the Malabar spiny dormouse(*Platacanthomys lasiurus)* and the brown palm civet (*Paradoxrus jerdonni*) visit the flowers. A total of 6 arboreal mammal species, 1 bat species, 16 bird species, 2 species of butterflies, one social bee sp, possibly several species of smaller insects visited the flowers of *Cullenia exarillata*. In the present study we have encountered 8 mammal species that includes the Dusky stripped squirrel(*Funambulus sublineatus)* and a rat (*Rattus sp*).The list of species is given in the table 1. At the ground level 4 species ate the seeds which also includes the Nilgiri langur and Spiny dormouse.

In fragments only 2 species visited the flowers. These included the Nilgiri langur and the Spiny dormouse. The species excluded were Lion-tailed macaque, Giant Squirrel, Palm

civet and flying squirrels. Disturbed forests recorded the maximum number of species. Fragments attracted all 4 species at the ground level while only 2 in disturbed sites.

Table: Checklist of frugivores recorded by camera traps in different sites in the canopy and in the ground.

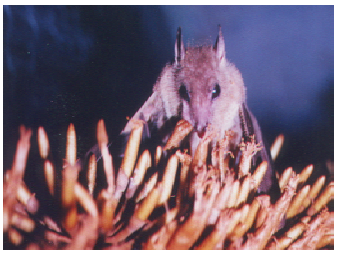
Species	Fragment		Disturbed		Undisturbed	
	Canopy	Ground	Canopy	Ground	Canopy	Ground
Brown palm civet			+		+	
Dusky stripped squirrel			+			
Flying squirrel			+		+	
Giant squirrel			+		+	
Lion tailed Macaque			+		+	
Mouse deer		+				
Nilgiri Langur	+		+	+	+	
Porcupine		+				
Rat		+	+			
Spiny dormouse	+	+	+	+		+?
Total	2	4	8	2	5	1

Note: + species presence. The species list is not complete for the disturbed sites.

Frequency of visitors

Cullenia exarillata flowers during the same time in fragmented forests and in undisturbed sites. The diversity and frequency of visits received by the trees from the flower visitors is shown in Fig 1. In terms of species more diversity is encountered during day than at night.

Plate 1. Visitors of *Cullenia exarillata*



Fulvous Bat

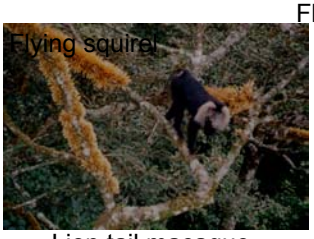
Dormouse

Niligiri langur

Flying Squirel

Giant Squirrel

Brown Palm Civet

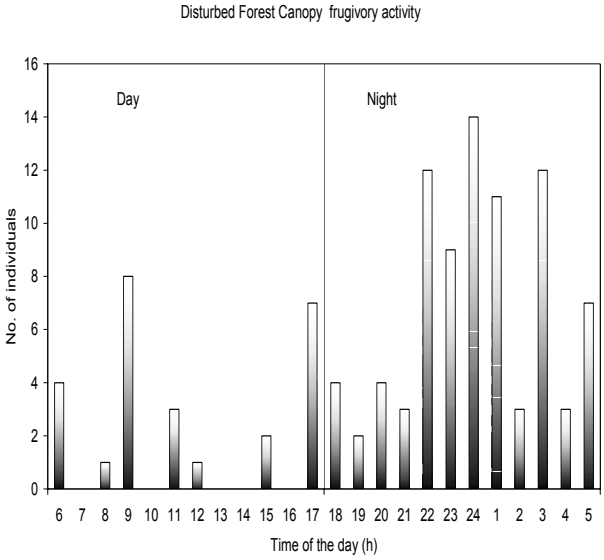


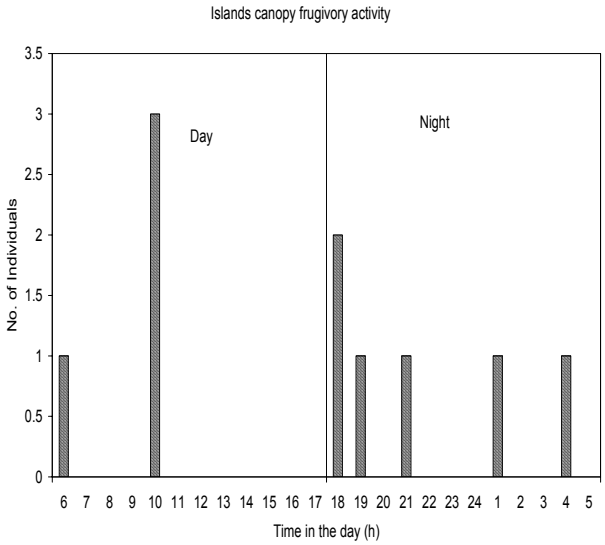
Flying squirel

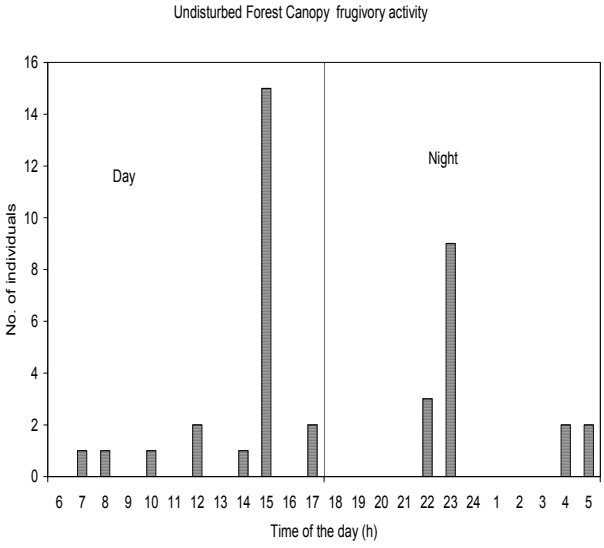
Lion tail macaque

The number of animals visiting the tree during day and night could be recorded using remotely operated camera traps. A continuous monitoring was done for several days in 2005 and the total number of animals visiting the tree during day and night is shown in Fig 1. The frequency of visitors to the flowers is more from diurnal flower visitors than by nocturnal visitors. Between 6.00 am to 6.00 pm the tree received a total of 23 visits over a period of 5 days. During the same period night visits between 6.00 pm to 6.00am was 18. The pattern of visits at a disturbed and undisturbed site shows different patterns. In the undisturbed sites visits happen both at night and during day where as in the disturbed and fragmented sites most visits happen at night.

Fig 1. Flower visitors visiting *Cullenia exarillata* trees in undisturbed, disturbed and fragmented forest sites.



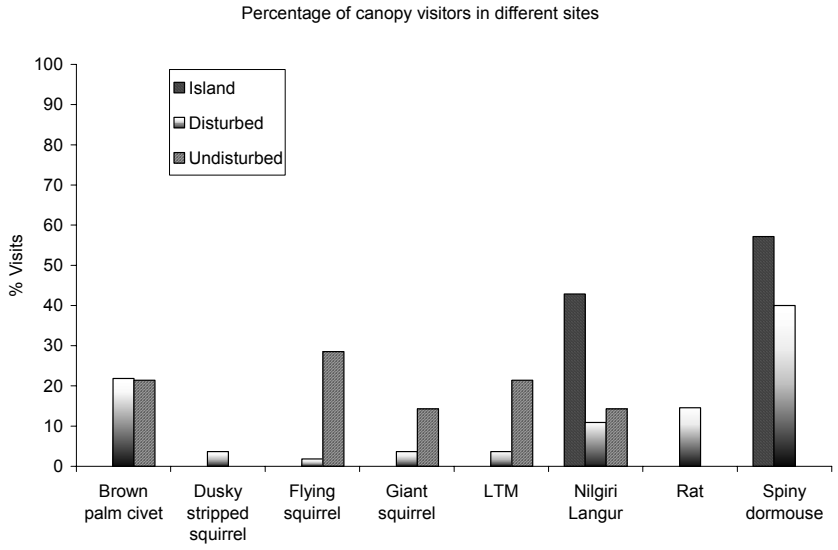




Assemblage of visitors

The assemblage of visitors based on camera trap data using photographic evidence is shown in fig 2. Two distinct patterns can be seen. The trees received very few visits from the Lion tailed macaque, Giant squirrel and Flying squirrel in the disturbed sites compared to the undisturbed. Contrary to this dormouse was the most often seen species in the fragments followed by the brown palm civet and Nilgiri langur (fig.2).

Fig 2 . Flower visitors frequency *Cullenia exarillata* trees in disturbed, fragment and undisturbed sites.

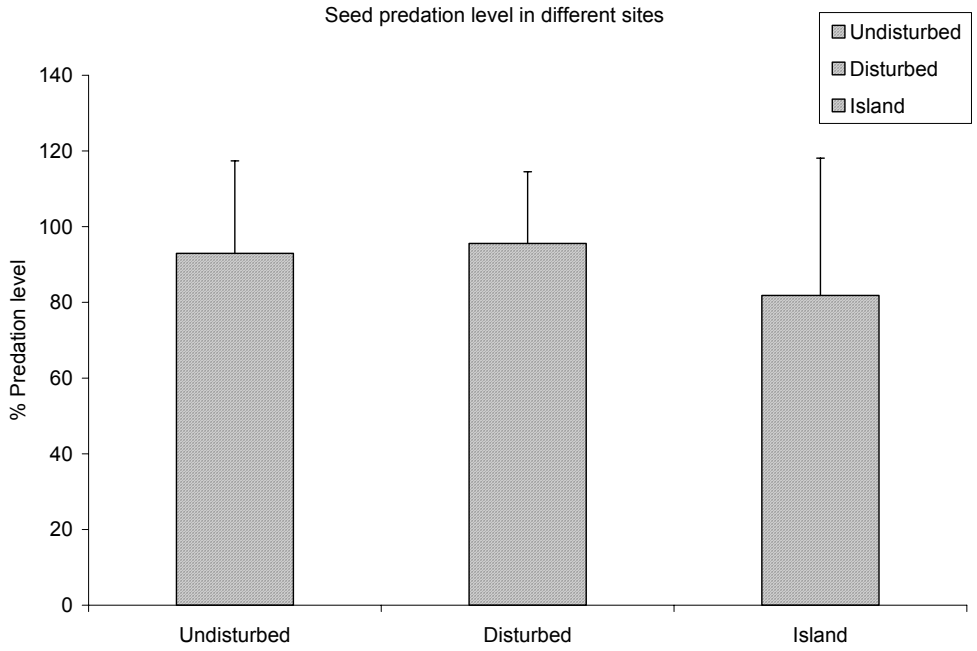


Seed dispersal and seed predation

Cullenia exarillata produces 8-11 large seeds inside each spiny fruits. These seeds are eaten by primates, squirrels in the canopy and by several other species when seeds fall on the ground. We estimated seed predation on the ground by placing 5 seeds per tree in the fragment and contiguous forest. The seed predation rates are compared between fragments and forest. Contiguous forests had marginally lower seed predation than the islands and disturbed forests (fig 3). We also documented seed predators in the different sites using camera traps near the seed. The major seed predators were the Mouse deer and Spiny dormouse. No other species appeared to take the seed from the ground. In exceptional cases even Nilgiri langur descended to eat seeds in some places where they had either lost fear of humans or the under storey was removed as in cardamom plantations. The relative number of each predator recorded is shown in fig 4. Nearly all

seed predation happened at night but in fragments there were few incidence of seed predation during the day as well. These were mainly by Mouse deer.

Fig 3. Post dispersal seed predation in *Cullenia exarillata* at different disturbance levels.



Seed predation at the ground level, fragments recorded visitors such as Mouse deer, rats and porcupines which were not recorded from disturbed forests. Spiny dormouse was most common in disturbed sites which are contrary to what has been seen in the canopy. No sampling could be done in the undisturbed sites.

Fig 4. Relative camera capture rates of seed predators of *Cullenia exarillata* in different sites.

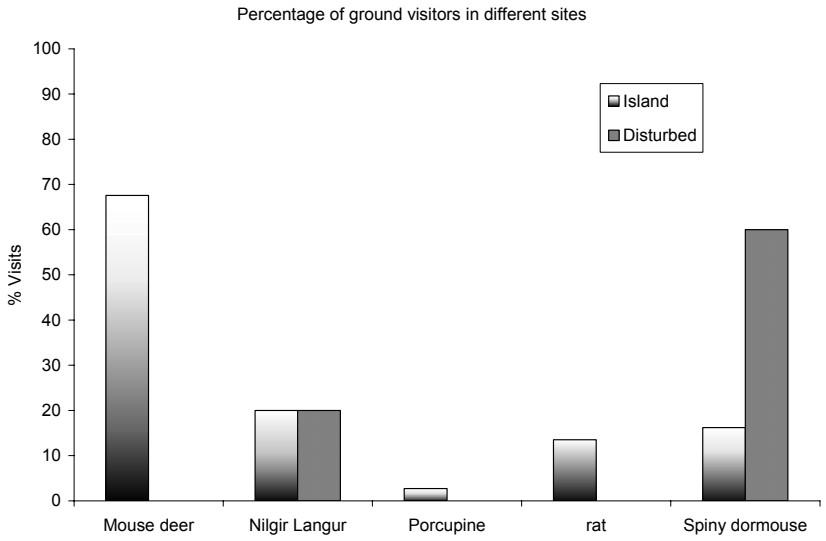
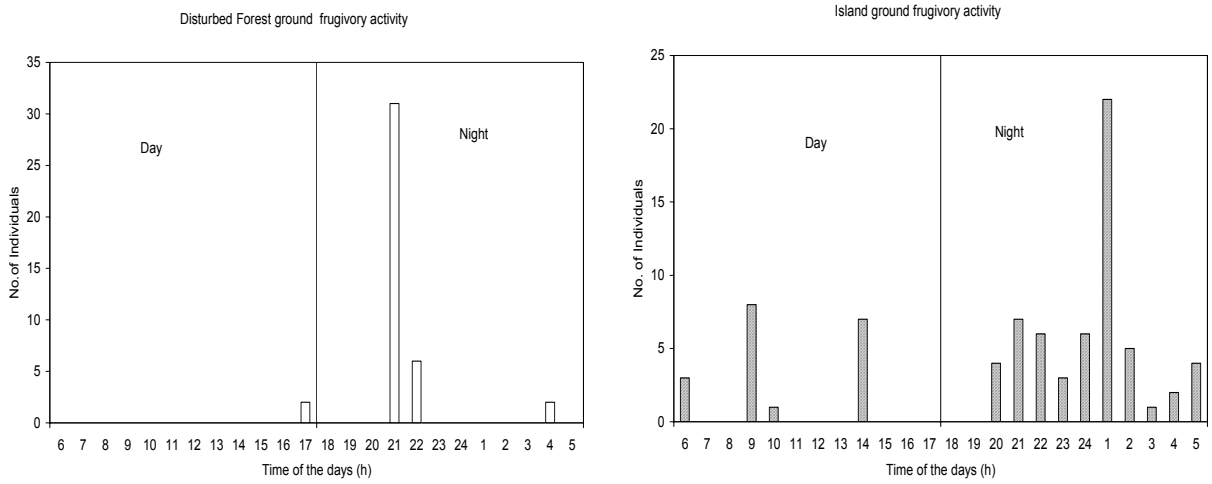


Fig 5. Seed predators intensity in fragmented, disturbed and undisturbed sites.

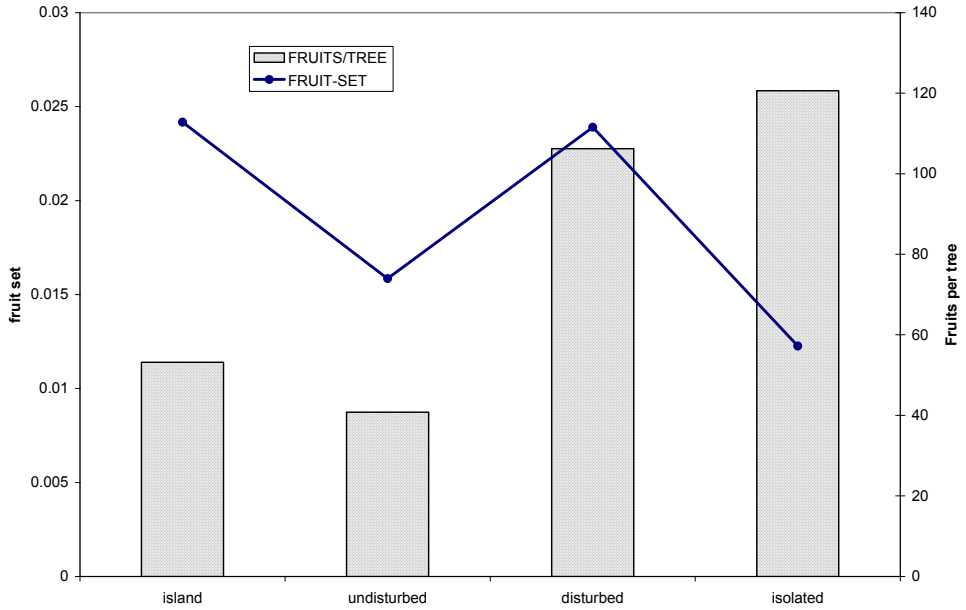


Fruit set and fruits per tree

Open fruit set

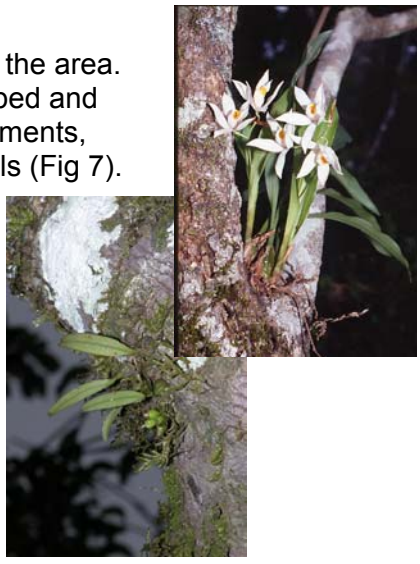
Mean fruit set of trees were not significantly different between fragments and contiguous forests but was significantly higher in disturbed forests and in isolated trees (Fig 6). The flower abundances in the three sites were not statistically significant but overall disturbed sites and isolated trees had more flowers per tree. Fruits per tree also followed the same pattern with disturbed forest and isolated having the maximum fruits.

Fig 6. Mean open fruit set and fruits/tree in *Cullenia exarillata* in fragments, isolated, disturbed and undisturbed sites.



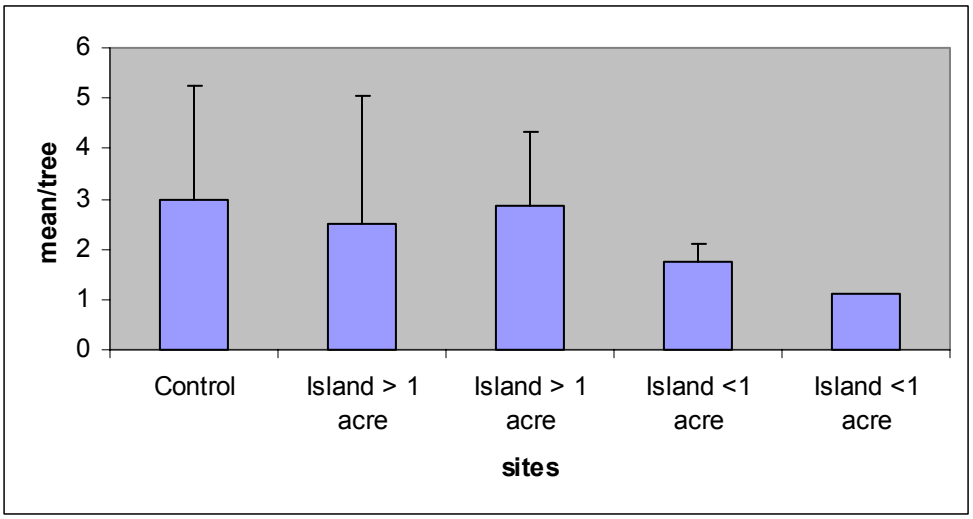
Biodiversity on *Cullenia exarillata* (*Epiphytes*)

Cullenia harboured about 40% of epiphytes species found in the area. Enumeration of epiphytic angiosperms showed that undisturbed and large fragments supported equal number of individuals. Fragments, which were less than an acre, had lower number of individuals (Fig 7). The epiphytic communities were dominated by one species each of the *Eria* and *Peperonia* genus and a couple of *Bulbophyllum* species. Our survey has also shown that the species turnover maybe high over a large spatial scale. More intense sampling might be required to capture the complete spectrum of epiphytic diversity.



Epiphytes on *Cullenia exarillata*

Fig 7. Average number of epiphytic abundance on *Cullenia exarillata*



Discussion

Our previous work in the same site had shown that the flowers of *Cullenia exarillata* requires pollinators for fruit set and how forest disturbance could substantially affect fruit production during certain years but not across all years. In this study we extend the effect to the fragments and see if the tree also suffers in fragments. Surprisingly forest fragments did not show any significant difference from contiguous forests in terms of fruit set, flower abundance and fruit per tree. All these parameters were however lower from disturbed forest and isolated trees. The major similarity between intact forest and fragment is the structure of the forest. To a very large extent the fragment forest is not disturbed except the under storey which is selectively cut at times. In the canopy the forest is very similar and in terms of density they are both the same. The disturbed forests are usually the cardamom plantations which have been logged and under storey cleared. There usually are more gaps in the canopy that probably allows for movement of bats which are responsible for a large amount of pollination and fruit set as mentioned in the earlier report.

In the earlier report we also mentioned the importance of Lion-tailed macaque in pollination and how these are important in undisturbed forest. If we consider fragments as less disturbed at least at the canopy level than the lack of LTMs in these forests does not appear to decrease fruit set. Does this mean the fruits seen in the fragments are all due to bats and those in contiguous forests are also due to bats? Bats may be pollinating flowers in the upper canopy but the lower and sub-canopy might hold maximum flowers in the disturbed sites which are pollinated by non-volant mammals. We need to study this aspect in greater detail during the next season.

Seed predation though not significantly different between sites, shows a marginal increase in disturbed sites. Islands being the most affected. This correlates well with the frequency of mammals visiting the seeds in the fragments. Fragments may be safe place from large predators for seed predators like Mouse deer. Its therefore likely that they show more frequency visits to the bait.

The ability of *Cullenia exarillata* to harbour epiphytes decreases in fragments especially in small fragments. This may be due to the higher exposure of smaller fragments to wind and temperature extremes and also to higher levels of desiccation especially in the canopies. However we have no clue on how other taxa associated with *Cullenia* respond to these changes.

References

Ali,R. 1999. Enclaves in Kalakad-Mundanthurai Tiger Reserve. Final report. Prepared for the Field Director, Project Tiger, KMTR, Funded by FREEP, World Bank

Bawa K.S.1990. Plant-pollinators interactions in tropical rainforests.Annu.Rev. Ecol.Syst. 21:399-422.

Baker H.G.1973. Evolutionary relationships between flowering plants and animals in America and Africa. IN: B.J. Meggers, E.S. Ayensu and W.D.Duckworth (Eds).Tropical forest ecosystems in Africa and Southe America: A comparative review, Smithsonian Institution Press, Washington D.C. pp 145-160.

Carthew S.M and E. Slater 1991. Monitoring animal activity with automated photography. J.Wildl.Manag. 55:689-92.

Cox P.A , T. Elmqvist and W.E. Rainey 1991. Flying foxes as strong interactors in south Pacific Island Ecosystems: A conservation hypothesis. Conser. Biol 5(4):448-454.

Devy.M.S. 1988. Bee pollination of the canopy tree species in a wet forest of southern Western Ghats, India, PhD dissertation, Madras University, Chennai, India.

Devy,M.S and P.Davidar. Pollination systems of trees in a mid-elevation wet forest of Western Ghtas, India: More specialised or generalised? (Submitted to American Journal of Botany).

Ganesh, T and P.Davidar 1997. Flowering phenology and flower predation of *Cullenia exarillata* (Bombacaceae) by arboreal vertebrates in Western Ghats, India. J. Trop.Ecol 13:459-468.

Ganesan R and P. Davidar (in press). Effect of logging on the structure and regeneration of important fruit trees in a wet evergreen of Southern Western Ghats, India. J.Trop. Forest.Sc.

Ganesh,T and M.S.Devy. 2000. Flower use by arboreal mammals and its consequence in the pollination of a rainforest tree in the south Western Ghats, India. *Selbyana,* (in press)

Howe,H.F. 1984. Constraints in the evolution of mutualism. Am.Nat. 123:764-777

Janson C.H , J.Terborgh, L.H.Emmons 1981. Non-flying mammals as pollinating agents in the Amazonian forests. Biotropica 13(suppl):1-6.

Kress, W.J. 1993. Coevolution of plants and animals : Pollination of flowers by primates in Madagascar. Current science 65(3): 253-257.

Kress,W.J and J.H.Beach 1994. Flowering plant reproductive system. In ed L.A.McDade, K.S.Bawa, H.A.Hespenheide and G.S.Hartshorn. La Selva- Ecology and Natural history of a Neotropical rainforest.Univ of Chicago press, Chicago pp 486.

Marcot,B.G. 1992. Conservation of Indian forests. Conservation Biology 6:12-16

Menon S.A. 1993. Ecology and conservation of the endangered Lion tailed Macaque (Macaca silenus) in the landscape mosaic of Western Ghats. Doctoral dissertation . Ohio State University.

Menon, S. and Poirier, F.E.: Lion-tailed macaques (*Macaca silenus*) in a disturbed forest fragment: Activity patterns and time budget. Int. J. Primatol. (1996) 17: 967-985.

Momose,K.,Yumoto,T.,Nagamitsu.,M.Kato,H.Nagamasu,S.Sakai,R.D.Harrison,.T.Itioka, A.A.Hamid and T.inoue. 1998. Pollination biology in low land dipterocarp forest in Sarawak Malaysia. I. Characteristics of plant –pollinator community in a low land dipterocarp forest. Am J.Bot. 85:1477-1501.

Myers,N., R A. Mittermeier, C.G. Mittermeier, A.B.Gustavo,D. Fonseca & J. Kent . 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853 – 858.

Nayar,T.S, M.P.Nayar and M.Balakrishnan. 1999. Species preferences of two endangered primates in the tropical rain forests of Silent Valley. In ed. Manoharan,T.M.,S.D.Biju, T.S.Nayar,P.S.Easa. Silent Valley-Whispers of reason. Kerala forest department and Kerala Forest Research Institute. Pp 456.

Petterson,M.W. 1991. Flower herbivory and seed predation in *Silene vulgaris* (Caryoptaceae): effects of pollination and phenology. Holartic ecology 14:45-50.

Primack R.B 1990. Regeneration-commentary. *In* Reproductive ecology of tropical forest plants (eds) K.S. Bawa and M.Hadeley. UNESCO and the Parthenon publishing group, Paris.

Roubik D.W, N.N Holbrook, and Patra G.V.1985. Roles of nectar robbers in the reproduction of the tropical treelet (*Quassia amara*). Oecologia 66:161-167.

Terborgh J. 1986. Keystone plant resources in the tropical forests .Pages 330-344.In M.E. Soule (ed). Conservation Biology: science of scarcity and diversity, Sinnauer Sunderland, MA.

Umapathy, G.and A.Kumar,2000. Impacts of the habitat fragmentation on time budget and feeding ecology of lion-tailed macaque *(Macaca silenus*) in rain forest fragments of Anamalai hills, south India. Primate report 58:67-82