

DEAD WOOD, WILDLIFE AND PROTECTED AREA MANAGEMENT

**A STUDY ON THE EXTENT OF USE OF DEAD WOOD BY WILDLIFE IN
PERIYAR TIGER RESERVE, KERALA, INDIA**

Dissertation Submitted to
Saurashtra University, Rajkot

By
SUSAANT

Under the supervision of
DR. S.A. HUSSAIN

In partial fulfillment of
Master's Degree in Wildlife Science

JUNE 2003



**भारतीय वन्यजीव संस्थान
Wildlife Institute of India**

WII L&DC
Acc.no. : WF6401



WF6401

WILDLIFE
INSTITUTE
OF INDIA



भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that Shri SUSAANT has carried out original research titled "DEAD WOOD, WILDLIFE AND PROTECTED AREA MANAGEMENT: A STUDY ON THE EXTENT OF USE OF DEAD WOOD BY WILDLIFE IN PERIYAR TIGER RESERVE, KERALA, INDIA" for the partial fulfillment of the Master of Science (Wildlife Science) Degree from the Wildlife Institute of India affiliated to the Saurashtra University, Rajkot, India. These investigations were carried out under my supervision from November 2002 to June 2003. I also certify that this research has not been submitted for any other degree to any University.

Date: 28th June 2003

Place: Dehradun

Dr. S.A. Hussain
Reader in Wildlife Science

LIST OF CONTENTS

ACKNOWLEDGEMENT	i
SUMMARY	iii
LIST OF TABLES	vii
LIST OF FIGURES	ix
1.0 INTRODUCTION	1
1.1 Ecological significance of decaying wood	2
1.1.1 Nutrient cycling and soil fertility	2
1.1.2 Moisture retention	2
1.1.3 Mycorrhizal associations	3
1.1.4 Surface erosion	3
1.1.5 Stand regeneration and ecosystem succession	3
1.1.6 Streams and riparian forests	4
1.2 Dead wood and down woody material	4
1.2.1 Habitat Use by Wildlife	4
1.3 Snags	5
1.3.1 Habitat use by Wildlife	6
1.4 Key ecological functions of wildlife species associated with decaying wood	7
1.5 Management considerations	8
1.5.1 Size and state of decay	8
1.5.2 Species, location and quantity of snags	9
1.6 Indian context	9
1.7 Review of literature	11
1.8 Objectives	14
2. STUDY AREA	15
2.1 Geographical location	15
2.2 History and legal status of the Reserve	15

2.3	Topography	17
2.4	Climate	18
2.5	Vegetation	18
2.5.1	West coast tropical evergreen forests	19
2.5.2	West coast semi-evergreen forests	19
2.5.3	Southern moist mixed deciduous forests	19
2.5.4	Southern hill-top evergreen forests	20
2.5.5	Southern montane wet temperate forests	20
2.5.6	South Indian subtropical hill savannahs	20
2.5.7	Southern montane wet grasslands	21
2.6	Floral Diversity	22
2.7	Faunal Diversity	23
2.8	Why Periyar Tiger Reserve	24
2.9	Intensive study sites	25
3.0	METHODS	29
3.1	Selection of habitat types	29
3.2	Sampling for dead wood, vegetation and disturbance in forests	29
3.2.1	Dead wood density estimation	30
3.2.2	Estimation of tree density	31
3.2.3	Sampling for quantification of disturbance	31
3.3	Estimating dead wood availability across seasons in the lake habitat	32
3.4	Collection of data on resource use and the users	32
3.4.1	General methods used across dead wood types	32
3.4.2	Specific methods used for cavities	34
3.4.3	Specific methods used for fallen logs	35
3.4.4	Specific methods used for snags and stumps	35
3.4.5	Usage of stakes by large cormorant for nesting	37
3.4.6	Usage of stakes and stumps by turtles	37
3.5	Analysis of data	37
3.5.1	Data entry and exploratory data analysis	37

3.5.2	Statistical analysis	38
3.6	Packages and books used	40
4.0	RESULTS	41
4.1	Dead wood, tree density and disturbance regimes	41
4.1.1	Densities of dead wood in the two forest types	41
4.1.2	Disturbance regimes observed in forests	43
4.1.3	Densities of dead wood in disturbed and undisturbed forests	43
4.1.4	Correlation between tree density and dead wood density	46
4.2	Dead wood availability during different seasons in the lake habitat	51
4.3	Usage of dead wood	51
4.3.1	Dead wood users	51
4.3.2	Use of cavities by different users, especially birds and mammals	53
4.3.3	Use of fallen logs by different mammals, birds, reptiles and invertebrates	56
4.3.4	Use of snags by different mammals, birds, reptiles and invertebrates	57
4.3.5	Use of stumps by different mammals, birds, reptiles and invertebrates	57
4.3.6	Turtle and dead wood in the lake habitat	60
4.3.7	Large cormorant nests and stakes	60
5.0	DISCUSSION	62
5.1	Dead wood density	62
5.2	Factors influencing dead wood density	63
5.2.1	Forest type	63
5.2.2	Extent of disturbance in forests	67
5.2.3	Water level in the lake	68
5.3	Usage of dead wood by different groups of users	68
5.3.1	Mammals	69
5.3.2	Birds	70
5.3.3	Reptiles	71

5.3.4	Amphibians and invertebrates with other users	72
5.4	Other important results	73
5.5	Conservation implications	73
6.0	REFERENCES	75
7.0	APPENDIX I	86
8.0	APPENDIX II	87
9.0	APPENDIX III	88
10.0	APPENDIX IV	91

ACKNOWLEDGEMENT

This work was possible because of the help and support extended to me by many people including the faculty members, researchers and my colleagues in the Institute and Officers and staff of the Periyar Tiger Reserve in the field.

In the Institute I would like to thank my supervisor Dr. S. A. Hussain for suggesting me this topic and for his support and guidance throughout this study.

I am thankful to all the faculty members of the WII for the care and the support, which they have extended to me during my study. I am especially grateful to Dr. G.S. Rawat and Dr. B.S. Adhikari, who ran our M.Sc. course smoothly and helped us in all possible ways. I would like to thank Shri Qamar Qureshi for giving me insight into quantitative ecology during the regular theory classes and for helping me in statistical analysis of my data.

Among the researchers I would first like to thank Miss Poonam Semwal, Miss Kalpana Ambastha, Miss Soumya Prasad, Miss Smitha Badrinarayanan, Mr. Asghar Nawab and Mr. Sabyasachi Dasgupta not in any particular order for the last minute help they provided for the successful completion of this thesis. I am also indebted all the researchers whom I have met here in WII, for the kind of information I shared and acquired from them about various aspects of life. I can't find words to thank my classmates, who have given both sorrows and happiness, but mainly because they tried to understand me and helped me enjoy life here in WII campus. Other people of WII whom I would like to thank are Mr. Khadak Singh, Shri Dubeyji, and everybody belonging to the WII family, but especially Shambhu. I would like to thank Ram and Roy, especially for helping me to keep up my faith in myself, when at times it seemed like faith had evaporated.

My dissertation won't be complete if I do not express my gratitude to Mr. Anoop K.R. for all the things (possible for him) he did both here in WII and there in field to make my dissertation a smooth affair. I cannot help myself but to express my

deep felt gratitude to Mr. Babu and his family, who had helped me here in Dehradun to remain connected to our common culture of a far away land. I am not going to thank many people whom I met during my fieldwork, because almost all of them showered on me such huge amount of love that I feel its beyond my capacity to thank them for that. But I will surely mention about few wonderful people I met in field. They are Mr. Pramod. G. Hrishnan (currently holding the post of EDO, Periyar Tiger Reserve - PTR), Mr. S. Shivdas (AFD, PTR), Mr. V.K. Uniyal (who need no introduction) and Dr. Veeramani (ecologist and the first person to help me in Kumily town, when I reached that place at midnight, way back in July 2002), all of them I would be never able to forget even in my next birth. I thank here the current Deputy Director (PTR – East Division) for giving me support during my final phase of the fieldwork. This acknowledgment would be incomplete if I don't express my deepest possible love to the tribals there in Mannakudy colony, Kumily, some of whom were my field assistants, who made my living in PTR possible and thus, made this work happen only because of their presence. To conclude, I don't think I will be able to express my sincere gratitude and love in this acknowledgment for Dr. S.K. Dutta, Dr. Pranjaleendu Ray (whom I used to call Ray Sir, but I stopped that as many people heard it wrongly as Razor/Racer) and Pratyush the person who introduced me to this field and whom I hold responsible for all the good things that happened to me after coming to this place.

SUMMARY

Dying, dead, and down trees form an integral component of forest ecosystems. They not only serve as critical microhabitats for many species, but also they are large reservoirs of organic matter and hence play a pivotal role in nutrient cycling. There are whole groups of organisms, which use and need dead wood for their survival in any forest ecosystem, ranging from conspicuous, well-known creatures like flying squirrels and owls to large numbers of invertebrates, fungi, lichens, mosses, and vascular plants. And not only these, there are microorganisms that exploit the pool of organic matter and nutrients deposited in the woody debris on the forest floor. Thus it becomes crucial to examine and study the wildlife use aspect of dead wood.

In recent years, the subject of 'decaying wood' has become a major conservation issue in managed forest ecosystems. This holds true for the Indian scenario as well, where disappearing forests and their far reaching consequences are a major focus of concern. The situation worsens in areas where extraction of different forms of dead wood from the existing forested areas by local communities living in the vicinity goes unabated. Critical ecosystem functions of dead wood, coupled with incomplete knowledge for management, make the topic of decaying wood a priority for future research and adaptive management. Unfortunately, there is scanty work done in India on this issue. This short-term study was conducted in the Periyar Tiger Reserve, Kerala, from December 2002 to April 2003. The study focused primarily on following objectives:

- 1) To quantify the abundance of different types of dead wood in different forest/habitat types.
- 2) To relate dead wood abundance to live tree abundance.
- 3) To quantify the extent of use of dead wood by different vertebrate taxa particularly by reptiles, birds and mammals.

An initial period of 15 days was spent in field for reconnaissance during which two different types of forests, namely Semi evergreen forest and moist deciduous forest were identified. Six areas were chosen in the forests around Edappalayam and Mullakudy such that each area had adjacent patches of semi evergreen forest and moist deciduous forest. The rationale behind this was that the disturbance levels in both the forest types within each of the areas would be nearly equal. Three areas were categorized as disturbed and the rest three as undisturbed based on movement of people through these areas.

After few trials 30 x 30 m plots were used in conjunction with short transects across the width of each forest patch to sample for different dead wood densities. In total 54 ha area was sampled in Semi Evergreen and Moist Deciduous Forests which is ca. 0.55 percent of the total range area. Tree densities were also estimated in the forest patches to relate with dead wood abundance. In the lake habitat eight stretches of 1 km each, with a gap of 0.5 km between successive stretches, were chosen for counting number of dead wood in water as well as shores in the high and low water level seasons.

In each forest patch and Lake Habitat all type of dead wood were randomly sampled and looked for animal signs and usage. Simultaneously different dead wood measurements were recorded, like height, girth, and stage. Disturbance surrounding the sampled dead wood was also recorded in terms of percentage of trampling in the forest patches. Data on turtle's usage of dead wood in lake habitat was sampled in the same stretch of lake for both the high and low water level seasons. All the stakes within the intensive study area with large cormorant nest were sampled to get the data on girth, height, numbers of branches and the nests present.

These data sets were statistically analysed and the following important results were obtained:

- (a) The over all density of different types of dead wood in the Thekkady range of Periyar Tiger Reserve was: Fallen logs = 109/ha. (0.354), Snags = 17.5/ha. (0.056), Stumps = 15/ha.

(0.048), Cavities = 9.5/ha. (0.030), and Dead branches = 5/ha. (0.016). In both the forest types fallen log (132.48 logs/ha.) is the most common form of dead wood encountered, followed by stumps (17.07 stumps/ha.) in SEF and snags (18.85 snags/ha.) in MDF. The overall tree density was 308 trees/ha, it was 376.60 ± 0.2516 trees/ha in Semi Evergreen Forests and 239.32 ± 0.2881 trees/ha in Moist Deciduous Forests.

(b) For all dead wood types, except dead branches, the density across different forest types were significantly different at 0.05 α . More logs were estimated in semi evergreen forest. Fallen log and snag density varied significantly across disturbance categories for both the forest types ($p = 0.0001$). Correlation between dead wood and tree density was highly significant for logs in both the forest types, and stumps in semi evergreen forests.

(c) Except for 'snags in water' dead wood counts in the lake habitat varied significantly for high and low water level seasons. And only 'logs in water' was more in high water level season. Turtles were found to use dead wood for basking more in low water level season. The number of large cormorant nests and number of branches on stakes were highly correlated.

(d) Many dead wood users were identified in Periyar Tiger Reserve and they were put into the most appropriate user categories based on field observations and their ecology. Of the 12 species of mammals found using dead wood, 7 were found using logs, 8 using snags, 5 using stumps and 4 using cavities. Around 56 species of birds found in Periyar Tiger Reserve were observed to be using dead wood for various purposes. Only 8 were found using logs, while 49, 23, and 18 were found using snags, stumps and cavities respectively.

- (e) Mammals were using cavities more in semi evergreen forests, that too mainly by bats, which use natural hollows more than excavated cavities. Similarly, birds were excavated cavities more than the natural hollows. Birds were found to use different girth classes of snags differentially across habitat types. Higher girth class snags were used more in semi evergreen forest than in moist deciduous forest, where medium girth class snags were being used.
- (f) Disturbance plays a major role in dead wood ecology and may affect dead wood users adversely. More studies needs to be done on this topic for better management of this one of the most neglected resource of forest as well as aquatic ecosystem, at least in the Indian context as the pressure on this resource is increasing due to human population growth.

Dead wood though being an important natural resource, highly valuable for the ecosystem, whether terrestrial or aquatic foresters and managers ignore its importance and allow this valuable resource to be harvested indiscriminately from the forest ecosystem for various reasons. Indiscriminate use of dead wood by humans causes severe harm to native flora and fauna, which need dead wood for their survival.

In India, the problem of clear felling in Protected Areas (PA) is virtually absent, thanks to the strict Wildlife Protection Act (1972). Nevertheless, the problem of extraction of dead wood by villagers in and around PAs for sustenance is rampant and is putting tremendous pressure on the PA managers to look for alternatives. Unfortunately it becomes difficult for PA managers in India to prove the importance of dead wood in forest ecosystems to any decision making body, because of the lack of study on dead wood and its users in forests of India. This study will hopefully set a benchmark that can be referred to by forest managers and ecologists alike for proving the importance of dead wood in the Indian context. This will most probably lead to the increased awareness about this neglected resource among the ecologists.

LIST OF TABLES

- | | |
|----------|---|
| Table 1 | Vegetation composition of Moist Deciduous Forest in Thekkady range, Periyar Tiger Reserve |
| Table 2 | Vegetation composition of Semi Evergreen Forest in Thekkady range, Periyar Tiger Reserve |
| Table 3 | Areas sampled in different sections of Thekkady range, Periyar Tiger Reserve |
| Table 4 | Description of the different stages of logs, snags and stumps. |
| Table 5 | Dead wood user categories |
| Table 6 | Density of dead wood in SEF and MDF in Periyar Tiger Reserve. |
| Table 7 | Density of dead wood in disturbed and undisturbed SEF in Periyar Tiger Reserve |
| Table 8 | Density of dead wood in disturbed and undisturbed MDF in Periyar Tiger Reserve |
| Table 9 | T statistics and p values for Dead wood density in SEF and MDF in Periyar Tiger Reserve |
| Table 10 | Overall-Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve. |
| Table 11 | In SEF-Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve |
| Table 12 | In MDF-Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve |
| Table 13 | T statistics and p values for Dead wood density in disturbed and undisturbed SEF in Periyar Tiger Reserve |

- Table 14 T statistics and p values for Dead wood density in disturbed and undisturbed MDF in Periyar Tiger Reserve
- Table 15 Wilcoxon matched paired test's significance values for dead wood numbers in summer and winter, in the lake habitat in Periyar Tiger Reserve.
- Table 16 Dead wood users and the user categories they were placed in
- Table 17 Dead wood types and the number of users in the Thekkady range, Periyar Tiger Reserve.
- Table 18 Use of 2 different types of cavities by mammals and birds across habitat types in Periyar Tiger Reserve.
- Table 19 Use of different log stages, girth and length classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve.
- Table 20 Use of different snag stages, girth and height classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve.
- Table 21 Use of different stump stages, girth and height classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve.
- Table 22 A comparison between fallen log densities of different forest types of temperate Oregon and Washington, USA and tropical Periyar Tiger Reserve, India

LIST OF FIGURES

- Figure 1. Location map of Periyar Tiger Reserve
- Figure 2. Locations of Intensive study sites in Periyar Tiger Reserve
- Figure 3. Linear correlations of log and tree densities
- Figure 4. Linear correlations of stump and tree densities
- Figure 5. Use of cavities by mammals and birds in various habitat types
- Figure 6. A comparison of the numbers of natural tree hollows and excavated cavities sampled for usage data in disturbed and undisturbed areas, and also in SEF and MDF

INTRODUCTION

"Nature doesn't waste anything". This is particularly true in natural ecosystems, where nothing goes waste. Dead woods are one such group of resources that are not wasted in a forest, even though, for traditional forest managers they may be of little use. Accumulations of decaying wood provide wildlife habitat and influence basic ecosystem processes such as soil development and productivity, nutrient mobilization and mineralisation and nitrogen fixation (Cornaby and Waide 1973). Decaying wood has a pivotal role in both estuarine and coastal marine ecosystems, supporting complex trophic webs from benthos to higher vertebrates (Gonor et al. 1988). Dead wood in a forest occurs in a variety of forms. Anything from dying trees to dead snags to woody debris is considered dead wood for all practical purposes. Most important form of dead wood from wildlife point of view are dead standing trees termed as 'snags', dying trees with soft rotting wood inside, 'stakes' (snags in water), dead stumps and fallen logs slowly decaying on the forest floor (Thomas 1979, Hunter 1990).

There are whole groups of organisms, which need dead wood for their survival in any forested ecosystem, ranging from conspicuous, well-known creatures like flying squirrels (Bendel and Gates 1987) and owls (Carey and Wilson 1997) to large numbers of invertebrates, fungi (Bennett 1997), lichens, mosses, vascular plants. And there are microorganisms that exploit the pool of organic matter and nutrients deposited in the woody debris on the forest floor. An estimate suggests that nearly a thousand species in Britain rely on dead and dying wood for food or habitat (Elton 1966).

Dead wood is an integral part of natural forests but in managed forests deadwood volumes are much reduced by harvesting and sanitation fellings (Green and Peterken 1997). Decaying wood has become a major conservation issue in managed forest ecosystems (Apps and Price 1986). But this applies in Indian context as well, where disappearing forests are a major cause of worry, and even more worrying situation is the extraction of different forms of dead wood from the existing forested areas by the local communities living in the vicinity. Critical ecosystem functions of wood, coupled with incomplete knowledge for management, make the topic of decaying wood a priority for future research and adaptive management.

1.1 Ecological significance of decaying wood

1.1.1 Nutrient cycling and soil fertility

Decaying wood has been described as a short-term sink, but a long-term source of nutrients in forest ecosystems (Harmon et al. 1986). The slow rate of nutrient release from decomposing wood may serve to synchronize nutrient release with nutritional demands in forests, and also to minimize nutrient losses via leaching to the ground water (Allen et al. 1997).

1.1.2 Moisture retention

Water stored in large decomposing wood accelerates microbial decay rates by stabilizing temperature and preventing desiccation during the summer (Amaranthus et al. 1989). Moist conditions within the wood favour decay by attracting burrowing and tunneling mammals and invertebrates that

improve aeration of wood, and by providing colonization substrate and moisture for mycorrhizae and other fungi (Cromack et al. 1979).

1.1.3 Mycorrhizal associations

Symbiotic associations formed with the growing seedlings and the decaying woody debris help in nitrogen fixation in the ecosystem. Mycorrhizal associations are a source of nutrients to promote wood decay (Rose et al. 2001).

1.1.4 Surface erosion

Large wood helps to anchor snow packs, limit the extent of snow avalanches, and may even stabilize debris flows depending on the depth of the unstable areas, particularly in higher altitudes and latitudes (Franklin and Spies 1991). Fallen logs oriented along the contours of a slope may also check soil erosion by slowing surface runoff (Thomas et al. 1979).

1.1.5 Stand regeneration and ecosystem succession

Decomposing wood serves as superior seedbed for some plants because of accumulated nutrients and water, accelerated soil development, reduce erosion and lower competition from mosses and herbs (Harmon and Franklin 1989). Elevated levels of nitrogen fixation in *Ceanothus velutinus* and red alder have been reported under old fallen logs (Binkley et al. 1993).

1.1.6 Streams and riparian forests

Small wood contributes to nutrient dynamics within streams and provides substrates to support biological activity by microorganisms, as well as invertebrates and other aquatic organisms (Gregory et al. 1991).

1.2 Dead wood and down woody material

Trees fall in forests due to various reasons; like cyclones or high winds and tornadoes (Hunter 1990), disease and pest attacks (Manson and Wickman 1991), toppling by elephants, felling by beavers, falling of decayed snags (natural death), heavy rain and landslides in mountainous regions and remain on the forest floor as fallen logs for varied periods of time.

1.2.1 Habitat Use by Wildlife

As a fallen log decomposes, the plant community surrounding it changes a gradually changing myriad of wildlife habitats (Graham 1925). The character, density, and distribution of logging debris may significantly affect both the number and species of vertebrate animals that use a site (Dimmock 1974). Vertebrates use fallen logs and in a variety of ways, the most obvious of which are for feeding and reproduction. A variety of animals use fallen logs as feeding sites (Deyrup 1975). Fallen log height, fallen log concentration, and fallen log class (residence time) are of variable significance to different vertebrate groups (Graham 1925). The differential use of different stages of fallen log are given as follows by Thomas et al. (1979):

Class 1- Bark and texture intact, elevated at points - Supports nesting grouses; looking posts for squirrels.

Class 2- Bark intact, texture intact to partly soft, sagging slightly - Cover for smaller animals as snakes, shrews, voles; feeding and nesting sites of wrens, thrush, mice.

Class 3- Bark in traces, texture in hard, large pieces, sagging near ground - Moist habitat of frogs, feeding sites for skinks and shrews, nesting porcupines.

Class 4- Bark absent, texture soft, small, blocky pieces; on ground - Burrows of mice, shrew, weasels and other small mammals, which are even used by reptiles and amphibians as reproduction sites.

Class 5- Bark absent, texture soft and powdery, on ground - Increased small animal activity, feeding and storing sites of squirrels, shrews, voles; reproduction of reptiles; dusting sites for grouse and other birds.

1.3 Snags

Standing trees die and form snags, because of the following reasons: dieback nature of some trees like Sal (*Shorea robusta*), natural death, pest and disease attacks, water logging due to creation of artificial lakes (like in the case of Mullaperiyar Dam), drought (Khan et al. 1994), debarking by animals like Sambar (*Cervus unicolor*) (Khan et al. 1994), excavation of cavities by primary excavators, strangulation by other trees, parasitic vine attacks.

In forestry parlance, a snag is a standing dead tree from which the leaves and most of the limbs have fallen. Any dead tree above 6.1 metres (20 feet) is called snag. If shorter than that, it is called stub. But for the purpose of wildlife values a snag is defined as any dead or partly dead tree at least 10.2 centimetres (4 inch) in diameter at breast height (dbh) and at least 1.8 metres

(6 feet) tall. This definition is based on the minimum diameter and height of dead trees used by birds for nesting (Thomas et al. 1979).

During stress such as drought or injury, trees release volatile compounds, which attract bark-boring beetles, and accelerate decay process (Dunn et al. 1986). This may lead to hollows in the trees. Such trees are usually deciduous species and sometimes called 'den trees' (McComb et al. 1986). Woodpeckers also create cavities on dying trees. However, fungi in many cases (Conner et al. 1976, Conner and Locke 1982) ease woodpeckers' work.

1.3.1 Habitat use by Wildlife

The species inhabiting snags can be divided into two categories those that excavate their own cavities and those that occupy existing cavities (USDA Forest Service). Conner (1978) suggested that to classify a tree as a suitable nest site for cavity excavators there should be some sign of heart rot at the height and diameter required by the primary excavators.

A snag undergoes a series of changes from the time the tree dies until final collapse (Keen 1955). Nine different stages have been identified from death of the tree to final decay. Each stage in the decay process has particular value to certain wildlife species (Thomas 1979). For example, stage 4 are used by bats to roost under loose bark, Stage 6 are heavily used by excavators, Stage 7 by birds excavating in soft wood and stages 8 and 9 as feeding sites for insectivorous birds and mammals.

Snag use by different groups of animals

<i>Form of life</i>	<i>Uses of snags</i>	<i>Examples</i>
Fungi, mosses and lichens	Decayed wood serves as a growth substrate	Fungi, mosses and lichens
Invertebrates	Space under bark serve as cover and as places for feeding	Scorpions, Moth, Beetle, Ant
Birds	Cavities are used for nesting or roosting. Snags are used as perches and to support nests	Woodpeckers
Mammals	Cavities serve as dens or as resting or escape cover. Areas under loose bark are used for roosting	Bat, Flying squirrels, Squirrels

Adapted from Thomas et al. (1979)

1.4 Key ecological functions of wildlife species associated with decaying wood

Associated wildlife species play diverse ecological roles in their ecosystems, which in turn can influence other species. Rose et al. (2001) have described a functional web for 96 vertebrate wildlife species associated with dead wood summarizing their ecological roles shows 40% of snag-associated species were primary consumers, 95% were secondary consumers, and 8% were carrion feeders. The primary consumers include spermivores or seed eaters (63%), frugivores (50%), sap feeders (18%). Various symbiotic relations can be described for the 96 snag-associated

species. 16 species were primary cavity excavators, 35 secondary excavators, eight primary burrow excavators, and 11 secondary excavators.

Snag associated species also contribute to dispersal of other organisms including seeds and fruits. 6 snag-associated species were found to improve soil structure and aeration through digging, two species fragmented standing trees and two down wood (Rose et al. 2001).

It has been recognized that birds play a significant role in regulating insect populations. There are instances where snag-dependent birds as woodpeckers have reduced outbreak of populations of forest insects as southern hard wood borers (Solomon 1969). Though they may not be able to break an insect plague, their function lies in preventing insect plagues (Thomas 1979).

1.5 Management considerations

Timber extraction in a managed forest means making do with fewer snags and fallen logs, especially when timber extraction involves clear cuts, short rotations, and thinning. To minimize the impact that this will have on wildlife, it is important that during a harvest operation a reasonable number of appropriate snags and fallen logs be left behind (Hunter 1990).

1.5.1 Size and state of decay

Diameter is the main consideration along with height. A greater variety of wildlife use tall, girthy snags, and also large snags are likely to last longer than small snags (Gibbs et al. 1993).

Woodpeckers are known for their chisel-like bill, thick skull, and tough neck, but not all primary excavators are as well equipped to excavate a cavity in a hard snag, and even many woodpeckers prefer to nest in a well-rotted tree. Consequently, it is important to have both soft and hard snags. Having snags in various stages of decay plus den trees—is also inevitable (Hunter 1990).

1.5.2 Species, location and quantity of snags

The simple, conservative approach would be to let snag species composition reflect the species composition of the live trees. Alternatively, a sample of trees may be inspected and the particular species may be favoured in leaving snags (Hunter 1990).

It is advisable to have many clusters of snags distributed through the forest (Raphael and White 1984). Snags must be well distributed to be most effective in the number of pairs of cavity-nesting birds they will support because of the territory requirements of the primary excavators. Deciding the number of snags to be left requires studies on habitat biology of snag users. There is a tremendous demand for firewood in developing countries like India where even today 50% of the fuel requirements are met by wood.

1.6 Indian context

According to ABE (1985) the firewood demand is going to be of the order of 300-330 metric tonnes in the year 2004 - 2005 (Vandana 2002). In India rural and tribal households are allowed to carry head loads of fallen twigs and small branches as fuel for family consumption and often for sale in

nearby markets. It is often alleged that rural and tribal communities remove fuel wood in a non-sustainable way, leading to forest degradation. The total annual increment for the Indian forests has been estimated to be 138 metric tones, of which branches and twigs account for 31% i.e. 42 metric tones. This can be subsequently harvested as firewood (Ravindranath and Hall 1995). But removal of down woody materials from forest will deplete the ecosystem of the diversity of special microhabitats for many species of plants and animals, and it also prevents enrichment of the forest soil (Hunter 1990). It is imperative to obtain a balance between economics as well as the concepts of silvicultural hygiene, and the goods of retaining dead and down woody materials for wildlife conservation purposes.

According to Panwar (1983) although no felling are envisaged in site preparation under social forestry, but still care is necessary for allowing such trees to remain standing. The value of such trees needs to be explained to villagers during extension and promotional activities. Sharma (1982) has pressed on the on the retention of snags and hollow trees for cavity user birds by leaving broken topped, twisted and many limbed snags and hollow trees from harvesting but at the same time suggesting the disposal of slash with <10 cm diameter in the forest as it increases fire hazard. While deciding this one must know the species, size and kind of requirements of the dead wood users, particularly birds inhabiting the area.

Dying, dead, and down trees are important components of forest ecosystems. Not only are dead trees critical microhabitats for many species, but also they are also large reservoirs of organic matter and hence play a role

in nutrient cycling. Timber extraction tends to minimize the number of snags and fallen logs in a stand (Hunter 1990).

1.7 Review of literature

Literature on dead wood and its ecological importance in general is voluminous, but almost all deal with dead wood in managed, heavily logged temperate forests of North America and Europe. Very few literature touch aspects of dead wood in natural, undisturbed and tropical forests.

Thomas et al. (1979) and Hokkanen et al. (1982) have described the silvicultural practices, like even-aged practice that commonly result in reduction of snags and live mast producing trees, which are important for cavity nesters, like flying squirrels. These practices also destroy under story vegetation and coarse woody debris on the ground, which are important for foraging as well as for cover to the flying squirrels (Sonenshine and Levy 1981, Bendel and Gates 1987, Taulman 1997, Taulman 1999).

According to Bennett (1995) timber harvesting represents a potential threat to hollow dependent fauna. The unoccupied hollows should not be considered as unused. Their use may be seasonal, or multiple. Greater gliders in southeast Queensland use 3 or 4 different dens a month and 4 – 18 over 10 months. Similarly yellow-bellied gliders change dens frequently. Due to territorial behaviour, many species of birds and marsupials defend vacant hollows and generally do not recolonize new areas, because of site fidelity. These animals are the primary food resource of predatory birds, such as forest owl. An estimate suggests that a forest owl need 250 – 300 opossums

annually. And a forested area of 1000 hectares is required for maintaining such a large population of these animals (Bennett 1995).

A study on the den site characteristics of female American Marten showed that 25% and 16% of den sites of these animals were snags and fallen logs respectively (Ruggiero et al. 1998). Many bat species also use hollows in trees, stumps and snags, like long-legged myotis, big-brown bat, long-eared myotis. For many of these they are critical for their survival (Kalcounis and Brigham 1998, Ormsbee and McComb 1998, Jung et al. 1999, Waldein et al. 2000). Vonhof and Barclay (1997) reported the widespread use of loose bark on stumps in clear-cuts as roosting sites by long-eared bats.

In a study in Australia, it was found that a native mammal, Yellow-footed Antechinus (*Antechinus flavipes*) occupies sites in significantly higher densities when wood loads (coarse woody debris) exceed 45 tonnes/ha. Similarly it was found that most day refuges of cotton mice (*Peromyscus gossypinus*) were associated with woody debris, including refuges in rotting stumps (69%) under upturned root boles (14%) and under fallen logs and brush (9%). Nighttime telemetry locations showed that cotton mice were closer to large logs more often than expected by chance ($P < 0.05$) (McCay 2000). Ground and coarse woody debris using birds are more prevalent, and in richer diversity in the vicinities of accumulations of woody debris (MacNally et al. 2001). Another study in Australia shows that *Hoplocephalus bungaroides*, a threatened snake species of southeastern Australia use the hollows in dead trees more often than any other resting site (even more than hollows in live trees) in summer for thermo-regulation (Webb and Shine 1997).

According to Dickson et al. (1983) snag retention increased bird use of a clear-cut. A study on use of snags by cavity nesting birds in the Sierra Nevada showed that 72% of the nests of these birds were on snags, even though the availability of snags was very little – only 7% of standing trees were (snags) (Raphael and White 1986). Cowardin et al. (1967) mentions about the extensive use of stumps and snags by Mallard and Black Ducks as nesting sites.

According to Zarnowitz and Manuwal (1985) species richness, densities and diversities of cavity nesting birds increased with increased snag densities. Schreiber and deCalesta (1992) tested correlation of snag density and species richness of cavity nesting birds, which was found to be positive ($P < 0.05$). In an experimental study done in a Loblolly Pine forest it was found that removal of snag and coarse woody debris reduced total breeding bird abundance, abundance of resident species, breeding species richness, and abundance of Great Crested Flycatchers (*Myiarchus cinerascens*) (Lohr et al. 2002).

Gibbs et al. (1993) had described results of a comparative study on the snag availability and communities of cavity nesting birds in tropical versus temperate forests generated. It was found that though snag densities in tropical and subtropical forests were lower than in forests of higher latitudes, and snags in low latitude forests were thicker in diameter than their higher latitude counterparts, they supported 2.5 times as many cavity nesting species and almost equal number of primary excavators as high latitude forests.

Sallabanks et al. (2001) describes about the association of 77 species of vertebrates with snag substrates during some part of annual cycle including 2 amphibians, 51 birds, and 24 mammals in the Eastside (interior) forest and woodland types. Sixty-eight other wildlife species found there have correlations with down wood, which includes 6 amphibians, 5 reptiles, 13 birds, and 44 mammals.

1.8 Objectives

- 1) To quantify the abundance of different types of dead wood in different forest/habitat types.
- 2) To relate dead wood abundance to live tree abundance.
- 3) To quantify the extent of use of dead wood by different taxa particularly mammals, birds and reptiles.

Following questions were asked:

- a) Does dead wood density differ across different forest types and disturbance regimes?
- b) Is there any seasonal change in the dead wood numbers available to the dead wood users in the lake habitat?
- c) What kinds of animals use dead wood and which user categories do they fall into?
- d) Do dead wood usage patterns differ in different forest types?
- e) Do animals use different stages and size classes of dead wood differentially?

STUDY AREA

2.1 Geographical location

One of the most famous protected areas of India, Periyar Tiger Reserve (PTR) is situated between Cardamom and Pandalam Hills of the Southern Western Ghats within 9° 15' and 9° 40' N latitudes and 76° 55' and 77° 25' E longitudes. It falls in the Idukki and Pathanamthitta districts of the state of Kerala (Figure 1).

Approximately 90 km long boundary of the reserve on north, northeast, and east is the state boundary between Kerala and Tamil Nadu. Madurai, Ramnada and Tirunelveli districts of Tamil Nadu form northern, eastern and southeastern boundaries of the reserve respectively. On the south the reserve is bordered by northern boundary of Ranni Forest Division of Kerala. Pamba River also forms part of the southern boundary. On western front lie the Kottayam Forest Division and few tea estates (Uniyal 2001).

2.2 History and legal status of the Reserve

The rulers of erstwhile states of Travancore and Madras had some understanding under which the state of Travancore permitted Madras state to construct a dam across Mullaperiyar river in order to take care of irrigation needs of Tamil Nadu. The lake was formed in 1895. In 1899, 600 km² of forest around Mullaperiyar lake, a part of the present Reserve, was declared as Periyar lake reserve forest No. 39 under section 18 of Travancore Regulation Act 1068. Mr. S.C.H. Robinson, a retired Land Commissioner was appointed as a Game Warden in 1933, by the Maharaja of Travancore with a view to

Figure 1. Location Map of Periyar Tiger Reserve

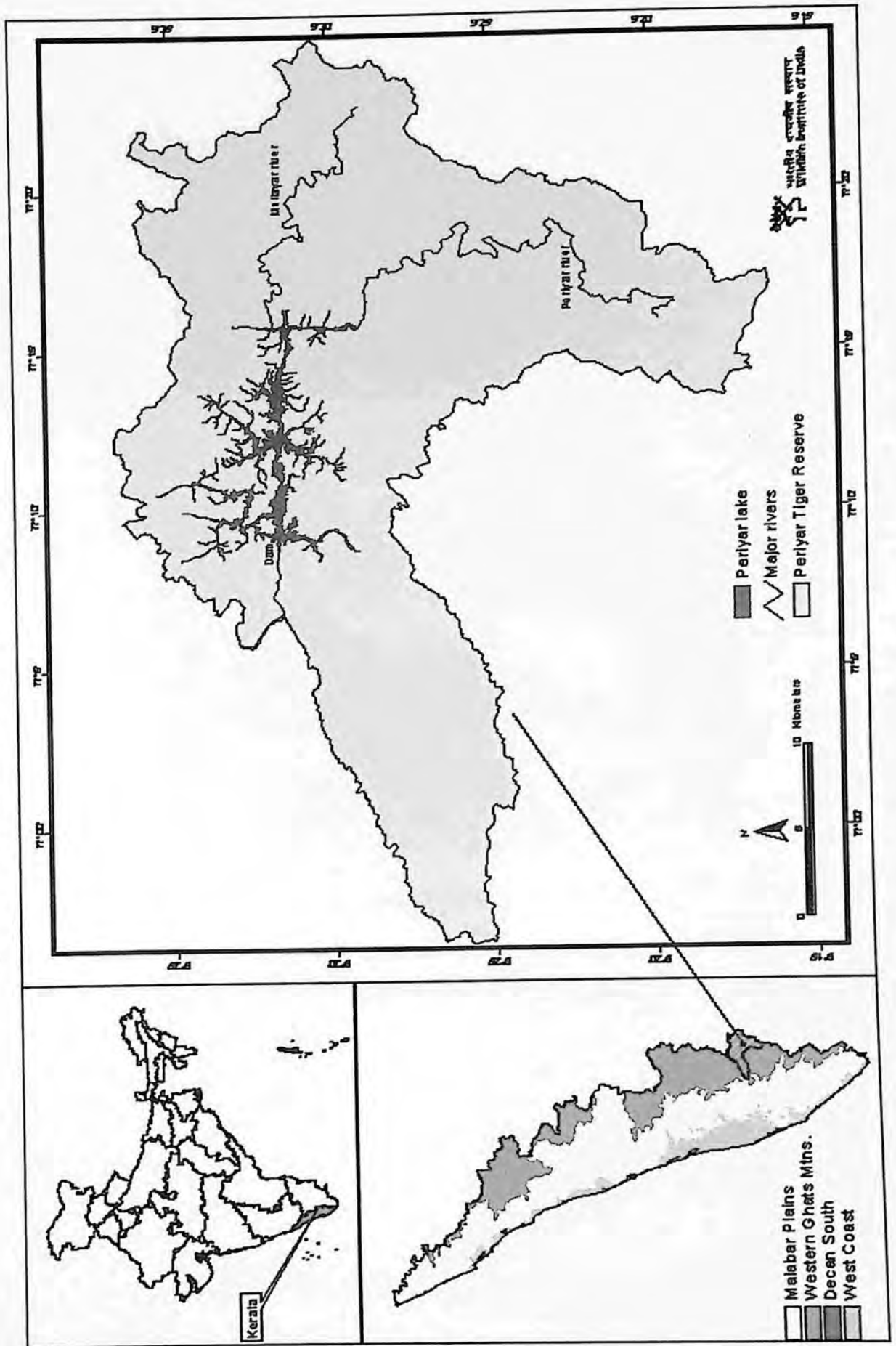


PLATE 1



Sunset in Periyar Tiger Reserve



Stakes in the Mullaperiyar Lake



Watch tower in Mangla Devi (PTR)

constitute and maintain a Wildlife Sanctuary around the lake. In the following year the sanctuary was constituted, which was named "Nellikampetty Sanctuary".

The present Periyar Wildlife Sanctuary was constituted in 1950 and was brought under Project Tiger in 1978 as Periyar Tiger Reserve, the 10th Tiger Reserve in the country. The core area was declared as a National Park in 1982 vide G.O. (P) 310/82/AD dated 27th October 1982 of Government of Kerala (Anoop 2001). In 1991 the area was declared as part of Project Elephant Reserve No.10. The reserve covers a total area of 777 km² separated into core, buffer and tourism zones.

Periyar Tiger Reserve functions as a single territorial division with its headquarters at Thekkady and has two territorial ranges, viz., Thekkady and Vallakkadavu. A functional division, Grass Land Afforestation Division, with its headquarters at Peermedu also operates within the bounds of the Tiger Reserve without any territorial control. This division was established to raise plantation for meeting pulp wood demand. But after the Supreme Court's verdict of February 2000, writ petition 202, no such activity takes place in the reserve (Uniyal 2001).

2.3 Topography

The terrain is undulating in general and rugged in some areas with lofty peaks and precipitous slopes. The altitudinal variation is from 100 m (Pamba Valley) to 2016 m (Vellimala) above mean sea level (msl). The northern half of the area surrounding the lake is undulating with an average altitude of 800 m. The terrain is very steep on the eastern side adjoining the

state boundary. Some of the well known peaks are Vellimala (2016 m), Chokkampattimala (1801 m), Kallimala (1637 m), Sundaramala (1808 m) Pachimala (1800 m), Nagamala (1733 m), Kottamala, Koyilmala. In the western side of the reserve there is an extensive tableland known as Mount Platen at an altitude of 1400 m.

2.4 Climate

Periyar Tiger Reserve experiences cool and humid climate with high rainfall (an average of 200 cm of rain per annum). The maximum temperature varies between 15 °C and 31 °C with April - May being the hottest and December – January the coolest months. The average humidity ranges between 60% and 85% round the year (Anoop 2001). With the exception of December and January the area receives few showers in all months. The five months from December to April is generally considered as the dry period. July is wettest and January is the driest months of the reserve. Though southwest Monsoon is responsible for most of the rainfall, the area also receives rain from the northeast Monsoon.

Since the reserve has four major perennial rivers and the Mullaperiyar lake of around 26 km², water is available throughout the year. The water level in the lake is lowest during the quarter of March, April and May (Uniyal 2001).

2.5 Vegetation

Major vegetation types in Periyar Tiger Reserve are: tropical evergreen and semi evergreen forests (74.6%), moist deciduous forests (12.7%), grasslands (1.5%) and Eucalyptus plantations (7.1%) (Anoop 2001).

Mullaperiyar Lake forms an important aquatic ecosystem, which occupies about (3.3%) of the area.

The forests of Periyar Tiger Reserve were classified into the following types according to Champion and Seth (1968) classification of forest types of India:

2.5.1 West coast tropical evergreen forests

This forest type is found in Koruthode-Sabarimala-Poongavanam areas where the altitude ranges from 100 to 1300 m. Comparatively taller trees with straight trunks are found in these evergreen forests. The major associations of trees in these areas are *Mesua-Palaquium-Cullenia* associations. *Hopea-Dipterocarpus-Vateria* association and *Polyalthia-Myristica-Calophyllum* association. The top canopy members are *Hopea parviflora*, *Dipterocarpus indicus*, *D. bourdillonii*, *Polyalthia coffeoides*.

2.5.2 West coast semi-evergreen forests

This forest type covers an area of around 190 km² of the Tiger Reserve. It is found in Thekkady, Swamikkayam and Vallakkadavu areas. The three tier structure of the tree canopy is evident in this forest type too. The major tree species in the top canopy layer are *Terminalia bellarica*, *Myristica dactyloides*, *Ficus drupacea*, *F. nervosa*, *F. virens*, *Bischofia javanica*.

2.5.3 Southern moist mixed deciduous forests

Around 100 km² of the Reserve is under this forest type. It is found at Thaannikkudy, Mullakkudy, Edappalayam, Pambavalley and Methaganam

areas. The three tier canopy structure is discernible in this forests also. The upper canopy trees are *Pterocarpus marsupium*, *Tectona grandis*, *Terminalia paniculata*, *T. crenulata*, *Bombax ceiba*, *Tetrameles nudiflora*, *Actinodaphne malabaricum*.

2.5.4 Southern hill-top evergreen forests

This type of forest is found in places south of Mlappara, east of Mullakkudy and Thaannikkudy, where the altitude in between 1300 and 1700 m. *Dysoxylum-Palaquium-Cullenia* association is found in places above Mullakkudy and Thaannikkudy. The upper storey trees in these areas are *Dysoxylum binectariferum*, *Palaquium ellipticum*, *Cullenia exarilata*, *Mesua ferrea*, *Acrocarpus fraxinifolius*, *Meliosma pinnata* var. *arnottiana*, *Syzygium gardneri*.

2.5.5 Southern montane wet temperate forests

This forest type is found in Vellimala, Kottamala, Uppermanalar, Pachayarmala, Sunderamala, Chokkampettimala, Mangaladevi and Kalvarimala. The canopy stratification is not found in this forest type. The trees have with short bole and stout branches. The major trees are *Garcinia cowa*, *Syzygium rubicundum*, *Eugenia discifera*, *S. parameswaranii*, *Cinnamomum wightii*, *Phoebe wightii*.

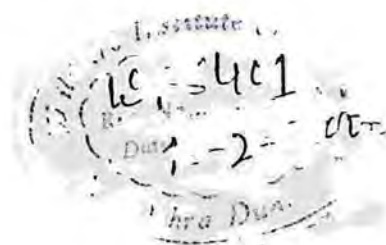
2.5.6 South Indian subtropical hill savannahs

Large tract of savannahs are found at Thaannikkudy, Edappalayam, Manakkavala and Kavalappara areas. Major trees found in this forest types

are *Terminalia paniculata*, *T. chebula*, *Careya arborea*, *Pterocarpus marsupium*, *Phyllanthus emblica*, *Buchanania lanzan*, *Dalbergia sissooides*, *Dillenia pulchellum*, *Vernonia divergens*, *V. indica* the dominant grasses are *Themeda cymbaria*, *Chrysopogon hackelii*, *Cymbopogon flexuosus*, *Apluda mutica*, *Panicum spp.*, *Ischaemum timorense*, *Eulalia trispicata*, *Capillipedium assimile*.

2.5.7 Southern montane wet grasslands

Extensive grasslands are found in Arjunankoyya, Uppupara, Kavalappara, Manaaladevi, Kumarikulam, Palkachimala, Kathiramudi, Swamikkayam mala and Kalvarimala. About 57 km² is dominated with grass growth. Major part of the grassland was converted into Eucalyptus plantations in the past. Among the savannahs and grasslands there are patches of marshy areas where a mixed growth of grasses like *Panicum spp.*, *Leersia hexandra*, *Eragrostis spp.*, *Isachne kunthiana*, *Pseudoraphis spinescens* along with a rich population of sedges is found. Major grasses are *Chrysopogon zeylanicum*, *Themeda cymbaria*, *Cymbopogon bromoides*, *Arundinella ciliata*, *A. mesorhiza*, *A. teretifolia*, *A. purpurea*, *Dimena lawsonii*, *D. thwaitesii*, *Ischaemum indicum*, *Ischaemum indicum*, *Eulalia trispicata*, *Ischaemum commutatus* apart from grasses, shrubs like *Phoenix humilis*, *Strobilanthes kunthianus*, *Indiofera pulchella*, *I. Wightii*, *Litium wightianum*, *Hypericum mysorense*, *Thalictrum japonicum* are also seen along with a rich herbaceous population.



2.6 Floral Diversity

Periyar Tiger Reserve has high species richness and diversity of plants that can be inferred from the fact that out of the 3800 species of Angiosperms estimated to be there in the state of Kerala, the 777 km² area of the reserve harbours 1966 species. Nowhere in the whole of the Indian subcontinent, such a large number of taxa have been recorded from an area comparable to that of Periyar Tiger Reserve. Of the 216 species of orchids reported from Kerala, 145 species are found in Periyar Tiger Reserve (Anoop 2001).

Twenty-six percent (515 of the 1966) species of the flowering plants found there are endemic to the Southern Western Ghats. Among the important families showing relatively high degree of endemism, Orchidaceae stands first with 55 endemic species, Rubiaceae second with 35 species. Acanthaceae with 32 species, Poaceae, Fabaceae, Lauraceae, Balsaminaceae, and Euphorbiaceae with 25 each follow suit. Other such families with endemic plants are Lamiaceae with 19, Melastomataceae 18 and Asteraceae 11 species. Periyar Tiger Reserve falls in the in the Anamalai High Range Centre, one of the 5 centres of endemism in the Southern Western Ghats. Out of the 49 species estimated to be endemic to this region, 25 occur in Periyar Tiger Reserve (Anoop 2001).

Seventeen of the 149 threatened species of plants collected from the reserve are considered 'possibly extinct.' Among the plants collected from Periyar Tiger Reserve, 4 are new records for India and 14 are new records for Kerala. The reserve is the only known home to the species such as *Habenaria*

periyarensis, *Syzygium periyarensis* and sub species such as *Mucuna pruriens thekkadiensis*. All the 3 Gymnosperms found in Kerala are found in the reserve. Periyar Tiger Reserve also has 150 Pteridophytes, one of which seen in the core areas, namely *Ophioglossum pendulum* is the first report from Peninsular India. Besides these there are about 350 species of medicinal plants identified from the reserve (Anoop 2001).

2.7 Faunal Diversity

Vertebrate diversity is also very high in Periyar Tiger Reserve, with 38 species of fish, 16 amphibians, 44 reptiles including 30 snakes, around 320 birds and 62 species of mammals. Endemism is also high in these taxa found in Periyar Tiger Reserve. For example, 10 out of 16 amphibians and 13 of the 30 snakes are endemic to the Western Ghats. Four fish of the 38 are endemic to the reserve. Of the 14 avian species endemic to the Southern Western Ghats (a zone of high avian endemism) 13 are found in Periyar Tiger Reserve in good numbers. Besides the endemism Southern Western Ghats is also characterized by disjuncts, relatives or same species occurring in Himalayas and nowhere in between. Species such as the Graet Indian horn bill (*Buceros bicornis*), the Forest eagle owl (*Bubo nipalenses*), the Ceylon frogmouth (*Batrachostomus monitiger*), the Rufous-bellied hawk eagle (*Lophotriorchis kienerii*), the Black crested baza (*Aviceda leuphotes*), the Broad-billed roller (*Eurustomus orientalis*) come under this category. All the disjunct species except the Grass owl (*Tyto cepeansis*) and the Bay owl (*Phadinus badius*) are reported from Periyar Tiger Reserve (Anoop 2001).

Of the many species of mammals the reserve is home to some of the rare and endangered mammals, like Nilgiri tahr, Nilgiri marten, Stripe necked mongoose, Mouse deer, etc. With such high diversity and endemism levels of higher life forms one can imagine what will be the scenario of diversity and endemism in small life forms, basically insects and invertebrates in the park. About 160 species of butterflies have been recorded from Periyar Tiger Reserve (Suresh Elamon, pers. comm.).

2.8 Why Periyar Tiger Reserve

Of all the places thought about for this study Periyar Tiger Reserve seemed best suited for the following reasons:

- a) The area has Mullaperiyar lake, in which numerous stakes and stumps are present, along with logs on its shore, which is very unusual for an artificial lake of its kind.
- b) Due to the topography, soil conditions and the heavy rainfall the area receives, a large number of trees fall in the forest, some of which reach up to the lakeshore and large streambeds carried by many seasonal as well as perennial streams.
- c) Being the part of the Southern Western Ghats (a biological hotspot) Periyar Tiger Reserve has a good diversity of fauna and thus large number of dead wood users across many taxa.
- d) The area also had old growth (natural) forests along with second forests. In this case they were Semi evergreen forests and Moist deciduous forests respectively.

2.9 Intensive study sites

After few weeks of survey in different parts of Periyar Tiger Reserve it was decided to conduct the study in and around Thekkady range of the Tiger Reserve's East Division. Since two different forest types, Semi evergreen forest and Moist deciduous forest in 4 different areas of the range near Edappalayam section were identified, it became the logistical choice for the intensive study area. Later another section, named Mullakudy could be identified, with both the forest types in two different areas. It also became a part of the overall intensive study area. The part of the lake between Boat Landing and Mullakudy was then the natural choice for the study site focusing on dead wood in the lake. The 6 different areas were Anchurli, Shivalodu, Edappalyam, Mullakudy, Mullakudy2 and Tamburan Turathu (Figure 2).

Details of vegetation composition of the 2 forest types, viz., Moist deciduous forest and Semi evergreen forest present in Thekkady range, which was the intensive study area compiled from Nair (2002) is given in Tables 1 and 2 respectively.

These secondary data shows the vegetation compositions of Moist deciduous forest and Semi evergreen forest in Thekkady range with frequency of occurrence of each species in the plots laid, and the percentage of that with respect to the total number of trees found in all the plots. Data comes from 8 vegetation plots for Moist deciduous forest and 5 plots for Semi evergreen forest.

Figure 2. Locations of Intensive study sites in Periyar Tiger Reserve

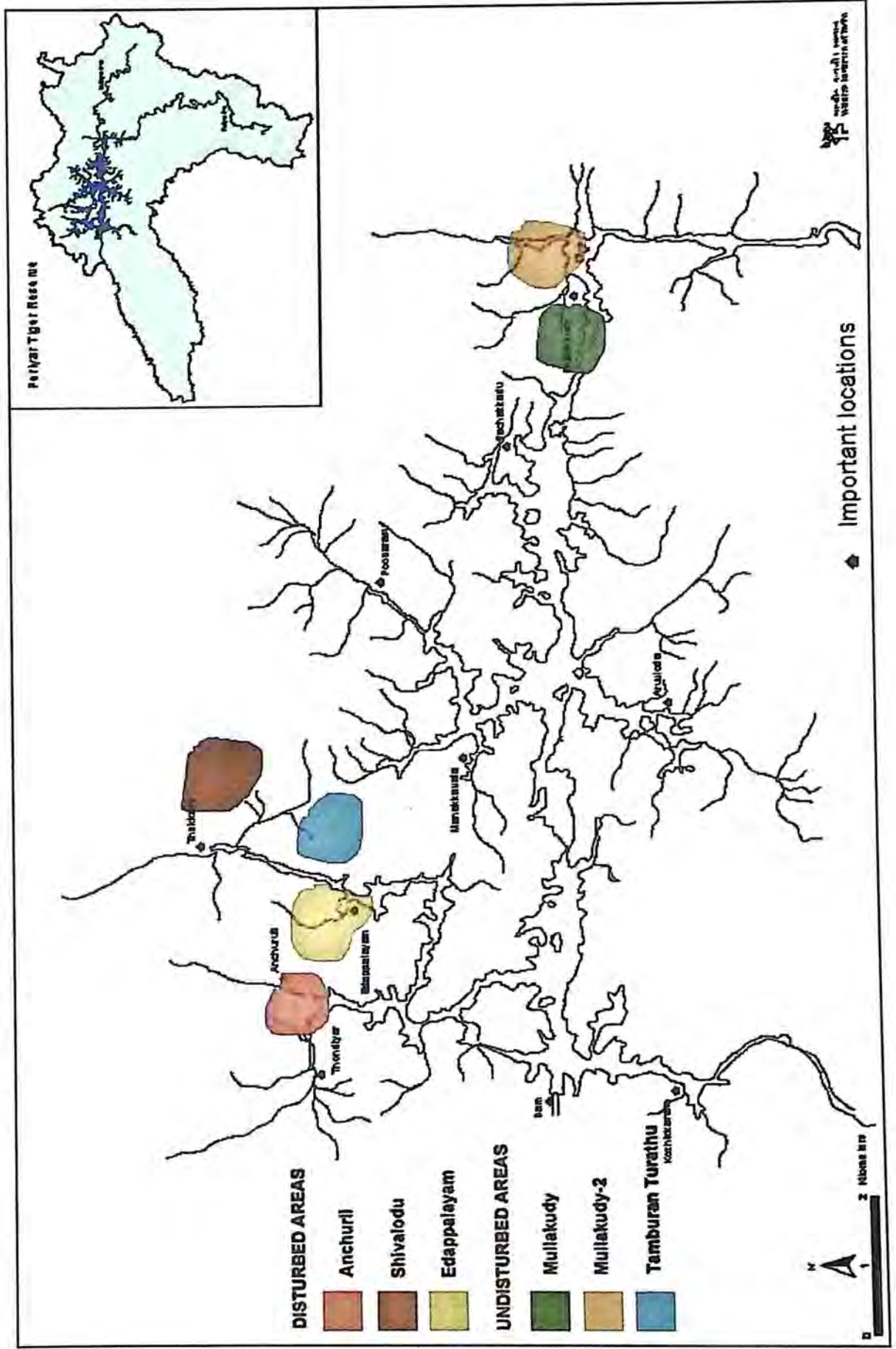


Table 1. Vegetation composition of Moist Deciduous Forests of Thekkady range, Periyar Tiger Reserve

Name	Frequency	Percent
<i>Alseodaphne semecarpifolia</i>	1	1.47
<i>Haldina cordifolia</i>	1	1.47
<i>Syzygium gardneri</i>	1	1.47
<i>Terminalia bellirica</i>	1	1.47
<i>Terminalia chebula</i>	1	1.47
<i>Careya arborea</i>	2	2.94
<i>Lagerstroemia microcarpa</i>	2	2.94
<i>Phyllanthus emblica</i>	2	2.94
<i>Pterocarpus marsupium</i>	2	2.94
<i>Santalum album</i>	2	2.94
<i>Terminalia crenulata</i>	3	4.41
<i>Olea dioica</i>	4	5.88
<i>Pterocarpus bridelie</i>	4	5.88
<i>Anogeissus latifolia</i>	5	7.35
<i>Terminalia paniculata</i>	16	23.53
<i>Tectona grandis</i>	21	30.88

Table 2. Vegetation composition of Semi Evergreen Forests of Thekkady range, Periyar Tiger Reserve

Name	Frequency	Percent
Velluramaram	1	1.72
<i>Aporusa lindleyana</i>	1	1.72
<i>Artocarpus hirsutus</i>	1	1.72
<i>Clausena indica</i>	1	1.72
<i>Diospyros sylvatica</i>	1	1.72
<i>Ficus nervosa</i>	1	1.72
<i>Grewia tiliifolia</i>	1	1.72
<i>Lannea coromandelica</i>	1	1.72
<i>Myristica dactyloides</i>	1	1.72
<i>Olea dioica</i>	1	1.72
<i>Pterocarpus marsupium</i>	1	1.72
<i>Saprosma zeylanica</i>	1	1.72
<i>Tabernaemontana heyneana</i>	1	1.72
<i>Terminalia crenulata</i>	1	1.72
<i>Antidesma menasu</i>	2	3.45
<i>Erythrina stricta</i>	2	3.45
<i>Filicium decipiens</i>	2	3.45
<i>Mussanda bellila</i>	2	3.45
<i>Schleichera oleosa</i>	2	3.45
<i>Actinodaphne malabarica</i>	3	5.17
<i>Anogeissus latifolia</i>	3	5.17
<i>Glochidion ellipticum</i>	3	5.17
<i>Lagerstroemia microcarpa</i>	4	6.90
<i>Mallotus philippensis</i>	4	6.90
<i>Stereospermum colais</i>	7	12.07
<i>Terminalia paniculata</i>	10	17.24

METHODS

3.1 Selection of habitat types

During the first few days of the study a reconnaissance was carried out, and three different types of forests, namely Semi evergreen forest, Moist deciduous forest and Savannah woodland were identified. These, as well as the lake habitat, were initially surveyed for dead wood availability. It was found that dead wood was sparsely distributed in Savannah woodland, thus it was excluded from the study. Six areas were chosen in the forests around Edappalayam and Mullakudy such that each area had adjacent patches of Semi evergreen forest and Moist deciduous forest. The rationale behind this was that the disturbance levels in Semi evergreen forest and Moist deciduous forest patches within each of the areas would be nearly equal. For the lake habitat, eight stretches of 1 km each, with a gap of 0.5 km between successive stretches, were chosen for intensive sampling. These stretches were located on the 12 km stretch of the lake between two corners of the intensive study area, viz., Edappalayam and Mullakudy sections.

3.2 Sampling for dead wood, vegetation and disturbance in forests

The total number of forest patches sampled was 12 (6 areas X 2 forest types). All the forest patches were narrow and elongated, starting near the lakeshore and continuing up the hill slopes. None of the forest patches was more than 600 m in width.

3.2.1 Dead wood density estimation

Trials with different plot sizes were initially carried out for the density estimation of dead wood. The plot size of 30 X 30 m was decided upon as the largest manageable one given time constraints and field conditions during the study period. Short transects were used to lay the square plots of 30 X 30 m in the forest patches. The starting point of the first such transect was randomly picked along the lengthwise edge of the forest patch. A compass bearing was taken almost perpendicular to the lengthwise edge so that, the straight line along the bearing passed through the width of the forest. The plots were laid along the line, successive plots being on the alternate sides of the line (Appendix 1). Once the edge of the forest patch was reached, 100 m were walked along the edge perpendicular to the straight line used. A back bearing was then taken to get a line parallel to the preceding line. Plots were again laid along the new line in the manner as described earlier. The gap between the parallel lines used to lay the plots was kept 100 m in order to prevent the repetition of plots in the same place. This sampling strategy was decided upon after consultation with local forest officials, who mentioned a similar way of sampling vegetation using 20 X 20 m plots on both sides of a long straightened out steel chain. In each forest patch sampled, 50 such plots were laid to sample for dead wood.

In each 30 X 30 m plot, numbers of dead wood were counted. It was decided a priori to sample snags at least 10.2 cm in diameter at breast height (dbh) and at least 1.8 m in height (Thomas et al. 1979). Dead trees less than 1.8 m in height were considered as stumps. Fallen logs on ground, and dead branches on live trees were enumerated. Only fallen logs with a minimum

girth of 20 cm were counted. Fallen logs below this girth were put into the category of woody debris and ignored in this study. The 20 cm cut off limit on fallen log was decided after the first few sample plots to simplify the effort. Natural tree hollows and excavated cavities were also counted in each plot. The total area sampled and the proportion of the areas sampled in different sections of Thekkady range is given in Table 3.

3.2.2 Estimation of tree density

In each of the 12 different forest patches, 30 plots of 30 X 30 m were laid in the manner as explained above. Total number of trees >30 cm diameter at breast height (at a height of 1.37 m) in each plot was counted irrespective of the tree species encountered, to get the density estimates of trees in each forest patch.

3.2.3 Sampling for quantification of disturbance

Of the six areas sampled, three were categorized as "disturbed" and the other three as "undisturbed" based on field observations of the presence of people, the presence of weeds and signs of removal of vegetation. The extent of disturbance in each of the two forest types in these six areas was measured using the percentage of trampling signs near sampled dead wood. The trampling data was tested for any significant differences between the disturbed and undisturbed categories, in order to see whether the classification done was meaningful or not.

In the forest patches, for each dead wood sampled, the disturbance level surrounding the dead wood was assessed by ocular estimation of

trampling percentages (only in tens and fives, for e.g., 10%, 15%, 20%, 25%) in eight circular plots of 2 m radius and 4 m away from the sample in eight different directions around the sample.

3.3 Estimating dead wood availability across seasons in the lake habitat

Periyar Tiger Reserve experiences basically three seasons, with respect to water level in the lake. They are "very high water level season" from June to October, "high water level season" from November to February and "low water level season" from March to May. With the fluctuating water level in the lake the number of dead wood available to their users also changes. To record this fluctuating data, as soon as the actual sampling begun, in the "high water level season", eight stretches of 1 km each, of the lake with a gap of 0.5 km between successive stretches were intensively sampled for stakes, stumps and fallen logs. Complete counts of above dead wood were done in these stretches, in water and on both shores by using a rowing boat and by walking along the shores. Same method was used to count dead wood in the same stretches of the lake in the "low water level season". Counts for both the seasons were done within a period of 5 days each time to minimize the effect of water level changes over days.

3.4 Collection of data on resource use and the users

3.4.1 General methods used across dead wood types

A completely random design was established for sampling the use of dead wood. A day was decided to sample a particular forest patch or part of

the lake for a particular type of dead wood. At a random point along the lengthwise edge of the patch or the lake, a random number was picked using a scientific calculator. Then the forest patch or stretch of lake was carefully searched using a strip transect of a width of 20 m for encountering that particular number of the type of dead wood being sampled. The strips were walked along the width of the forest patch or lake. For example, if the number generated was three and the dead wood type being sampled was cavity, the third cavity encountered in the strip walked was sampled. The strips were parallel to each other and the central lines of the successive strips walked were 60 m apart.

Once that particular dead wood was spotted, it was approached very carefully, simultaneously observing the presence of any animal (mostly birds, mammals and reptiles) on or near it. On reaching the spot, signs of usage by mammals and reptiles (digging signs, scratch marks and mud-rubbing) were looked for. Then small animals were looked for in and around the dead wood and if possible, also under it. Insect and invertebrate specimens were searched for and collected from a random point on the dead wood in zip-lock covers, always within a time limit of half a minute, this being the constant factor throughout. Wherever possible, the species of the live tree that contributed to the dead wood was identified (Appendix II) using the knowledge of the field assistants, who relied mostly on bark characteristics, wood texture, colour and smell of the chipped wood.

Canopy cover was measured in four different directions around the sampled dead wood using a densiometer. After this, the sampled dead wood was left as intact as possible and watched carefully for seven minutes from a

distance of 10 m for birds (identified with the help of a field-guide for birds (Grimmett et al., 1999)) and mammals that might return to the dead wood, using a pair of 7 X 35 Minolta binoculars. The time and distance limits of seven minutes and 10 metres respectively were determined in field, as they were found to be practical and effective limits for the specific work, in the extant field conditions.

When one such sample was finished, the whole process was repeated again starting with a new random number. Usually, only single and double-digit numbers ranging from 1 to 15 were considered for ease of sampling and to be absolutely sure that the corresponding dead wood sample could be found.

The insect and invertebrate specimens were classified up to classes and orders as possible and also into morpho-species with the help of a dissection microscope setup in field station, created with two magnifying lens and two stands.

3.4.2 Specific methods used for cavities

Two types of cavities were identified during the first few days of survey, viz., natural tree hollows and excavated cavities. Cavities were sampled for in all the 12 forest patches. Twelve cavities were sampled in each of the 12 forest patches. Only large tree hollows where a hand could be put inside to collect invertebrate specimens were sampled for invertebrates. In such tree hollows often bats were seen and they used to flutter so much when torch light was shown that it was possible to hear them from a close distance and even feel the wind, thus generated. After few such experiences I learned

to identify the sound and the wind (with smell) as positive signs of bat presence. The tree species bearing the hollows and cavities were also recorded.

3.4.3 Specific methods used for fallen logs

Three different stages of fallen logs (Table 4) were identified in the field based on the modified classification of down-woody debris and fallen logs made by Maser et al. (1979) keeping field conditions in mind. Six fallen logs of each stage were sampled in each of the 12 forest patches. Whenever possible fallen logs or parts of the fallen logs were turned over to check for use. Girth or width as well as length of the sampled fallen logs were also recorded. Once shrews were found to use fallen logs, and their nests and pellets were seen on fallen logs in the lake habitat during the first few days of field work, usage of fallen logs by shrews were at many instances identified by the presence of nests, nesting materials and pellets.

3.4.4 Specific methods used for snags and stumps

In the forest patches two different stages of snags and stumps (Table 4) were identified after modifying the classification made by Thomas et al. (1979) according to the field realities. In each of the 12 forest patches, six snags and stumps of each of the two stages were sampled. Height (measured using a clinometer and trigonometric calculations for snags and stakes) and girth of snags/stakes and stumps were also collected.

Table 3. Areas sampled in different sections of the Thekkady range, Periyar Tiger Reserve

Name of Sections	Area in ha.	Sampled area in ha.	Proportion of area sampled in %
Thekkady	1300	9	0.69
Edappalayam	1800	18	1.
Nellikampetty	3200	9	0.28
Medakanam	800	0	0
Mullakudy	2800	18	0.64
Total	9900	54	0.55

(Lake area sampled not included in the sampled area column)

Table 4. Description of the different stages of logs, snags and stumps

Dead wood	Stage	Description
Log	1	Freshly fallen trees or branches with bark intact, look like live one
Log	2	Logs with most of the bark lost, but have not decomposed yet
Log	3	Logs with most part decomposed and mixed with soil
Snag	1	Standing dead tree with most of the bark intact, just dead
Snag	2	Snag with very little bark and in which wood is visible
Stump	1	Short standing parts of freshly fallen logs or short snag of stage 1
Stump	2	Stumps with no bark on them and wood exposed completely

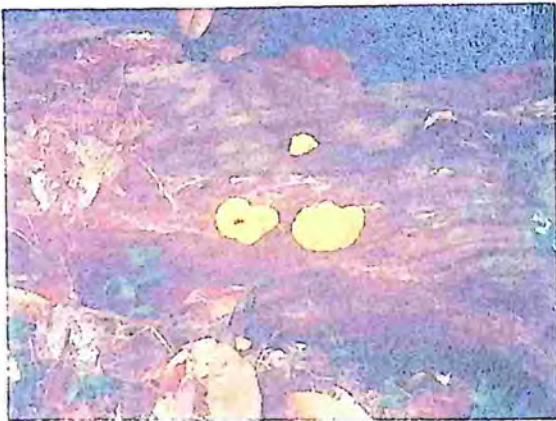
PLATE 2



Civet droppings on a first stage log



A second stage log



Fungus growing on a fallen log



Nesting large cormorants



A vine snake on a log



An excavated cavity

3.4.5 Usage of stakes by large cormorant for nesting

While doing dead wood count in lake habitat in “high water level season” nesting activities of large cormorant on stakes were also observed. Number of nests, the size characteristics of the stakes, number of branches, and species of the live trees, the stakes were once upon a time, were recorded.

3.4.6 Usage of stakes and stumps by turtles

Turtle were seen using stakes and stumps and even fallen logs for basking. Since, they dive into water when approached, the species could not be identified. As the number of dead wood available to turtles changed with fluctuating water level, data on number and group size of turtles (if they had any) and number of such groups were collected in two different seasons (high and low water level seasons) in a three km stretch of the lake. These were recorded for 16 days in January – February and 16 days in April – May. On each of these recording days the same data was recorded twice, between 0900 to 1100 hours and 1400 to 1600 hours, so that the effect of local weather conditions on the turtles’ basking behaviour is nullified across different days. Moreover, it was taken care off, that this data was collected only on sunny days.

3.5 Analysis of data

3.5.1 Data entry and exploratory data analysis

Data entry was done using Excel spreadsheet. Three of the six different areas sampled were taken as disturbed and the other three were

taken as undisturbed areas. Each of these two categories had two types of forest. So most of the data sets were rearranged and thus, count data for dead wood and tree densities and data on usage of each type of dead wood in each forest type were made into two different sets based on disturbed or undisturbed areas sampled.

Many of the users were clumped together for ease, like mammals, birds, reptiles, invertebrates. Each user was assigned to only one of the seven categories of users developed a priori using user matrix given in Thomas (1979) (Table 5). This was done with ecological information collected about the species from personal observations in field and from literature depending on the species concerned. For bird species Ali and Ripley (1983) was consulted. For mammals Prater (1971) and Wilson (1997) were consulted. But during the task of assigning of species to a user category more emphasis was given on ecological data available and observation in the field. When a species was found to be falling into more than one category, then it was put into a category, which seemed to be the ecological priority of the species concerned. The list of users found in Periyar Tiger Reserve and the categories they were placed into are given in Appendix III.

3.5.2 Statistical analysis

Differences between count data for density estimates of dead wood in different forest types were tested for by using independent sample t-test. Independent sample t-test was also used for testing differences between dead wood densities in disturbed and undisturbed areas. T-test was also used for testing differences between disturbance regimes (trampling percent) in two

Table 5. Dead wood user categories

User Code	Description	Example
U - 1	Live and reproduce in own hole excavated in snags or dead woods but forage elsewhere.	Woodpeckers
U - 2	Live and reproduce in hole made by another species or in a natural hole or under the decaying bark and forage elsewhere.	Parakeets, owls, bats
U - 3	Do not excavate but build nest on snags, stumps or on dead wood but forage elsewhere.	Cormorant, shrews
U - 4	Forage on the dead wood or nearby woody debris, though they may be living elsewhere.	Porcupine, pangolin, ants
U - 5	Make burrows, dens or use as cover under dead woods but forage elsewhere.	Geckos, skinks, frogs, snails, scorpions
U - 6	Use as perch or table while foraging nearby or traveling, or as scent post but forage and reproduce elsewhere.	Turtles, civets, otters, monitor lizards, raptors
U - 7	Live on dead wood most of their life.	Termites, caecilians

forest types and two categories of areas (disturbed and undisturbed) in each of the forest types.

One-way ANOVA was used for testing differences in disturbance regimes. Tukey's Post Hoc tests were used in conjunction with one-way ANOVA to understand which of the areas were similar and which were different with respect to the variable concerned.

Correlation between tree densities of each area and corresponding dead wood densities, in two different forest types and also in overall area was found by using Linear regression.

The data on enumeration of dead wood in eight 1 km stretches of the lake in high and low water level seasons were compared for significance differences using Wilcoxon matched pair test. For comparing differences between turtle numbers in high and low water level season the same test was used.

Cross tabulations were used to get frequencies of different user groups, like mammals, birds, reptiles and invertebrates for the subcategories, such as stages of dead wood and size classes (Appendix IV). Contingency tables were also obtained using the above method for size classes and stages. Then Chi-square analyses were done on appropriate contingency tables along with correlation analysis on some of them to get the trends.

3.6 Packages and books used

SPSS 8.0 was used for all analysis. Standard biostatistic books (Zar 1984, Sokal and Rohlf 1987) were used for interpretation of results.

RESULTS

4.1 Dead wood density, tree density and disturbance regimes

Densities of five different types of dead wood, viz., fallen logs, snags, stumps, cavities and dead branches, and also tree density were measured in Semi evergreen forests (SEF) and Moist deciduous forests (MDF). The overall densities of different types of dead wood in the Thekkady range of Periyar Tiger Reserve were as follows: Fallen logs = 109/ha. Snags = 17.5/ha. Stumps = 15/ha. Cavities = 9.5/ha. and Dead branches = 5/ha. In both the forest types fallen log (132.48 logs/ha.) is the most common form of dead wood encountered, followed by stumps (17.07 stumps/ha.) in SEF and snags (18.85 snags/ha.) in MDF. The densities of live trees in SEF and MDF are 376.60 and 239.32/ha, respectively. The dead wood densities of different types of dead wood have been summarised in table in Tables 6, 7 and 8. The overall tree density was 308 trees/ha, it was 376.60 ± 0.2516 trees/ha in SEF and 239.32 ± 0.2881 trees/ha in MDF. In the Thekkady range about 6 % of the all trees are snags.

4.1.1 Densities of dead wood in the two forest types

Densities of fallen logs, snags, stumps and cavities in two forest types were found to be significantly different at an α value of 0.05. T statistics was used (where sample size (n) was 600), the values of which, df and the 2-tailed significance (p) values are given in table 9. Only densities of dead branches were found to be similar across the forest types.

Table 6. Density of dead wood in SEF and MDF in Periyar Tiger Reserve

Types of Dead wood	Density in ha. for SEF	SE on density in SEF	Density in ha. for MDF	SE on density in MDF
Logs	132.48	± 0.1388	85.56	± 0.1157
Snags	16.11	± 0.0053	18.85	± 0.0057
Stumps	17.07	± 0.0053	12.78	± 0.0048
Cavities	11.52	± 0.0048	7.59	± 0.0046
Dead branches	4.44	± 0.0031	5.19	± 0.0034
Trees	376.60	± 0.2516	239.32	± 0.2881

Table 7. Density of dead wood in disturbed and undisturbed SEF in Periyar Tiger Reserve

Types of Dead wood	Density in ha. disturbed SEF	SE on density in disturbed SEF	Density in ha. undisturbed SEF	SE on density in undisturbed SEF
Logs	112.74	± 0.1332	152.20	± 0.1310
Snags	12.81	± 0.0069	19.41	± 0.0073
Stumps	13.19	± 0.0066	20.96	± 0.0072
Cavities	12.67	± 0.0063	10.37	± 0.0071
Dead branches	5.48	± 0.0047	3.41	± 0.0039
Trees	348.15	± 0.2072	405.06	± 0.2534

Table 8. Density of dead wood in disturbed and undisturbed MDF in Periyar Tiger Reserve

Types of Dead wood	Density in ha. disturbed MDF	SE on density in disturbed MDF	Density in ha. undisturbed MDF	SE on density in undisturbed MDF
Logs	73.33	± 0.1478	97.78	± 0.1251
Snags	14.74	± 0.0074	22.96	± 0.0077
Stumps	12.37	± 0.0062	13.19	± 0.0073
Cavities	7.78	± 0.0067	7.41	± 0.0063
Dead branches	4.59	± 0.0043	5.78	± 0.0052
Trees	205.43	± 0.2706	273.21	± 0.2273

4.1.2 Disturbance regimes observed in forests

One-way ANOVA was used to test for difference in the extent of disturbance across the 6 different forest patches. In semi evergreen forest, moist deciduous forest, and the overall, trampling signs in percentage differed significantly at an α level of 0.05 with F and p values of $\{(F = 233.459, n = 324, df = 318, p = 0.0001), (F = 264.380, n = 324, df = 318, p = 0.0001) \text{ and } (F = 497.564, n = 648, df = 642, p = 0.0001)\}$ respectively. The groups of areas with similar disturbances found using Tukey's HSD statistics are listed in Tables 10, 11 and 12 for overall, semi evergreen forest and moist deciduous forest respectively. The groups of area were as follows: Mullakudy and Tamburan Turathu were one of the groups in the undisturbed category and Mullakudy2 was the other stand-alone group that was more disturbed than the first group. In the disturbed category Anchurli and Shivalodu formed the first group, while Eddapalayam formed a more disturbed group by itself. T-test was used to test for a difference in trampling signs between areas categorized as 'disturbed' and 'undisturbed'. In semi evergreen forest and moist deciduous forest, and the overall, trampling signs in percentage were found to differ significantly between the 2 categories at .05 α with T and p values of $\{(T = 27.046, n = 324, df = 322, p = 0.0001), (T = 29.279, n = 324, df = 322, p = 0.0001) \text{ and } (T = 39.822, n = 648, df = 646, p = 0.0001)\}$ respectively.

4.1.3 Densities of dead wood in disturbed and undisturbed forests

Densities of fallen logs, snags, stumps, cavity and dead branches in disturbed and undisturbed semi evergreen forest were found to differ

Table 9. T statistics and p values for Dead wood density in SEF and MDF in Periyar Tiger Reserve

Dead wood	T statistics	df	Significance value
Logs	23.375	598	0.0001
Snags	3.157	598	0.002
Stumps	5.418	598	0.0001
Cavities	5.348	598	0.0001
Dead branches	1.454	598	0.147

Table 10. Overall-Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve

Area	Group 1	Group 2	Group 3	Group 4
Undisturbed category				
Mullakudy	13.43			
Tamburan Turathu	18.06			
Mullakudy2		34.86		
Disturbed category				
Anchurli			64.49	
Shivalodu			66.71	
Edappalayam				81.39
Significance	0.101	1.000	0.817	1.000

Table 11. In SEF–Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve

Area	Group 1	Group 2	Group 3	Group 4
Undisturbed category				
Mullakudy	12.87			
Tamburan Turathu	19.81			
Mullakudy2		35.46		
Disturbed category				
Anchurli			62.78	
Shivalodu			66.48	
Edappalayam				80.37
Significance	0.069	1.000	0.692	1.000

Table 12. In MDF–Tukey's HSD and clusters of areas with similar disturbance along with the significance of the differences within the groups in Periyar Tiger Reserve

Area	Group 1	Group 2	Group 3	Group 4
Undisturbed category				
Mullakudy	13.98			
Tamburan Turathu	16.30			
Mullakudy2		24.26		
Disturbed category				
Anchurli			62.20	
Shivalodu			66.94	
Edappalayam				82.41
Significance	0.942	1.000	1.000	1.000

significantly at an α level of 0.05. The T statistics (where n was 300), df and p values are listed in Table 13.

Within the moist deciduous forest type, only fallen log and snag densities differed significantly across disturbed and undisturbed categories at 0.05 α . The T statistics (where n was 300), df and p values are listed in Table 14.

4.1.4 Correlation between tree density and dead wood density

4.1.4.1 Fallen logs

Fallen log densities were found to be highly correlated having very high significance values, with tree densities in semi evergreen forest and moist deciduous forest, and overall, with correlation coefficient "R", coefficient of determination " R^2 ", and significance of correlation as follows: {(R = 0.984, R^2 = 0.968, p = 0.0001), (R = 0.976, R^2 = 0.953, p = 0.001), (R = 0.965, R^2 = 0.932, p = 0.0001)} respectively at 0.05 α . The graphs for these are given in Figure 3.

4.1.4.2 Snags

Snag densities were slightly correlated with tree densities in semi evergreen forest and moist deciduous forest, but poorly correlated overall, with correlation coefficient "R", coefficient of determination " R^2 ", and significance of correlation as follows: {(R = 0.683, R^2 = 0.466, p = 0.135), (R = 0.711, R^2 = 0.505, p = 0.113), (R = 0.029, R^2 = 0.001, p = 0.928)} respectively. But none of the correlations were significant at 0.05 α .

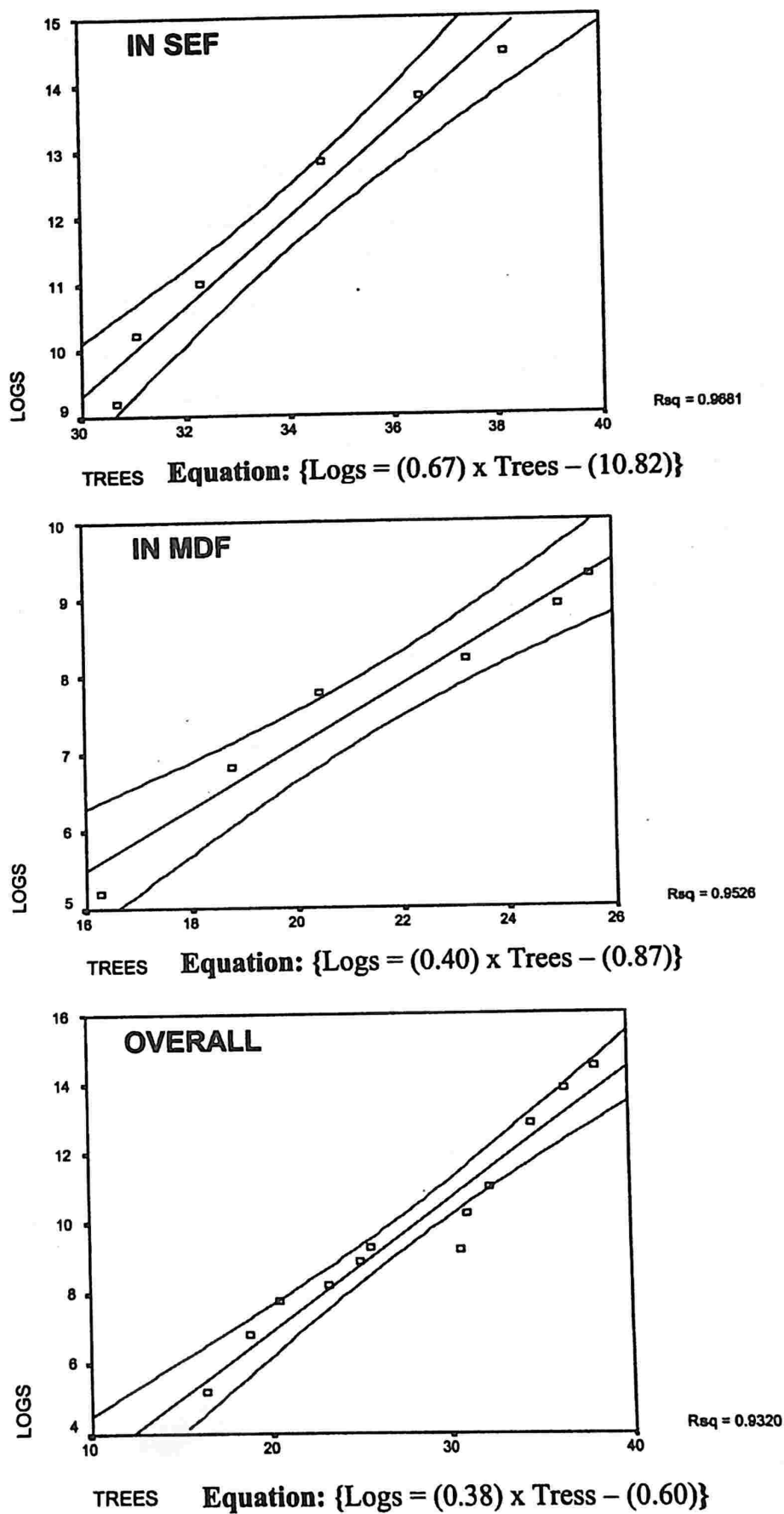
Table 13. T statistics and p values for Dead wood density in disturbed and undisturbed SEF in Periyar Tiger Reserve

Dead wood	T statistics	df	Significance value
Logs	19.017	298	0.0001
Snags	5.902	298	0.0001
Stumps	7.156	298	0.0001
Cavities	2.177	298	0.030
Dead branches	3.056	298	0.002

Table 14. T statistics and p values for Dead wood density in disturbed and undisturbed MDF in Periyar Tiger Reserve

Dead wood	T statistics	df	Significance value
Logs	11.362	298	0.0001
Snags	6.937	298	0.0001
Stumps	0.764	298	0.445
Cavities	0.723	298	0.716
Dead branches	0.003	298	0.115

Figure 3. Linear correlations of log and tree densities



4.1.4.3 Stumps

Stump densities were slightly correlated with tree densities in semi evergreen forest and, overall, but poorly correlated in moist deciduous forest. The correlation coefficient "R", coefficient of determination "R²", and significance of correlation of the above were as follows: {(R = 0.891, R² = 0.793, p = 0.017), (R = 0.634, R² = 0.402, p = 0.027), (R = 0.306, R² = 0.094, p = 0.555)} respectively. The correlations for semi evergreen forest and overall were significant at 0.05 α . The graphs are given in Figure 4.

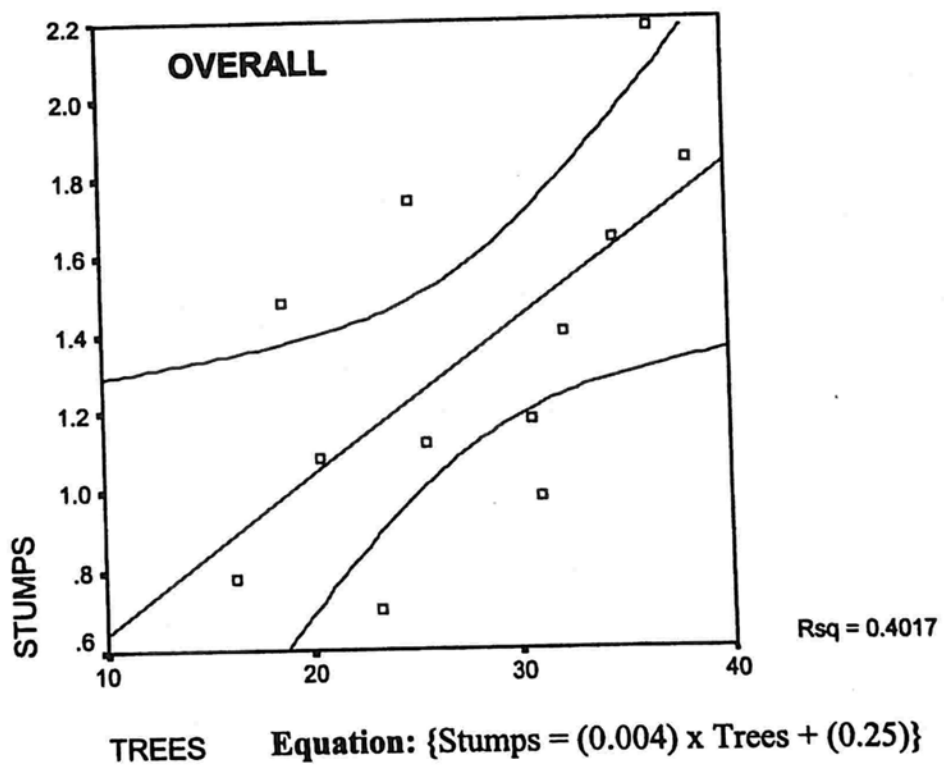
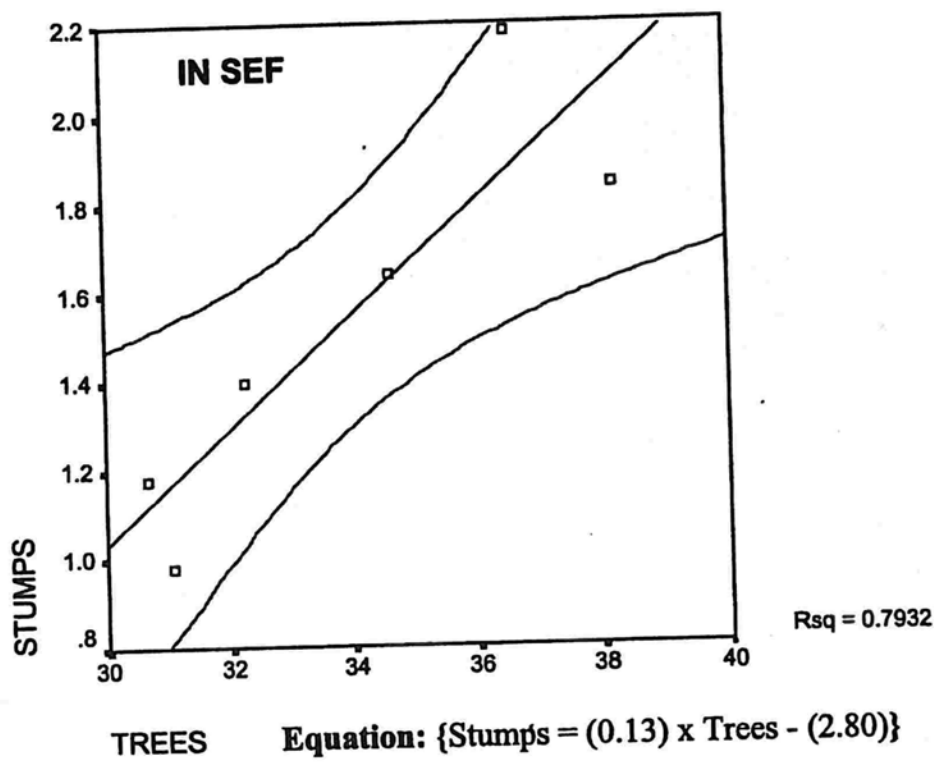
4.1.4.4 Cavities

Cavity densities were not correlated with tree densities in semi evergreen forest and moist deciduous forest, and overall. The correlation coefficient "R", coefficient of determination "R²", and significance of correlation of were as follows: {(R = 0.205, R² = 0.042, p = 0.696), (R = 0.106, R² = 0.011, p = 0.841), (R = 0.444, R² = 0.198, p = 0.148)} respectively.

4.1.4.5 Dead branches

Dead branch densities were slightly correlated with tree densities in semi evergreen forest and moist deciduous forest, but poorly correlated overall. The correlation coefficient "R", coefficient of determination "R²", and significance of correlation were as follows: {(R = 0.792, R² = 0.627, p = 0.061), (R = 0.665, R² = 0.442, p = 0.150), (R = 0.373, R² = 0.139, p = 0.233)} respectively. But both the correlations were not significant at 0.05 α .

Figure 4. Linear correlations of stump and tree densities



4.2 Dead wood availability during different seasons in the lake habitat

Dead wood density for the entire lake habitat was not estimated, as it would have been highly inappropriate to do so, because of the huge differences in the number of dead wood in different stretches of lake. Instead low and high water level season count data of dead wood in 8 different stretches of lake (i.e., n was 8), each stretch being 1 km in length were used to find whether there is any difference in number of dead wood between the seasons. The differences were tested with Wilcoxon matched paired test using ranks. The p values (2-tailed test significance values) for each pair of dead wood in the two seasons, the degrees of freedom (df) and the inferences drawn are given in Table 15. In Periyar Tiger Reserve winter and summer are high and low water level seasons respectively.

4.3 Usage of dead wood

4.3.1 Dead wood users

All dead wood users found in Periyar Tiger Reserve were put into the seven categories of users (Table 5). Each user was put into only one category out of the seven, even though some users belonged to more than one category (if category definition is to be taken into account). This was done to simplify the effort of analyzing the data, and with a definite plan, which involved finding the most important ecological use of the dead wood for those users and then placing the user in the corresponding user category. All users were also put into one of the many taxonomic classes. Table 16 gives the taxonomic groups and the corresponding user categories. The taxonomic

Table 15. Wilcoxon matched paired test's significance values for dead wood numbers in summer and winter, in the lake habitat in Periyar Tiger reserve

Dead wood	p values	df	Inference
Logs in water	0.038	7	More in winter
Logs on shore	0.016	7	More in summer
Stakes	0.012	7	More in summer
Snags	0.317	7	No difference between seasons
Stumps in water	0.012	7	More in summer
Stumps on shore	0.012	7	More in summer

Table 16. Dead wood users and the user categories they were placed in

Users	U1	U2	U3	U4	U5	U6	U7	Total
Mammals	-	2	1	4	1	4	-	12
Birds	10	10	1	1	-	34	-	56
Reptiles	-	-	-	-	2	3	-	5
Amphibians	-	-	-	-	2	-	1	3
Fish	-	-	-	-	-	1	-	1
Ants	-	-	-	7	-	-	-	7
Beetles	-	-	-	-	6	-	-	6
Spiders	-	-	-	-	4	-	-	4
Termites	-	-	-	-	-	-	2	2
Dipterans	-	-	-	-	3	-	-	3
Other Insects	-	-	1	-	-	4	-	5
Scorpions	-	-	-	-	3	-	-	3
Other Invertebrates	-	-	-	-	5	-	-	5
Epiphytes	-	-	-	-	2	-	-	2
Total	10	12	3	12	28	46	3	114

groups, ants, beetles, spiders, termites, dipterans, other insects, scorpions and other invertebrates were clumped together to form a group of user named 'invertebrates' for the ease of analysis. The total number of users observed using dead wood in Periyar Tiger Reserve during this study were 114 (Table 16). Of the 114 total users, 12 were mammals, 56 were birds, 5 were reptiles, and 35 were 'invertebrates'. The number of species of each taxonomic group using the four different kinds of dead wood is summarized in Table 17. Of the major dead wood users logs were being used maximum by mammals (58% i.e., 7 out of 12), snags by birds (87.5% i.e., 49 out of 56), stumps and cavities by mammals (42% and 33% respectively).

4.3.2 Use of cavities by different users, especially birds and mammals

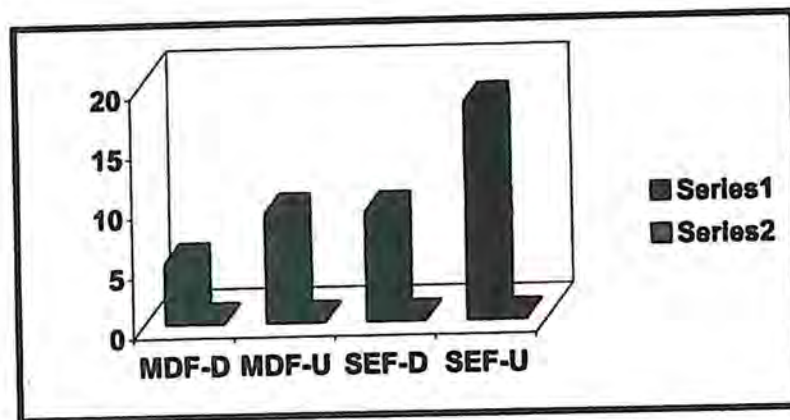
Use data for cavities was collected in four different habitat types (moist deciduous forest-D, moist deciduous forest-U, semi evergreen forest-D and semi evergreen forest-U). The groups of animals given in Table 17 were analysed for differences in degree of use with respect to the type of the cavity i.e., natural hollows and excavated cavities. The likelihood ratio values (LR) were used for interpretation (n for each habitat type was 36). Usage by mammals and birds differed significantly between the two cavity types across habitats (Table 18). Mammals were using natural hollows more than excavated cavities in semi evergreen forests than in moist deciduous forests, whereas, birds were using more excavated cavities in moist deciduous forests (Figure 5).

Table 17. Dead wood types and the number of users in the Thekkady range, Periyar Tiger Reserve

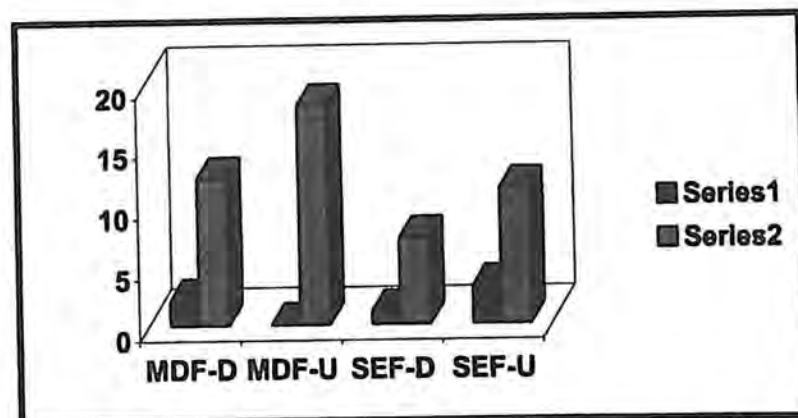
Users	Logs	Snags	Stumps	Cavities
Mammals	7	8	5	4
Birds	8	49	23	18
Reptiles	4	3	2	1
Amphibians	3	-	-	-
Fish	1	1	-	-
Ants	7	6	6	3
Beetles	6	6	6	4
Spiders	4	4	4	2
Termites	1	2	2	2
Dipterans	3	2	1	-
Other Insects	3	5	4	2
Scorpions	3	1	1	1
Other Invertebrates	6	3	3	2
Epiphytes	-	2	1	-
U1	-	10	6	9
U2	-	10	3	11
U3	1	2	-	1
U4	11	10	11	4
U5	26	19	17	11
U6	16	39	19	1
U7	2	2	2	2
Total Users	56	92	58	39

Figure 5. Use of cavities by mammals and birds in various habitat types

Mammals - Series 1 represents natural hollows and Series 2 represents excavated cavities.



Birds - Series 1 represents natural hollows and Series 2 represents excavated cavities.



Though reptiles and invertebrates were found to use cavities, they could be sampled only in natural tree hollows. So analysing that data set for the specific purpose (as done above for mammals, and birds) was not proper.

4.3.3 Use of fallen logs by different mammals, birds, reptiles and invertebrates

Use data for fallen log was collected in five different habitat types (moist deciduous forest-D, moist deciduous forest-U, semi evergreen forest-D, semi evergreen forest-U and Lake habitat). The groups of animals (Table 19) were analysed for differences in degree of use with respect to different fallen log stages, girth and length classes. Usage by mammals differed significantly with fallen log length across habitat types. Use by invertebrates differed significantly across habitat types only with respect to fallen log length across habitat types (n for each habitat was 54, except for lake habitat, for which it was 32). Shrews were using fallen logs only in lake habitat for nesting. Civets were using them for marking territory. Pangloins and bears were using later decay stages more than first decay stage.

4.3.3.1 Auto correlations of log stages to different size classes

Fallen log girth and length classes were significantly correlated to log stages (girth: LR = 74.482, $n_1 = n_2 = n_3 = n_4 = 54$, $df = 12$, $p = 0.0001$; length: LR = 53.47, $df = 12$, $p = 0.0001$).

4.3.2 Use of snags by different mammals, birds, reptiles and invertebrates

Use data for snags was collected in five different habitat types (moist deciduous forest-D, moist deciduous forest-U, semi evergreen forest-D, semi evergreen forest-U and Lake habitat). The organisms (Table 20) were analysed for differences in degree of use with respect to different snag stages, snag girth and height classes. The only significant relationship exhibited was shown in usage of different snag girth classes across habitat types by birds (n for each habitat was 36, except for lake habitat, for which it was 32).

4.3.4.1 Auto correlations of snag stages to different size classes

Snag girth and height classes were significantly correlated to snag stages (girth: LR = 22.21, $n_1 = n_2 = n_3 = n_4 = 36$, $df = 6$, $p = 0.001$; height: LR = 20.29, $n_1 = n_2 = n_3 = n_4 = 36$, $df = 6$, $p = 0.002$).

4.3.5 Use of stumps by different mammals, birds, reptiles and invertebrates

Use data for stumps was collected in 5 different habitat types (moist deciduous forest-D, moist deciduous forest-U, semi evergreen forest-D, semi evergreen forest-U and Lake habitat). The groups of animals (Table 21) were analysed for differences in degree of use with respect to different stump stages, stump girth and height classes. Usage by birds and invertebrates differed significantly across habitat types with respect to stump-girth. Usage by mammals, birds and invertebrates differed significantly with stump-height (n for each habitat was 36, except for lake habitat, for which it was 32).

Table 18: Use of 2 different types of cavities by mammals and birds across habitat types in Periyar Tiger Reserve. LR is likelihood ratio; df is degree of freedom; p is the probability; Sample sizes across the habitat types for cavities sampled are as follows: MDF-D = 36, MDF-U = 36, SEF-D = 36, SEF-U = 36.

User Category	Cavities		
	LR	df	p
Mammals	77.07	4	0.0001 *
Birds	59.25	4	0.0001 *

(Significant results are indicated by asterix)

Table 19: Use of different log stages, girth and length classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve. LR is likelihood ratio; df is degree of freedom; p is the probability; Sample sizes across the habitat types for logs sampled are as follows: MDF-D = 54, MDF-U = 54, SEF-D = 54, SEF-U = 54, Lake habitat = 32.

Users	Log Stage			Log Girth			Log Length		
	LR	df	p	LR	df	p	LR	df	p
Mammals	2.29	8	0.97	32.77	30	0.33	45.80	30	0.032 *
Birds	7.23	6	0.30	21.15	24	0.63	25.01	24	0.40
Reptiles	3.14	8	0.93	32.67	24	0.11	32.01	24	0.13
Invertebrates	3.43	8	0.09	38.12	30	0.15	53.30	30	0.006 *

(Significant results are indicated by asterix)

Table 20: Use of different snag stages, girth and height classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve. LR is likelihood ratio; df is degree of freedom; p is the probability; Sample sizes across the habitat types for snags sampled are as follows: MDF-D = 36, MDF-U = 36, SEF-D = 36, SEF-U = 36, Lake habitat = 32.

Users	Snag Stage			Snag Girth			Snag Height		
	LR	df	P	LR	df	p	LR	df	p
Mammal	1.36	4	0.851	40.19	30	0.10	40.56	30	0.09
Bird	1.423	4	0.840	54.26	30	0.004 *	29.12	30	0.312
Reptile	0.62	4	0.96	23.84	30	0.78	37.25	30	0.17
Invertebrate	2.79	4	0.59	43.45	30	0.053	37.72	30	0.16

(Significant results are indicated by asterix)

Table 21: Use of different stump stages, girth and height classes by mammals, birds, reptiles, invertebrates across habitat types Periyar Tiger Reserve. LR is likelihood ratio; df is degree of freedom; p is the probability; Sample sizes across the habitat types for stumps sampled are as follows: MDF-D = 36, MDF-U = 36, SEF-D = 36, SEF-U = 36, Lake habitat = 32.

Users	Stump Stage			Stump Girth			Stump Height		
	LR	df	p	LR	df	p	LR	df	p
Mammal	3.12	4	0.54	38.77	30	0.13	46.76	30	0.02 *
Bird	1.03	4	0.91	44.14	30	0.046 *	57.70	30	0.002 *
Reptile	0.75	4	0.95	21.97	30	0.855	30.61	30	0.435
Invertebrate	0.22	4	0.99	78.36	30	0.0001 *	63.31	30	0.0001 *

(Significant results are indicated by asterix)

4.3.5.1 Auto correlations of stump stages to different size classes

Stump girth and height classes were not significantly correlated to stump stages (girth: LR = 3.876, $n_1 = n_2 = n_3 = n_4 = 36$, $df = 6$, $p = 0.69$; height: LR = 1.22, $n_1 = n_2 = n_3 = n_4 = 36$, $df = 6$, $p = 0.976$).

4.3.6 Turtle and dead wood in the lake habitat

Usage (basking on) of dead wood by turtles was recorded in morning and evening hours of 16 days in winter and in summer in a 3 km stretch of lake habitat. They were using dead wood in significantly different numbers in winter and summer. T-tests were done on morning and evening data in the 2 different seasons separately. (Morning: $T = 12.90$, $n_{winter} = n_{summer} = 16$, $df = 30$, $p = 0.0001$), (Evening: $T = 12.06$, $n_{winter} = n_{summer} = 16$, $df = 30$, $p = 0.001$). Turtles were using more dead wood for basking in summer than winter. Even the numbers of turtles basking on each dead wood sample were more in summer, which ranged from 1 to 16. In winter the maximum number of basking on any particular dead wood sample was 2.

4.3.7 Large cormorant nests and stakes

4.3.7.1 Height class and number of nests

Numbers of large cormorant nests in each of the seven different height classes of stakes (Appendix IV) were analysed using Chi-square along with correlation analysis (n was 23). The result was as follows: (LR = 15.854, $df = 10$, $p = 0.104$). So the number of nests did not differ significantly across different height classes of stakes at 0.05 α . But the number of nests and the height classes of stakes were slightly correlated with a high degree of

significance. R and p values as follows: ($R = 0.59$, $p = 0.003$). As the number of branches increased so do the number of nests.

4.3.7.2 Girth class and number of nests

Different girth classes of stakes (Appendix IV) and the number of nests were cross tabulated. The result is as follows: ($LR = 12.60$, $df = 6$, $p = 0.05$). Thus, the number of nests didn't differ significantly across different girth classes at 0.05α . Even though the number of nests didn't differ significantly with girth classes they were slightly correlated with a high degree of significance. R and p values as follows: ($R = 0.55$, $p = 0.006$).

4.3.7.3 Number of branches and number of nests

After cross tabulation following results were generated: ($LR = 23.46$, $df = 6$, $p = 0.001$). Therefore, the number of nests varied significantly with number of branches on the stakes at an α level of 0.05 . Furthermore number of nests and number of branches on the stakes were highly correlated with a very high significance, whose correlation coefficient and significance values are as follows: ($R = 0.82$, $p = 0.001$).

DISCUSSION

5.1 Dead wood density

Dead wood density is the most important factor that affects dead wood users in a particular area. So before going into the details of the results of this study, a comparison of dead wood density results found in various studies is necessary. But as there is no Indian study to compare, here an attempt is being made to compare this study with studies done in temperate forests of other countries. MacMillan et al. in 1977 reported the estimated rate of fallen log recruitment to be 1.2 logs per ha. (0.49 log/acre) per year in a mid elevation, unmanaged old growth (470 year old) Douglas-fir stand. This means the density of fallen logs in the particular stand is roughly 470×1.2 per ha. = 564 per ha. This calculation is required here to compare with my study, because in most of the studies (MacMillan et al. 1977, McCay 2000) the fallen log density is given in metric tones (MT) per ha. In this study semi evergreen forest is the old growth forest type. So when compared to fallen log density in semi evergreen forest (Table 6) to the 470 year old Douglas fir forest stand one finds that the value of 132.48 fallen logs/ha. is very small compared to 564 fallen logs per ha. The reason for this difference could be that, in the humid tropical forests like the semi evergreen forest in this study decomposition rate would be faster (because of higher relative humidity and temperature) than it would be in the Douglas-fir forests of the temperate region, and secondly there could be a very high difference in the recruitment rate of fallen logs in the semi evergreen forest or other forest types of the tropics. This can be also said about other types of dead wood density, like

snags (Gibbs et al. 1993). In that study the Gibbs et al. (1993) discussed the comparative snag availability in tropical versus temperate forests and states that snag densities in tropical and subtropical forests were lower than in forests of higher latitudes (temperate forests).

Just for comparison the density of fallen logs in various forest types in Oregon and Washington compiled by Rose et al. (2001) is given in Table 22. In this the authors have estimated mean fallen log pieces per acre with standard error (SE) in 10 different wildlife habitat types (forest types) in different successional stages. In the Table 22 only the fallen log density for all successional stages is mentioned and compared with the current study.

5.2 Factors influencing dead wood density

5.2.1 Forest type

Log and tree densities were higher in semi evergreen forest than in moist deciduous forest (Table 6). Higher tree density in semi evergreen forest in comparison to moist deciduous forest was as expected (Nair 2002). Tree and log densities were highly correlated with very high degree of significance in both the forest types (Figure 3). Similar results were found by Christensen et al. (1996), where they got strong positive correlation between coarse woody debris (log) density and riparian tree density (which is similar to semi evergreen forest) with $R^2 = 0.78$. This could be the reason of very high log density in semi evergreen forest when compared to moist deciduous forest. Similar results were mentioned by Bilby and Ward (1991), Goodburn and Lorimer (1998). They found more amount of large woody debris (logs) in old

Table 22. A comparison between fallen log densities of different forest types of temperate Oregon and Washington, USA and tropical Periyar Tiger Reserve (PTR), India

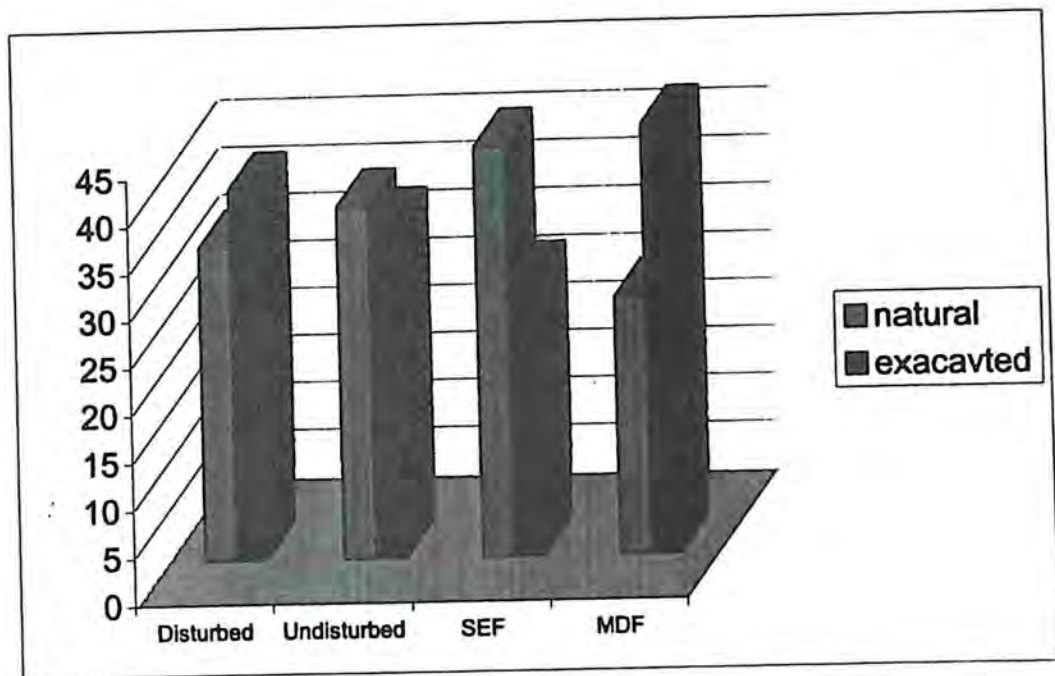
Wildlife Habitat	Mean log pieces/acre	SE	Reference
Westside conifer hardwood	110	± 2.1	Rose et al. (2001)
Westside white oak Douglas fir	48.9	± 3.8	-do-
SW or mixed conifer hardwood	63.5	± 2.3	-do-
Montane mixed conifer	99.8	± 1.9	-do-
Subalpine parkland	47.8	± 5.1	-do-
Eastside mixed-conifer	58.5	± 0.9	-do-
Lodgepole pine	77.3	± 2.8	-do-
Ponderosa pine (eastside)	29.7	± 0.9	-do-
Western juniper	7.8	± 1.4	-do-
All wildlife habitat types	71.0	± 0.7	-do-
Semi evergreen forest (PTR)	53.0	± 0.1	This study
Moist deciduous forest (PTR)	34.2	± 0.1	-do-
Overall (PTR-Thekkady range)	43.6	± 0.1	-do-

growth forests (similar to semi evergreen forest of my study area) compared to second growth forests (similar to moist deciduous forest of the study area).

Stump density was also found to be higher in semi evergreen forest than moist deciduous forest. This could be because of the fact that most of the stumps found were the stumps that remained after tree falls. And as fallen trees (logs) were more in semi evergreen forest, it was purely on the expected line that stump density was higher in semi evergreen forest. This could be the reason for significant correlation between stump and tree densities in semi evergreen forest.

While snag density was higher in moist deciduous forest, cavity density was higher in semi evergreen forest. The possible reason for higher snag density in moist deciduous forest could be that in semi evergreen forest few snags stand for long and they become logs (after falling). This is due to the predominantly moist soil conditions present in semi evergreen forest, which were mostly observed along the streams. Moreover, semi evergreen forests were observed on steeper gradients than moist deciduous forest patches, where trees were more likely to topple. This also possibly explains the higher log density in semi evergreen forest than moist deciduous forest. Higher cavity density in semi evergreen forest (Table 6) was because of higher number of natural tree hollows. In fact, the number of excavated cavities was less in semi evergreen forest, though this data comes from the use data, which was collected differently (Figure 6). The reason could be that many trees in semi evergreen forest have buttresses and tend to be bigger. However excavated cavities were more in moist deciduous forest, which could

Figure 6. A comparison of the numbers of natural tree hollows and excavated cavities sampled for usage data in disturbed and undisturbed areas, and also in SEF and MDF



be due to the fact that more snags were found in moist deciduous forest than in semi evergreen forest.

5.2.2 Extent of disturbance in forests

As presumed while forming the two categories of areas in forests, viz., "disturbed" and "undisturbed", the disturbance levels as measured by trampling were significantly different. In semi evergreen forest and moist deciduous forest, and the overall, trampling signs in percentage were found to be more in disturbed in comparison to undisturbed areas.

The disturbance regime data based on trampling percentage in both the forest types and overall gave same 'groups of areas' (Tables 10, 11 and 12). In the undisturbed category, Mullakudy² was found to be more disturbed than Mullakudy and Tamburan Turathu. The reason for this could be the annual pilgrimage where tribals congregate in large numbers in Mullakudy². They camp for several days along riverine tracts in the area, thus causing disturbance. In the disturbed category Edappalayam was found to be more disturbed than Anchurli and Shivalodu (Tables 10, 11 and 12). This result showed up despite the observed fact that tribal fishermen were using Shivalodu and Anchurli more than Edappalayam. It could be probably because of following reasons:

- 1) Fishermen, rarely venture inside forest, and they mostly stay near lake shore and small grassy islands during night and in day time involved in selling fish in the local market or angling fish sitting on the shore.

- 2) Edappalayam area has few places where tourists come and stay and also tribals frequent the forest patches in the area to collect minor forest

produce (observed) and to cross over to Anchurli side of their colony. In general, log density was higher in the undisturbed categories of both forest types. This is probably due to the extraction of fallen logs by humans in the disturbed areas. However, higher densities of snags in undisturbed forests of both types, and the higher densities of stumps, cavities and dead branches in undisturbed semi evergreen forest could not be attributed to any specific reason.

5.2.3 Water level in the lake

Numbers of dead wood in the lake habitat differ across low and high water level seasons differently for various types of dead wood (Table 15). Number of 'snags on shore' did not vary across seasons, because water level did not drop as much as to expose 'stakes' and to make them 'snags on shore'. During high water level season, i.e., during the winter, the logs present near shoreline were counted as 'logs in water' but in summer due to lower water level they were counted as 'logs on shore'. This explains more 'logs in water' during winter and higher number of 'logs on shore' in summer season (low water level). The drop in water level (summer) explains higher number of 'stakes', and stumps on both, shore as well as water.

5.3 Usage of dead wood by different groups of users

Here the various aspects of third, fourth and fifth objectives are discussed together under each taxonomic groups for ease of discussing.

5.3.1 Mammals

Of the 12 species of mammals found using dead wood (Appendix III), 7 were found using logs, 8 using snags, 5 using stumps and 4 using cavities (Table 17). The most interesting of the findings about usage of dead wood by mammals were as follows:

a) Shrews were the most important mammal users on lakeshore. Pruitt (1959) says that most shrews depend on burrow environments with a high relative humidity, like logs and stumps. They were using it for nesting. Some logs had more than 1 nest inside them. Menzel et al. (1999) also mentions the use of coarse woody debris (logs) by shrews and rodents. Rhoades (1986) discusses the importance of logs for 32 small mammals, including shrews. According to Rhoades, fungi growing on downed wood are major food resource for the small mammals.

b) Bats were using natural tree hollows for roosting (Wilson 1997, Kalcounis and Brigham 1998, Ormsbee and McComb 1998, Jung et al. 1999, Waldein et al. 2000) and that too more in semi evergreen forest (Figure 5), as the number of natural tree hollows in semi evergreen forest was more than that of the moist deciduous forest (Figure 6)

c) Pangolins, porcupines and bears were found to be using the more decayed stages (2nd and 3rd stages) of logs rather than earlier stages. They were using them for feeding on termites, ants, and other insects (Prater 1971). This was proven by the following results obtained for log stages and length classes. Stages and length classes of logs were highly correlated, and it was generally observed during field sampling that logs of highly decayed classes (i.e., later stages) were shorter in length across habitat types. This

was because most parts of older logs were decomposed to become soil. And then such logs were harbouring more termites and ants, which show up as significant degree of difference in usage of length classes of logs by invertebrates.

d) Civet droppings were found on many logs, mostly first stage ones, but the importance of logs for civets for marking territories could not be inferred because of another observation of civet droppings on live roots of large trees on many occasions.

e) Another interesting finding during this study was the use of dead wood on the lakeshore by wild boar. They were most probably feeding on the termites or other insects, like beetles and ants, found in those dead wood.

5.3.2 Birds

During the study 56 species of birds found in Periyar Tiger Reserve were observed to be using dead wood for various purposes. Only 8 were found using logs, while 49, 23, and 18 were found using snags, stumps and cavities respectively (Table 17). The major findings related to birds were as follows:

a) Birds were found to use excavated cavities more than natural hollows. This was on the expected line with more number of bird species there in Periyar Tiger Reserve those which use excavated cavities than the ones which use natural hollows (Ali and Ripley 1983) – {8 species of woodpeckers, 2 species of parakeets, 1 lorikeet, 2 species of mynas, 2 species of barbets and 3 species of owls were found to use excavated

cavities, as against only 2 species of hornbills which use natural hollows – See Appendix III).

b) Birds were found to use different girth classes of snags differentially across habitat types (Table 20). Higher girth class snags were used more in semi evergreen forest than in moist deciduous forest, where medium girth class snags were being used. This could be due to the differential size class of snags present in semi evergreen forest and moist deciduous forest or it could be due to different species using snags in different forest types. But for a proper explanation of this result may be some better analysis needs to be done on the data set or this has to be studied in further detail.

c) Another important result related to birds was the significant difference in the number of large cormorant nests in relation to the number of branches of stakes. Numbers of nests were found to be higher on stakes with more number of branches. Large cormorants are social birds (Ali and Ripley 1983) and this may be the reason for the above observation. And none of the stakes with nests were less than 90 cm in girth.

5.3.3 Reptiles

Out of the 5 species of reptiles found to be using dead wood, 4 were using logs, 3 snags, 2 stumps and 1 cavity (Table 17). The most important finding regarding reptiles was the significant difference in the usage of dead wood in general by turtles for basking in the lake habitat between winter (high water level season) and summer (low water level season). Significantly higher numbers of turtles were found basking in summer than in winter. This could

be because of the significantly higher number of dead wood available to bask in summer when compared to winter, due to lower water level. Lindeman (1999) mentions about the correlation between total turtle density and dead wood density and also talks about the basking densities, which were never high in places where dead wood densities were low.

5.3.4 Amphibians and invertebrates with other users

The numbers of species of amphibians observed using dead wood during my study were 3 (two were frogs and one was a caecilian) (Table 17 and Appendix III), all of which were using logs in the lake habitat. Sightings of fish using dead wood were limited to the logs and snags (Table 17) in the lake. Epiphytes were seen on snags and stumps only (Table 17). One of the 2 epiphytes recorded was a species of *Ficus*. Data on dead wood usage by amphibians, fish and epiphytes were collected. But due to the low sample size they could not be analysed statistically for deriving any conclusion.

In all 34 morphospecies of various kinds of invertebrates were found to use dead wood during my study, of which 33 were using logs, 29 using snags; 27 using stumps and 16 using cavities (Table 17). The most important of these users were termites, of which 2 morphospecies were found. Other major invertebrate groups found using dead wood were ants, beetles, and scorpions. Snails, flatworms and earthworms were also found using dead wood. Occasional snails were found inside cavities 8 – 9 feet above forest floor. McCay (2000) describes fallen logs as habitat for many invertebrates (McCay 2000). Invertebrates are one of the causes of for creation of snags and help in decomposition of dead wood also, for example, pseudoscorpions,

earwigs, mites, nematodes, slugs, millipedes, earthworms make use of downed wood and help in its decay (Hunter 1990).

5.4 Other important results

Snag girth and height classes were correlated to snag stages. This is explained easily by the fact that as snags decay they lose barks, loose woody xylem and their top portions break (Hunter 1990). Thus, they lose their girth and height with progressive decay stages.

5.5 Conservation implications

As mentioned several times in this study, 'dead wood' though being an important natural resource, highly valuable for the ecosystem, whether terrestrial (Hagan and Grove 1999) or aquatic (Gregory et al. 1993, Gippel 1995), foresters and managers ignore its importance and allow this valuable resource to be harvested indiscriminately from the forest ecosystem for various reasons (Hagan and Grove 1999). Indiscriminate use of dead wood by humans causes severe harm to native flora and fauna (Sonenshine and Levy 1981, Hokkanen et al. 1982), which need dead wood for their survival (Ganey 1999).

In India, the problem of clear felling in Protected Areas (PA) is virtually absent, thanks to the strict Wildlife Protection Act of 1972. Nevertheless, the problem of extraction of dead wood by villagers in and around PAs for sustenance is rampant and is putting tremendous pressure on the PA managers to look for alternatives. Unfortunately it becomes difficult for PA managers in India to prove the importance of dead wood in forest ecosystems

to any decision making body, because of the lack of study on dead wood and its users in forests of India. This study will hopefully set a benchmark that can be referred to by forest managers and ecologists alike for proving the importance of dead wood in the Indian context. This will most probably lead to the increased awareness about this neglected resource among the ecologists.

Though due to the short study period, various important aspects of dead wood ecology, like user density, decay rate, recruitment rate of dead wood in the ecosystem could not be studied, there is very good scope for further studies on this relatively new topic in the Indian context.

REFERENCES

- ABE*. 1985. Towards a perspective on energy demand and supply in India in 2004/05. Advisory Board on Energy, Government of India, NewDelhi, India.
- ALI, S., AND S.D. RIPLEY. 1983. Handbook of the birds of India and Pakistan. Compact Edition. Oxford University Press, New Delhi, India.
- ALLEN, R.B., P.W. CLINTON, AND M.R. DAVIS. 1997. Cation storage and availability along a *Nothofagus* forest development sequence in New Zealand. *Canadian Journal of Forest Research* 27:323-330.
- AMARANTHUS*, M.P., D.S. PARRISH, AND D.A. PERRY. 1989. Decaying logs as moisture reservoirs after drought and wildfire: Proceedings of watershed 89: A conference on the stewardship of soil, air and water resources: 191-194. E.B. Alexander (Ed.). U.S. Forest Service, Juneau, Auckland.
- ANOOP, K.R. 2001. Factors affecting habitat selection and feeding, habits of smooth coated otter (*Lutra perspicillata*) in Periyar Tiger Reserve, Kerala. M.Sc. dissertation, Rajkot: Saurashtra University.
- APPS, M.J., AND D.T. PRICE. 1996. Forest ecosystems, forest management and the global carbon cycle. Springer. New York.
- BENDEL*, P.R., AND J.E. GATES. 1987. Home range and microhabitat partitioning of the southern flying squirrel (*Glaucomys volans*). *Journal of Mammalogy* 68:243-255.
- BENNETT, B. 1995. Isn't it funny how possums like hollows? *Ecos* 83:36.
- BENNETT, B. 1997. Fungi, fast food of the forest. *Ecos* 91:36.

- BILBY, R. E., AND J. W. WARD. 1991. Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in southwestern Washington. *Canadian Journal of Fisheries and Aquatic Sciences* 48:2499-2508.
- BINKLEY, D., K. CROMACK, JR., AND R.L. FREDRICKSEN. 1982. Nitrogen accretion and availability in some snowbrush ecosystems. *Forest Science* 28(4):720-724.
- CAREY*, A.B., AND M.L. JOHNSON. 1995. Small mammals in managed, naturally young, and old-growth forests. *Ecological applications* 5:336-352.
- CAREY, A.B., T.M. WILSON, C.C. MAGUIRE, AND B.L. BISWELL. 1997. Dens of northern flying squirrels in the Pacific Northwest. *Journal of Wildlife Management* 61:684-699.
- CHAMPION, H.G., AND S.K. SETH. 1968. A revised survey of the forest types of India. Manager of Publications, Delhi, India.
- CHRISTENSEN, D. L., B. R. HERWIG, D. E. SCHINDLER, AND S. R. CARPENTER. 1996. Impacts of lakeshore residential development of coarse woody debris in north temperate lakes. *Ecological Applications* 6:1143-1149.
- CONNER*, R.N. 1978. Snag management for cavity nesting birds: In proceedings of the workshop on management of southern forests for nongame birds: 120-129. R M. Degraaf, (Ed.). USDA Forest Service Southeast Asheville, N.C.
- CONNOR*, R.N., AND B.A. LOCKE. 1982. Fungi and red-cockaded woodpeckers' cavity trees. *Wilson Bulletin* 94:64-70.

- CONNOR*, R.N., AND O.K. MILLER, JR., AND C.S. ADKISSON. 1976. Woodpecker dependence on trees infected by fungal heart rots. *Wilson Bulletin* 88:575-581.
- CORNABY, B.W., AND J.B. WAIDE. 1973. Nitrogen fixation in decaying chestnut logs. *Plant and Soil* 39(2):445-448.
- COWARDIN, L.M., G.E. CUMMINGS, AND P.B. REED, JR. 1967. Stump and tree nesting by mallards and black ducks. *Journal of Wildlife Management* 31:229-235.
- CROMACK*, K., C.C. DELWICHE, AND D.H.M.C. NABB. 1979. Prospects and problems of nitrogen management using symbiotic nitrogen fixers: 210-223. In *Symbiotic nitrogen fixation in the management of temperate forests*: J.C.Gordon, C.T.Wheeler and D.A.Perry, (Ed.). Forest Research Lab. Corvallis, Oregon.
- DEYRUP*, M.A. 1975. The insect community of dead and dying Douglas-fir. The Hymenoptera - Coniferous Forest Biome, Ecosystem Analysis Study Bulletin 6:104. Seattle, Washington.
- DICKSON, J.G., R.N. CONNER, AND J.H. WILLIAMSON. 1983. Snag retention increases bird use of a clear-cut. *Journal of Wildlife Management* 47:799-804.
- DIMOCK*, E.J. 1974. Animal populations and damage: A state of knowledge compendium. USDA Forest Service General Technical Report PNW-GTR-24.
- DUNN*, J.P., T.W. KIMMERER, AND G.L. NORDIN. 1986. Attraction of the two-lined chestnut borer, *Agilus bilineatus* (Weber) (Coleoptera: Buprestidae),

- and associated borers to volatiles of stressed white oak. *Canadian Entomology* 118:503-509.
- ELTON*, C.S. 1966. *The pattern of animal communities*. Methuen, London. 432 pp.
- EVERETT, R. A., AND G. M. RUIZ. 1993. Coarse woody debris as a refuge from predation in aquatic communities an experimental test. *Oecologia (Berlin)* 93:475-486.
- FLEBBE, P. A. 1999. Trout use of woody debris and habitat in Wine Spring Creek, North Carolina. *Forest Ecology and Management* 114:367-375.
- FRANKLIN*, J.F., AND T.A. SPIES. 1991. Composition, function and structure of old-growth Douglas-fir forests: Wildlife and vegetation of unmanaged Douglas fir forests. U.S. Forest Service, General Technical Report, PNW-GTR-285: 71-82: L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H Huff (Technical Coordinators). Pacific Northwest Research Station, Portland, Oregon.
- GANEY, J.L. 1999. Snag density and composition of snag populations on two National Forests in northern Arizona. *Forest Ecology and Management* 117:169-178.
- GIBBS, J.P., M.L. HUNTER, JR., AND S.M. MELVIN. 1993. Snag availability and communities of cavity nesting birds in tropical versus temperate forests. *Biotropica* 25:236-241.
- GIPPEL, C.J. 1995. Environmental hydraulics of large woody debris in streams and rivers. *Journal of Environmental Engineering-ASCE* 121:388-395.
- GONOR*, J.J., J.R. SEDELL, AND P.A. BENNER. 1988. What we know about large trees in estuaries in the sea, and on coastal beaches: From the forest to

- the sea: A story of fallen trees. U.S. Service, General Technical Report PNW-GTR-229: 83-112: C. Maser, R.F. Tarrant, J.M. Trappe, and J.F. Franklin, (Technical editors). Pacific Northwest Research Station, Portland, Oregon.
- GOODBURN, J. M., AND C. G. LORIMER. 1998. Cavity trees and coarse woody debris in old-growth and managed northern hardwood forests in Wisconsin and Michigan. *Canadian Journal of Forest Research* 28:427-438.
- GORDON*, K. 1943. The natural history and behavior of the western Chipmunk and the mantled ground squirrel. Oregon State Monograph. Std .Zool.5,104.Oregon State college University Press,Corvallis.
- GRAHAM, S.A. 1925. The felled tree trunk as an ecological unit. *Ecology* 6(4):397-411.
- GREEN, P., AND G.F. PETERKEN. 1997.Variation in the amount of dead wood in the woodlands of the lower Wye valley, UK in relation to the intensity of management. *Forest Ecology and Management* 98:229-238.
- GREGORY, K.J., R.J. DAVIS, AND S. TOOTH. 1993. Spatial-distribution of coarse woody debris dams in the Lymington Basin, Hampshire, UK. *Geomorphology* 6:207-224.
- GREGORY, S.V., F.J. SWANSON, W.A. MCKEE, AND K.W. CUMMINS. 1991. An ecosystem perspective of riparian zones. *Bioscience* 41:540-551.
- GRIER*, C.C., AND R.S. LOGAN. 1977. Old-growth *Pseudotsuga menziesii* communities of a western Oregon watershed: biomass distribution and production budgets. *Ecological Monographs* 47:373-400.
- GRIMMETT, R., C. INSKIPP, AND T. INSKIPP. 1999. Pocket guide to the birds of the Indian subcontinent. Oxford University Press, New Delhi, India.

- HAGAN, J.M., AND S.L. GROVE. 1999. Coarse woody debris. *Journal of Forestry* 97:6-11.
- HARMON, M.E., AND J.F. FRANKLIN. 1989. Tree seedlings on logs in Picea-Tsuga forest of Washington and Oregon. *Ecology* 70(1):48-59.
- HARMON, M.E., J.F. FRANKLIN, F.J. SWANSON, P. SOLLINS, S.V. GREGORY, J.D. LATTIN, N.H. ANDERSON, S.P. CLINE, N.G. AUMEN, J.R. SEDELL, G.W. LIENKAEMPER, K. CROMACK JR., AND K.W. CUMMINS. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15:133-302.
- HOKKANEN*, H., T. TORMALA., AND H. VUORINEN. 1982. Decline of the flying squirrel *Pteromys volans* L. populations in Finland. *Biological conservation* 23:273-284.
- HUNTER, M.L., JR. 1990. *Wildlife, Forests, and Forestry – Principles of Managing Forests for Biological Diversity*. Prentice-Hall Inc. New Jersey, USA.
- JUNG, T.S., AND I.D. THOMPSON, R.D. TITMAN, AND A.P. APPLEJOHN. 1999. Habitat selection by forest bats in relation to mixed-wood stand types and structure in central Ontario. *Journal of Wildlife Management* 63:1306-1319.
- KALCOUNIS, M.C., AND R.M. BRIGHAM. 1998. Secondary use of aspen cavities by tree-roosting big brown bats. *Journal of Wildlife Management* 62:603-611.
- KEEN, F.P. 1955. The rate of natural falling of beetle-killed ponderosa pine snags. *Journal of Forestry* 53(10):720-723.

- KHAN, J.A., W.A. RODGERS, A.J.T. JOHNSINGH, AND P.K. MATHUR. 1994. Tree and shrub mortality and debarking by Sambar *Cervus unicolor* (Kerr) in Gir after a drought in Gujarat, India. *Biological Conservation* 68:149-154.
- LINDEMAN, P.V. 1999. Surveys of basking map turtles *Graptemys* spp. In three river drainages and the importance of deadwood abundance. *Biological Conservation* 88:33-42.
- LOHR, S.M., S.A. GAUTHREUX, AND J.C. KILGO. 2002. Importance of Coarse Woody Debris to Avian Communities in Loblolly Pine Forests. *Conservation Biology* 16:767-777.
- MACMILLAN, P., J. MEANS, G.M. HAWK, K. CROMACK, JR., AND R. FEGEL. 1997. Log decomposition in an old-growth Douglas-fir forest. North-west Science. Assoc. Program and Abstract at 50th annual mtg. Pullman, WA, Washington State university Press, WA, USA.
- MACNALLY, R., A. PARKINSON, G. HORROCKS, AND M. YOUNG. 2002. Current loads of coarse woody debris on South-eastern Australian Floodplains: Evaluation of change and implications for restoration. *Restoration Ecology* 10(4):627-635.
- MACNALLY, R., A. PARKINSON, G. HORROCKS, L. CONOLE, AND C. TZAROS. 2001. Relationships between terrestrial vertebrate diversity, abundance and availability of coarse woody debris on South-eastern Australian floodplains. *Biological Conservation* 99:191-205.
- MANSON, R.R., AND B.E. WICKMAN. 1991. Integrated pest management of the Douglas-fir tussock moth. *Forest Ecology and Management* 39:119-130.
- MASER*, C., R.G. ANDERSON, K. CROMACK, JR., J.T. WILLIAMS, AND R.E. MARTIN. 1979. Dead and down woody material. In *Wildlife habitats in*

- managed forest: the Blue Mountains of Oregon and Washington: 78-95.
J.W. Thomas (Ed.). Washington, DC: United States Department of
Agriculture Forest Service Agricultural Handbook No. 553.
- MCCAY, T.S. 2000. Use of Woody Debris by Cotton Mice (*Peromyscus
gossypinus*) in a Southeastern Pine Forest. *Journal of Mammalogy*
81:527-535.
- MCCOMB*, W.C., S.A. BONNEY, R.M. SHEFFIELD, AND N.D. COST. 1986. Den
tree characteristics and abundance in Florida and South Carolina. *Journal
of Wildlife Management* 50:584-591.
- MENZEL, M. A., W. M. FORD, J. LAERM, AND D. KRISHON. 1999. Forest to wildlife
opening: Habitat gradient analysis among small mammals in the southern
Appalachians. *Forest Ecology and Management* 114:227-232.
- NAIR, P.V. 2002. Base line mapping of Periyar Tiger Reserve and surrounding
areas. KFRI 322/99. Kerala Forest Research Institute, Thrissur, Kerala,
India
- ORMSBEE, P.C., AND W.C. MCCOMB. 1998. Selection of day roosts by female
long-legged myotis in the central Oregon Cascade Range. *Journal of
Wildlife Management* 62: 596-603.
- PANWAR, H.S. 1983. Community and private forests as habitat supplement to
wildlife. A presentation to the seminar-cum workshop on social forestry at
the Indian Institute of Forest Management, Bhopal, India
- PRATER, S.H. 1971. The book of Indian animals. Eleventh Impression.
Bombay Natural History Society. Oxford University Press, Mumbai, India.

- PRUITT*, W.O., JR. 1959. Microclimate and local distribution of small mammals on the George reserve, Michigan. *Miscellaneous Publications of the Museum of Zoology, University of Michigan* 109:1-27.
- RAPHAEL, M.G., AND M. WHITE. 1984. Use of snags by cavity nesting birds in the Sierra-Nevada California. *Wildlife Monograph* 86:1-66.
- RAPHAEL, G.M., AND M. WHITE. 1986. Use of snags by cavity-nesting birds in the Sierra Nevada. *Wildlife Monographs* 86:1-66.
- RAVINDRANATH, N.H., AND D.O. HALL. 1995. *Biomass, Energy and Environment: A developing Country perspective from India*. Oxford University Press Inc., New York.
- RHOADES, F. 1986. Small mammal mycophagy near woody debris accumulations in the Stehekin River Valley, Washington [USA]. *Northwest Science* 60:150-153.
- ROSE, C.L., MARCOT, B.G. MELLEN, T.K. OHMANN, J.L. WADELL, K.L. LINDLEY, D.L., AND B. SCHREIBER. 2001. Decaying wood in Pacific Northwest Forests: Concepts and tools for habitat management. In *Wildlife Habitat Relationships in Oregon and Washington*: D.H Johnson and T.A. O'Neil (Managing Directors). Oregon University Press, Corvallis, USA.
- RUGGIERO, L.F., D.E. PEARSON, AND S.E. HENRY. 1998. Characteristics of American Marten den Sites in Wyoming. *Journal of Wildlife Management* 62:663-673.
- SALLABANKS, R., B.G. MARCOT, R.A. RIGGS, C.A. MEHL, AND E.B. ARNETT. 2001. Wildlife of Eastside (interior) forests and woodlands. In *wildlife – habitat relationships in Oregon and Washington*: 213-238. D.H. Jhonson

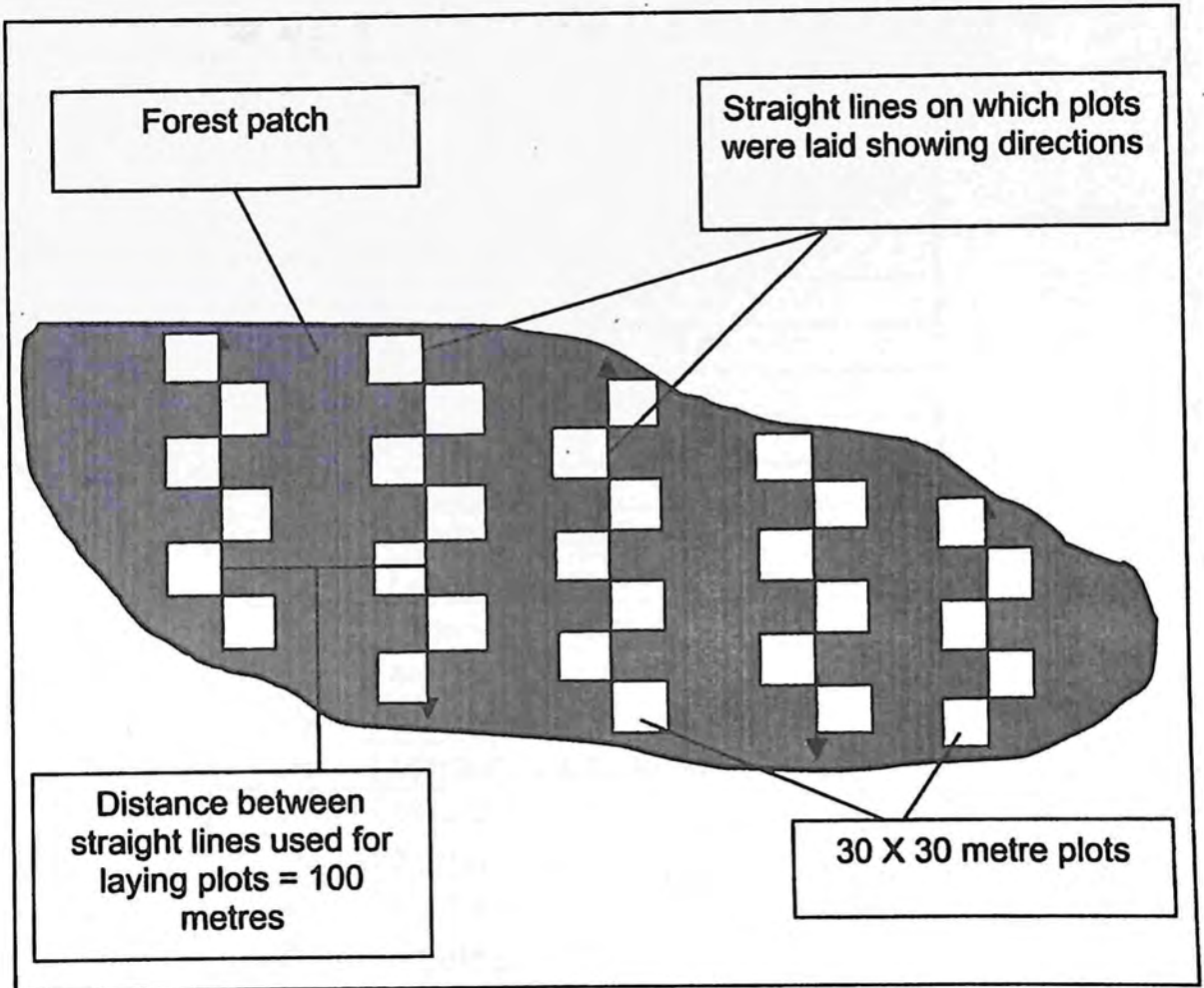
- and T.A. O'neil (Managing Directors). Oregon State University Press, Oregon, USA.
- SARRE, A. 1999. Hearts of darkness. *Ecos* 98:10-16.
- SCHREIBER, B., AND D.S. DECALESTA. 1992. The relationship between cavity-nesting birds and snags on clearcuts in western Oregon. *Forest Ecology and Management* 50:299-316.
- SHARMA, S.K. 1982. Guidelines on wildlife habitat management vis a vis forest management. Bhopal, India.
- SHIVA, V. 2002. Alternative energy. APH Publishing Corporation, New Delhi, India.
- SOKAL, R.R., AND F.J. ROHLF. 1987. Introduction to Biostatistics. II Edition. W.H. Freeman and Company, New York, USA.
- SOLOMON, J.D. 1969. Woodpecker predation in insect borers in living hardwoods. *Ann. Entomol. Soc. Am.* 62 (5):1214-1215.
- SONENSHINE*, D.E., AND G.F. LEVY. 1981. Vegetative associations affecting *Glaucomys volans* in central Virginia. *Acta Theriol* 26:359-371.
- TAULMAN*, J.F. 1997. Effect of forest alterations on population dynamics, home range, and habitat selection of the southern flying squirrel, *Glaucomys volans*. PhD. Dissertation. Fayetteville: University of Arkansas.
- TAULMAN, J.F. 1999. Selection of nest trees by southern flying squirrels (Sciuridae: *Glaucomys volans*) in Arkansas. *Journal of Zoology* 248:369-377.
- THOMAS, J.W. (Ed). 1979. Wildlife habitats in managed forest: the Blue Mountains of Oregon and Washington. Washington, DC: United States Department of Agriculture Forest Service Agricultural Handbook No. 553.

- THOMAS, J.W., R.G. ANDERSON, C. MASER, AND E.L. BULL. 1979. Snags. In *Wildlife Habitats in Managed Forest: the Blue Mountains of Oregon and Washington*: 60-77. J.W. Thomas (Ed.). Washington, DC: United States Department of Agriculture Forest Service Agricultural Handbook No. 553.
- UNIYAL, V.K. 2001. Management Plan: 2001 – 2002 to 2011 – 2012. Field Director, Project Tiger, Periyar Tiger Reserve, Kerala Forest Department, Kerala, India.
- VONHOF, M.J., AND R.M.R. BARCLAY. 1997. Use of stumps as roosts by the western long-eared bat. *Journal of Wildlife Management* 61:674-684.
- WALDIEN, D.L., J.P. HAYES, AND E.B. ARNETT. 2000. Day-roosts of female long-eared myotis in Western Oregon. *Journal of Wildlife Management* 64:785-796.
- WEBB, J.K., AND R. SHINE. 1997. Out on a limb: Conservation implications of tree-hollow use by a threatened snake species (*Hoplocephalus bungaroides*: Serpentes, Elapidae). *Biological Conservation* 81:21-33.
- WILSON, D.E. 1997. Bats in question. The Smithsonian answer book. Smithsonian Institution Press, Washington, USA.
- ZAR, J.H. 1984. *Biostatistical Analysis*. II Edition. Prentice-Hall Inc. New Jersey, USA.
- ZARNOWITZ, J.E., AND D.A. MANUWAL. 1985. The effects of forest management on cavity-nesting birds in northwestern Washington. *Journal of Wildlife Management* 49:255-263.

NOTE: References marked with asterisk (*) were not consulted in original

Appendix I

Design used to lay plots



Appendix II

The tree species found to have contributed to the sampled dead wood in Periyar Tiger Reserve

Sl. No.	Tree species
1	<i>Actinodaphne malabarica</i>
2	<i>Anogeissus latifolia</i>
3	<i>Artocarpus hirsutus</i>
4	<i>Bischofia javanica</i>
5	<i>Bombax ceiba</i>
6	<i>Clausena indica</i>
7	<i>Dalbergia latifolia</i>
8	<i>Diospyros sylvatica</i>
9	<i>Ficus nervosa</i>
10	<i>Grewia tiliifolia</i>
11	<i>Haldina cordifolia</i>
12	<i>Lagerstroemia microcarpa</i>
13	<i>Lagerstroemia microcarpa</i>
14	<i>Mallotus philippensis</i>
15	<i>Olea dioica</i>
16	<i>Pterocarpus marsupium</i>
17	<i>Scleichera oleosa</i>
18	<i>Syzygium gardneri</i>
19	<i>Tabernaemontana heyneana</i>
20	<i>Tectona grandis</i>
21	<i>Terminalia paniculata</i>

Appendix III

The List of dead wood users encountered in Periyar Tiger Reserve

Birds		
Sl. No.	Common Name	Scientific Name
1	Crimson fronted Barbet	<i>Megalaima australis</i>
2	White-cheeked Barbet	<i>Megalaima viridis</i>
3	Malabr Grey Hornbill	<i>Ocyceros griseous</i>
4	Great Hornbill	<i>Buceros bicornis</i>
5	Lorikeet	<i>Loriculus vernalis vernalis</i>
6	Blue-winged Parakeet	<i>Psittacula coluboides</i>
7	Plum headed Parakeet	<i>Psittacula cyanocephala</i>
8	Greater Flame Back	<i>Chrysocolaptes lucidus</i>
9	Common Flame back	<i>Dinopium javanense</i>
10	Black-rumped Flameback	<i>Dinopium benghalense</i>
11	Lesser Yellownape	<i>Picus chlorolophus</i>
12	Rufous Woodpecker	<i>Celeus brachyurus</i>
13	White-bellied Woodpecker	<i>Dryocopus javensis</i>
14	Brown capped Pygmy woodpecker	<i>Dendrocopus nanus</i>
15	Heartspotted woodpecker	<i>Hemicircus canente</i>
16	Great Cormorant	<i>Phalacrocorax carbo</i>
17	Little Cormorant	<i>Phalacrocorax niger</i>
18	Indian Shag	<i>Phalacrocorax fuscicollis</i>
19	Darter	<i>Anhinga melanogaster</i>
20	Little egret	<i>Egretta garzetta</i>
21	Intermediate Egret	<i>Mesophoyx intermedia</i>
22	Great Egret	<i>Casmerodius albus</i>
23	Black eagle	<i>Ictinaetus malayensis</i>
24	Brahminy Kite	<i>Haliastur indus</i>
25	Grey-headed Fish Eagle	<i>Ichthyophaga ichthaetus</i>
26	Osprey	<i>Pandion haliaetus</i>
27	Shikra	<i>Accipiter badius</i>
28	Brown Hawk Owl	<i>Ninox scutulata</i>
29	Oriental Scops Owl	<i>Otus sunia</i>
30	Jungle Owlet	<i>Glaucidium radiatum</i>
31	Hill Myna	<i>Gracula religiosa</i>
32	Jungle Myna	<i>Acridotheres fuscus</i>

Sl. No.	Common Name	Scientific Name
33	Red-vented Bulbul	<i>Pycnonotus cafer</i>
34	Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>
35	Great Tit	<i>Parus major</i>
36	Magpie Robin	<i>Copsychus saularis</i>
37	Pompadour Pigeon	<i>Treron pompadora</i>
38	Green Imperial Pigeon	<i>Ducula badia</i>
39	Green Bee-eater	<i>Merops orientalis</i>
40	Chestnut-headed Bee-eater	<i>Merops leschenaulti</i>
41	White-throated Kingfisher	<i>Halcyon smymensis</i>
42	Common Kingfisher	<i>Alcedo atthis</i>
43	Blue-eared Kingfisher	<i>Alcedo meninting</i>
44	Grey Heron	<i>Ardea cinerea</i>
45	Woolly-necked Stork	<i>Ciconia episcopus</i>
46	Jungle Crow	<i>Corvus macrorhynchos</i>
47	Fairy Blue Bird	<i>Irena puella</i>
48	Malabar Trogon	<i>Harpactes erythrocephalus</i>
49	Malabar Whistling Thrush	<i>Myophonus horsfieldii</i>
50	Orange-headed Thrush	<i>Zoothera citrina</i>
51	Red-winged crested cuckoo	<i>Clamator coromandus</i>
52	Ashy Swallow Shrike	<i>Artamus fuscus</i>
53	Common Woodshrike	<i>Tephrodomis pondicerianus</i>
54	Large Woodshrike	<i>Tephrodomis gularis</i>
55	Brown Shrike	<i>Lanius cristatus</i>
56	Southern Grey Shrike	<i>Lanius meridionalis</i>

Mammals		
Sl. No.	Common Name	Scientific Name
1	Mouse Deer	<i>Tragulus meminna</i>
2	Shrew	
3	Bat	
4	Porcupine	<i>Hystrix indica</i>
5	Bear	<i>Melursus ursinus</i>
6	Otter	<i>Lutra Iperspicillata</i>
7	Civet	
8	Flying Squirrel	<i>Petaurista petaurista</i>
9	Pangolin	<i>Manis crassicaudata</i>
10	Wild Boar	<i>Sus scrofa</i>
11	Tiger	<i>Panthera tigris</i>
12	Elephant	<i>Elephas maximus</i>

Reptiles		
Sl. No.	Common Names	No. of morpho species
1	Turtle	1
2	Gecko	1
3	Varanus	1
4	Wine Snake	1
5	Skink	1

Other Users		
Sl. No.	Common Names	No. of morpho species
1	Frog	2
2	Caecilian	1
3	Fish	1
4	Ant	7
5	Beetle	6
6	Dragon Fly	1
7	Damsel Fly	1
8	Spider	4
9	Termite	2
10	Dipteran	3
11	Harvestman	1
12	Praying Mantis	1
13	Moth	1
14	Bee	1
15	Snail	3
16	Earthworm	1
17	Epiphytes	2

Appendix IV

The height, length and girth classes of various dead wood sampled in Periyar Tiger Reserve

Stumps	
Class id	Height Class (m)
1	0.3-0.5
2	0.5-0.7
3	0.7-0.9
4	0.9-1.1
5	1.1-1.3
6	1.3-1.5
7	>1.5

Stumps	
Class id	Girth Class (cm)
1	30-50
2	50-70
3	70-90
4	90-110
5	110-130
6	130-150
7	>150

Snag	
Class id	Height Class (m)
1	3.0-5.0
2	5.0-7.0
3	7.0-9.0
4	9.0-11.0
5	11.0-13.0
6	13.0-15.0
7	>15.0

Snag	
Class id	Girth Class (cm)
1	30-50
2	50-70
3	70-90
4	90-110
5	110-130
6	130-150
7	>150

Fallen log	
Class id	Length Class (m)
1	1.0-3.0
2	3.0-5.0
3	5.0-7.0
4	7.0-9.0
5	9.0-11.0
6	11.0-13.0
7	>13.0

Fallen log	
Class id	Girth Class (cm)
1	30-50
2	50-70
3	70-90
4	90-110
5	110-130
6	130-150
7	>150