Patterns of herbivory on *Macaranga peltata*, a pioneer species in the mid-elevation forests of the Western Ghats, India

The spatial complexity in plant–herbivore dynamics has been identified as an area requiring more detailed studies[1,2]. Among the key attempts to explain relationships between plant diversity and herbivore populations, from the herbivores' point of view, Elton's 'enemies hypothesis' states that less diverse plant communities undergo greater herbivory due to presence of fewer predators in contrast to complex communities[3]. A corresponding 'resource concentration hypothesis' argues that specialist herbivores get attracted to and stay longer in patches with high host plant density[4,5]. Conversely, Feeny's 'plant apparency theory' suggests that evolution of plant defence mechanisms and their allocation are a function of risk of discovery by herbivores, cost of defence and value of that plant part[3,5,7,8]. The 'resource availability hypothesis' suggests that defensive capabilities of plants are determined by their growth rate, photosynthetic capabilities and nutrient availability[2]. Both of these are based on resource allocation from a plant's point of view. Subsequent studies suggest that soil characteristics, nutrient availability, light conditions and community composition play a significant role in determining the extent and direction of herbivory[1,9,10]. Several studies and meta-analyses have examined various hypotheses on herbivory[2,11,12]; however, few studies have empirically tested them in tropical evergreen forests of India. Studies in a gradient of disturbance where plants and herbivores respond differently could result in a better understanding of the effects of conversion of primary forests on plant communities through changing patterns of herbivory.

This study empirically examines patterns of herbivory on *Macaranga peltata* (Roxb.) Mueller, a pioneer tree species distributed across primary and secondary forests. This species suffers from a high degree of herbivory, which is visually detectable. *M. peltata* is generally distributed in high light environments such as secondary forests and also in large tree-fall gaps within primary forests[13,14], and herbivores such as *Aphthona macarangae* specific to Macaranga have been recorded in India[15], thus making it suitable for studying patterns of variability in herbivory.

The Kalakad Mundanthurai Tiger Reserve (KMTR) located in the southern Western Ghats, Tamil Nadu, has both undisturbed and disturbed forests. In primary evergreen forests, *M. peltata* is restricted to small gaps and light-deficient conditions, where the best strategy for gap colonizers like *M. peltata* would be to have higher growth rates compared to shade-tolerant trees in accordance with the resource availability hypothesis. *M. peltata* also has related species such as *Mallotus tetracoccus* and *Epiprinus mallotiformis*, occurring sympatrically, which could mean higher concentration of resources for the herbivores[16]. This is supported by observations of the same herbivore species *Apthona* being recorded in both *M. peltata* and *M. tetracoccus*. This allows us to test the resource concentration hypothesis, that occurrence of related species would mean additional resources for herbivores. Our study also identified variation in patterns of herbivory on *M. peltata* in primary and secondary forests, to understand effects of the surrounding plant community on herbivory.

The study was conducted during May 2012 in the wet evergreen forests of KMTR (08°39′0″N and 77°22′30″E), situated between 1200 and 1400 amsl. KMTR supports diverse vegetation types, including tropical wet evergreen and southern tropical moist deciduous forests[17–19]. The site encompasses a mosaic of habitats, including primary forests, secondary growth forests resulting from selective felling to complete clearing interspersed with tea plantations. Generally many light-tolerant species emerge in these patches which have been logged, and are marked by lower canopy height and cover with relatively higher light penetration into the understorey[17].

We compared differences in herbivory for *M. peltata* between primary and secondary forests, and examined the influence of species composition, structure and extent of leaf damage. We established a total of 30 plots, 15 each in both forest types. Each plot covered $10 \times 10\ m^2$ and replicates were separated by at least 500 m. We measured the DBH for every *M. peltata* tree and estimated their height visually. We also included other trees in the plots with DBH greater than 10 cm. For *M. peltata* trees with DBH above 30 cm, three observers chose three random samples of 10 leaves each from the upper and lower branches. We calculated the ratio of non-predated to predated leaves for the upper and lower branches. The average of the three sets of observations was used to arrive at the overall levels of herbivory. Levels of herbivory were categorized into low and high based on this information. We disregarded the number of leaves with low predation, and only considered the highly predated leaves, for upper and lower branches of *M. peltata* trees, as the response variable for herbivory for further analysis.

We checked normality of data using the Shapiro–Wilk test following which one-way ANOVA and one-way ANCOVA were performed. Wilcoxon rank sum test was used for data not normally distributed. We found significant differences in herbivory, with higher *M. peltata* density (ANOVA $F_{1,28} = 20.51$, $df = 1, 28$, $P = 0.00004$), lower species richness ($F = 6.931$, $df = 1, 28$, $P = 0.013$), and lower tree height ($F = 4.83$, $df = 1, 28$, $P = 0.036$) in secondary forests. Higher herbivory was recorded on the upper branches of *M. peltata* in both forest types ($W = 179.5$, $P = 0.006$). The incidence of herbivory in *M. peltata* in primary forests was significantly high compared to secondary forests ($W = 163$, $P = 0.04$), when herbivory on both branches was considered (Figure 1). The statistical significance was found to increase if only the upper branches of *M. peltata* were compared across forest types ($F = 7.498$, $df = 1, 28$, $P = 0.010$).

The incidence of herbivory on *M. peltata* decreased significantly with increase in the number of *M. tetracoccus*. Analysis of covariance showed significant decrease in herbivory with an increase in *M. tetracoccus* ($F = 5.397$ $df = 1, 28$, $P = 0.03$) with forest types as the control predictor ($P = 0.009$) (Figure 2). Species richness had no effect on the herbivory patterns across forest types. Density of *M. peltata* did not influence herbivory patterns. Habitat structure and species

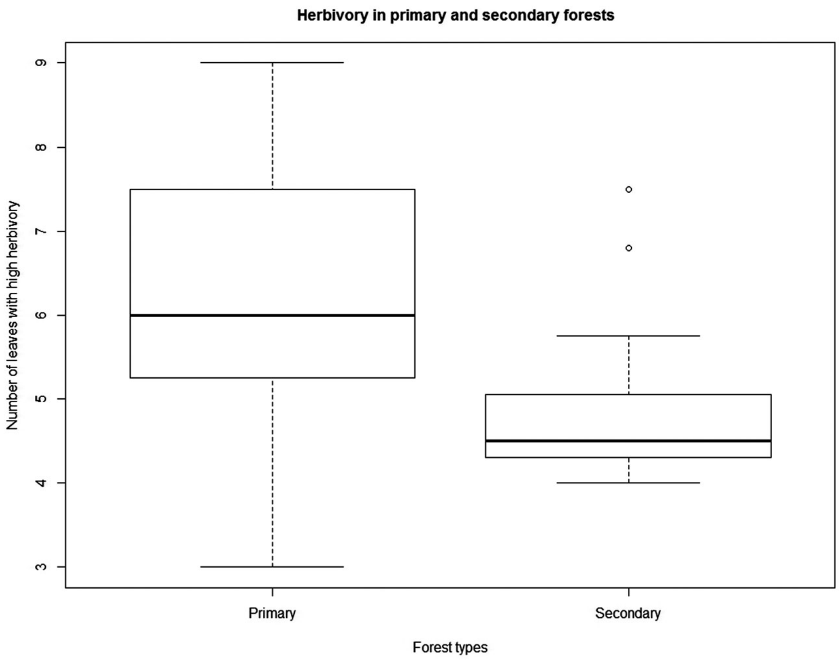

Figure 1. *Macaranga peltata* in primary forests displaying higher herbivory on upper branches than in secondary forests. Box and whiskers indicate the mean number of leaves with high herbivory per plot.

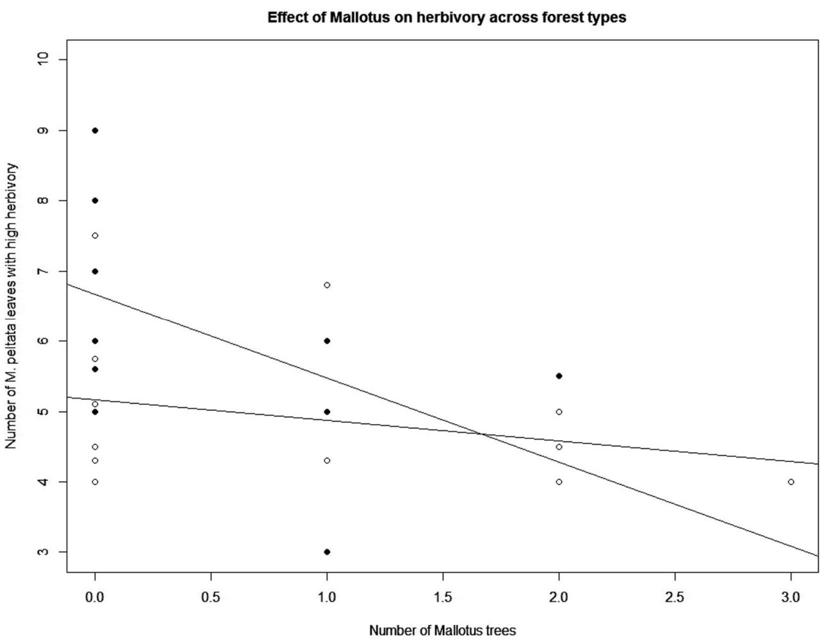

Figure 2. Decline in herbivory in the presence of *Mallotus tetracoccus* across primary (solid circles, slope = –1.1938) and secondary (open circles, slope = –0.2913) forest types.

composition appear to be the most important factors in determining the extent of herbivory on *M. peltata.*

Light and canopy exposure play an important role in leaf structure and herbivory, especially insect herbivory[20,21]. Increased light in the upper canopy could also result in higher temperatures, making it more conducive for insect herbivores in certain habitats[13,20]. The position of the upper branches could also be more favourable to insect attack due to higher visibility. This might possibly explain the greater extent of herbivory on the upper branches as observed in our study.

Our study did not find sufficient evidence to support the enemies hypothesis and resource concentration hypothesis, as *M. peltata* in primary forests suffered greater herbivory despite having a higher diversity of tree species, while even the higher density of host plants observed in secondary forests did not result in higher herbivory. However, there seems to be a dampening effect in herbivory in *M. peltata* with the increase in *M. tetracoccus*, which is related and has common herbivores[16]. However, the limitations of a short field period and the inability to measure microclimate parameters in the canopy hinder us from making conclusive statements. Further studies on plant–insect herbivore interactions in tropical forests could reveal how the dynamics changes in relation to varying habitat composition and microclimatic conditions.

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Unusual weather condition causing the transfer of seahorses *Hippocampus kuda* onto the sandy beach of Sindhudurg district, Maharashtra

While surveying for raptors along the Achara beach in Malvan taluk of Sindhudurg district, Maharashtra, seahorses *Hippocampus kuda* belonging to the family Syngnathidae were noticed on the beach on 23 June 2015. All seahorses belong to one genus *Hippocampus*, in which there are 34 species recognized all over the world[1–4]. Despite their small size, seahorses form a valuable fisheries resource in some areas and support a sizeable international trade. Hence all *Hippocampus* species are listed under Appendix II of the CITES and are categorized as vulnerable in the IUCN 2015 Red List of species[5,6]. The Government of India has banned the export permits for all Syngnathids and kept them under Schedule-I of the Indian Wildlife (Protection) Act, 1972. This communication documents the environmental condition rather than the trade aspects associated with seahorses in Malvan taluk.

We observed four individuals of seahorses *Hippocampus kuda* on the Achara beach (16°11′59.91″N, 73°26′6.65″E) (Figure 1). Their length was found to vary between 12.5 cm to 18 cm, three were found thrown alive onto the beach by the waves that lashed the coast in our presence. We also found one dead specimen on the beach. They seemed to be stranded and were unable to move back into the water. Therefore, we photographed the seahorses, measured their length and released them back into the sea. We attribute this unusual find of the seahorses on shore to the high wind velocity measuring up to 25 miles/h (Figure 2) during the afternoon from 1300 to 1400 h on 23 June 2015 on a day which was also overcast and gloomy. The period also coincided with the passage of *Ashoba* cyclone through the Arabian Sea which could have led to changes in the water currents and the increased wind velocity. We shared our observation and photographs (Figure 3) with Riley Pollom, Syngnathid Research Biologist and IUCN Red List Authority Coordinator in the Project Seahorse – Institute for the Oceans and Fisheries, The University of British Columbia. She confirmed the species as *Hippocampus kuda* and stated that it was not an usual phenomenon to find seahorses on beaches in live condition, but can be expected at times of unusual environmental conditions.

Seahorses have been reported from the coast of Maharashtra and Goa[7] as the

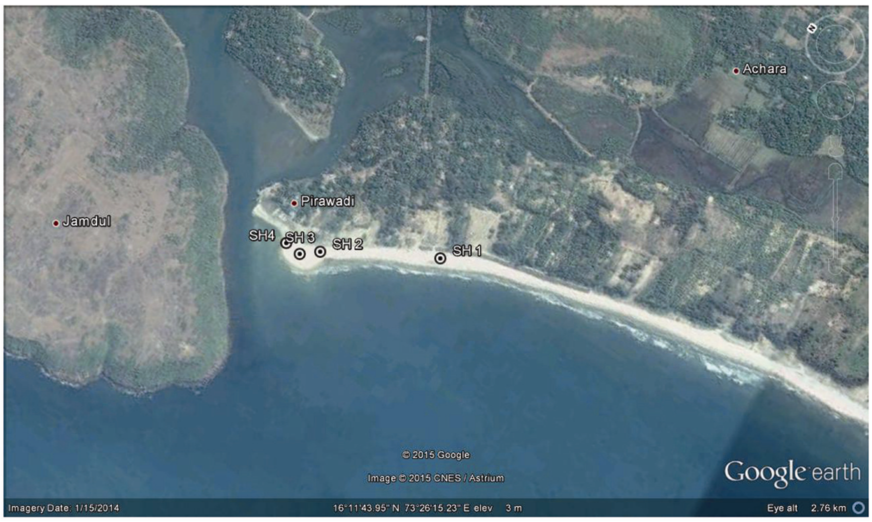

Figure 1. Google imagery showing locations of seahorses encountered on Achara beach.