# Seedling mortality in two vulnerable tree species in the sacred groves of Western Ghats, South India

Sacred groves form a significant component of the traditional conservation movement in many parts of the tropical world[1]. The Western Ghats, one of the two mega-diversity centers in India, is dotted with sacred groves, with the highest concentrations located in the central Western Ghats[2]. Sacred groves are believed to serve as the last refugia for a number of taxa, particularly for rare, endangered and threatened species[3,4]. Of late due to encroachments and land-use changes, the sacred groves have been increasingly threatened and fragmented[4]. During the last century alone, the total area under the groves in Kodagu district in the central Western Ghats decreased by 42%. Besides, more than 46% of the sacred groves in the district are less than 0.4 ha in area. The increased fragmentation of the groves could undermine the utility of these groves in serving as a refugium for the rare, endangered and threatened (RET) species. Here we examine the effects of grove area on the seedling mortality of two economically important and vulnerable tree species.

The study was conducted in the sacred groves of Ponnampet range (12°N, 75°E), Kodagu district in the central Western Ghats of India (Figure 1). The groves are set against a matrix of coffee plantation and agricultural landscape[6,7]. The vegetation of the groves is predominantly evergreen, with a small proportion of semi-evergreen and deciduous patches. The sacred groves within 20-km radius of Ponnampet were visited and 15 groves with area ranging from 0.37 to 11.28 ha were selected for the study. The latitude and longitude of the sacred groves were recorded using a global positioning system (GPS) and digitized using GIS software (MAPINFO)[8]. Based on the GPS data, inter-grove distance was estimated for each grove.

The study was conducted on two economically important and vulnerable tree species. *Artocarpus hirsutus* Lam. (Moraceae) is a dominant canopy tree, vulnerable globally[9] and endemic to the Western Ghats[10]. The fruits are yellow, ovoid, covered with spines, containing numerous white seeds, 0.5–0.75 inches long with viability period of three weeks[11]. Because of its edible fruit collection and extensive harvesting of highly prized timber, *A. hirsutus* has been threatened in the Western Ghats. *Canarium strictum* Roxb. (Burseraceae) is reportedly vulnerable in Karnataka[9] and is known for its medicinal resin[6]. Fruits are ovoid or ellipsoid, often-trigonous drupe with 1–3 celled, 1–3 seeded stone[11]. *C. srictum* is being mainly threatened for its valuable resin extracted by partially burning the trees. The species is distributed sparsely in the evergreen forests of the Western Ghats and Eastern Himalaya in India[10]. Both species are pollinated by small insects and are animal-dispersed.

Seeds or fruits of both species were collected from randomly chosen trees from groves ($n = 13$ groves for *Artocarpus*, and $n = 11$ groves for *Canarium*). The seeds/fruits of the trees were collected during the respective fruiting phenologies (for *Canarium strictum* during January–February while for *Artocarpus hirsutus* during May–June). Immediately after collection, seeds/fruits were washed, weighed and a number of seed/fruit parameters (such as seed abortion, seed predation, etc.) were determined.

Sufficient care was taken to avoid sampling errors, including over- or under-representation for samples across the grove area. The seeds were sown separately in polythene bags filled with soil mixture, and allowed to germinate under shade in greenhouse conditions. Aborted seeds that were rudimentary and scleretorized were not considered. The germination percentage was calculated as the ratio of number of seeds germinated to the total number of sown seeds. The ratio of the number of dead seedlings (two months after germination for *Artocarpus* and three months for *Canarium*) to the total number of germinated seeds was computed for each grove and referred to as per cent seedling mortality.

We found a significant decline in per cent seedling mortality with increase in area of the grove ($P < 0.05$ in both the species; Figure 2 *a* and *b*). For *Artocarpus*, the per cent seedling mortality ranged from as high as 100% in the small groves to none in the large groves. On the other hand, for

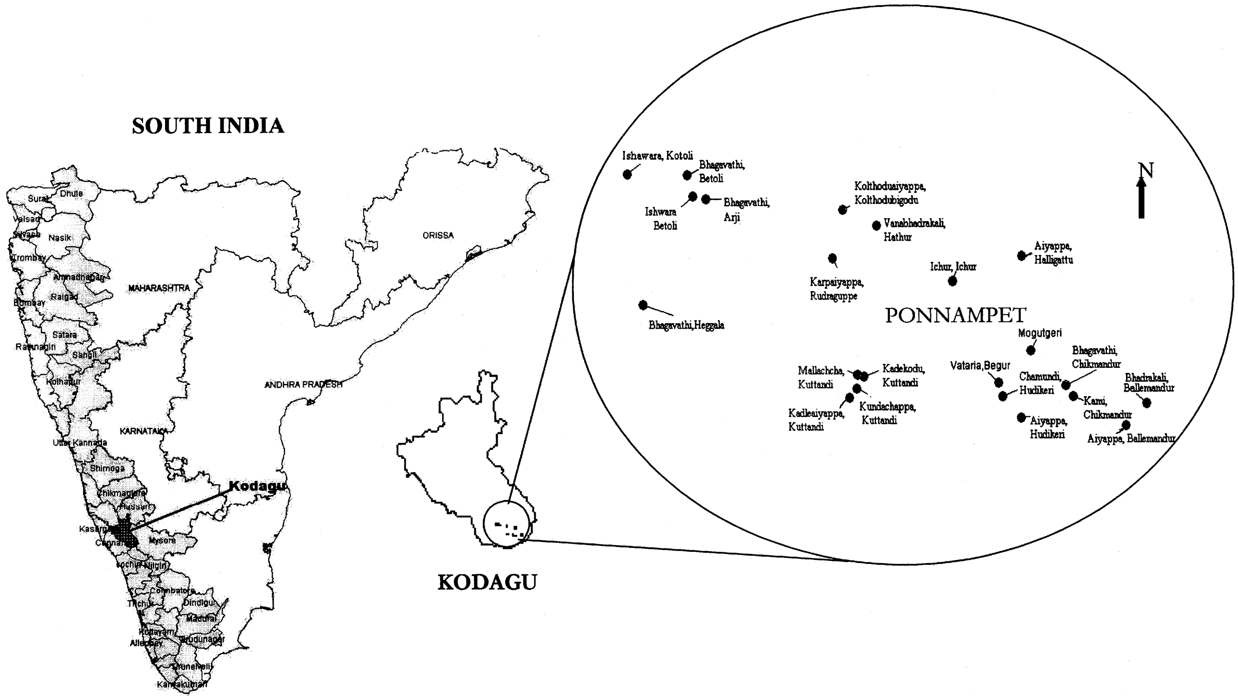


**Figure 1.** Distribution map of study sites (sacred groves) in Kodagu district, central Western Ghats, India.

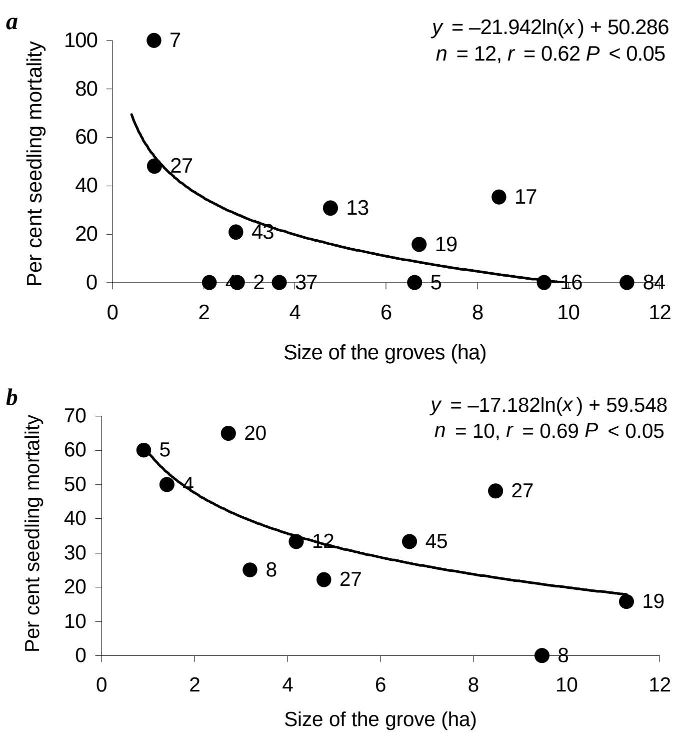


**Figure 2.** Per cent mortality of seedling (***a***) *Artocarpus hirsutus* and (***b***) *Canarium strictum* across grove area. Data points from 1.411 ha grove for *Artocarpus* and 2.711 ha grove for *Canarium* are not included in the regression analysis, since only single seedling was recovered from these groves. Numbers next to datapoint indicate number of seedlings used for analysis from that grove.

*Canarium* the mortality ranged from about 60% in the smaller groves to about 10% in the larger groves. Per cent seed germination increased nonlinearly with grove area though not significantly (for *Artocarpus* $y = 9.59\ln(x) + 41.014$, $R^2 = 0.070$ and for *Canarium* $y = 3.72\ln(x) + 11.37$, $R^2 = 0.111$).

Thus, in both species, seedling fitness decreased with increased fragmentation of sacred groves. Seedling mortality was not correlated to other seed features such as seed weight or seed predation. There was no significant differences in the densities of adult trees of both species across the size of the groves; however it likely that the smaller groves harbour fewer individuals compared to the larger groves. Thus the observed increase in per cent seedling mortality with decrease in grove size could be due to the closed mating among the fewer individuals in the small groves compared to the large. The average distance separating the selected groves is about 6.5 km, a distance that might constrain pollinator movements such as small insects (e.g. moths in *Artocarpus* and flies in *Canarium*). Thus the increased mortality in the smaller groves could reflect the consequences of inbreeding and the accumulation of developmental lethals. While the consequences of fragmentation on seedling fitness are well known and have been reported by several earlier workers[12–15], our results are significant as they hold strong implications for the conservation of vulnerable species in the sacred groves[3,6,7]. The study underscores the importance of protecting the sacred groves from fragmentation if they have to serve as refugia for the vulnerable species.


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