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Ecology, distribution and population status of *Elaeocarpus venustus* Bedd. (Oxalidales: Elaeocarpaceae), a threatened tree species from Agasthiyamalai Biosphere Reserve, southern Western Ghats, India

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Abstract: This paper deals with the ecology, population size, status of regeneration, habitat degradation and threat status of *Elaeocarpus venustus* Bedd. an endemic and threatened tree species restricted to Agasthiyamalai Biosphere Reserve, southern Western Ghats, India. The population sites of this species in the study area were recorded using Global Positioning System and mapped using Arc GIS software. The population of this species is highly fragmented due to anthropogenic activities. The total stem count in all population sites from the study area was carried out to understand the population structure. A total of 181 saplings were recorded from the entire study area of which 180 are from a single site. Nearly 64% of the stems recorded in this study are mature stems. Poor regeneration was seen in population sites that were highly disturbed. In spite of good adult population, the low number of saplings shows poor germination of seeds and establishment of seedlings.

Keywords: Conservation, *Elaeocarpus venustus,* endemic, Kanyakumari District, population status, propagation, southern Western Ghats.

The Western Ghats, known for its rich species diversity and endemism, is a chain of mountain ranges stretching ca. 1,600km in length that run in a south-north direction parallel to the western coast from Tamil Nadu to Gujarat. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has recognized the Western Ghats as one of the Natural World Heritage sites based on its significant natural habitats (UNESCO 2012). Nayar (1996) recognized eight micro-endemic centers in the Western Ghats among which the Agasthyamalai Region has a greater concentration of endemic species. Gopalan & Henry (2000) have reported 150 taxa as strict endemics to the Agasthiyamalai region of which 24 are tree taxa. Species belonging to the genera such as *Elaeocarpus*, *Garcinia*, *Myristica*, and *Syzygium* occur in swamps.

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Table 1. Distribution pattern of *Elaeocarpus* species in India

Region	Number of taxa recorded	Number of endemic taxa
Northeastern India	18	1
Western Ghats	16	8
Andaman and Nicobar Islands	8	1
Pan India	8	0

The genus *Elaeocarpus* is distributed in tropical and warm old world regions except Africa. This genus is represented by about 350 species in the world (Mabberley 2008). Thirty three species occur in India of which 10 are endemic (Murthi 1993) (Table 1). Eighty percent of the endemic *Elaeocarpus* species are confined to the Western Ghats including four steno endemics namely, *E. blascoi* Weibel, *E. gaussenii* Weibel, *E. recurvatus* Corner and *E. venustus* Bedd. This paper is a detailed study on the ecology, population size, status of regeneration, habitat degradation and threat status of *E. venustus* Bedd., a narrow endemic and endangered species, restricted to the Agastyamalai Biosphere Reserve (Images 1–3). *E. venustus* was first collected and described by Beddome (1872) from Muthukuzhivayal.

Materials and Methods

Study site: The study site is the Western Ghats of Kanyakumari District which is a part of Agastyamalai Biosphere Reserve, India (Fig. 1) that comprises ca. 458km^2 of forests (Chitrapu 1998).

Collection of data and field survey: Data on species distribution was collected from the literature (Chithra 1983; Murthi 1993; Ramesh & Pascal 1997; Gopalan & Henry 2000; Zmarzty 2001) and herbaria such as Madras Herbarium (MH), Coimbatore, Tropical Botanic Garden and Research Institute (TBGT), Thiruvananthapuram, and French Institute (HIFP), Pondicherry. Intensive field surveys were carried out for a period of eight years from 2001 to 2009 to locate the places of occurrence of *E. venustus* in Kanyakumari District. Help was also sought from Chandran and Kumar belonging to the Kani tribe and from private estate workers to locate the species.

Population study: Total stem count was carried out for all the population sites recorded. Standard methodology of constructing quadrat was not carried out due to the varying sizes of fragmented patches (0.60–5 ha). Girth at Breast Height (gbh) was taken for all the stems of *E. venustus*. Based on the girth class, populations were grouped into three classes. Stems <30 cm gbh were classified as saplings. Stems between 30–

Image 1. Flowering twig of *Elaeocarpus venustus*

Image 2. Fruits of *E. venustus*

Image 3. Seeds of *E. venustus*

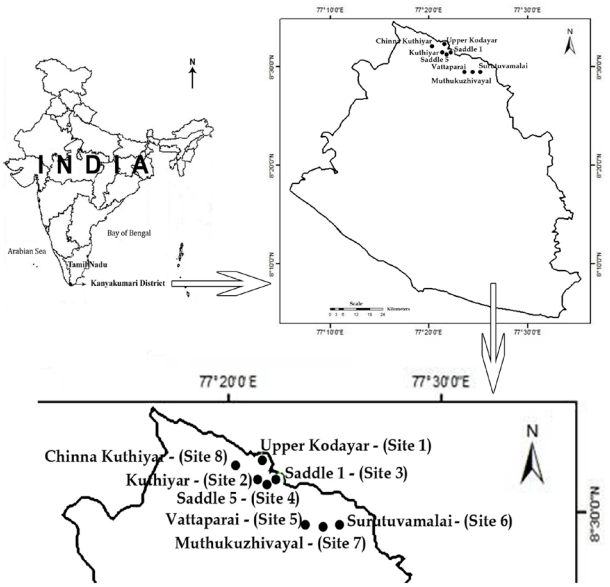

Figure 1. Population sites of *Elaeocarpus venustus* in Kanyakumari District, Tamil Nadu

60 cm gbh were treated as sub adults. Stems >60 cm gbh were classified as mature trees.

Adult sapling ratio was calculated to find the rate of saplings transformed to adults. The adult sapling ratio was calculated using the following formula (Ganesan 2001).

$$\text{Adult sapling ratio} = \frac{\text{Total number of adult stems}}{\text{Total number of saplings}}$$

Mapping: Precise locations of *E. venustus* in Kanyakumari District were mapped using Garmin eTrex Vista Global Positioning System (GPS) handheld receiver. The GPS data were plotted using ArcGIS software and a distribution map was prepared.

Propagation studies

Seed germination: Seed germination studies were carried out using five different media: sand, cow dung, silt, sand mixed with silt and cow dung and soil from its own habitat. Untreated seeds were used for this study. Seed viability was also tested using Tri phenyl tetrazolium chloride (TTC) (ISTA 1985; Sawma & Mohler 2002).

Stem cutting: Stem cuttings each measuring about 15cm were taken during February–April and June–August from tender, semi-hard and hardwood branches. The control cuttings were dipped in distilled water and others were treated with Indole-Acetic Acid (IAA), Indole-Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) in different concentrations (200, 500, 1000, 1200, 1500, 2000 and 2500 ppm) for about three hours. Cuttings were then planted in sand mixed with silt.

Air layering: Mature trees were selected for air layering. The bark was girdled 25–30 cm away from the tip of the branch. The girdles were covered with cotton dipped in IAA, IBA and NAA in different concentrations (200, 500, 1000 ppm) chosen on the basis of the results obtained from stem cuttings. They were then covered with moss and coconut fibre and sealed by a polythene sheet. Layerings were observed regularly for root initiation.

Results and Discussion

Distribution: *Elaeocarpus venustus* is located in eight sites covering an area of about 9 hectares (Table 3). Each site is spaced 3–8 km apart. This species occupies an area of about 0.089km^2 of the total area of the forest in Kanyakumari District. It is seen growing between 1250–1500 m exclusively in swamps (Image 4). This species is found growing in association with *Aglaia bourdillonii* Gamble, *Calophyllum austroindicum* Kosterm., *Cullenia exarillata* Robyns, *Myristica dactyloides* Gaertn., *Elaeocarpus munronii* (Wight) Mast., *E. tuberculatus* Roxb., *Garcinia travancorica* Bedd., *G. rubro-echinata* Kosterm., *Holigarna nigra* Bourd., *Syzygium mundagam* (Bourd.) Chithra and *S. rama-varmae* (Bourd.) Chithra.

Ecology: Ganesan (2002) classified *E. venustus* swamps into three types: (1) Open swamps bordered by *E. venustus,* (2) Swamps with monospecific stand of *E. venustus*, and (3) Mosaics of primary forest vegetation and swampy vegetation. Second and third type of swamps were observed in the study area. Site 7 fits the description of the second type and other sites can be classified under the third type.

Presence of stilt roots, an adaptation to swampy habitat, was observed in most of the trees in the study

Image 4. Swampy habitat of *E. venustus*

area. Appearance of basal branches from the trunk close to the ground in clusters was a common phenomenon found in the populations at sites 5 and 7. Trunks of several trees were observed leaning on the ground and rooting at its base. All these features are attributed to the marshy habitat (Ganesan 2001). Trees above three-meter girth show hollow trunks throughout the study area. Copious flowering alternates with poor flowering.

Population Details: A total of 701 stems of *E. venustus* were recorded of which, 449 were mature stems, 71 were sub-adults and 181 are saplings (Fig. 2). The count was taken during 2009. In general, mature stems were more in number than the saplings. The total number of sub-adults was relatively poor. Fruit setting was relatively good in spite of the irregular flowering frequency. However, a majority of the sites showed poor seed regeneration as evidenced by the low number of saplings.

Habitat Degradation: The forests of Kanyakumari District have undergone severe habitat degradation due to anthropogenic activities. The construction of eight dams for hydroelectric power generation and irrigation is a prime cause for the disappearance of vegetation (Samraj 1998; Sundarapandian et al. 2005) (Table 2). The area cleared for the construction of the dams is more than the area of the existing forests (464km^2). The extant populations are further fragmented by the construction of roads to reach the hydroelectric dams and power stations. Fragmentation is a major cause that severely affects the regeneration, genetic exchange and spread of populations (Benitez-Malvido 1998; Laurance et al. 1998).

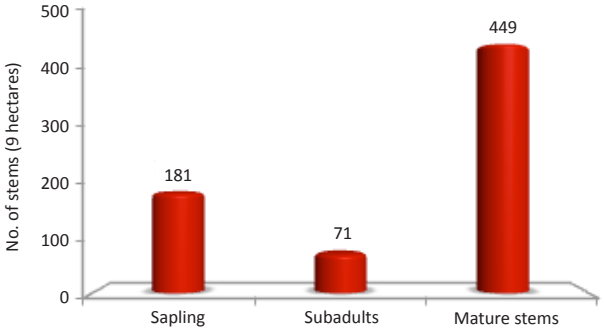

Figure 2. Population Structure of *E. venustus* in Kanyakumari District

Regeneration versus Habitat Degradation: Adult-sapling ratio is a good indicator of the rate of regeneration. If the ratio is close to or more than one, the population is said to be regenerating well with a large number of saplings being converted into adults (Ganesan 2001). Of the eight sites, four sites (site 1,2,3 & 8) are highly disturbed due to the construction of dams and roads (Table 3). Population sites which were highly disturbed due to anthropogenic interference show very poor regeneration (Table 3) and show zero adult-sapling ratio. In sites 6 and 8 only a single stem was recorded. Perhaps, *E. venustus* is a recent introduction to the swamps of these sites as evidenced by the relatively young stems. Site 5 shows a good population of adults (71 stems) and a lower number of sub-adults (12 stems). Saplings were completely absent at this site. The absence of saplings, in spite of good adult population, indicates poor germination of seeds and establishment of seedlings. The reasons for this phenomenon need to

Table 2. Major reservoirs in Western Ghats of Kanyakumari District

S. No	Dams	Area (Km^2)	Purpose of construction
1	Pechiparai	207.20	Irrigation
2	Perunchani	160.24	Irrigation
3	Kuthiyar	1.52	Hydro - Electric Power & Irrigation
4	Upper Kodayar	29.14	Hydro - Electric Power & Irrigation
5	Lower Kodayar	29.14	Hydro - Electric Power & Irrigation
6	Chittar II	26.16	Irrigation
7	Chittar I	22.02	Irrigation
8	Chinnakuthiyar	2.59	Hydro - Electric Power& Irrigation

Modified from Samraj (1998)

Table 3. Habitat degradation and adult sapling ratio

Name of the Sites	Nature of site disturbance	Type of disturbance	Adult sapling ratio
Site 1 (Upper Kodayar)	Highly disturbed	Road	0
Site 2 (Kuthiyar)	Highly disturbed	Dam & Road	0
Site 3 (Saddle 1)	Highly disturbed	Dam	0
Site 4 (Saddle 5)	Less disturbed	Dam	0
Site 5 (Vattaparai)	Less disturbed	-	0
Site 6 (Surutuvamalai)	Less disturbed	-	0
Site 7 (Muthukuzhivayal)	Less disturbed	-	1.3
Site 8 (Chinnakuthiyar)	Highly disturbed	Dam & Road	0

be explored through more intensive field studies.

Only Site 7 showed a better adult-sapling ratio (1.3). Site 7 has a monospecific strand of *E. venustus* that can be recognized as a flagship species of this area. Of the 181 saplings recorded from the entire district 180 occurred at this site. This site was once a heavily disturbed site that was cleared for planting cardamom during the 1870s (Jacob 1917). However, the plantations were abandoned about two decades ago. Occurrence of more saplings in this site proves that if an area is left undisturbed, regeneration of native species is promoted naturally, especially of endemic species. On the other hand, occurrence of more saplings may be due to the high rate of seed germination. Clearing the forests in this site, for cardamom plantations, could have paved the way for more light thus enhancing seed germination. Similar observations have been made for a number of endemic species in tropical forests (Baskin & Baskin 1998; Ganesan 2001; Ganesan et al. 2001; Castellanos & Stevenson 2011). There has been little anthropogenic interference in this region after declaring it as a biosphere reserve in 2005 (MoEF 2012).

Seed germination and vegetative propagation: Fifty seeds randomly drawn from different populations were tested for viability and 100% viability was observed. About 1% of the seeds were found to be infected by stem borer. A set of 200 viable untreated seeds were sown in different media to study the rate of germination. Seeds started to germinate after 75 days. Germination of 40% was observed in silt mixed in sand and about 8% in sand mixed with silt and cow dung. Seeds sown in other media did not germinate. However, a study by Saravanan et al. (2011) stated that *E. venustus* showed 0% germination in spite of various treatments.

IBA was the most effective hormone in initiating roots. IBA (1000 ppm) produced rooting in 90% of the stem cuttings whereas, NAA in the same concentration produced only in 10% of cuttings. Rooting was 100% for air layering in 1000 ppm of IBA (Image 5) when compared to the 16% success as reported by Saravanan et al. (2011).

A few plantlets raised through cuttings were planted in the premise of a few private estates within the biosphere reserve for close monitoring and safety from wild animals some of which have shown remarkable establishment. Image 6 shows a five year old *E. venustus* growing in a private estate in Kanyakumari District which has attained a girth of 30 cm.

Conservation measures: *E. venustus* is confined to a swampy habitat which is a specialized ecological niche and is assessed as Vulnerable in the IUCN Red List of

Image 5. Air-layered twig

Image 6. A five year old *E. venustus* growing in an ex situ habitat

Threatened Species (WCMC 1998). Endemic species which are confined to a particular ecological region, once lost, will be a great loss to the biodiversity forever. Hence, conservation priority should be given to these endemic species (Raven 1988; Nayar 1997). Agasthyamalai and its environs have been affected by the conversion of the reserve forests into plantations, reservoirs and roads which is a severe threat to the species (Gadgil & Meher-Homji 1986; Pascal 1990; Bawa & Dayanandan 1998; Menon et al. 2001). Ramesh et al. (1997) suggest that fragmented populations of endemic species need continuous monitoring for better conservation and management. A long term study is required as *E. venestus* show poor seed germination, poor fruit dispersal as well as requires specialized environment for germination, as emphasized for all tropical tree species (Ashton 1969, 1981; Gomez-Pompa et al. 1972; Bawa 1974). Given that the previous assessment by the IUCN Red List was in 1998 and the ongoing threats impacting negatively on the habitat, the species may even be more highly threatened. Its current status must be assessed immediately and suitalbe conservation action mooted.

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