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**Cover: Fish species recorded in the Gowthami-Godavari Estuary, Andhra Pradesh: *Lutjanus johnii* (top left), *Triacanthus biaculeatus* (top right), *Acentrogobius cyanomos*, *Elops machnata*, *Trypauchen vagina*, *Oxyurichthys microlepis*. © Paromita Ray.**

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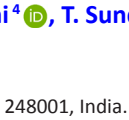

COMMUNICATION

# A new population record of the Critically Endangered *Dipterocarpus bourdillonii* Brandis from the Anamalai Tiger Reserve, India

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**Abstract:** *Dipterocarpus bourdillonii*, a Critically Endangered tree species endemic to the Western Ghats, India, has hitherto been reported mainly from the states of Kerala and Karnataka on the western slopes of the mountain range. In Tamil Nadu, this species has been reported to occur in two locations, but no population details have been documented and the species has neither been listed in state floras nor in a recent compendium of plant species. The present study documents the occurrence of a population of the species, with at least 40 individuals, in the Anamalai Tiger Reserve, Tamil Nadu, extends the known upper limit of its altitudinal range to 733 m, and suggests further surveys and in situ conservation efforts.

**Keywords:** Anamalai Hills, new distribution records, threatened plants, tropical rainforest, Western Ghats.

**சுருக்கக் குறிப்பு:** *டிப்டெரோகார்பஸ் போர்டில்லோனி* (கரஞ்சிலி), இந்தியாவின் மேற்குத் தொடர்ச்சி மலைகளில் மட்டுமே காணப்படும் (ஓரிடவாழ்வி), அழிவின் விளிம்பிலுள்ள ஒரு மரமாகும். இது கேரளா, கர்நாடகா மாநிலங்களின் மலைச்சரிவுகளில் (மேற்குத் தொடர்ச்சி மலையின் மேற்குச் சரிவுகளில்) இருப்பதாகத் பதிவுசெய்யப்பட்டுள்ளது. இந்த இனம், தமிழ்நாட்டில் இரண்டு இடங்களில் இருப்பதாகப் பதிவுசெய்யப்பட்டுள்ளது. ஆனால், இவற்றின் எண்ணிக்கை விவரங்கள் எதுவும் பதிவுசெய்யப்படவில்லை. மேலும், மாநிலத் தாவரப் பட்டியலிலோ, சமீபத்தில் வெளியான தாவர இனத் தொகுப்பிலோ பட்டியலிடப்படவில்லை. எங்களது ஆய்வின்படி தமிழ்நாட்டின் ஆனைமலை புலிகள் காப்பகத்தில் குறைந்தபட்சம் 40 மரங்கள் இருப்பதாகக் கண்டறியப்பட்டுள்ளது. இந்த மரங்கள் தரைமட்டத்திலிருந்து மலைப்பகுதியின் 733 மீட்டர் உயரம்வரை இருப்பதாகவும் கண்டறியப்பட்டுள்ளது. இந்த மரங்களை, அதன் பூர்வீக இடத்தில் பாதுகாக்க, ஆய்வுகள், பாதுகாப்பு முயற்சிகளை எடுக்குமாறு பரிந்துரைக்கப்படுகிறது.

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**Competing interests:** The authors declare no competing interests.

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**Author contributions:** NP, SK, KB, GM, and TS contributed to the field survey, data collection, and plant identification; NP, SK, KB, TRSR, and DM jointly wrote the manuscript; DM, TRSR, SK, and KB conceptualised the study, secured funding, and contributed to data curation and analysis.

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## INTRODUCTION

The family Dipterocarpaceae includes a diverse group of tropical trees that form dominant stands with some of the tallest standing tree species in southern and southeastern Asian lowland tropical forests (Appanah & Turnbull 1998; Ashton 2014). About 500 species in 17 genera of Dipterocarpaceae are known around the world (Ashton 2003), of which five genera and 34 species, including 10 species in the type genus *Dipterocarpus*, occur in India (Kundu 2008). Within India, *Dipterocarpus* is distributed largely in lowland tropical forests of the north-east, the Andaman & Nicobar Islands, and the south-west in the Western Ghats (Brandis 1906). The two species endemic to India, *Dipterocarpus indicus* and *D. bourdillonii*, are both restricted to the Western Ghats in southwestern India (Ramesh & Pascal 1997; Sreekumar et al. 2021).

*D. bourdillonii* has been assessed as a Critically Endangered species by the IUCN Red List, with the global population currently estimated at under 250 mature individuals and the largest known subpopulation having less than 50 mature individuals (Deepu et al. 2021). The species is considered rare and has so far been recorded only in scattered locations in the states of Kerala, Karnataka, and Tamil Nadu, mainly on the western aspect of the Western Ghats mountain range of India (Ramesh & Pascal 1997; Swarupanandan et al. 2013; Sreekumar et al. 2021). It is reported to occur between 175 m and 600 m elevation in valleys along river courses (Jose et al. 2010; Puttaswamy et al. 2010). Within Tamil Nadu, *D. bourdillonii* occurrence has been reported from the Nilgiris and Megamalai hill ranges (Ramesh & Pascal 1997) but nothing is known of its population and associated species in the state. The present paper describes the occurrence of a population of *D. bourdillonii* in the Anamalai Tiger Reserve, in the Tamil Nadu Western Ghats.

## METHODS

The field survey was carried out in the Anamalai Tiger Reserve (ATR), Tamil Nadu, India (core zone: 958 km², 10.216$^0$N, 76.816$^0$E – 10.566$^0$N, 77.416$^0$E) and the adjoining Valparai Plateau (220 km², 10.25$^0$N, 76.866$^0$E – 10.366$^0$N, 76.983$^0$E) in the Anamalai Hills. The Valparai Plateau is a landscape dominated by tea and coffee plantations with about 45 embedded rainforest fragments ranging in area from 1 ha to over 300 ha (Muthuramkumar et al. 2006; Mudappa & Raman 2007). As the focus of this study was on threatened and endangered tree species found in the mid-elevation tropical wet evergreen forest (tropical rainforest), the fieldwork was confined to the western parts of the Reserve in Valparai, Manamboli, and Ulandy Ranges that contain most of the remaining rainforests. The natural vegetation type falls mainly within the mid-elevation (700–1,400 m) tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type (Pascal 1988).

Between October 2020 and March 2022, 64 routes (29 sites) of 119.2 km total length were surveyed on foot, spanning an elevation range of 580 m to 2,000 m in the rainforests of the Anamalai Tiger Reserve and rainforest fragments in the Valparai Plateau. After two *D. bourdillonii* trees were first observed along one of the survey routes (11 km, walked on 30 January 2021) passing through the Ayyankulam area (Figure 1), the same area was subsequently explored covering 0.81 km and 2.63 km (in March–April 2021) and in four trails covering 3.31 km, 3.89 km, 3.0 km, and 4.1 km (in March 2022) recording additional individuals. The total length of 28.74 km of trails were tracked using a hand-held GPS (Garmin GPSMAP 64sc) and a checklist of all tree species encountered along the trail (10 m on either side) was recorded. Plant species were identified using available floras and field guides (Gamble & Fischer 1935; Pascal & Ramesh 1997; Page 2017) and based on the prior experience of the authors with floristic and ecological research in the region (Muthuramkumar et al. 2006; Page et al. 2010; Osuri et al. 2017, 2019; Page & Shanker 2018, 2020). Species names were updated with reference to Plants of the World Online, http://www.plantsoftheworldonline.org/ (POWO 2022).

At each of the 40 *D. bourdillonii* trees found during the survey, the following data centred on the tree were recorded: GPS coordinates and elevation (using GPS unit), girth at breast height (GBH, at 1.3 m, or higher in case of presence of buttresses), and tree height in metres measured with a rangefinder. For measurement of additional variables, a subset of 23 *D. bourdillonii* trees was chosen after excluding individuals that were less than about 30 m from previously-measured conspecifics (to ensure independence of samples). For these 23 trees, the following additional variables were measured keeping the focal tree as the centre: slope (flat, gentle, moderate, steep), canopy height (average height of trees in the immediate vicinity of focal tree measured with a rangefinder in metres), and canopy cover (0%, 1–25%, 26–50%, 51–75%, 76–100%). The number of *D. bourdillonii* seedlings (GBH <10 cm) and

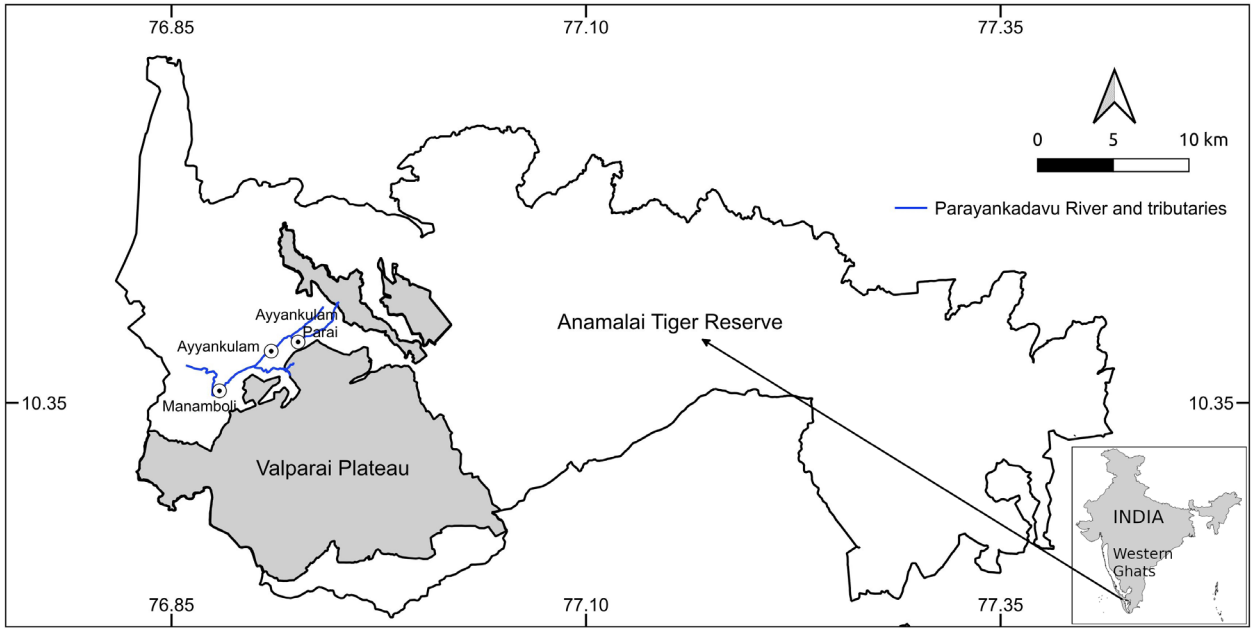


**Figure 1. Map of Anamalai Tiger Reserve showing the main locations along the Parayankadavu River where *Dipterocarpus bourdillonii* was recorded.**

saplings (GBH 10–30 cm) in a 5 m radius around each focal tree were also recorded. Observations on canopy shape, buttresses, and phenophase (leafing, flowering, fruiting) were noted. To record nearby tree species, point-centred quarter (PCQ) plots were placed keeping focal trees at the centre and the nearest individual tree >30 cm GBH in each of the four quarters was recorded, noting the species and GBH. As these were trees in the immediate vicinity of the focal trees, the frequency of different species was considered as indicative of species association with *D. bourdillonii*. Together, the survey trails enabled rapid coverage across wider areas to document species occurrence, while the PCQs around focal trees helped document tree species associated with *D. bourdillonii*.

Herbarium specimens were examined at the Madras Herbarium (MH), Botanical Survey of India, at Coimbatore, the Herbarium at the French Institute in Pondicherry (HIFP), the Herbarium of the Kerala Forest Research Institute (Sreekumar et al. 2021), Peechi (KFRI), and at the Forest Research Institute, Dehradun (DD). No specimens were available at the herbaria of the Botanical Survey of India in Pune (BSI). From select trees observed during this study, leaves, flowers, and maturing fruit were collected and photographed. These were subsequently used for preparing herbarium specimens and deposited into Herbarium JCB (Accession No.: JCB-1337) at the Centre for Ecological Sciences, Indian Institute of Science, Bengaluru. A sample of 11 maturing fruits, fallen on the ground in the vicinity of the trees, were individually measured for weight using a digital Ohaus scale, and nut length (along main longitudinal axis) and width (along two axes perpendicular to the longitudinal and to each other) were measured using Vernier calipers. The length and width of the two wings (enlarged sepals) of each of the fruits were also measured using Vernier calipers (except in the case of 1 fruit where 1 wing was broken, for which only width was measured and not the length). Data from the study are available on Zenodo (Page et al. 2022).

## RESULTS

Tropical wet evergreen forest areas between 580 m and 700 m elevation were present only along six survey routes within the Manamboli Range in ATR. These routes were in the Ayyankulam-Manamboli area located along the Parayankadavu Ār (Ār = river) that flows into the Parambikulam Reservoir in neighbouring Kerala State (Figure 1). In 2021, 20 *Dipterocarpus bourdillonii* trees were recorded along three trails passing through two main locations along the Parayankadavu Ār within ATR: 13 trees at Ayyankulam (10.381$^0$N, 76.910$^0$E) and 7 trees at Ayyankulam Parai (10.386$^0$N, 76.926$^0$E), the latter about 2.4 km (1.8 km straight line distance) upstream from the former location. In March 2022, another 20 trees were recorded, including two trees at Ayyankulam

Parai and 18 along three of the four additional trails surveyed along the same river: Ayyankulam Parai to Ayyankulam (left bank 9; right bank 8), and Manamboli Powerhouse to Ayyankulam (left bank 1; right bank 0). *D. bourdillonii* was not recorded in any of the other 59 trails surveyed in Anamalai Tiger Reserve and Valparai Plateau.

The 40 *D. bourdillonii* trees were located at elevations between 627 m and 733 m and from the edge of the river to less than 100 m away from the river banks. Two tall trees of the species, when first noted on 30 January 2021 along the river banks at Ayyankulam, were flowering (Image 1). On two subsequent visits to the area, on 26 March 2021 (Ayyankulam) and 10 April 2021 (Ayyankulam Parai), fruiting trees were observed with different stages of fruit developments, a sample of which were measured (Table 1) and photographed (Image 2). In March 2022, subsequently, flowering trees and trees with immature fruits were also observed.

The 40 *D. bourdillonii* trees recorded averaged 375.4 cm in girth at breast height (range 90–622 cm) and 40.0 m in height (range 12–51.3 m, Table 1). In the PCQ plots centred on 23 individual *D. bourdillonii* trees, a total of 37 tree species (92 individual trees >30 cm GBH) were recorded, with the most frequently associated species being *Paracroton pendulus* (13 individuals), *Monoon fragrans* (8), *Cullenia exarillata* (8), and *Reinwardtiodendron anamalaiense* (5). In the vicinity of these *D. bourdillonii* trees, the average density of conspecific seedlings was higher than that of saplings, which were in turn higher than the density of *D. bourdillonii* trees (Table 1). Twelve (52%) of 23 trees were noted to be emergent and the remainder were canopy trees. Canopy shape was oval in 19/23 trees (remainder had spreading canopies) and most (20/23) were located at spots with 75–100% canopy cover (2 trees in spots with 51–75% canopy cover, 1 at <25% cover). While four trees were on flat terrain, the remainder were on gentle (7), moderate (6), or steep (6) slopes. Nine trees had buttresses.

## Taxonomy

*Dipterocarpus bourdillonii* Brandis in Hook., Ic. Pl. t. 25. 1895; Gamble, Fl. Madras 81(58). 1915; K.P. Janardh. in B.D. Sharma & Sanjappa, Fl. India 3: 210. 1993; Subram., Fl. Thenmala Div. 27. 1995; Sasidh., Fl. Periyar Tiger Reserve 27. 1998; Anil Kumar et al., Fl. Pathanamthitta 74. 2005; K.P. Janardh. & W. Arisdason in P. Daniel, Fl. Kerala 1: 360. 2005.

Lofty, evergreen trees, up to 51 m tall. Young parts covered with tawny stellate pubescence; leaf buds obtuse, setose or woolly. Stipules large, amplexicaul, leaving an annular scar. Leaves simple, alternate; petiole 4–5.5 cm long, swollen at the apex, tomentose; lamina

**Table 1. *Dipterocarpus bourdillonii* focal tree characteristics: number of conspecific seedlings, saplings, and trees, and fruit and seed measurements in the Anamalai Tiger Reserve, Tamil Nadu. N = number of trees (tree measurements) and number of fruits (fruit measurements).**

| Variable | Mean | Standard error | Minimum | Maximum | N |
|---|---|---|---|---|---|
| **Tree measurements** | | | | | |
| Girth at breast height (cm) | 375.4 | 22.2 | 90 | 622 | 40 |
| Tree height (m) | 40.0 | 1.3 | 12 | 51.3 | 39[†] |
| Canopy height (m) | 40.0 | 1.0 | 30 | 48.8 | 23[#] |
| Seedlings (number/78.5 m²) | 0.9 | 0.3 | 0 | 6 | 23[#] |
| Saplings (number/78.5 m²) | 0.2 | 0.1 | 0 | 2 | 23[#] |
| Trees (number/78.5 m²) | 0.1 | 0.1 | 0 | 1 | 23[#] |
| **Fruit measurements** | | | | | |
| Mass of maturing fruit (g) | 1.31 | 0.11 | 0.75 | 1.80 | 11 |
| Nut length (cm) | 2.20 | 0.03 | 2.10 | 2.40 | 11 |
| Nut width 1 (cm) | 1.28 | 0.02 | 1.15 | 1.40 | 11 |
| Nut width 2 (cm) | 1.20 | 0.03 | 1.10 | 1.40 | 11 |
| Longer wing length (cm) | 9.56 | 0.30 | 8 | 11 | 10 |
| Longer wing width (cm) | 1.84 | 0.10 | 1.3 | 2.3 | 11 |
| Shorter wing length (cm) | 9.18 | 0.26 | 7.8 | 10.5 | 10 |
| Shorter wing width (cm) | 1.79 | 0.12 | 1 | 2.3 | 11 |

[†]—missing data from 1 tree | [#]—focal trees >30 m from conspecifics.


**Image 1. *Dipterocarpus bourdillonii* tree and leaves: a—view of emergent tree | b—abaxial surface of leaf | c—adaxial surface of leaf | d—view of basal portion of trunk | e—flowering branchlets. © NCF, CC-BY 4.0**

ovate or obovate, 18–45 x 12–25 cm, coriaceous, abaxially stellate hairy, adaxially sparsely silky-villous, lateral vein 13–23 pairs, parallel, conspicuously raised abaxially, base rounded, subcordate or cuneate, margins undulate, ciliate, gradually or abruptly acuminate at apex. Flowers bisexual, in axillary racemes, 10 cm long, and 3-5 flowered. Calyx segments 5, 2 rather long and linear, 3 shorter and triangular. Petals pinkish and white, elliptic oblong, 3.5 cm long, densely pubescent outside, margin slightly upcurved, obtuse at apex. Stamens (27–)30; anthers linear to lanceolate, ca. 0.9 cm long, sagittate at base, coherent; connective appendages as long as anthers; filaments filiform, dilated at base. Ovary narrowly ovoid, sericeous, 3-loculed, with 2 ovules per locule; style finely terete, with long silky hairs on lower half. Nut ca. 2 cm in diam., ellipsoid, crowned by thickened, accrescent calyx lobes; calyx tube to 3.5 cm in diam., 5 winged; wing-like calyx segments 2, pinkish-red, linear-lanceolate, to 14 × 3 cm, leathery, 3-veined, rounded at apex (Table 1).

**Flowering:** January to March; fruiting: March–June.

**Herbarium specimens examined:** India, Tamil Nadu, Coimbatore District, Anamalai Tiger Reserve, Ayyankulam (10.380$^0$N & 76.909$^0$E, 628 m), 30 January 2021, coll. Srinivasan Kasinathan, Kshama Bhat, G. Moorthi, T. Sundarraj, T. R. Shankar Raman, and Navendu Page s.n. (Accession No.: JCB-1337).

**Additional specimens examined:** India, Kerala, Travancore, 1894, Brandis 2403 (K!); undated, 534 (MH!); Kollam District: Achankovil, 22 September 1977, N. Sasidharan 108 (KFRI!); 109 (KFRI!); Palakkad District, 550 m, 22 January 1980, P. Bhargavan 65660 (MH!); 350 m, 4 April 1983, P. Bhargavan 78309 (MH!); Ernakulam District: Anakulam, 14 March 1986, K.K.N. Nair 8079 (KFRI!); 7704 (KFRI!); Malayattoor, February 1936, Forest Ranger 160 (FRI!, 9x); March 1936, Forest Ranger 767 (FRI!, 2x), May 1937, Forest Ranger 74608 (FRI!), 10 February 1898, T.F. Bourdillon 918 (FRI!); Tamil Nadu, Nilgiris District, 11 February 1984, B.R. Ramesh 5521 (HIFP!).

The present study extends the known distribution of the Critically Endangered endemic *Dipterocarpus bourdillonii* to the Anamalai Tiger Reserve in Tamil Nadu. It also extends the known upper limit of the altitudinal range of the species to at least 733 m, higher than the range of 200–400 m reported from Kerala (Swarupanandan et al. 2013), and 176–271 m reported from Kodagu in Karnataka (Puttaswamy et al. 2010). The two MH herbarium specimens examined were from trees located at 350 m and 550 m elevation, while the BIOTIK website (Ramesh et al. 2010) reports the species may occur in low elevation wet evergreen forests up to 600 m (BIOTIK 2021). While *D. bourdillonii* has not been listed as occurring in Tamil Nadu in state floras (Gamble & Fischer 1935; Nair & Henry 1983; Matthew 1999; Narasimhan & Irwin 2021), there are two earlier reports from Tamil Nadu, from Nadugani Ghat area in western Nilgiris District (Ramesh & Pascal 1997) and a possible record in Megamalai Wildlife Sanctuary (V. Ravichandran, pers. comm. July 2022), but no additional details are available. Although the Ayyankulam area within the Anamalai Tiger Reserve falls within the zone of very high to excellent in terms of habitat suitability for *D. bourdillonii* as identified by species distribution modeling in an earlier study (Swarupanandan et al. 2013), the present report is the first to confirm the occurrence of *D. bourdillonii* in this area and is a new population record for the state.

## DISCUSSION

The present report is also significant as it confirms the presence of a significant population (at least 40 mature trees) of *D. bourdillonii* in the Anamalai Hills. As in earlier studies, *D. bourdillonii* trees were confined to areas close to rivers on relatively flat to moderate slope. The trees were located mainly along the river between Ayyankulam and Ayyankulam Parai, both within the core area of the Anamalai Tiger Reserve, but the occurrence of one individual further downstream along the Parayankadavu Ār indicates there may be more individuals in the intervening area. Given that the species has an estimated global population of under 250 mature individuals, with less than 50 mature individuals in the largest known sub-population (Deepu et al. 2021), the Anamalai Hills population of least 40 mature individuals gains significance as an important site for in situ conservation of this Critically Endangered species.

Most (37) of the 40 trees observed were of large girth (>200 cm) and only few seedlings and saplings were recorded in their vicinity. The species has been reported to have intrinsically poor reproduction besides probably being affected by past selective logging (Swarupanandan et al. 2013). Future studies on population structure and regeneration of *D. bourdillonii* are required to assess the regeneration status in the study area.

In other parts of its distributional range, *D. bourdillonii* is reported to occur with species such as *Vateria indica*, *Turpinia malabarica*, *Dipterocarpus indicus*, *Humboldtia brunonis*, and *Nothopegia beddomei* (Pascal 1988; Puttaswamy et al. 2010; Swarupanandan et al. 2013). In


**Image 2. *Dipterocarpus bourdillonii* flowers, fruits, and seedling: a–b—fresh fallen flowers | c—view of flower with sepal and petal partially removed | d—maturing fruits | e—seedlings showing tawny stellate pubescence on young parts. © NCF, CC-BY 4.0**

the Anamalais, while *Paracroton pendulus* and *Monoon fragrans* were most frequent near *D. bourdillonii* trees, other lower elevation rainforest species such as *Vateria indica* and *Reinwardtiodendron anamalaiense* were also recorded in plots, besides species such as *Strombosia ceylanica* and *Anacolosa densiflora* in the Ayyankulam area. The expected natural vegetation types for this region include lower elevation (<700 m) tropical wet evergreen forest of the *Dipterocarpus indicus – Dipterocarpus bourdillonii – Strombosia ceylanica* type and medium elevation (700–1,400 m) tropical wet evergreen forest of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* type (Pascal 1988). While *Dipterocarpus indicus* was not recorded in the Ayyankulam Area during the present survey, it is the fifth most common tree species in the Varagaliar area (c. 6 km straight line distance) within ATR (Ayyappan & Parthasarathy 1999) and was also recorded there during the present survey.

The newly-discovered Anamalai population also showed some morphological peculiarities. The shape of the leaf apex of *D. bourdillonii* is described in the literature as shortly acuminate (Brandis 1906). On mature individuals in the Anamalai Hills, the leaves, particularly those at the top of the canopy exhibited an abruptly acuminate leaf apex, which may represent minor intra-specific variation.

Future surveys for *D. bourdillonii* should cover a wider altitudinal range (0–800 m) in evergreen forest areas along rivers. As the species can be clearly identified from flowers and fruits, carrying out surveys between January and April during the flowering and fruiting season is suggested. The existing population in the Ayyankulam area should continue to be protected, and in situ conservation efforts should focus on areas within the known ranges of this Critically Endangered species.

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