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## REPORT ON EXPEDITION / PROJECT

**Expedition/Project Title:** Exploring an enigma – the geographic and temporal origins of the Western Ghats flora  
August – September 2022

**Travel Dates:** Karnataka and Kerala, India

**Location:** Madhavi Sreenath, Mark Hughes

**Group Members:** To understand the age and origin of floristic diversity in the Western Ghats forests of Karnataka and Kerala

**Aims:**

**Photography consent form attached:**  Yes  
(please refer to your award letter)  No

### Outcome (a minimum of 500 words):-

#### Abstract

The Western Ghats (Ghats) are an ancient mountain range with an extraordinarily diverse flora and an origin that dates back to the Late Jurassic period. The biodiversity of these sky islands has been influenced by the separation of India from Gondwana in the Late Jurassic followed by its ultimate collision with the Eurasian plate in the Late Cretaceous. As a consequence of this, the flora of the Western Ghats has the potential to have accreted from several regions, including Africa, the Himalayas, Continental Asia, and the Sunda Shelf. There is an emerging paradigm of tropical floras being geologically young and driven by high rates of species turnover. However, the unique journey of the Indian subcontinent alludes to the presence of an entirely unique floristic diversity in the Western Ghats. The aim of this project was to understand the temporal and geographic origins of the Western Ghats flora with the help of a herbarium genomics (Whole Genome Sequencing) and phylogenetic approach using native or endemic taxa from representative families.

#### Introduction

India separated from Gondwana between the Late Jurassic and early Cretaceous epochs (Briggs, 2003; Chatterjee et al., 2013) resulting in the formation an extremely large faulted edge range – the Western Ghats (Figure 1.1) (Gunnell and Fleitout, 1998; Radhakrishna et al., 2019). Its ensuing collision with the Eurasian plate then created the still rising Himalayas (Ali and Aitchison, 2008; Chatterjee et al., 2013). This tropical mountain system is one of the oldest ranges in the world (c.150 mya) and when combined with the island of Sri Lanka is considered one large biodiversity hotspot (Bossuyt, 2004). From the state of Gujarat in the north to the states of Kerala and Tamil Nadu in the south, they span a length of 1,600 km (Joshi and Karanth,

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2013). The range is discontinuous (Robin et al., 2010) and situated with the Arabian Sea on the left and the Deccan Plateau on the right. The entire mountain chain can be divided into three major sections – the Northern, Central and Southern Western Ghats (Joshi and Karanth, 2013).

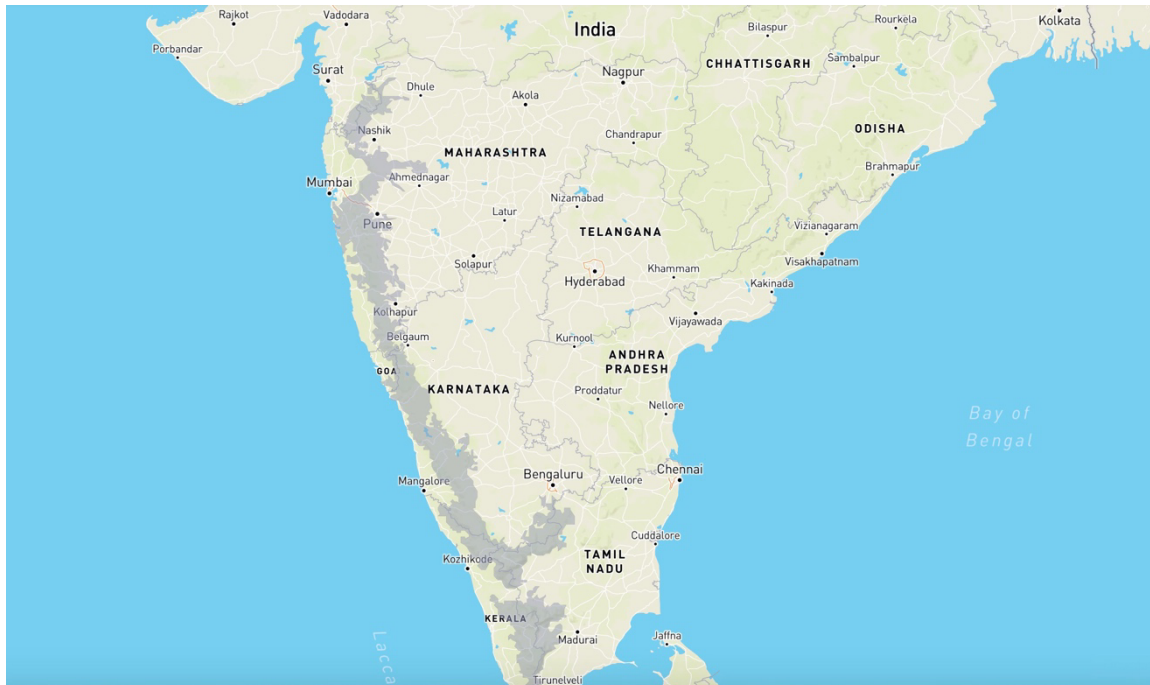


Figure 1.1: Peninsular India with the colour grey demarcating the boundaries of the Western Ghats. Image taken from [indiabiodiversity.org](http://indiabiodiversity.org).

These magnificent sky islands (Robin et al., 2010) house four known gaps – the Goa, Moyar (Mysore), Palakkad (Palghat) and Shencottah gaps; each of which have a different geological age and size (Robin *et al.*, 2010). The widely known Palghat or Palakkad gap is 30-40 km wide and found in the Southern Western Ghats (SWG) just past Silent Valley, Mukkali (Robin *et al.*, 2010; Joshi and Karanth, 2013). There is evidence to suggest that biodiversity varies within and on either sides of these gaps (Anoop *et al.*, 2010; Robin *et al.*, 2010; Rajasri *et al.*, 2017). The Indian subcontinent witnesses an extended monsoon from June to December and the Ghats are the first barrier encountered by these rain bearing clouds moving in from the Arabian Sea (Gunnell and Fleitout, 1998; Venkatesh and Jose, 2007). The combination of age, latitude, topography and climate makes for the presence of an entirely unique floral and faunal biodiversity in the Western Ghats (Dray, 2003; Sundarapandian and Swamy, 2015). This mountain range currently houses c.5.588 species of flowering plants, of which c.1,200 are endemic (Prakash, 2015). Endemism has been found to be much higher in the SWG past the Palghat gap (Davidar et al., 2005; Gopal et al., 2023; Ramesh et al., 2010). The Ghats are an area of high and unequally distributed biodiversity (Prasad *et al.*, 2009). This unequal distribution and clustering of biodiversity forms hotspots scattered throughout the Ghats adding to its already non-homogenous flora.

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## Aims

The aim of this project was to understand the temporal and geographic origins of the Western Ghats flora. This was accomplished with the help of dated molecular phylogenies and biogeographic models, depicting the build-up of species over geological time from areas surrounding the Indian subcontinent. The objective of this field expedition was to collect specimens of endemic/native Western Ghats taxa of specific angiosperm families. The collected taxa were then extracted for DNA using an altered Qiagen DNeasy Protocol, sequenced with the next generation short read sequencing method – genome skimming, and incorporated into existing datasets. The individual datasets were subsequently used to generate time calibrated phylogenies that were analysed using the R package BioGeoBEARS (Matzke, 2013). Geological ages and ancestral areas for each immigration event was then collated from the dated phylogenies and biogeographic models respectively, to identify the overarching patterns of arrival into the region.

## Study Site



A field expedition was conducted to the Western Ghats forests of Karnataka and Kerala in the monsoon months of August and September in 2022. Samples were collected from the territorial forests of Karnataka and the protected areas of Kerala, covering a total length of c.350 km of the Ghats. In the state of Karnataka, permission to collect botanical specimens was granted only for territorial forests (forests that do not fall under that category of a wildlife sanctuary or protected area). Collections were made in the designated forests in the district of Kodagu, Madikeri and Somwarpet talukas (Figure 1.2). In the state of Kerala, permission to collect botanical specimens was granted for protected areas and wildlife sanctuaries. Collections were made in the two major wildlife sanctuaries – Bhavani Range, Silent Valley National Park (Figure 1.3), and Muthanga Wildlife Sanctuary (Figure 1.4).

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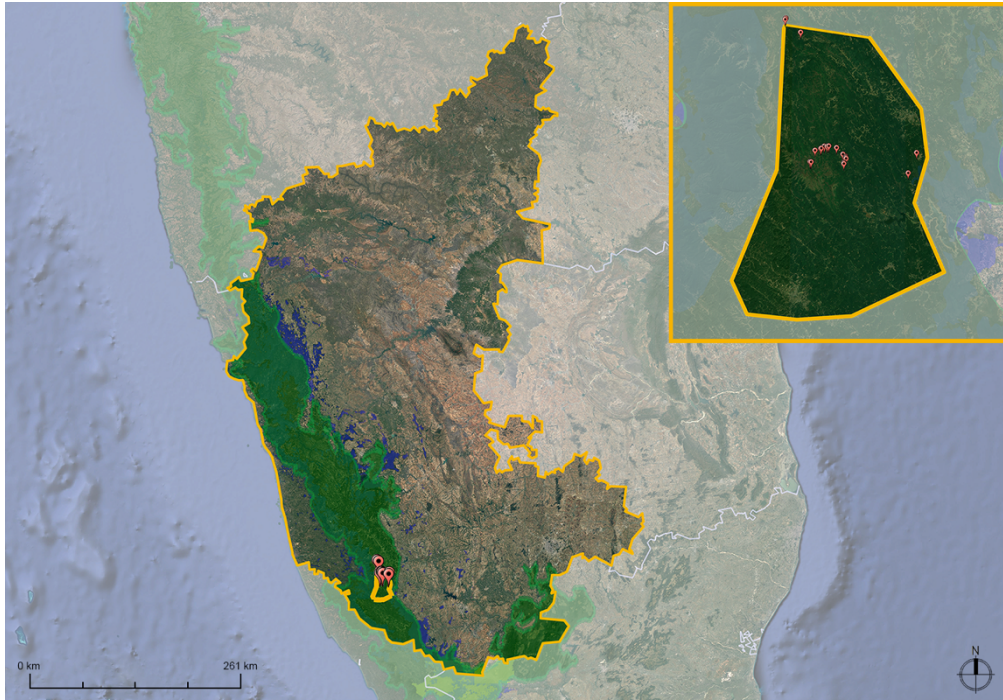


Figure 1.2: Specimen collection locations in the Kodagu district of Karnataka.

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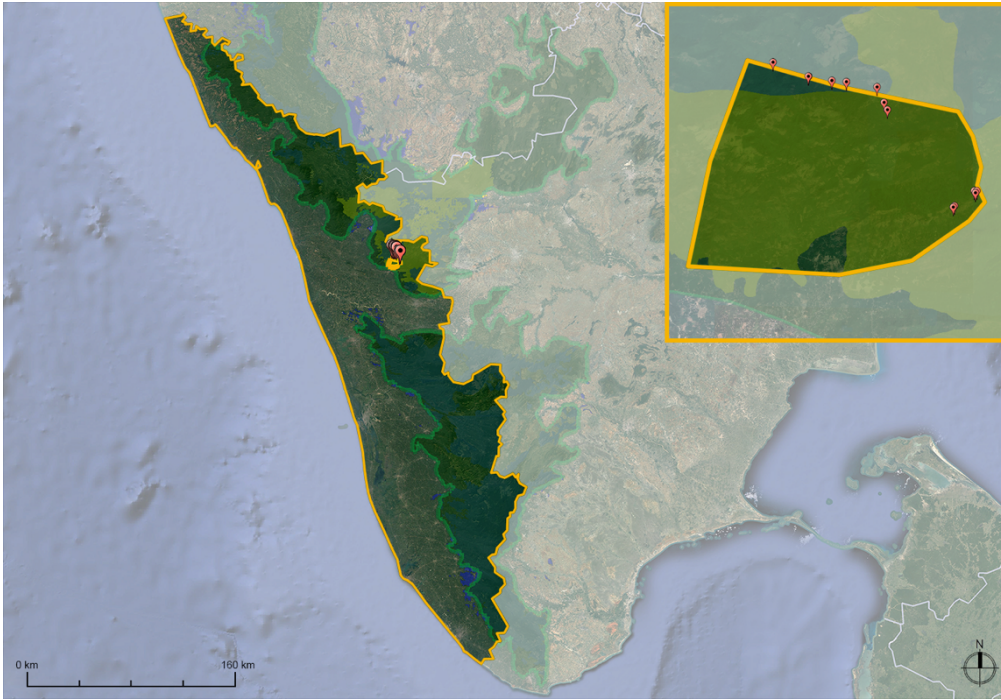


Figure 1.3: Specimen collection locations in Silent Valley National Park, Kerala.

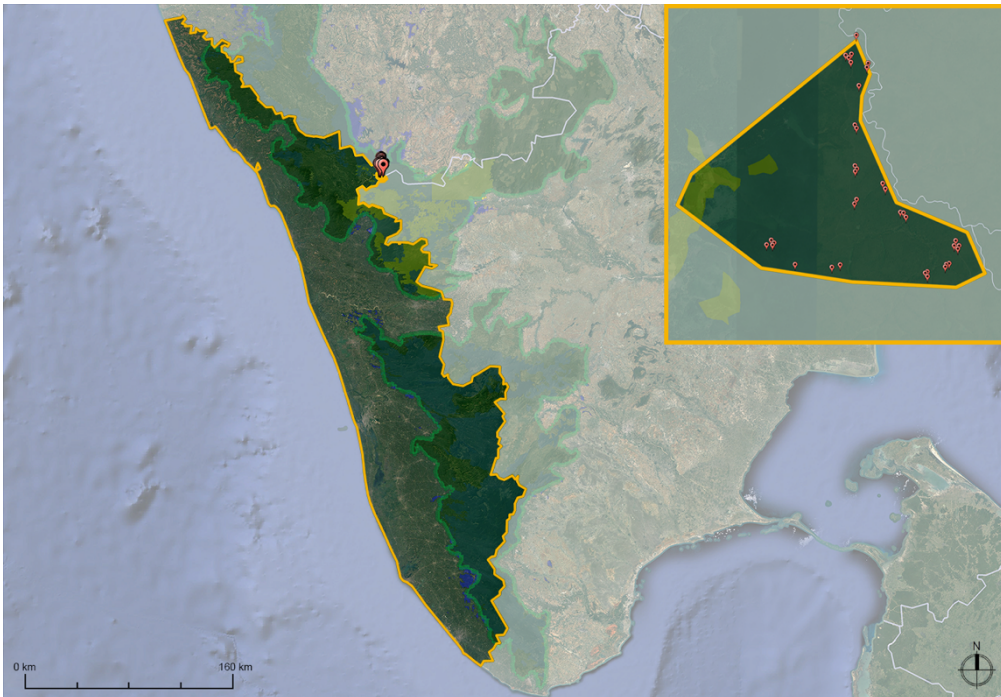


Figure 1.4: Specimen collection locations in the Muthanga Wildlife Sanctuary, Kerala.

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### Collection Method

Collection permits were requested and acquired for endemic/native species of nine angiosperm families – *Annonaceae*, *Begoniaceae*, *Chloranthaceae*, *Ebenaceae*, *Gesneriaceae*, *Hernandiaceae*, *Lauraceae*, *Sapotaceae*, and *Zingiberaceae*. Samples were collected in two forms – silica dried and herbarium. Where possible samples for herbarium sheets were collected in triplicates for each specimen. As it was the monsoon season specimens were collected in the field and pressed in newspaper upon moving to a dry location. Leaf sample of c. 5 grams was collected in a tea bag and dehydrated using silica. At each collection point, an image of the sample, the habit, the habitat, any descriptive notes, and the GPS coordinates of the area were recorded. GPS coordinates were acquired using a Garmin eTex30 set to World Geodetic System 84 (WGS84). Collected specimens will be available at a Botanical Society of India herbarium, as agreed upon with the National Biodiversity Authority of India.

### Outcomes

The field season was greatly affected by the monsoon, however it was still possible to collect 91 samples in the form of herbarium sheets and silica samples. Collections belonged to 7 families – *Annonaceae*, *Begoniaceae*, *Ebenaceae*, *Gesneriaceae*, *Lauraceae*, *Sapotaceae*, and *Zingiberaceae*. Of the 91 samples 50 were extracted for DNA and sent to the Bengaluru based genomics company Genotypic for Whole Genome Sequencing. Data from the sequenced taxa were then combined with data from previous herbarium DNA extractions and existing phylogenies. Table 1.1 provides information on the collected and sequenced taxa that were part of the final analyses. Taxa from this field season were vital additions to our current understanding of the flora of the Western Ghats. We found that the flora of the Ghats, as depicted by the Age of Disjunction graph (Figure 1.5), appeared to be geologically young, with many of the clades arriving between the Oligocene and the Pliocene. The scatter plot in Figure 1.5 represents dispersal events for fifteen angiosperm families, with 66 clades added from this study; 44 taxa across the 66 clades were collected during this field season.

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Taxon Name	Family	Collector Name(s)	Collecto Number	Country	Material Type	User DNA ID	Location	Collection Date	Sample name in phylogeny	Notes
<i>Begonia malabarica</i>	<i>Begoniaceae</i>	Madhavi Sreenath	MASR001	IN	SD	MSF1	Office of the Deputy Wildlife Warden Madikeri Division	15/08/2022	MSF1	
<i>Heydychium</i>	<i>Zingiberaceae</i>	Madhavi Sreenath	MASR003	IN	SD	MSF2	Madikeri, Coorg	08-Aug-22	<i>Heydychium villosum_ MSF2</i>	
<i>Begonia malabarica</i>	<i>Begoniaceae</i>	Madhavi Sreenath	MASR010	IN	SD	MSF3	Office of the Deputy Wildlife Warden Madikeri Division	16/08/2022	MSF3	
<i>Cinnamomum malabatrimum</i>	<i>Lauraceae</i>	Madhavi Sreenath	MASR011	IN	SD	MSF4	Suntikoppa, Madikeri	16/08/2022	<i>Cinnamomum_sp_MS F4</i>	
<i>Polyalthia longifolia</i>	<i>Annonaceae</i>	Madhavi Sreenath	MASR021	IN	SD	MSF12	Range Forest Office, Somwarpet		<i>Polyalthia_l ongifolia_ MSF12</i>	
<i>Cinnamomum sp</i>	<i>Lauraceae</i>	Madhavi Sreenath	MASR022	IN	SD	MSF6	Somwarpet, Madikeri	18/08/2022	<i>Cinnamomum_sp_MS F6</i>	
<i>Artabotrys zeylanica</i>	<i>Annonaceae</i>	Madhavi Sreenath	MASR023	IN	SD	MSF27	Devarkadu, Shanthahalli, Somwarpet Range	18-Aug-22	<i>Artabotrys_ zeylanica_ MSF27</i>	
<i>Cucurma sp</i>	<i>Zingiberaceae</i>	Madhavi Sreenath	MASR024	IN	SD	MSF7	Shanthahalli, Devarkadu, Somwarpet	18-Aug-22	<i>Cucurma_s p_MS F7</i>	
<i>Amomum sp</i>	<i>Zingiberaceae</i>	Madhavi Sreenath	MASR025	IN	SD	MSF23	Shanthahalli, Devarkadu, Somwarpet	18-Aug-22	<i>Amomum_s p_MS F23</i>	

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Taxon Name	Family	Collector Name(s)	Collecto Number	Country	Material Type	User DNA ID	Location	Collection Date	Sample name in phylogeny	Notes
<i>Begonia malabarica</i>	Begoniaceae	Madhavi Sreenath	MASR027A	IN	SD	MSF8	Office of the Assistant Wildlife Warden Tholpetty Range, Begur, Wayanad	19/08/2022	MSF8	
<i>Begonia malabarica</i>	Begoniaceae	Madhavi Sreenath	MASR027B	IN	SD	MSF9	Office of the Assistant Wildlife Warden Tholpetty Range, Begur, Wayanad	19/08/2022	MSF9	
<i>Begonia malabarica</i>	Begoniaceae	Madhavi Sreenath	MASR027C	IN	SD	MSF10	Office of the Assistant Wildlife Warden Tholpetty Range, Begur, Wayanad	19/08/2022	MSF10	
<i>Begonia sp</i>	Begoniaceae	Madhavi Sreenath	MASR032	IN	SD	MSF18	Office of the Assistant Wildlife Warden Tholpetty Range, Begur, Wayanad	19/08/2022	MSF18	
<i>Begonia hydrophila</i>	Begoniaceae	Madhavi Sreenath	MASR033	IN	SD	MSF13	Mukkali, Bhavani Range, Silent Valley	19/08/2022	<i>Begonia_hydrophila_MS13</i>	
<i>Begonia anaimalaie nsis</i>	Begoniaceae	Madhavi Sreenath	MASR034	IN	SD	MSF17	Mukkali, Bhavani Range, Silent Valley	22/08/2022	MSF17	
<i>Begonia anaimalaie nsis</i>	Begoniaceae	Madhavi Sreenath	MASR035	IN	SD	MSF22	Mukkali, Bhavani Range, Silent Valley	22/08/2022	MSF22	
<i>Begonia anaimalaie nsis</i>	Begoniaceae	Madhavi Sreenath	MASR036A	IN	SD	MSF19	Mukkali, Bhavani Range, Silent Valley	22/08/2022	MSF19	
<i>Begonia anaimalaie nsis</i>	Begoniaceae	Madhavi Sreenath	MASR036B	IN	SD	MSF20	Mukkali, Bhavani Range, Silent Valley	22/08/2022	<i>Begonia_anaimalaie nsis_MS20</i>	



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Taxon Name	Family	Collector Name(s)	Collecto Number	Country	Material Type	User DNA ID	Location	Collection Date	Sample name in phylogeny	Notes
<i>Annona reticulata</i>	Annonaceae	Madhavi Sreenath	MASR038	IN	SD	MSF16	Mukkali, Bhavani Range Gate, Silent Valley National Park	22-Aug-22	MSF16	
<i>Globba sessiliflora</i>	Zingiberaceae	Madhavi Sreenath	MASR039	IN	SD	MSF21	Mannarkkad, Bhavani Range, Silent Valley National Park	22-Aug-22	<i>Globba_ses siliflora_MS F21</i>	
<i>Begonia dipetala</i>	Begoniaceae	Madhavi Sreenath	MASR040A	IN	SD	MSF14	Bhavani Range, Silent Valley National Park, Karuvar	23/08/2022	<i>Begonia_dipetala_MS F14</i>	
<i>Begonia dipetala</i>	Begoniaceae	Madhavi Sreenath	MASR040B	IN	SD	MSF15	Bhavani Range, Silent Valley National Park, Karuvar	23/08/2022	MSF15	
<i>Litsea sp</i>	Lauraceae	Madhavi Sreenath	MASR041	IN	SD	MSF24	Bhavani Range, Silent Valley National Park	23/08/2022	<i>Litsea_sp_ MSF24</i>	
<i>Alpinia sp</i>	Zingiberaceae	Madhavi Sreenath	MASR042	IN	SD	MSF43	Panthanthode, Bhavani Range, Silent Valley National Park	23-Aug-22	<i>Alpinia_sp_ MSF43</i>	
<i>Alpinia sp</i>	Zingiberaceae	Madhavi Sreenath	MASR044	IN	SD	MSF25	Panthanthode, Bhavani Range, Silent Valley National Park	23-Aug-22	<i>Alpinia_sp_ MSF25</i>	
<i>Neolitsea</i>	Lauraceae	Madhavi Sreenath	MASR047	IN	SD	MSF39	Bhavani Range, Silent Valley National Park	23/08/2022	MSF39	
<i>Begonia dipetala</i>	Begoniaceae	Madhavi Sreenath	MASR053	IN	SD	MSF41	Bhavani Range, Silent Valley National Park	23/08/2022	MSF41	
<i>Cinnamomum zeylanicum</i>	Lauraceae	Madhavi Sreenath	MASR055	IN	SD	MSF32	Kottebetta, Madhapura Range, Somwarpet	01/09/2022	<i>Cinnamomum_sp_MS F32</i>	

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Taxon Name	Family	Collector Name(s)	Collecto Number	Country	Material Type	User DNA ID	Location	Collection Date	Sample name in phylogeny	Notes
<i>Cinnamomum malabattrum</i>	Lauraceae	Madhavi Sreenath	MASR056	IN	SD	MSF31	Kottebetta, Madhapura Range, Somwarpet	01/09/2022	<i>Cinnamomum_malabattrum_MS31</i>	
<i>Madhuca</i> sp	Sapotaceae	Madhavi Sreenath	MASR057	IN	SD	MSF45	Madapura Range, Somwarpet, Madikeri District	01-Sep-22	<i>Madhuca_sp_MS45</i>	
<i>Elettaria cardamomum</i>	Zingiberaceae	Madhavi Sreenath	MASR058	IN	SD	MSF29	Sirangalli, On the way to Kooti Betta, Madapura Range, Somwarpet	01-Sep-22	<i>Elettaria_cardamomum_MS29</i>	
<i>Zingiber</i> sp	Zingiberaceae	Madhavi Sreenath	MASR059	IN	SD	MSF38	On the way to Kooti Betta, Madhapura Range, Somwarpet	01-Sep-22	<i>Zingiber_sp_MS38</i>	
<i>Zingiber</i> sp	Zingiberaceae	Madhavi Sreenath	MASR072	IN	SD	MSF35	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Zingiber_nimmonii_MS35</i>	
<i>Cinnamomum</i> sp	Lauraceae	Madhavi Sreenath	MASR077	IN	SD	MSF26	Muthanga Wildlife Sanctuary, Wayanad	03/09/2022	<i>Cinnamomum_sp_MS26</i>	
<i>Hopea</i> sp	Dipterocarpaceae	Madhavi Sreenath	MASR086	IN	SD	MSF46	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Hopea_sp_MS46</i>	Sample was misidentified at collection
<i>Globba</i> sp	Zingiberaceae	Madhavi Sreenath	MASR087	IN	SD	MSF40	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Globba_bulbifera_MS40</i>	
<i>Zingiber</i> sp	Zingiberaceae	Madhavi Sreenath	MASR088	IN	SD	MSF42	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Zingiber_sp_MS42</i>	
<i>Zingiber officinale</i>	Zingiberaceae	Madhavi Sreenath	MASR089	IN	SD	MSF34	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Zingiber_officinale_MS34</i>	
<i>Cucurma</i> sp	Zingiberaceae	Madhavi Sreenath	MASR090	IN	SD	MSF44	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Cucurma_sp_MS44</i>	
<i>Cucurma</i> sp	Zingiberaceae	Madhavi Sreenath	MASR091	IN	SD	MSF36	Muthanga Wildlife Sanctuary, Wayanad	03-Sep-22	<i>Cucurma_sp_MS36</i>	
<i>Persea macarantha</i>	Lauraceae	Madhavi Sreenath	MASR092	IN	SD	MSF47		03/09/2022	<i>Persea_macarantha_MS47</i>	
<i>Mimusops elengi</i>	Sapotaceae	Madhavi Sreenath	MASR093	IN	SD	MSF48	Karnataka	31-Aug-22	<i>Mimusops_elengi_MS48</i>	
<i>Diospyros sylvatica</i>	Ebenaceae	Madhavi Sreenath	MASR094	IN	SD	MSF49	Bengaluru, Karnataka	31-Aug-22	MSF49	
<i>Madhuca longifolia</i>	Sapotaceae	Madhavi Sreenath	MASR095	IN	SD	MSF50	Karnataka	31-Aug-22	MSF50	

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Table 1.1: Specimen Information for collected and sequenced taxa from the Western Ghats forests of Karnataka and Kerala, India.

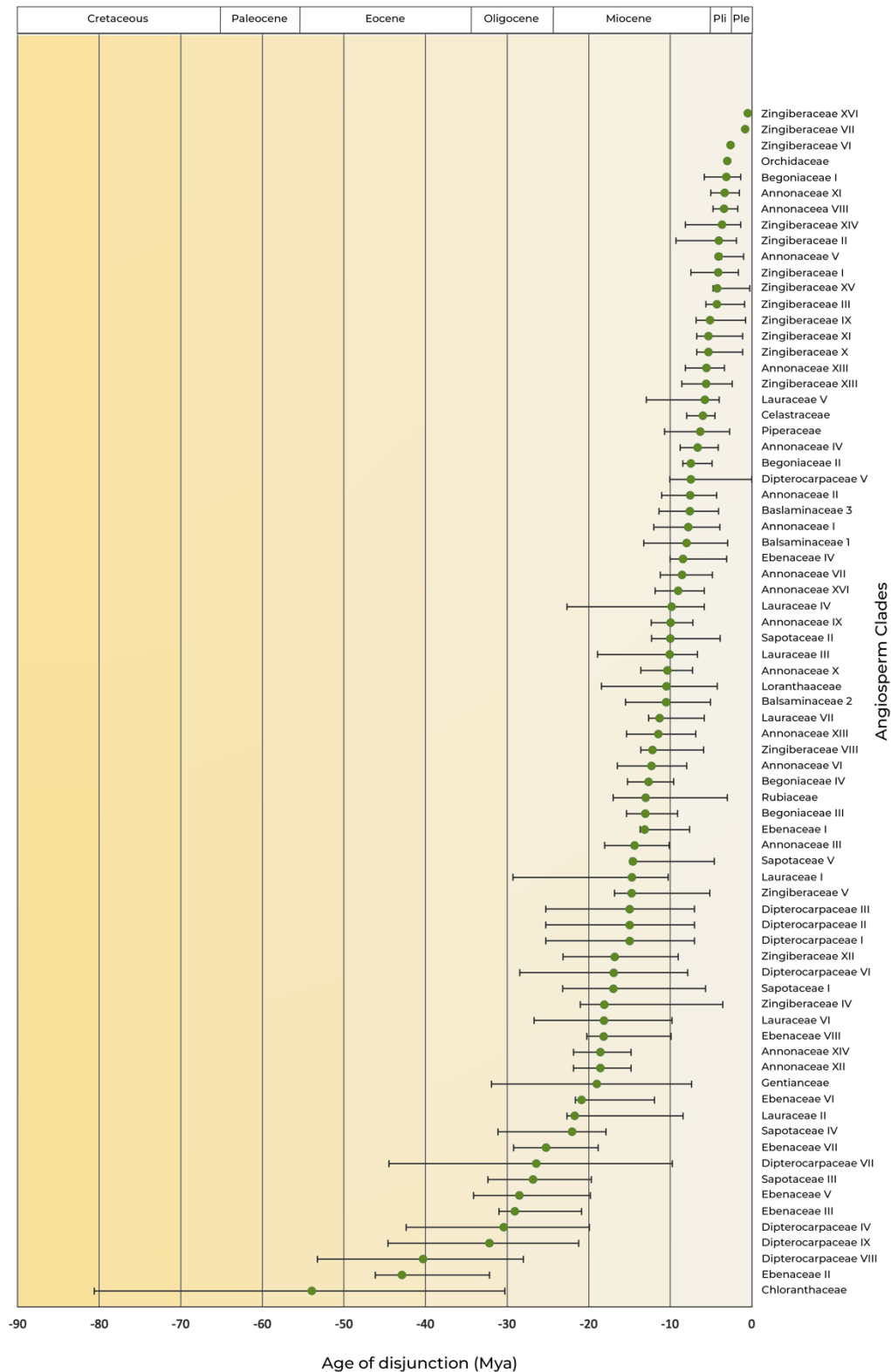


Figure 1.5: Scatter plot depicting the minimum ages of 75 Western Ghats clades.

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The clades are ordered youngest to oldest going down the y-axis. Error bars depict the 95% HPD ages of the clades. 66 clades were added from this study with 9 added from other published studies within the region (Bajpe et al., 2023; Liu et al., 2018; Neupane et al., 2017; Puri et al., 2016; Sen et al., 2019; Tsai et al., 2020; Yuan et al., 2005).

## Photos from the field



*Begonia animalaiensis*



*Begonia animalaiensis*



Collecting *Begonia hydrophila*

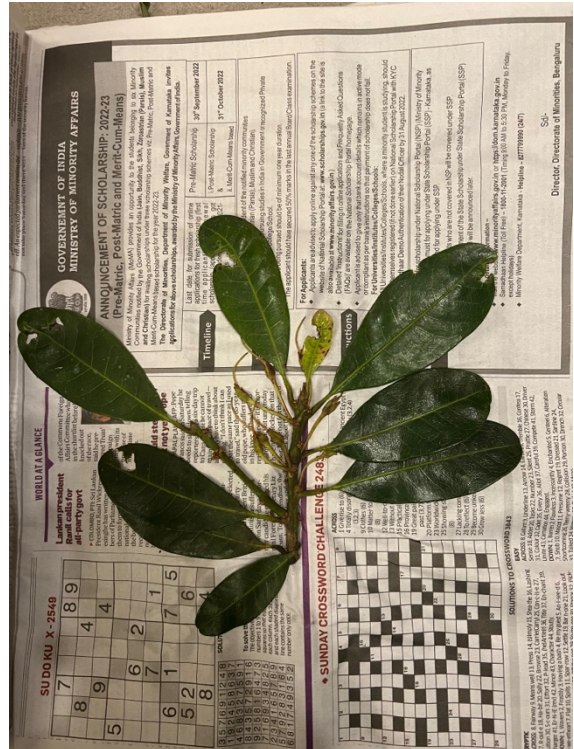


*Alpinia sp*

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*Madhuca sp*



*Madhuca sp*



*Elettaria cardamomum*



*Artabotrys zeylanicus*

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*Cinnamomum sp*



*Zingiber sp*

### Acknowledgements

This field season in the Western Ghats was possible thanks to the Davis Expedition Fund. The final analysis (Figure 1.5) consisted of 44 taxa collected during this field season. We would like to thank the National Biodiversity Authority, Karnataka Forest Department, and Kerala Forest Department for giving us the permission to enter the forests and collect botanical specimens. We would also like to thank the range officers who accompanied us into the forests and were extremely generous with their knowledge of the areas. A special mention to our collaborators at the Ashoka Trust for Research in Ecology and the Environment (ATREE) for helping us with the permit process and allowing us to use their labs and herbarium.

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