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Refuting the hypothesis of Centinelan extinction at its place of origin

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Scientists' limited understanding of tropical plant communities obscures the true extent of species loss caused by habitat destruction[1]. The Centinelan extinction hypothesis[2,3] posits an extreme but widely referenced scenario wherein forest clearing causes the immediate extinction of species known only from a single geographic location. It remains unclear, however, whether the disappearance of such microendemics reflects their global extinction or insufficient collection effort at larger scales. Here we test these hypotheses by synthesizing decades of floristic data from the heavily deforested tropical cloud forest (TCF) at Centinela, Ecuador. We find that 99% of its putative microendemics have been collected elsewhere and are not extinct. Our field work also revealed new species, highlighting the enduring conservation value of TCFs and the intense efforts required to illuminate such plant diversity 'darkspots'[4]. Field and herbarium research remain essential to the conservation action needed to forestall large-scale plant extinctions in Earth's beleaguered cloud forests.

Centinela is a fog-draped mountain ridge in the Andean foothills of western Ecuador, measuring 40 km^2 in area and separated from the main cordillera by a lowland valley (map in Fig. 1b). In 1991, botanists Calaway Dodson and Alwyn Gentry, who had worked for years to inventory the site, published a seminal paper reporting a flora that included '90 plant species endemic to Centinela'[2], many of them undescribed. The authors went on to report that the last forests on Centinela had been felled and converted to agricultural land, and that all its unique plants were probably extinct[2,5–7]. Within the context of >85% of western Ecuador's forests being felled since World War II[2,8], Centinela became a notorious example of how deforestation of hyperdiverse tropical cloud forests (TCFs) could cause the almost instant extinction of a large number of narrowly endemic and undescribed plant species[9–11], an idea solidified by E. O. Wilson's coining of the term 'Centinelan extinction'[3].

A careful reading of Dodson & Gentry[2], however, makes it clear that their claims of microendemism were not intended as empirical facts but rather as hypotheses to be tested. Over the past two decades, many plants first discovered at Centinela have been collected elsewhere, prompting the competing hypothesis that the high levels of microendemism reported at Centinela were an artefact of incomplete botanical exploration[12–14] (see also ref. 15), especially of the Tumbes–Chocó–Magdalena biodiversity hotspot where Centinela lies.

We tested these hypotheses using an unpublished 1983 checklist of the Centinela flora prepared by Dodson & Gentry[2] (Supplementary Table 1 and Fig. 1), analyses of global herbarium records, a review of the scientific literature, expert input and targeted botanical field work (Fig. 1a). Thirty-three years after the seminal paper on Centinela[2], our updated checklist of its flora (Supplementary Table 3) contains only

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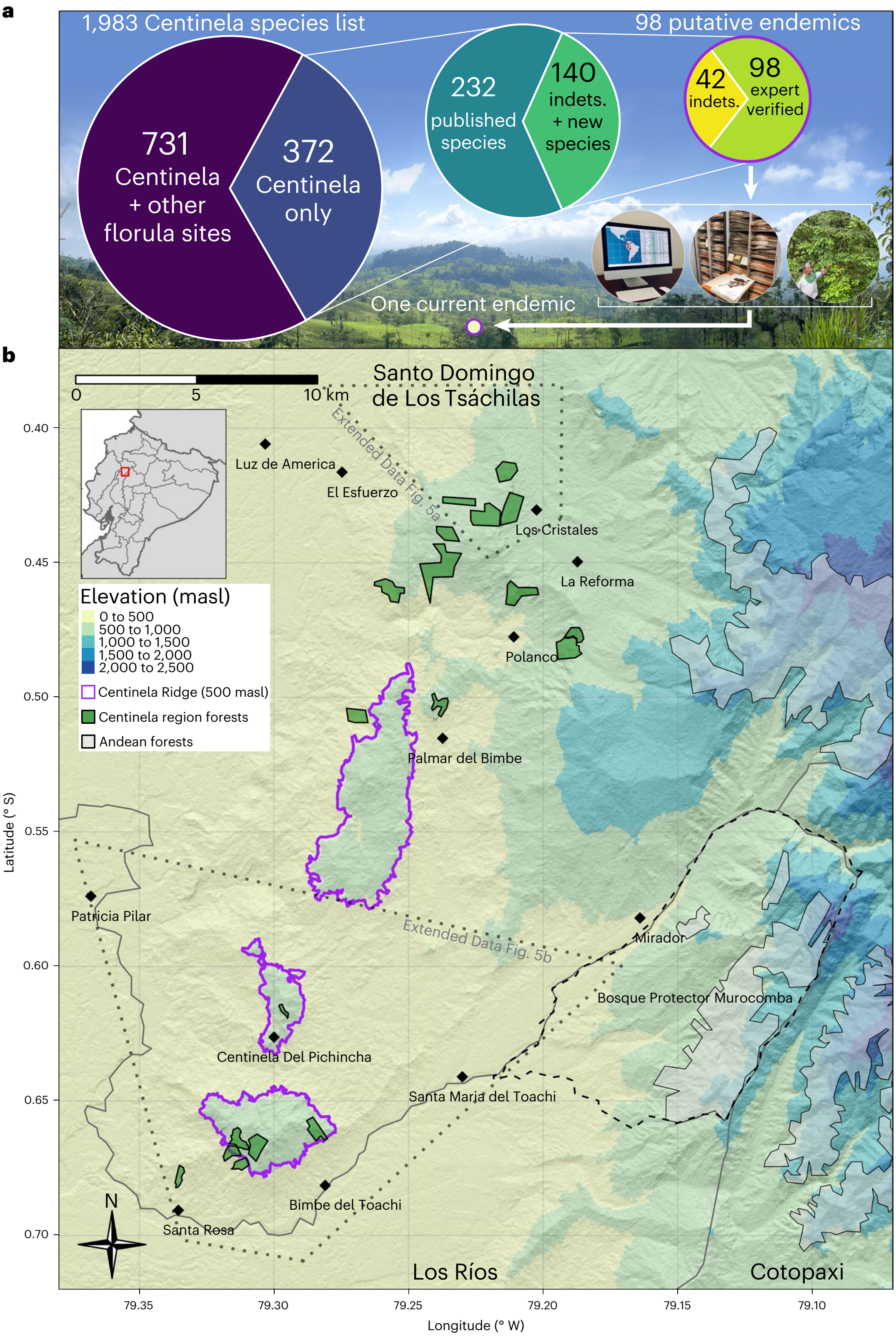

Fig. 1 | Methods used to reconstruct the putative and actual endemic floras of Centinela, Ecuador, and map of surviving forest fragments. a, The list of previous putative Centinela endemics was reconstructed by filtering the 1,103 species and morphospecies in the unpublished checklist down to 98 expert-verified species that were originally published as known only from Centinela or marked as 'indets' (unidentified to species) by checklist authors. We then synthesized collection data for these 98 species from the scientific literature, global floristic databases, local herbaria and our own targeted field work to determine that all but one species have been collected outside Centinela. Photos by D.M.W. **b**, Map of the Centinela region and forest fragments in the southern Santo Domingo de Los Tsáchilas Province. The Centinela ridge sensu Dodson & Gentry[2] is shown in purple polygon as three 'islands' over 500 masl. Polygons indicate extent of primary forest cover estimated from field work and satellite imagery (green) and adjacent Andean slopes (grey) as identified from satellite imagery.

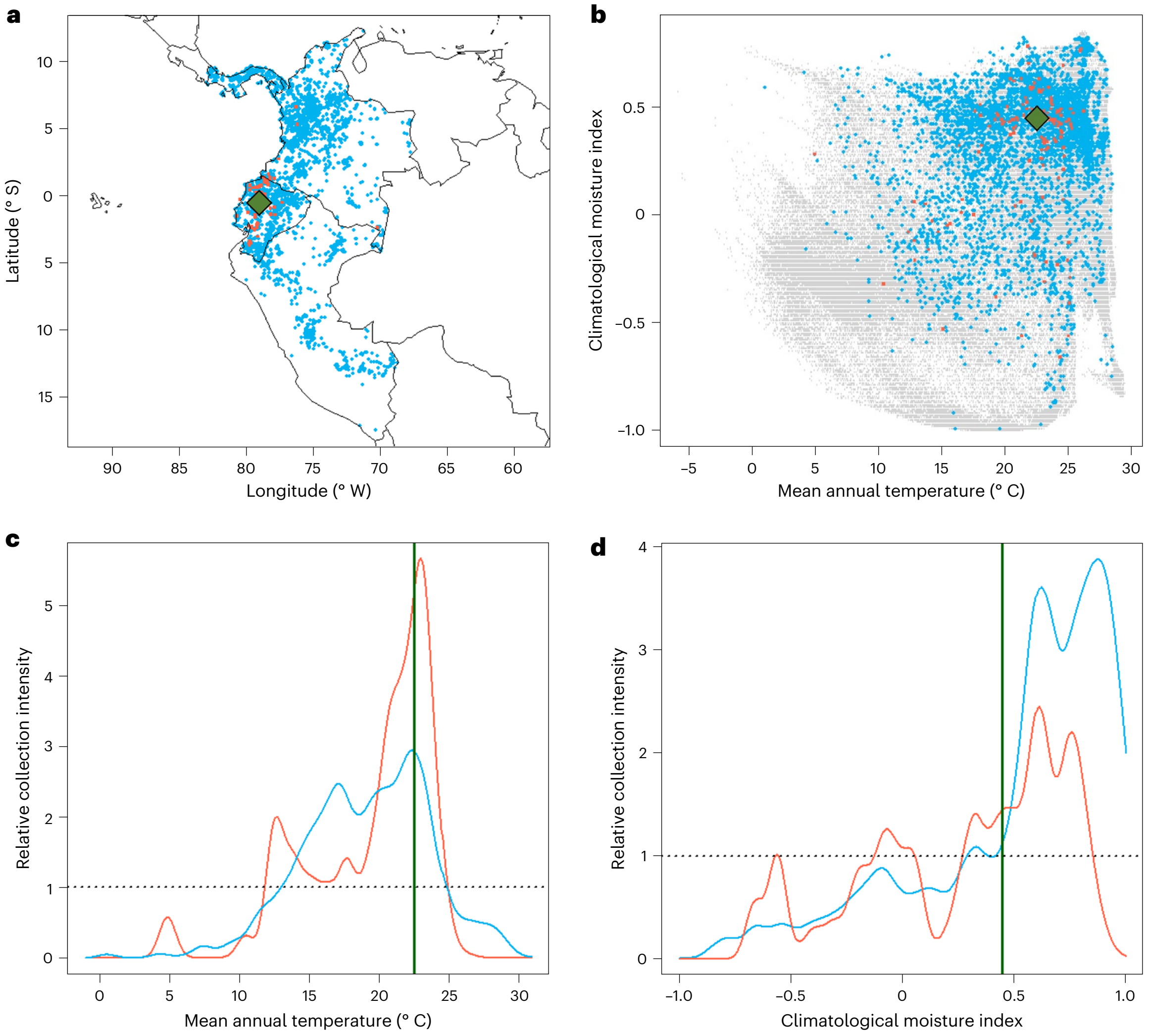

Fig. 2 | Modern-day geographic and climatic distributions of 98 species previously hypothesized as endemic to the Centinela range (green). Data are coloured by our estimation of species' globally threatened (red) or non-threatened (blue) status and are restricted to Ecuador, Colombia, Panama and Peru. **a**, Geographic locations of GBIF occurrence records. **b**, Mean annual temperature and climatic moisture index at occurrence locations (blue and red) and all possible land areas (grey). **c**, Histogram of the relative collection intensity (see Methods) for putative endemics in relation to mean annual temperature. Dotted lines at a value of 1 indicate a null model of random collection intensity relative to climate availability. **d**, Histogram of the relative collection intensity for putative endemics in relation to climatic moisture index.

one putative endemic that has not been recorded elsewhere: the tiny epiphytic orchid *Bifrenaria integrilabia*.

Several independent lines of evidence reinforce the conclusion that the reports of extreme microendemism at Centinela[2] were an artefact of incomplete exploration. First, plant occurrence records across Ecuador, Peru, Colombia and Panama during the period 1965–2022 reveal a rapid decline in the number of species known only from Centinela as hundreds of thousands of plant collections were made across northwestern South America (Extended Data Fig. 1). By 1991, the year that Dodson & Gentry's final Centinela paper was published[2], the proportion of the Centinela flora collected nowhere else was already close to 0% (Extended Data Fig. 1a), a trend only visible now that these collections have been digitized and synthesized. The authors' overestimation of endemism reflects both the limited availability of collection information at the time[10] and a speculative judgement call by botanists concerned about the alarming habitat destruction they were witnessing in one of Earth's original and 'hottest' biodiversity hotspots[11].

Second, the high environmental heterogeneity of the localities where putative endemics have been recorded outside of Centinela (Fig. 2) offers compelling evidence against the hypothesis that endemism at Centinela might derive from unique climatological conditions there[2]. Species once thought endemic to Centinela have since been found not only in TCFs, but also in hundreds of other localities spanning an enormous range of vegetation types[16], elevation (1–99% quantiles = 5–2,925 metres above sea level (masl)), precipitation (climatological moisture index scores from −0.56 to 0.8) and mean annual temperature (9.9–27.8 °C; Fig. 2). Likewise, no unique geologic features at Centinela substantiate an edaphic driver of in situ speciation there[17].

Third, Centinela's putative microendemics share no obvious traits or taxonomic affinities that might indicate a reduced ability to disperse to adjacent Andean forests and maintain a larger geographic range[18]. On the contrary, the list of putative Centinela endemics features trees, treelets, understory herbs and epiphytes from across the plant kingdom, the majority (73%) of which exhibit animal (primarily bird) dispersal (Extended Data Fig. 2).

Finally, extra-Centinelan populations of putative Centinelan endemics have proven easy to locate via targeted field work in adjacent Andean forests. In November 2021, we surveyed a TCF where the Centinela range joins the Andean slopes in search of the four species

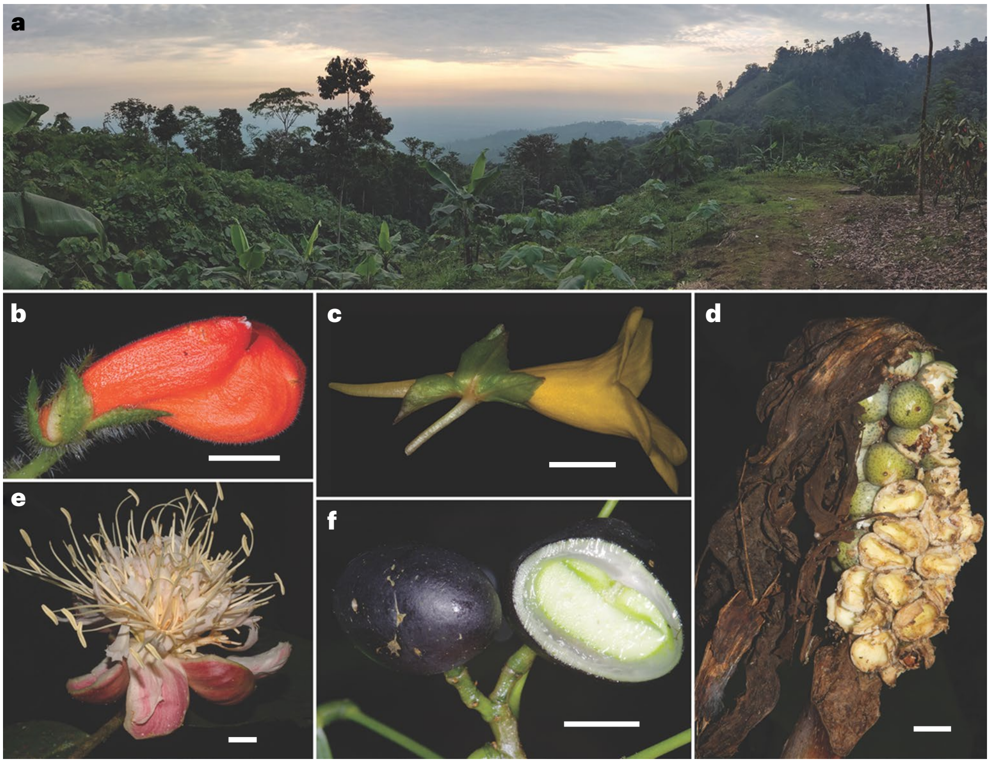

Fig. 3 | Landscape of Centinela, Ecuador, and five plant species once hypothesized to have gone extinct in the region but now confirmed as extant. a, A typical landscape dominated by pasture and agriculture, with small remnant patches of forest (Photo by J.N.Z.). **b**–**d**, Herbs *Gasteranthus extinctus* (**b**), *Gasteranthus atratus* (Gesneriaceae) (**c**) and *Dracontium croatii* (Araceae) (**d**). **e**,**f**, Trees *Browneopsis macrofoliolata* (Fabaceae) (**e**) and *Amyris centinelensis* (Rutaceae) (**f**). Photos **b**–**f** by J.L.C. All scale bars, 1.0 cm.

still only known from Centinela at that time. That survey located two of the four species within the first hour (the understory herb *Gasteranthus extinctus* and the tree *Browneopsis macrofoliolata*; see ref. 19). A third species, *Amyris centinelensis*, was observed in the first hour of surveying another nearby Andean site in September 2023.

These factors strongly suggest that Centinela's only remaining putative endemic will eventually be found elsewhere, as will the 42 still-unidentified morphospecies from the 1983 checklist (Fig. 1a). Instances of apparently high plant microendemism at other Andean TCFs and continental habitats (see refs. 20–22) should be treated as hypothetical until tested in a similar fashion. We believe Centinelan extinctions reported from actual islands are more likely to be confirmed[23,24].

To better understand the spatial distribution of Centinela's flora, we estimated the range sizes of 848 plant species recorded there so far. While small ranges are frequent (median 301,772 km^2), most species have total ranges larger than Ecuador (283,561 km^2; Extended Data Fig. 3). We found that 193 species (~23%) have extents of occurrence of less than 30,000 km^2, the area of western Ecuadorian Chocó TCFs[25], and 30 species (~3.5%) have a total range less than 500 km^2, the size of Centinela and surrounding region (Fig. 1b). However, the distributions of these species rarely correspond to mountain ridges or other small-scale geographic features and instead represent disjunctions between distant sites (for example, *Amyris centinelensis* and *Ardisia pichinchana* are also known from sites over 150 km south of Centinela), suggesting that rare species' distributions remain negatively biased by incomplete exploration and collection[26,27].

Even if Centinela had harboured 90 endemic plant species, those species would not necessarily be extinct today given the inaccuracy of another infamous assertion about the site: that its forests were completely destroyed in the 1980s[2,5]. After those reports led plant collectors to avoid Centinela for 25 years (Extended Data Fig. 4), our visits in 2021–2023 revealed numerous small remnants of the original forest and thousands of mature trees left standing in pastures, fencerows, ravines and forest patches, both of which were found to harbour a number of the original putative Centinela endemics[19] (Fig. 3). While the vast majority of TCFs at the site have indeed been converted to cattle pastures or plantations, our field work and survey of satellite imagery suggest that at least 19 forest fragments of 8–144 ha in size remain standing (Fig. 1b and Extended Data Fig. 5). The discovery of these fragments offers a critical and urgent chance to save some of western Ecuador's threatened flora, but this opportunity is tempered by a potentially looming extinction debt[28] in once-viable populations reduced to a handful of individuals in a few scattered forest patches (Extended Data Fig. 5). Thus, while Centinela's putative endemics and other rare species are not extinct now, many will inevitably become extinct without targeted in situ and ex situ conservation efforts to maintain their genetic diversity and long-term fitness[29].

Although reports of Centinela's floristic uniqueness and wholesale destruction are not supported by the evidence, its reputation as a wellspring of botanical novelty has a strong basis in fact. The sense of wonder pervading early reports on the region's flora is justified by our finding that every third plant species collected at Centinela in the first full year of exploration (1976) was undescribed at that time (Supplementary Table 2). Dodson & Gentry's 1983 unpublished checklist of 1,103 species and morphospecies (Supplementary Table 1 and Fig. 1) contained 140 species that were new, unidentified or not confidently identified (~13%; Fig. 1a). The still ongoing taxonomic effort by dozens of specialists to identify and describe those new and unknown plants has resulted in the description of 51 new species, including fully 18 original descriptions based solely on Centinela collections. Another 47 have been determined to belong to other, previously described species (thus constituting our 98 putative endemics) with a spectrum of geographic range sizes from 10–2 M km^2 (Supplementary Table 3).

Table 1 | Eleven species known only from the Centinela region (Fig. 1, whole map)

Species	Voucher	Source	Herbarium
Amalophyllon miraculum Clark[a]	J. L. Clark 16805	Collections 2022	QCA, SEL, US
Anthurium minutiglandulum Croat	T. Croat 73281	Literature	MO
Bifrenaria integrilabia (Dodson) Meneguzzo & Chase[b]	Dodson 6113, 6850	1983 checklist	SEL
Dieffenbachia centinelasensis ined. Croat	Dodson 14674	1983 checklist	MO
Epidendrum monicarmasiae Cornejo & Hágsater[a]	X. Cornejo 10028	Collections 2022	GUAY
Gasteranthus extinctus Skog & Kvist	D. M. White 825	1983 checklist	QCNE, F
Lacunaria sp. nov.[a]	J. C. Cerón 4871	Collections 2023	QCNE
Monopyle sp. nov.[a]	J. L. Clark 16618, 16648	Collections 2022	QCA, SEL, US
Sarcaulus sp. nov.[a]	A. Fernández 92	Collections 2024	QCNE, QCA
Sciodaphyllum pilarense ined. Lowry & Plunkett	Borchsenius 107	1983 checklist	NY
Sloanea sp. nov.[a]	J. Guevara s.n.	Collections 2021	QCNE

[a] New species identified in recent field work. At least two more new species have been recently identified, *Eschweilera podoaquilae* Cornejo and *Phragmotheca centinelensis* ined., but each of these have also been found at a single other site outside the Centinela region. [b] This small orchid remains the only species that has not been found outside of the 40-km^2 Centinela ridge sensu Dodson & Gentry[2]. QCA, Pontificia Universidad Católica del Ecuador; SEL, Marie Selby Botanical Gardens; US, United States National Herborium; MO, Missouri Botanical Garden Archives; GUAY, Universidad de Guayaquil; QCNE, Herbario Nacional del Ecuador; F, Field Museum of Natural History; NY, New York Botanical Garden.

Further illustrating the complexity of taxonomic synthesis, 61 of our 98 putative endemic species have from 1 to 150 synonymous species names. The remaining 42 species from the checklist (30% of the total) remain unidentified and invisible to biodiversity data networks.

The trend of novelty has continued in recent field work, both in the Centinela range itself and where the range meets the Andean slopes. In the 782 collections made between 2021 and 2023 (Supplementary Table 2), botanists have encountered at least 8 species new to science, 2 since published[30,31] and 6 unpublished but confirmed by taxonomic experts (Table 1). Rather than evidence for microendemism, we view these new species as confirmation that TCFs in the Tumbes–Chocó–Magdalena biodiversity hotspot remain poorly explored by botanists[4]. Research at Centinela has taught us that botanists working in Andean TCFs will undoubtedly encounter new and rare species, and once these species are described, the decades-long process of understanding their geographic ranges can commence.

Our work also highlights the immense conservation value of forest remnants in the larger Centinela region. Of the 886 total plant species recorded at Centinela, 156 qualify as globally threatened under the International Union for Conservation of Nature (IUCN) Criterion B1 (ref. 32), including 9 that are critically endangered due to an estimated range size of less than 10 km^2 in area (Supplementary Table 3). Another 38 species are unclassified due to a lack of information and are a high priority for further investigation and threat classification. Approximately a quarter of plant species at Centinela are endemic to Ecuador and many unique to the devastated forests of the western region[33]. At larger spatial scales, the 500-km^2 region (Fig. 1b) surrounding the area studied by Dodson and Gentry harbours the only known populations of 11 plant species (Table 1). Because data on the threat to these species must also be considered in the light of a potentially large-scale extinction debt[28], conservation efforts should be focused on preserving and connecting habitats and understanding species population sizes, structure, demography and reproductive biology[29,34]. As such, Centinela remains emblematic of the harrowing challenges facing plant conservation throughout western Ecuador and severely fragmented ecosystems globally[35–37]: an archipelago of forest remnants in a sea of farmland, harbouring dwindling populations of regionally unique and globally threatened species.

Similar to much of the Ecuadorian Chocó, surviving forests in the Centinela region lack formal protection. The region has been identified repeatedly as a priority for conservation, and multiple protection efforts are finally underway, but additional resources and integration are needed to improve floristic knowledge and educational programming, conserve and connect remaining forest fragments, and safeguard threatened species in situ and in botanical gardens[29,38]. It is the outcome of these efforts that will determine what Centinela ultimately comes to symbolize: the careless loss of a spectacular plant community, or the resilience, value and enduring biological complexity of TCFs.

Research at Centinela also highlights the irreplaceable importance of curated biological collections, field exploration, taxonomic expertise and global floristic databases for understanding the extinction risk faced by Earth's plants. Despite the >396 million plant specimens in >3,500 herbaria worldwide[39], major gaps in our knowledge of plant species diversity and distributions continue to hamper science and conservation[4,15,29,40–42]. This is especially true for TCFs, whose extraordinary species richness requires commensurate efforts in exploration, specimen collection, herbarium curation and taxonomic circumscription. Instead of closing herbaria (see ref. 43), a sustainable future for our planet demands renewed support for biological collections and the communities that curate and integrate them[39]. Without sustained investment in boots-on-the-ground and eyes-in-the-herbarium science, plant extinctions are likely to advance unnoticed in TCFs such as Centinela, just as Dodson & Gentry[2] warned.

Methods

Because a full list of species presumed endemic to Centinela was never published by Dodson & Gentry[2], testing the hypothesis of Centinelan extinction required that we first build a full checklist for the site and then reconstruct a list of putative endemics. We achieved this by synthesizing data from the Global Biodiversity Information Facility (GBIF.org), numerous herbaria (see Data availability statement), taxonomic experts, and an unpublished checklist of the Centinela Flora (Supplementary Table 1 and Fig. 1).

To build our database of all plant species recorded so far at Centinela (Supplementary Table 2), our primary sources were GBIF queries for all vascular plant records in Ecuador (https://doi.org/10.15468/dl.r6fwph), Colombia (https://doi.org/10.15468/dl.3anwv6) and Peru (https://doi.org/10.15468/dl.ajrxp3) from which we extracted records whose locality fields include the word 'Centinela' or 'Montañas de Ila', plus variations.

We added to this dataset via searches for Centinela specimens in the TROPICOS database and digital collections databases from the New York Botanical Garden, Field Museum and Marie Selby Botanical Gardens, as well as the physical collections of Ecuadorian herbaria: Universidad de Guayaquil (GUAY), Pontificia Universidad Católica del Ecuador (QCA) and the Herbario Nacional del Ecuador (QCNE)[44], which represent the pertinent 'local' herbaria for our study. Searches of digital collections were carried out by D.M.W. in June–August 2023 and searches of physical collections were carried out by X.C. and J.E.G.-A. in July–November 2021. From these results, we removed spurious records by reading locality fields and by flagging records whose coordinates were >5 km outside the Centinela ridge boundary (Fig. 1b).

We also carried out a literature search in the Web of Science and Google Scholar databases, and reviewed all articles citing Dodson and Gentry's relevant publications[2,5–7,45] on Google Scholar. Bibliographic databases were searched between 28 April and 5 May 2021.

The dataset was supplemented with a typewritten list deposited in the Alwyn Gentry Papers in the Missouri Botanical Garden (MO) Archives, dated 26 November 1983 and titled 'Centinela flora' (Supplementary Table 1 and Fig. 1). The list includes 1,103 species or morphospecies names, a habit code, voucher specimen information and an indication for each species of where it had been recorded at Dodson and Gentry's five florula sites in western Ecuador. There were 42 voucher specimens from the 1983 list that were not present in GBIF or any of the other sources.

We accumulated a total of 2,156 unique vascular plant collections from Centinela (Supplementary Table 2). Nomenclature of all datasets was standardized with the Taxonomic Name Resolution Service (TNRS[46,47]), with World Flora Online (worldfloraonline.org) and World Checklist of Vascular Plants (powo.science.kew.org) set as the taxonomic source. Of these, 399 records were identified only to genus or family and 1,756 were identified to species level or below, resulting in 886 unique and taxonomically valid species. The GBIF backbone taxonomy contained 873 of these species.

To reconstruct a list of presumed Centinela endemics sensu Dodson & Gentry[2], we first selected from the unpublished checklist (Supplementary Table 1) all 372 species and morphospecies marked as collected only at Centinela and no other sites. From these, we identified 140 collections with new or undetermined status: unidentified morphospecies (for example, '*Anthurium* sp. D7728'; 95 species), species with qualified determinations (for example, 'aff.', 'cf.'; 23 species), new species ('sp. nov.'; 10 species) or species that were published citing collections only from Centinela (18 species). We then used the TROPICOS database, herbarium work and correspondence with taxonomic experts to update species determinations for all the cited collections (that is, vouchers), and standardized with TNRS as above, resulting in 98 taxonomically verified species. Two more species were added from our literature search: *Erythrochiton giganteus*, described as endemic in ref. 2, and *Gongora ilense*, published in 1992 on the basis of the Dodson collections[48]. This resulted in 98 taxonomically verified species plus 42 collections that remain undetermined at species level, which we find corresponds well to Dodson and Gentry's '90 plant species endemic to the Centinela ridge'[2] (p. 277). Investigating the distributions of these 98 putative endemic species via GBIF, TROPICOS, herbarium records and correspondence with taxonomic experts, we found that only one of these species, *Bifrenaria integrilabia*, has not been reported to exist outside the Centinela ridge.

To analyse the collection trends and environmental and geographic profiles of the putative Centinela endemics, we conducted a GBIF query for all records for the 886 species in the Centinela checklist using the rgbif package[49,50] (28 November 2023; https://doi.org/10.15468/dl.ncd94z). The resulting database was reduced to occurrences in Colombia, Ecuador, Panama and Peru and cleaned with CoordinateCleaner (v.3.0.1)[51] to remove collections of individuals in country capitals, centroids, botanic gardens and arboreta, and incorrect countries, resulting in 381,331 records with 174,735 unique latitude and longitude occurrences across species.

To assess rates and patterns of discovery, we characterized the number of putative endemics collected outside of Centinela through time, area and collection effort. For the spatial analysis (Extended Data Fig. 1b), we drew random samples of raster grid cells at 30-arcsecond resolution from Panama, Colombia, Ecuador and Peru, and tabulated the number of putative endemics that had been collected at any time from these cells to generate a species accumulation curve showing the number of putative endemics collected vs total sampling area. For the temporal analysis (Extended Data Fig. 1c), we tabulated the year that each putative endemic had been collected outside of Centinela. We reiterated this process 5,000 times to calculate 95% confidence intervals. We used a similar procedure for the analysis of collection effort. Specifically, we drew random samples of collections of plant species from Panama, Colombia, Ecuador and Peru, and tabulated the number of putative endemics included in these collections to generate another species accumulation curve (in this case, number of putative endemics collected vs total number of plant collections). As before, we reiterated this process 5,000 times to calculate 95% confidence intervals.

The collection locations of the putative endemic species were then overlaid on maps of mean annual temperature and climatic moisture index derived from the WorldClim extrapolated current (1970–2000) climate database at a 30-arcsecond resolution[52]. To calculate relative collection intensities, we divided the density of collections by the density of available land area with corresponding climates, such that values of >1 indicate that collections of the putatively endemic species are more common than expected by random chance in the corresponding climates and values <1 indicate that collections are less common than random at the corresponding climates. We conducted the same analysis using elevation, but given the near-perfect correlation between elevation and mean annual temperature in the study area (Pearson's $R = 0.97$; cor() function in R), the patterns were indistinguishable from those shown in Fig. 2b,c.

We used the cleaned GBIF occurrence records to model species range sizes as a convex hull, the minimum boundary containing all the sites of occurrence and with no internal angle exceeding 180°, that was clipped to include forested areas[53] only within the elevational range of the species. The 38 species with less than three unique occurrence records were omitted, leaving 848 species. We calculated elevational ranges by taking values from GBIF records and, for species with fewer than five GBIF records and those with elevational ranges >3,000 m, from TROPICOS records. We selected the source that maximized the range and manually curated the set to remove errors such as units in feet. Species with elevational ranges less than 200 m were increased to this value around the mean. We combined the custom scripts to create the elevational range maps using the EOO.computing function in ConR (v.2.1)[54] to generate the clipped convex hulls of species ranges within forested areas.

Note that this analysis truncated the range estimates of widespread species because we restricted occurrence records to four countries. This was done to remove the effects of large disjunctions that probably represent distinct species (for example, *Mikania leucophylla* in Bolivia) and therefore provide a better estimate for the ranges of rare and threatened species.

To assign IUCN threat categories, we classified the range sizes under the thresholds of Criterion B1 of the Red List Guidelines[32]. Species with less than three unique records were considered data deficient. Chord plots in Supplementary Fig. 3 were generated with the circlize R package[55]. Satellite imagery in Supplementary Fig. 5 was acquired from Planet[56].

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Literature searches were conducted with Google Scholar (scholar.google.com). Collection data were obtained from the National Herbarium of Ecuador, the Pontifical Catholic University of Ecuador Herbarium, University of Guayaquil Herbarium, Field Museum Herbarium (collections-botany.fieldmuseum.org/), New York Botanic Garden Herbarium (sweetgum.nybg.org/science/vh/), Marie Selby Botanic Gardens Herbarium, the US National Herbarium (collections.nmnh.si.edu/search/botany/), the Pteridophyte Collections Consortium (pteridoportal.org), the Global Biodiversity Information Facility (GBIF.org) and TROPICOS (tropicos.org). GBIF datasets can be downloaded at: https://doi.org/10.15468/dl.r6fwph, https://doi.org/10.15468/dl.3anwv6, https://doi.org/10.15468/dl.ajrxp3, https://doi.org/10.15468/dl.ncd94z. All Centinela collection metadata, IUCN conservation assessments and unpublished 1983 Centinela Flora checklist are available in Supplementary Information.

Code availability

Scripts for generating species range maps are available in GitHub[57].

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Author contributions

D.M.W., N.C.A.P., K.J.F. and J.E.G.-A. conceptualized the project. D.M.W., N.C.A.P., K.J.F., G.R.-T. and J.E.G.-A. developed the methodology. D.M.W., N.C.A.P., K.J.F., J.L.C., C.U.U., X.C., M.P., G.B., C.B., J.C.C., A.F., R.P., J.N.Z. and J.E.G.-A. curated data. All authors conducted investigations. D.M.W., K.J.F., D.N.-M. and J.E.G.-A. conducted formal analysis. D.M.W. and G.R.-T. performed validation. D.M.W., N.C.A.P., K.J.F., J.L.C. and J.E.G.-A. performed visualization. D.M.W., N.C.A.P., K.J.F., G.R.-T., S.B.-S., F.S.-P., T.L.P.C. and J.E.G.-A. acquired funding. D.M.W., N.C.A.P., G.R.-T., S.B.-S., F.S.-P., M.P., J.C.C., A.F. and J.E.G.-A. administered the project. D.M.W., G.R.-T., S.B.-S., F.S.-P., J.L.C., C.U.U., M.P. and J.E.G.-A. acquired resources. D.M.W. developed software. D.M.W., N.C.A.P. and J.E.G.-A. supervised the project. D.M.W. and N.C.A.P. wrote the original draft. D.M.W., N.C.A.P., K.J.F., G.R.-T., J.L.C., C.U.U., X.C., T.L.P.C. and J.E.G.-A. reviewed and edited the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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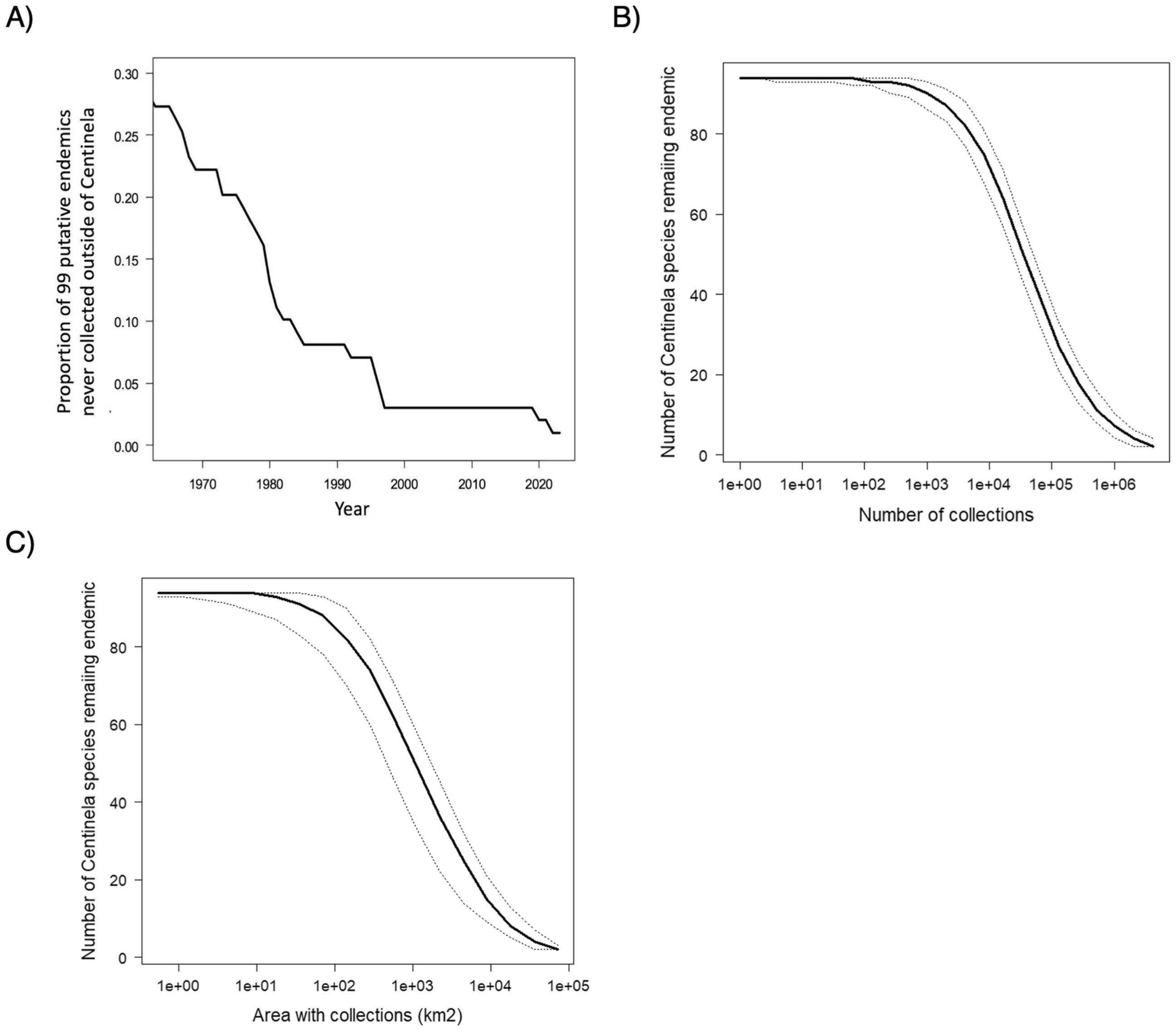
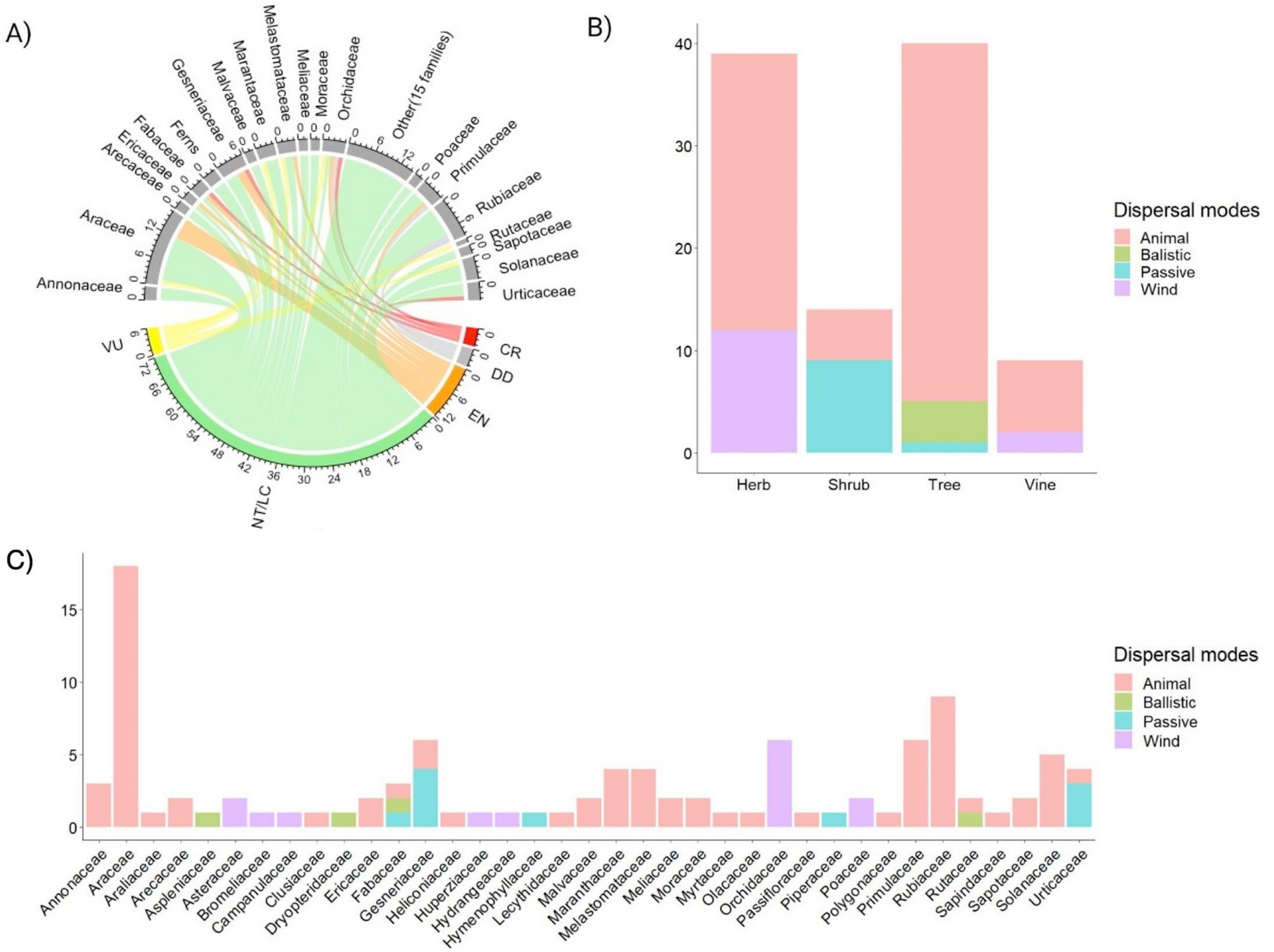
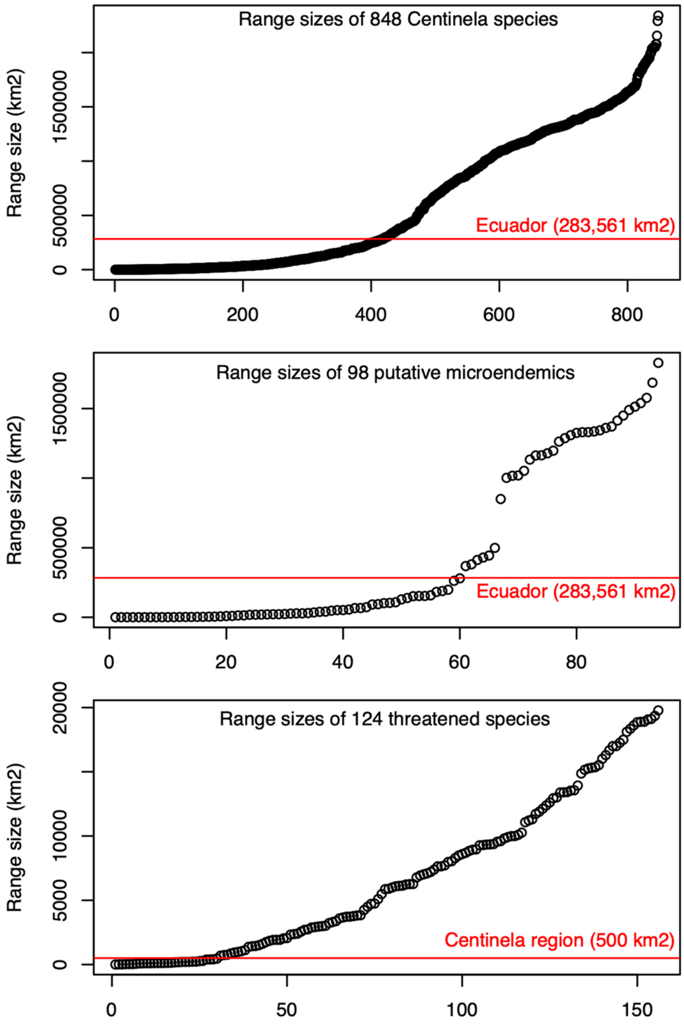


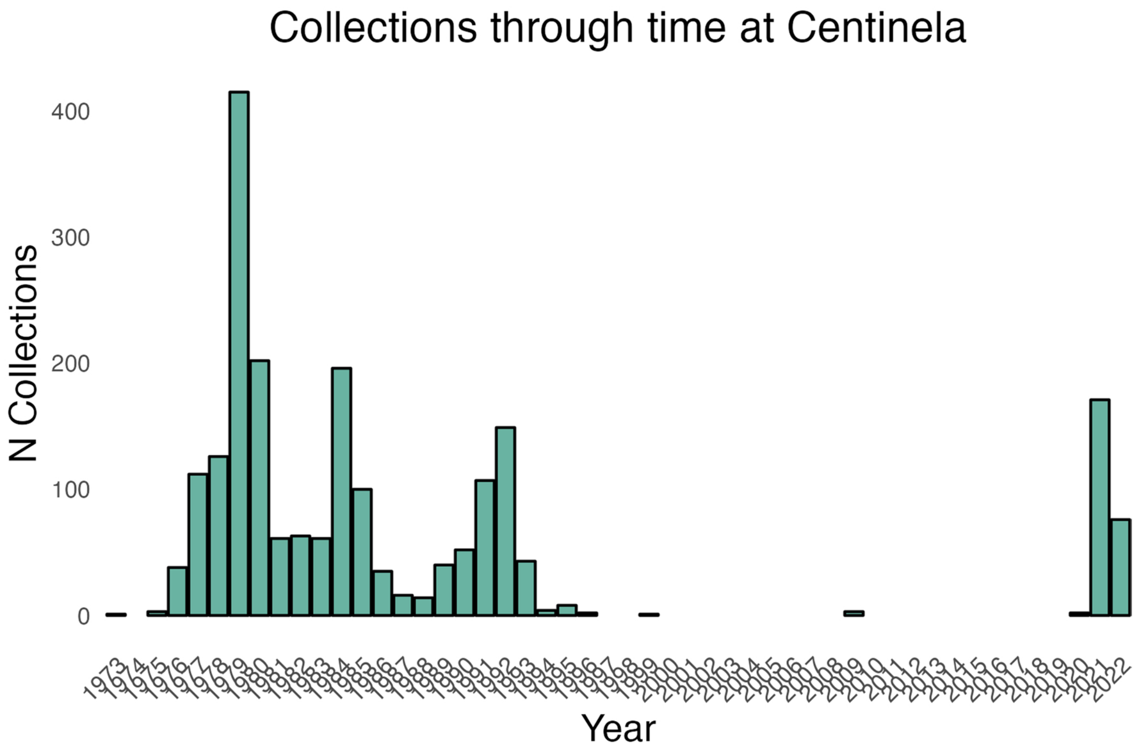
Extended Data Fig. 1 | Patterns of rare species collections. a) Proportion through time of putative microendemic species that had not been collected outside of the Centinela region. **b**) The number of putative microendemic species never collected outside of Centinela as a function of the number of collections in Colombia, Ecuador, Panama, and Peru. **c**) The same as A and B, but as a function of the number of square-kilometer grid cells in those countries with collections.



Extended Data Fig. 2 | Ecological characteristics of the 98 putative endemic species. **a**) Taxonomic composition by family and threat status under Criterion B1 of IUCN Red List guidelines. The numerical values below each family are the number of threatened species for each category as follows: CR=Critically Endangered, EN=Endangered, VU=Vulnerable, LC/NT=Least Concern or Near Threatened and DD=Data Deficient. **b**) Distribution of dispersal modes and life forms. Animal dispersal is dominant across all life forms; wind dispersed species were restricted to herbs and vines. **c**) Taxonomic distribution of dispersal modes. Some taxonomic groups such as Araceae exhibit a disproportionately high number of animal dispersed species compared to other tree species groups such as Annonaceae, Primulaceae, Sapotaceae, and Meliaceae.



Extended Data Fig. 3 | Estimated range sizes of Centinela species. Range sizes estimated as a convex hull from the extent of occurrence records and clipped to only forested areas within the elevational range of species.



Extended Data Fig. 4 | Chronology of plant collections at Centinela, Ecuador. Histogram of the number of collections made at Centinela from 1973 to 2022.

https://doi.org/10.1038/s41477-024-01832-7

Extended Data Fig. 5 | Satellite imagery and topography of the Centinela region. The five surviving forest fragments (red polygons) at the southern end of the Montañas de Ila in the Centinela region, bordered by the Río Toachi Grande (top; imagery © Planet Labs PBC, April 29, 2023) Forest fragments in the north of the Centinela region near the community of Los Cristales (bottom; imagery © Planet Labs PBC, April 22, 2023).

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n/a | Confirmed

☒ ☐ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☒ ☐ A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
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☒ ☐ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted
Give P values as exact values whenever suitable.
☒ ☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒ ☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☐ ☒ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection
Species occurrence records requiring software were downloaded with rgbif v.3.7.9 and via the TROPICOS® system.

Data analysis
Codes for data analysis are available at github.com/Erythroxylum/Centinela/

Species range maps created with the following R session information:

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language (EN)
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ctype    en_US.UTF-8
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date     2024-08-21
rstudio  2023.12.1+402 Ocean Storm (desktop)
pandoc   NA

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cli              3.6.2      2023-12-11 [1] CRAN (R 4.3.0)
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tmap          * 3.3-4      2023-09-12 [1] CRAN (R 4.3.0)
tmaptools       3.1-1      2021-01-19 [1] CRAN (R 4.3.0)
tzdb            0.4.0      2023-05-12 [1] CRAN (R 4.3.0)
units           0.8-5      2023-11-28 [1] CRAN (R 4.3.0)
urlchecker      1.0.1      2021-11-30 [1] CRAN (R 4.3.0)
usethis       * 2.2.3      2024-02-19 [1] CRAN (R 4.3.2)
utf8            1.2.4      2023-10-22 [1] CRAN (R 4.3.0)
V8              4.4.2      2024-02-15 [1] CRAN (R 4.3.2)
vctrs           0.6.5      2023-12-01 [1] CRAN (R 4.3.0)
viridisLite     0.4.2      2023-05-02 [1] CRAN (R 4.3.0)
whisker         0.4.1      2022-12-05 [1] CRAN (R 4.3.0)
withr           3.0.0      2024-01-16 [1] CRAN (R 4.3.0)
XML             3.99-0.16.1 2024-01-22 [1] CRAN (R 4.3.2)
xml2            1.3.6      2023-12-04 [1] CRAN (R 4.3.0)
xtable          1.8-4      2019-04-21 [1] CRAN (R 4.3.0)

[1] /Library/Frameworks/R.framework/Versions/4.3-x86_64/Resources/library
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For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A description of any restrictions on data availability
- For clinical datasets or third party data, please ensure that the statement adheres to our policy

Literature searches were conducted with Google Scholar (scholar.google.com). Collection data were obtained from the National Herbarium of Ecuador, the Pontifical Catholic University of Ecuador Herbarium, University of Guayaquil Herbarium, Field Museum Herbarium (collections-botany.fieldmuseum.org/), New York Botanic Garden Herbarium (sweetgum.nybg.org/science/vh/), Marie Selby Botanic Gardens Herbarium, the US National Herbarium (collections.nmnh.si.edu/search/botany/), the Pteridophyte Collections Consortium (pteridoportal.org), the Global Biodiversity Information Facility (GBIF.org), and TROPICOS® (tropicos.org). GBIF datasets can be downloaded at: doi.org/10.15468/dl.r6fwph, doi.org/10.15468/dl.3anwv6, doi.org/10.15468/dl.ajrxp3, doi.org/10.15468/dl.ncd94z. All Centinela collection metadata, IUCN conservation assessments, and unpublished 1983 Centinela Flora checklist are available in the supplementary materials.

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	N/A
Reporting on race, ethnicity, or other socially relevant groupings	N/A

Population characteristics	N/A
Recruitment	N/A
Ethics oversight	N/A

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	To characterize the number of species endemic to the Centinela ridge and evaluate if they are extinct, we used an unpublished checklist of the Centinela Flora from 1983, physical and digital herbarium records, scientific literature review and correspondence with taxonomic specialists to assemble all plant collection records from Centinela with associated geographic and temporal metadata. With the 886 total species known from Centinela, we analyzed collection records from Colombia, Ecuador, Panama, and Peru to characterize the geographic distributions of the species and generated new collections from our own targeted field work to verify if the rare species were still extant and if they occurred outside Centinela.
Research sample	All past and present plant collection records from Centinela, Ecuador. All GBIF records from Colombia, Ecuador, Panama, and Peru of the 886 species known from Centinela.
Sampling strategy	N/A
Data collection	Digital data were collected by DMW and KJF. Physical herbarium specimens were reviewed by XC and JEGA. All authors contributed to field collections.
Timing and spatial scale	Data has been collected from June 2021 to September 2023.
Data exclusions	None.
Reproducibility	All collection metadata, GBIF datasets, and analysis scripts are made available.
Randomization	N/A
Blinding	The reliability and validity of our findings are maintained without the implementation of blinding procedures.

Did the study involve field work? ☒ Yes ☐ No

Field work, collection and transport

Field conditions	Plants collected and records analyzed from throughout the year from Centinela, Santo Domingo de Los Tsáchilas province, and Colombia, Ecuador, Panama, and Peru.
Location	Centinela: -0.602218, -79.293523
Access & import/export	Herbarium vouchers were collected under permit MAE-DNB- CM-2018-106 of the Universidad San Francisco de Quito, MAATE-DBI-CM-2021-0187 of the Universidad de Las Américas and MAE-DNB-CM-2018-0082 of the Potificia Universidad Católica del Ecuador.
Disturbance	Given the nature of our study, it was necessary to make minimal herbarium voucher collections for rare and threatened species for taxonomic determinations and to confirm their living status.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study	
☒	☐	Antibodies
☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology and archaeology
☒	☐	Animals and other organisms
☒	☐	Clinical data
☒	☐	Dual use research of concern
☐	☒	Plants

Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
☒	☐	Flow cytometry
☒	☐	MRI-based neuroimaging

Dual use research of concern

Policy information about dual use research of concern

Hazards

Could the accidental, deliberate or reckless misuse of agents or technologies generated in the work, or the application of information presented in the manuscript, pose a threat to:

No	Yes	
☒	☐	Public health
☒	☐	National security
☒	☐	Crops and/or livestock
☒	☐	Ecosystems
☒	☐	Any other significant area

Experiments of concern

Does the work involve any of these experiments of concern:

No	Yes	
☒	☐	Demonstrate how to render a vaccine ineffective
☒	☐	Confer resistance to therapeutically useful antibiotics or antiviral agents
☒	☐	Enhance the virulence of a pathogen or render a nonpathogen virulent
☒	☐	Increase transmissibility of a pathogen
☒	☐	Alter the host range of a pathogen
☒	☐	Enable evasion of diagnostic/detection modalities
☒	☐	Enable the weaponization of a biological agent or toxin
☒	☐	Any other potentially harmful combination of experiments and agents

Plants

Seed stocks	N/A
Novel plant genotypes	N/A
Authentication	N/A