Towards a checklist of the Vascular Flora of Vanuatu

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Abstract

PLUNKETT, G.M., T.A. RANKER, C. SAM & M.J. BALICK (2022). Towards a checklist of the Vascular Flora of Vanuatu. *Candollea* 77: 105–118. In English, English and French abstracts. DOI: http://dx.doi.org/10.15553/c2022v771a8

Vanuatu is an archipelago in the southwest Pacific that, to date, has no modern checklist of its flora, despite the fact that it sits in the midst of several other archipelagos of known species richness (New Caledonia, Fiji, and the Solomon Islands, among others). The present study describes our effort to establish a checklist of accepted species names that apply to taxa known or thought to occur in Vanuatu. In collating data from the Vanuatu National Herbarium (PVNH) and online databases (including virtual herbaria and database compilations), we have developed a checklist of 1,631 species of vascular plants, of which 1,262 (77.4%) are putatively native, and 360 (22.1%) introduced (the distributional status of the remaining 0.5% are uncertain). Endemics represent 10.1% of all species (native plus introduced), but 13.1% when considering native species only. This article is linked to a dynamic checklist available online that will be continually updated, and we encourage members of the global botanical community, especially those with expertise in the taxa listed or the general floristics of the Pacific Islands, to provide corrections and additions.

Résumé

PLUNKETT, G.M., T.A. RANKER, C. SAM & M.J. BALICK (2022). Vers une check-list de la flore vasculaire de Vanuatu. *Candollea* 77: 105–118. En anglais, résumés anglais et français. DOI: http://dx.doi.org/10.15553/c2022v771a8

Il n'existe aucune check-list de la flore du Vanuatu, un archipel situé dans le sud-ouest Pacifique, bien que ce pays est situé au milieu d'autres archipels connus pour leur richesse en espèces de plantes (la Nouvelle-Calédonie, Fidji et les Iles Salomon, entre autres). Cette étude résume un travail visant à établir une check-list des noms des espèces acceptés pour les taxons connus du Vanuatu ou présumés présents. La compilation de données de l'Herbier National du Vanuatu (PVNH) et des bases de données en ligne (y compris des herbiers virtuels et de compilations de bases de données) nous a permis de développer une check-list comprenant 1631 espèces de plantes vasculaires dont 1262 (soit 77,4%) considérées comme indigènes et 360 (22,1%) introduites (le statut des 0,5% restant est incertain). Les espèces endémiques constituent 10,1% des espèces totales (indigènes et introduites confondues) mais elles représentent 13,1% des espèces indigènes. Cet article est associé à une check-list dynamique, accessible en ligne, qui sera continuellement mise à jour. Nous sollicitons la communauté internationale de botanistes, en particulier ceux qui ont une expertise sur les taxons listés ou la flore des îles du Pacifique, pour y apporter corrections et compléments.

Keywords

Checklist – South Pacific – Melanesia –Vanuatu – New Hebrides – PVNH – Vascular flora

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Submitted on May 11, 2021. Accepted on April 29, 2022. First published online on June 1, 2022.

ISSN: 0373-2967 – Online ISSN: 2235-3658 – *Candollea* 77(1): 105–118 (2022)

Introduction

Vanuatu is a Y-shaped (or, more accurately, Ψ-shaped) archipelago in the southwest Pacific region of Melanesia (Fig. 1), and comprises 83 habitable islands (plus some number of smaller, uninhabitable islets) (see Siméoni, 2009). Excluding Matthew and Hunter Islands (whose ownership is disputed between Vanuatu and New Caledonia), the archipelago lies between the southern latitudes of 13°00' and 20°30', and the eastern longitudes of 166°30' and 170°15'. Most islands are high, and five of them have elevations exceeding 1,000 m. The highest point, Mount Tabwemasana (1,879 m), is found on the nation's largest island, Espiritu Santo. Among its immediate neighbors, Vanuatu exceeds the maximum elevation of both New Caledonia (Mount Panié; 1,628 m) and Fiji (Mount Tomanivi; 1,324 m), but not that of the Solomon Islands (Mount Popomanaseu; 2,335 m). Located at the western edge of the Pacific plate (at the subduction zone with the Indo-Australian plate), Vanuatu forms part of the Ring of Fire, experiencing frequent earthquakes and hosting 22 volcanoes, nine of which are active (including three that are currently submarine). Neither New Caledonia nor Fiji have any active volcanoes, but there are eight in the Solomon Islands (of which four are active). Compared to nearby archipelagos, Vanuatu is relatively young. The western chain of Vanuatu (viz. Malekula, Espiritu Santo, and the Torres group; Fig. 1) is the oldest, dating from the Oligocene to the middle Miocene, followed by the eastern chain (Maewo and Pentecost), which date to the end of the Miocene to the early Pliocene; the islands forming the long central chain (stretching from the Banks group in the north to Aneityum in the far south) are the youngest, dating from the early Pleistocene to the present (see Zielske & Haase, 2014). Hamilton et al. (2010) reviewed evidence for repeated cycles of emergence and submergence of the archipelago, with evidence that the latest period of emergence dates to only 2 Ma, suggesting that Vanuatu's flora is of very recent origin.

The first botanical collections in what is now Vanuatu were made during Captain James Cook's Second Voyage to the Pacific in 1774, on which the father-and-son team of botanists, Johann Reinhold Forster and Georg Forster, collected plant specimens in Malekula and Tanna (see Nicolson & Fosberg, 2003). During the same trip, Cook named the archipelago the New Hebrides, a name maintained until the nation achieved its independence in 1980, after which it adopted its present name. Despite this long history, nearly 250 years, Vanuatu is one of the few countries to lack a modern checklist of its native and naturalized plants. Two earlier attempts represent important landmarks along this path. First, Guillaumin (1948) published a "compendium" of the seed plants from the New Hebrides (but did not include ferns or lycophytes) based on his important studies of collections dating from the Forsters, several 19th Century collectors (e.g. John Milne and William MacGillivray, Frances A. Campbell, and David Levat), and early 20th Century collectors, including Edgar Aubert de la Rue, John R. Baker, J.P. Wilson, and (most importantly) S. Frank Kajewski. A separate history of botanical exploration in Vanuatu is currently being prepared (Plunkett et al., unpubl. data), and therefore the details of these early collectors will not be repeated here. Later, Schmid (1973) assembled a "florule" for Vanuatu, issued as a report by the French research organization ORSTOM (now IRD), which added ferns and lycophytes, but was otherwise an update of Guillaumin's (1948) compendium. Efforts to document the flora of the archipelago accelerated in the 1970s and beyond, starting in 1971 with the Royal Society and Percy Sladen Expedition to the New Hebrides (see Lee, 1975a) and continuing to the present day, but no modern checklist of Vanuatu's vascular plants has been generated that incorporates the new findings of the past 50 years. The many collections generated from the past half-century's effort, together with the rapid pace of advancements in systematics (including the revolution in molecular phylogenetics) have led to many changes in the names of Vanuatu's plants, along with the description of many new species.

Similarly, few studies have detailed the biogeographic relationships involving Vanuatu, largely because its flora has remained so poorly documented. Gillison (1975) provided a much-needed perspective of Vanuatu's phytogeography, using Balgooy's (1971) general study of Pacific Islands as a starting point, but he focused mostly on vegetation types rather than shared taxa. Within Vanuatu, Gillison (1975) recognized 12 vegetation types, and argued that 18°S latitude marked a major phytogeographic discontinuity, dividing the northern islands from the southern ones, confirming Cheesman's (1957) study of zoogeography; Hamilton et al. (2010) later referred to 18°S as "Cheesman's Line". Gillison's (1975) conclusion was based largely on a much greater complexity of vegetation types in the northern islands, where 10 of 12 of the vegetation types were found. By contrast, the southern islands (now recognized as Tafea Province) had only two. Tafea Province is the most remote part of the archipelago, and its northernmost island, Erromango, is separated by roughly 110 km from its closest neighbor to the north, Efate, in adjacent Shefa Province. This distance is nearly twice as far as the two next-most-distant islands (64 km), which separate Ureparapara from Toga, the closest two islands found in the Banks and Torres groups (which together form the northernmost province of Torba). There are also many examples of floristic elements that drop out (in both directions) at or near 18°S latitude, so this line does seem to represent an important division within Vanuatu. That said, Tafea Province comprises only five of the 83 habitable islands of Vanuatu (representing only 7% of these islands, and just 14% of the total landmass of Vanuatu). Even in Gillison's analysis, two of the four northern islands (N of 18°S) they studied have only three to four vegetation types (viz. Espiritu Santo and Efate, the largest and third largest

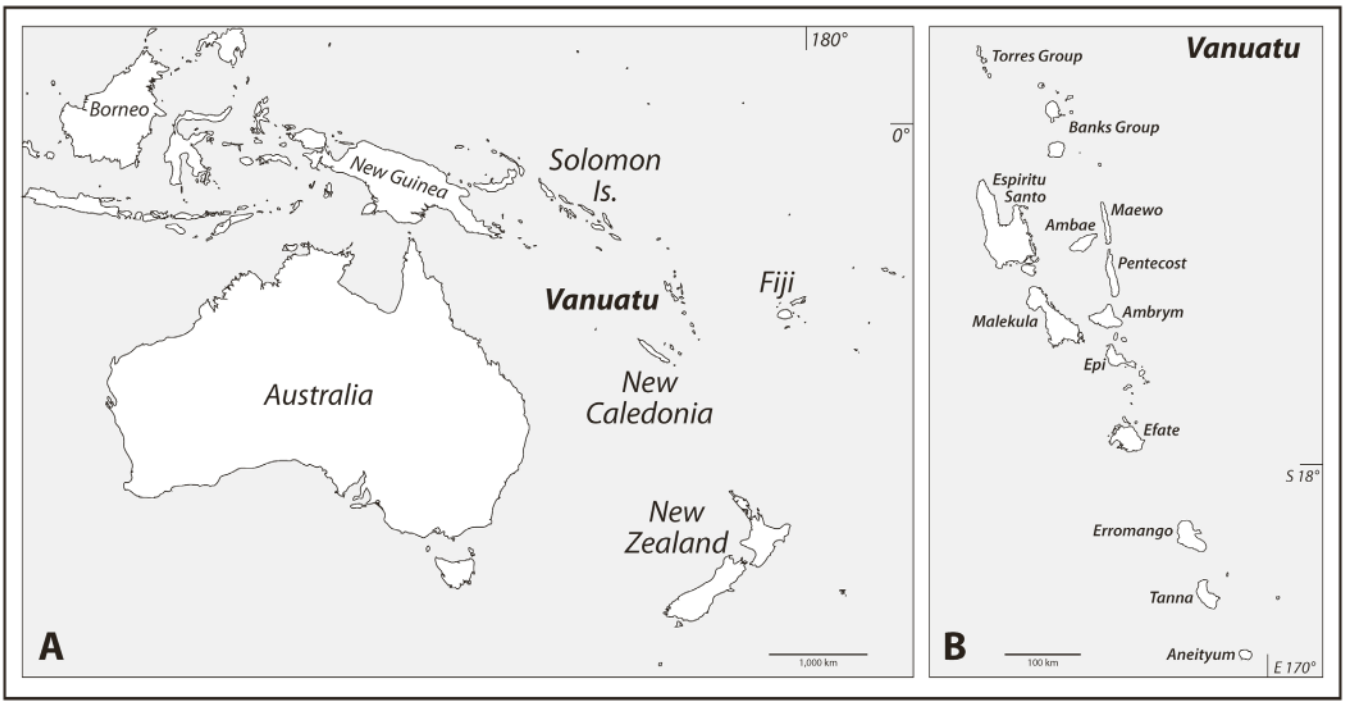

Fig. 1. – A. Map of the Southwest Pacific region; **B.** Vanuatu, with major islands or island groups labeled.

islands in the archipelago). Nearly a quarter-century later, Mueller-Dombois & Fosberg (1998) presented a much more detailed description of Vanuatu's vegetation types, but not in a biogeographic context.

More recently, Keppel et al. (2009) provided an assessment of biogeographic relationships in the Pacific Islands. This differed from the earlier studies by including both plants and animals, and it differed from Gillison's (1975) approach by comparing shared taxonomic elements (at the genus level) rather than vegetation types. Like Balgooy's (1971) study, its focus was the Pacific Islands in general, rather than any specific archipelago. Nevertheless, the results were highly informative for island groups such as Vanuatu. In analyses based on Balgooy's (1971) extensive dataset of plants, they confirmed an overall positive relationship between number of plant genera and archipelago size (i.e. larger aggregated landmasses had richer floras), and a negative relationship between generic richness and distance from the continental island of New Guinea, which has long been thought to represent a major source area for the biota of volcanic islands in the adjacent southwest Pacific. As Keppel et al. (2009) pointed out, these results confirmed long-held hypotheses in island biogeography (MacArthur & Wilson, 1967). An analysis of the same data suggested that Malesia (including New Guinea) represented the source area for 50–65% of genera in the oceanic archipelagos of the southwest Pacific. Shared floristic elements with the Hawaiian Islands ranged from 25–35%, but since the Hawaiian Islands are also oceanic, it was not possible to assess the directionality of the source. Shared elements with New Caledonia suggest that its continental Grande Terre represented the source for 15–30% of the plants found on the volcanic islands of the southwest Pacific, and all other regions (Australia, New Zealand, the Americas) fell below 5%. However, Keppel et al. (2009) found that the picture is a bit different when factoring in phylogenetic and geographic conclusions based on molecular studies, in which it was hypothesized that Malesia and New Caledonia were each the source for c. 20% of the generic plant diversity, with an increased role for Australia (15–20%), New Zealand (5–15%), and the Americas (5–15%), but a decreased association with the Hawaiian Islands (5–10%).

Braithwaite's (1975) analysis of ferns is the only detailed study of phytogeographical relationships for any plant group in Vanuatu at both the genus and species levels. Broadly speaking, Braithwaite documented closer relationships between the fern flora of Vanuatu to both Fiji and the Solomon Islands, and a much weaker relationship to New Caledonia. He also found a strong affinity between the fern floras of Vanuatu and the Indomalesian-Pacific region (i.e. what he described as Ceylon/India, Malaya/Burma, Borneo/Philippines, and New Guinea). Braithwaite's analysis was based on 249 species of ferns, compared to the 307 native Vanuatu species we have documented here. That fact, combined with increased knowledge of other fern floras in the Pacific and elsewhere since 1975, suggests that updated biogeographic analyses are necessary.

It is clear that the poor knowledge of Vanuatu's flora has prevented a more accurate understanding of biogeographic

relationships, both within the archipelago and across the region. In addition, the lack of an up-to-date checklist also hinders conservation efforts. Vanuatu has been included in the East Melanesian Islands Hotspot, together with the Solomon Islands, the Bismarck Archipelago, and the Admiralty Islands (the latter two politically part of Papua New Guinea) (see Mittermeier et al., 2004), with indications of nearly 40% of vascular plants as endemic. This estimate is not supported for Vanuatu (see below). Despite this, only a tiny fraction of the species of Vanuatu's flora has been assessed for the IUCN Red List (see Discussion). Since inclusion on the Red List is generally a prerequisite for funding of species-level conservation efforts, the lack of an authoritative checklist is a serious obstacle for advancing Vanuatu's conservation goals to protect and manage its threatened species, particularly those that are endemic.

We represent an ongoing collaboration called *Plants mo Pipol blong Vanuatu*, which includes researchers from the Vanuatu National Herbarium (PVNH, part of the Department of Forestry), the Vanuatu and Tafea Kaljoral Sentas, the New York Botanical Garden, the University of Hawai'i, and the University of the South Pacific, among others. The current paper seeks to remedy some of the current challenges by describing a recently completed updated checklist based on the most current data available, and by also providing information regarding the distributional status of each species as endemic, otherwise native, or introduced. In so doing, we seek to provide greater resources for the national and international scientific communities to help better understand the flora of Vanuatu. The ultimate goal is to prepare a formal floristic manual for the country, similar to efforts on other nearby archipelagos (*Flora Vitiensis Nova*, Smith 1979–1996; *Flora of the Marquesas Islands,* Lorence & Wagner, 2019, 2020; *Flore de la Nouvelle-Calédonie*, Aubréville et al., 1967–2004 and recently published volumes). The list described here is an early step in this long process.

Materials and methods

The starting point for the preliminary checklist was generated from a spreadsheet of specimen data assembled by Curry (1995), who served as a forest botanist with the Vanuatu Department of Forestry. Curry had compiled data from two separate databases (one generated by French botanists, another by British botanists) that were initiated in the 1980s. In 2014, Laurence Ramon and PVNH curator Chanel Sam began an effort to transfer the data from Curry's spreadsheet to a modern database, called *Vanuaflora*, using the Pl@ntNote software (Birnbaum et al., 2009) with technical assistance from Philippe Birnbaum of CIRAD at the IRD Centre in Nouméa, New Caledonia, along with staff and volunteers from PVNH (including Frazer Alo, Philemon Ala, Stephanie Sali, Thomas Doro, James Ure, Kimson Perie, Elisha Tekak, and Tamata Tui). With growing needs, the Vanuatu National Herbarium migrated the information to yet another database platform in 2020, this time using Symbiota (Gries et al., 2014), which would allow the data to be shared more easily on the Internet and through the *Consortium of Pacific Herbaria* [https://serv.biokic.asu.edu/pacific] and other Symbiota-based portals, and with the hope that Symbiota would be more regularly updated and supported. The technical details of the migration were carried out by Dominik Ramík, and the Flora of Vanuatu website [http://pvnh.net] went public in December 2020. Upon completion of the migration, there were just under 14,000 specimens in the PVNH database. The *Plants mo Pipol blong Vanuatu* project has further added over 3,600 specimens, bringing the total to approximately 17,600 specimens. To date, almost none of the non-vascular plants have been databased, and for this reason, the current effort focuses exclusively on vascular plants. An effort to document non-vascular plants (as well as fungi and lichens) is underway, so we hope to remedy those deficiencies in the near future.

Using the list of names found in the PVNH database together with our own recent collections as starting points, we then used various online databases to assess the accepted names of these species and their distributions. Among these databases were "Plants of the World Online" (POWO, 2022), "World Plants" (Hassler, 2022), the "International Plant Name Index" (IPNI, 2022), "Tropicos" (Tropicos, 2022), and "Global Plants" (JSTOR, 2022). Each of these online databases has its own limitations, so we also cross-referenced data obtained from them with lists available for nearby archipelagoes, especially the comprehensive checklists available for New Caledonia (*Florical*, Morat et al., 2012; Munzinger et al., 2021; and its online updates), and Fiji (*Flora Vitiensis Nova*, Smith 1979–1996; nomenclatural updates for ferns and lycophytes, Brownsey & Perrie, 2011; and for seed plants, G. Keppel & I. Rounds, unpubl. data). For ferns, the *Illustrated Flora of Ferns and Fern Allies of South Pacific Islands* (Nakamura & Matsumoto, 2008), *The Pteridophyte Flora of Fiji* (Brownlie, 1977), and *SOL Amazing Lycophytes & Ferns of the Solomon Islands* (Chen et al., 2017) were also consulted, and for *Orchidaceae*, the names provided in the *Orchids of Vanuatu* (Lewis & Cribb, 1989) were assessed and updated. Similarly, taxonomic treatments for *Arecaceae* (Dowe & Cabalion, 1996) and *Araliaceae* (Lowry, 1989; see also Lowry & Plunkett, 2021) were also consulted and updated. Beyond these groups, we know of no comprehensive treatments of any major group of Vanuatu's flora at the rank of family or above, but many studies dealing with the circumscription and nomenclature of Pacific plants have made changes to species that are represented in Vanuatu, and these were assessed in completing the list (references provided at the end of the online checklist).

We stress that this list remains preliminary. There is still much to be done to finalize it, including a more thorough

Fig. 2. – A. *Diplazium oblongifolium* (Hook.) Jermy (*Athyriaceae*); **B.** *Tmesipteris vanuatensis* A.F. Braithw. (*Psilotaceae*); **C, D.** *Caryota ophiopellis* Dowe (*Arecaeae*); **E.** *Licuala grandis* (T. Moore) H. Wendl. (*Arecaeae*); **F.** *Dracaena* sp. nov. (*Asparagaceae*). [**A:** *Plunkett 5255*; **B:** *Plunkett 2861*; **C, D:** *Plunkett 4558*; **E:** *Plunkett 5653*; **F:** *Plunkett 4869*] [Photos: **A, C–F:** G. Plunkett; **B:** T. Ranker]

review of the determinations of species represented in PVNH and other herbaria by experts for particular taxonomic groups. Moreover, many historical collections have no duplicates deposited in PVNH, and these must also be carefully examined. Among the most important collections of Vanuatu's plants outside the country include those held by Paris (P), Kew (K), Nouméa (NOU), and Harvard (A), but many other herbaria hold duplicates that should be consulted as well.

For the purpose of assembling statistics, we have attempted to limit the number of distribution categories to three: "endemic", "native but not endemic", and "introduced". However, because Vanuatu has lacked an authoritative checklist, its species are often missing from regional and global lists and databases that provide information about geographic distributions. Due to the resulting uncertainty (across several levels), it was necessary to add a few intermediate categories, including "likely native" and "likely introduced" (which form a continuum between the more certain categories of "native" and "introduced"). For some species that have not previously been recorded in Vanuatu, we used our best judgement to decide which status to assign, based on the availability of collection information from Vanuatu (including localities that might suggest native or introduced habitats) and our own field experience. For example, species previously unrecorded from Vanuatu but collected in primary forests at several locations across the country, and also considered native in nearby archipelagos (viz. Fiji, New Caledonia, and/or the Solomon Islands), were recorded as "native". When the situation was slightly less clear, then "likely native" was entered. When a species was present in any one of the three adjacent archipelagos but restricted to heavily populated areas in Vanuatu (especially on Efate and Espiritu Santo, which have the country's only two urban areas), then they were recorded as "likely introduced". In cases where the limits of the native distribution were considered to be farther away (e.g. New Guinea to the west, or Samoa or Tonga to the east), then the species was considered "introduced". We stress that it is difficult to be 100% consistent across the checklist we prepared, especially when key pieces of information are often lacking, but we believe that the sliding scale of uncertainty (from "native" to "likely native" to "likely introduced" to "introduced") provides sufficient warning to the user to understand the nature of these data.

We also used the category of "near endemic" to capture the distribution of species that are limited to Vanuatu and the Santa Cruz Islands, which are politically part of the Solomon Islands but are geologically related and physically closer to Vanuatu (see Whitmore, 1969), and a few cases where a species was restricted to southern Vanuatu and also found in the Loyalty Islands (an archipelago of three coral islands) but not any of the other islands of New Caledonia (especially the main island of Grande Terre).

Some uncertainty remains as to whether particular species are truly present in Vanuatu. In one set of cases, there may be reliable evidence that a genus is represented in the country, but no indication of which species it might be. This may simply represent lack of sufficient knowledge about the genus and its species here, or alternatively, the taxon may represent a new species in need of formal description. The distributional status for such names was entered as "not known due to uncertainty". Another aspect of uncertainty deals with species names that have been applied to specimens in PVNH and would appear to be native based on their distributional patterns within Vanuatu, but where we have strong reason to believe that they may have been misidentified, especially if such species are otherwise absent from the immediate vicinity in the broader region of Melanesia. In these cases, we have included information in the notes that follow the entry, indicating that the species may be misidentified and therefore misattributed to Vanuatu.

Results

The current preliminary checklist of the vascular flora of Vanuatu includes 1,631 species (Table 1). Nearly one-third (31.3%, 511 taxa) of the species names being used in Vanuatu required nomenclatural updates, and many additional species were added to the checklist during our research. The detailed checklist is posted online at the Flora of Vanuatu website [http://www.pvnh.net], which will permit continual updating as new information becomes available. This list includes the scientific name of each species (organized by major taxonomic group, and then alphabetically by family, genus and species), the distributional status, habit, and common synonyms. Where known, the vernacular name of the plant in Bislama (the creole language used as the "lingua franca" in Vanuatu) is included, to make the list more useful and accessible to the local stakeholders.

The numbers and proportions of species by major group (Tables 1, 2) included 20.9% ferns (318 spp.) plus lycophytes (23 spp.), 0.5% gymnosperms (8 spp., representing a single cycad, a single gnetophyte, and five native conifers restricted to just two families, *Araucariaceae* and *Podocarpaceae*, plus an introduced species of *Pinaceae*). Among the angiosperms, monocots represent 23.1% of the vascular flora (376 spp.). For the sake of simplification, the category of "dicots" includes both the eudicots plus a small number of early-diverging angiosperms, represented in Vanuatu by the orders *Chloranthales* (*Chloranthaceae*, 2 spp.), *Laurales* (*Hernandiaceae*, 3 spp.; *Lauraceae*, 14 spp.; *Monimiaceae*, 1 sp.), *Magnoliales* (*Annonaceae*, 8 spp.; *Myristicaceae*, 2 spp.), and *Piperales* (*Aristolochiaceae*, 2 spp.; *Piperaceae*, 14 spp.), for a total of only 46 species (2.8%). Altogether, the dicots (s.l.) comprise over half (55.5%) of the vascular flora, with 903 species (and the eudicots, with 861 spp., comprise 52.8% of the flora).

Fig. 3. – A. *Tapeinochilos* sp. nov. (*Costaceae*); **B.** *Dendrobium mooreanum* Lindl. (*Orchidaceae*); **C.** *Dendrobium vanuatuense* Schuit. & P.B. Adams (*Orchidaceae*); **D.** *Pandanus halleorum* B.C. Stone (*Pandanaceae*); **E, F.** *Meryta neoebudica* (Guillaumin) Harms (female and male) (*Araliaceae*). [**A:** *Plunkett 4670*; **B:** *Plunkett 4666*; **C:** *Plunkett 5634*; **D:** *Plunkett 5053*; **E:** *Plunkett 4163*; **F:** *Plunkett 4164*] [Photos: G. Plunkett]

Native species of Vanuatu account for 77.4% (1,262 spp.) of the flora, including 165 endemic taxa (including near-endemics), representing 10.1% of the total flora and 13.1% of the native flora (Table 3). Figures 2–5 provide a representative sampling of some of the endemic species found in Vanuatu. The gymnosperms, all but one of which are native, have the greatest proportion of endemics (25% of all species and 28.6% of native species), but represent only a very small group of 8 species. Among the larger groups, the dicots have the greatest proportion of endemics, with 13.5% endemic among all species, and 19.7% among native species. The ferns and lycophytes have a much higher proportion of native species than any other major group (96.2% and 100%, respectively), but low levels of endemics (less than 3% across all measures). Among the monocots, 8.5% of all species (and 10.4% of native species) are endemic. Within *Orchidaceae*, all 172 species are considered native, but only 11 of these are endemic (representing 6.4% of the total), which seems rather low for the region. By contrast, two-thirds (15 of the 21 species, 71%) of all palms (*Arecaceae*) are endemic or nearly so. Among the dicots, all but one of the 11 species of *Gesneriaceae* (limited to the genus *Cyrtandra* J.R. Forst. & G. Forst.) are endemic. Other dicot families with high proportions of endemic plants include *Araliaceae* (8 of 16 spp., 50%), *Myrtaceae* (8 of 27 spp., 30%), *Primulaceae* (9 of 14 spp., 64%), and *Rubiaceae* (10 of 53 spp., 19%).

Introduced plants (including the status category of "likely introduced") represent 22.1% of the overall vascular flora, but the distribution of these introduced species is not uniformly spread across major taxonomic groups (Table 3). The lycophytes have no introduced species. The ferns have only 8 (2.5%) and the gymnosperms only a single introduced species (12.5%). Among the monocots, 67 (17.8%) of species are introduced. The dicots have the greatest proportion, with 31.3% of species introduced. Among the monocots, the grasses (*Poaceae*) are predictably a major source of introductions, with 32 of 62 (52%) species introduced. Other monocot families with high proportions of introduced species include *Araceae* (8 of 13 spp., 62%), *Commelinaceae* (3 of 7 spp., 43%), and *Zingiberaceae* (6 of 11 spp., 55%). Among the dicots, some families with high percentages of introduced species include *Acanthaceae* (14 of 25 spp., 56%), *Amaranthaceae* (12 of 13 spp., 92%), *Asteraceae* (28 of 37 spp., 76%), *Convolvulaceae* (9 of 19 spp., 47%), *Euphorbiaceae* (16 of 52 spp., 31%), *Fabaceae* (39 of 85 spp., 46%), *Lamiaceae* (12 of 25 spp., 48%), *Malvaceae* (13 of 31 spp., 42%), *Passifloraceae* (4 of 5 spp., 80%), and *Solanaceae* (16 of 20 spp., 80%). Doubtless, some of these numbers will change as the preliminary checklist becomes more fine-tuned.

Discussion

Regional comparisons

The number of species in Vanuatu (1,631 spp.) is low compared to levels of species richness found in the two adjacent archipelagos with well-established checklists, New Caledonia (3,645 species, 2.2 times larger) and Fiji (2,590 species, 1.6 times larger) (Table 4). While the flora of Vanuatu has sometimes been characterized as somewhat depauperate compared to nearby countries in Melanesia (e.g. Corner, 1975; Lee, 1975b; Schmid, 1975), it should be pointed out that New Caledonia (18,333 km^2) and Fiji (18,575 km^2) are each slightly more than 1.5 times larger in total land area than Vanuatu (12,189 km^2). Area and species richness are not related in a linear fashion (see Arrhenius, 1921; Wilson & MacArthur, 1967), but a broader analysis of archipelagos from throughout the region would be required to interpret these data more comprehensively. Nevertheless, it is worth

Table 1. – Numbers of species in the preliminary Checklist. The list is broken down in two ways: the upper list divides species into only two categories (and omits species with "status uncertain"), while the lower list is more fine scale, separating out several categories. Totals are based on the lower list (which also includes the species of uncertain status).

Status	Lycophytes	Ferns	Gymnosperms	Monocots	Dicots	ALL
1. Total native (incl. likely native & endemics/near endemics)	23	306	7	307	619	1,262
2. Total introduced or likely introduced	0	8	1	67	284	360
1a. Endemics	0	9	2	29	113	153
1b. Near Endemics	0	0	0	3	9	12
1c. Native (but not endemic)	20	261	5	269	483	1,038
1d. Likely Native	3	36	0	6	14	59
2a. Introduced	0	3	1	65	280	349
2b. Likely introduced	0	5	0	2	4	11
3. Status uncertain or species identification ambiguous	0	4	0	2	3	9
TOTALS	23	318	8	376	906	1,631

Fig. 4. – A. *Geissois denhamii* Seem. (*Cunnioniaceae*); **B.** *Hibiscus cooperi* Meehan (*Malvaceae*); **C.** *Medinilla heteromorphophylla* Guillaumin (*Melastomataceae*); **D.** *Didymocheton aneityensis* (Guillaumin) Harms (*Meliaceae*); **E, F.** *Myristica guillauminiana* A.C. Sm. (*Myristicaceae*); **G.** *Syzygium aneityense* Guillaumin (*Myrtaceae*).
[**A:** *Plunkett 5303*; **B:** *Plunkett 4751*; **C:** *Plunkett 5626*; **D:** *Plunkett 4541*; **E, F:** *Plunkett 5595*; **G:** *Plunkett 4687*]
[Photos: G. Plunkett]

noting that the difference in land area between Fiji and Vanuatu (1.52 times larger) accounts for the greater part of the difference in species richness between the two archipelagos. It does not, however, explain the massive differences found between Vanuatu and New Caledonia. Like all Pacific islands, New Caledonia has been subject to repeated rounds of submergence and emergence, but its Grand Terre is an old, continental island that has probably been continually emergent for 37 Ma (Grandcolas et al., 2008). It is also known to support one of the world's most diverse floras with some of the highest rates of endemism on earth (e.g. Lowry et al., 2004). In fact, this disparity is even greater because the 3,645 species listed on *Florical* (Morat et al., 2012; Munzinger et al., 2021) includes almost no introduced species, while the lists for Fiji and Vanuatu do. The gymnosperms provide a good example of this general trend among New Caledonia, Fiji, and Vanuatu. Vanuatu has only 8 gymnosperm species, a tiny fraction of the 51 species found in New Caledonia. By contrast, Fiji has 12 species, and when corrected 4 for differences in land area, the gymnosperm diversity of the two archipelagos is almost perfectly comparable. It should also be noted that Vanuatu is among the youngest island chain in the region, and if the number of species as a function of the age of each archipelago is factored in, Vanuatu's flora may in fact represent a remarkable diversity, but a formal analysis of this statistic must wait until the checklist is further refined.

Problematic taxa

In assessing the families, genera, and species of Vanuatu's flora, we have identified several groups that are in need of a great deal of additional study. Among the ferns, there are several problematic taxa in the genus *Asplenium* L. (D. Ohlsen, pers. comm.). For example, samples that we have tentatively determined to be *A. australasicum* (J. Sm.) Hook. in Vanuatu, might actually be a different species, but further study is needed. Similarly, the delimitation between *A. caudatum* G. Forst. and *A. horridum* Kaulf. is challenging and must be studied more closely. Other species complexes in need of closer inspection include *A. listeri* C. Chr. – *A. polyodon* G. Forst. – *A. falcatum* Lam. and *A. contiguum* Kaulf. – *A. parvum* Watts. Among the angiosperms, great confusion remains among many or most taxa in *Sapindaceae* and *Sapotaceae* (especially the latter). In *Euphorbiaceae*, it is difficult to distinguish species within *Acalypha* L., *Claoxylon* A. Juss., and *Cleidion* Blume. Few if any botanists on the ground can distinguish the 11 species of *Cyrtandra* (*Gesnariaceae*), the 7 species of *Maesa* Forssk. and the 3 species of *Tapeinosperma* Hook. f. (both *Primulaceae*), or the 5 species of *Hoya* R. Br. (*Apocynaceae*). In *Rubiaceae*, problems of species circumscription persist in *Psychotria* L. and its segregate *Eumachia* DC., as well as *Ixora* L. Recent studies of *Syzygium* P. Browne ex Gaertn. (*Myrtaceae*; see Tuiwawa et al., 2013) and *Melicope* J.R. Forst. & G. Forst. (*Rutaceae*; see Hartley, 2000) have helped to clarify species circumscriptions in these genera, but many of their species remain difficult to distinguish. Other genera with problematic species include *Cryptocarya* R. Br. and *Litsea* Lam. (both *Lauraceae*), *Geniostoma* J.R. Forst. & G. Forst. (*Loganiaceae*), *Stephania* Lour. (*Menispermaceae*), *Glochidion* J.R. Forst. & G. Forst. (which requires a taxonomic transfer to *Phyllanthus* L.; *Phyllanthaceae*), and *Piper* L. (*Piperaceae*).

Future prospects

One long-term goal of our project is to generate a more finalized checklist that also includes lists of specimens for each species, and eventually the production of a floristic manual for Vanuatu. In the shorter term, we hope that this checklist will be more immediately useful in several ways. First, we invite taxonomic experts in all plant families and/or regional floristics in the Pacific to provide their opinions of the checklist in terms of correctness and completeness. We recognize that the sources

Table 2. – Percentages of species representing different higher-level groups.

Major Group	% of Flora
Ferns & Lycophytes	20.9%
Gymnosperms	0.5%
Monocots	23.1%
Dicots	55.5%

Table 3. – Percentages of species across different distributional status categories. The "native" category here includes likely natives, as well as endemics and near endemics (which are therefore not included in the calculations of the totals).

Status	Lycophytes	Ferns	Gymnosperms	Monocots	Dicots	ALL
Native (incl. likely native, endemics & near endemics)	100%	96.2%	87.5%	81.6%	68.3%	77.4%
Endemics (incl. near endemics) as a percentage of all species	0%	2.8%	25.0%	8.5%	13.5%	10.1%
Endemics (incl. near endemics) as a percentage of native species only	0%	2.9%	28.6%	10.4%	19.7%	13.1%
Introduced & likely introduced	0%	2.5%	12.5%	17.8%	31.3%	22.1%
Status uncertain or species identification ambiguous	0%	1.3%	0%	0.5%	0.3%	0.5%

Fig. 5. – A. *Turrillia lutea* (Guillaumin) A.C. Sm. (*Proteaceae*); **B.** *Palaquium neoebudicum* Guillaumin (*Sapotaceae*); **C, D.** *Phaleria pentecostalis* Leandri (*Thymelaeaceae*).
[**A:** *Plunkett 4194*; **B:** *Plunkett 4546*; **C, D:** *Plunkett 5433*]
[Photos: G. Plunkett]

of information we relied upon most heavily are not always compiled by researchers with intimate knowledge to the systematics of each plant group, and therefore we seek assistance from the global community of plant taxonomists to improve our list. Moreover, through active fieldwork, we are generating a large number of new collections and could provide herbarium duplicates and/or silica-dried leaf-tissue samples (for molecular-phylogenetic studies) to researchers interested in select taxa. Secondly, the checklist will be used to update specimen names in the PVNH collections and database, to more accurately reflect current circumscriptions and nomenclature. Thirdly, the list will be an invaluable resource within Vanuatu as it develops or updates lists of endemic species and/or species that are potentially threatened and in need of conservation management. For example, the country's National Biodiversity Strategic Action Plan includes a list of endemic species that is both woefully incomplete and badly out of date. Moreover, only 7% of the flora has been assessed for the IUCN Red List, and the vast majority of this small number (91%) are species that have widespread distributions (across large parts of the Pacific, and sometimes well beyond), almost all of which are not threatened. The lack of threat assessments for Vanuatu's most narrowly distributed (and potentially most threatened) species puts the country at a distinct disadvantage when it comes to raising funds for species-conservation work, which are generally tied to species assessed in one of the three "threatened" categories of "Vulnerable" [VU], "Endangered" [EN], or "Critically Endangered" [CR]. Finally, we hope that the checklist will help raise awareness of Vanuatu's remarkable flora, and encourage researchers to include the native species from this archipelago in their studies. With the completion of checklists for New Guinea (Cámara-Leret et al., 2020) and now Vanuatu, one of the few remaining Pacific archipelagoes to lack an inventory of vascular plants is the Solomon Islands, for which a list only of the lycophytes and ferns is available (Chen et al., 2017).

Checklist

The detailed checklist and additional plates can be accessed at the Flora of Vanuatu website [http://pvnh.net].

Acknowledgements

We gratefully acknowledge our many colleagues who provided information or assistance in the completion of this study, chief among whom are the staff of the Vanuatu National Herbarium and the Vanuatu Department of Forestry. In particular, we acknowledge Presley Dovo for the countless ways he has facilitated this research both in the field and in Port Vila, as well as other Herbarium and Forestry staff and students, including Thomas Doro, James Ure, Frazer Alo, James Samuel, Stephanie Sali, and the late Philemon Ala. Two anonymous reviewers generously provided many useful comments and corrections to both the manuscript and the accompanying checklist. Field aspects related to this study were significantly aided by members of the Tafea Kaljoral Senta, especially Jean-Pascal Wahe. We acknowledge other partners in the *Plants mo Pipol blong Vanuatu* project, including Sean Thackurdeen, Marika Tuiwawa, K. David Harrison, Tamara Ticktin, Brian Perry, Anthony Amend, Jonathan del Rosario, Andre Boraks, and Ashley McGuigan. Others who participated in field work and plant identification include Kate Armstrong, Jérôme Munzinger, and David Bruy, along with Laurence Ramon, who also did so much to help advance the condition and operation of the Vanuatu National Herbarium. We thank Dominik Ramík for his vital assistance in migrating the PVNH specimen data to a new database, a process that proved very useful in assembling the checklist. We also thank Pete Lowry for generously translating the abstract into French. We are grateful to the many community members who assisted in field studies, particularly from the islands of Tanna, Aneityum, Futuna, Pentecost, and Vanua Lava (including Abraham Junior Eldads, Albert André, Alexis Taknik Tupun, Alfred Kausiama, Alfred Reva, Alick Edmond, Alick Nauka, Alick Ravirus, Alivereti Naikatini, Andrew Danife, Andrew Namre, Arby Barone, Ben Nambo, Benjamin Nasawman, Benjamin Tom, Bill Garae, Bob Kew Matai, Casimir George, Charlie Bride Paul, Chessie Church, Clement Georges, Clenson Lewani, Colin Dovo, Daddly Lolowia, Dan Tanife, David Celesta Sero, David Kapwia, David Tom, Desmond Ala, Dominique Henri, Eden Linge, Erik Usua, Eva Namry, Fabian Din, Francis George, Francis Wahe, Francisco Wahe, Frank Joely, Ghislaine George,

Table 4. – Comparisons of land area and vascular-plant diversity between Vanuatu and two adjacent archipelagos.

	Area		Flora		
Archipelago	**km² of land area**	**× larger than Vanuatu**	**Total # spp.**	**# spp./km²**	**× larger than Vanuatu**
Vanuatu	12,189	—	1,631	0.13	—
New Caledonia	18,333	1.5	3,645	0.20	2.2
Fiji	18,575	1.52	2,590	0.14	1.6

Glenson Leiwani, Greg Matai, Helen Morris, Hervé Sero, Iawia Jack, Iawilu Naumus Apen, Iliesa Koroi, Jack Nawen, James Rawi Karpa, James Ronnie, Jean Paolo Nawarau, Jeffline Tasale, Jerolyn Sigel, Jerome Neru Iarapat, Jimmy Nakapue Asim, Jimmy Takaronga Kautonga, Jocelyn Usua, Joe Hinge, John Basses, John Ivan, John Pascua, John Yawa, Johnny Jack, Johnny Rawi, Johnny Simon Yawiko, Johnson Kamkari, Johnson Noar, Joseph Dabauh, Joseph Kabir Kemah, Joseph Kahi Narkahau, Joseph Kema, Joshua Andrew, Jouvil Vanega, Julian George, Juliusatalay Sesbah, Kalpapen Naven, Karahi Sam, Kati Katawa, Kavahak Mary, Keith Clancy, Keith Meava, Keith Yaiyaho, Kenson Hinge, Kevin Kausei, Kimson Perei, Kissel Edmond, Konapo Nauperi, Kuanabo Johnny, Lacey Strong, Lalep Thomas Japanesei, Lee Bango, Leisongi Bulesulu, Leo Feimaga, Madeleine Manke Kemah, Margaret Morris, Marian Nalau, Martial Wahe, Martin Kasu, Mary Nialou Ken, Maryann Alick, Matthias Din, Mesek Avia, Miles Thomas, Morris Kawas, Moses Tohn, Nako Maur, Nako Robinson, Nalau Nasep, Namaka Thierry, Napuar David, Naume Naven, Naumeta Rose, Nigel Nesua, Numeta Rose, Pascal George, Paul Fatapa, Paulin Kalip, Peter Nisian, Peter Tanife, Philip Wahe, Pierric Sero, Quincy Motua, Raymond Kanawi Sero, Raymond Namri Namri, Rebecca Barone, Remy Kali, René Theimu, Rennedh Kaltong, Reuben Neriam, Rexly Tombu, Rick Malau, Rosalina Nijae, Sam Natou, Sam Nauka, Samson Jimmy Nakapue, Samson Kwanpiken, Samson Numake Nakabue, Samuel Herwaen Kemah, Samuel Seru, Sandra Toa, Selwyn Dovo, Sero Ervé, Smith Paul, Stephanie Sali, Steven Tanife, Sylvan Nawarau, Tamalifu Takyajeia, Tanife Rawi Karpa, Tarpu Rawi Karpa, Teresa Wahe, Thomas Japanesei Lalep, Thomas Kamisak, Thomas Sam Nakuramu, Tiery George, Titus Johnny, Titus Karpa, Titya Lalep, Tom Johnson, Tom Ravei Kahi, Tony Keith, Vagaha Damien Hinge, Wewei Wahe, Wina Nasauman, Wopa Nasauman, Yawa Yawa, Yawiko Johnny Karpa, Yesua Nakapue, and Yoli Sivi). Many other colleagues provided helpful comments regarding questions of species status or circumscription. Among the fern and lycophyte experts, we gratefully acknowledge Pat Brownsey, Cheng-Wei Chen, Wen-Liang Chiou, Atsushi Ebihara, Ashley Field, Daniel Ohlsen, Barbara Parris, Leon Perrie, Dhahara Ranatunga, and Michael Sundue. Angiosperm experts included Osia Gideon, Theo Damen, William Baker, Phillip Cribb, John Dowe, Martin Callmander, Vincent Lebot, Daniel Nickrent, Donald McClelland, Lex Thomson, Robert Naczi, Fabian Michelangeli, and Zacky Ezedin. This work was supported by grants from the U.S. National Science Foundation (under grants DEB 1555657 and 1555793), the National Geographic Society, The Christensen Fund, the Critical Ecosystem Partnership Fund, the Franklinia Foundation, the Marisla Foundation, the Gildea Foundation, and the Silicon Valley Community Fund.

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Towards a checklist of the Vascular Flora of Vanuatu

Authors: Plunkett, Gregory M., Ranker, Tom A., Sam, Chanel, and Balick, Michael J.

Source: Candollea, 77(1) : 105-118

Published By: The Conservatory and Botanical Garden of the City of Geneva (CJBG)

URL: https://doi.org/10.15553/c2022v771a8