

# Insights from natural history collections: analysing the New Zealand macroalgal flora using herbarium data

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## Abstract

Herbaria and natural history collections (NHC) are critical to the practice of taxonomy and have potential to serve as sources of data for biodiversity and conservation. They are the repositories of vital reference specimens, enabling species to be studied and their distribution in space and time to be documented and analysed, as well as enabling the development of hypotheses about species relationships. The herbarium of the Museum of New Zealand Te Papa Tongarewa (WELT) contains scientifically and historically significant marine macroalgal collections, including type specimens, primarily of New Zealand species, as well as valuable exsiccatae from New Zealand and Australia. The herbarium was initiated in 1865 with the establishment of the Colonial Museum and is the only herbarium in New Zealand where there has been consistent expert taxonomic attention to the macroalgae over the past 50 years. We examined 19,422 records of marine macroalgae from around New Zealand collected over the past 164 years housed in WELT, assessing the records in terms of their spatial and temporal coverage as well as their uniqueness and abundance. The data provided an opportunity to review the state of knowledge of the New Zealand macroalgal flora reflected in the collections at WELT, to examine how knowledge of the macroalgal flora has been built over time in terms of the number of collections and the number of species recognised, and identify where there are gaps in the current collections as far as numbers of specimens per taxon, as well as with respect to geographical and seasonal coverage.

## Keywords

Herbarium, macroalgae, Museum of New Zealand Te Papa Tongarewa, regional floras

## Introduction

Herbaria and natural history collections (NHC) are critical to the practice of taxonomy. They are the repositories of vital reference specimens, enabling species to be studied and their distribution in space and time to be documented and analysed, as well as enabling the development of hypotheses about species relationships. Krishtalka and Humphrey (2000) describe natural history museums as “sentinel observatories of life on Earth” and also “stewards of its future”. Repeatable and testable biological sciences are reliant on taxonomy and vouchered specimens. Within the past decade or so, there has been an increasing recognition of the value of collections in the analysis of biodiversity, with interest in their potential applications for example in conservation and ecology, inferring threats associated with anthropogenic change (e.g. McCarthy 1998, Shaffer et al. 1998, Ponder et al. 2001, Graham et al. 2004, Frey 2009, Newbold 2010, Pyke and Ehrlich 2010, Johnson et al. 2011, Tomizuka et al. 2012, Ward 2012). A number of studies have explored the ways in which NHC may be used to evaluate responses of biota to climate change, including examination of apparent shifts in species ranges, detecting the presence of possible introduced species, and prediction of the future changes in species distributions and patterns of species richness under future climate scenarios (e.g. Graham et al. 2004, Johnson et al. 2011).

There are many challenges when using NHC for analyses of biota, particularly the potential sources of errors, accuracy and biases (Graham et al. 2004, Boakes et al. 2010, Newbold 2010, Pyke and Ehrlich 2010, Huisman and Millar 2013). On the one hand, NHC provide an “unambiguous record of a taxon at a particular place and time” with the advantage that vouchered material enables identifications to be verified and additionally taxonomic concepts can be updated (Johnson et al. 2011). However there are significant issues about the quality of the identifications, that is, whether these have been provided by a subject specialist, and also whether taxonomic concepts, changes in nomenclature, and synonymies are being updated.

In terms of spatial and temporal data, older collections tend to be geo-referenced post-collection which may introduce location errors. The data associated with specimens are often highly variable as far as the level of detail provided, for example, the precision of the locality of the collection, habitat information, associated species, collection method, and whether multiple collections were made from within different habitats within a site. Some early collections (19<sup>th</sup> century, early 20<sup>th</sup> century) have only the year or month of collection provided with the specimen. Biases affect different aspects of the collections. Spatial biases can result from the position of access roads and settlements, particularly in the case of coastal collecting. Access to collection methods and equipment is also critical, for example, in the case of marine macroalgae in New Zealand there are large sections of coastline where access is only possible from the sea, and thus the use of boats is critical. Weather can have a significant impact on accessibility of sites and can lead to seasonal biases. For an important part of the flora sampling is only possible via SCUBA and via dredge equipment for deep-water samples. The location of active collectors has an impact on the number

of collections obtained from particular regions, as does the perception of areas being of specific interest. Temporal biases can result from experts working actively on particular taxonomic groups, as well as from particular curatorial practices and personal interests (e.g. discarding damaged individuals, only accessioning a certain number of individuals) (Ward 2012).

Collections result from targeted investigations as well as from opportunistic sampling. Sometimes remote areas are infrequently visited but have detailed and thorough collections because major effort is required to reach the area and very deliberate collections are undertaken. There are inevitably biases as far as which species are collected, with the potential for larger or more conspicuous species to be over-represented and with smaller or more difficult to collect species under-represented. In addition, sometimes common species are under-collected whereas rare or unusual species are collected more frequently. Graham et al. (2004) consider that “nonrepresentative sampling in environmental space remains the most difficult source of error to detect and correct”. The material in NHCs only provide presence data, establishing that the species was present at that locality when collected. Interpretation of species absences is complex - the species may not have been at the locality, or was not collected, or not detected.

## Macroalgal collections from New Zealand

In the mid to late 19th century there was a period of research on New Zealand algae by overseas research workers, particularly W.H. Harvey (Trinity College, Dublin), J.D. Hooker (Kew, London) and J.G. Agardh (Botanical Museum, Lund). In some cases material was deposited in New Zealand collections, e.g. collections made by William Colenso were sent to Hooker and Harvey and some material retained in New Zealand; collections made by Sven Berggren in 1874 were sent to Agardh with some duplicate material returned to New Zealand (Bagnall 1970). However this was followed by many years when there was very little activity on the description or study of New Zealand algae. Collections made by New Zealanders rather than foreign visitors began with the work of R.M. Laing and W.A. Scarfe, and compilations of species were prepared by Laing (e.g. Laing 1900, 1902, 1909, 1926, 1930).

From the mid-1930s very significant collections were made by Victor Lindauer (Cassie 1971, Cassie Cooper 1995) who corresponded with several international phycologists and also received specimens from Eileen Willa on Stewart Island. From the 1930s onwards Lucy Cranwell and Lucy Moore, at that time students at Auckland University College, made important collections and ecological observations. The establishment of algal research within Botany Division of the Department of Scientific and Industrial Research (DSIR) saw the development of collections by Moore and Nancy Adams. In the late 1940s both Dr T. Levring and Professor G.F. Papenfuss visited New Zealand. The collections made by Papenfuss provided material for many of his graduate students who made major contributions to the understanding of the New Zealand macroalgal flora (e.g. Wagner 1954, Norris 1957, Sparling 1957, Hom-

mersand 1963). Taxonomic treatments of the flora began to be published (e.g. Levring 1955, Chapman 1956, 1969, 1979, Lindauer et al. 1961, Chapman and Dromgoole 1970, Chapman and Parkinson 1974), but to date there has been no comprehensive treatment of the macroalgal flora.

The major macroalgal collections are held in New Zealand in the herbaria of the Museum of New Zealand Te Papa Tongarewa (WELT), Landcare Research Manaaki Whenua (CHR) and at the Auckland Museum (AK) (Thiers 2012). However, WELT is the only herbarium in New Zealand where there has been consistent expert taxonomic attention to the macroalgae over the past 50 years (Nancy Adams 1969–1987, Wendy Nelson 1987–2002, Jenn Dalen 2002–present). The herbarium was initiated in 1865 with the establishment of the Colonial Museum (1865–1906), subsequently known as the Dominion Museum (1906–1973), National Museum of New Zealand (1973–1992) and the Museum of New Zealand Te Papa Tongarewa (Te Papa) (from 1992). Algal specimens were received into the collections in the 1860s and 1870s, from the inception of the herbarium, including a collection from the British Museum of more than 200 algal specimens from throughout the British Isles dating from 1806–1860 and algal specimens from the Thompson/J.G. Baker herbarium (Nelson et al. 1998). The Te Papa herbarium contains scientifically and historically significant marine macroalgal collections including, type specimens, primarily of New Zealand species, as well as valuable exsiccatae from New Zealand and Australia (Nelson et al. 1998).

In the absence of a complete flora, there has been considerable recent effort directed to compiling and updating lists of currently accepted names and the taxonomic hierarchy, with published lists produced as part of the Species 2000 project documenting the New Zealand biota (Broady et al. 2012, Harper et al. 2012, Nelson 2012), and also updated current lists provided on the Te Papa website (e.g. Dalen and Nelson 2013 a–c). Much of New Zealand macroalgal taxonomic and biogeographic literature is based on the WELT collections including Adams (1994) and a series of regional floral lists (Adams 1972, Adams et al. 1974, South and Adams 1976, Nelson and Adams 1984, Adams and Nelson 1985, Hay et al. 1985, Nelson and Adams 1987, Nelson et al. 1991, Nelson et al. 1992, Neale and Nelson 1998, Nelson et al. 2002) based on targeted collections. In addition some specific projects were undertaken to improve collections and knowledge of the flora (e.g. coralline algae, Harvey et al. 2005, Broom et al. 2008, Farr et al. 2009; macroalgae from soft sediment environments, Neill et al. 2012; Ulvaceae, Heesch et al. 2007, 2009).

The WELT collections have been databased over a period of ca. 15 years. The recent focus within the herbarium has been on improving collection data and checking the dataset for errors, particularly grooming collection date data and mapping and verifying locality data. The collections at both AK and CHR have not been fully databased to date and have not received the level of scrutiny and identification that has been directed to the WELT collections. The AK and CHR collections currently do not have specialist marine phycologists associated with the collections. Because WELT collections have received expert identification and curation, they have been used as the primary source of data on the distributions of marine macroalgae for a number of



research projects and government databases (e.g. Booth et al. 2006) and WELT is also where voucher specimens have been deposited (e.g. for the Marine Invasives Taxonomic Service, contracted to NIWA by the Ministry for Primary Industries).

## **The purpose of this study**

The grooming and updating of the database has provided an opportunity to review the state of knowledge of the New Zealand macroalgal flora reflected in the collections at WELT, and to ask a series of questions. Which regions of New Zealand are represented by the most comprehensive collections/least comprehensive collections? How has knowledge of the macroalgal flora built over time in terms of the number of collections and the number of species recognised? Are there patterns that can be discerned in the collection history and coverage? What proportion of the flora is represented by sufficient individuals for study and comparative investigation (number of specimens, geographic range, seasonal distribution)? Do these collections have the potential to enable other types of biodiversity analyses?

## **Materials and methods**

The data presented in this paper are drawn from the database of the Te Papa herbarium. Definitions for terms used in this paper are provided in Table 1. Data were assembled following several steps:

### **History of data and specimen information verification**

Until the early-1990s, herbarium specimen data were available from the specimen labels and a hard copy register. The first electronic database system at Te Papa, Te Kahui, was custom-designed and implemented in 1993. Data were retrieved from the specimen labels and entered into the system by trained data-entry technicians. Where appropriate, extra information was sourced - the majority of this being latitude and longitude information derived from maps (NZMS 260 series). Most of the existing New Zealand algal specimens in the collection had an electronic record completed by ca. 2001. However, the record error rate was relatively high – in the order of 30-40%, with respect to coordinate data and locality information.

In 2005, all of the museum's electronic records were migrated to an electronic collection information management system, KE EMu® (referred to as EMu), a relational database customised for museum collections. With the implementation of the new database, there was scope to improve the quality of information recorded. Features of EMu, such as sophisticated search functions and global updating options, have facilitated cross-checking for consistency in the locality records, use of place names and

**Table 1.** Definitions of terms used in this paper.

Term	Definition
Collecting event	For each region collections were sorted by year, then collection date and precise location. Each unique combination of date and precise location was treated as a collection event.
Duplicate records	Specimen duplicates, i.e. same taxon with identical collection data. (Only 1 example of duplicate sheets (e.g. labelled a–c) was retained; duplicates with different registration numbers were removed.)
Season	Collection dates were grouped by month and allocated to seasons as follows: December–February = summer; March–May = autumn; June–August = winter; September–November = spring
Record	Single packet, box or specimen sheet
Taxon	Name used in database which includes identifications to family, genus and species level as well as tag names (informal names assigned usually in preliminary stages of investigations or for entities recognised in the field)

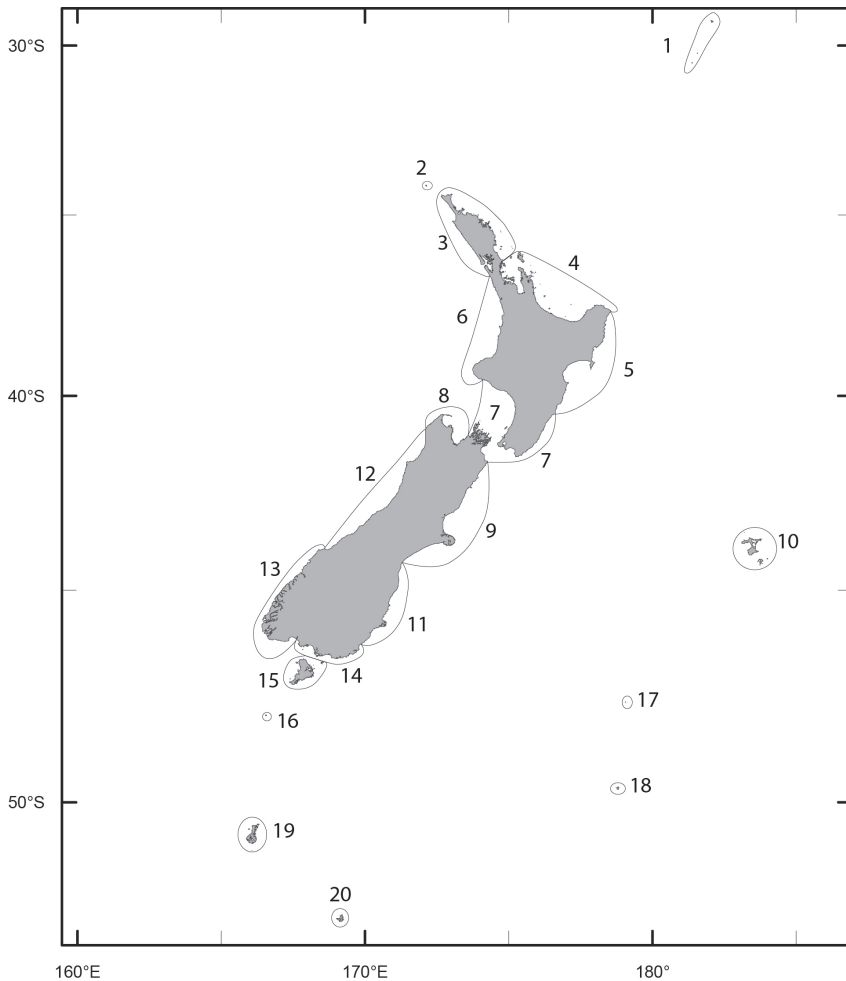
collector details. The verification and grooming of the algal data (e.g. cross checking of longitude and latitude, consistency of locality records, use of place names, collector details, identifying missing data fields and locating information where available) has become a core collection management activity since this time. However, much of this grooming effort has been somewhat opportunistic (for example, new acquisitions prompt a cross-checking of data for similar/nearby locations). Several special projects and requests for data have prompted more comprehensive data verification efforts. As part of this, several thousand backlog algal specimens were identified and databased; the database component of the work further prompted refinement to the consistency and accuracy of the locality data. Attention to the application of taxonomic concepts and names across the collection was also undertaken as part of this work.

### Taxonomic framework

In the absence of a published flora, a current species names list and taxonomic hierarchy is maintained on the Te Papa website (<http://www.tepapa.govt.nz/> - Dalen and Nelson 2013a–c). Changes to current taxonomic names and classification have been drawn from primary literature and updated into Te Papa's database and the application of name changes to the collections has also been part of this effort.

### Regional categorisation

Figure 1 illustrates the regional boundaries applied in this exercise. The boundaries reflect a combination of biogeographic boundaries in previously published accounts of the marine biota (e.g. Adams 1994, Nelson 1994, Shears et al. 2008), as well as province definitions employed by Te Papa for the plant collections.



**Figure 1.** Map of New Zealand indicating the boundaries of the regions investigated in this study (1 Kermadec Is 2 Three Kings Is 3 North I. (NI) North 4 NI Bay of Plenty (BOP) 5 NI East 6 NI West 7 Wairarapa-Cook 8 South I. (SI) Northwest (NW) 9 SI Kaikoura 10 Chatham Is 11 SI Southeast (SE) 12 SI Westland 13 SI Fiordland 14 SI Southern 15 Stewart I. 16 Snares Is 17 Bounty Is 18 Antipodes Is 19 Auckland Is 20 Campbell I.).

### Download of data from Te Papa database

All New Zealand marine algal records were searched and grouped by latitude and longitude coordinates corresponding to the regions as defined above (20 categories) in Te Papa's database. Records, current to December 2011, were exported by region into Excel spreadsheets. Table 2 summarises the data used in the analyses undertaken. The number of taxa includes all recognised entities present in the collections, including some that have been recognised as distinct at a family, genus or species level but are currently unnamed. It is important to note that the publicly accessible flora lists

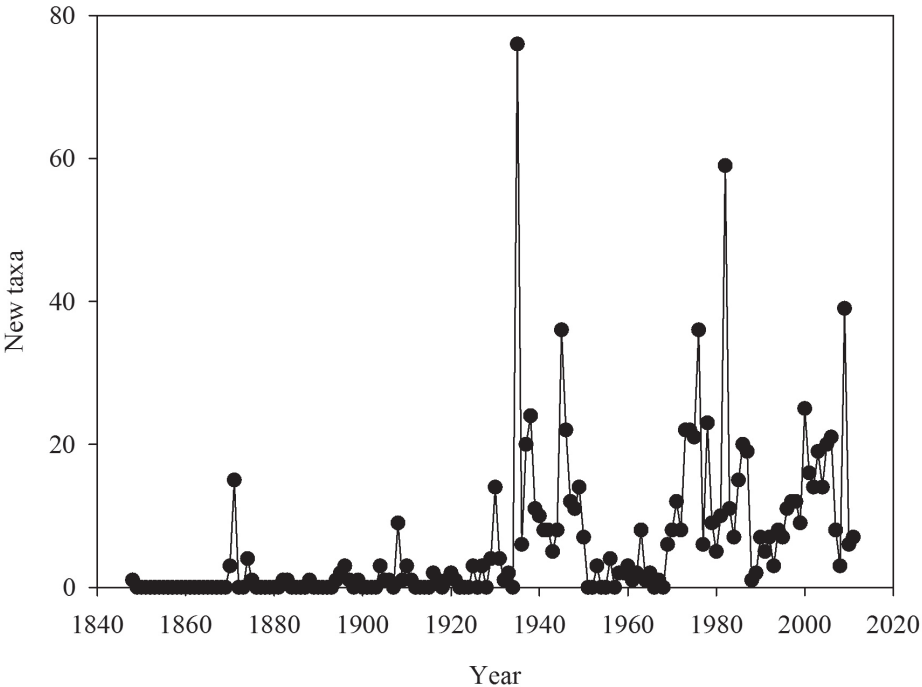
**Table 2.** Summary of the specimen records and taxa analysed in dataset:

	<b>Greens</b>	<b>Browns</b>	<b>Reds</b>	<b>Total</b>
Number of records	2,859	5,495	17,043	25,397
Number of unique records	2,213	4,580	12,629	19,422
Number of taxa	118	199	679	996
Number of classes	3	3	4	10
Number of orders	7	13	20	40
Number of families	16	30	52	98
Number of genera	<b>25</b>	<b>75</b>	210	310

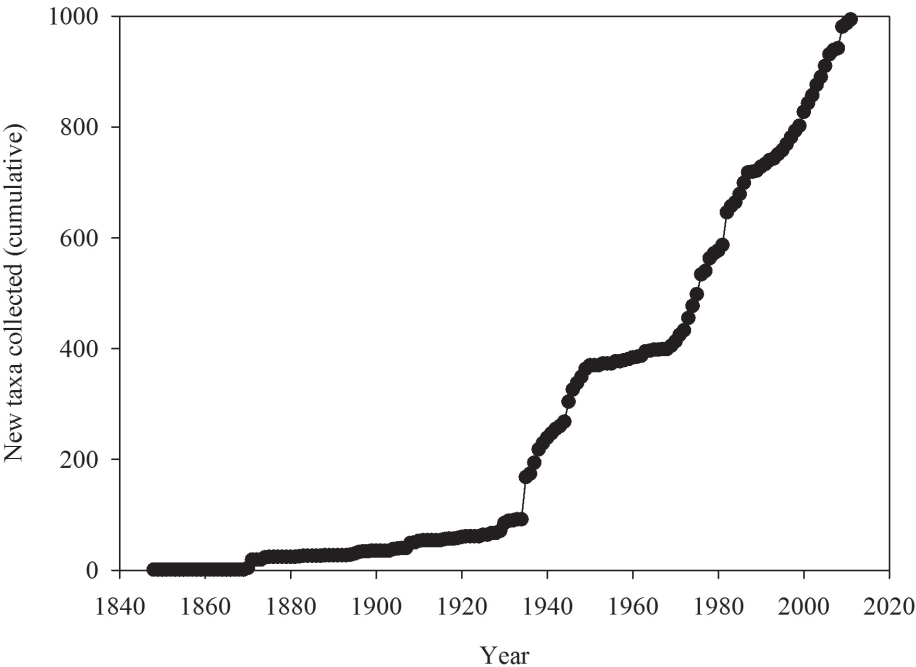
(Dalen and Nelson 2013a-c) only include published names, including some published tag names, that not all published taxa are represented in the WELT collections, and that there are more taxa recognised as being distinct than have been published currently. The Green algae or Division Chlorophyta includes data for three classes, Prasinophyceae, Ulvophyceae, and Trebouxiophyceae. (There are no marine macroalgal Chlorophyceae represented in Te Papa's collections.) The Brown algae or Ochrophyta include members of the classes Chrysomerophyceae, Xanthophyceae, and Phaeophyceae, and the Red algae or Rhodophyta are represented by members of 4 classes, Compsopogonophyceae, Stylonematophyceae, Bangiophyceae, and Florideophyceae.

## Results and interpretation

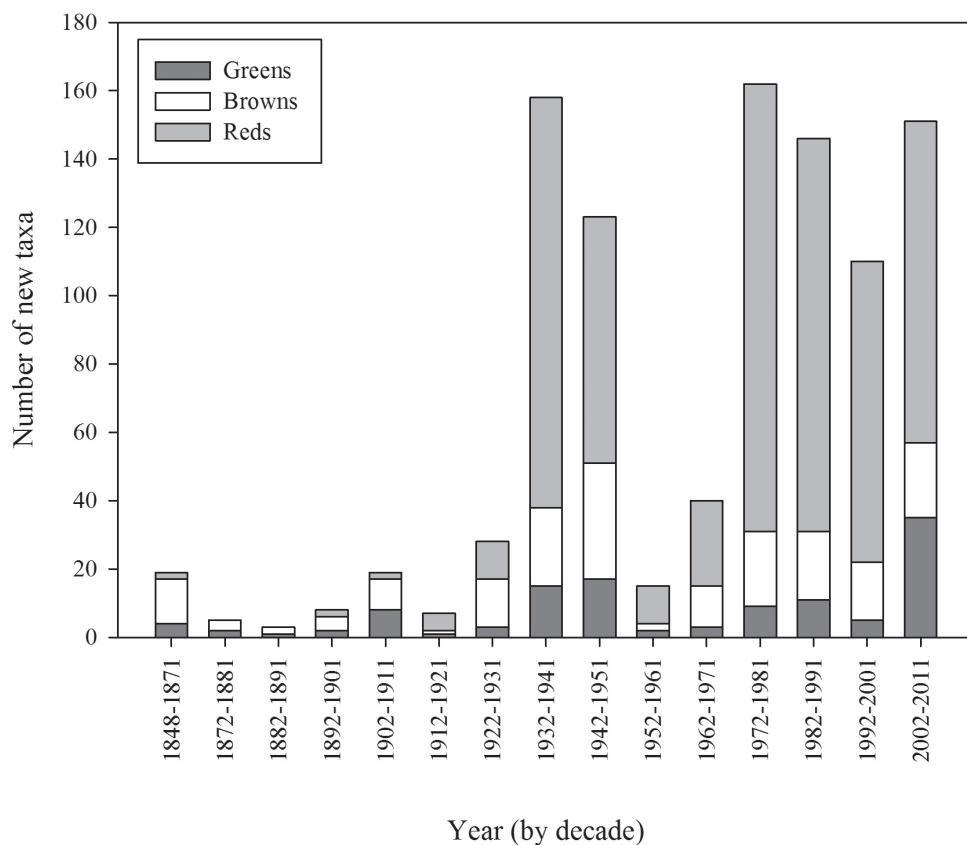
The number of new taxa represented in the collection by year of collection is presented in Figure 2, the cumulative total of taxa in the collections in Figure 3, and the number of taxa in the collections by decade of collection broken into divisions (red, brown, and green algae) in Figure 4. The surge in the number of collections around the 1870s reflects the material collected by both S. Berggren and H.H. Travers that was sent to Lund for examination by J.G. Agardh with duplicate material returned to New Zealand. Most specimens lodged prior to the 1930s were collected by W.A. Scarfe and R.M. Laing. In 1935 Josephine Tilden from the University of Minnesota, and a group of associates, visited New Zealand collecting in the Bay of Islands as well as on Stewart Island, and material was distributed as "South Pacific Plants". V.W. Lindauer, the school teacher at Russell, Bay of Islands, was introduced to seaweeds by Tilden, resulting in his major contributions to New Zealand phycology (Cassie 1971, Cassie Cooper 1995, Nelson and Phillips 1996). Lindauer assembled the *Algae Nova-Zelandicae Exsiccatae* (ANZE), consisting of 350 sheets and distributed in 14 fascicles between 1939 and 1953, incorporating his own collections, those of family and pupils and also material he received from Mrs Eileen Willa on Stewart Island. The peaks in the annual number of new taxa between 1930 and ca. 1955 are largely based on the Lindauer collections and exsiccatae. The peaks in collections and the upward surge in cumulative number of taxa from 1969 coincides with the arrival of Nancy Adams at WELT, with collecting primarily in the Wellington and Wairarapa regions. The increased availability and use of SCUBA resulted



**Figure 2.** Number of new taxa represented in the collection by year of collection.



**Figure 3.** Cumulative total of taxa in the collections.



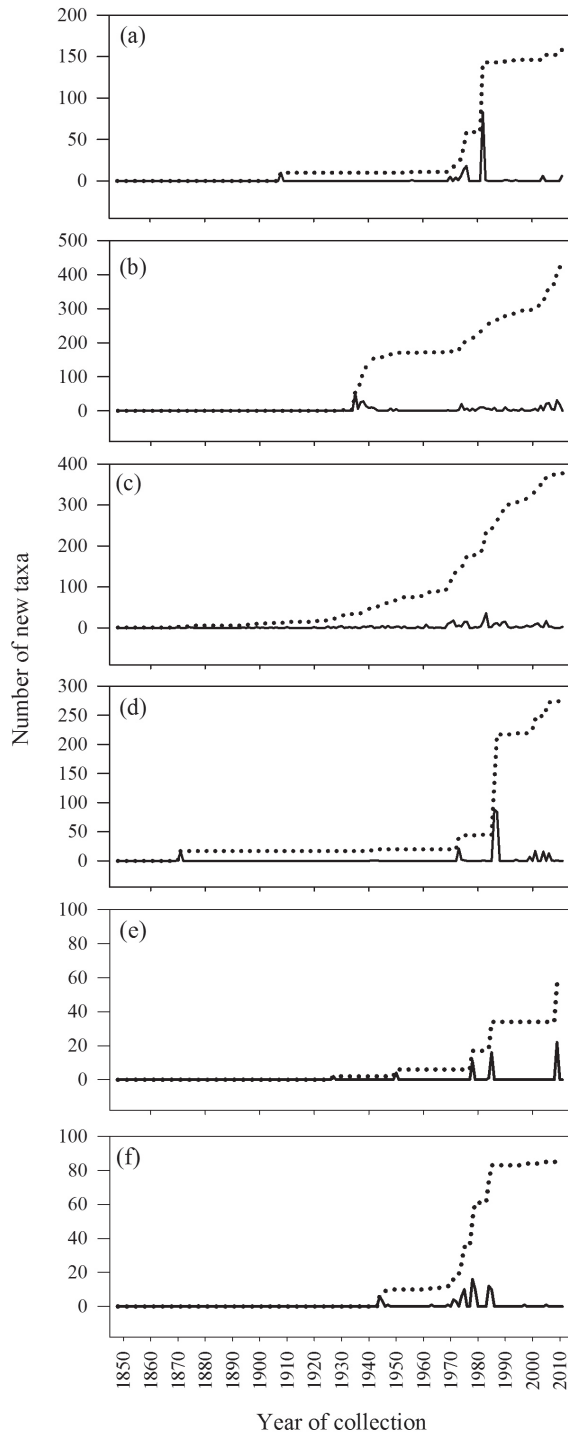
**Figure 4.** Number of taxa in the collections by decade of collection and division (green, brown, and red algae).

in new collections deposited by other marine research workers. During the 1980s and 1990s collections for the series of regional flora lists resulted in many new collections as well as new taxa. During the 2000s specific projects on elements of the flora (e.g. *Bangiales* (Nelson et al. 2001, 2003, 2005, 2006), *Ulvaceae* (Heesch et al. 2007, 2009), non-geniculate coralline algae (Harvey et al. 2005, Farr et al. 2009), macroalgae associated with soft sediments (Neill et al. 2012)) contributed to peaks in particular groups of algae. Figures 5a–f present the cumulative number of species recorded from selected regions (Kermadec Islands, NI North (Northern North Island), Wairarapa-Cook, Chatham Islands, Bounty Islands, Campbell Island), revealing the patterns of collecting history in greater detail.

Analysis revealed that many entities in the flora are known from very few records (Table 3). Of the 996 taxa in this analysis there are only 210 taxa in the collection for which there are more than 30 records (20 greens, 51 browns, 139 reds). Over the whole collection 17% of the taxon records are known from a single record and 44% from five or fewer records.

The data available for each of the 20 regions within New Zealand are summarised in Table 4. This lists the number of taxa, the composition of the flora in each region,

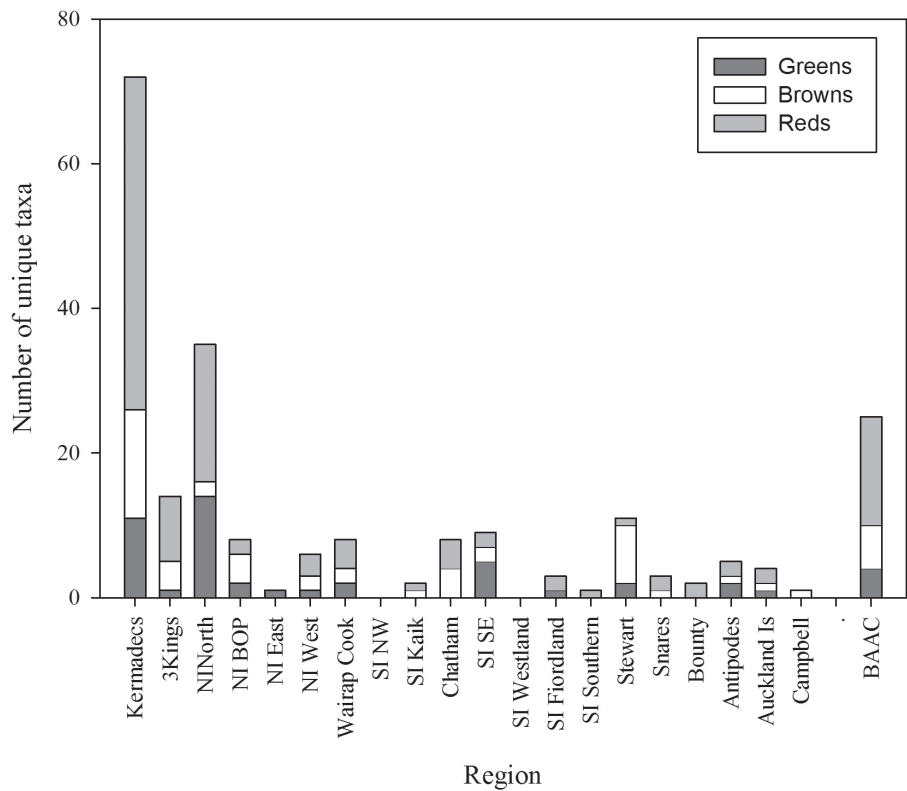




**Figure 5.** Annual (solid line) and cumulative (dashed line) new taxa from selected regions: **a** Kermadec Is **b** NI North **c** Wairarapa-Cook **d** Chatham Is **e** Bounty Is **f** Campbell I.

**Table 3.** Number of taxa and records by class of algae.

	Greens	Browns	Reds	Total
Number of taxa:	118	199	679	996
Number of taxa known from a single record:	26 (22%)	42 (21%)	97 (14%)	165 (17%)
Number of taxa known from 5 or fewer records	65 (55%)	84 (42%)	294 (43%)	443 (44%)
Number of taxa known from > 30 specimens	20 (17%)	51 (25%)	139 (20%)	210 (14%)
Number of taxa known from >100 records	3 (3%)	8 (4%)	15 (2%)	26 (3%)



**Figure 6.** Number of taxa unique to each region by division (BAAC = Bounty, Antipodes, Auckland, Campbell Islands).

the number of records that the data are based on, the composition of the flora by region in terms of the number of classes, orders and families represented, the number of years in which collections were made (of a potential 164 years between 1848–2011), and the seasons in which collecting events occurred. In some regions the collections have been made over an extended period, and span all seasons, whereas it is clear that some other regions are infrequently visited and no collections made in some seasons. Overall the impact of season is relatively modest with the number of collections from the winter months being only two thirds of the total from the summer months. Figure 6 summarises the number of taxa unique to each region by class.

**Table 4.** Distribution of macroalgal collections by region.

	Kermadec	3 Kings	NI North	NI BOP	NI East	NI West	Wairarapa-Cook	SI NW	SI Kaikoura	Chatham	SI SE	SI Westland	SI Fiordland	SI Southern	Stewart	Snares	Bounty	Antipodes	Auckland	Campbell
Region (Fig. 1)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of taxa	159	178	421	314	127	205	381	173	233	275	276	195	271	145	282	111	56	140	101	86
Number of greens	22	19	61	37	14	21	42	22	24	27	43	19	32	16	31	8	5	17	12	9
Number of browns	35	36	86	77	34	41	93	32	57	61	60	41	53	31	81	20	10	23	19	16
Number of reds	102	123	274	200	79	143	246	119	152	187	173	135	186	98	170	83	41	100	70	61
Regional taxa as % of total flora	16.1	18.0	42.5	31.7	12.8	20.7	38.5	17.5	23.5	27.8	27.9	19.7	27.4	14.6	28.5	11.2	5.7	14.1	10.2	8.7
Number of unique taxa	72	14	35	8	1	6	8	0	2	8	9	0	3	1	11	3	2	5	4	1
Number of records	532	714	2998	1372	339	645	3222	565	659	1527	1070	918	1588	407	1289	310	147	552	349	219
Number of taxa known from: a single record (%)	63 (40)	61 (34)	104 (25)	93 (30)	77 (31)	73 (38)	73 (19)	49 (28)	97 (42)	50 (18)	86 (31)	33 (17)	69 (25)	52 (36)	61 (22)	46 (41)	22 (39)	52 (37)	36 (36)	38 (44)
Number of taxa known from 5 or fewer records (%)	131 (82)	134 (75)	254 (60)	237 (75)	116 (91)	177 (86)	208 (55)	144 (83)	207 (89)	170 (62)	222 (80)	143 (73)	180 (66)	130 (90)	195 (69)	97 (87)	52 (93)	105 (75)	83 (82)	76 (88)
Number of taxa known from > 30 specimens	0	1	10	4	0	0	14	0	0	0	0	1	3	0	0	0	0	0	0	0
Collecting events	92	74	707	420	84	226	957	93	261	196	253	110	272	84	272	59	28	79	84	46
Number of years collected	18	13	60	54	23	48	87	22	47	23	56	26	30	28	47	14	6	9	19	16
Springs collected	7	5	37	30	11	19	53	5	24	4	28	15	10	8	26	6	2	4	4	7
Summers collected	1	9	40	29	13	22	54	14	19	16	31	17	21	15	31	13	0	2	15	8
Autumns collected	9	3	33	32	5	25	55	8	18	7	20	7	10	8	19	1	4	4	3	5
Winters collected	5	0	26	24	5	22	47	3	21	5	17	6	6	7	14	1	0	0	2	1
Number of classes	5	6	8	5	4	5	6	5	7	6	6	4	5	5	7	4	5	6	6	5
Number of orders	25	30	36	30	24	29	31	28	33	32	33	29	30	25	32	26	19	29	27	25
Number of families	50	55	83	73	44	57	75	53	64	72	67	59	62	49	69	44	29	46	48	42

## Discussion

These analyses have provided an opportunity to review the state of knowledge of the New Zealand macroalgal flora and to investigate how well the current collections at Te Papa represent the macroalgal flora of New Zealand. The cumulative total of taxa in WELT shows that the flora is not reaching asymptote, suggesting that more discoveries are likely with further investigations of the flora. It is clear that some regions of New Zealand have received greater attention (number of records, collecting events) (Table 4), and as a consequence the flora is better understood in these areas (in particular Wairarapa-Cook, NI North). The number of collections available by region is in large part a consequence of the presence of active research workers, research institutions or programmes, as well as the accessibility of the coastline. The northern and southern island groups - Kermadec and Three Kings Islands, and Snares, Bounty, Antipodes, Auckland, Campbell Islands - are all difficult to reach, subject to inclement weather and are relatively infrequently sampled, i.e. collections made in fewer than 20 years in the 164 years since the first New Zealand collections were lodged in WELT (Table 4).

The knowledge of the flora in different regions has been built up in quite different ways. Macroalgae were first collected from the Kermadec Islands by New Zealand based scientists in 1908, although material had been collected in 1854 and 1874 by expeditions and lodged in European herbaria (Nelson and Adams 1984). It was not until collections were made by a trained phycologist in 1982 that the flora was more thoroughly understood (Fig. 5a). There have been no subsequent targeted collections from the Kermadec Islands with only occasional opportunistic collections deposited in WELT (Fig. 5a). This collection history, coupled with the fact that 82% of the flora is currently known from 5 or fewer records (Table 4), strongly suggests that the macroalgae of this region are under-represented in the collection. The flora of the Kermadec Islands differs markedly from the rest of New Zealand, with strong affinities to the warm-water regions of the Pacific and Indian Oceans (Nelson and Dalen in press). Of the 152 taxa recorded in our data from the Kermadec Islands, almost half of these are represented in the New Zealand region only in these northern islands (Figure 6).

The collection history of the NI North (Fig. 5b) and Wairarapa-Cook (Fig. 5c) are interesting to compare. These are the most diverse and intensely sampled regions. The Bay of Islands is a key collecting area in the NI North and has seen bursts of collecting activities by Tilden and Lindauer in particular. The collecting history of the Wairarapa-Cook region reflects the presence of phycologists and collectors, with a steady growth in the knowledge and representation of the flora over an extended period. The first collections of macroalgae from the Chatham Islands that formed the basis of a published account were made in 1863-64 and then in 1871, with further collections made by a German research expedition in 1897. However it was not until the mid-1980s that thorough and detailed collections were made of the flora (Fig. 5d). In the intervening 80-90 years there were only scattered and infrequent collections made on the islands (summarised in Nelson et al. 1991). Based on the number of collections the Chatham Islands flora is now relatively well represented at Te Papa, although 18% of

the flora is still known from only a single record. The collecting history of the southern Bounty Islands (Fig. 5e) (which are only 1.3 km<sup>2</sup> in area and 700 km distant from the nearest landmass) and Campbell Island (Fig. 5f) (113 km<sup>2</sup> in area, also 700 km distant from the nearest landmass) reflect problems of access. This is also shown in the seasonal breakdown of collecting years (Table 4).

In terms of regional diversity the northern North Island has the most taxa recorded, contains the highest proportion of the total flora, and has the greatest phylogenetic diversity (as represented by the highest numbers of classes, orders and families present). Although there are almost 3000 specimen records from the region, 25% of the taxa from the area are known from a single record, and 60% from 5 or fewer records. The offshore Three Kings Islands and the southern islands (Snarres, Bounty, Antipodes, Auckland and Campbell Islands) are represented by the smallest number of collections resulting from few collecting events. The mainland areas that have received the least collecting effort (fewest collection events) are North Island East, South Island North-west, and the South Island Southern.

The proportion of the flora that is represented by a very small number of records is salutary, with ca. 44% of the flora known from 5 or fewer records (Table 3). When the data are examined by region (Table 4) the differences in the coverage of collections can be assessed. For phenological studies and comparative investigations it is important to have a number of specimens to evaluate variation and attributes that may be influenced by maturity, seasonality, and/or reproductive status. There are 210 taxa in the collections, identified to species, for which there are more than 30 records: in our view, this number of records provides sufficient individuals for such comparative studies. In terms of the application of NHC collections for understanding the responses of the flora to human-induced environmental changes, Johnson et al. (2011) consider that collections with “large numbers of common taxa are the most useful as time series for determining species level responses” although they note that such collections “typically have been perceived as of low priority for acquisition or curatorial effort”.

Our analyses have enabled us to test the quality of the data associated with the specimens. The data grooming exercises prior to these analyses have minimised location errors (e.g. latitude and longitude, place names) but opportunity for minor transcription errors still remains. The main issues affecting data quality are the level and standard of identification, which are directly influenced by the current state of the systematic knowledge of the flora. There have been few monographic studies of macroalgal taxa in New Zealand, but recent research across a range of orders has revealed new taxa, and the need for significant taxonomic revisions. These studies have also concluded that understanding the diversity in the flora is still in a discovery phase (e.g. Broom et al. 2004, Heesch et al. 2009, D’Archino et al. 2011). Although Te Papa’s collection data are the best available at present within New Zealand, our analyses have revealed that the macroalgal flora is currently poorly represented in terms of numbers of records for many taxa, as well as in the geographic and seasonal spread of specimens.

Although it is questionable whether the Te Papa collections constitute a comprehensive or sufficient baseline with which to evaluate change in the environment or in

the flora composition, these herbarium specimens are a very significant source of data both for current biodiversity assessment and planning and also for future applications in biodiversity analysis, conservation and ecology. There are areas within the collection that have been developed from specific research programmes (e.g. collections for the regional floral list series, Bangiales, coralline algae, macroalgae from soft sediment environments, Ulvaceae) where the specimens have been collected in a systematic and targeted way, and in some cases can be associated with other key environmental data. These collections provide a reference baseline if there are opportunities for the regions or habitats to be resampled in the future. The analyses performed here are repeatable if the collection continues to receive the same attention, i.e., expert identification and application of current names, precision of data entry with respect to consistency of place names, and coordinate data

This analysis has identified gaps in the macroalgal collections, both taxonomically and geographically, and also data that can inform future collection development. A number of recent papers reviewing the role of NHCs have stressed the function of museums and herbaria as “part of the essential infrastructure of science” (Johnson et al. 2011) and their value to conservation biologists and ecologists for studying species’ distributions and abundance (Newbold 2010). Institutions faced with the expense of care and maintenance of NHCs need to have strategically focused research and collection development policies which identify the opportunities for their collections to serve not only research on biosystematics, distribution and evolution of biotas, but also to have wider applications for environmental and conservation science. Whilst opportunistic collections can be valuable in providing material to complement existing material, and have often resulted from collectors seeking to maximise field opportunities and access to infrequently visited areas, there is a need to move to a more systematic approach to the sampling of diversity to provide higher quality data. Ward (2012) recommends that NHCs “must become drivers of biodiversity science” and suggested four key priorities for NHCs – mass databasing, analysis of holdings, identification of ecological datasets, and repositories of ecological projects. We have addressed the first two of these priority areas and have also identified datasets within the Te Papa macroalgal herbarium that have potential to serve as baselines for future research. At present the herbarium is not equipped to serve as a repository for ecological projects. This aspect of future-focused work is challenging and considerable care will be needed to develop data protocols to record information about sampling effort, population size and other ecological attributes.

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## References

- Adams NM (1994) Seaweeds of New Zealand. Canterbury University Press, Christchurch, New Zealand, 1–360.
- Adams NM (1972) The marine algae of the Wellington area. Records of the Dominion Museum 8: 43–98.
- Adams NM, Conway E, Norris RE (1974) The marine algae of Stewart Island. Records of the Dominion Museum 8: 185–245.
- Adams NM, Nelson WA (1985) The marine algae of the Three Kings Islands. National Museum of New Zealand, Miscellaneous Series 13: 1–29.
- Bagnall AG (1970) Sven Berggren in New Zealand: part 1. Turnbull Library Record 3(1): 29–42.
- Boakes EH, McGowan PJK, Fuller RA, Chang-qing D, Clark NE (2010) Distorted views of biodiversity: spatial and temporal bias in species occurrence data. PLoS Biol 8(6): e1000385. doi: 10.1371/journal.pbio.1000385
- Booth J, Nelson W, Notman P (2006) NABIS Marine Plant Distributions. Final Research Report for Ministry of Fisheries Research Project ZBD2004-05 Objective 1. NIWA, April 2006.
- Broady PA, Flint EA, Nelson WA, Cassie Cooper V, de Winton MD, Novis PM (2012) Phyla Chlorophyta and Charophyta: green algae. In: Gordon DP (Ed) New Zealand Inventory of Biodiversity. Volume Three. Kingdoms Bacteria, Protozoa, Chromista, Plantae, Fungi. Canterbury University Press, 347–381.
- Broom JES, Farr TJ, Nelson WA (2004) Phylogeny of the *Bangia* flora of New Zealand suggests a southern origin for *Porphyra* and *Bangia* (Bangiales, Rhodophyta). Molecular Phylogenetics and Evolution 31: 1197–1207. doi: 10.1016/j.ympev.2003.10.015
- Broom JES, Hart DR, Farr TJ, Nelson WA, Neill KF, Harvey AH, Woelkerling WJ (2008) Utility of *psbA* and nSSU for phylogenetic reconstruction in the Corallinales based on New Zealand taxa. Molecular Phylogenetics & Evolution 46: 958–973. doi: 10.1016/j.ympev.2007.12.016
- Cassie V (1971) Contributions of Victor Lindauer (1888–1964) to New Zealand. Journal of the Royal Society of New Zealand 1: 89–98. doi: 10.1080/03036758.1971.10419343
- Cassie Cooper V (1995) Victor Wilhelm Lindauer 1888–1964: His life and works. Tuhinga: Records of the Museum of New Zealand Te Papa Tongarewa 1: 1–14.
- Chapman VJ (1956) The marine algae of New Zealand. Part I: Myxophyceae and Chlorophyceae. Journal of the Linnean Society of London 55: 333–501, fig. 1–153, pl. 24–50.
- Chapman VJ (1969) The marine algae of New Zealand. Part III: Rhodophyceae. Issue 1: Bangiophycidae and Florideophycidae (Nemalionales, Bonnemaisoniales, Gelidiales). J. Cramer, Lehre, 1–113.
- Chapman VJ (1979) Issue 4: Gigartinales. In: The marine algae of New Zealand. Part III. Rhodophyceae. Cramer, Lehre, 279–506.
- Chapman VJ, Dromgoole FI (1970) The marine algae of New Zealand. Part III. Rhodophyceae. Issue 2: Florideophycidae: Rhodymeniales. Lehre: Cramer, 115–154.
- Chapman VJ, Parkinson PG (1974) Issue 3: Cryptonemiales. In: The marine algae of New Zealand. Part III. Rhodophyceae, 155–278.

- Dalen J, Nelson WA (2013a) <http://www.tepapa.govt.nz/SiteCollectionDocuments/Te.Papa.list.of.marine.macroalgae.Chlorophyta.pdf>
- Dalen J, Nelson WA (2013b) <http://www.tepapa.govt.nz/SiteCollectionDocuments/Te.Papa.list.of.marine.macroalgae.Ochrophyta.pdf>
- Dalen J, Nelson WA (2013c) <http://www.tepapa.govt.nz/SiteCollectionDocuments/Te.Papa.list.of.marine.macroalgae.Rhodophyta.pdf>
- D'Archino R, Nelson WA, Zuccarello GC (2011) Diversity and complexity in New Zealand Kallymeniaceae (Rhodophyta): recognition of the genus *Ectophora* and description of *E. marginata* sp. nov. *Phycologia* 50: 241–255. doi: 10.2216/10-14.1
- Farr T, Broom J, Hart D, Neill K, Nelson W (2009) Common coralline algae of northern New Zealand: an identification guide. NIWA Information Series 70: 1–249.
- Frey JK (2009) Distinguishing range extensions from previously undocumented populations using background data from museum records. *Diversity and Distributions* 15: 183–187. doi: 10.1111/j.1472-4642.2008.00552.x
- Graham CH, Ferrier S, Huettman F, Moritz C, Peterson AT (2004) New developments in museum-based informatics and applications in biodiversity analysis. *Trends in Ecology and Evolution* 19: 497–503. doi: 10.1016/j.tree.2004.07.006
- Harper M, Cassie Cooper V, Chang FH, Nelson W, Broady P (2012) Phylum Ochrophyta: brown and golden-brown algae, diatoms, silicoflagellates, and kin. In: Gordon DP (ed) *New Zealand Inventory of Biodiversity. Volume Three. Kingdoms Bacteria, Protozoa, Chromista, Plantae, Fungi*. Canterbury University Press, 114–163.
- Harvey A, Woelkerling W, Farr T, Neill K, Nelson W (2005) Coralline algae of central New Zealand: an identification guide to common 'crustose' species. NIWA Information Series 57, 145 pp.
- Hay CH, Adams NM, Parsons MJ (1985) The marine algae of the subantarctic islands of New Zealand. National Museum of New Zealand, Miscellaneous Series 11: 1–70.
- Heesch S, Broom J, Neill K, Farr T, Dalen J, Nelson W (2007) Genetic diversity and possible origins of New Zealand populations of *Ulva*. Final Research Report for Ministry of Fisheries Research Project ZBS2004-08, 203 pp.
- Heesch S, Broom JE, Neill K, Farr T, Dalen J, Nelson WA (2009) *Ulva*, *Umbraulva* and *Gemina*: genetic survey of New Zealand Ulvaceae reveals diversity and introduced species. *European Journal of Phycology* 44: 143–154. doi: 10.1080/09670260802422477
- Hommersand MH (1963) The morphology and classification of some Ceramiaceae and Rhodomelaceae. University of California Publications in Botany 35: vii +165–366, 52 figs, 6 pls.
- Huisman JM, Millar AJK (2013) Australian seaweed collections: use and misuse. *Phycologia* 52: 2–5. doi: 10.2216/12-089.1
- Johnson KG, Brooks SJ, Fenberg FB, Glover AG, James KE, Lister AM, Michel E, Spencer M, Todd JA, Valsami-Jones E, Young JR, Stewart JR (2011) Climate change and biosphere response: unlocking the collections vault. *BioScience* 61(2): 147–153. doi: 10.1525/bio.2011.61.2.10
- Krishtalka L, Humphrey PS (2000) Can Natural History Museums Capture the Future? *BioScience* 50(7): 611–617. doi: 10.1641/0006-3568(2000)050[0611:CNHMCT]2.0.CO;2
- Laing RM (1900) Revised list of New Zealand seaweeds. Part 1. *Transactions and Proceedings of the New Zealand Institute* 29: 446–450.

- Laing RM (1902) Revised list of New Zealand seaweeds, Part II. Transactions and Proceedings of the New Zealand Institute 34: 384–408.
- Laing RM (1909) The marine algae of the subantarctic islands of New Zealand. In: Chilton C (Ed), The Subantarctic Islands of New Zealand, Volume 2. Philosophical Institute of Canterbury, Christchurch, 493–527.
- Laing RM (1926) A reference list of New Zealand marine algae. Transactions and Proceedings of the New Zealand Institute 57: 126–185.
- Laing RM (1930) A reference list of New Zealand marine algae. Supplement 1. Transactions and Proceedings of the New Zealand Institute 60: 575–583.
- Lavring T (1955) Contributions to the marine algae of New Zealand. I. Rhodophyta: Goniotrichales, Bangiales, Nemalionales and Bonnemaisoniales. Arkiv för Botanik Ser. 2(3): 407–432.
- Lindauer VW, Chapman VJ, Aitken M (1961) The marine algae of New Zealand. II: Phaeophyceae. Nova Hedwigia 111(2): 129–350, pi. 57–97.
- McCarthy MA (1998) Identifying declining and threatened species with museum data. Biological Conservation 83: 9–17. doi: 10.1016/S0006-3207(97)00048-7
- Neale D, Nelson W (1998) Marine algae of the west coast, South Island, New Zealand. Tuhinga 10: 87–118.
- Neill K, D'Archino R, Farr T, Nelson W (2012) Macroalgal diversity associated with soft sediment habitats in New Zealand. NZ Aquatic Environment and Biodiversity Report 87: 1–127.
- Nelson WA (1994) Distribution of macroalgae in New Zealand - an archipelago in space and time. Botanica Marina 37: 221–233. doi: 10.1515/botm.1994.37.3.221
- Nelson WA (2012) Phylum Rhodophyta: red algae. In: Gordon DP (Ed) New Zealand Inventory of Biodiversity. Volume Three. Kingdoms Bacteria, Protozoa, Chromista, Plantae, Fungi. Canterbury University Press, 327–346.
- Nelson WA, Adams NM (1984) Marine algae of the Kermadec Islands. National Museum of New Zealand, Miscellaneous Series 10: 1–29.
- Nelson WA, Adams NM (1987) Marine algae of the Bay of Islands area. National Museum of New Zealand, Miscellaneous Series 16: 1–47.
- Nelson WA, Adams NM, Fox JM (1992) Marine algae of the northern South Island. National Museum of New Zealand, Miscellaneous Series 26: 1–80.
- Nelson WA, Adams NM, Hay CH (1991) Marine algae of the Chatham Islands. National Museum of New Zealand, Miscellaneous Series 23: 1–58.
- Nelson WA, Broom JE, Farr TJ (2001) Four new species of *Porphyra* Bangiales, Rhodophyta) from the New Zealand region. Cryptogamie Algologie 22: 263–284. doi: 10.1016/S0181-1568(01)01060-1
- Nelson WA, Broom JE, Farr TJ (2003) *Pyrophyllon* and *Chlidophyllon* Erythropeltoidales, Rhodophyta), two new genera for obligate epiphytic species previously placed in *Porphyra*, and a discussion of the orders Erythropeltoidales and Bangiales. Phycologia 42: 308–315. doi: 10.2216/i0031-8884-42-3-308.1
- Nelson WA, Dalen JL (in press) Marine macroalgae of the Kermadec Islands. Bulletin of the Auckland Museum.

- Nelson WA, Farr TJ, Broom JE (2005) *Dione* and *Minerva*, two new genera from New Zealand circumscribed for basal taxa in the Bangiales (Rhodophyta). *Phycologia* 44: 139–145. doi: 10.2216/0031-8884(2005)44[139:DAMTNG]2.0.CO;2
- Nelson WA, Farr TJ, Broom JE (2006) Phylogenetic relationships and generic concepts in the red order Bangiales: challenges ahead. *Phycologia* 45: 249–259. doi: 10.2216/05-26.1
- Nelson WA, Phillips L (1996) The Lindauer legacy - current names for the Algae Nova-Zelandicae Exsiccatae. *New Zealand Journal of Botany* 34: 553–582. doi: 10.1080/0028825X.1996.10410136
- Nelson WA, Phillips LE, Adams NM (1998) Algal type material and historical phycological collections in the herbarium of the Museum of New Zealand Te Papa Tongarewa (WELT). *Tuhinga* 10: 63–85.
- Nelson WA, Villouta E, Neill K, Williams GC, Adams NM, Slivsgaard R (2002) Marine macroalgae of Fiordland. *Tuhinga* 13: 117–152.
- Newbold T (2010) Applications and limitations of museum data conservation and ecology, with particular attention to species distribution models. *Progress in Physical Geography* 34: 3–22. doi: 10.1177/0309133309355630
- Norris RE (1957) Morphological studies on the Kallymeniaceae. *University of California Publications in Botany* 28(5): 251–333, Plates 28–40.
- Ponder WF, Carter GA, Flemons P, Chapman RR (2001) Evaluation of museum collection data for use in biodiversity assessment. *Conservation Biology* 15: 648–657. doi: 10.1046/j.1523-1739.2001.015003648.x
- Pyke GH, Ehrlich PR (2010) Biological collections and ecological/environmental research: a review, some observations and a look to the future. *Biological Reviews* 85: 247–266. doi: 10.1111/j.1469-185X.2009.00098.x
- Shaffer HB, Fisher RN, Davidson C (1998) The role of natural history collections in documenting species decline. *Trends in Ecology and Evolution* 13: 27–30. doi: 10.1016/S0169-5347(97)01177-4
- Shears NT, Smith F, Babcock RC, Duffy CAJ, Villouta E (2008) Evaluation of biogeographic classification schemes for conservation planning: application to New Zealand's coastal marine environment. *Conservation Biology* 22: 467–481. doi: 10.1111/j.1523-1739.2008.00882.x
- South GR, Adams NM (1976) Marine algae of the Kaikoura coast. *National Museum of New Zealand, Miscellaneous Series* 1: 1–67.
- Sparling SR (1957) The structure and reproduction of some members of the Rhodymeniaceae. *University of California Publications in Botany* 29(3): (i-iv +) 319–396, 15 figs, 1 table, plates 48–59.
- Thiers B (2012 – continuously updated) Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. <http://sweetgum.nybg.org/ih/>
- Tomizuka T, Iwatsuki K, Miyata M (2012) Estimation of environmental changes on shallow seawater by the use of voucher specimens of seaweeds preserved in Universities and Museums. *Japanese Journal of Botany* 87: 31–40.

- Wagner FS (1954) Contributions to the morphology of the Delesseriaceae. University of California Publications in Botany 27: [i–iv], 279–346, 290 figs.
- Ward DF (2012) More than just records: analysing natural history collections for biodiversity planning. PLoS ONE 7(11): e50346. doi: 10.1371/journal.pone.0050346





# A new cryptically dioecious species of bush tomato (*Solanum*) from the Northern Territory, Australia

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## Abstract

A new species of dioecious *Solanum* from the Australian “Dioicum Complex” of *Solanum* subgenus *Leptostemonum* is described. *Solanum cowiei* Martine **sp. nov.**, is allied with other members of this problematic lineage, but differs in its slender leaves, limited armature and diminutive habit. The species was first segregated by botanists at the Northern Territory Herbarium as *Solanum* sp. Litchfield (*I.D. Cowie 1428*); and specimens representing this species have also been referred to by Symon as *Solanum* sp. Fitzmaurice River. Collections suggest that this is an endemic of the sub-arid tropical zone of the Northern Territory. SEM images support initial assumptions that the new species is cryptically dioecious via production of inaperturate pollen grains in morphologically hermaphrodite flowers.

## Keywords

Bush tomato, Kimberley, new species, Limmen National Park, Litchfield National Park, Northern Territory, *Solanum*, *Solanum cowiei*, *Solanum dioicum*, *Solanum* sp. Litchfield, cryptic dioecy, inaperturate pollen

## Introduction

More than three decades ago the late David Symon published the first comprehensive monograph of *Solanum* in Australia (1980), a collection of species descriptions for 125 native and exotic solanums including fourteen species newly described by the author. Symon (1980) included a set of 18 native Australian “spiny solanums” of *Solanum* subgenus *Leptostemonum* within his interpretation of *Solanum* section *Melongena*, thus allaying them with the cultivated eggplant (*Solanum melongena*). All nine morphologi-

cally androdioecious spiny solanums known in Australia at that time were included in this group. These nine species were later confirmed by Anderson and Symon (1989) to be cryptically dioecious, with morphologically hermaphrodite flowers producing pollen without pores (inaperturate) – thus rendering the flowers (and the plants that bear them) functionally female. The remaining Australian native species included in *Solanum* section *Melongena* sensu Symon are andromonoecious, and were assumed to represent the ancestral condition from which cryptic dioecy arose in the group (Symon 1980, Anderson and Symon 1989) – first by a separation of male and hermaphrodite flowers and then a loss of pollen apertures (Martine and Anderson 2007).

Research using molecular phylogenetics approaches (Martine et al. 2006, Martine et al. 2009) found that the Australian *Solanum* section *Melongena* sensu Symon is not a monophyletic group, but appeared to support the evolutionary pathway from andromonoecy to dioecy in Australian *Solanum*. These studies also identified two clades of dioecious species, 1) the “Kakadu Clade” of The Northern Territory, consisting of *Solanum asymmetriphyllum* and *S. sejunctum*, a species described in 2006 (Brennan et al. 2006) and 2) the “Dioicum Complex,” a group of 8–9 described species and several geographic variants/forms with its center of diversity in the Kimberley region of Western Australia, a few species extending into the Northern Territory and one species ranging as far as Queensland.

The Dioicum Complex, in particular, is a taxonomically challenging group, as acknowledged by Symon (1980) and confirmed by phylogenetic studies (Martine et al. 2006, Bohs et al. 2007, Martine et al. 2009). While the clade is well supported, the relationships among the included taxa are difficult to resolve and species boundaries are sometimes blurry – especially in the field. Still, collections and observations made over the last decade by C.T. Martine (CTM) and others (e.g. Barrett 2013) have begun to not only clarify relationships of the Dioicum Complex, but should allow for the formal description of previously unnamed taxa – including the one described herein.

In 2009, CTM followed up on collections by local botanists (including K. Brennan, I. Cowie, D. Lewis, and J. Westaway) of a taxon that had been segregated in the Northern Territory Herbarium as *Solanum* sp. Litchfield (*I.D. Cowie 1428*). New field collections from Litchfield National Park by CTM and colleagues were then used for molecular work (Martine et al. 2011) inferring that *Solanum* sp. Litchfield was closely allied with *S. dioicum* and a member of the “Dioicum Complex” sensu Martine et al. (2006).

Unfortunately, few collections had been made of this taxon that included reproductive elements and field surveys made in April–May 2009 and May 2013 located no individuals in flower or fruit. However, multiple new reproductive collections (and some older collections now recognized as this taxon) were deposited/filed at DNA between 2009 and the present day, thus allowing for a species description to now be completed.

Among the specimens now annotated as *Solanum* sp. Litchfield is a sheet that had been in an *indet.* folder until recently. This specimen, *Barritt 1396*, of a staminate plant in flower, was identified by the collector as *Solanum dioicum*. During a visit to the Northern Territory Herbarium in 2004, Symon encountered the specimen, annotated it as *Solanum* sp. Fitzmaurice River, and recorded a page of notes on the morphological characteristics setting this taxon apart from others. Those notes, left in the

specimen folder, are here incorporated and used, in part, to describe *Solanum cowiei* – a posthumous contribution described further in Martine (2013).

## Taxonomic treatment

### *Solanum cowiei* Martine, sp. nov.

urn:lsid:ipni.org:names:77134228-1

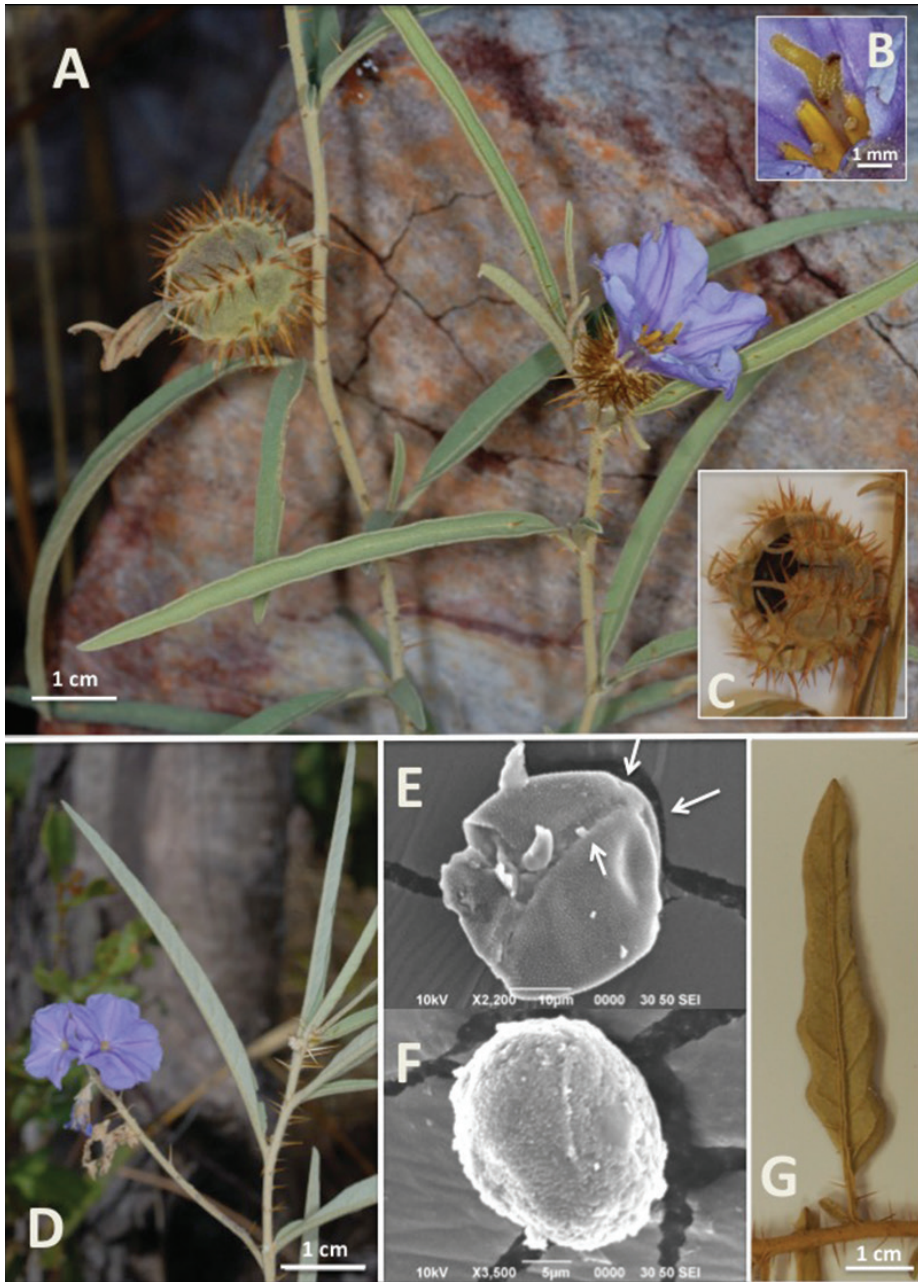
[http://species-id.net/wiki/Solanum\\_cowiei](http://species-id.net/wiki/Solanum_cowiei)

Figs 1–2

**Diagnosis.** This species is distinguished from other dioecious Australian solanums by its slender leaves, fine (or absent) armature, and diminutive habit.

**TYPE:** AUSTRALIA. The Northern Territory: Macadam Range, 14°41'07"S, 129°44'39"E, 15 June 2007 (staminate and pistillate flowers; fruit), *Kym G. Brennan* 7274 (holotype: DNA! [D0182846]; isotype: PERTH)

**Description.** Clonal, erect subshrub to 80 cm. Single woody stems 4–5 mm diameter from slender, scarcely-rooted underground stolons, splitting at ca. 40 cm into 2–6 branches. Overall plant aspect yellow-green to gray-green (becoming slightly red-tinged), with older stems eventually woody and gray. Stems with short, dense indumentum of stellate trichomes. Prickles straight, even throughout or slightly widened at base, fine, 5–12 mm long, scattered or absent on stems, rarely dense, tending to be absent on woody growth, except near base. Leaves 4–9 cm × 5–10 (–22) mm (largest on newer resprout growth), alternate, linear – lanceolate; margins entire to wavy or rarely lobed; the base tapering to a short petiole 1–1.5 mm long, apex acute; dark green above, slightly lighter beneath, both sides slightly scabrous with short, dense trichomes; trichomes mostly short stalked, porrect-stellate with short central ray. Flowers borne on new growth. *Male* inflorescence a cyme to at least 6 cm long with 9–12 flowers that are shed successively, only 1–2 flowers open at a time; pedicel 5–7 mm, unarmed; calyx 7 mm long with or without a few prickles towards the base, the lobes ending with a slender filiform acumens ca. 3 mm long; petals 5, fused; corolla 1 cm long, purple, broadly stellate to rotate, acumens 0.5 mm; stamens 5, anthers 2–5 mm long, oblong-lanceolate to somewhat tapered, poricidal, filaments 2 mm; in a loose anther cone; ovary, style, and stigma vestigial and not exerted beyond the stamens. Morphologically *hermaphrodite* flowers solitary, functionally *female* with anthers producing inaperturate pollen (Fig. 1F). Female flower on short pedicel; calyx ca. 5 mm, densely armed with long, straight prickles and stellate trichomes; lobes 6 mm, unequal and linear, prickly; corolla ca. 2 cm diameter, 2 cm long, stellate-funnelform, purple; acumens ca. 2 mm; ovary glabrous, 1 mm diameter at anthesis; style erect, 10 mm (including stigmatic surfaces); bifid stigmas 1.5 mm long; stamens of same proportions as in staminate flowers. Peduncle 1.5 cm long, 1.5 mm diameter, sparsely armed with small prickles to 2 mm long. Fruit a green berry 1.2–1.5 cm diameter, globular, drying to black-green and apparently detaching and falling from calyx. Fruiting calyx 2 cm wide, 1.5 cm long, densely armed



**Figure 1.** **A** Functionally female plant with morphologically hermaphrodite flower and developing fruit (from type collection, Brennan 7274) **B** Close-up of functionally female flower showing bifid stigma **C** Mature fruit with enlarged fruiting calyx (pressed specimen) **D** Staminate plant in flower (also from type collection) **E** SEM of aperture pollen grain of staminate flower (from herbarium specimen and partially degraded), arrows showing three germination pores **F** Inaperturate pollen grain of functionally female flower **G** Leaf showing lobing pattern and armed midvein (both infrequent). Photos A–C by Kym Brennan. SEM images by Renata Mammone.

along sutures, prickles widened (0.5–1 mm) at base and 5–7 mm long, tapering to long fine tip; calyx short stellate-pubescent, more so on sutures and around bases of prickles; calyx lobes extending to slender filiform acumen 5–7 mm long, covered in fine stellate trichomes at tip of each lobe; expanding and surrounding fruit except for ca. 1.5 cm opening at mouth. Calyx retained on stem following fruit drop, at times remaining on plant into next season. Seeds 1.5–2 mm, brown, conspicuously and minutely reticulate.

**Distribution and ecology.** *Solanum cowiei* is presently known from a handful of localities in the sub-arid tropical zone of the Northern Territory (a region known colloquially as the “Top End”), most of these habitats are classified under the Tropical eucalypt woodlands/grasslands Major Vegetation Group (National Land and Water Resources 2002). The species is associated with low sandstone outcrops and open eucalypt woodlands, where it typically grows among small boulders or in sandy grassy areas between or around rock formations. The areas where *S. cowiei* has been collected are fire-prone and burn at semi-regular intervals (Fig. 2A, B), allowing for this taxon to compete effectively with species of lesser fire tolerance. While the specific pollination biology is unknown, the flowers are clearly buzz pollinated and are likely visited by bees in the genera *Xylocopa* and *Amegilla*, among others (Anderson and Symon 1988). Seed dispersal seems, by initial impressions, to be mechanical. Fruits appear to detach upon maturation, leaving the calyces behind on the plant.

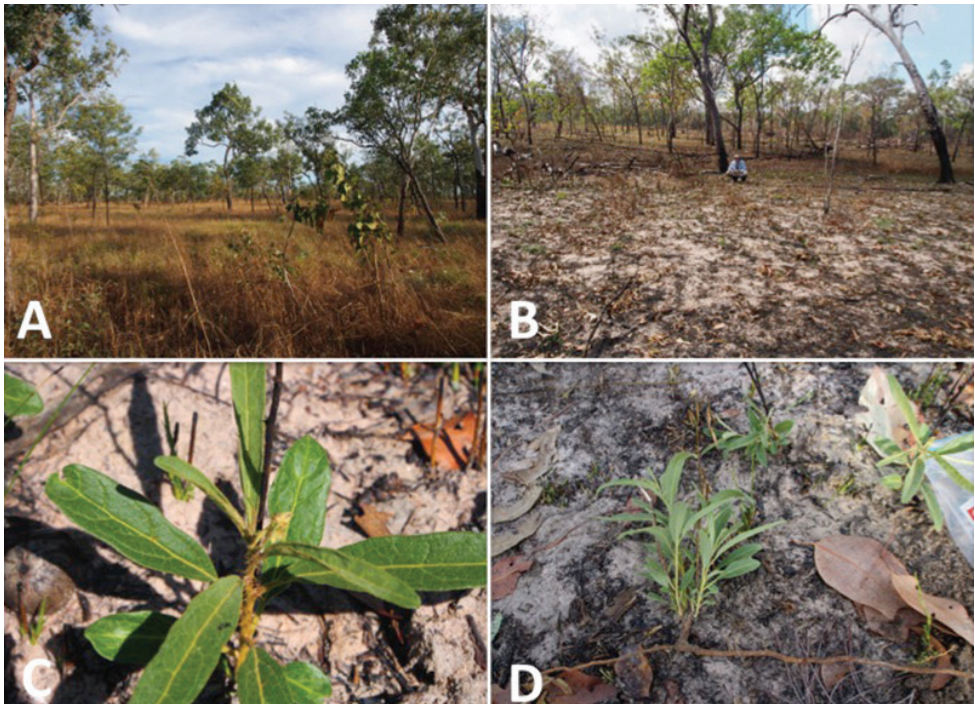
**Phenology.** Most flowering specimens have been collected from October–November and March–May, with fruiting specimens collected in Jan–Feb and May. Blooming appears to occur on new shoots soon after burns, as evidenced by dozens of male plants found to be in bud within weeks of managed burns set in the Lost City area of Litchfield National Park in late May, 2013.

**Etymology.** *Solanum cowiei* is named for Dr. Ian Cowie, Chief Botanist at the Northern Territory Herbarium (DNA) and one of the first to recognize the distinct nature of the taxon.

**Preliminary conservation status.** Based on IUCN Red List Categories (IUCN 2011), *S. cowiei* is considered Data Deficient (DD). The species is relatively widespread, occurring over a geographic range of over 800 km, but it has been collected in fewer than 10 localities. The small number of collections, coupled with the fact that populations outside of Litchfield National Park were only confirmed within the last several years, suggest that the species is common in some localities but uncommon on the regional and global scales. The clonal nature of the species is worth considering, as “populations” of *S. cowiei* often appear to be large multi-stemmed genets connected by an underground network of stolons. Because the species is dioecious, individual genets cannot self-fertilize, leading to the potential for reproductively isolated clonal individuals. Further data are required before a certain conservation status can be determined. Key populations are protected in Litchfield, Limmen and Keep River National Parks and appear secure given current fire management regimes.

**Specimens examined. AUSTRALIA. Northern Territory:** Bullo River Station, 15°35'22"S, 129°29'11"E, 7 May 2008 (fl), *I.D. Cowie 12068* (DNA); Bullo River Station, 15°40'14"S, 129°37'31"E, 11 May 2008 (fl), *J.O. Westaway 2653* (DNA, NSW); Bullo





**Figure 2.** *Solanum cowiei* habitat near the Lost City in **A** unburned condition and **B** burned condition **C** Post-fire resprout growth with deep green color and widened leaves **D** Excavated ramet showing below-ground stolon leading to additional ramets of same genet.

River Station, 15°39'31"S, 129°34'57"E, 9 May 2008, *I.D. Cowie* 12095 (DNA, DREF); Bullo River Station, ca. 25 km NW of homestead, 15°16'15"S, 129°47'23"E, 22 March 2009, *D.L. Lewis* 1192 (DNA, AD); Litchfield National Park, Lost City, 13°13.137'S, 130°44.216'E, 26 May 2009 (fr), *C.T. Martine* 1753 (DNA, BUPL); Litchfield National Park, Lost City, 13°12'50"S, 130°44'43"E, 8 March 2006 (fr), *J.L. Egan & D. Lucas* 5716 (DNA); Litchfield National Park at turnoff to Florence Falls, 13°07'S, 130°48'E, 23 November 1990 (fl), *I.D. Cowie* 1428 & *C.R. Dunlop* (DNA); Litchfield National Park opposite Florence Falls Rd. turnoff, 13°07'38"S, 130°48'20"E, 20 January 2005 (fl), *J.L. Egan s.n.* (DNA, AD); 2 km south of Fitzmaurice River Narrows, 14°49'19"S, 129°58'42"E, 14 May 1994 (fl), *I.D. Cowie* 5030 & *D.E. Albrecht* (DNA, MEL); Fitzmaurice River, 14°47'28"S, 130°01'04"E, 14 May 1994 (fl), *M.J.A. Barritt* 1396 (DNA); Bradshaw Field Training Area, ca. 94 km NW of Timber Creek, 15°02'35"S, 129°52'03"E, 4 April 2007 (st), *B.M. Stuckey & I.D. Cowie* 106 (DNA); Keep River National Park, Spirit Hills area, ca. 27 km NW of Bulloo River Homestead, 15°18'38"S, 129°34'12"E, 18 April 2007 (fr), *I.D. Cowie* 11692 (DNA, AD); Macadam Range, S of Port Keats, 14°44'00"S, 129°44'00"E, 16 June 2007 (fl), *J.O. Westaway* 2368 (DNA); Limmen State Park, St. Vidgeons block, 65 km from ruins, 15°16'46"S, 134°31'03"E, 20 April 2009 (st), *D.L. Lewis* 1160 (DNA).

**Discussion.** *Solanum cowiei* has been known for some time as a local morphotype, having been described by Cowie as *Solanum* sp. Litchfield as early as 2007. In Litch-



field National Park, perhaps the most visited recreation area in the Northern Territory, three primary populations are on routes well travelled by day visitors and campers. The most collected population sits along the road to Florence Falls, with tour buses and cars passing on macadam nearly every day within 10 m of individual plants. Thanks to a series of biodiversity surveys undertaken by staff of the NT Herbarium over the last decade or so (e.g., Cowie et al. 2011, Lewis et al. 2010), the species is now known to have a broader distribution spanning from one side of the Top End from Limmen National Park near the Gulf of Carpentaria in the east to Keep River National Park and northward into the Macadam Range in the west. Across this range many characters remain constant, with leaf lobing (unlobed to slightly lobed) and density of prickles (absent to rarely dense) tending to vary the most.

Vigorous post-fire regrowth has been noted in some areas of deep sand beneath open canopies, with one apparently clonal population in a ca. 20 × 20 m area around the Lost City consisting of ca. 40 ramets (Martine, Evans and Dugan pers. obs.). Resprout growth in this grouping was vigorous and well-armed (Fig. 2C), with numerous male flower buds produced on ramets 12–15 cm tall. While other species in this burn area had also begun to resprout, most had not yet developed flower buds – leading one to believe that the flowers of *S. cowiei*, once opened, would face little local competition for pollinators. While fire is thought to influence the life histories of other species in the Dioicum Complex (Symon 1980), little data exist on its direct effects on recruitment patterns.

Previous molecular work (Martine et al. 2011) reveals that *Solanum cowiei* is a lineage within the Dioicum Complex – but its relationship to other species in the complex remains unresolved pending continued work in the group (CTM, in progress). Based on morphology, the species appears closely allied to *S. dioicum* and *S. carduiforme*, the latter species also collected during the Limmen and Keep River surveys. On sight, it differs most from *S. carduiforme* in its leaf shape, lobing, and overall growth form. The leaves of *S. carduiforme* are wider (5 cm across), “long-triangular” in shape, with well-developed lobes. Compared to all other solanums in the complex, *S. cowiei* is rather slight of habit, rarely getting taller than knee height and having poorly developed branching. Aerial shoots, while becoming weakly woody, are much like temporary structures, dying back to the underground stolons during fire or when outcompeted during gaps in the fire cycle – only to spring back to life soon after fires have burned.

In support of its disturbance-adapted nature, much of the biomass in populations of *S. cowiei* appears to be below-ground. Stolons function in vegetative reproduction (Fig. 2D), but are also likely important for short-term energy and water storage in the sandy soils inhabited by the species. Stolons unearthed in the field snapped crisply and bore the smell of potato starch. Root systems extending from these stolons are coarse and poorly developed.

The link of this species to fire may be the key determinant of the success of the species in individual sites. In unburned sites surveyed by the first author in the Lost City area of Litchfield National Park (in 2009 and 2013) (Fig. 2A), individual plants were difficult to locate and devoid of reproductive structures. In recently burned areas (Fig. 2B) plants were locally abundant, with budding ramets emerging from the sand at high densities.

The designation of *S. cowiei*, along with the recent description of *S. zoeae* and allied unnamed variants in the Kimberley region (Barrett 2013), brings the count of cryptically dioecious *Solanum* taxa in Australia to 15. The preponderance of this unusual breeding system in this Australian lineage continues to generate questions regarding the evolution of the condition (e.g., Martine and Anderson 2007) and related ecological interactions (Dugan and Martine 2013, Martine and Evans 2013).

The poor resolution of the relationships among Australia's dioecious *Solanum* species is a function of both overlapping morphological characteristics (see Symon 1980) and general difficulties in defining lower level relationships across all Old World "spiny solanums" (Bohs et al. 2007, Vorontsova et al. 2013). Further resolution of the relationships among Australian taxa will hopefully be achieved by combining greater sampling of populations (especially in the Kimberley) with Next Generation molecular techniques (C.T.Martine, studies in progress).

## Acknowledgements

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## References

- Anderson GJ, Symon DE (1988) Insect foragers on *Solanum* flowers in Australia. *Annals of the Missouri Botanical Garden* 75: 842–852. <http://www.jstor.org/stable/2399372>, doi: 10.2307/2399372
- Anderson GJ, Symon DE (1989) Functional dioecy and andromonoecy in *Solanum*. *Evolution* 43: 204–219. <http://www.jstor.org/stable/2409175>, doi: 10.2307/2409175
- Barrett RL (2013) *Solanum zoeae* (Solanaceae), a new species of bush tomato from the North Kimberley, Western Australia. *Nuytsia* 23: 5–21. <http://florabase.dpaw.wa.gov.au/science/nuytsia/655.pdf>
- Bohs L, Martine CT, Stern S, Myers NR (2007) Phylogeny of the Old World clade of the spiny solanums (*Solanum* subg. *Leptostemonum*). Abstract. Botany and Plant Biology Joint Congress, Chicago, IL July 7–11. <http://2007.botanyconference.org/engine/search/index.php?func=detail&aid=1868>
- Brennan K, Martine CT, Symon DE (2006) *Solanum sejunctum* (Solanaceae), a new functionally dioecious species from Kakadu National Park, Northern Territory, Australia. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory* 22: 1–7.

- [http://www.academia.edu/1542271/Solanum\\_sejunctum\\_Solanaceae\\_a\\_new\\_functionally\\_dioecious\\_species\\_from\\_Kakadu\\_National\\_Park\\_Northern\\_Territory\\_Australia](http://www.academia.edu/1542271/Solanum_sejunctum_Solanaceae_a_new_functionally_dioecious_species_from_Kakadu_National_Park_Northern_Territory_Australia)
- Cowie ID, Lewis DL, Stuckey BM (2011) Flora and Vegetation Survey of Limmen National Park (proposed), Northern Territory. Northern Territory Herbarium, Department of Natural Resources, Environment, The Arts and Sport, Northern Territory Government, Technical Report Number 20/2011D, Palmerston.
- Dugan G, Martine CT (2013) Sex-differential insect herbivory in dioecious Australian nightshades. Abstract. Botany 2013: New Orleans, LA July 27–31. <http://www.botanyconference.org/engine/search/index.php?func=detail&aid=586>
- IUCN (2013) IUCN Red List of Threatened Species. Version 2013.2. [www.iucnredlist.org](http://www.iucnredlist.org)
- Lewis DL, Hill J, Cowie I (2010) Bullo River Station Flora and Vegetation Survey and Reconnaissance Soil-Landscape Investigation, Northern Territory. Northern Territory Herbarium, Department of Natural Resources, Environment, The Arts and Sport, Northern Territory Government, Technical Report Number 02/2010D, Palmerston. [http://lrm.nt.gov.au/\\_\\_data/assets/pdf\\_file/0016/17431/bullo\\_river\\_survey.pdf](http://lrm.nt.gov.au/__data/assets/pdf_file/0016/17431/bullo_river_survey.pdf)
- Martine CT (2013) Even in Death, Scientists Make New Discoveries. Huffington Post 17 July 2013. [http://www.huffingtonpost.com/dr-chris-martine/even-in-death-scientists-make-new-discoveries\\_b\\_3604185.html](http://www.huffingtonpost.com/dr-chris-martine/even-in-death-scientists-make-new-discoveries_b_3604185.html)
- Martine CT, Evans EC (2013) Is inaperturate pollen produced by Australian dioecious *Solanum* a false reward for pollen foraging bees? Botany 2013: New Orleans, LA July 27–31. <http://www.botanyconference.org/engine/search/index.php?func=detail&aid=487>
- Martine CT, Vanderpool D, Anderson GJ, Les DH (2006) Phylogenetic relationship of andromonoecious and dioecious Australian species of *Solanum* subgenus *Leptostemonum* section *Melongenae*: Inferences from ITS sequence data. Systematic Botany 31: 410–420. <http://www.bioone.org/doi/pdf/10.1600/036364406777585801>, doi: 10.1600/036364406777585801
- Martine CT, Anderson GJ (2007) Dioecy, pollination and seed dispersal in Australian spiny *Solanum*. Acta Horticulturae 745: 269–285. [http://www.academia.edu/1535452/Dioecy\\_pollination\\_and\\_seed\\_dispersal\\_in\\_Australian\\_spiny\\_Solanum](http://www.academia.edu/1535452/Dioecy_pollination_and_seed_dispersal_in_Australian_spiny_Solanum)
- Martine CT, Anderson GJ, Les DH (2009) Gender-bending aubergines: Molecular phylogenetics of cryptically dioecious *Solanum* in Australia. Australian Systematic Botany 22: 107–120. <http://www.publish.csiro.au/?paper=SB07039>, doi: 10.1071/SB07039
- Martine CT, Lavoie E, Tippery NL, Vogt FD, Les DH (2011) DNA analysis identifies *Solanum* from Litchfield National Park as a lineage of *S. dioicum*. Northern Territory Naturalist 23: 29–38. [https://www.academia.edu/1535437/DNA\\_analysis\\_identifies\\_Solanum\\_from\\_Litchfield\\_National\\_Park\\_as\\_a\\_lineage\\_of\\_S.\\_dioicum](https://www.academia.edu/1535437/DNA_analysis_identifies_Solanum_from_Litchfield_National_Park_as_a_lineage_of_S._dioicum)
- National Land and Water Resources Audit (2002) Native Vegetation in Australia: Major Vegetation Groups. Natural Heritage Trust, Commonwealth of Australia.
- Symon DE (1980) A revision of genus *Solanum* in Australia. Journal of the Adelaide Botanic Garden 4: 1–367.
- Vorontsova MS, Stern S, Bohs L, Knapp S (2013) African spiny *Solanum* (subgenus *Leptostemonum*, Solanaceae): a thorny phylogenetic tangle. Botanical Journal of the Linnean Society. doi: 10.1111/boj.12053



# Revision of *Cyrtandra* (Gesneriaceae) in the Marquesas Islands

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## Abstract

During the preparation of the *Vascular Flora of the Marquesas Islands* three new species of *Cyrtandra* (Gesneriaceae) have come to light and are described herein: *C. uapouensis* W. L. Wagner & Lorence, *C. uahukaensis* W. L. Wagner & Lorence, and *C. kenwoodii* W. L. Wagner & A. J. Wagner. Amended descriptions of the eight previously described Marquesan species are also provided as well as a key to the species. With the description of these the new species *Cyrtandra* in the Marquesas Islands consists of 11 species, six of which have been included in recent molecular phylogenetic studies of Pacific *Cyrtandra*, and appear to have arisen from one original introduction. If the other five species are members of this Marquesas clade then *Cyrtandra* would represent the largest lineage of Marquesas vascular plants. *Psychotria* is largest genus in the Marquesas Islands with 13 species, but is thought to consist of three separate lineages.

## Keywords

*Cyrtandra*, Gesneriaceae, Marquesas Islands, French Polynesia, conservation

## Introduction

*Cyrtandra* J.R. Forster & G.Forster (Gesneriaceae) is a genus of about 650 species with a paleotropical distribution from Southeast Asia and throughout the Pacific islands (Atkins et al. in press). *Cyrtandra* represents approximately 15–20% of the species within the family Gesneriaceae, and is a major component of the Old World members

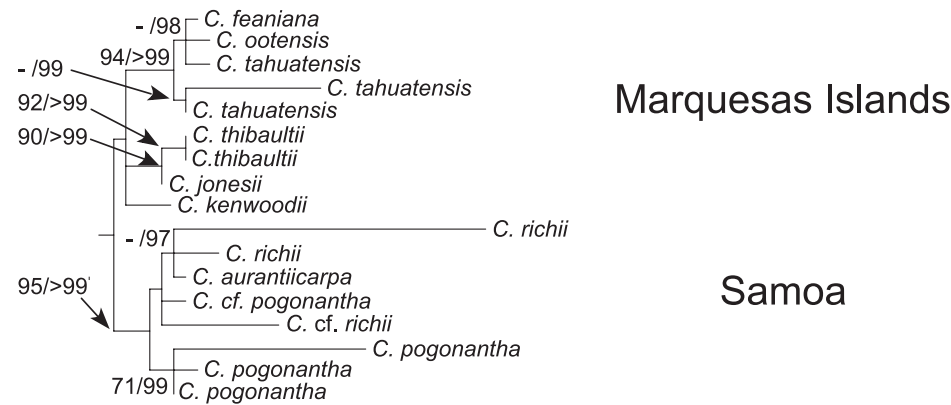
of the family, which are members of subfamily Cyrtandroideae Endlicher (Burt et al. 1995). The greatest concentration of species is in the Malesian region where 450 to 600 species occur (Atkins et al. in press). *Cyrtandra* species form a conspicuous component of the understory in forests across this vast region. Although the genus is readily dispersed, occurring on virtually all archipelagoes across the Pacific islands to the remote Hawaiian Islands, most species are local endemics, with distributions on one island or occasionally on several within a single archipelago. Recent phylogenetic studies of *Cyrtandra* (Burt 2001; Cronk et al. 2005; Clark et al. 2008, 2009) support a Southeast Asian origin of the genus, with subsequent dispersal and diversification throughout the Pacific. These studies identify a single strongly supported Pacific oceanic island clade that dates back  $\pm 22$  million years (Clark et al. 2009).

Brown (1935) described the first species of *Cyrtandra* from the Marquesas Islands in his Gesneriaceae treatment for the *Flora of Southeastern Polynesia*. In the treatment he recognized four species (*C. feaniana*, *C. ootensis*, *C. nukuhivensis*, and *C. toviaiana*), all currently recognized here, but both *C. ootensis* and *C. nukuhivensis* with modified delimitations. Brown also described a fifth species, *C. jonesii*, but placed it in a new genus, *Cyrtandroidea*, which he erroneously believed to be a member of the Campanulaceae. He mentioned the stamens and style as features that place this plant with otherwise clear features of a *Cyrtandra* in the Campanulaceae. Gillett (1973) provided an updated revision of the Marquesas species as part of a reconsideration of the south Pacific species. He recognized the same five species as Brown and made the combination for *Cyrtandroidea jonesii* to bring it properly into the genus as *Cyrtandra jonesii*. Fosberg and Sachet (1981) in their revision of Marquesan *Cyrtandra* maintained all five species. They also added three more species revealed by then recent collecting (*C. tahuatensis*, *C. revoluta*) and by a new interpretation of collections from Nuku Hiva considered by Gillett to represent *C. jonesii* (now *C. thibaultii*). Collecting in the Marquesas Islands intensified greatly with the initiation of the current *Vascular Flora of the Marquesas Islands* project under the direction of Warren L. Wagner and David H. Lorence (Lorence and Wagner 2011; Wagner and Lorence 1997) resulting in discovery of two additional species (*C. uahukaensis*, *C. kenwoodii*) and a reinterpretation of *C. nukuhivensis* to exclude the Ua Pou populations as *C. uapouensis*, bringing the total to 11 species in the Marquesas Islands (Table 1).

The Marquesas Island species form a weakly supported clade in the recent maximum likelihood molecular analyses (Clark et al. 2009) with six of the 11 species sampled. Figure 1 presents a portion of the overall tree with the Marquesas species and the sister group to them from Clark et al. (2009). The Marquesas species are divided into two major strongly supported clades with one outlier, *C. kenwoodii* from Ua Pou, that is unplaced in a polytomy with the other two clades. The two primary clades in the molecular analysis are corroborated by morphology: species with calyx divided nearly to the base forming one clade (with all three species sampled, *C. feaniana*, *C. ootensis*, and *C. tahuatensis*), and the species with plicate calyx, which are divided less than  $\frac{3}{4}$  of their length forming the second clade (with only *C. jonesii* and *C. thibaultii* sampled). Within the divided calyx clade there are three samples of *C. tahuatensis*. They do not

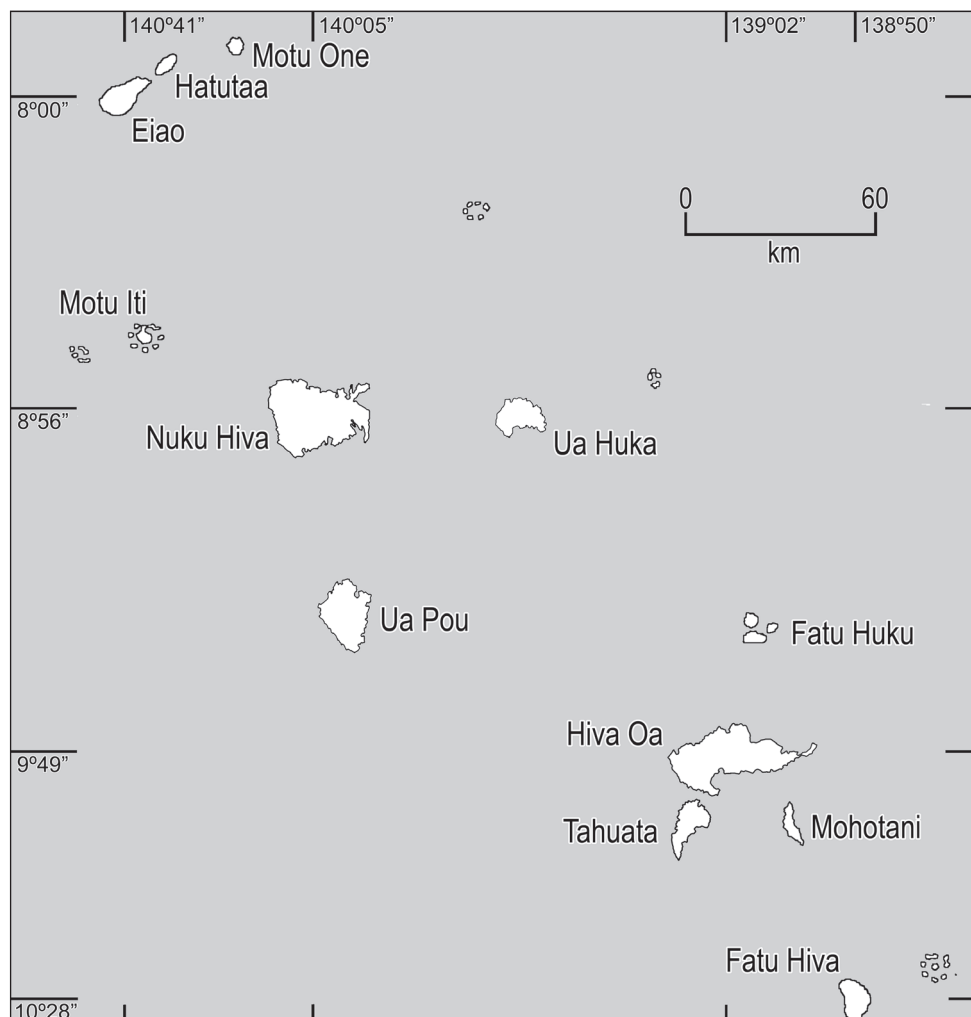
**Table 1.** Island distribution of Marquesas species of *Cyrtandra*. Islands arranged from oldest to youngest.

Species / Island	Nuku Hiva	Ua Huka	Ua Pou	Hiva Oa	Tahuata	Fatu Hiva
<i>C. jonesii</i>	X?	X				
<i>C. nukuhivensis</i>	X					
<i>C. thibaultii</i>	X		X			
<i>C. uahukaensis</i>		X				
<i>C. uapouensis</i>			X			
<i>C. kenwoodii</i>			X			
<i>C. feaniana</i>	X	X		X	X	
<i>C. ootensis</i>		X		X	X	X
<i>C. tahuatensis</i>				X	X	X
<i>C. revoluta</i>						X
<i>C. tovana</i>	X					
Totals	4	4	3	3	3	3



**Figure 1.** A portion of the Maximum likelihood phylogram from Clark et al. (2009) based on analysis of ITS, ETS and psbA-trnH regions. Numbers along branches indicate branch support (bootstrap support / Bayesian posterior probabilities).

form a clade but rather the two samples from Tahuata form a clade sister to a polytomy of the Fatu Hiva sample and the single samples of the other two species. Several of the unique Marquesas species were not included, especially the peltate-leaved *C. tovana* and the revolute-leaved *C. revoluta*, in the analyses so that a conclusion of a single introduction for all of the species cannot be substantiated until there has been further sampling and perhaps more variable sequence data added since support for some parts of the clade are not robust (Clark et al. 2009). The plicate calyx clade occurs on the older islands of the Northern Marquesas group (Nuku Hiva, Ua Huka, and Ua Pou) while the divided calyx clade occurs primarily on the younger islands of the southern group (Hiva Oa, Tahuata, and Fatu Hiva)(see Fig. 2 for Map of the the Marquesas Islands) . There are a few collections of the divided calyx clade from the older islands, all of which were collected by the Pacific Entomological Survey in 1929–1930. If the



**Figure 2.** Map of the Marquesas Islands.

locality information on the labels of these collections is correct, the species of the divided calyx clade appear to no longer occur on the older islands.

When evaluated using the IUCN Red list categories and criteria for threatened species version 3.1 (IUCN 2001, see also [http://www.iucnredlist.org/static/categories\\_criteria\\_3\\_1](http://www.iucnredlist.org/static/categories_criteria_3_1)), all 11 of the Marquesan species of *Cyrtandra* fall into the Endangered (EN) or Critically Endangered (CR) categories, which designate species facing the highest risk of extinction in the wild. Marquesan species of *Cyrtandra* meet the IUCN criteria by having known ranges less than 100 km<sup>2</sup>, an area of occupancy of less than 10 km<sup>2</sup>, and continuing decline in the quality of habitat across the Marquesas Islands (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).



All measurements given herein are taken from dried herbarium specimens, although certain features such as shapes were supplemented with information from alcohol-preserved flowers and fruits, field notes, and color slides or digital photos. Measurements are presented in the descriptions as follows: length  $\times$  width, followed by units of measurement (mm or cm). Specimens from the following herbaria were studied: AD, BISH, BKL, CBG, CHR, E, HAST, K, L, MO, MPU, NSW, NY, P, PAP, PTBG, S, UC, US, and WU). Many of the Marquesas *Cyrtandra* species are very narrowly distributed so distribution maps would not be especially useful so we provide here (Fig. 2) a map of the Marquesas Islands to show the islands and their relationship to one another.

## Taxomic part

### Artificial key to species of Marquesas *Cyrtandra*

- 1 Leaves suborbicular, peltate ..... *C. tovana*
- Leaves elliptic, elliptic-ob lanceolate or lanceolate, not peltate ..... 2
- 2 Leaves strongly revolute ..... *C. revoluta*
- Leaves flat or very inconspicuously revolute ..... 3
- 3 Plant less than 1 m tall; leaves 1–2.1 cm wide ..... *C. kenwoodii*
- Plant (1–) 2–5 m tall; leaves (1.3–)5–25 cm wide ..... 4
- 4 Calyx divided less than 3/4 the way to the base, plicate ..... 5
- Calyx divided nearly to the base, not plicate ..... 9
- 5 Leaves rugose, 26–40  $\times$  10–25 cm; bracts rhombic, 18–20 mm ..... *C. jonesii*
- Leaves not rugose, 14–29  $\times$  5–13 cm; bracts triangular, 3–11 mm ..... 6
- 6 Inflorescence 14–30 cm; peduncles 80–90 mm; calyx 25–45 mm ..... *C. thibaultii*
- Inflorescence 0–7 cm; peduncles 0–35 mm; calyx 15–25 mm ..... 7
- 7 Lower surface of leaves densely dark ferruginous pubescent ... *C. uahukaensis*
- Lower surface of leaves pale ferruginous pubescent when young, glabrate or pubescent primarily along veins on lower surface at maturity ..... 8
- 8 Leaves elliptic, occasionally elliptic-ob lanceolate, 14–24.5  $\times$  5–7.5 cm; calyx 15–23 mm ..... *C. nukuhivensis*
- Leaves elliptic-ob lanceolate to elliptic, 19–28  $\times$  8–13 cm; calyx 20–25 mm .. *C. uapouensis*
- 9 Plants glabrous, or occasionally with a few scattered hairs ..... *C. feaniana*
- Plants pubescent, at least on the youngest parts of the plant ..... 10
- 10 Plant densely ferruginous pubescent; peduncles 2–3 mm in diameter ..... *C. tabuatensis*
- Plant sparsely to moderately whitish to ferruginous pubescent; peduncles 1–2 mm in diameter ..... *C. ootensis*

## Plicate calyx group

### 1. *Cyrtandra jonesii* (F. Br.) G. W. Gillett, *Univ. Calif. Publ. Bot.* 66: 55. 1973.

[http://species-id.net/wiki/Cyrtandra\\_jonesii](http://species-id.net/wiki/Cyrtandra_jonesii)

Fig. 3

**Basionym.** *Cyrtandroidea jonesii* F. Br., Bernice P. Bishop Mus. Bull. 130: 324. 1935.

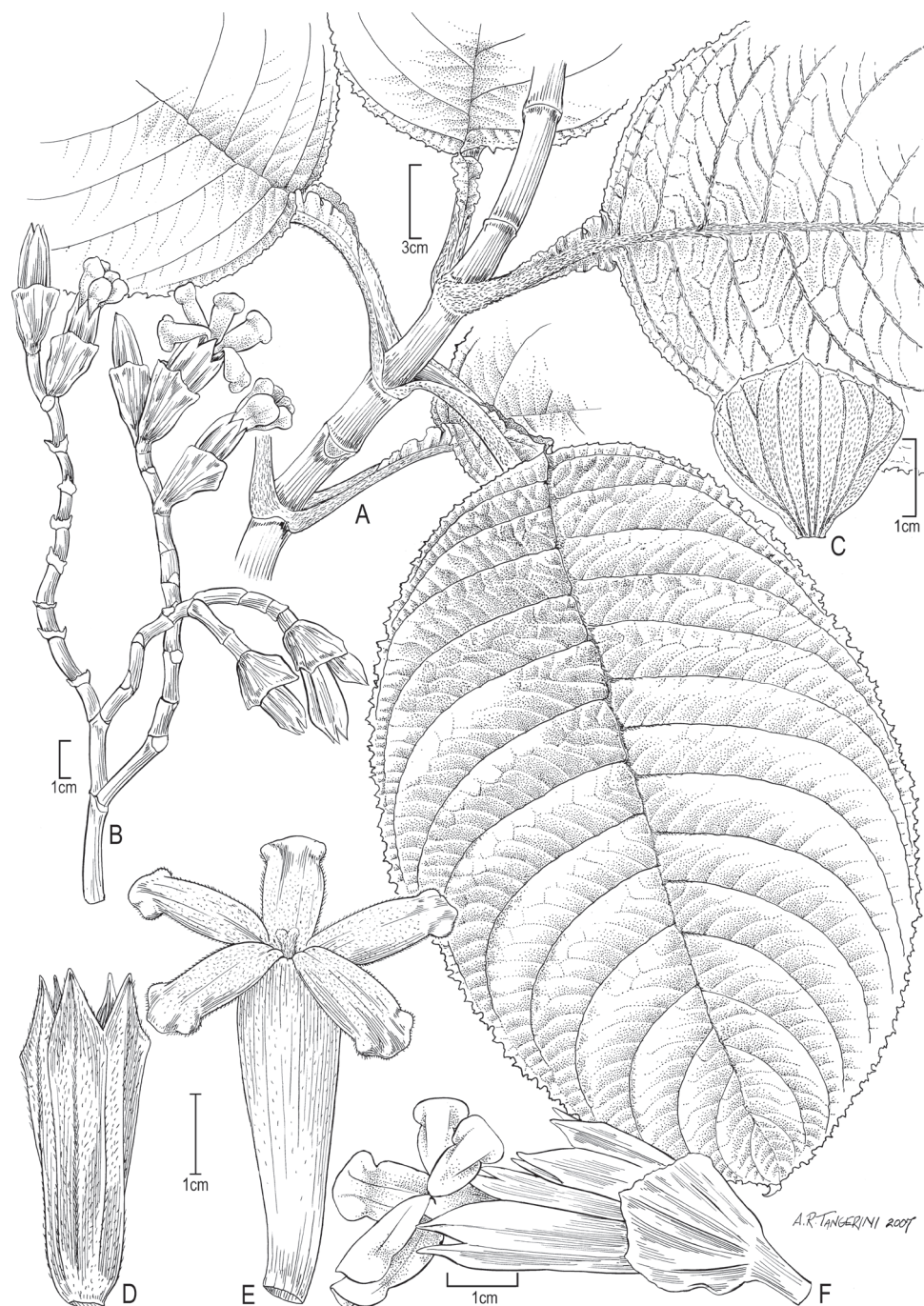
**Type.** Marquesas Islands: Ua Huka: Hanay [Hane] Bay, 500 m, 16 November 1922, W. B. Jones 1712 (lectotype: BISH-501566!; designated by G. W. Gillett, *Univ. Calif. Publ. Bot.* 66: 55. 1973). H. St. John made a superfluous lectotypification (*Phytologia* 33: 422, 1976). A second syntype, Quayle 1243 (BISH) [now referred to *C. thibaultii*] was mentioned as a “second type sheet” by Brown.

**Description.** Shrubs 2–6 m. Leaves opposite, borne on upper 2–5 nodes, leathery when fresh, drying chartaceous, broadly elliptic to broadly elliptic-oblongate, 26–40 × 10–25 cm, rugose, upper surface glossy, green, sparsely pubescent when young, especially along major veins, quickly glabrate, lower surface pale green, moderately ferruginous appressed pubescent, especially along major veins, quickly glabrate, margins irregularly serrate-dentate, apex broadly rounded, ± with an often long, acuminate tip, base broadly rounded, truncate or abruptly attenuate, petioles 2.5–7.0 cm long. Flowers in loose, open cymes 8–20 cm long, basally cauliflorous on the main stem, cymules 1–3 flowered, peduncles up to 30 mm long, ca. 3–4 mm in diameter, pedicels 0–1 mm, bracts rhombic, whitish brown, 18–20 mm, soon deciduous; calyx funnelform, whitish brown, plicate, 33–46 mm long, the lobes 10–20 mm long, unequal, triangular, sparsely minutely appressed pubescent, appearing glabrate, deciduous after anthesis; corolla white, tube funnelform, 40–50 mm long, slightly exceeding the calyx, lobes suborbicular, 8–15 mm long; style ca. 7 mm long, glabrous or with a few scattered hairs. Mature berry unknown, but young ones ovoid, ca. 10 mm long.

**Distribution.** Marquesas Islands, endemic to Ua Huka, scattered in Hitikau area to Vaikivi summit and drainage, from 500 to 870 m. One collection (Mumford & Adamson 561, BISH) made in 1929 is from Nuku Hiva, but it is possible that the locality on the label is incorrect and the plant was actually collected on Ua Huka, where Adamson was for four days in October 1929 (N. Evenhuis, pers. comm. May 2013).

**Ecology.** *Cyrtandra jonesii* is known only in montane wet shrubland with *Freycinetia impavida* (Gaudich. ex Hombr.) B. C. Stone and *Hibiscus tiliaceus* L. dominant.

**Conservation status.** IUCN Red List Category: Endangered EN B1ab (i,ii,iii) + 2 ab (i,ii,iii): B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 423 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra jonesii* on Ua Huka (ca. 83 km<sup>2</sup>) and possibly on Nuku Hiva (ca. 340 km<sup>2</sup>), is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-



**Figure 3.** *Cyrtandra jonesii* (F. Br.) G. W. Gillett **A** Habit **B** Inflorescence **C** Bract **D** Calyx **E** Corolla **F** Flower, lateral view. Drawn from Wood 10744 (PTBG) and field photographs.

Dombois and Fosberg 1998; Meyer and Salvat 2009). If this species is restricted to only Ua Huka, then its conservation status would be CR.

**Specimens examined. Marquesas Islands. Nuku Hiva:** Puokohe, 3500 ft [1067 m], 22 October 1929, Mumford 561 (BISH, S). **Ua Huka:** Hitikau region, ascended via the Matukuoha Ridge over-looking Hane, constitutes the summit of the single crater of Ua Huka, 730 m, UTM 0661697 – 9015668, 5 Dec 2003, Wood 10493 (PTBG), 780 m, Wood 10474, (PTBG), 700 m, Wood 10484 (PTBG); summit of Hitikau area, 872 m, 8°54'30.6"S, 139°31'46.9"W, 15 June 2004, Perlman & Wood 19017 (PTBG, US); Hitikau summit area, 686 m, 8°54'19.7"S, 139°31'7.3"W, 26 July 2005, Perlman & Meyer 19741 (BISH, P, PAP, PTBG, US); Hitikau and the Vaikivi summit region, 870 m, 8°54'40.5"S, 139°31'32.5"W, 14–15 June 2004, Wood & Perlman 10744 (PAP, PTBG, US); Vaikivi summit region and drainage, boulder-strewn stream-bed running south and west below Hitikau, 700 m, 8°54'S, 139°31'W, 14–15 June 2004, Wood & Perlman 10751 (PTBG).

**Discussion.** Brown described the genus *Cyrtandroidea* for this species in the Campanulaceae, but Gillett (1973) effectively placed the generic name in synonymy when he transferred it to *Cyrtandra*. Gillett, however, did not recognize that the second syntype, Quayle 1243 (BISH) represented another species, subsequently described by Fosberg and Sachet (1981) as *C. thibaultii*. Fosberg and Sachet pointed out that Gillett's description of *C. jonesii* was based primarily on his own collection of the then undescribed *C. thibaultii*. Here we have revised the description, based on new collections and on the description from original material provided by Fosberg and Sachet (1981).

## 2. *Cyrtandra nukuhivensis* F. Br., Bernice P. Bishop Mus. Bull. 130: 274. 1935.

[http://species-id.net/wiki/Cyrtandra\\_nukuhivensis](http://species-id.net/wiki/Cyrtandra_nukuhivensis)

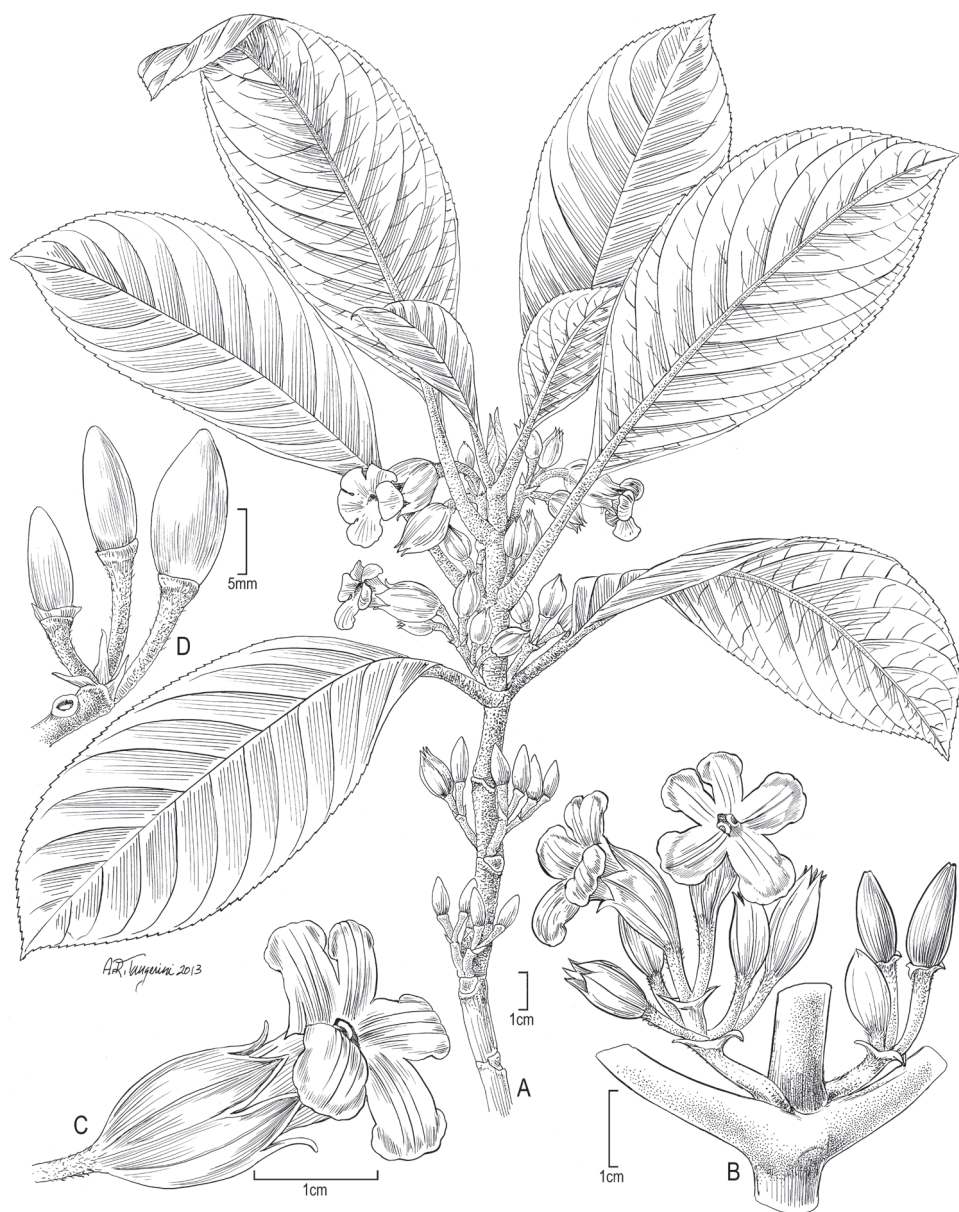
Fig. 4

**Type.** Marquesas Islands: Nuku Hiva: Rain forest, 800 m, September 1922, E.H. Quayle 1233 [1293] (holotype: BISH-509954!; isotypes: BISH!, BKL).

**Description.** Shrubs (1.5–) 2–5 m tall; stems usually few. Leaves opposite, borne on upper 4–8 nodes, elliptic, occasionally elliptic-oblongate, 14–24.5 × 5–7.5 cm, glabrate, upper surface glossy, dark green, lower surface pale green, margins serrulate, apex rounded and usually with acuminate tip, base attenuate, petioles 3–6 cm. Flowers in congested cymes 2.0–7 cm arising in the upper leaf axils, flowers 1–9, ferruginous pubescent, quickly glabrate, peduncles 10–35 mm long, ca. 1–2 mm in diameter, pedicels 2–18 mm, bracts triangular, ca. 3–5 mm; calyx ellipsoid, white, plicate, 15–23 mm long, the lobes 6–11 mm long, deciduous after anthesis; corolla broadly funnel-form, tube ca. 22–30 mm, slightly exceeding the calyx, the lobes ca. 8–10 mm long; style ca. 3 mm long, pubescent. Young berry cylindrical-ovoid, 10–18 mm long.

**Distribution.** Marquesas Islands, uncommon, endemic to Nuku Hiva, Toovii Plateau to Mt. Ooumu, from 800 to 1150 m.





**Figure 4.** *Cyrtandra nukuhivensis* F. Br. **A** Habit **B** Inflorescence **C** Flower, lateral view **D** Fruit. Drawn from field images and Perlman 15060 (US, PTBG), except A from Perlman 15034 (US).

**Ecology.** *Cyrtandra nukuhivensis* is known from montane wet forest with *Metrosideros collina* (J. R. Forst. & G. Forst.) A. Gray and *Weinmannia marquesana* F. Br. forest with diverse fern understory along with other shrubs and trees such as species of *Cheirodendron*, *Coprosma*, *Crossostylis*, *Ilex*, *Melicope*, and *Xylosma*.

**Conservation status.** IUCN Red List Category: Endangered EN B1ab (i,ii,iii) + 2 ab (i,ii,iii): B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 340 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra nukuhivensis* on Nuku Hiva (ca. 340 km<sup>2</sup>), is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Nuku Hiva:** Toovii, 800 m, Quayle 1293 (BISH [2]); Toovii, flanc N de l'épaulement SE du Mt. Ooumu, 960 m, 29 May 1984, Florence 6851 (BISH, P); Toovii, épaulement S du Mt. Ooumu, 930 m, 8°51'S, 140°8'W, 8 December 1982, Florence 4337 (BISH [2], K, NY, P, US); Toovii, flanc SE du Mt. Ooumu, 1020 m, 8°50'S, 140°09'W, 11 March 1986, Florence 7523 (BISH, US); Toovii Plateau, spur of Mt. Ooumu, 950 m, 18 July 1977, Gagné 1104 (BISH) Gagné 930 m, 1105 (BISH, US); Toovii Plateau, l'Economie Rurale, summit, above new road, on crest, 1152 m, 16 July 1988, Perlman, Wagner, Lorence & Florence 10100 (BISH, E, MO, PAP, PTBG, US); ravine en forêt de Toovii, 2 March 1973, Hallé 2073 (US); between Taiohae Bay and Hooumi Bay, 900 m, 20 July 1977, Gagné & Montgomery 1160 (BISH); S slope of Mt. Tapuaooa, 10 July 1970, Gillett 2178 (BISH, US); Mt. Ooumu, 3500 ft, 28 March 1960, Decker 376 (BISH, US [2]); Toovii, Ooumu area, top of Tapueahu Valley off new hwy, 1067–1128 m, 8°51'S, 140°19'W, 20–22 September 1995, Wood & Perlman 4626, (PAP, PTBG, US, WU); Ooumu area, top of Tapueahu Valley off new Hwy, 1067–1128 m, 8°51'53"S, 140°10'6.3"W, 23 June 1997, Wood, Meyer, Luce & Tetuanui 6340 (PTBG); summit of ridge S of Tekao, 0.5 mile N New Airport Road, between Airport Road & Tekao, main ridge above Toovii, 1128 m, 25 September 1995, Perlman & Wood 15060 (BISH, P, PAP, PTBG, US, WU); along new Airport road, along summit crest above Toovii, Peak #1227 M., summit of Mts. S of Tekao, 1122 m, 22 September 1995, Perlman & Wood 15034 (BISH, MO, P, PAP, PTBG [2], US, WU).

**Discussion.** *Cyrtandra nukuhivensis* is delimited in a more restricted way than previously and is here considered to be endemic to Nuku Hiva. The Ua Pou plants are here considered a distinct, but closely related species.

**3. *Cyrtandra thibaultii* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 28. 1981.**  
[http://species-id.net/wiki/Cyrtandra\\_thibaultii](http://species-id.net/wiki/Cyrtandra_thibaultii)

Fig. 5

**Type.** Marquesas Islands: Nuku Hiva: Toovii, 850–900 m, 9 July 1975, J.-C. Thibault 134 (holotype: US-02969235!; isotype: US!).

**Description.** Shrubs 2–5 m. Leaves opposite, borne on upper 4–8 nodes, oblong-elliptic to elliptic, 16–29 × 6.5–13 cm, upper surface glabrate or ferruginous pubescent on veins, lower surface densely or moderately ferruginous pubescent, apex acuminate,



**Figure 5.** *Cyrtandra thibualtii* Fosberg & Sachet **A** Habit, S. Perlman et al 10095 (PTBG) **B** Flower, lateral view **C** Corolla, longitudinal section. Drawn from Perlman et al 10095 (US) and field images.



base cuneate, petioles 2–6 cm long, appressed ferruginous pubescent. Flowers in open, loose cymes, 14–30 cm long, arising in the upper leaf axils, appressed ferruginous pubescent, peduncle 80–90 mm long, ca. 1–2 mm in diameter, pedicels 10–15 mm, elongating to 25–30 mm in fruit, bracts triangular, ca. 6–11 mm; calyx cylindrical-ellipsoid, pale green, plicate, 25–45 mm long, appressed ferruginous pubescent, lobes 5–17 mm long, deciduous after anthesis; corolla funnellform, tube 25–50 mm long, lobes about 15–20 mm long; style 10 mm long, appressed to spreading pubescent. Berry fusiform, ca. 45 mm long. Seeds broadly elliptic or ovoid, 0.3–0.4 mm long, reticulate.

**Distribution.** Marquesas Islands, scattered, on Nuku Hiva from the Toovii Plateau to Mt. Ooumu, and on Ua Pou from Oave, Teavahaakiti, and Pouakei, from 700 to 1050 m.

**Ecology.** *Cyrtandra thibaultii* is known from *Metrosideros collina*, *Weinmannia marquesana*, and *Freycinetia impavida* forest with an association with diverse shrubs and trees such as species of *Cheirodendron*, *Coprosma*, *Crossostylis*, *Hernandia*, *Ilex*, *Melicope*, *Psychotria*, *Trimenia*, and *Xylosma*.

**Conservation Status.** IUCN Red List Category: Endangered EN B1ab (i,ii,iii) + 2 ab (i,ii,iii). B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 445 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra thibaultii* on Nuku Hiva (ca. 340 km<sup>2</sup>) and Ua Pou (ca. 105 km<sup>2</sup>), is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens Examined. Marquesas Islands. Nuku Hiva:** Toovii Valley, 3 July 1970, Gillett 2156 (BISH, US); forêt de montagne à l'ouest de Toovii, 2 March 1973, Hallé 2064 (US); Toovii region, NW of l'Economie Rurale complex along new road to airport over flanking mountains, 1020–1030 m, 3 August 1988, Lorence, Wagner, Montgomery, Florence & Bishop 6268 (PAP); Toovii, épaulement S du Mt. Ooumu, 880 m, 8°51'S, 140°8'W, 1 December 1982, Florence 4232 (BISH [2], K, NY, P, US); Toovii, vallon du réservoir, 830 m, 8°52'S, 140°9'W, 26 May 1984, Florence 6737 (BISH [2]); Toovii Plateau, spur of Mt. Ooumu, 790 m, 16 July 1977, Gagné 1048 (BISH, US); W part of Toovii, along new road W of l'Economie Rurale, 1170 m, 16 July 1988, Wagner, Lorence, Florence & Perlman 6096 (BISH, P, US) & 6097 (BISH, MO, US); Toovii Plateau, l'Economie Rurale, along new road, 994 m, 16 July 1988, Perlman, Wagner, Lorence & Florence 10095 (BISH, PTBG, US); Toovii, N of agriculture station, along drainage and up to ridge, 808 m, 8°50'8.6"S, 140°8'6.8"W, 22 June 1997, Wood & Meyer 6325 (MPU, P, PAP, PTBG, US, WU), Wood & Meyer 6325-A (PTBG); between Taiohae Bay and Hooumi Bay, >700 m, 20 July 1977, Gagné 1150 (BISH, US); S of Airport road, drainages of Tapueahu gulch, to NW of Toovii over summit crest, 963 m, 21 September 1995, Perlman & Wood 15020 (BISH, MO, P, PAP, PTBG, US, WU). **Ua Pou:** Vallon en contrebas de la crête reliant Poumaka et la crête sommitale Oave-Teavahaakiti, 750 m, 22 July 2003, Meyer 2541 (BISH, P, PAP, PTBG, US); Pou Maka, ridge between Pou Maka and



Oave, 792 m, 9°23'7.7"S, 140°4'W, 22 July 2005, Perlman 19730 (P, PAP, PTBG, US); forested ridge and slopes up to Pouakei, northwest side, 930 m, 9°24'S, 140°5'W, 21 Nov 2003, Wood 10428 (PTBG, US); forested ridge and slopes up to Teavahaakiti, northwest side, 914 m, 24 Nov 2003, Wood 10449 (PTBG, US).

**Discussion.** The sample used (Wood 10428) in the molecular study by Clark et al. (2009) was identified as *C. nukuhivensis*, but during this taxonomic revision it was re-identified as the closely related *C. thilbaultii*.

#### 4. *Cyrtandra uahukaensis* W. L. Wagner & Lorence, sp. nov.

urn:lsid:ipni.org:names:77134229-1

[http://species-id.net/wiki/Cyrtandra\\_uahukaensis](http://species-id.net/wiki/Cyrtandra_uahukaensis)

Fig. 6

**Type.** Marquesas Islands: Ua Huka: Summit of ridge near Hitikau, *Hibiscus tiliaceus* forest, 820 m, 28 June 1997, S. Perlman, K. Wood, & J.-Y. Meyer 15844 (holotype: PTBG-026355!; isotype: US!).

**Description.** Shrubs 1–2 m tall; stems apparently few. Leaves opposite, borne on upper 2–5 nodes, broadly elliptic, 18–26 × 7–10 cm, lower surface densely ferruginous appressed pubescent, upper surface glabrate, irregularly dentate, the teeth variable in size, petiole 5–6.5 cm, ferruginous appressed to spreading pubescent. Flowers in cymes arising in the upper leaf axils, apparently 1–3 flowered, peduncle 0–2 mm, ca. 1–2 mm in diameter, pedicels up to 6 mm; calyx cylindrical-ellipsoid, white, plicate; corolla much longer than calyx; style up to 10 mm, flower parts otherwise unknown. Partly mature berries up to 14 mm long.

**Distribution.** Marquesas Islands, rare, endemic to Hitikau summit area, Ua Huka, from 820–870 m.

**Ecology.** *Cyrtandra uahukaensis* is known only from *Freycinetia impavida* - *Hibiscus tiliaceus* shrubland.

**Etymology.** The specific epithet refers to the island of Ua Huka where the only known populations occur.

**Conservation status.** IUCN Red List Category: Critically Endangered CR B2a + 2b (i, ii, iii). B2: total area of occupancy less than 10 km<sup>2</sup> (ca. 5 km<sup>2</sup>). B2a, a single population known; b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra uahukaensis* on Ua Huka (ca. 83 km<sup>2</sup>) is indicated as an endangered environment, threatened feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Ua Huka:** 13 May 1918, Henry 7 (P); Hitikau summit region, large bowl-like plateau, 823–884 m, 8°54'22"S, 139°31'66"W, 28 June 1997, Wood 6380 (PTBG); Hitikau and the Vaikivi summit region, 790 m, 8°54'S, 139°31'W, 14–15 June 2004, Wood & Perlman 10756 (PTBG).

**Discussion.** Little is known about this species as it has been collected only four times. None of the collections were preserved with any flowers, only young fruit.



Figure 6. *Cyrtandra uahukaensis* W. L. Wagner & Lorence (Perlman et al. 15844, isotype US).

*Cyrtandra uahukaensis* is characterized by the densely pubescent leaves and condensed inflorescences. It grows in the same area as *C. jonesii* and appears to be closely related. Their relationships and ecology should be studied as it seems atypical for two very closely related species of the genus to grow in near sympatry.

**5. *Cyrtandra uapouensis* W. L. Wagner & Lorence, sp. nov.**

urn:lsid:ipni.org:names:77134230-1

[http://species-id.net/wiki/Cyrtandra\\_uapouensis](http://species-id.net/wiki/Cyrtandra_uapouensis)

Fig. 7

**Type.** Marquesas Islands: Ua Pou: Ua Pou: Ridge just north of Oave, between Oave and Matahenua, high mountain peaks along main backbone ridge, 945 m, 9°23'455"S, 140°4'433"W, 3 July 2004, S. P. Perlman & K. R. Wood 19085 (holotype: PTBG-042428!; isotypes: BISH!, MO, NY, P, PAP, US!).

**Description.** Shrubs 1.5–3 m tall; stems usually few. Leaves opposite, borne on upper 3–5 nodes, elliptic-oblongate to elliptic, 19–28 × 8–13 cm, upper surface glossy, dark green, glabrate, lower surface pale green, ferruginous pubescent when young, when maturing pubescent primarily along the veins, margins serrulate, apex rounded and usually acuminate, base attenuate, petioles 4.5–7 cm. Flowers in congested cymes 1–3 cm long arising in the upper leaf axils, flowers 1–6, ferruginous pubescent, quickly glabrate, peduncles 3–15 mm long, ca. 1–2 mm in diameter, pedicels 0–10 mm, bracts triangular, ca. 8–11 mm; calyx ellipsoid, white, plicate, 20–25 mm long, the lobes 8–13 mm long, deciduous after anthesis; corolla broadly funnelform, tube ca. 22–35 mm, slightly exceeding the calyx, the lobes ca. 8–10 mm long; style ca. 3 mm long, pubescent. Young berry ellipsoid-ovoid, 15–25 mm long.

**Distribution.** Marquesas Islands, rare, endemic to high ridges of Ua Pou, from Oave, Matahenua, Teavahaakiti, Tekahuipu, and Tekohepu, 680–945 m.

**Ecology.** *Cyrtandra uapouensis* is known only in *Metrosideros collina*–*Weinmannia marquesana* wet forest with diverse fern understory and other shrubs and trees such as species of *Cheirodendron*, *Coprosma*, *Crossostylis*, *Ilex*, *Melicope*, and *Xylosma*.

**Etymology.** The specific epithet refers to the island of Ua Pou where the only known populations occur.

**Conservation status.** IUCN Red List Category: Critically Endangered CR B2a + 2b (i, ii, iii). B2: total area of occupancy less than 10 km<sup>2</sup> (ca. 5 km<sup>2</sup>). B2a, a single population known; b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra uapouensis* on Ua Pou (ca. 105 km<sup>2</sup>) is indicated as an endangered environment, threatened feral animals and invasive plants, reducing the extent of the forest (Lorence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined.** Marquesas Islands. **Ua Pou:** Mt. Tekahoipu, 800 m, 9 September 1922, Quayle 1151 (BISH); crête sud menant au mont Teavahaakiti, val-lon à pente forte, zone semi-ouverte, 810 m, 20 Jun 2004, Meyer 2847 (P, PAP, PTBG, US); Teavahaakiti, steep slopes of main ridge to S of Oave, N & E facing cliffs





**Figure 7.** *Cyrtandra uapouensis* W. L. Wagner & Lorence **A** Habit **B** Flower, lateral view **C** Flower, face view. Drawn from Perlman 19085 (isotype, US) [**A**, **C**] and Perlman 15904 (PTBG) [**A**, **B**] and field images.

between Teavahaakiti & Tekohepu, 683 m, 5 July 1997, Perlman & Wood 15904 (MO, P, PAP, PTBG, US, WU).

**Discussion.** Gillett (1973) included the only known specimen of *Cyrtandra uapouensis* at that time (Quayle 1151) within his delimitation of *C. nukuhivensis*; populations from Ua Pou are here separated based on its occurrence on a different island and its consistently larger leaves. *Cyrtandra uapouensis* grows sympatrically with *C. kenwoodii*, and there are several collections (cited in hybrid section) that are morphologically intermediate between them that appear to represent hybrids. The fact that *C. kenwoodii* forms a separate branch in the phylogenetic analyses (Clark et al. 2009; fig. 1) from both the divided calyx group and the plicate calyx group suggests that perhaps this hybridization has impacted the genome of *C. kenwoodii* or that the species is of hybrid origin.

## 6. *Cyrtandra kenwoodii* W. L. Wagner & A. J. Wagner, sp. nov.

urn:lsid:ipni.org:names:77134231-1

[http://species-id.net/wiki/Cyrtandra\\_kenwoodii](http://species-id.net/wiki/Cyrtandra_kenwoodii)

Fig. 8

**Type.** Marquesas Islands: Ua Pou: Tekohepu, windswept and cloud-shrouded summit, shrubland of *Metrosideros collina* with *Dicranopteris linearis*, *Paesia rugulosa*, *Freycinetia*, *Blechnum*, *Oleandra sibbaldii*, and *Selligoea feeioides*, 2500–3000 ft [762–914 m], 4–5 July 1997, K. R. Wood & S. Perlman 6467 (holotype: US-3390815!; isotype: PTBG!).

**Description.** Shrubs 0.2–1 m. Leaves opposite, clustered on upper 2–5 nodes, brittle, elliptic to elliptic-oblongate, 4–7.6 × 1.0–2.1 cm, upper surface glossy, green, glabrous, lower surface pale green, glabrous, margins irregularly and inconspicuously serrulate, apex acuminate, base attenuate, petioles 0.2–1.6 cm long. Flowers in loose, open cymes 3–6 cm long, arising in the upper leaf axils, cymes 1–3 flowered, peduncles 15–40 mm long, ca. 1–1.5 mm in diameter, pedicels 10–18 mm, bracts lanceolate, ca. 6–8 mm; calyx funnelform, white, ca. 11–15 mm long, lobes 5–9 mm long, subequal, glabrous, deciduous after anthesis; corolla white, funnelform, tube ca. 24–26 mm long, lobes ca. 6–8 mm long. Immature berry 15 mm long.

**Distribution.** Marquesas Islands, rare, endemic to high ridges of Ua Pou, from Oave and Matahenua to Teavahaakiti, Tekahuipu, and Tekohepu, 790–945 m.

**Ecology.** *Cyrtandra kenwoodii* is known only in cloud-swept summits with *Metrosideros collina* shrubland with other shrubs and small trees such as *Apetahia*, *Freycinetia*, and *Hibiscus*.

**Etymology.** This new species is named for Kenneth R. Wood, who first collected it and who has contributed greatly to our knowledge of the flora of the Marquesas and the Hawaiian Islands through his collections and field observations.

**Conservation status.** IUCN Red List Category: Critically Endangered EN B2a + B2b(i–iii). B2: total area of occupancy less than 10 km<sup>2</sup> (ca. 5 km<sup>2</sup>). B2a, a single population known; b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra kenwoodii* on Ua Pou (ca. 105 km<sup>2</sup>) is indicated as an endangered environ-



**Figure 8.** *Cyrtandra kenwoodii* W. L. Wagner & A. J. Wagner **A** Habit **B** Flower, lateral view **C** Corolla, longitudinal view **D** Pistil. Drawn from Wood 10804 (US), except **A** from Wood 6467 (holotype, US).

ment, threatened feral animals and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Ua Pou:** Central Ua Pou including the summit crest regions around Oave and the near-by peak of Matahenua, 899–924 m, 9°23'45.4"S, 140°4'43.3"W, 2 July 2004, Wood & Perlman 10804 (PTBG, US), 10813 (PTBG); ridge just north of Oave, between Oave and Matahenua, high mountain peaks along main backbone ridge, 945 m, 9°23'45.5"S, 140°4'43.3"W, 3 July 2004, Perlman & Wood 19088 (PTBG, US); Teavahaakiti, steep slopes of main ridge to S of Oave, N & E facing cliffs between Teavahaakiti & Tekohepu, 869 m, 5 July 1997, Perlman & Wood 15911 (MO, P, PAP, PTBG, US, WU).

**Discussion.** The sample of *Cyrtandra kenwoodii* used (Wood & Perlman 10804) in the molecular study by Clark et al. (2009) was identified as *C. feaniana*, prior to realization that the diminutive plants from Ua Pou represented an undescribed species. The molecular data show that *C. kenwoodii* is in a polytomy along with the two primary clades of Marquesan species, but is grouped here with the plicate species as it has the calyx only divided about half way to the base, but is not plicate as far as is known.

## Divided calyx group

### 7. *Cyrtandra feaniana* F. Br., Bernice P. Bishop Mus. Bull. 130: 272. 1935.

[http://species-id.net/wiki/Cyrtandra\\_feaniana](http://species-id.net/wiki/Cyrtandra_feaniana)

Fig. 9

**Type.** Marquesas Islands: Hiva Oa: Feani, 800 m, 8 December 1921, F.B.H. Brown 827 (holotype: BISH-509530!)

**Description.** Shrub 1.5–3 m; stems glabrous or with a few scattered hairs when young. Leaves opposite, lanceolate to elliptic, 2.5–19 × 1.3–7.2 cm, glabrous, margins crenulate-serrulate, apex acute or acuminate, base cuneate, petioles 1–5 cm. Flowers 1–3 in cymes arising in the leaf axils, usually somewhat shorter than the leaves, glabrous or with scattered hairs, peduncles 10–45 mm long, ca. 0.5–1.5 mm in diameter, pedicels 18–35 mm long, bracts inconspicuous, narrowly lanceolate or triangular, 1–5 mm long, deciduous; calyx usually white, occasionally greenish white, 10–24 mm, divided nearly to the base, lobes lanceolate, tardily deciduous; corolla white, glabrous externally, tube 18–23 mm long, the lobes subequal, broadly obovate, 10–12 mm long; ovary narrowly ovoid, glabrous, style ca. 7 mm long, minutely puberulent. Berries pale orange, ca. 15 mm long, narrowly ovoid, glabrous.

**Distribution.** Marquesas Islands, occurring on Hiva Oa and Tahuata, and known from a few collections made in 1922 on Nuku Hiva and Ua Huka, from 700 to 1100 m.

**Ecology.** *Cyrtandra feaniana* is known from ridges and summit areas of montane wet forest dominated by *Metrosideros collina* and other shrubs and trees such as *Weinmannia marquesana* forest with diverse fern understory and other shrubs and trees such as species of *Coprosma*, *Crossostylis*, *Freycinetia*, *Ilex*, *Melicope*, *Polyscias*, *Psychotria*, and *Xylosma*.

**Conservation status.** IUCN Red List Category: Endangered EN B1ab (i,ii,iii) + 2ab (i,ii,iii). B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 799 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra feaniana* on Nuku Hiva (ca. 340 km<sup>2</sup>), Ua Huka (ca. 83 km<sup>2</sup>), Hiva Oa (ca. 315 km<sup>2</sup>), and Tahuata (ca. 61 km<sup>2</sup>) is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined.** **Marquesas Islands. Nuku Hiva:** Toovii, 800–1000 m, October 1922, Quayle 1335 (BISH, BKL, US). **Ua Huka:** 9 November 1922, Quayle, 1792 (BISH); 9 November 1922, Quayle 1750 (BISH). **Hiva Oa:** Feani, 800 m, Brown 827





**Figure 9.** *Cyrtandra feaniana* F. Br. **A** Habit **B** Inflorescence **C** Flower, lateral view **D** Calyx **E** Flower, face view **F** Fruit. Drawn from Perlman 18476 (US) and photographs of Perlman 14932 (**A**, **F**), Perlman 14863 (US) and Photographs (**B**, **C**, **E**), and Schäfer 980 (**D**).

(BISH); Feani, 3900 ft, 23 January 1932, LeBronnec 804 (BISH); Feani ridge to upper slopes of dry side of island, 1050 m, 12 February 1975, Oliver & Schäfer 3152 (BISH, CBG, US); Feani, 1000 m, 11 November 1989, MacKee & Cherrier 44704 (BISH);

sentier d'Atuona à la crête de Feani, haute vallée côté Atuona, 980 m, 6 November 1975, Schäfer 5943 (BISH, CBG, CHR, NSW, PTBG, US [2]); Atuona–Feani Trail, crest of ridge and top of leeward slope, 1200–1300 m, 24–26 September 1963, Sachet & Decker 1152 (BISH, CBG, CHR, MO, NSW, PTBG, US [2]); Mt. Feani, trail from Atuona to Hanamenu, 1180 m, 10 February 1975, Oliver & Schäfer 3101 (BISH, CBG, CHR, L, MO, NSW, PTBG, US); Mt. Feani, trail from Atuona to Hanamenu, 1180 m, 11 February 1975, Oliver & Schäfer 3111 (BISH, US); Mt. Feani, trail from Atuona to Hanamenu, 1120 m, 5 March 1975, Oliver & Schäfer 3238 (BISH, CBG, CHR, NSW, US), Oliver & Schäfer 3239 (BISH, CBG, US); 30 m above camp near “the source” (Vaiumete) on trail from Atuona to Hanamenu, 1000 m, 29 Jan 2003, Price, Dunn & Lorence 200 (P, PAP, PTBG, US); Feani area, on Hanamenu trail, summit crest, heading from Vaiumete et Vaiumioi (source) toward Hanamenu, 1090 m, 9°47'9.86"S, 139°4'7.06"W, 30 Jan 2003, Perlman, Wood, Lorence, Meyer & Dunn 18348 (BISH, P, PAP, PTBG, US); Atuona, piste de Hanamenu, NW du Mt. Temetiu, 1090 m, 9°48'S, 139°5'W, 30 July 1988, Florence, Lorence, Perlman & Wagner 9634 (BISH, K, P, PAP, PTBG, US); chemin d'Atuona à Hanamenu par Feani, 1040 m, 11 February 1975, Schäfer 5174 (MPU), Schäfer 5174B (MPU), Schäfer 5174C (MPU); Vaipahee Falls area, ridge crest, Kaava ridge further toward Feani, 914 m, 9 August 1988, Perlman 10261 (AD, BISH, E, F, MO, NY, P, PTBG, US); trail to Feani and Hanamenu, 3300 ft [1006 m], 29 July 1988, Perlman, Wagner, Lorence & Florence 10178 (BISH); trail to Feani and Hanamenu, along plateau rim and ridge trail, 1097 m, 30 July 1988, Perlman 10184 (BISH, PAP, PTBG); trail to Hanamenu, 1000 m, 9°47'9.29"S, 139°4'56.7"W, 1 August 2005, Perlman 19760 (AD, BISH, NY, P, PAP, PTBG, US); Matauuna, 27 February 1930, Pacific Entomol. Surv. HO 1004 b (BISH); above Atuona, 700 m, 6 October 1930, Pacific Entomol. Surv. Ex 47 (BISH); 3900 ft [1189 m], 23 January 1932, Pacific Entomol. Surv. 6B 804 (BISH); windswept summit, along trail between Mt. Feani and Timetiu, 1100 m, 30 July 1988, Wagner & Lorence 6223 (BISH, P, PTBG, US); N side of Mt. Temetiu, 1100 m, 23 March 1929, Mumford & Adamson 151 (BISH, S, UC); NE slope of Mt. Temetiu, 2200 ft, 24 July 1929, Mumford & Adamson 467 (BISH, S); N side of Mt. Temetiu, 1100 m, 9 October 1930, Pacific Entomol. Surv. 151 (BISH); Temetiu, 1189 m, 9°48'S, 139°4'W, 25 August 1995, Wood 4378 (BISH, MO, PAP, PTBG, US); summit of Temetiu, top of highest peak, 1262 m, 25, August 1995, Perlman, Wood & Meyer 14880 (PAP, PTBG, US, WU); summit of Mt. Ootua, 920 m, 10 May 1929, Mumford & Adamson 388 (BISH, S, UC); Mt. Ootua, central part, 860 m, 29 July 1977, Gagné 1214 (BISH, US); Mt. Ootua, off road between Airport and Puamau, along ridge and summit, on N facing slope, 841–866 m, 21 August 1995, Perlman & Wood 14863 (AD, BISH, MO, P, PAP, PTBG, US, WU); Mt. Ootua, summit area, 830 m, 9°46'25"S, 138°58'27.5"W, 19 Feb 2003, Perlman 18476 (BISH, P, PAP, PTBG, US); Mt. Ootua summit area, 838 m, 9°45'9.90"S, 138°58'29.5"W, 19 July 2004, Perlman & Wood 19215 (BISH, P, PAP, PTBG, US). **Tahuata:** Summit of ridge above Vaitahu, near Haaiputeomo, on ridge near antenna, along ridge crest between Vaitahu & Hanatetena, 823 m, 1 September 1995, Perlman, Wood & Luce 14923 (PAP, PTBG, US); summit ridge near Haaiputeomo, satellite dish region NE of Vaitahu, 762–823 m,

9°57'19"S, 139°5'7.4"W, 17–19 July 1997, Wood 6570 (BISH, P, PAP, PTBG, US, WU); Haaioputeomo, on SE side of slope above village of Hanatetena, summit ridge of island, 793 m, 2 September 1995, Perlman, Wood & Luce 14932 (BISH, P, PAP, PTBG, US, WU); ridge between Amatea & Haaioputeomo, SE facing slopes and cliffs over Hanatetena village, 835 m, 11 July 1997, Perlman, Wood & Luce 15953 (PTBG, US) & 847 m, 15956 (P, PAP, PTBG, US, WU); ridge between Amatea and Haaioputeomo, S facing slope, 786 m, 9°56'S, 139°4'W, 19 July 1997, Perlman 16025 (PAP, PTBG, US), 750 m, Perlman 16017 (MO, P, PAP, PTBG, US, WU); au-dessus de Hamatea, sur la crête centrale de U'ua'o, 850 m, 31 May 1975, Thibault 82 (BISH, CBG, PTBG, US).

**Discussion.** *Cyrtandra feaniana* along with the closely related *C. ootensis* are the most commonly occurring species of *Cyrtandra* in the Marquesas Islands. In addition *C. feaniana* has the widest distribution, along with *C. ootensis*, occurring on four islands, although seemingly rare on Nuku Hiva and Ua Huka and has not been collected on either island since 1922. Specimens with more than a few hairs on various parts of the plant are here identified as *C. ootensis*. This includes all of the specimens from Fatu Hiva that are nearly glabrous, but have much larger leaves like other populations of *C. ootensis*. Alternatively, it is possible that these glabrate Fatu Hiva populations represent hybrids or hybrid derivatives between *C. feaniana* and *C. ootensis*. This hypothesized hybridization if correct would require the colonization of Fatu Hiva by *C. feaniana* followed by hybridization with *C. ootensis* to produce the glabrate larger-leaved plants.

## 8. *Cyrtandra ootensis* F. Br., Bernice P. Bishop Mus. Bull. 130: 273. 1935.

[http://species-id.net/wiki/Cyrtandra\\_ootensis](http://species-id.net/wiki/Cyrtandra_ootensis)

Fig. 10

*Cyrtandra ootensis* F. Br. var. *fatuhivensis* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 30. 1981.

**Type.** Marquesas Islands: Fatu Hiva: Teavapuhiau Pass (above Ouia Valley), under *Hibiscus*, *Crossostylis*, *Metrosideros*, 720 m, 1–3 August 1977, B. H. Gagné 1244 (holotype: US-02969231!; isotypes: BISH [4]!).

*Cyrtandra ootensis* F. Br. var. *mollissima* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 30. 1981.

**Type.** Marquesas Islands: Hiva. Oa: Montagnes NW du Temetiu, entre la haute vallée de Hanamenu et la crête de Temetiu-Feani, 960 m, 23 October 1975, P. A. Schäfer 5923 (holotype: US-2969230!; isotypes: BISH!, P).

*Cyrtandra ootensis* F. Br. var. *quaylei* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 31. 1981.

**Type.** Marquesas Islands: Ua Huka: 600 m, 9 November 1922, E. H. Quayle 1755 (holotype: BISH-145694!).

**Type.** Marquesas Islands: Hiva Oa: Ootua, 800 m, 15 December 1921, F.B.H. Brown 961 (holotype: BISH-509956!).

**Description.** Shrub 1.5–4 m. Leaves opposite, elliptic to ovate, 12–28 × 5–15 cm, whitish to ferruginous pubescent, or rarely nearly glabrous, and then youngest leaves with at least some hairs, margin crenate-serrate, base unequal and broadly cuneate to attenuate, apex obtuse to acute or acuminate, petioles (1.5–) 4–10 cm. Flowers 1–3 in cymes arising in the leaf axils, peduncles 5–90 mm long, ca. 1–2 mm in diameter, pedicels subtending a central pedicel 2–50 mm long, bracts lanceolate, 2–10 mm long; calyx pale green or occasionally white, 11–20 mm long, divided nearly to base, deciduous, usually densely pubescent externally; corolla tube 25–32 mm long, lobes 5–6 mm long; ovary 7–15 mm long pubescent, style 6–18 mm long, pubescent. Berries pubescent, cylindrical, 2.1 cm long. Seeds ovoid, 0.4–0.5 mm long, the coats sculptured with coarse polygonal reticulations.

**Distribution.** Marquesas Islands, occurring on Hiva Oa and Tahuata, and two collections from Ua Huka, 670–1130 m.

**Ecology.** *Cyrtandra ootensis* is known from ridges and summit areas of montane wet forest dominated by *Metrosideros collina* and other shrubs and trees such as species of *Coprosma*, *Crossostylis*, *Freycinetia*, *Ilex*, *Melicope*, *Polyscias*, *Psychotria*, *Weinmannia*, and *Xylosma*.

**Conservation Status.** IUCN Red List Category: Endangered EN B1ab (i,ii,iii) + 2ab (i,ii,iii). B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 564 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra ootensis* on Ua Huka (ca. 83 km<sup>2</sup>), Ua Pou (ca. 105 km<sup>2</sup>), Hiva Oa (ca. 315 km<sup>2</sup>), and Tahuata (ca. 61 km<sup>2</sup>) is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Ua Huka:** 9 November 1922, Quayle 1790 (BISH). **Hiva Oa:** Mt. Feani, trail from Atuona to Hanamenu, 1120 m, 4 March 1975, Oliver & Schäfer 3237 (BISH, CBG, US); Hanamenu region, up Hanamenu Valley to the drainages below and west of Temetiu, 884 m, 9°76'S, 139°W, 25 June 2003, Wood 10235 (PTBG); Hanamenu Valley off Hanamenu trail, 908 m, 9°47'49.6"S, 139°5'35"W, 2 August 2005, Perlman 19768 (BISH, NY, P, PAP, PTBG, US); trail toward Hanamenu, 884 m, 3 August 1988, Perlman 10207 (BISH, P, PAP, PTBG[2], US); Temetiu region, drainages to southeast of Vaimete et Vaiumioi (source), headwaters of Hanamenu, 1067 m, 30 Jan 2003, Wood 10047 (PTBG); Temetiu, 1128 m, 9°49'S, 139°4'W, 25 August 1995, Wood 4404 (BISH, P, PAP, PTBG, US); N side of Mt. Temetiu, 1100 m, 23 March 1929, Pacific Entomol. Surv. 141, (BISH, UC); Teakatau, Valley on N side of Hanamenu Trail heading down to Hanamenu past summit crest, valley between Teakatau and Tepuna, 927 m, 26 August 1995, Perlman & Meyer 14896 (PAP, PTBG, US), 933 m, 14893 (PAP, PTBG, US, WU); Atuona, 1000 m, 8 December 1921, Brown 828 (BISH); Atuona, 1100 m, 9 October 1930, Pacific Entomol. Surv. Ex 141 (BISH); chemin d'Atuona à Hanamenu par Feani, hautes pentes, côté Atuona, 935 m, 12 February 1975, Schäfer 5213 (MPU, US); Ootua, 800 m, Brown 961 (BISH); Mt. Ootua, central part, 650





**Figure 10.** *Cyrtandra ootensis* F. Br. **A** Habit **B** Inflorescence **C** Flower, lateral view **D** Flower, face view **E** Fruit. Drawn from Perlman 19768 (US), except B from Wood 10235 (PTBG) and A also from Wagner 6193 (US) **B, C, D** augmented with photographs of Wood 10235.

m, 27 July 1977, Gagné 1176 (BISH), 900 m, 29 July 1977, Gagné 1213 (BISH); Mt. Ootua, off road between Airport and Puamau, on NW side of summit, 853 m, 21 August 1995, Perlman & Wood 14865 (PTBG, US, WU); Mts. of Vaipikopiko, new road from Hanaiaapa, cut off to Vaipahee Falls, on Kaava Ridge, Vaipikopiko side, 890 m, 8 August 1988, Perlman 10232 (BISH, MO, P, PAP, PTBG, US). **Tahuata:** Haaioputeoma, near satellite dish, NE from Vaitahu to summit ridge, 610–762 m, 1–2 September 1995, Wood 4456 (BISH, P, PAP, PTBG, US); summit ridge near Haaioputeoma, satellite dish region NE of Vaitahu, 762–823 m, 9°57'19"S, 139°5'74"W, 17–19 July 1997, Wood 6571 (PTBG, US), 6578 (BISH, PAP, PTBG, US); ridge between Amatea and Haaioputeoma, S facing slope, below old antenna site, 768 m, 9°56'S, 139°4'W, 19 July 1997, Perlman 16018 (AD, BISH, MO, P, PAP, PTBG, US, WU), 741 m, 16016 (BISH, P, PAP, PTBG, US). **Fatu Hiva:** 'Omo'a Valley, 800 m, 20 January 1922, Brown 935 (BISH); slopes of Mounanui above Vaieenui Falls, on ridge top, below Maunanui, 847 m, 26 July 1988, Perlman & Florence 10171 (BISH, PTBG), 10172 (BISH, PTBG); slopes of Mounanui, 719 m, 10°28'6.63"S–138°38'18"W, 16 July 2005, Perlman 19668 (BISH, P, PAP, PTBG, US); on ridges and gulches W side of Mounanui, 2400 ft, 10 September 1995, Perlman 14978 (AD, BISH, MO, MPU, NY, P, PAP, PTBG, US, WU); slopes of Moouanui above Vaieenui Falls, on ridge top, below Mounanui, 2300 ft, 26 July 1988, Perlman & Florence 10174 (BISH, PTBG, US); Mounanui, on SW side of peak, in gulch back, at base of waterfall, 677 m, 9 September 1995, Perlman 14969 (AD, BISH, MO, P, PAP, PTBG, US, WU); Mt. Touaouoho, on NW side of peak, along ridges between Touaouho and Teavapuhiau, 616 m, 8 September 1995, Perlman & Wood 14964 (AD, BISH, MO, P, PAP, PTBG, US, WU), 725 m, 14962, (PTBG), 793 m, 14961 (PTBG, US), 2200 ft, 14965 (PTBG, US); Teavapuhiau Pass (above Ouia Valley), 700 m, 1–3 August 1977, Gagné 1245 (BISH); slopes and summit from Punaitai to Tekou summit, 830–1120 m, 25 July 1988, Wagner et al. 6193 (BISH, US), 850 m, 6201 (BISH, US).

**Discussion.** When Fosberg and Sachet (1981) described the three varieties of *Cyrtandra ootensis* they stated that the species was not uniform in the variation of density of pubescence, density of toothing on leaf margins, length of petiole, in the length and openness of the inflorescence, and in the width of the corolla. They also pointed out that there was not much correlation among these variable characters, but nevertheless subdivided *C. ootensis* into four varieties. The significant amount of new collections since those available to Fosberg and Sachet since 1981 have shown that there is essentially complete intergradations among these characters and there are no clear ecologically or geographically based morphological patterns, and we have therefore placed these names into synonymy. The only pattern of variation noted is the large-leaved more glabrate plants discussed under *C. feaniana* that may represent hybridization on Fatu Hiva. Another case of possible hybridization on Tahuata is noted by the collections Wood 6571, which is included in *C. ootensis*, but is intermediate toward *C. feaniana*. Wood 6570 collected close by is typical of *C. feaniana*.

**9. *Cyrtandra tahuatensis* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 31. 1981.**

[http://species-id.net/wiki/Cyrtandra\\_tahuatensis](http://species-id.net/wiki/Cyrtandra_tahuatensis)

Fig. 11

**Type.** Marquesas Islands: Tahuata: Above Hamatea, on central crest of U'ua'o, 850 m, 31 May 1975, *J.-C. Thibault* 83 (holotype: US-2969232! & US-2969234!, mounted on 2 sheets; isotype: US!).

**Description.** Shrub to 1–4 m tall; stems ferruginous pubescent. Leaves opposite, densely ferruginous pubescent, elliptic to broadly elliptic, 12–22 × 5–9.5 cm, apex acuminate, base attenuate, margins serrate, petioles 2–5 cm long. Flowers 1–3 in cymes to 20 cm, peduncles 6–8.5 cm long, ca. 2–3 mm in diameter, pedicels 20–35 mm, bracts ca. 4 mm; calyx green, 12–20 mm, divided almost to base, densely ferruginous pubescent deciduous; corolla ca. 25 mm long, tube cylindrical, 18–20 mm long, lobes suborbicular; ovary ca. 8–14 mm, densely pilose, style 4–5 mm, densely pilose. Immature fruit narrowly ovoid, ca. 15 mm long, densely pubescent.

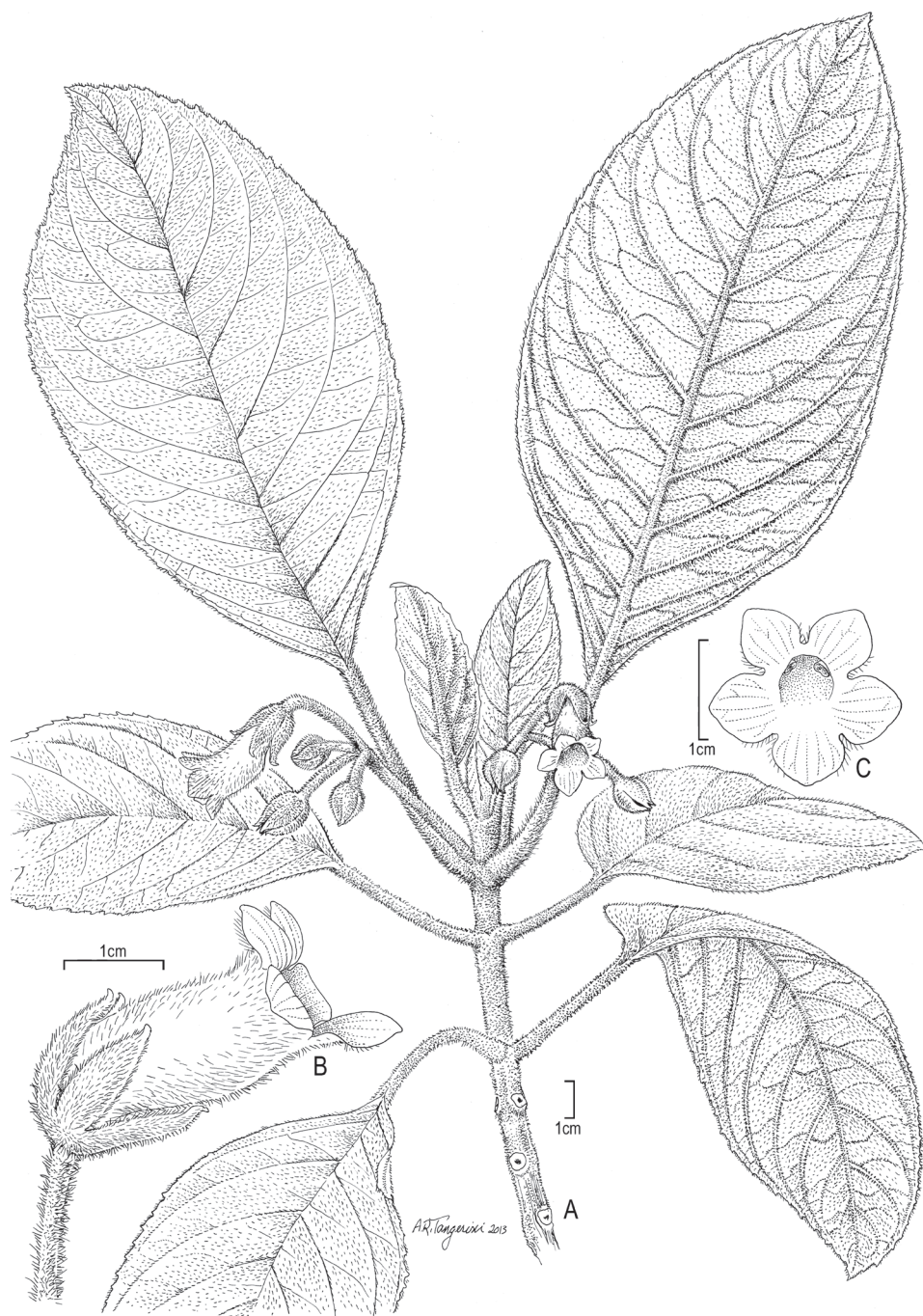
**Distribution.** Marquesas Islands, occurring on Hiva Oa and Tahuata, from 690 to 830 m.

**Ecology.** *Cyrtandra tahuatensis* is known from ridges and summit areas in wet forest and shrubland with shrubs and trees such as species of *Coprosma*, *Crossostylis*, *Freycinetia*, *Ilex*, *Melicope*, *Metrosideros*, *Polyscias*, and *Weinmannia*.

**Conservation status.** IUCN Red List Category: Endangered EN B1ab(i,ii,iii) + 2ab(i,ii,iii). B2: total area of occupancy less than 5000 km<sup>2</sup> (ca. 376 km<sup>2</sup>). B1a, severely fragmented; B1b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra tahuatensis* on Hiva Oa (ca. 315 km<sup>2</sup>), and Tahuata (ca. 61 km<sup>2</sup>) is restricted to mountain slopes and summits, indicated as an endangered environment that is threatened by human activity (deforestation and fire), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Hiva Oa:** Mt. Ootua, 750 m, 27 February 1975, Oliver & Schäfer 3223 (BISH, US); road from Atuona to Puamau, just below Mt. Ootua, 660–690 m, 22 January 1975, Sachet, Oliver & Schäfer 2127 (BISH, CBG, CHR, NSW, PTBG, US). **Tahuata:** ridge from Amatea to Moteve passing Meikaea, view down is on village of Hanatetena, on W side of ridge, 823 m, 13 July 1997, Perlman, Wood & Luce 15976 (MO, NY, P, PAP, PTBG, US, WU); ridge E of trail ridge up to Amatea from Kuaea, W facing slope, 774 m, 9°56'S, 139°4'W, 18 July 1997, Perlman, Wood & Luce 16010 (BISH, F, HAST, K, MO, NY, P, PAP, PTBG, US, WU); summit ridge near Haaiputeomo, satellite dish region NE of Vaitahu, 762–823 m, 9°57'19"S, 139°5'7.4"W, 17–19 July 1997, Wood 6553 (PTBG), Wood 6563 (AD, BISH, HAST, MO, NY, P, PAP, PTBG, US, WU); Amatea region, locations around Haaiputeomo satellite dish (parabowl), 823 m, 9°9.2'S, 139°8'W, 4 Jul 2003, Wood 10266 (PAP, PTBG, US). **Fatu Hiva:** Mounanui slopes,





**Figure 11.** *Cyrtandra tabuatensis* Fosberg & Sachet **A** Habit, Wood 6563 (US) **B** Flower, lateral view, Perlman 18399 (US, PTBG) and photographs by Wood from greenhouse specimens grown at NTBG **C** Flower, face view, Perlman 18399 (US, PTBG) and photographs by Wood from greenhouse specimens at NTBG.

from Teavapuhiau pass, in gulches below mt., 680 m, 10°28'49.7"S, 138°38'17.0"W, 6 Feb 2003, Perlman 18399 (BISH, P, PAP, PTBG, US); slopes of Mounanui, 719 m, 10°28'6.63"S, 138°38'18"W, 16 July 2005, Perlman 19667 (BISH, P, PAP, PTBG, US); Crete du Mt. Mounanui, 805 m, 10°28'S, 138°37'W, 26 July 1988, Florence & Perlman 9589 (PTBG, US).

**Discussion.** *Perlman 18399*, *Wood 6563*, and *Wood 10266* were identified as *Cyrtandra ootensis* var. *mollissima* in the molecular study of Clark et al. (2009), but are here considered to represent *Cyrtandra tahuatensis*.

**10. *Cyrtandra revoluta* Fosberg & Sachet, Smithsonian Contr. Bot. 47: 31. 1981.**  
[http://species-id.net/wiki/Cyrtandra\\_revoluta](http://species-id.net/wiki/Cyrtandra_revoluta)

**Type.** Marquesas Islands: Fatu Hiva: Base of Mt. Natahu, on cliff face, 828 m, 1–3 August 1977, B. H. Gagné (S. L. Montgomery coll.) 1276 (holotype: BISH-510504!; isotype: US!).

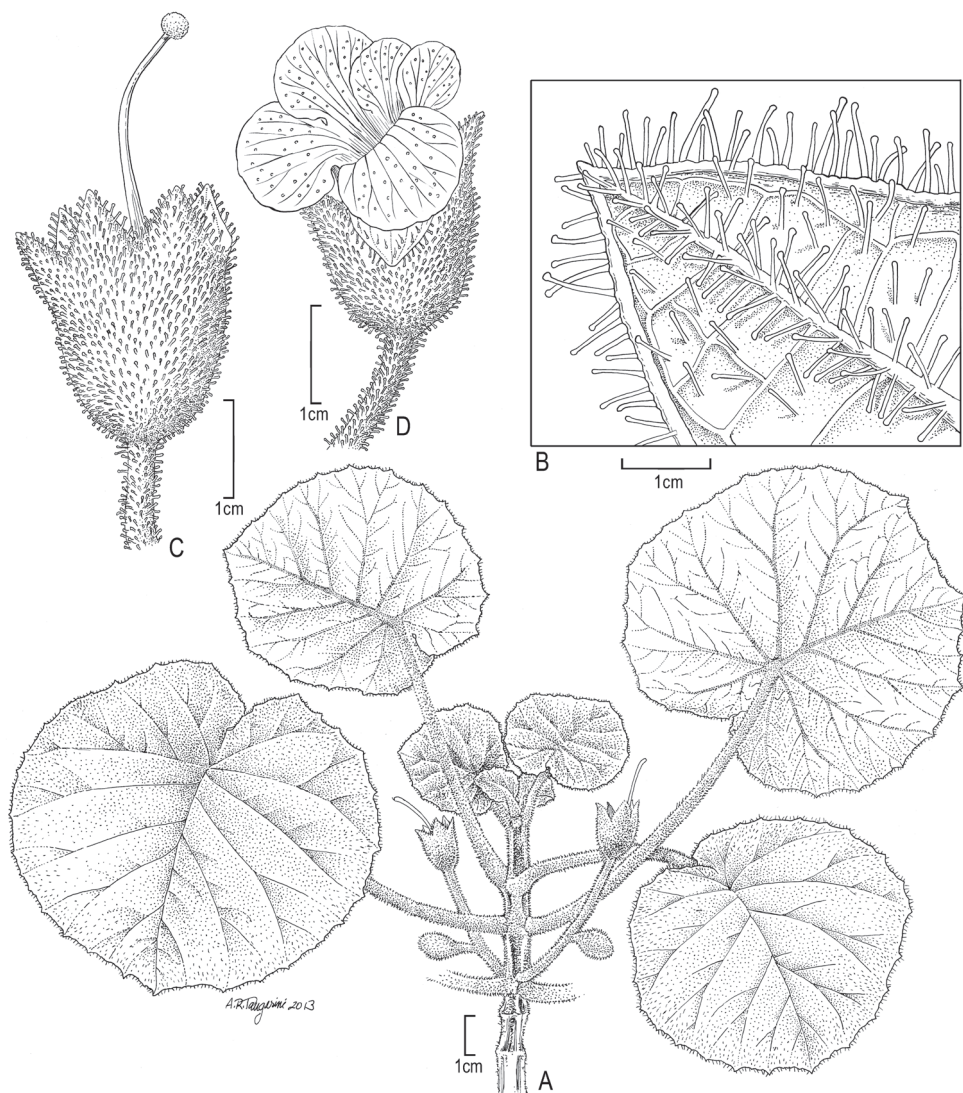
**Description.** Shrub ca. 0.2–0.3 m, with thick fleshy stems, densely woolly pubescent. Leaves opposite, very crowded on upper 2–3 nodes, stiff-coriaceous, elliptic, 7–10 × 3–5 cm, margins strongly revolute, apex obtuse, bases attenuate to cuneate, upper surface thinly long pilose, glabrate, lower surface densely ferruginous pubescent, petioles 0.5–1 cm. Flowers in condensed cymes, 2–2.5 cm, crowded between the leaves, bracts elliptic, ca. 10–15 mm long, peduncles 5–8 mm, ca. 1–2 mm in diameter, pedicels 6–13 mm; calyx ca. 13–15 mm long, divided ca.  $\frac{3}{4}$  its length; corolla white (none available on specimen). Berry unknown.

**Distribution.** In the Marquesas known only from the type collections on Fatu Hiva at 830 m.

**Ecology.** The type was collected on a cliff face, but the specific ecology of *Cyrtandra revoluta* is unknown.

**Conservation status.** IUCN Red List Category: Critically Endangered CR B2a + 2b (i, ii, iii). B1, total extent of occurrence less than 100 km<sup>2</sup> (ca. 85 km<sup>2</sup>), a,b, known from a single location; B2a, estimated area of occupancy estimated to be less than 10 km<sup>2</sup> [one collection known]; B2b (i–iii), habitat continuing decline inferred. The estimated area of occupancy for *Cyrtandra revoluta* on Fatu Hiva (less than 10 km<sup>2</sup>) is indicated as an endangered environment, threatened by human activity (deforestation and fire), feral animals, and invasive plant species, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Discussion.** *Cyrtandra revoluta* is quite distinctive in its short stature and its stiff-coriaceous, revolute leaves. It is known from only one incomplete specimen making assessment of its relationships difficult. The deeply divided, green calyx suggests that it is part of the divided calyx group.



**Figure 12.** *Cyrtandra tovana* F. Br. **A** Habit **B** Leaf apex abaxial view **C** Calyx with pistil **D** Flower. Drawn from Florence 4324 (BISH).

**11. *Cyrtandra tovana* F. Br., Bernice P. Bishop Mus. Bull. 130: 271. 1935.**

[http://species-id.net/wiki/Cyrtandra\\_toviana](http://species-id.net/wiki/Cyrtandra_toviana)

Fig. 12

**Type.** Marquesas Islands: Nuku Hiva: Tovii, 800 m, October 1922, E. H. Quayle 1279 (holotype: BISH-509964!).

**Description.** Shrubs 1.5–2 m tall; stems usually few. Leaves opposite, borne on upper few nodes, peltate, suborbicular, 7–10 × 6–9 cm, ferruginous glandular pubescent, margins coarsely dentate, petioles 5–10 cm. Cymes few-flowered, ca. 2.5–3 cm; bracts ca. 5–6 mm, deciduous, peduncles ca. 10 mm, ca. 1.5–2 mm in diameter, pedicels 12–25 mm; calyx campanulate, 10–17 mm, densely ferruginous glandular pubescent, divided ca. ¼–1/3 of length, lobes acute, 4–5 mm; corolla funnelform, tube ca. 25–35 mm, the lobes rounded, ca. 6–10 mm; ovary conical-ovoid, 5 mm, glabrous; style ca. 13 mm long, glabrous in the lower portion, slightly pubescent near the apex. Berry ovoid, ca. 15 mm long.

**Distribution.** Marquesas Islands, very rare or perhaps extinct, endemic to Toovii Plateau, Nuku Hiva, ca. 800–900 m. It is known from three collections collected in 1844, 1922, and the most recent in 1982.

**Ecology.** *Cyrtandra toiviana* is known only in *Metrosideros collina* woodland.

**Conservation status.** IUCN Red List Categories: Critically Endangered CR B2a + 2b (i, ii, iii). B1, extent of occurrence estimated to be less than 100 km<sup>2</sup>; B2, area of occupancy estimated to be less than 10 km<sup>2</sup> (ca. 9 km<sup>2</sup>), and B2a, a single population known; b (i–iii), habitat continuing decline inferred. The suitable habitat for *Cyrtandra toiviana* on Nuku Hiva (ca. 340 km<sup>2</sup>) is indicated as an endangered environment, threatened by human activity (deforestation), feral animals, and invasive plants, reducing the extent of the forest (Florence and Lorence 1997; Mueller-Dombois and Fosberg 1998; Meyer and Salvat 2009).

**Specimens examined. Marquesas Islands. Nuku Hiva:** 1844, Le Bâstard (P [2]); Toovii, Quayle 1279 (BISH); Toovii, épaulement au-dessus du réservoir, 895 m, 8°52'S, 140°9'W, 7 December 1982, Florence 4324 (BISH, P).

**Discussion.** *Cyrtandra toiviana* is unique within Marquesan *Cyrtandra* with its peltate leaves and small campanulate calyx. In fact, it could well represent a separate introduction of the genus to the Marquesas Islands.

## Putative hybrids

*Cyrtandra feaniana* × *C. tahuatensis*

**Tahuata:** au-dessus de Hamatea, sur la crête centrale de U'ua'o, 850 m, 31 May 1975, Thibault 79 (US).

*Cyrtandra uapouensis* × *C. kenwoodii*

**Ua Pou:** central Ua Pou including the summit crest regions around Oave and the near-by peak of Matahenua, 2950–3030 ft [899–924 m], 9°23'45.4"S, 140°4'43.3"W, 2–4 July 2004, Wood & Perlman 10830 (PTBG); ridge just north of Oave, between Oave and Matahenua, high mountain peaks along main backbone ridge, 945 m,



9°23'45.5"S, 140°4'43.3"W, 3 July 2004, Perlman & Wood 19082 (BISH, P, PAP, PTBG, US); Teavahaakiti, steep slopes of main ridge to S of Oave, N & E facing cliffs between Teavahaakiti & Tekohepu, 869 m, 5 July 1997, Perlman & Wood 15923 (PAP, PTBG, US, WU); Tekohepu, summit ridge, 762–914 m, 9°24'31"S, 140°4'21"W, 4–5 July 1997, Wood & Perlman 6477 (PAP, PTBG, US).

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## References

- Atkins H, Bramley GLC, Clark JR (in press) Current Knowledge and Future Directions in the Taxonomy of *Cyrtandra* (Gesneriaceae), with a New Estimate of Species Numbers. *Selbyana*.
- Brown FBH (1935) Flora of southeastern Polynesia. III. Dicotyledons. *Bernice P. Bishop Museum Bulletin* 130: 1–386.
- Burtt BL (2001) A survey of the genus *Cyrtandra* (Gesneriaceae). *Phytomorphology*. Golden Jubilee Issue: 393–404.
- Burtt BL, Wiehler H (1995) Classification of the family Gesneriaceae. *Gesneriana* 1: 1–4.
- Clark JR, Ree R, Alfaro M, King MG, Wagner WL, Roalson EH (2008) A comparative study in ancestral range reconstruction methods: Retracing the uncertain histories of insular lineages. *Systematic Biology* 57: 693–707. doi: 10.1080/10635150802426473

- Clark JR, Wagner WL, Roalson EH (2009) Patterns of diversification and ancestral range reconstruction in the Southeast Asian-Pacific angiosperm lineage *Cyrtandra* (Gesneriaceae). *Molec. Phylogen. Evol.* 53: 982–994. doi: 10.1016/j.ympev.2009.09.002
- Cronk QCB, Kiehn M, Wagner WL, Smith JF (2005) Evolution of *Cyrtandra* (Gesneriaceae) in the Pacific Ocean: The origin of a supertramp clade. *Amer. J. Bot.* 92: 1017–1024. doi: 10.3732/ajb.92.6.1017
- Florence J, Lorence DH (1997) Introduction to the flora and vegetation of the Marquesas Islands. *Allertonia* 7: 226–237.
- Fosberg FR, Sachet M-H (1981) Polynesian Plant Studies 6–18. *Smiths. Contr. Bot.* 47: 1–38. doi: 10.5479/si.0081024X.47
- Gillett GW (1973) The genus *Cyrtandra* (Gesneriaceae) in the South Pacific. *Univ. Calif. Publ. Bot.* 66: 1–59.
- IUCN (2001) IUCN Red List categories (version 3.1). IUCN Species Survival Commission. Gland, Switzerland. <http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria>
- Lorence DH, Wagner WL (2011) Introduction to Botany of the Marquesas Islands: New taxa, combinations, and revisions. *PhytoKeys* 4: 1–4. doi: 10.3897/phytokeys.4.1781
- Meyer J-Y, Salvat B (2009) French Polynesia, Biology. In: Gillespie RG, Clague DA (Eds) *Encyclopedia of Islands*. University of California Press, Berkeley, 332–338.
- Mueller-Dombois D, Fosberg FR (1998) *Marquesas. Vegetation of the Tropical Pacific Islands*. Springer, New York, 444–460.
- Wagner WL, Lorence DH (1997) Studies of Marquesan vascular plants: Introduction. *Allertonia* 7: 221–225.

# Whatever happened to *Bishopanthus* (Compositae, Liabeae)?

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## Abstract

The enigmatic monospecific *Bishopanthus* of the tribe Liabeae (Compositae/Asteraceae) has never been fully understood. It has not been possible to examine it in detail since it was described, because most of the type material was destroyed shortly after it arrived at the US National Herbarium, the morphology is insufficient to assign it to a subtribe, and the small amount of leaf material that remains is unsuitable for DNA extraction. A detailed description in English, image of the type specimen, photograph, and original illustration are included along with an estimation of where it was collected in the hopes that this information will encourage other field botanists who collect in northern Peru to search for it.

## Keywords

Asteraceae, *Bishopanthus*, Compositae, Liabeae, Neotropics, Peru

## Introduction

Robert Merrill King (1930–2007) was associated with the Smithsonian Institution from 1962 until 1998. During that time he organized many collecting trips to gather Compositae, mostly in the Neotropics. Among the most successful trips made by King, were those with Luther Earl Bishop (1943–1993). Thus, it was during a trip to Peru in early 1983 that Bishop, who frequently left the roadside and hiked into nearby areas, walked up a trail beside a small shop with hanging potted plants and returned within a half hour with a plant that has caused us problems for 30 years.



*Problem 1)* The collection arrived at the US National Herbarium (Smithsonian Institution) only a short time before the publication of a monograph by Robinson (1983a) that was supposed to be a complete summary of the Asteraceous tribe Liabeae. The collection was immediately recognized as a new genus (by HR) and, in effect, it made the monograph he had completed obsolete before it was published. *Bishopanthus* was published later that year in *Phytologia* (Robinson 1983b).

*Problem 2)* The original five ample sheets of the gathering were destroyed except for a few small scraps hidden under a bookcase that ultimately became the type.

*Problem 3)* Attempts by Michael Dillon (F) to collect the plant, based on information from King provided to Robinson, failed to find any sign of the species.

*Problem 4)* The locality data were skimpy and the original collector, Bishop, and the leader of the expedition, King, have since died, so it is not possible to obtain any additional information.

*Problem 5)* Morphological analyses have failed to definitively place the species in a subtribe (Funk et al. 2012). Some of the characters link it to the Liabinae and others to a more remote position, as yet undefined. As a result, the genus is currently designated *insertae sedis*.

*Problem 6)* Dried leaf material that was collected for chemical analysis (Singh et al. 1985) was apparently discarded after the retirement of both Bohlmann & Jakupovic.

*Problem 7)* During the King & Bishop expeditions the herbarium material was placed in alcohol before being dried and so it is not suitable for current methods of DNA analysis.

In summary, what survives of the species is the herbarium specimen that has only the small scraps that became the type (Fig. 1), a color photograph taken by Earl Bishop (Fig. 2; Funk et al. 1996: 550, in black and white), a microscope slide prepared by Robinson from material before the specimens were destroyed (remade from the original Hoyer's solution slide during this study), the results of the chemical analysis by Singh et al. (1985) from a sample sent to him by R.M. King, and a picture of the pollen published in the pollen study of the Liabeae (Robinson and Marticorena 1986). From this material we have reconstructed the plant and an illustration has been produced (Fig. 3).

## Materials and methods

The dried specimen material of *Bishopanthus* (what remained of the type specimen after it was destroyed) consisted of small fragments of leaves, a few small stems, an immature head and one mature head with three broken ray flowers (Fig. 1). The disk flowers fared better because they were protected if somewhat compressed. Additional material consisted of one slide of the dissected disk flowers with a complete ray and a sectioned disk flower showing the anthers and style. From this material Tangerini was able to piece together the leaf fragments to form a few almost whole



**Figure 1.** Image of the holotype of *Bishopanthus soliceps* H. Rob. from the US National Herbarium (US).

leaves and mounted these and other fragments and stems on two archival 4" by 5" cards (Fig. 1). Tiny mylar packets were made to hold the two heads and dissected disk flowers. Drawings of all of the floral details were made using a combination of



**Figure 2.** Field photograph of *Bishopanthus soliceps* H. Rob. by L. E. Bishop for whom the genus was named.

the dried and slide material and the habit was reconstructed from the single photograph which provided an invaluable reference for the structure of the habit and leaf insertion. Conversations with Robinson (who had seen all of the original five duplicates) provided information on the flower position on the stem. The final drawing was done with a variety of polycarbonate pencils (Turquoise Filmograph, Mars Duralar and Mars Dynagraph, and L. & C. Hardtmuth Koh-I-Lar pencils) on Grafix double matte drafting film. These pencils produce a denser black than regular graphite pencils and the subtle gray tones give the impression of the bullate leaf surface and the woolly texture of the involucres. Shading is applied with the softer leads first followed by the harder leads to add fine lines and smaller details. The polycarbonate leads are waxier and do not smudge as much as graphite. Unfortunately the polycarbonate leads went out of production in the mid 1990's so this technique has a limited lifetime dependent on acquisition of the remaining stock of pencils. Some botanical art schools have supplies for illustration classes and perhaps resurgence in interest will spur new production.

The microscope slide was made using Hoyer's solution with a formula as given by Anderson (1954): Distilled water 50 cc; Gum arabic (U.S.P. Flake) 30 grams; Chloral hydrate 200 grams; Glycerin 20 cc. Since the original application of this method, Chloral hydrate has become a controlled substance, which limits access. More important is the impermanent nature of Hoyer's slides unless the cover slips are ringed with waterproof sealant (e.g., clear fingernail polish). The fact that microscope slides in Hoyer's solution can dry up does not mean they should be discarded. The water





**Figure 3.** Illustration of *Bishopanthus soliceps* H. Rob.: **A** habit **B** head in pre-flowering stage **C** flowering head from above **D** involucral bract **E** ray flower **F** disc flower **G** longitudinal view of disc flower **H** achene with pappus. [Illustration by Alice Tangerini]

miscible solution that makes the medium so useful as a rapid mounting medium also allows for recovery of any material on old dried slides. This should be noted by anyone inclined to discard old slides that often contain valuable type material.

Until this paper, *Bishopanthus* was the only genus of the Liabeae that had not been illustrated by Tangerini using the method described above (Robinson 1983a, Funk and Robinson 2001, 2009, Robinson and Funk 2011). Now that we have this final drawing it is possible to look at all of the genera and compare the morphology.

## Systematics

***Bishopanthus* H. Rob., *Phytologia* 54(1): 63. 1983.**

<http://species-id.net/wiki/Bishopanthus>

<http://www.biodiversitylibrary.org/item/46790#page/71/mode/1up>

**Type species.** *Bishopanthus soliceps* H. Rob.

**Type.** Peru; Amazonas, mountains behind Tingo, 6500 Ft., 21 Jan 1983, *R.M. King & L.E. Bishop* 9280 (holotype: US).

**Description.** *Shrubs* to 0.5 m tall, moderately to multi branched; *stems* with latex, pale reddish, internodes short, jointed, densely white-wooly strongly invested by leaf bases. *Leaves* opposite, bases strongly vaginate, vagination usually ca. 5 mm long, longer than the internode, imbricate parts of vaginate bases wooly-tomentose externally; *petioles* short, ca. 0.5 mm long; *blades* oblong-ovate, mostly 2–4 cm long and 8–16 mm wide, base rounded, margins with many distinct small teeth, apex shortly acute, sub-longitudinally trinervate from near base, upper surface bullate with bulging areoles, major nerves sunken and diffusely arachnoid-tomentose, undersurface densely, grayish-wooly tomentose, major veins raised. *Inflorescence* abruptly terminal on leafy branches. *Heads* solitary, over-topped by lateral branches, ca. 10 mm high, ca. 12 mm wide, excluding rays; *involucral bracts* subequal, ca. 25, in ca. 2 series, oblong-lanceolate, 7–8 mm long and ca. 1.5 mm wide, outer bracts with apices reflexed, outer surface distally green, subglabrous, below densely white wooly-tomentose, inner bracts not reflexed distally, acute, subglabrous. *Ray flowers* ca. 20, female; corollas yellow, basal tube 2.5–3.5 mm long, narrowly funnelform with sparse spreading trichomes; *limbs* linear, 11–12 mm long, to 2 mm wide, apices tridentate, basally with minute, short biseriate trichomes, distally rather densely arachnoid-tomentose and gland-dotted. *Disc flowers* ca. 25, bisexual; *corollas* yellow, 7.0–7.5 mm long, basal tube ca. 2.5 mm long, hirtellous with sparse straight-spreading trichomes, trichomes with one row of cells, throat ca. 2.5 mm long, subcylindrical, below with few short biseriate trichomes and fewer uniseriate trichomes, distally with almost no trichomes and sparsely gland-dotted, lobes linear, ca. 2.8 mm long and 0.5 mm wide, near margins distally with few stomata and many glandular dots, rather densely arachnoid-tomentose. *Anther* filament collars ca. 0.25 mm long, with cells shortly oblong, cell walls firm, in-ornate; *thecae* ca. 2.5 mm long, endothecial cells obscure, somewhat oblong, shields tenuously irregularly areolate; *apical appendage* oblong-ovate, ca. 0.4–0.5 mm long, 0.22 mm wide, glabrous. *Style* base with distinct expanded node, hispidulous upper part of style shaft ca. 3 mm long; *branches* ca. 1 mm long. *Achenes* ca.



2.7 mm long, 8–10-ribbed, with short trichomes, setulae and glands, setulae numerous, contorted, distally on achenes longer, trichomes very sparse, with single row of cells, glands sparse, short-stipitate, with minute capitula; *carpopodia* shortly stopper-shaped, sub-annuliform, ca. 0.35 mm wide, 0.15 mm high; with cells in 12–15 series, 12–15  $\mu\text{m}$  in diameter, with thickened walls. *Pappus* setae densely congested, larger setae ca. 35, sometimes irregularly elongate, mostly 4.5–6.0 mm long, apices tenuous, outer series of setae shorter, narrower, mostly 0.7–1.0 mm long, scabrous, simple. *Pollen* ca. 37  $\mu\text{m}$  in diameter, irregularly spinulose.

**Diagnosis.** Small shrub with milky sap; opposite leaves that are tri-nervate with a bullate upper surface and an under surface covered with a dense, grayish-wooly tomentum; two rows of subequal involucre bracts; short (~ 1 mm) style branches; 8–10 ribs on the achenes and a bi-seriate pappus of subequal bristles (Table 1).

All members of the Liabeae have opposite leaves although some have very short internodes so they appear to have rosettes. Also, all members have milky sap and/or woolly light colored tomentum on the undersurface of the leaves.

The specimen label says that the plants are ½ m tall, have yellow flowers and lots of milky sap. An examination of the field notebook from the King & Bishop expedition did not provide any additional information about the plant or the location, however, an examination of their route that day shows that on the 21st of January their collecting started as they drove south from Tingo (6°22'18.14"S, 77°54'38.54"W). Their first stop was 3 km south of Tingo and they proceeded south stopping occasionally until they reached their fifth stop at 31 kms south of Tingo, probably near the village of Yerbabuena (6°33'57.92"S, 77°49'49.35"W). The first five stops are all listed as ca. 5500 ft in elevation (based on Google Earth this seems a bit low) but with different kilometer distances. The next stop (# 6) is where they collected *Bishopanthus*, however at this point they stopped giving the kilometers and just said "mountains behind Tingo ca. 6500 ft" and it is the only collection at that stop. The final stop of the day (# 7) has the same location with an elevation of 7000 ft. At the 7<sup>th</sup> stop they collected *Cronquistianthus bishopii* King & H. Rob., also restricted to this area. The next day (22 January 1983) the first collecting stop was 61 kms along the road from Chachapoyas NW of Jaen. Evidently they were working out of Chachapoyas. We think that on the 21st of January they turned around at the 5th stop (31 km) and headed back to Chachapoyas, passed through Tingo, and stopped somewhere on the more eastern road between Tingo and Chachapoyas at 6500 Ft. The elevation on this road reaches 9000 ft. According to Google Earth the elevation is just about correct at the following coordinates: 6°21'40"S; 77°54'4"W. Of course this is a guess because the real location has never been found.

## Conclusion

In their 2012 paper Funk et al. suggested that the shrubby habit and bullate leaves of *Bishopanthus* were similar to the taxa found in the basal grade of the subtribe Liabinae

**Table 1.** Diagnostic characters of the genera of the Liabaceae. Note the dual placement of *Bishopanthus*.

Genus	Habit	latex	veination	bullate lvs	under surface	Ray fls	anther color	Pollen spines	ray fl	style	achene	inner pappus	outer pappus
<i>Cacosmia</i>	Erect shrubs	yes	3	yes	wooly	yes	light yellow	irregular	yellow	short	4–5 angled	none	none
<i>Bishopanthus</i>	<b>Shrub 0.5 m</b>	<b>yes</b>	<b>3</b>	<b>yes</b>	<b>wooly</b>	<b>yes</b>	<b>light yellow</b>	<b>irregular</b>	<b>yellow</b>	<b>short</b>	<b>8 to 10 ribs</b>	<b>bristles</b>	<b>bristles</b>
<i>Ferreyranthus</i>	Shrub-sm trees	no	pinnate	yes	wooly	yes	light yellow	irregular	yellow	long	~10 ribs	bristles	bristles
<i>Oligactis</i>	Shrubs/vines	no	pinnate	yes	wooly	yes	light yellow	irregular	yellow	long	5 to 8 ribs	bristles	scales/ bristles
<i>Dillandia</i>	Herbs	no	pinnate	yes	wooly	yes	light yellow	irregular	yellow	long	7 to 10 ribs	bristles	lost
<i>Sampera</i>	Shrubs	no	pinnate	yes/no	wooly	yes	light yellow	irregular	yellow	long	5 to 8 ribs	bristles	scales
<i>Liabum</i>	Perennial herbs/subshrubs	no	pinnate/ weakly 3	no	wooly	yes	light yellow	irregular	yellow	long	10 ribs	bristles	bristles
<i>Sinclairia</i>	perennial herbs/woody vines/ subshrubs/sm trees	yes	3	no	wooly	yes & no	light yellow	irregular	yellow	long	8 to 10 ribs	bristles	scales
<i>Sinclatriopsis</i>	Shrub	yes	3	no	wooly	yes	light yellow	irregular	yellow	long	~10 ribs	bristles	lost
<i>Munnozia</i> 1	Shrubs	yes	3	no	wooly	yes	dark	regular	white	short	6 to 10 ribs	bristles	scales
<i>Chrysactinium</i>	Perennial herbs	yes	3	no	wooly	yes	dark	regular	yellow	short	~10 ribs	bristles	none
<i>Munnozia</i> 2 & 3	Annual/perennial herbs; shrubs/subshrubs	yes	3	no	wooly	yes	dark	regular	yellow	short	6 to 10 ribs	bristles	scales
<i>Chionopappus</i>	Erect shrubs	yes	3	no	wooly	yes	light yellow	irregular	red	short	8 to 10 ribs	plumose	none
<i>Erato</i>	Perennial herbs/subshrubs	yes	palmate	no	glabrous	yes	dark	irregular	yellow	short	4-sided	bristles	none
<i>Philoglossa</i>	Decumbent or creeping herbs	yes	3	no	glabrous	yes	dark	irregular	yellow	short	2-compressed	none	none
<i>Panaphelium</i>	Perennial herbs	yes	pinnate	yes/no	wooly	yes	light yellow	irregular	yellow	short	~10 ribs	bristles	bristles
<i>Pseudonoseris</i>	Perennial herbs	yes	pinnate	yes/no	wooly	yes	light yellow	irregular	red	short	~10 ribs	bristles	scales
<i>Bishopanthus</i>	Shrub 0.5 m	yes	3	yes	wooly	yes	light yellow	irregular	yellow	short	8 to 10 ribs	bristles	bristles
<i>Stephanbeckia</i>	Perennial herbs	yes	3	no	wooly	yes	light yellow	irregular	yellow	short	2-compressed	plumose	none
<i>Microliabum</i>	Annual-perennial herb/ subshrub	yes	3	no	wooly	yes	light yellow	irregular	yellow	short	8 to 10 ribs	scales/ bristles	scales/ bristles
<i>Bishopanthus</i>	<b>Shrub 0.5 m</b>	<b>yes</b>	<b>3</b>	<b>yes</b>	<b>wooly</b>	<b>yes</b>	<b>light yellow</b>	<b>irregular</b>	<b>yellow</b>	<b>short</b>	<b>8 to 10 ribs</b>	<b>bristles</b>	<b>bristles</b>

(e.g., *Ferreyranthus*), but those genera lack latex and have pinnate venation and long style branches, in contrast to *Bishopanthus* (Table 1). *Bishopanthus* shares a number of characters with *Cacosmia* which is sometimes placed as the sister group of the Liabinae (Table 1). But *Cacosmia* has lost its pappus and has a unique (to Liabeae) achene (Table 1; first placement). In addition, *Cacosmia* is unique in the tribe in that it has a small cylindrical head (5 ray flowers and 5–6 disc flowers) with a highly imbricate involucre (5 series and mostly ranked) while *Bishopanthus* has a broadly campanulate head (like most of the other genera in the tribe) that is larger (20/25) and an involucre of two subequal series; it also has a very different habit. Now that we have the additional information on *Bishopanthus*, it looks as though it may be related to the *Austroliabum* element of *Microliabum* (Table 1; second placement) except that it does not have bulate leaves. Such a relationship would place it in the Paranepheliinae subtribe. Typical *Austroliabum* has been placed with some doubt as a synonym of *Microliabum*. Two of the typical species of *Microliabum* have been sequenced and now we need fresh material of *Bishopanthus* so we can see if either of our predictions is correct.

## References

- Anderson LE (1954) Hoyer's solution as a rapid mounting medium. *The Bryologist* 57: 242–244.
- Dillon MO, Funk VF, Robinson H, Chan R (2009) Chapter 27. Liabeae. In: Funk VA, Sussanna A, Stuessy TF, Bayer RJ (Eds) *Systematics, Evolution, and Biogeography of Compositae*. International Association of Plant Taxonomists, Vienna, Austria, 417–427.
- Funk VA, Robinson H (2001) A bully new genus from the Andes (Compositae: Liabeae). *Systematic Botany* 26: 216–225.
- Funk VA, Robinson H (2009) *Sampera*, a new genus of Liabeae (Compositae or Asteraceae) from the northern Andes. *Proceedings of the Biological Society of Washington* 122(2): 155–161. doi: 10.2988/08-31.1
- Funk VA, Robinson H, Dillon MO (1996) Liabeae: Taxonomy, phylogeny and Biogeography. In: Hind DJN, Beentje HJ (Eds) *Compositae: Systematics*. Proceedings of the International Compositae Conference, Kew (1994). Royal Botanic Gardens, Kew, 1: 545–567.
- Robinson H (1983a) A generic review of the tribe Liabeae (Asteraceae). *Smithsonian Contributions to Botany* 54: 1–69. doi: 10.5479/si.0081024X.54
- Robinson H (1983b) Studies in the Liabeae (Asteraceae). XVI. New taxa from Peru. *Phytologia* 54(1): 62–65.
- Robinson H, Funk VA (2011) *Stephanbeckia plumosa* (Liabeae: Asteraceae): A new genus and species from southern Bolivia. *Brittonia* 63: 75–82. doi: 10.1007/s12228-010-9136-2
- Robinson H, Marticorena C (1986) A palynological study of the Liabeae (Asteraceae). *Smithsonian Contributions to Botany* 64: 1–50. doi: 10.5479/si.0081024X.64
- Singh P, Jakupovic J, Bohlmann F, King RM, Robinson H (1985) Highly oxygenated guaianolides from *Bishopanthus soliceps*. *Phytochemistry* 24(9): 2110–2112. doi: 10.1016/S0031-9422(00)83133-7

