The lure and intrigue of *Yunquea tenzii* Skottsb. (Cardueae: Centaureinae)

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ABSTRACT

We discuss the history of the monospecific genus *Yunquea*, which is endemic to the highly inaccessible peak El Yunque on Robinson Crusoe Island, Juan Fernández Archipelago. The allure of the genus rests largely on the difficulty of reaching the one known population; we trace the history of the few persons who succeeded in climbing to the summit where the genus occurs. The genus remains of interest to botanists because of the lack of flowering material, having been described only from leaves! During the near century since its description, *Yunquea tenzii* remains a mysterious species. Molecular phylogenetic studies identify the Juan Fernández endemic *Centaurodendron* and the continental genus *Plectocephalus* as closest relatives. However, resolution of relationships among the four genera has not been achieved, leaving biogeographic relationships unknown. Whether *Yunquea tenzii* evolved anagenetically from continental colonists or cladogenetically from a common ancestor with *Centaurodendron* remains a mystery. Viable seeds have been collected from the natural population, suggesting sporadic sexual reproduction, but lack of mature floral tissue precludes insights into the floral evolution and reproductive biology of *Yunquea*.

Keywords: Chile, conservation, evolution, island biology, Juan Fernández, Robinson Crusoe

Imagine a genus of Compositae that is nearly impossible to collect, virtually inaccessible, for which only poor specimens exist, and whose taxonomic affinities are still not entirely clear. This is the genus *Yunquea* Skottsb., with the single species *Y. tenzii* Skottsb. This reclusive taxon grows only on the top of El Yunque (Figure 1), the highest peak of the oceanic Robinson Crusoe Island in the Juan Fernández Archipelago, 667 kms west of continental Chile in the Pacific Ocean (insert map).

The history of attempts to collect *Yunquea tenzii* goes back to the first efforts to scale El Yunque (Woodward, 1969; Stuessy, 2020). In 1794 the governor of the island, Fernando Amador de Amaya, wanted to inventory the plants on the island, including the tallest peak. To achieve this objective, he offered a cash incentive and even freedom to any convict who would be willing to attempt the climb and return with information. Two prisoners, Ramón Negrete and Francisco Clavel, responded to this challenge, and on 19 November they successfully scaled the peak, which measures 915 m elevation, up the ridge from El Camote. Although the height of El Yunque is child's play for any experienced mountaineer, the volcanic rock is friable, easily becoming dislodged, and this is what makes the ascent dangerous. Due to fog, the adventurers stayed overnight until visibility

Robinson Crusoe & Santa Clara Islands, Juan Fernández Archipelago

Large triangle shows the location of the single population of *Yunquea tenzii* Skottsb. on Cerro El Yunque on Robinson Crusoe Island in the Pacific. Smaller triangles indicate other prominent peaks on the island. The village of San Juan Bautista on Cumberland Bay is the only permanent settlement on the island, with some 900 residents (Stuessy, 2020).

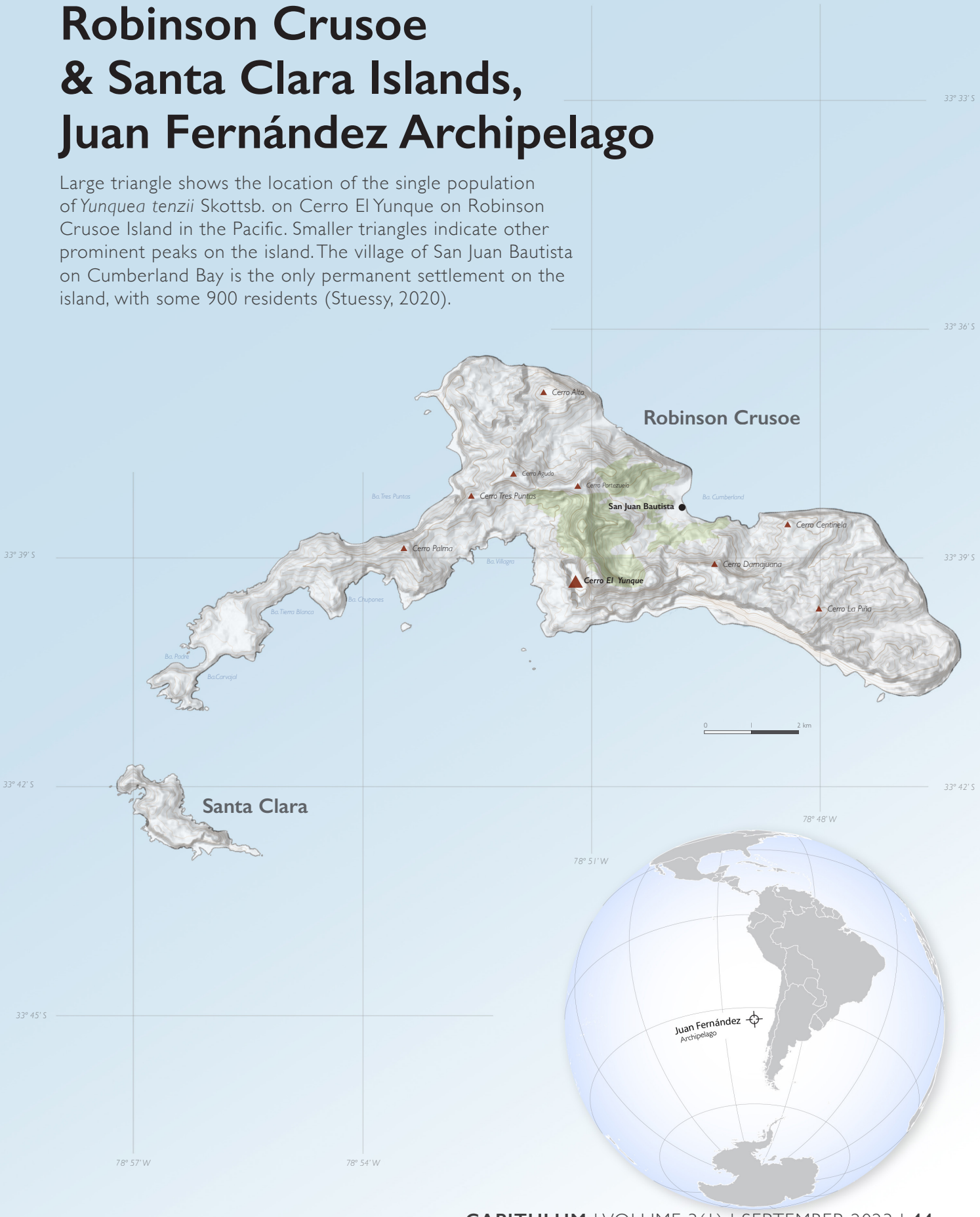

Figure 1. El Yunque ("The Anvil"), the tallest peak on Robinson Crusoe Island, Juan Fernández Archipelago. **A.** View of El Yunque behind the village of San Juan Bautista. **B.** View from El Camote, at the base of the southern (and only) route up to the summit of El Yunque. From Stuessy (in press).

returned for a safe descent on the following day, but the fog had made it impossible to provide a suitable inventory for the governor. Hence, they were sent back on 24 November, this time with the soldiers Pedro José Gutiérrez and Marcel Boza, staying two days until returning on 26 November. They made observations on the vegetation and endemic flora (from Woodward, 1969: 97-98), noting the tree "cinamon" (= canelo; *Drimys confertifolia* Phil.), the robust herb "pangue" (*Gunnera bracteata* Steud. ex Benn.), plus ferns and grasses. To indicate to the townspeople and governor that they really had climbed to the summit, they set fire to the top, which supposedly burned for "eight days" (Woodward, 1969: 98). This was a beginning for understanding the botanical resources of El Yunque, but these early efforts provided only a sketch of the complete flora.

The first naturalist to attempt to scale El Yunque was Dr. Otto Tenz. He was from the Institut für allgemeine Botanik in Hamburg, Germany (Skottsberg, 1929), who came to Chile and made a trip to Robinson Crusoe Island, staying about 1.5 months in 1922. In the early decades of the 20th century, a number of the islanders had now scaled El Yunque as a physical challenge to gain prestige within the village of San Juan Bautista. Uberlindo Andauer was one of these adventurers, and he offered to escort Tenz to the top. Their climb began early on 7 February, arriving successfully at the summit, which provided time for observations and collections. Weather mandated staying on the peak until the following day, followed by a safe descent to the village.

Tenz had made the first botanical collections from the summit of El Yunque, and after his death these were sent for study to Carl Skottsberg, a Swedish botanist of long experience with the flora of the archipelago (Skottsberg, 1921). Among the collections were two large leaves, which Tenz had tentatively assigned to the endemic Compositae genus, *Dendroseris* D. Don (Cichorieae). Skottsberg realized that this referral was inaccurate, but dealing with only two leaves made assignation problematic. He noticed, however, that the leaves bore many shiny glandular trichomes on the upper surface, similar to what he had observed on leaves of another endemic genus of the archipelago, *Centaurodendron* Johow (Cardueae; Johow, 1896; Skottsberg, 1938). But the structure of the leaves of this enigmatic taxon--large (more than 30 cm long), ovate, and serrate-dentate at the margins--did not fit with the species of *Centaurodendron* known at that time (*C. dracaenoides*; a second species, *C. palmiforme* Skottsb., was described by Skottsberg in 1957, and a third, *C. schilleri* Penneck., N. Garcia & Susanna, has recently been described as new from the far island, Alejandro Selkirk, by Penneckamp et al., 2022). Skottsberg described it as a new genus, certainly Asteraceae, with a possible connection to *Centaurodendron*. Skottsberg's understanding of the flora was sufficiently expert that he had confidence in describing this new genus and species (Skottsberg, 1929), *Yunquea tenzii*, based on only two isolated leaves!

During Skottsberg's last trip to the Juan Fernández Archipelago in 1955 (he died in 1963; Peterson, 1964), a young German writer and botanist, Günther

Figure 2. One of the few herbarium specimens of *Yunquea tenzii* Skottsb., collected in 1957 by G. Kunkel, at Chile National Museum of Natural History herbarium (SGO). Image courtesy of SGO herbarium.

Kunkel, living on Robinson Crusoe Island, offered to make the ascent in the company of the local resident, Jorge Charpentier. This effort took place on 6 March and was more successful with regard to inventorying the flora (Kunkel, 1957) and also regarding *Yunquea*, from which they brought back a leaf and old inflorescences with fruits (Figure 2). Skottsberg successfully germinated some of these fruits in the Bergius Botanical Garden in Stockholm, but none of the seedlings survived to flowering stage. Based on the new, but scant material, Skottsberg (1958) confirmed the familial referral of *Yunquea*, and now armed with three leaves, portions of old stems, and several inflorescence stalks with very old heads (Figure 2), he provided an updated description of the genus and also emphasized the relationship with, but still generically distinct from, *Centaurodendron*. Material from both genera were sent by Skottsberg to Sherwin Carlquist at the Rancho Santa Botanic Garden (now the California Botanical Garden), and he published on the vegetative and reproductive anatomy (Carlquist, 1958), concluding that the genera were related to each other, but generically distinct, and with general affinities with *Centaurea* L., *Plectocephalus* D. Don, and *Serratula* L.

These previous efforts stimulated us to attempt an ascent of El Yunque. The idea was to employ a professional rock climber to make the ascent and then use ropes and harnesses for us to struggle to the top. We submitted a proposal in 1983 to the National Geographic Society to obtain funding for the effort. The objectives were to complete the inventory of the vegetation on the summit of El Yunque, collect more rock samples for additional radiometric dating, and most importantly, to find, inventory, and collect *Yunquea*. The technical climber on the project was Timothy H. Jefferson, a Ph.D. in geology and paleobotany from Cambridge University. But one month after the proposal was submitted, the shocking news came that Tim had been killed on 12 September 1983 in an avalanche in Peru while on an expedition with the Institute of Polar Studies from Ohio State University (Holland, 1983). He was only 27 years old and just starting his academic career (and entire life). We worked to find a substitute climber, but this tragedy cast such an ominous shroud that we decided not to pursue the project further.

Two recent successful efforts to ascend El Yunque have taken place. Philippe Danton, a botanist from Grenoble, France, made the ascent on 15 February 1999 with the national park (CONAF: Corporación Nacional Forestal) guides Ramón Schiller, his son Rodrigo, Alfonso Andauer, and Oscar Chamorro. Again, the objective was to inventory the vegetation and flora of this peak, which at the summit has a sloping flat surface of 3 ha (7.4 acres; hence the name, "The Anvil" in Spanish). Danton (2000) did publish a good description of the vegetation with a list of the flora, including a photograph of a plant of *Yunquea*, with its rosette of ovate leaves (Figure 3), but it was once again a sterile individual, and it was not collected. In total, he observed 25 sterile adults and about 100 juveniles (*in litt.*). Another scaling of El Yunque occurred in 2015 by several CONAF guides (Alarcón, 2015), and several photographs of *Yunquea* were taken, again in sterile condition. These recent explorations document that *Yunquea tenzii* still survives on the top of El Yunque, but little still

Figure 3. Isolated individual of *Yunquea tenzii* Skottsb. showing rosette tree habit (copyright Ph. Danton, photo RC3612, Feb 1999)

is known about reproductive structures, pollination mechanisms, and flowering phenology.

Due to lack of detailed reproductive morphological information on *Yunquea*, investigations have turned to molecular phylogenetic analyses. Susanna et al. (2011) carried out a combined analysis of two nuclear (ITS, ETS) and three chloroplast (*trnL-trnL-F*, *rpl32-trnL*^{UAG}, *ndhF*) markers for genera of subtribe Centaureinae. Working with available herbarium material, they sampled only *Centaurodendron palmiforme*. They accepted the previous taxonomic viewpoints in Dittrich (1977), Bremer (1994), and Susanna and Garcia-Jacas (2007) that *Yunquea* belongs more properly in *Centaurodendron* as *C. tenzii*. The results demonstrated that *C. palmiforme* nests among species of *Centaurea* and *Plectocephalus*, with the limits between these other two genera unclear (Penneckamp et al., 2000, 2022). Susanna et al. (2011) and Herrando-Moraira et al. (2019) elected to continue to accept *Centaurodendron* as a distinct genus because of its morphological distinctions from continental South American taxa. Herrando-Moraira et al. (2019) using Hyb-Seq data have examined phylogeny among 76 representative species of Cardueae, including *Centaurodendron dracaenoides*, and of particular interest is that *Centaurodendron* is hypothesized to have originated within *Plectocephalus* about 4 Mya, the age of Robinson Crusoe Island (Stuessy et al., 1984, 2022). Recent unpublished phylogenomic studies by Alfonso Susanna and colleagues (pers. comm.), which included all three species of *Centaurodendron* and species of *Plectocephalus*, have so far failed to resolve affinities among the taxa.

Resolution of phylogenetic relationships among species of *Plectocephalus, Centaurodendron* and *Yunquea* would provide the potential for interpreting the evolution of floral traits and reproductive biology in this fascinating group. The recently discovered *Centaurodendron schilleri* lacks both the peripheral staminate florets found in *C. palmiforme* and the large showy peripheral sterile florets of Chilean *Plectocephalus*, the latter presumably functioning to attract floral visitors. The hermaphroditic (monoclinous) central florets and the peripheral staminate florets with slightly curved tubular corollas in *C. palmiforme* (Skottsberg, 1957) make the plants andromonoecious, which is rare in Asteraceae (Burtt, 1977; Torices et al., 2011), and could promote outcrossing. Inadequate floral material of *Centaurodendron dracaenoides* and *Yunquea tenzii* precludes determination of the sexual expression of their peripheral florets.

The breeding systems of these endemic island species, e.g., whether plants are self-compatible or self-incompatible, remain unknown, but have important implications for sexual reproduction in the small populations. Field observations reveal one or very few, if any, plants with floral remains in populations, meaning there would be few or no mates for outcrossing when a self-incompatible plant flowers. By contrast, a single self-compatible plant could produce viable cypselae, especially if it were self-pollinating as well. Numerous small plants in one population (*Stuessy et al. 12094*; OS, CONC) of *Centaurodendron dracaenoiodes*, plants of different sizes in *Yunquea tenzii* (Danton, 2000; Alarcón, 2015), and the many plants in a population of *C. palmiforme* (*Stuessy et al. 15151*; OS, CONC) indicate periodic seedling recruitment within populations. As indicated above, cypselae from old inflorescences of *Yunquea* were germinated by Skottsberg but no plants survived to flowering

in the botanical garden in Stockholm. Many viable cypselae were found in the population (five plants) of *C. schilleri* and facilitated the establishment of seedlings in the Jardín Botánico Nacional, Viña del Mar, Chile (Penneckamp et al., 2022). Lastly, segregation of alleles at four of the 16 allozyme loci in 13 plants from one population of *C. palmiforme* (*Stuessy et al. 15151*) indicates sexual reproduction in that population (Crawford et al., unpubl.).

Regarding pollination, Brooke (1987) observed hummingbirds visiting *C. palmiforme* (cited by Bernardello et al., 2001); whether they effect pollen transfer is not known. As far as we are aware, there are no other reports of floral visitors to these insular taxa under discussion; this is not surprising given how rarely they flower and the paucity of floral visitors on Robinson Crusoe Island (Anderson et al., 2001; Bernardello et al., 2001). The purple to pink color of *Centaurodendron* flowers is common for bird-pollinated plants.

What is obviously needed are new samples of *Yunquea* that show all reproductive features, and from which more comprehensive molecular analyses can be completed. It will also be important to learn about the biology of the species, especially breeding system, genetic variation, and chromosome number (none yet recorded for *Centaurodendron* or *Yunquea*; Stuessy & Baeza, 2018), so as to establish more firmly its relationships and conservation status. There is no question that *Y. tenzii* is highly endangered, surviving only on the top of El Yunque, but more information is needed to take steps to ensure its survival in situ as well as ex situ in the botanical garden administered by CONAF on the island and perhaps also in the Jardín Botánico Nacional at Viña del Mar on the Chilean continent.

Historically, the lure of *Yunquea* has resided largely on it being a plant with huge leaves and no flowers that occurs exclusively on a highly inaccessible mountain top on an infrequently visited, generally unknown island. The observations made and materials collected from recent field expeditions raise questions and suggest evolutionary hypotheses about *Yunquea* and *Centaurodendron*, making them an intriguing group for further study.

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