Systematic Botany (2018), 43(2): pp. 628–632

DOI 10.1600/036364418X697346
Date of publication June 21, 2018

A New Species Endemic to the Atacama Region of Chile: *Eryngium crassifolium* (Apiaceae, Saniculoideae)

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Abstract—This study reports a new species of *Eryngium* (Apiaceae, Saniculoideae) from the desert scrubs, in the south of the III Atacama Region, Chile. This new species is singular within the genus by its succulency in vegetative and reproductive leaves. We provide a morphological description, the geographical distribution, habitat, informal IUCN conservation status assessment, and illustrations of this new species. We also describe the anatomical and morphological differences between ***Eryngium crassifolium*** and *E. macracanthum*, its most similar species.

Keywords—Conservation status, *Eryngium macracanthum*, leaf anatomy, morphology, succulence.

Eryngium L. is one of the most diverse genera of Apiaceae, being extremely variable morphologically and distributed in temperate regions of every continent (Calviño et al. 2008). Thirteen of the almost 250 species of *Eryngium* occur in Chile, most of which are endemic to this country (Reiche 1902; Wolff 1913). These few species represent an interesting sample of the morphological variation of *Eryngium*, with some species possessing unique characters within the genus such as the shrubby ones from the Juan Fernández Islands. Within Chile, the species inhabit from -40° to -25° of latitude in hyperhumid temperate bioclimates to ultrahyperarid mediterranean bioclimates that include temperate deciduous forests to desert scrubs (sensu Luebert and Pliscoff 2006).

Deserts are hostile habitats for plants. Drought, high solar radiation, low water retention capacity of sandy soils, and high levels of salinity challenge plants with absorption, conduction, and water storage problems. Under these conditions, many lineages of plants have developed structures and/or physiological traits to tolerate or limit dehydration (Gibson 1996; Sandquist 2014). One of the most remarkable adaptive characteristics are succulent photosynthetic organs which store water in very large vacuoles of the cells of their tissues (Gibson 1996). Succulence is associated with different adaptive strategies such as storage of organic acids in the crassulacean acid metabolism (CAM), water reserve for drought times, and dilution of salts (Gibson 1996; Vendramini et al. 2002; Sandquist 2014; Grigore et al. 2014). Therefore, succulence may represent an adaptive solution for halophytes, xerohalophytes, and xerophytes to face desiccation in the most arid areas of the world (Gibson 1996). The Atacama Desert and Chilean Matorral, and their coastal areas in particular, harbor a high diversity of succulent plants, most of which represent endemic lineages (Mooney et al. 1980; Rundel et al. 1991; Duarte et al. 2014; Larridon et al. 2015).

During a botanical field study along the coast of the III Atacama Region of Chile, a species of *Eryngium* with succulent leaves was recognized. The presence of fleshy leaves, or leaves with some degree of succulence is rare in *Eryngium*, and is restricted to a few species such as *E. maritimum* L. (from coastal dunes of the Mediterranean region), *E. sarcophyllum* Hook. & Arn. (from the Juan Fernández Islands), *E. bonplandii* F. Delaroche (from Mexico), and *E. floribundum* Cham. & Schltdl. and *E. serra* Cham. & Schltdl. (from southern Brazil, northeastern Argentina, and Paraguay). Succulence is also rare within the whole family Apiaceae (Nyffeler and Eggli 2010). Therefore, the presence of succulent leaves makes this species remarkable within the genus and even within the family.

In the present paper we provide a morphological description of this new species, including its geographical distribution, habitat, and informal IUCN conservation status assessment, and illustrations. We also describe the anatomical and morphological differences between *Eryngium crassifolium* and *E. macracanthum* Phil., its most similar species.

Materials and Methods

Morphological terminology of the descriptions follows the Systematics Association Committee for Descriptive Terminology (1962) and Ellis et al. (2009). All measurements of reproductive characters were taken on the terminal capitule of first or second order branches of the distal cyme of the main axis. Flowers and bracts were hydrated using hot water and detergent, and were examined under a dissecting microscope. For anatomical studies, cauline leaves and distal floral bracts of specimens of the new species and the most similar species (*Eryngium macracanthum*) were hydrated in hot water and cut free-hand in cross sections. These sections were clarified using sodium hypochlorite 12.5 g/L and stained with Cresyl Violet following the technique in Padin et al. (2015). The distribution map was produced from GPS data from specimen labels using QGIS v. 2.14.0-Essen (GIS Development Team 2016). The informal conservation status is based on the IUCN guidelines, following criteria B2 and D (IUCN 2017). To calculate area of occupancy (AOO) GeoCAT (Bachman et al. 2011) was used, based on a user defined cell of 2 km.

Taxonomic Treatment

Eryngium crassifolium A.Padin & C.I.Calviño, sp. nov. Type: Chile. III Región Atacama: Provincia de Huasco, cerca de Tres Playitas [-28.413°, -71.194°], 6 December 2015, *Padin 205* (holotype: SI!; isotypes: CONC!, BCRU!).

Annual herb, prostrate, up to 28 cm long. **Taproot** 5–8 × 0.2–0.3 cm. **Main axis** very short, 0.5–4 cm, branching apically in a dichasium or pleiochasium that repeatedly branches, and sometimes also branching laterally in dichasia from basal leaf-axils. **Basal leaves** ephemeral, slightly succulent to succulent, 0.8–3 cm long, venation pinnate; sheath semiamplexicaul; petiole absent or brief, 0.2–0.4 cm long; blade obovate or narrowly obovate, 0.6–2.1 × 0.2–1.1 cm, pinnatifid or less frequently pinnatipartite, base acute, apex obtuse; lobes 3–7, triangular, 2–3 mm long × 2–3 mm wide, entire, apex spinose, becoming smaller towards the base of the blade. **Cauline leaves** 2–4 at the distal node, slightly succulent to succulent, 1.2–3 cm long; sheath and petiole absent; blade obovate or narrowly obovate, 1.2–3 × 0.6–1.6 cm, pinnatifid or less frequently pinnatipartite, base acute, apex obtuse; lobes 3–5, triangular, 2–8 mm long × 2–4 mm wide, becoming smaller towards the base of the blade, entire, apex spinose. **Prophylls** succulent, 1–2 × 0.4–1.6 cm; sheath and petiole absent; blade

obovate, pinnatisect or pinnatipartite or less frequently pinnatifid, base acute, apex obtuse; lobes 3(–5) at the apex, triangular, 3–8 mm long × 1–5 mm wide, subequal, entire, apex spinose. **Capitules** globose to ovoid, 7–12 × 6–9 mm (without the bracts), peduncles 3–15 mm long; involucral bracts 6–8, succulent, green, subequal, conspicuous, reflexed at maturity, narrowly oblong or rarely narrowly ovate, 9–15 × 2.5–3 mm, entire, apex acute, spinose; floral bracts narrowly obovate, 1.8–5 × 0.6–1 mm, entire; distal floral bracts recurved, cymbiform, larger and succulent, forming a coma, narrowly obovate or narrowly elliptic, 7–12 × 1.5–2.6 mm, entire or rarely with 1–2 spinose teeth. **Flowers** sessile, sepals green and leathery with white or violet-blue scarious margins, circular to elliptic, 1.1–1.4 × 0.9–1.1 mm, entire, apex acute or obtuse, recurved, spinose; petals white, obovate, 0.6–0.7 × 0.4–0.5 mm, entire, apex inflexed, fimbriate; stamens yellow; stylopodium annular. **Fruits** broadly obovoid to globose, uncompressed, 2.5–2.9 × 2–2.3 mm; mericarps densely papillate, papillae white, unordered, oblong, longer than the mericarp body width. Figures 1–2.

Distribution and Habitat—This species appears to be endemic to the Provincia de Huasco, in the south of the III Atacama Region, Chile (Fig. 3). It is found along the Pacific coast and also a few kilometers towards the interior, in sandy and slightly humid soils with scarce vegetation (Fig. 2D).

Phenology—This species flowers between mid-October and December and fruits in December.

Etymology—The specific epithet refers to the consistency of the vegetative and reproductive leaves of the plant. It is the only herbaceous species of *Eryngium* from Chile that presents succulent leaves. *Eryngium sarcophyllum,* from the Juan Fernández Islands, show some degree of succulence, but this is a shrubby species with fleshy, linear, parallel-veined vegetative leaves.

Conservation Category—We recommend that the species should be considered critically endangered according to criterion B2ab (IUCN 2017), since it is only known from two localities, with an area of occupancy of less than 10 km^2, and an expected decline of extent and/or quality of habitat because one of the two known populations is close to a developing village. Also, it should be considered in this category according to criterion D, because the known populations have less than 50 individuals. In addition, at the moment, the known populations are outside any protected areas.

Leaf Anatomy—The distal floral bracts that form the coma, in transverse section (Fig. 4A), present an epidermis composed of cells with slightly thickened outer tangential walls. Stomata are on both adaxial and abaxial sides of the bracts (amphistomatic), and the occlusive cells are at the same level as their adjacent epidermal cells. Trichomes are absent (glabrous).

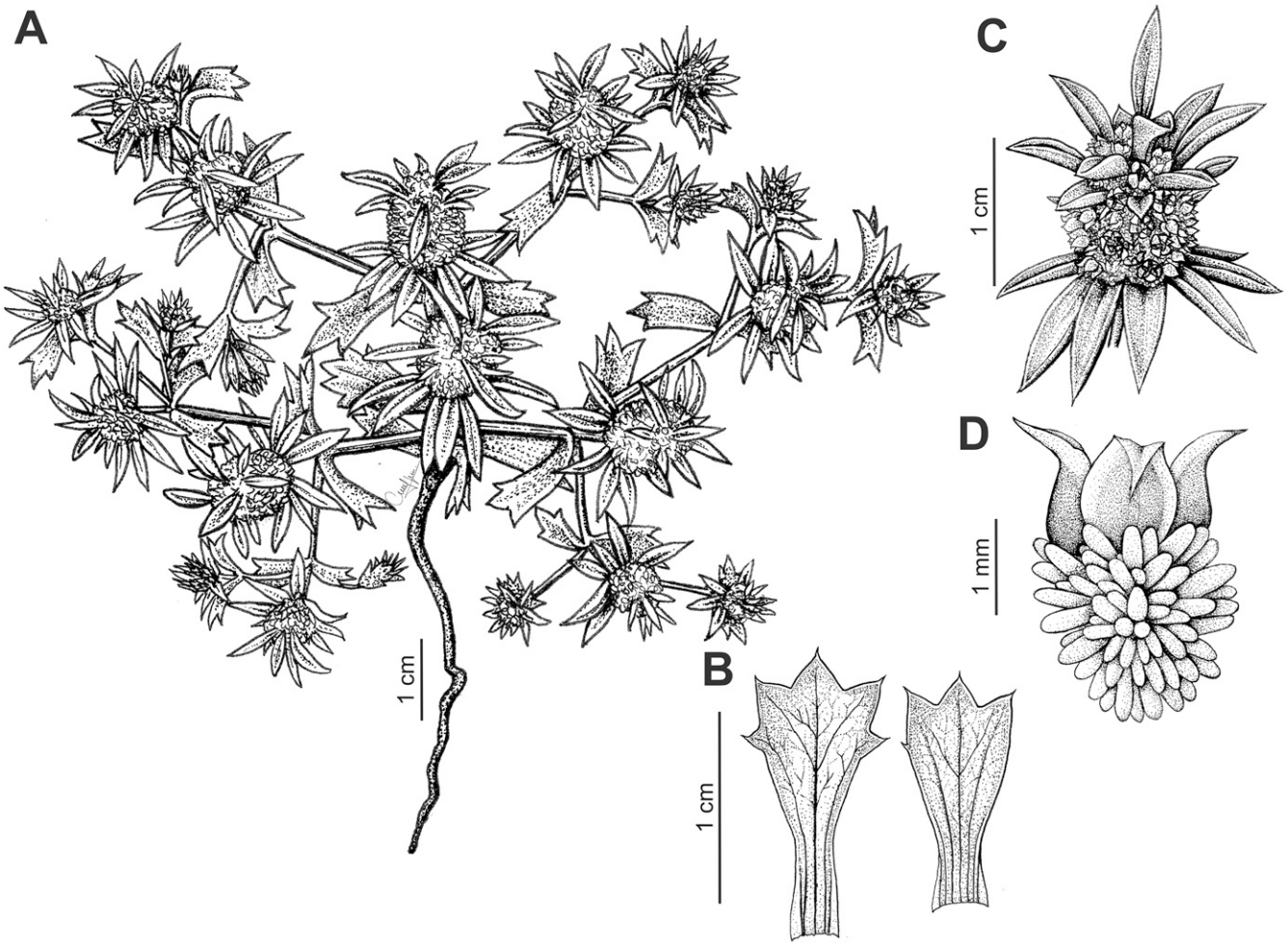

FIG. 1. *Eryngium crassifolium*. A. Habit. B. Basal leaves. C. Capitule. D. Fruit mericarp in dorsal view. A, C from *Padin 205* (SI), B from *Padin 205* (BCRU), and D from *Teillier 4703* (CONC). Drawn by Ailén Santome.

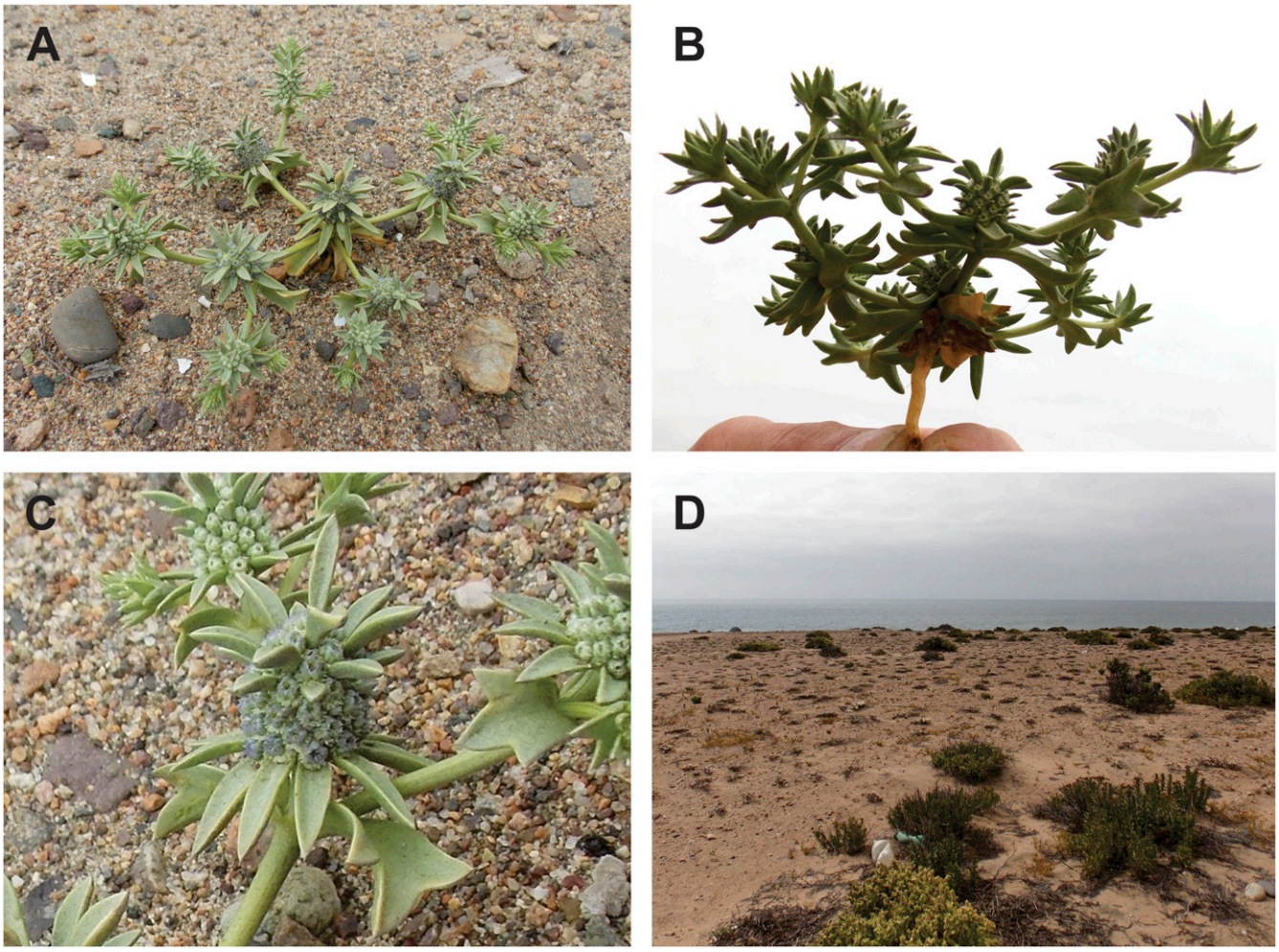

FIG. 2. *Eryngium crassifolium*. A–B. Habit. C. Capitule. D. Habitat in Tres Playitas, Provincia de Huasco, Chile. Photographs by Ariana L. Padin.

Sclerenchyma represents less than 1% of the tissue in cross section; it is found in three strands, occupying a central position in the mesophyll and also located along the margins, under the epidermis. The mesophyll is isolateral; on each side it is composed of two to three layers of palisade chlorenchyma that presents elongated cells, and in the center of two to four layers of water storage parenchyma that presents rounded isodiametric cells. Seven secretory canals are present: one central and dorsal, two at the dorsal side of the two lateral vascular bundles associated with the central sclerenchyma, and the other two under the marginal sclerenchyma.

Cauline leaves in transverse section (Fig. 4C) present the same characteristics of the epidermis as the distal floral bracts. Hypodermic sclerenchyma strands are found along the middle vein on the abaxial side and on the margins. Schlerenchyma is also associated with the xylem of the central vascular bundle. The mesophyll is isolateral; it is composed of two or three layers of compact palisade chlorenchyma that presents elongated cells, and of three or four layers of water storage parenchyma composed of rounded isodiametric cells that are similar in size or larger than the cells of the palisade chlorenchyma. Water storage parenchyma represents ca. 60% of the mesophyll in cross section. Secretory canals are present under the vascular bundles.

Morphological Affinities—Distinguished from other species of *Eryngium* from continental Chile by its succulent leaves and bracts (vs. coriaceous). Morphologically, *E. crassifolium* is

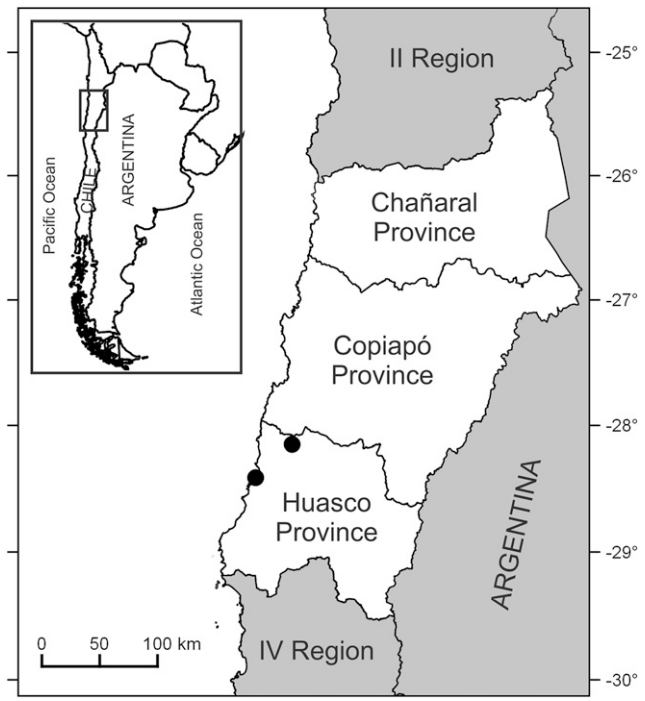

FIG. 3. Map showing the geographical distribution of *Eryngium crassifolium*, endemic to the III Atacama Region, Chile.

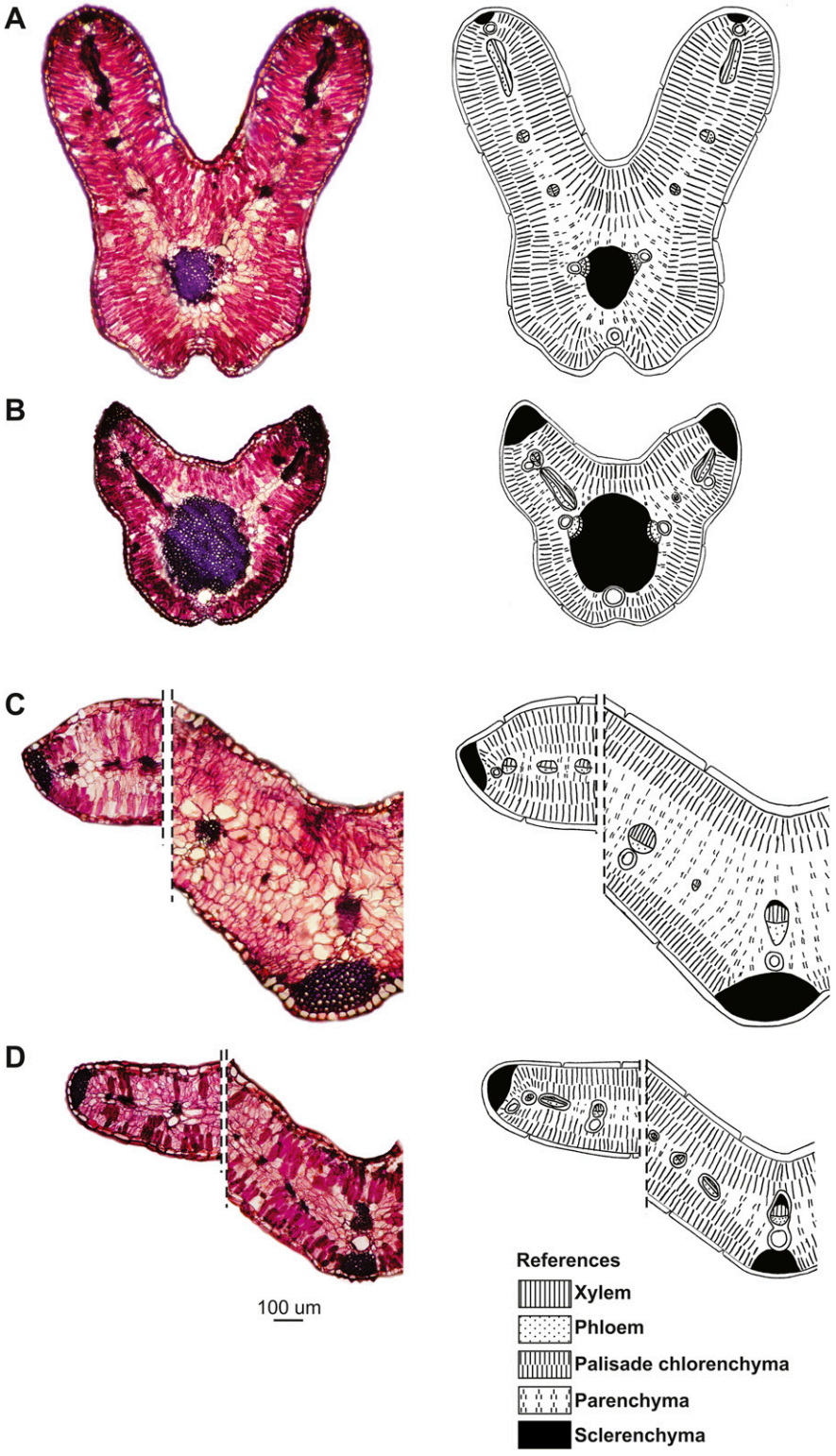

FIG. 4. Leaf anatomy. A–B. Distal floral bracts in cross section, photographs and schemes. C–D. Cauline leaves in cross section, photographs and schemes. A, C. *Eryngium crassifolium*. B, D. *E. macracanthum*. A, C from *Padin 205* (BCRU), and B, D from *Calviño 774* (BCRU).

most similar to *E. macracanthum* from which it differs by characteristics of the involucral bracts, coma, and fruits (Table 1). The species also shows anatomical differences in the coma and cauline leaves (Fig. 4). *E. macracanthum* presents a coma with more sclerenchyma (ca. 40% of the tissue in cross section), less parenchyma (one or two layers of smaller cells), and more conspicuous secretory canals than those of *E. crassifolium*. The cauline leaves of *E. macracanthum* differ from *E. crassifolium* by having a palisade chlorenchyma as the predominant tissue of the mesophyll (representing at least 80% of this tissue in cross section), more conspicuous secretory canals, and vascular bundles surrounded by a sheath.

Table 1. Morphological differences between *Eryngium crassifolium* and *E. macracanthum.*

Characteristics	*E. crassifolium*	*E. macracanthum*
Leaves and bracts consistency	Succulent	Coriaceous
Involucral bracts width	2.5–3 mm wide	1–2 mm wide
Involucral bracts length/width ratio	Ratio 3:5	Ratio 4.5:11
Involucral bracts shape	Narrowly oblong or narrowly ovate	Very narrowly to narrowly ovate or very narrowly to narrowly triangular
Distal bract shape	Cymbiform (deeply sulcate)	Acicular (shallowly sulcate)
Distal bracts width	1.5–2.6 mm wide	1–1.5 mm wide
Distal bracts direction	Recurved	Straight
Fruit width	2–2.3 mm wide	1.4–2 mm wide

***Paratype*—Chile**. III Región Atacama: Provincia de Huasco. Quebrada del Carrizal [-28.15°, -70.867°], 19 October 1997, *Teillier 4703* (CONC).

Acknowledgments. We are grateful to Alicia Marticorena for her kind help during our visits to CONC, Ailen Santomé for the illustrations, Sebastián Teillier and Patricio Novoa for advice with Chilean localities, and Cecilia Ezcurra and two anonymous reviewers for comments on the manuscript. We also acknowledge CONICET, Argentina, for a Doctoral fellowship to AP. This work was supported by the following institutions from Argentina: Agencia Nacional de Promoción Científica y Tecnológica [grant number PICT 2014-0584]; CONICET PIP [grant number 112-201301-00357]; Universidad Nacional del Comahue [grant number PIN B205].

Author Contributions. AP collected the new species, perfomed the morphological and anatomical analyses, analyzed the results, and wrote the manuscript. CC collected specimens of *E. macracanthum*, analyzed the results, and wrote and edited the manuscript.

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