

The Genus *Radula* (Hepaticae) in the Galapagos Islands

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Contribution No. ... of the Charles Darwin Foundation.

Abstract. Seven species of *Radula* are reported from the Galapagos Islands, including *Radula santacruziana* spec. nov. The majority of the species are common and widespread in the neotropics; two (including the new species) are endemic to the Galapagos. *R. cornucopiae* Spruce and *R. mollis* Lindenb. et Gott. are reduced to synonymy, resp. under *R. episcia* Spruce and *R. quadrata* Gott. et al.

In the spring of 1976, Dr. W.A. Weber and Miss J. Lanier (University of Colorado) together with Dr. H.J.M. Sipman and the junior author (University of Utrecht) made a bryological and lichenological expedition to the Galapagos Islands and collected about 1800 specimens of bryophytes and lichens, including seventeen specimens of the genus *Radula*. Gradstein and Weber (1982) reported the occurrence of six species of *Radula* in the Galapagos Islands based on their collections and previous records. Recently, we have reexamined the material from the 1976 expedition and were able to recognize seven species, including one species new to science. Voucher specimens are kept in the herbaria of U, COLO, and NICH.

It appears that the majority of the

species, viz. *R. gottscheana* Tayl., *R. quadrata* Gott. et al., *R. subinflata* Lindenb. et Gott., and *R. voluta* Tayl., are common and widespread in the neotropics. *R. episcia* Tayl. is an Andean species, whilst *R. galapagona* Steph. and *R. santacruziana* Yamada et Gradst. are endemic to the Galapagos.

Key to the species

1. Plants usually dichotomously branched 1. *R. episcia*.
1. Plants usually irregularly or regularly pinnately branched.....

2. Leaf-lobes with discoid gemmae on margins..... 3
2. Leaf-lobes without discoid gemmae..... 4
3. Leaf-lobules imbricate, dorsally covering the stem and usually extending beyond the farther edge of the stem.. 4. *R. quadrata*.
3. Leaf-lobules remote, not covering the..... 5. *R. santacruziana*.
4. Leaf-lobes constantly caducous 2. *R. galapagona*.
4. Leaf-lobes not or little caducous..... 5
5. Leaf-lobules covering the stem for 1/5 of the stem-width and not auriculate or volute at base..... 6. *R. subinflata*.
5. Leaf-lobules extending far beyond the farther edge of the stem and auriculate or volute at base..... 6
6. Leaf-lobules subquadrate to quadrate with volute base; keels long and almost straight..... 7. *R. voluta* (*R. ramulina*).
6. Leaf-lobules elliptical with strongly auriculate base; keels very short and concave 3. *R. gottscheana*.

1. *Radula episcia* Spruce, Trans. & Proc. Bot. Soc. Edinburgh 15: 318 (1885).

Radula cornucopiae Spruce, Trans. & Proc. Bot. Soc. Edinburgh 15: 318. 1885. Type. "In montis Chimborazo devexis sylvaticis, alt. 1200 m, e ramulis pendula", *Spruce s.n.* (holotype, MANCH; isotypes, MICH, NY, YU),

syn. nov.

Specimens examined: SAN CRISTOBAL. Gorge W of El Junco, in *Cyathea-Miconia* vegetation, forming carpets under tree ferns, 600 m, *Gradstein & Lanier H269*.

Habitat: creeping over shaded, moist stones or roots. On San Cristobal found in a gorge in dense tree-fern bush, on Santa Cruz found in a cavern with *Dumortiera hirsuta*.

General distribution: Andes (Colombia, Ecuador, Peru, Bolivia), Galapagos Islands.

Radula episcia belongs in *R. sect. Dichotomae* and is characterized by the irregularly dichotomously branching stem, the remote to loosely imbricate, orbicular leaf-lobes without trigones, and the remote, oblong leaf-lobules covering the stem for 1/5 of the stem-width and with sinuate, somewhat decurrent keels.

The species is very similar to *R. cornucopiae* Spruce, which is known from Colombia, Ecuador, Peru, and Bolivia (Castle 1959). Castle separated *R. cornucopiae* from *R. episcia* by the dimension of the leaf-lobes but we have been unable to satisfactorily distinguish between the two. Therefore, *R. cornucopiae* is reduced to a synonym of *R. episcia*.

2. *Radula galapagona* Steph., Spec. Hep. 4: 176. 1910.

Specimens examined: ISABELA. Rim of volcano Alcedo, on rotten, fibrous bark of old *Zanthoxylum*, 1100-1200 m, *Gradstein & Weber H224*. PINTA. S-exposed slope near the summit of the volcano, appressed mats on *Zanthoxylum* bark, 400-550 m, *Gradstein et al., H520*. SANTA CRUZ. Pampa, S-slope of Mt. Crocker, on branches of isolated *Scalesia* tree, ca. 800 m, *Gradstein, Sipman & Weber H52*. SAN CRISTOBAL. River valley SW of El

Junco, in *Miconia-Psidium guajava* bush, on *Miconia* stem, 500 m, *Gradstein & Lanier H307/a*.

Habitat: *Radula galapagona* is common on Pinta and Santiago, but rare on the other islands. It grows in moist woodlands at higher elevations, on rotten bark of stems and thick branches of old *Scalesia pedunculata* and *Zanthoxylum fagara*, on San Cristobal occasionally also on *Miconia*.

General distribution: Endemic to the Galapagos Islands.

The diagnostic characters of *R. galapagona* are: the fragile, highly caducous, and falcate-ovate to narrowly ovate leaf-lobes with obtuse apices, the thin-walled cells of leaf-lobes without trigones, and the subquadrate leaf-lobules with subacute to obtuse bases (but very variable in form), and the arched (often strongly so), not decurrent keels.

Castle (1967) discussed *R. galapagona* in detail and considered it a member of *R. sect. Ampliatae* (subgen. *Radula*). The species is now placed in the sect. *Caducae* Schust. ex Yamada et Piippo (subgen. *Radula*) because of its highly caducous leaf-lobes. Stephani (1910) described *R. galapagona* based on a specimen collected by C.M.J. Andersson in the Galapagos; the precise locality of the type collection is not known.

3. *Radula gottscheana* Tayl., London J. Bot. 5: 374. 1846.

Specimens examined: SAN CRISTOBAL. Tres Palos towards El Junco, on shaded rocks in river valley, 400 m, *Gradstein & Lanier H301*.

Habitat: Common on steep rocks and soil in *Miconia* bush along permanent streamlet, shaded, with *Plagiochila guilleminiana* and *P. gradsteinii*.

General distribution: Mexico, West Indies (Yamada 1988), Guianas (*Gradstein & Hekking* 1989, as *R. boryana*), Colombia (*Gradstein & Hekking* 1979), Ecuador (*Spruce* 1885), Galapagos Is. (*Gradstein & Weber* 1982, as *R. boryana*), Peru (Yamada 1987), Brazil (*Spruce* 1885, Stephani 1910, Yano 1984, as *R. boryana*).

Castle (1937) reduced *R. gottscheana* to a synonym of *R. boryana* (Web.) Nees. However, *R. gottscheana* differs from *R. boryana* by the well-developed and irregularly pinnately branched stems and the well-developed leaf-lobules which are rounded at apex and have very large auricles. *R. gottscheana* is easily recognized by the long, ascending, regularly pinnate stems which are light green in the field but dull brownish in the herbarium, and by its peculiar, strongly auriculate lobules. A somewhat similar leaf-lobule is found in *R. voluta* (= *R. ramulina*), but in that species the auricle is not extended downwards beyond the base of the keel and the keel is at least twice longer. Furthermore, *R. voluta* is in the Galapagos invariably founded on trees or shrubs, and in the herbarium the plants retain their yellowish-green colour.

4. *Radula quadrata* Gott. et al., Syn. Hep. 255. 1845.

Radula mollis Lindenb. et Gott., Syn. Hep. 725. 1847. Type. "Habitat in Pico de Orizaba, altitudine 10,000 ped., ubi Sept. 1842 legit cel. Liebman" (isotypes, BM, G), *syn. nov.*

Specimens examined: PINTA. S-exposed slope near the summit of the volcano, on decayed, horizontal *Pisonia* stem in grassy *Zanthoxylum fagara* woodland, 400-500 m, *Gradstein & Sipman H522, H523*. ISABELA. Rim of Volcano Alcedo, SE side, on rocks and stem of *Zanthoxylum* in shade, 1100-1200 m, *Gradstein & Weber H231*. FLOREANA. Cerro "Wittmer" above the spring, NW-exposed slope with mixed *Psidium-Zanthoxylum* woodlands, 450-550 m, *Gradstein H172*.

Habitat: Rather common on Pinta and Floreana (Cerro Wittmer), apparently rare on the other islands. The species grows in rather dense, mesic scrub on stem-bases and thick branches of *Zanthoxylum*, *Tournefortia*, *Psidium guajava*, *Cestrum* etc., and occasionally on shaded rocks or decayed logs.

General distribution: SE-U.S.A., Mexico, Central America, West Indies, Venezuela, Colombia, Ecuador (Castle 1965), Peru (Castle 1965; Hegewald 1985), Brazil.

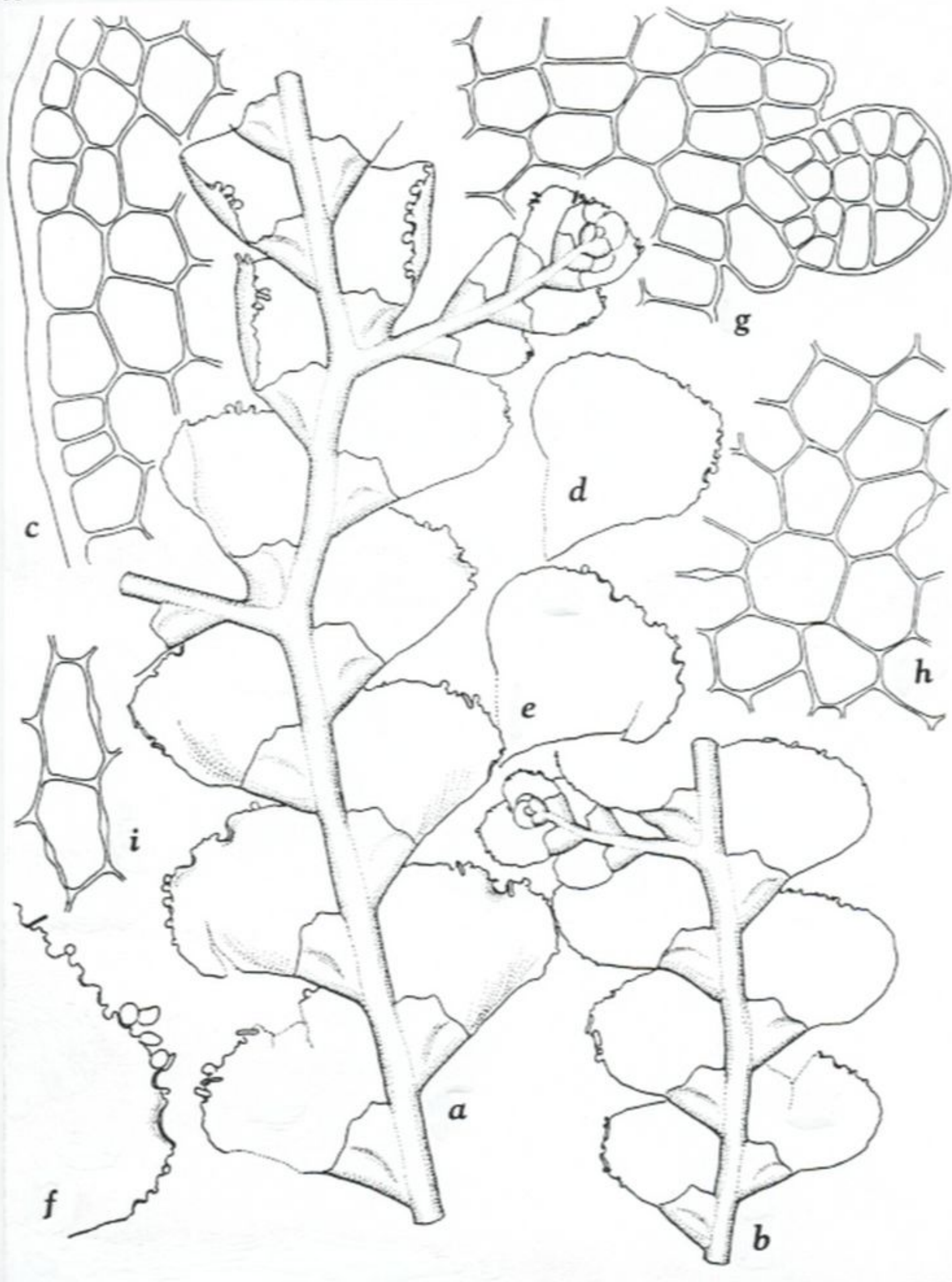


Fig. 1: *Radula santacruziana* Yamada et Gradstein. a, b. Portions of stem, ventral view x 12. c. Portions of cross section of stem, x 320. d, e. Leaf-lobes, x 12. f. Apical margin of leaf-lobe with gemmae, x 30. g-i. Cells of lobe of stem leaf (g from margin with gemmae, h from middle, i from base) x 320. Drawn from the holotype.

Radula quadrata is easily recognized in the field by the compact, bright green patches. It is furthermore distinguish readily from other *Radula* species of the island by the abundant marginal gemmae of leaf-lobes (present also in *R. santacruziana*) and the subquadrate leaf-lobules with arched bases, usually fully covering the stem.

Radula quadrata is very similar to *R. mollis*. Lindenb. et Gott. Castle (1965) differentiated between *R. mollis* and *R. quadrata* in his key as follows:

1. Lateral margins of lobules of the stem and branch leaves incurved and narrowly reflexed*R. quadrata*
 1. Lateral margins of lobules of the stem and branch leaves with a slight outward curve and not narrowly reflexed *R. mollis*

The senior author recently examined the types and many neotropical specimens determined as *R. mollis* or *R. quadrata* and found the differences as mentioned by Castle not significant. They seem to be merely based on environmental modification. *R. mollis* is therefore reduced to a synonym of *R. quadrata*.

5. *Radula santacruziana* Yamada et Gradstein, *spec. nov.* (Fig. 1)

Planta mediocris, brunnea; caulis 8-15 mm longus, irregulariter pinnatim ramosus; folia laxe imbricata, in plano late ovata, apice obtuso, gemmis marginalibus abundantibus; cellulae medianae 18-21(-26) x 13-16(-18) μ m, parietibus tenuibus, trigonis indistinctis vel nullis; cuticula laevis; lobuli remoti, in plano subquadrati, oblique patuli, basi caulem haud tegente, carina a caule 50-55° patens, sinu lato, fere nullo. Sterilis.

Type. GALAPAGOS ISLANDS. SANTA CRUZ. *Miconia* scrub around Media Luna, rare, loosely creeping with long slender stems on *Miconia* branches, 600-650 m alt., April 17, 1976, Gradstein & Weber H104 (holotype, U; isotype, NICH).

Plants medium-sized, brown in herb. Stem 8-15 mm long, 0.19-0.2 mm in diam., with leaves 2.5-2.7 mm wide, irregularly pinnately branched,

branches obliquely spreading, 2-4 mm long, 0.1-0.15 mm in diam., with leaves 0.9-1.1 mm wide; stem 8 cells thick, epidermal wall equally thickened, pale brown, medullary cells and cortical cells of equal size and thin-walled with (or without) minute trigones, subhyaline. Leaf-lobes loosely imbricate, widely spreading, concave, when flat widely ovate, 1.2-1.3 mm long and wide, apices obtuse, dorsal bases subtruncate or slightly arched (never auriculate at bases), dorsally covering the stem 1/2-1/3 of the stem-width (at apical portion of stem, however, slightly extending beyond the farther edge on apical to dorsal margins of leaf-lobes); all cells thin-walled, trigones indistinct or absent, often small intermediate thickenings seen, marginal cells 15-18 x 8-13 μ m, median cells 18-21(-26) x 13-16(-23) μ m, basal cells 25-28 x 12-14 μ m; cuticle smooth; leaf-lobules remote, obliquely spreading, when flat subquadrate, ca. 1/2 the lobe-length, 0.4-0.6 mm long, 0.5-0.7 mm wide, apices bluntly angular to obtuse, depressed to the lobe, abaxial margins subtruncate and usually slightly sinuate at middle, bases not covering the stem, insertions long and substraight, carinal regions \pm inflated; rhizoid-initial area slightly convex, rhizoids rarely seen, pale brown; keel spreading at angles of 50-55° with the stem, 0.52-0.65 mm long, straight, not decurrent. Sexual organs not seen.

Specimens examined: only known from the type.

The diagnostic characters of *R. santacruziana* are: the widely ovate leaf-lobes with abundant marginal gemmae on apical and dorsal margins of lobes, the thin-walled cells without or with very small trigones, the subquadrate leaf-lobules not covering the stem, and the straight keel spreading at an angle of about 50° with the stem.

The species is unique in the above-cited characters and no close relative is known in the neotropics.

6. *Radula subinflata* Lindenb. et Gott., Syn. Hep. 724. 1847.

Specimens examined: SANTA CRUZ. *Scalesia pedunculata* woodland N of Mt. Croo-

ker - Puntudo area, on smooth bark of young *Scalesia* tree, 650-700 m, *Gradstein & Weber H83*; *ibid.*, on smooth bark of *Avocado* tree in dense woodland, 650-700 m, *Gradstein & Weber H72*.

Habitat: On smooth bark of *Scalesia* and wild growing *Avocado* trees.

General distribution: Mexico, Guatemala, West Indies (Guadeloupe, Martinique), Surinam, Venezuela, Ecuador (Castle 1963), Galapagos Is. (Gradstein & Weber 1986, as *R. fendleri*), Brazil (Schiffner & Arnell 1964).

The diagnostic characters of *Radula subinflata* are: the narrowly ovate leaf-lobes with widely rounded apices, the thin-walled cells without trigones, and the subquadrate leaf-lobules with bluntly angular apex, arched keel, basal portion covering the stem for 1/5 of the stem-width and strongly inflated carinal region. The Galapagos material was previously misidentified as *R. fendleri* Steph. (Gradstein & Weber 1982). *R. subinflata* belongs to subsect. *Saccatae* of the subgenus *Radula*.

7. *Radula voluta* Tayl., Syn. Hep. 255. 1845.

Specimens examined: ISABELA. Rim of Volcano Alcedo, SE side, on stems and branches of old *Tournefortia rufo-sericea*, 1100-1200 m, *Gradstein H243*. PINTA. S-exposed slope near the summit of the volcano, in mossy *Zanthoxylum* woodlands, on rotting bark, 550-600 m, *Gradstein et al. H524*. SANTA CRUZ. Edge of crater above Santa Rosa, on branches of *Scalesia pedunculata*, 500 m, *Gradstein & Sipman H361*; between Puntudo and Mt. Crocker, pendulous on decayed *Scalesia pedunculata* stem, 650-750 m, *Gradstein H15*.

Habitat: Not uncommon in moist *Zanthoxylum* or *Scalesia pedunculata* woodlands, forming arcuate to pendulous masses on thick branches densely covered by liverworts (*Plagiochila*, *Frullania*, *Omphalanthus*, *Lejeunea flava*, *Bryopteris*, etc.). On the rim of Alcedo found once on *Tournefortia*.

General distribution: Great Britain, eastern U.S.A. (Mescal et al. 1980; Schuster 1980), and throughout the neotropics including the Galapagos Islands.

This beautiful *Radula* species is easily recognized in the field by its arcuate to more or less pendulous, regularly pinnate habit and its bright yellowish-green colour, which it usually retains in the dried condition.

R. voluta was first reported from Galapagos Islands by Gradstein & Weber (1982) as *R. ramulina* Tayl. Based on examination of numerous specimens from different geographical areas, the senior author considers *R. ramulina* conspecific with *R. voluta*, originally described from Great Britain. *R. voluta* agrees with *R. ramulina* in many respects, although the shape of the basal portion of the leaf-lobules is somewhat different in the two. The latter character, however, varies considerably in the two species, even in single plants, and scarcely warrants separation of *R. voluta* and *R. ramulina*.

Acknowledgements. We wish to express our sincere thanks to Dr. S. Hattori of the Hattori Botanical Laboratory for his criticism and suggestions.

Literature cited

- Castle, H. 1937. A revision of the genus *Radula*. Introduction and part I. Subgenus *Cladoradula*. Ann. Bryol. 9: 13-56.
 —, 1959. —. Part II. Suggestus *Acroradula*. Section 3. *Dichotomae*. J. Hattori Bot. Lab. 21: 1-52.
 —, 1963. —. Section 6. *Saccatae*. Rev. Bryol. Lichénol. 32: 1-48.
 —, 1965. —. Section 9. *Densifoliae*. Rev. Bryol. Lichénol. 33: 328-398.
 —, 1967. —. Section 10. *Ampliatae*. Rev. Bryol. Lichénol. 34: 1-35.
 Gradstein, S.R. & W.H.A. Hekking, 1979. A catalogue of the Hepaticae of Colombia. J. Hattori Bot. Lab. 45: 93-144.
 — & —. 1989. Bryophytes of Guianas I. Hepaticae and Anthocerotae. J. Hattori Bot. Lab. 66: 197-230.
 — & W.A. Weber. 1982. Bryogeography of the Galapagos Islands. J. Hattori Bot. Lab. 52: 127-152.
 Hegewald, E. & P. Hegewald. 1985. Eine Moossammlung aus Peru. III. Nova Hedwigia 41: 219-271.
 Mescal, Y.M., K. Yamada & D.K. Smith. 1980. *Radula voluta* Tayl. new for North America. Misc. Bryol. Lichenol. 8: 153-154.
 Schiffner, V. & S. Arnell. 1964. Hepaticae. In Ergebnisse der botanischen Expedition der Kaiserlichen Akademie

- der Wissenschaften nach Südbrasilien 1901. Oesterr. Akad. Wiss. Math. Naturwiss. Kl., Denkschr. 111: 1-156.
- Schuster, R.M. 1980. The Hepaticae and Anthocerotae of North America East of the Hundredth Meridian, vol. 4: 1-1334.
- Spruce, R. 1885. Hepaticae of the Amazon and Andes of Peru and Ecuador. Trans. & Proc. Bot. Edinburgh 15: 1-589.
- Stephani, F. 1910. *Radula*. In Species Hepaticarum 4: 151-234.
- Yamada, K. 1982. Notes on Latin American species of the genus *Radula* from Cuba. J. Hattori Bot. Lab. 65: 379-390.
- Yano, O. 1984. Checklist of Brazilian liverworts and hornworts. J. Hattori Bot. Lab. 56: 481-548.