

Hepatic and hornwort flora of Singapore

Sinikka Piippo¹, Xiao-Lan He¹, Aino Juslén², Benito C. Tan³,
Dennis Hugh Murphy³ & Tamas Pócs⁴

¹) Botanical Museum, P.O. Box 47, FIN-00014 University of Helsinki, Finland

²) Department of Ecology and Systematics, Division of Systematic Biology,
P.O. Box 7, FIN-00014 University of Helsinki, Finland

³) Department of Biological Sciences, National University of Singapore,
Singapore 119260

⁴) Felsotarkany, Ady E.u. 67, H-3324 Hungary

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The primary aim of this study was to investigate and document the hepatic and hornwort floras of Singapore. The secondary aim was to compare and understand the changes in the species composition through time in a highly urbanized island environment like Singapore. As presented, a total of 74 species in 37 genera of Hepaticae and Anthocerotae are known from Singapore. *Aneura*, *Cololejeunea*, *Cyathodium*, *Folioceros*, *Harpalejeunea*, and *Notothylas* are new generic records. Thirty-eight species are reported as new for Singapore. Identification keys to the genera and species of Singapore hepatic and hornwort floras are provided. Short descriptions are provided for each species. Of the 74 species, 21 are regarded as possibly extinct from the island on the basis of no recent collections. An additional 16 records could not be confirmed due to lack of voucher specimens and recent collections. Taxa suffered most from the urbanization of environment seem to be those of the genera *Bazzania* and *Frullania*. A moderate 40% extinction rate over a period of two centuries was calculated for the liverwort and hornwort floras of Singapore. Their local disappearance is probably caused by forest clearing and the subsequent change of air humidity and, in the case of corticolous species, most probably due to the increased air pollution.

Key words: Anthocerotae, distribution, flora, Hepaticae, Singapore, urbanization



Fig. 1. A view over Singapore showing parks and skyscrapers. (Photo: Sinikka Piippo 11.XI.1995)

Introduction

The Republic of Singapore consists of the main island of Singapore and formerly 58 small islands, of which Pulau Tekong, P. Ubin and P. Sentosa are the three larger ones. Many of the small islands have been joined today by land reclamation. The total land area, including the islets, is currently over 640 km².

Singapore lies about 137 km north of the equator and between 103°38′–104°06′E. Geographically, it is situated at the southern tip of Peninsular Malaya and linked to the mainland by two causeways across the Straits of Johor. To the south, the country is separated from the islands of Riau Province of Indonesian Sumatra by the narrow Straits of Singapore.

The topography of Singapore consists mainly of lowland plain, the highest point being Bukit Timah hill, which is 162 m above the sea level. The country has a mild tropical climate with no distinct dry and wet seasons. The mean daily temperature is between 23.9 °C and 30.8 °C and the mean annual relative humidity is 84%, but there are large diurnal variations from 60% in the afternoon to over 95% in the morning. The rain falls throughout the year, with sudden heavy showers occurring mostly in the afternoon during the northeast monsoon season from November to January. Annual average precipitation is 2415 mm.

Because of limited land resource, much of the original vegetation or forest had been cleared by the end of 19th century for agricultural crops such as gambir, pepper and rubber, and later for

industrial, commercial and residential purposes (Fig. 1). Today, the island has only a small patch of original primary forest (Fig. 2) of about 50 hectares called Bukit Timah Nature Reserve located near the center of the main island adjacent to the Central Catchment Reserve comprising a number of large water catchment areas, namely the Upper and Lower Seletar, Upper and Lower Peirce and MacRitchie. At present the catchment areas are covered with secondary forests of variable ages.

There are roughly eight types of forests found on the island today: (1) the primary rain forest, which forms the core of Bukit Timah Nature Reserve; (2) secondary forests of 50–70 years old around the central water catchment areas; (3) the heath forest of *Adinandra dumosa* in very disturbed and nutrient poor sites; (4) the fresh water swamp forest of *Palaquium–Lophopetalum–Eleiodoxa* at Nee Soon; (5) mangrove forest along sheltered coves and inlets of rivers; (6) remnants of seashore forests of *Terminalia–Casuarina–Scaveola–Hibiscus* formation; (7) man-made *Casuarina* forest on reclaimed seaward land; and (8) managed forest of ornamental trees and palms, such as *Samanea saman* (rain tree), *Cyrtostachys renda* (lipstick palm), *Pterocarpus indicus* (Angsana) and *Peltophorum pterocarpum* (yellow flame) planted in city parks, along roadsides and around housing areas. Additionally, there is a large part of the central island made up of savannah wastelands. The hepatic flora, especially the epiphyllous liverworts, appears to be most diverse in fresh water swamp forest and then in the primary and

old growth forests, poorer in *Casuarina* coastal forest and the *Adinandra* heath forest, and poorest in savannah wasteland.

The first record of Singaporean hepatics appears in Gottsche *et al.* (1845), who described a *Lejeunea singaporensis* Lindenb. Schiffner (1898) in his *Conspectus Hepaticarum Archipelagi Indici* listed ten species from Singapore. This was followed by Verdoorn (1934), who reported 11 species of Singaporean Jubuleae, based on the collections made by Ridley in 1889, Schiffner in 1893, Fleischer in 1913, and Holtum and Verdoorn in 1930. Benedix (1953) described *Cololejeunea pluripunctata* based on Verdoorn's collection and reported *C. floccosa* from Singapore.

The hepatic and hornwort floras of Singapore are poorly known. Johnson (1958) mentioned six hepatic and one hornwort species in her paper on the thallose liverworts found in Malaya and Singapore. Later, the same author (Johnson 1969) published a key to the genera of hepatics and hornworts found in Singapore but did not mention any species names. Turner and Tan (1994) listed 52 hepatics and one hornwort species from Singapore. Sixteen of these and other published species records, however, lack voucher specimens needed for confirmation. More recently, Wee and Mohamed (1995) reported 15 taxa of liverworts from the rain forest of Bukit Timah Nature Reserve, many of which are identified only to genus.

In November of 1998, Ms Aino Juslén from the University of Helsinki visited Singapore for two weeks to study the liverwort flora for a thesis project. Together, the three of us (AJ, BCT and DHM) made several trips around the island and collected in various types of forests in Singapore (*see* Mischler *et al.* 1998). The resulting bulk of 253 specimens from 11 localities constituted the most recent basis to account for the surviving diversity of hepatic and hornwort floras in Singapore after more than a century of intense urbanization.

It is the primary aim of this study to document and clarify the present state of hepatic and hornwort floras of Singapore. The effort is designed to produce the baseline information needed for the conservation of the local flora. To do so, we have studied, in addition, the many historical specimens preserved at the two local



Fig. 2. Nee Soon freshwater swamp, with Prof. Dennis Murphy. (Photo: Aino Juslén 9.XI.1998)

herbaria (SING and SINU). In the case of the SING at the Singapore Botanic Gardens, its collections consist of 93 hepatic and hornwort specimens identified to 18 genera and 34 species. The two oldest liverwort collections at SING were made in 1880 and 1884, and the newest one in 1959. Many of these old specimens were collected by H. N. Ridley, J. Sinclair and F. Verdoorn, either from the jungle forest in the Singapore Botanic Gardens or the Bukit Timah Nature Reserve. On the other hand, the herbarium of the National University of Singapore (SINU) has 47 newly collected hepatic and hornwort specimens, mainly identified to the genus level.

The secondary aim of this study is to provide the basis for a comparison and understanding of the changes in the species composition of the hepatic and hornwort floras through time in a highly urbanized island environment like Singa-

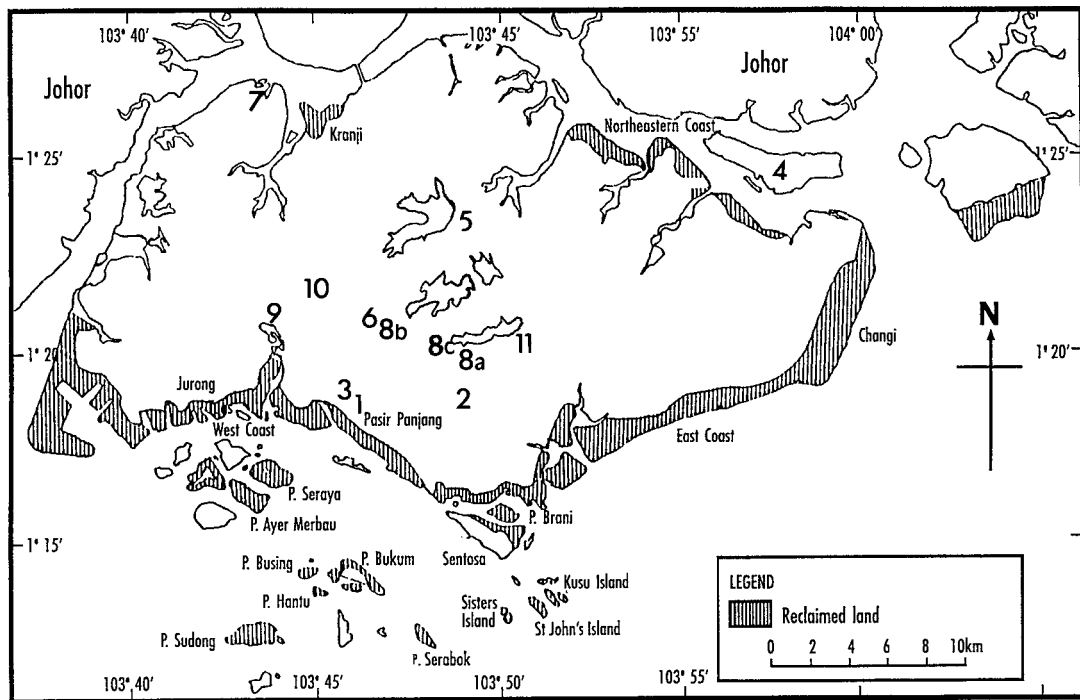


Fig. 3. Map showing the collecting localities of Aino Juslén in Singapore. See the text for more details.

pore. Hopefully, we may be able to learn a few lessons about the survival of plants and their conservation in an island environment undergoing rapid urbanization.

Collecting areas (Figs. 1–3) and collecting numbers

1. Kent Ridge Hill. — Situated behind the campus of the National University of Singapore. The hill is about 100 ft above the sea level and consists of buildings and parking lots surrounded by much disturbed heath forest of *Adinandra* mixed with rubber trees and resam fern (*Dicranopteris linearis*) (5.XI.1998 Juslén 490–498).
2. The National Botanical Garden. — A large area of planted and introduced tropical trees and horticultural plants with a small patch of about 20 hectares of very disturbed old forest called the Gardens Jungle. The garden is divided into different sections, for instance, “Jungle”, “Palm Valley” and “National Orchid Garden”. The numerous well-watered clay pots for orchids and several of the large and old tree trunks on garden ground offer excellent growing substrates for the hepatics (6 and 14.XI.1998 Juslén 499–523, 692–703).
3. Campus of the National University of Singapore. — Another example of man-made area full of concrete buildings, ornamental trees and moist lawns, which, expectedly, have few favorable habitats for hepatics (7, 15 and 17.XI.1998 Juslén 524–534, 711–713, 741, 742).
4. Pulau Ubin. — One of the islets of Singapore situated in the Strait of Johore between Singapore and Peninsular Malaya. The vegetation on the island consists mainly of secondary forest, with a large segment of abandoned rubber plantations and coconut groves and also with dense mangrove vegetation of *Rhizophora* and *Avicennia* along the coast and inlets (8.XI.1998 Juslén 535–564).
5. Nee Soon freshwater swamp. — The last remaining fresh water forest formation around

the firing range at Nee Soon. It is a type of lowland rain forest growing in very wet, seasonally flooded site (Whitmore 1975). Some of the characteristic and dominant trees and palms include *Palaquium xanthochyllum*, *Lophopetalum mutinervium*, *Eleiodoxa conferta* and rattans, such as *Daemonorops sabut* (9.XI.1998 *Juslén* 565–613).

6. Bukit Timah Nature Reserve. — A primary forest reserve located in the centre of the main island. Externally, this small piece of very old forest has the distinctive structure, undergrowth diversity, and all the life forms that are typical of lowland *Dipterocarpus* rain forest in the region. However, the large tree trunks and the few fallen decaying logs do not have many epiphytic bryophytes probably because of the drying up of the forest due to the wind penetration or due to the air pollution (6 and 17.XI.1998 *Juslén* 614–622, 725–740).
7. Sungei Buloh Nature Park. — About 87 hectares of protected mangrove vegetation preserved mainly for the migrating birds. The seaward mangrove trees lack epiphytic hepatics. The liverworts are found growing mostly at the "back mangroves" bordering with the terrestrial forest (11.XI.1998 *Juslén* 623–637).
- 8a. Forested stream in Upper MacRitchie Catchment area at the end of Rifle Range road with disturbed old secondary growth forest (13.XI.1998 *Juslén* 638–648).
- 8b. Lasia Valley. — A narrow patch of secondary forest with abandoned village plantations following a sandy stream on the southeastern edge of the Bukit Timah Nature Reserve (13.XI.1998 *Juslén* 649–673).
- 8c. Sime road. — Access to another forest stream in Upper MacRitchie Catchment (13.XI.1998 *Juslén* 674–691).
9. The Chinese and the Japanese Gardens. — Two parks showing Chinese and Japanese architectures and landscapes. In these two gardens hepatics grew mainly on man-made decorative structures and on plant pots (15.XI.1998 *Juslén* 704–707).
10. The Bukit Batok Park. — An artificial lake created by the past quarry activity and surrounded by secondary forest; also known as

Little Guilin (15.XI.1998 *Juslén* 708–710).

11. Upper reach of MacRitchie catchment where a cement cascade from Upper Peirce Reservoir delivers into the former. The moist bottom and walls of the cement canal offer good growing places for thalloid liverworts as do shaded banks of tracks through surrounding secondary forest (16.XI.1998 *Juslén* 714–724).

Key to the Singapore hepatics and hornworts (unconfirmed records for Singapore are given inside parentheses)

1. Gametophore rosette-like or thalloid-like; chloroplast single or two per cell, large; archegonia and antheridia embedded in thallus, sporophyte erect horn-like or prostrate 2
1. Gametophore thalloid or with leaves and stem; chloroplasts numerous, small; archegonia and antheridia on branches, embedded in thallus or naked or protected on thallus; sporophyte not horn-like 4
2. Thallus strap-shaped or rosette-like; sporophyte long, producing spores continuously 3
2. Thallus rosette-like; sporophyte short, producing spores only during short period. *Notothylas javanica*
3. Thallus strap-shaped; gemmae at thallus margins; pseudoelaters thick-walled and long *Folioceros glandulosus*
3. Thallus rosette-like; gemmae absent; pseudoelaters thin-walled and short (*Phaeoceros laevis*)
4. Gametophore with stem and leaves or thalloid; inner structure simple; dorsal surface smooth, on ventral surface rarely with scales; rhizoids only of one kind (smooth) 5
4. Gametophore thalloid; inner structure differentiated into photosynthetic and storage regions; dorsal surface reticulate, grooved or with stomata, scales common on ventral surface; rhizoids both smooth and pegged Marchantiales (88)
5. Gametophore thalloid; archegonia and antheridia usually on dorsal surface of thallus, sometimes ventrally, either embedded in thallus or on surface naked or protected by scales or on short branches Metzgeriales (83)
5. Gametophore with stem and leaves, leaves transversely or obliquely inserted; archegonia and antheridia on branches or on stem Jungermanniales (6)
6. Leaves complicate-bilobed 7
6. Leaves not complicate-bilobed 58
7. Underleaves lacking; leaf lobule pocket-shaped and with rhizoids *Radula* (8)
7. Underleaves present (except *Cololejeunea*); leaf lobule not pocket-shaped, without rhizoids 10
8. Leaf margins dentate *Radula anceps*

8. Leaf margins not dentate 9
9. Leaf lobules not revolute; leaf lobes ovate
..... *R. borneensis*
9. Leaf lobules revolute; leaf lobes narrowly oblong-ovate *R. reflexa*
10. Plants usually with reddish or purplish pigmentation; leaf lobules almost free from leaf lobes; archegonia usually 2–4 in each gynoecium *Frullania* (11)
10. Plants without reddish or purplish pigmentation; leaf lobules broadly attached to leaf lobes; one archegonium in each gynoecium Lejeuneaceae (19)
11. Leaf lobes with acute apices *Frullania apiculata*
11. Leaf lobes with \pm rounded apices 12
12. Stem leaves with explanate lobules *F. intermedia*
12. Stem leaves with bottle- or helmet-shaped lobules 13
13. Leaves and underleaves with retuse margins 14
13. Margins flat or squarrose 15
14. Autoicous; larger plant; innermost bracts and bracteoles broad *F. nodulosa*
14. Dioicous; small plant; innermost bracts and bracteoles long-lanceolate *F. brotheri*
15. Margins flat 16
15. Margins squarrose (*F. ericoides*)
16. Leaf lobes with basal ocelli *F. gracilis*
16. Leaf lobes without ocelli 17
17. Large plants to 10 cm long *F. gaudichaudii*
17. Plants less than 4 cm long 18
18. Leaf lobule at angle of (10–)20–25(–30) $^\circ$ to stem
..... *F. hypoleuca*
18. Leaf lobule almost parallel with the stem
..... *F. sublignosa*
19. Underleaves absent; very small plants often on leaves *Cololejeunea* (20)
19. Underleaves present 30
20. Leaf lobes with hyaline margin 21
20. Leaf lobes without hyaline margin 23
21. Ocelli absent in leaf lobes *Cololejeunea cuneata*
21. Ocelli in 1–2 rows and 2–4 cells long 22
22. Lobule 1-toothed *C. siamensis*
22. Lobule 2-toothed (*C. pluripunctata*)
23. Leaf margins with distinct spinose teeth
..... *C. haskarliana*
23. Leaf margins entire or toothed, toothed but teeth not spinose 24
24. Leaves narrow with a long acute apex *C. wightii*
24. Leaf apices obtuse 25
25. Lobules reduced and with a long, acute, cilia-like apex *C. stoniana*
25. Lobules without such apex 26
26. Lobules more than half of leaf length
..... *C. minutissima* subsp. *myriocarpa*
26. Lobules half or less than half of leaf length 27
27. Lobule with a strongly involute free margin, which has 3–10 ciliate teeth *C. inflectidens*
27. Lobules different, with fewer teeth 28
28. Leaf margin denticulate *C. cordiflora*
28. Leaf margin entire 29
29. No vitta formed of ocelli *C. goebelii*
29. Distinct vitta formed of ocelli present (*C. floccosa*)
30. Plants usually green or greenish (except *Ceratolejeunea*); cortical stem cells usually in 7 longitudinal rows; underleaves 2-lobed; leaf lobule with one apical tooth 31
30. Plants usually brown, blackish or reddish; cortical cells in 10–50 longitudinal rows; underleaves undivided; leaf lobule with 1–9 marginal teeth 46
31. Hyaline papilla of lobule distal *Cheilolejeunea* (32)
31. Hyaline papilla of lobule proximal 35
32. Plants large, stem with leaves 1.2–1.8 mm wide 33
32. Plants small, stem with leaves less than 1.0 mm wide 34
33. Leaves imbricate; lobules linear to rectangular
..... *Cheilolejeunea longiloba*
33. Leaves contiguous; lobules ovate (*C. tenella*)
34. Leaf lobules ca. $0.3 \times$ lobe length *C. intertexta*
34. Leaf lobules ca. $0.8 \times$ lobe length *C. ventricosa*
35. Plants with blackish pigmentation
..... *Ceratolejeunea singapurensis*
35. Plants without blackish pigmentation 36
36. Ocelli scattered in leaves and underleaves, ocelli of the same size as other cells *Lepidolejeunea* (37)
36. Ocelli scattered or basal in leaf lobes, but lacking in underleaves, larger than other cells, or ocelli absent 38
37. Leaf apices acute; small plant (less than 0.7 cm long and 0.75 mm wide) *Lepidolejeunea borneensis*
37. Leaf apices obtuse; middle-sized plant (less than 3.5 cm long and 2 mm wide) *L. bidentula*
38. Underleaf discus with elongated marginal cells and smaller cells inside; scattered ocelli (typically) usually forming a broken line in leaf lobes
..... *Leptolejeunea elliptica*
38. Underleaf discus without elongated marginal cells; ocelli basal in leaf lobes or absent 39
39. Plants small to minute and filiform; leaves distant to contiguous, erect or suberect, convex; lobules often inflated, $(0.4\text{--})0.5\text{--}0.85 \times$ lobe length 40
39. Plants medium-sized; leaves \pm imbricate or contiguous, obliquely to widely spreading, flat or convex; lobules inflated or not, $0.3\text{--}0.5 \times$ lobe length 43
40. Underleaf lobes spreading and usually narrow
..... (*Drepanolejeunea vesiculosa*)
40. Underleaf lobes not spreading 41
41. Stem with (3–)4–7 rows of medullary cells; leaves often with 1–3 basal ocelli *Harpalejeunea filicuspis*
41. Stem with 3 rows of medullary cells; leaves without basal ocelli *Microlejeunea* (42)
42. Dioicous *Microlejeunea punctiformis*
42. Monoicous *M. ulicina*
43. Ocelli absent; leaves flat, \pm imbricate; plants usually greenish *Lejeunea* (44)
43. Large ocelli at leaf bases; leaves convex, contiguous; plants usually yellowish brown
..... *Pycnolejeunea contigua*

44. Leaves obliquely spreading, stem with leaves 0.5–0.8 mm wide *Lejeunea parva*
44. Leaves widely spreading, stem with leaves 0.8–1.2 mm wide 45
45. Underleaves subcordate or rounded at base, 3–4 times as wide as stem *L. flava*
45. Underleaves narrowed toward base, 2–3 times as wide as stem *L. catanduana*
46. Leaves blackish but translucent *Lopholejeunea* (47)
46. Leaves violet, green or brown, not translucent 48
47. Leaf apex acute or apiculate
..... *Lopholejeunea nigricans*
47. Leaf apex rounded *L. subfusca*
48. Plants usually violet, julaceous; leaves \pm toothless ...
..... *Schiffneriolejeunea* (49)
48. Plants green or brown; leaves toothed or at least crenulate 51
49. Lobules with 3–4 teeth
..... *Schiffneriolejeunea cumingiana*
49. Lobules with 2 teeth 50
50. Lobules not saccate, free margin plane, leaves not squarrose *S. pulopenangensis*
50. Lobules saccate, free margin inrolled, leaves \pm squarrose *S. tumida*
51. Cells of ventral epidermis in cross-section of the stem distinctly higher than medullary cells 52
51. Cells of ventral epidermis in cross-section of the stem not distinctly higher than medullary cells 55
52. Perianth 4–10-keeled; leaves when dry densely convolute; lobule with 2 to several marginal teeth
..... *Acrolejeunea* (53)
52. Perianth 3-keeled; leaves when dry \pm spreading to weakly convolute; lobule with 1 apical tooth
..... (*Caudalejeunea cristiloba*)
53. Lobules with 4–10 teeth *Acrolejeunea fertilis*
53. Lobules with 1–3 teeth 54
54. Leaves squarrose ... *A. securifolia* subsp. *hartmannii*
54. Leaves not squarrose *A. pycnoclada*
55. Leaves and underleaves not long lanceolate 56
55. Leaves and underleaves long lanceolate
..... *Dendrolejeunea fruticosa*
56. Underleaves toothed or, if entire with a vitta on leaf lobe; three fringed winged keels on the perianth
..... *Thysananthus* (57)
56. Underleaves entire; no vitta on leaf lobe; \pm entire keels on the perianth... (*Mastigolejeunea auriculata*)
57. Leaves entire *Thysananthus comosus*
57. Leaves toothed *T. spathulistipus*
58. Leaves entire or 2–4-lobed, shallowly or even deeply lobed, when 2–4-lobed, lobes never wholly as filiform segments nor plants stoloniferous; in reduced plants cells not conspicuously leptodermous 71
58. Leaves usually 2–7-lobed, deeply or shallowly lobed, whole lobes filiform or not; when 2–4-lobed, lobes either as filiform segments or plants very reduced and having leptodermous leaf cells or plants with aerial or rhizoidous stolons 59
59. Leaves deeply 4–5-lobed, cilia numerous and branched; stem with spines *Trichocolea pluma*
59. Leaves deeply or shallowly 2–7-lobed, toothed or ciliate, cilia rarely branched; stem without spines 60
60. Leaves with filiform segments, discus very shallow .
..... 61
60. Filiform segments lacking, discus higher 64
61. Discus almost absent; leaves with 1–2 or 3–4 segments 62
61. Discus well-defined; leaves with 3–4 segments ... 63
62. Leaves with 1–2 segments *Arachniopsis major*
62. Leaves with 3–4 segments
..... (*Blepharostoma trichophyllum*)
63. Plants rigid; underleaves minute, 2-lobed
..... *Kurzia gonyotricha*
63. Plants soft; underleaves larger, 4-lobed and segments 4–5 cells long *Telaranea neesii*
64. Branch apices turning into flagellae; plants translucent *Lepidozia* (65)
64. No flagellae present, but stolons may be present; plants not translucent 66
65. Leaf and underleaf cells bulging
..... *Lepidozia mamillosa*
65. Leaf cells not bulging *L. wallichiana*
66. Ventral terminal branching present; underleaves almost entire or 3-lobed, leaves if lobed asymmetricaly 2(–3)-lobed *Acromastigum* (67)
66. Ventral terminal branching lacking; underleaves entire or 4-lobed; leaves 2–3-lobed *Bazzania* (68)
67. Leaf cell thickenings uniform, papillae tubercles slightly developed, cell walls without yellowish pigmentation *Acromastigum inaequilaterum*
67. Leaf cell trigones well-developed, papillae tubercles distinct, cell walls with yellowish pigmentation
..... (*A. echinatum*)
68. Underleaves hyaline *Bazzania tridens*
68. Underleaves not hyaline 69
69. Leaves very asymmetrical, their apex poorly toothed
..... *B. recurva*
69. Leaves less asymmetrical, teeth well developed 70
70. Underleaves lacinate-toothed *B. paradoxa*
70. Underleaves less toothed *B. wallichiana*
71. Leaves incubous *Calypogeia arguta*
71. Leaves succubous 72
72. Well-developed leaves and underleaves
..... *Heteroscyphus* (73)
72. Underleaves absent or poorly developed 76
73. Leaves entire *Heteroscyphus succulentus*
73. Leaves toothed or lobed 74
74. Leaves toothed 75
74. Leaves lobed (*H. splendens*)
75. Leaf apices with more than 3 teeth *H. argutus*
75. Leaf apices with 1–3 teeth *H. zollingeri*
76. Plants minute and filiform; leaves 2-lobed
..... *Cephaloziella kiaeri*
76. Plants middle-sized, not filiform; leaves entire 77
77. Leaves usually toothed *Plagiochila* (78)

77. Leaves toothless 80
 78. Large ciliate underleaves; well-developed sac with ciliate margins on ventral leaf base
 *Plagiochila bantamensis*
 78. Small or lacking non-ciliate underleaves; no sac or less distinct and without cilia 79
 79. Marginal teeth small and triangular in leaves; non-ciliate small sac on ventral leaf base *P. kurzii*
 79. Marginal teeth long and cilia-like; no sac
 *P. sciophila*
 80. Leaf cells with large trigones *Jackiella* (81)
 80. Leaf cells without or with medium-sized trigones that are not bulging *Jungermannia* (82)
 81. Leaves with acute apices *Jackiella singaporensis*
 81. Leaves with obtuse apices (*J. javanica*)
 82. 2–4 marginal leaf cells thick-walled
 *Jungermannia truncata*
 82. Marginal leaf cells similar to other leaf cells
 (*J. ariadne*)
 83. Thallus translucent, or if not, then blackish and undulating 84
 83. Thallus not translucent, firm 86
 84. Gametoezia dorsal on leading, expanding vegetative fronds; androecia under distinct scales, never spicate; gynoecia surrounded by cup-like involucre 85
 84. Gametoezia on very short, reduced, ventral-intercalary branches from lower, stipe-like portions of vegetative fronds, whitish, ± hidden; androecia spicate, in alveoli; gynoecia on expanded apex of slender stipe, surrounded by incised-laciniate-ciliate involucre
 *Podomitrium malaccense*
 85. Androecia with male scales in 2 parallel rows, a median stripe free of scales *Pallavicinia lyellii*
 85. Androecia with male scales irregularly arranged along the midrib and ± wholly covering it (*P. levieri*)
 86. Thallus (1.5–)2–6(–12) mm wide; branching 1–2-pinnate; gemmae absent *Aneura pinguis*
 86. Thallus (0.05–)0.5–2(–4) mm wide; branching (1–)2–4-pinnate; endogenous gemmae common
 *Riccardia* (87)
 87. Mucilage hairs on thallus surfaces ... *Riccardia graeffei*
 87. Mucilage hairs marginal (*R. tenuicostata*)
 88. Very delicate and thin plants; gynoecia terminal, becoming displaced ventrally beneath frond apex
 *Cyathodium* (89)
 88. Usually more firm and thick plants; gynoecia stalked or embedded in thallus 90
 89. Not glossy plant (*Cyathodium cavernarum*)
 89. Glossy plant (*C. smaragdinum*)
 90. Small rosettes; gynoecia and sporangia inside thallus scattered along its middle line *Riccia treubiana*
 90. Strap-like large plants; gynoecia and sporangia on stalked receptacles 91
 91. Pores of dorsal thallus surface barrel-shaped; male receptacles with long stalk *Marchantia acaulis*
 91. Pores of dorsal thallus surface simple; male receptacles without stalk (*Wiesnerella denudata*)

The Hepaticae and Anthocerotae flora

(The bold and italic number represents the locality cited above. All collection numbers belong to Juslén unless otherwise identified. The voucher specimens are at H and duplicates at SINU. Novelties for Singapore are marked with *).

Anthocerotaceae Dumort. (by S. Piippo)

**Folioceros glandulosus* (Lehm. & Lindenb.) Bharadw.

Thallus strap-shaped, often almost blackish, thallus margins deeply lobed with fairly large, spongy gemmae on dorsal surface and margins. The sporophytes are long and thin, the pseudoelaters long, dark and thick-walled; spores dark. — Illustration: Piippo 1993a: 34 (fig. 4a–e).

RANGE IN SINGAPORE: **2.** 1924 *I. H. Burkill* (SING-0017062). **4.** 543, on mesic clay. **6.** Fern Valley, 19.2.1998 *B. C. Tan* (SINU). **8a.** 645, on sand on brook side. **10.** 708, on clay.

TOTAL RANGE: Sikkim, Indonesia, Malaysia, Singapore, Philippines, Papua New Guinea, Oceania, and Australia (cf. Piippo 1993a).

Notothyladaceae (Milde) Müll. Frib. ex Prosk. (by S. Piippo)

**Notothylas javanica* (Sande Lac.) Gottsche

The radiate thallus does not continue its growth after fertilization; also growth of the sporophyte is terminated. Sporophytes are short and spores are produced synchronously. — Illustration: Hasegawa 1979: 24 (fig. 3d–g).

RANGE IN SINGAPORE: **2.** Plant House, 1898 *H. N. Ridley* 594 (SING-0017061). **4.** 536, secondary growth forest, on sand. Mostly growing on ground and soil cover.

TOTAL RANGE: Southern Japan, Taiwan, Philippines, Indonesia (Java), and Singapore (cf. Hasegawa 1979, 1984).

Trichocoleaceae Nakai (by S. Piippo)

Trichocolea pluma (Reinw. et al.) Dumort.

An easily recognized, medium-sized to large species, plants are soft and woolly due to multi-ciliate leaves

and stems with paraphyllia. — Illustration: Piippo 1984a: 32 (fig. 9c–d) as *T. tomentella* (Ehrh.) Dum. s. lato.

RANGE IN SINGAPORE: 5. Chan Chu Kang (Nee Soon Swamp), 1894 *H. N. Ridley* 442 (SING-0017150).

TOTAL RANGE: Widely distributed in SE Asia (Kitagawa 1973, but see Piippo 1984a).

Lepidoziaceae Limpr. (by S. Piippo)

Acromastigum inaequilaterum (Lehm. & Lindenb.) A. Evans

Fairly small to medium-sized plants; leaves with dorsal lobe straight and outward pointed, ventral lobe forward pointed, sinus between them narrow; cell walls are uniformly thickened without trigones, and each cell has one large central papilla; underleaves are asymmetrically 3-lobed with one unicellular tooth on both margins. — Illustration: Piippo 1991: 31 (fig. 4a–f).

RANGE IN SINGAPORE: 2. 1900 *H. N. Ridley* 27 (SING-0017118, as *Bazzania echinata*). 6. 1900 *Anonymous* 73 (SING-0017114, as *Mastigobryum echinatum*). Ca. 200 m alt., 1930 *Verdoorn* 12 (SING-0017103, as *Thysananthus comosus*). 1993 *W. S. Chee, B. K. W. Phuah & A. C. P. Ng* 2176; 1993 *W. S. Chee, W. L. Goh, W. F. Ng, H. T. W. Tan & G. C. H. Tan* 2050 (SING). Dry boulder, in rain forest, 1975 *S. G. Harrison* (SING-0019593). 11. 723, on clay on road side. North side, 1954 *J. Sinclair* 8007 (SING-0017113), by stream in shore, 1954 *J. Sinclair* 40228 (SING-0017112). — Mandai Road off the 10 1/2 mile, old secondary forest in dry ground, 1966 *J. Sinclair* 10902 (SING-0017127/036729, with *Lepidozia wallichiana*). Selitar, 1904 *Anonymous* 257 (SING-0017115, as *Mastigobryum echinatum*). *Acromastigum echinatum* was listed in Turner & H. Tan (1994) but not seen in the present study.

TOTAL RANGE: Widely distributed in Indomalaysia, Nepal, Cambodia, and the Nicobars (Grolle 1978).

**Arachniopsis major* Herz.

A small, delicate and cobwebby plant. The whole plants are translucent; leaves 1–2-lobed, lobes uniseriate, 5–7 cells long, often fragile, discus is absent. Underleaves are minute, 2-lobed and both lobes 2-celled and with an apical hyaline papilla. — Illustration: Piippo 1985a: 171 (fig. 1a and b).

RANGE IN SINGAPORE: 5. On decaying wet log, 1998 *B. C. Tan* (SINU).

TOTAL RANGE: Sri Lanka, Malaysia, Singapore, Indonesia, Papua New Guinea (cf. Piippo 1985a).

Bazzania paradoxa (Sande Lac.) Steph.

Fairly large plants, 4–5 cm long, dull brownish in color, leaves are widely spreading, 3-toothed, teeth are sharp, ventral bases with distinct toothed appendage, leaf cells with large nodulose trigones; underleaves are deeply lacinate, 4-lobed. — Illustration: Evans 1933: pl. XVIII: 1–11.

RANGE IN SINGAPORE: Sungei Jurong, 1897 *H. N. Ridley* 364 (SING-0017122, as *Bazzania loricata*). Sungei Morai, 1894 *H. N. Ridley* 302 (SING-0017125). Kranji, 1897 *H. N. Ridley* 11274 (SING-0017123, as *B. loricata*); 1909 *Anonymous* 265 (SING-0017116, as *Bazzania malacense*). Woodland, 1906 *H. N. Ridley* 12602 (SING-0017121, as *Bazzania loricata*). Reported from Singapore as *B. natunensis* Steph. in Turner & H. Tan (1994).

TOTAL RANGE: Thailand, Malaya, Indonesia, Borneo, Fiji, Samoa (Kitagawa 1967).

**B. recurva* (Mont.) Trevis. (Fig. 4)

Plants large and rigid; leaves densely imbricate, triangularly ovate, apex often incurved and rounded with small teeth, margins serrulate, dorsal leaf base strongly cordate; underleaves reniform, without basal auricles.

RANGE IN SINGAPORE: 2. 1893 *H. N. Ridley* 615 (SING-0017119, as *B. loricata*).

TOTAL RANGE: widely distributed in SE Asia (Kitagawa 1979).

B. tridens (Reinw. et al.) Trevis.

Small to medium-sized, olive green or brownish plants; sometimes leaves caducous, 3-toothed, teeth triangular and acute; underleaves about twice as wide as stem, subquadrate, entire or toothed, hyaline, not connate with leaves. — Illustration: Mizutani 1967: 74 (fig. 1).

RANGE IN SINGAPORE: 5. 571, root stump of tree; 587, 599, 602, 609, on tree bases; 594, on tree trunk; 586, on base of *Eleiodoxa* palm; 605, on stump. On base of *Madhuca*, 1998 *B. C. Tan* s.n. (SINU); 1998 *B. C. Tan* s.n. (SINU). 6. 727, primary forest, on fallen log; 729, on tree trunk; 731, on dead tree trunk; 733, on tree base. 1993 *W. S. Chee, W. L. Goh, W. F. Ng, H. T. W. Tan & G. C. H. Tan* 1965 (SING). — Bukit Mandai, 1894 *Anonymous* 306 (SING-0017124).

TOTAL RANGE: one of the commonest species of *Bazzania* in SE Asia (see Mizutani 1967, Long & Grolle 1990).

B. wallichiana (Lindenb.) Trevis.

Otherwise very similar to *B. tridens*, but underleaves are hyaline only along the margins; they are as wide as stem and slightly connate at base with lateral leaf (leaves). —

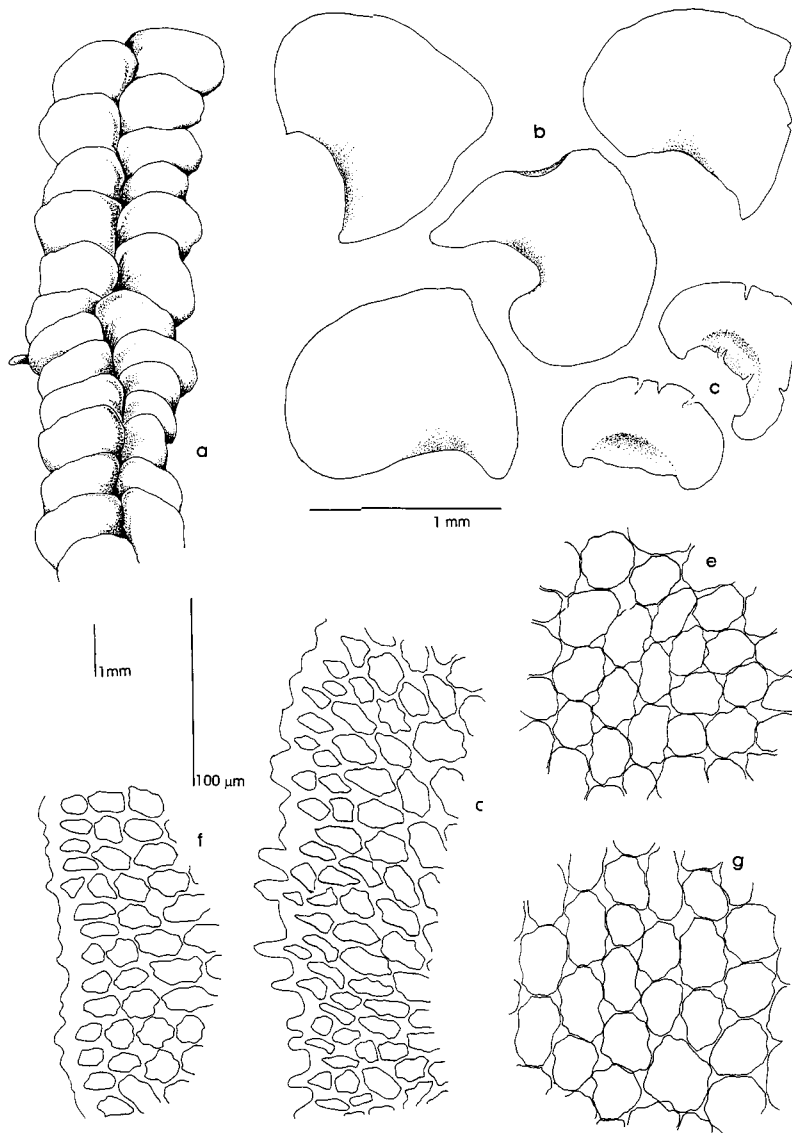


Fig. 4. *Bazzania recurva* (Mont.) Trevis. (from Ridley 615). — **a:** Habit. — **b:** Leaves. — **c:** Underleaves. — **d:** Apical leaf cells. — **e:** Cells from middle portion of leaf. — **f:** Apical underleaf cells. — **g:** Cells from the basal portion of underleaf. — Use the 1 mm (short) scale for **a**, 1 mm (long) scale for **b–c**, 100 μm scale for **d–g**.

Illustration: Mizutani 1967: 87 (fig. VII: 1–12).

RANGE IN SINGAPORE: **2.** Jungle, on tree trunk, 1881 *H. N. Ridley* 201 (SING-0017117). Only known from Singapore (Mizutani 1967) but not mentioned in Turner & H. Tan (1994).

TOTAL RANGE: Endemic to Singapore.

Kurzia gonyotricha (Sande Lac.) Grolle

Small, pale, green plants; leaves are rigid, obliquely spreading, unequally 3–4-lobed near the leaf bases, lobes uniseriate, tips acute-pointed, dorsal lobe shorter than the other lobes; underleaves minute, 2-lobed. — Illustration:

Piippo 1985a: 177 (fig. 5f).

RANGE IN SINGAPORE: **6.** Earth bank by roadside in rain forest, 1975 *S. G. Harrison* (SING-0019592).

TOTAL RANGE: Japan, Malaysia, Indonesia, Papua New Guinea (Piippo 1985a).

Lepidozia mamillosa Schffn.

Similar to *L. wallichiana*, but the cells may be more rounded, and the perianth cells are mamilliose. — Illustration: Piippo 1984b: 315 (fig. 4d, g, i, k).

RANGE IN SINGAPORE: **9.** 704, Chinese Garden, on artificial ditch side, on clay. — Labrador Park, on salt

sprayed rock, 16.8.1998 *B. C. Tan s.n.* (SINU). Sungei China, Lim Chu Kang, elevations of mud in the mangrove, 1965 *J. Sinclair 10780* (SING-0017126/036728).

TOTAL RANGE: Borneo, Singapore, New Guinea (*see Mizutani 1974*).

L. wallichiana Gottsche

Fairly small, pale green, irregularly pinnate-branched plants; leaves widely spreading, nearly flat, subrhombic, (3–)4-lobed to 1/3–1/2 of the leaf length, lobes 3–5 cells long, 1–2 cells wide at base, discus 4 cells high; stem underleaves small, distant, low-rectangular, usually 4-lobed, lobes distant; cell walls thin; perianth cells smooth. — Illustration: Piippo 1984b: 315 (fig. 4a–c, e, f, h, j).

RANGE IN SINGAPORE: *5.* 572, in full shade on tree branch; 575, on tree base; 577, on twig; 582, on tree stump; 583, on tree branch; 585, 593, on tree bases. On decaying log, 1998 *B. C. Tan s.n.* (SINU). *6.* 617, primary forest; 619, on twig on brook side; 622, in road side on sandy clay. 1900 *H. N. Ridley 11* (SING-0017128). *8c.* 677, secondary growth forest, on tree base; 682, on trunk of *Adinandra*. — Mandai Road off the 10 1/2 mile, old secondary forest in dry ground, 1966 *J. Sinclair 10902* (SING-0017127/036729, with *Acromastigum inaequilaterum*).

TOTAL RANGE: Japan, Taiwan, India, Nepal, Sri Lanka, Indonesia, Malaysia, Singapore, Papua New Guinea, Oceania (cf. Piippo 1984b).

Telaranea neesii (Lindenb.) Fulford

Small, pale to yellowish, hyaline, sparsely branched plants, leaves 4–5-lobed, discus 1 1/2 cells high, 8–10 cells wide, segments uniseriate with 5–6 cells; underleaves 4-lobed, segments 4–5 cells long. — Illustration: Grolle 1966: 287 (Abb. 4).

RANGE IN SINGAPORE: *5.* 566, 567, 579, on rotten logs. 14.2.1992 *B. C. Tan s. n.* (SINU). *6.* 617, primary forest, on brook side on stone; 726, on trail on sand; 735, Tiup-Tiup path, primary forest, 1993 *W. S. Chee, W. H. L. Lim & W. F. Ng 1816* (SING). Earth bank in rain forest, 1975 *S. G. Harrison* (SING-0019594).

TOTAL RANGE: Indonesia, Malaysia, Papua New Guinea (Piippo 1984b).

Calypogeiaceae (Müll. Frib.) Arnell (by S. Piippo)

Calypogeia arguta Nees & Mont.

Fairly small, slender, green plants; leaves asymmetrical, the apex shallowly 2-lobed, underleaves small, distant, as

wide as stem, 2-lobed at least to 1/2 of the underleaf length; leaf cells thin. — Illustration: Piippo 1984b: 330 (fig. 10b–f).

RANGE IN SINGAPORE: *1.* 497, on concrete wall. *4.* 563, in road side on mesic sand. *6.* 734, Tiup-Tiup path. *8b.* 653, 657, on brook side on sand. *8c.* 681, 686, on brook side on clay. Mostly in secondary growth, occasionally in primary rain forests.

TOTAL RANGE: Widely distributed from Subatlantic and Mediterranean Europe to tropical areas of Palearctica (Piippo 1984b).

Cephaloziellaceae Douin (by S. Piippo)

**Cephaloziella kiaeri* (Austin) Douin

Small, green, filiform plants, to 1 cm long and 0.2–0.3 mm wide; stems thick; leaves distant, widely spreading, 2-lobed to 0.5 of their length, lobes somewhat subequal, triangular; underleaves absent; cells thick-walled. — Illustration: Vána & Piippo 1989a: 265 (fig. 1c, f, j).

RANGE IN SINGAPORE: *1.* 490, secondary growth forest, tree base, on sand. *3.* 712 (with *Riccardia graeffei*), on clay.

TOTAL RANGE: Africa, Seychelles, China, Taiwan, India, Sri Lanka, Himalaya, Bhutan, Thailand, Malaysia, Singapore, Borneo, Indonesia (Java, West Irian), Philippines, Papua New Guinea, New Caledonia, Samoa, Solomon Islands (cf. Vána & Piippo 1989a, Long & Grolle 1990).

Jackiellaceae R. M. Schust. (by S. Piippo)

Jackiella singaporensis Schiffn. (Fig. 5)

Olive green, less than 2.5 cm long simple plants; leaves ovate-triangular, apices acute to acuminate with gemmae at their tips; apical cells with large trigones, basal cells large, ca. 50 µm long, trigones small.

RANGE IN SINGAPORE: *11.* 719, on trail on clay.

TOTAL RANGE: Endemic to Singapore (Grolle 1970).

Jungermanniaceae Reichenb. (by J. Vána)

**Jungermannia truncata* Nees

Usually green but also other coloured plants with numerous colourless to purplish rhizoids; leaves variable, from ovate to ligulate; cells along leaf margins have subequally thickened walls in 1–4 rows, trigones are absent to medium-sized. Perianths are also variable, ovate, fusi-

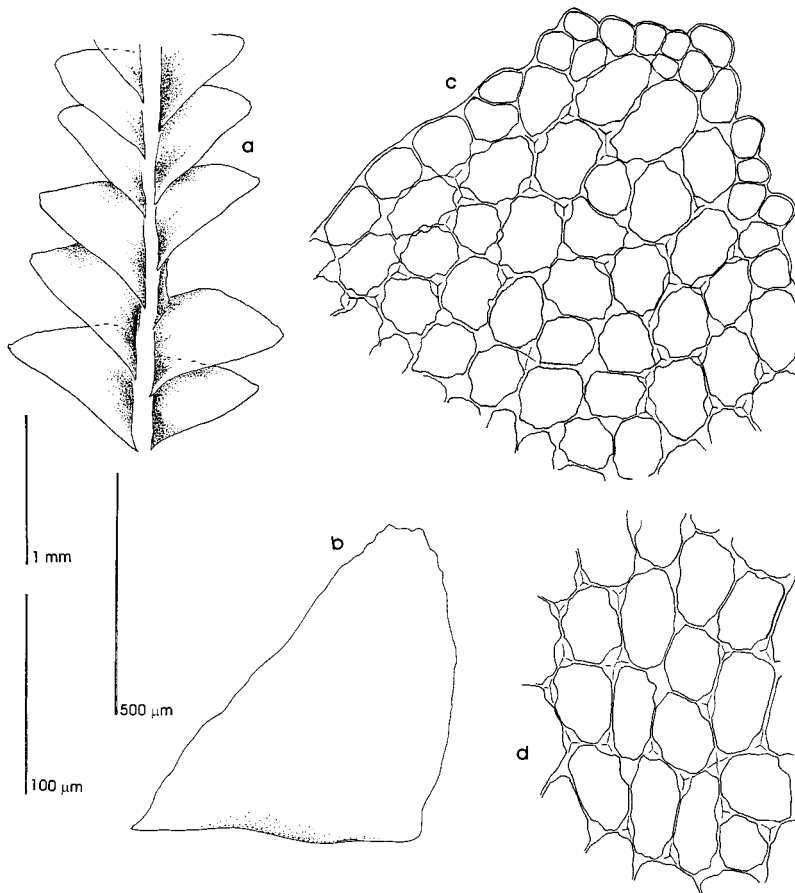


Fig. 5. *Jackiella singapurensis* Schiffn. (from Juslén 719). — **a:** Habit. — **b:** Leaf. — **c:** Leaf. — **d:** Cells from middle portion of leaf. — Use the 1 mm scale for **a**, 500 μm for **b**, 100 μm scale for **c–d**.

form or campanulate, mouth narrowed or not. — Illustration: Vána & Piippo 1989b: 114 (fig. 2a–d).

RANGE IN SINGAPORE: **3.** On soil bank, 1998 *B. C. Tan* (SINU). **6.** 615, 644, in road side on sandy clay. **8b.** 652, 653, on brook side on sand; 656, 661, 691, on clay. — Nanyang Technological University, Nanyang Terrace, drain at E side of Yunnan corner sited at side of drained gravel cementation, *S. P. Ngee* 12/3198 (SING). Very common in Singapore.

TOTAL RANGE: Widely distributed species in SE Asia (cf. Vána & Piippo 1989b).

Geocalyceae Klinggr. (by S. Piippo)

**Heteroscyphus argutus* (Reinw. et al.) Schiffn.

Medium-sized, 2–3 cm long and less than 3 mm wide, yellowish or green, not translucent plants; leaves flat, symmetrical, apices with (2–)4–8(–10) teeth; underleaves small, distant, deeply 4-lobed. — Illustration: Piippo 1985b: 138 (fig. 4k–m).

RANGE IN SINGAPORE: **1.** 493, secondary growth forest, on stone. **2.** 504, on tree base on sandy clay; 695, in bamboo area, on stump; 696, on humus near *Ficus celebensis*; 701, “Jungle”, on asphalt. **4.** 556, 562, secondary growth forest, on mesic sand; 558, on clay. **5.** 574 (with *Plagiochila bantamensis*), on tree trunk; 588, on tree branch. **6.** 616, 617, primary forest, on brook side on stone; 620, on tree branch; 736, on stone; 738, Fern Valley, on fallen log. — Loyang, on wet soil creek bank, 1998 *B. C. Tan* s. n. (SINU).

TOTAL RANGE: Himalaya, Bhutan, widespread in tropical Asia, south to Australia, New Zealand, Oceania (cf. Piippo 1985b, Long & Grolle 1990).

H. succulentus (Gottsche) Schiffn.

Plants medium-sized, flaccid; leaves ligulate-triangular, narrowing towards their apices, entire; underleaves large, twice as wide as long, 2-lobed and ciliate-toothed; cells large and thin-walled. — Illustration: Piippo 1985b: 147 (fig. 10a–d).

RANGE IN SINGAPORE: **4.** 1896 *H. N. Ridley* 433

(SING-0017059, with *Riccardia graeffei*).

TOTAL RANGE: Malacca, Indonesia (Java, Sumatra, West Irian), Borneo, Papua New Guinea, Tahiti (Piippo 1985b).

H. zollingeri (Gottsche) Schiffn.

Plants medium-sized, usually larger and paler than *H. argutus*, leaf margins arched, apex with 1–3 teeth; underleaves very small, each margin with a single tooth. — Illustration: Piippo 1985b: 138 (fig. 4h–j).

RANGE IN SINGAPORE: **2.** 509, “Jungle”, on clay. **3.** 527, Kent Ridge Hall, beside Block B, on moist sand; 530, beside block E, on moist sand; 741, near DBS botanical garden. **4.** 542, secondary growth forest, on mesic sand; 549, on clay. **6.** On rock, 1997 *B. C. Tan* (SINU); Fern Valley, 1998 *B. C. Tan* (SINU). **8b.** 659, secondary growth forest, on brook side, on rotten log. — Cluny Road, 1895 *H. N. Ridley* 588 (SING-0017057, with *Riccardia graeffei*).

TOTAL RANGE: Japan, Malaysia, Singapore, Indonesia, Philippines, Papua New Guinea (cf. Piippo 1985b).

Plagiochilaceae (Joerg.) Müll. Frib. (by S. Piippo)

Plagiochila bantamensis (Reinw. et al.) Dumort.

Plants variable, 3–6 cm long; branches rare; leaves oblong, teeth on the ventral margin ciliate, on dorsal and apical margins spinose, ventral leaf base with ovate ciliate-dentate sac; underleaves rather large, 2(–3)-lobed with ciliate-dentate margin. — Illustration: Inoue 1984: pls. 12–14.

RANGE IN SINGAPORE: **5.** 574, 589, 592, on tree trunk; 603, on leaf of a climber. On branch base of trunk, 1999 *B. C. Tan* (SINU). Chan Chu Kang (Nee Soon Swamp), *Anonymous* 284 (SING-0017105, as *Thysanolejeunea fruticosa*). **6.** 1900 *H. N. Ridley* 31 (SING-0017142, as *P. mutabilis*); Fern Valley, on granite boulder, 1953 *J. Sinclair* 7221 (SING-0017144, as *P. parvistipula*). — Pasir Panjang, 1900 *H. N. Ridley* 54 (SING-0017143, as *P. mutabilis*). Stagmount (?), 1891 *Anonymous* s.n. (SING-0017138).

TOTAL RANGE: Solomon Islands, Indonesia, Malaysia, Singapore, Philippines, Japan, Cambodia, Nicobars, Sri Lanka (cf. Piippo 1993b).

**P. kurzii* Steph.

Plants 2.5–4 cm long, branches quite few; leaves oblong-quadrate, usually about twice as long as wide, marginal teeth small and triangular; ventral base with indistinct sac usually with entire margin; underleaves vestigial. —

Illustration: Inoue 1984: pls. 3–4.

RANGE IN SINGAPORE: **5.** 589 (with *P. bantamensis*), on tree trunk; 584 (with *Lejeunea catanduana*), on leaf of a climber. **6.** 1896 *H. N. Ridley* 691 (SING-0017140, -0017141, as *P. belangeriana*?).

TOTAL RANGE: India (Andamans), Borneo, Indonesia (Sumatra), Singapore (cf. Inoue 1984).

**P. sciophila* Nees

Plants yellowish green or brownish, usually soft-textured, branches few; leaves often caducous, with rather broad insertion lines, short to long rectangular or oblong, teeth usually ciliate or spinose at leaf apex; underleaves vestigial. — Illustration: Inoue 1984: pls. 74–75.

RANGE IN SINGAPORE: **2.** 1895 *H. N. Ridley* 621 (SING-0017139).

TOTAL RANGE: Arkansas in North America, otherwise widespread in tropical and temperate SE Asia (cf. Piippo 1989, Long & Grolle 1990).

Radulaceae (Dumort.) Müll. Frib. (by X.-L. He)

**Radula anceps* Sande Lac.

This species is distinctive in the irregularly toothed leaf lobes, the long-toothed leaf apex, the lacking trigones of the leaf lobes, and the short teeth of the perianth-mouth. — Illustration: Yamada 1979: 211 (fig. 1).

RANGE IN SINGAPORE: **6.** 740, Fern Valley, primary forest, on brook side, on stone.

TOTAL RANGE: Nicobar Is., Malay Peninsula, Singapore, Indonesia (Sumatra, Java), Borneo, Philippines, Japan (Ryukyu), New Guinea, New Caledonia, Carolines (cf. Yamada 1979).

**R. borneensis* Steph.

Leaf lobules are with strongly inflated carinal regions, the abaxial margins are straight, decurrent to the ventral margins of leaf lobes, and keels sinuate, more or less decurrent. — Illustration: Yamada 1979: 224 (fig. 7).

RANGE IN SINGAPORE: **5.** Chan Chu Kang (Nee Soon Swamp), 1889 *H. N. Ridley* (SING-0017149).

TOTAL RANGE: Borneo, Singapore (cf. Yamada 1979).

R. reflexa Nees & Mont.

The species is characterized by the narrowly oblong-ovate leaf lobes with a flat apex, the leaf lobules with

often strongly recurved from 2/3 of adaxial margin, and the decurrent sinuate keel. — Illustration: Yamada 1979: 249 (fig. 24).

RANGE IN SINGAPORE: 7. *J. S. Goodenough* (SING-0017147). — Bukit Mandai, 1896 *Anonymous 694* (SING-0017146); 1897 *H. N. Ridley 360* (SING-0017145).

TOTAL RANGE: Ceram, Borneo, Singapore, New Guinea (cf. Yamada 1979).

Frullaniaceae Lorch (by X.-L. He)

Frullania apiculata (Reinw. et al.) Dumort.

This species is characterized by the apiculate-acuminate leaf apices, the large, nodulose, often confluent trigones of leaf lobes, the short-cylindrical lobules remote from and almost parallel to the stem, and the underleaves often narrowly recurved along margins. — Illustration: Hattori 1972: 110–112 (figs. 1–3).

RANGE IN SINGAPORE: Kranji, 1910 *H. N. Ridley 307* (SING-0017064).

TOTAL RANGE: widely distributed in tropical Asia and the Pacific Islands (cf. Hattori 1972, 1974, 1980a).

F. brotheri Steph.

Plants medium-sized to large, leaves densely imbricate, leaf lobes widely ovate or orbicular, apices rounded, cell walls thin, with subnodulose to nodulose trigones; leaf lobules small, pendent, clavate, with obtuse apices, stylus at base, minute, composed of 4–5 seriate cells; underleaves imbricate, large, reniform, often with narrowly recurved upper and middle margins, lobed 1/5 of their length, lobes triangular, apices acute. — Illustration: Hattori 1980b: 223 (fig. 36).

RANGE IN SINGAPORE: No locality, 2.1900 *H. N. Ridley 60* (SING-0017074).

TOTAL RANGE: Sri Lanka, Thailand, Malay Peninsula, Singapore, Indonesia (Sumatra, Java), Borneo, Philippines, Japan (cf. Hattori 1976, 1980b).

F. gaudichaudii Nees & Mont.

This species is characterized by the long and almost longitudinal insertions of leaf lobes, the comparatively longer leaf lobes, the wide-appendaged ventral base of leaf lobes, and very short gynoeical branches. — Illustration: Hattori 1972: 124–127 (figs. 10–13).

RANGE IN SINGAPORE: 5. Chan Chu Kang (Nee Soon Swamp), 1896 *H. N. Ridley 434* (SING-0017081, as *Frullania recurvata*). — Kranji, 1889 *J. S. Goodenough 700* (SING-0017084, as *Frullania recurvata*); 1892 *H. N. Ridley 283* (SING-0017065); 1909 *Anonymous 261* (SING-

0017085, as *Frullania recurvata*); 1910 *H. N. Ridley 306* (SING-0017083, as *Frullania recurvata*). Bajau, *H. N. Ridley 1208* (SING-0017082, as *Frullania recurvata*). Pasir Panjang, 1904 *Anonymous 252* (SING-0017086, as *Frullania recurvata*).

TOTAL RANGE: widely distributed in Asia, Pacific Islands, Auckland Is., the Antarctic, Brazil, and Guyana (cf. Hattori 1972).

F. gracilis (Reinw. et al.) Dumort.

This species is distinctive in the reddish, small plants, ocelli present at the leaf base, and the densely toothed lobes of the innermost female bracts. — Illustration: Hattori 1976: 505 (fig. 200 i–n).

RANGE IN SINGAPORE: 2. 500, on trunk of *Borassus flabellifera*; 502, on trunk of *Ceiba pentandra*; 513, on tree base. Hattori & Thaithong (1978). 6. (Hattori 1975a). — Kranji, 1892 *H. N. Ridley 283* (SING-0017065). Chua Chu Kang, 1930 *Verdoorn s.n.* (SING-0017066).

TOTAL RANGE: India, Sri Lanka, Andaman, Burma, Malay Peninsula, Singapore, Indonesia (Java), Borneo, Philippines, Vietnam, Palau I. (cf. Verdoorn 1930, Hattori 1976, 1980a).

F. hypoleuca Nees

Plants medium-sized, leaves densely imbricate, leaf lobes orbicular to ovate, apices rounded, obtuse or rarely minutely apiculate, leaf cells with conspicuous, often confluent trigones; leaf lobules clavate, distant from the stem, widely spreading or subparallel, rounded at base, stylus ca. 1/3 of lobule length, triangular from a broad base; underleaves imbricate, orbicular, lobed to 1/3 of their length, lobes obtuse or acute. — Illustration: Evans 1900: pl. XLVII (figs. 1–11).

RANGE IN SINGAPORE: 2. *Ad arb trunc. et viar. lat.*, ca. 20 m, 1930 *F. Verdoorn 252* (SING-0017070); *F. Verdoorn 263* (SING-0017068). 6. *In silvis primig., in decl. et in cacumine*, 1930 *F. Verdoorn 1* (SING-0017069); *F. Verdoorn 3* (SING-0017067).

TOTAL RANGE: widely distributed in Oceania and tropical Asia (cf. Verdoorn 1930, Hattori 1980a).

F. intermedia (Reinw. et al.) Dumort.

Plants large, leaves imbricate, leaf lobes oblong-ovate, apices minutely apiculate-acute, trigones subnodulose, confluent; leaf lobules small, often pendent, clavate, usually conic-mammillose; underleaves remote, usually flattened, ovate-cordate, lobed 2/5 of lobe length, lobes triangular with sharply apiculate apices. — Illustration: Hattori 1980b: 187, 189, 192–194 (figs. 13–16).

RANGE IN SINGAPORE: **6.** *H. N. Ridley 619* (SING-0017072). — Bukit Mandai, 1892 *H. N. Ridley 286* (SING-0017071). Chua Chu Kang, 1889 *H. N. Ridley* (SING-0017148); 1890 *H. N. Ridley 290* (SING-0017073).

TOTAL RANGE: widely distributed in tropical Asia and the Pacific Islands (cf. Hattori 1976, 1980b).

F. nodulosa (Reinw. et al.) Nees

Plants robust, leaf lobes densely imbricate, concave with strongly involute distal margins, nearly orbicular, wider than long, apices widely rounded, dorsal bases with rounded appendages, leaf lobules pendent, widely clavate with rounded apices, stylus minute with 3 uniseriate cells; underleaves imbricate, often with 3 longitudinal folds and strongly recurved lateral margins. — Illustration: Hattori 1980b: 209, 212 (figs. 28 and 29)

RANGE IN SINGAPORE: **2.** *Ad arb. trunc. et viar. lat.*, ca. 20 m, *F. Verdoorn 261* (SING-0017079). **5.** Chan Chu Kang (Nee Soon Swamp vicinity), 1891 *H. N. Ridley 1202* (SING-0017077); 1892 *H. N. Ridley 287* (SING-0017080). **7.** 1889 *J. S. Goodenough 1207* (SING-0017075). — No exact locality, *H. N. Ridley 3011* (SING-0017076); 1898 *H. N. Ridley 782* (SING-0017078).

TOTAL RANGE: widely distributed in tropical regions of the world (cf. Kamimura 1961, Hattori 1980b).

F. sublignosa Steph.

This species is characterized by the imbricate, squarrose leaves, the orbicular leaf lobe with a long, inverted J-shaped insertion, the large, asymmetric leaf lobule with a wide, oblique mouth, the small stylus, and the imbricate and widely reniform underleaves. — Illustration: Hattori 1975b: 307 (fig. 153).

RANGE IN SINGAPORE: **2.** *Secus viam* (Orchard Road) *et in horto botanico*, ca. 15 m, 1893 *V. Schiffner 80* (SING-0017087).

TOTAL RANGE: Malay Peninsula, Banka, Borneo, New Guinea (cf. Verdoorn 1930, Hattori 1976).

Lejeuneaceae Casares-Gil (by X.-L. He, except *Cololejeunea* partly by T. Pócs)

Acrolejeunea fertilis (Reinw. et al.) Schiffn.

This species is distinctive among the other members of the genus in having large, semiorbicular lobules with 5–9 conspicuous, regularly spaced marginal teeth. When dry the leaves are flattened, hardly clasping the stem, but they become strongly squarrose in wet condition. — Illustration: Gradstein 1974: pl. XIII, figs. 1–14.

RANGE IN SINGAPORE: **2.** 1925 *R. E. Holttum 20993*

(SING-0017131); *ad arb. trunc. et viar. lat.*, ca. 20 m, 1930 *F. Verdoorn 266* (SING-0017100, as *Ptychocoleus wichurae*). **3.** 524, 533, Kent Ridge Hall, Block A, on tree trunk. On tree trunk, 22.1.1998 *B. C. Tan* (H). **4.** 546, 560, secondary growth forest, on tree trunk.

TOTAL RANGE: Indo-Malesia (cf. Gradstein 1975).

A. pycnoclada (Tayl.) Schiffn.

The species can be readily recognized by the lobule, in which the first lobule tooth is situated at the extreme end of the free margin near the junction of the lobule and the lobe. Other diagnostic characters are cucullate female bracteole, and the immersed perianth gradually contracted into a long beak. — Illustration: Gradstein 1974: pl. XVI, figs. 1–10.

RANGE IN SINGAPORE: **2.** *Ad arb. trunc. et viar. lat.*, ca. 20 m, 1930 *F. Verdoorn 253* (SING-0017097, as *Ptychocoleus pycnocladus*); *F. Verdoorn 260* (SING-0017098, as *Ptychocoleus pycnocladus*).

TOTAL RANGE: widely distributed in Indo-Malesia, Pacific, Africa (cf. Gradstein 1975).

**A. securifolia* (Tayl.) Schiffn. subsp. *hartmannii* (Steph.) Gradst.

This subspecies somewhat resembles *A. fertilis*, but it has the ovate lobule with typically two short marginal teeth, and the very shallowly bifid inner bracts of the gynoecium. — Illustration: Gradstein 1974: pl. XV (figs. 3, 9 and 12).

RANGE IN SINGAPORE: **2.** 510, on trunk of *Koompassia malaccensis*; 511, on trunk of *Melaleuca genistifolia*; 512, on tree base; 522, on trunk of *Garcinia dulcis*; 503, 692, on tree trunk; 693, on trunk of *Fagrea fragrans*. **3.** 528, 529, Block E, on tree trunk; 531, on tree trunk. **4.** 551, 552, secondary growth forest, on tree trunk. **7.** 635, mature mangrove forest, “back mangrove”, on trunk of coconut. **8b.** 650, secondary growth forest, on trunk of coconut on brook side. **11.** 724, on fallen log.

TOTAL RANGE: Philippines, Ambon, E New Guinea, Singapore (cf. Gradstein 1975).

Ceratolejeunea singaporensis (Lindenb.) Schiffn.

Plants small, dark brown in dry condition, up to 1.5 cm long and 1.2 mm wide. Leaf lobes oblong, apex rounded, margins entire, ocelli 1–5 at the base of the lobe; leaf lobules ca. 1/4 of lobe length, hyaline papilla proximal; underleaves imbricate, orbicular, bifid, lobed to 2/5 of their length, lobes triangular, sinus acute, insertions sinuate. — Illustration: Mizutani 1981: 308 (fig. 2).

RANGE IN SINGAPORE: **8b.** 664, secondary growth forest, on trunk of *Campnosperma* on brook side. **8c.** 683, secondary growth forest, on trunk of *Adinandra*.

This species was collected again by Juslén 153 years after it was first described as *Lejeunea singaporensis* Lindenb. in 1845. Mizutani (1981) stated that *Ceratolejeunea singaporensis* is closely related to a common and widely distributed Asiatic species, *C. oceanica* (Mitt.) Steph., or may be an extreme form of the latter. Therefore, the taxonomic position of *Ceratolejeunea singaporensis* awaits verification. We did not see the types of the above two species. Turner and H. Tan (1994) did not mention *Ceratolejeunea singaporensis* in the Singapore hepatic flora.

TOTAL RANGE: Singapore (Mizutani 1981).

Cheilolejeunea intertexta (Lindenb.) Steph.

Plants small, up to 1.0 cm long and 0.6 mm wide, often densely branched; ventral merophytes 2 cells wide; leaves imbricate, leaf lobes orbicular, apex rounded; leaf lobules small, ca. 1/3 of lobe length, hyaline papilla distal; underleaves distant, nearly orbicular, bifid, lobed to 1/2 of their length, lobes triangular, sinus acute, insertions subtransverse. — Illustration: Mizutani 1982: 171 (fig. 9).

RANGE IN SINGAPORE: **1.** 494, 495, secondary growth forest, on trunk of *Samanea saman*. **2.** 694, 697, on trunk of a palm, 501, secondary growth forest, on trunk of *Coffea canephora*. **6.** 737, parking place, on tree trunk. **8b.** 665, 666, 667, secondary growth forest; 649, on coconut tree trunk; 664, on trunk of *Campnosperma*, on brook side. — Pulau Jong, on dead branch, 1924 R. E. Holttum 21140 (SING-0017129). Clementi town, on roadside tree, 10 m, 1999 T. Pócs 99203/D (H).

TOTAL RANGE: China (Hong Kong, Yunnan), Japan (Kyushu, Ryukyu), Bonin Is., Micronesia, Ambon, Philippines, New Guinea, New Hebrides, Caroline Is., Marshall Is., Samoa, Tahiti, Singapore, Indonesia (Java, Sumatra), Borneo, Sri Lanka, Africa (cf. Mizutani 1972, 1982, Menzel 1988, So & Zhu 1996, Zhu & So 1999).

**C. longiloba* (Hoffm.) Kachr. & R. M. Schust.

Plants rather large, up to 2.0 cm long and 1.8 mm wide, ventral merophytes 2 cells wide, leaves imbricate, leaf lobes ovate, apex rounded, trigones usually small, leaf lobules large, rectangular, ca. 1/2 of lobe length, lobule tooth 1–3 cells long, hyaline papilla distal; underleaves distant to contiguous, bifid, lobed to 2/5 of their length, lobes triangular, sinus narrow, insertions nearly transverse.

This species resembles another common Asiatic species *Cheilolejeunea trapezia* (Nees) Kachroo & R. M. Schust.; however, the latter has more robust plants, 4 cells wide ventral merophytes, and large and conspicuous trigo-

nes in leaves. — Illustration: Mizutani 1980: 328 (fig. 5).

RANGE IN SINGAPORE: **4.** 550, secondary growth forest, on tree trunk.

TOTAL RANGE: Thailand, Indonesia (Java, Sumatra), Borneo, Philippines, Singapore (cf. Mizutani 1980).

C. ventricosa (Schiffn.) X.-L. He

Plants small, up to 0.7 cm long and 1.0 mm wide, leaves imbricate, leaf lobes ovate, apex rounded, margins entire, leaf lobules extremely large, ca. 0.8 of lobe length, the distal portion of the lobule much narrower than the proximal one, hyaline papilla distal; underleaves contiguous to distant, orbicular, 2-lobed to 2/5 of their length, lobes triangular, insertions cuneate. — Illustration: He 1995: 254 (fig. 2a–g).

RANGE IN SINGAPORE: *Prope lacum dictum* “Reservoir”, in silvis, ca. 50 m, 1930 F. Verdoorn 241 (SING-001790). This species was first reported from Singapore as *C. fitzgeraldii* (Steph.) He by X.-L. He (1995).

TOTAL RANGE: Malaysia, Singapore, Vietnam, China (Yunnan), Indonesia, New Guinea (see He 1995, 1999, Zhu & So 1999).

**Cololejeunea cordiflora* Steph.

This species is characterised by the dentate leaf margin and small lobules of 1/4 lobe length. — Illustration: Tixier 1985: 279 (fig. 49).

RANGE IN SINGAPORE: **5.** Plot 27.1, epiphyllous, 14.1.1999 D. H. Murphy s.n. (H).

TOTAL RANGE: Japan, Vietnam, Singapore, Borneo (cf. Tixier 1985, Menzel 1988).

**C. cuneata* (Lehm. & Lindenb.) Steph.

Plants small, up to 0.5 cm long and 1.5 mm wide, leaves imbricate, leaf lobes flat, ovate, apex rounded, margins bordered by one row of hyaline cells, ocelli lacking; leaf lobules ca. 1/3 of lobe length, oblong, lobule tooth large, 2 cells long, 1–2 cells wide at base; perianths flattened, apex truncate or emarginate, bordered by hyaline cells. — Illustration: Tixier 1985: 48 (fig. 20).

RANGE IN SINGAPORE: **5.** 591, on leaf of a climber, in full shade.

TOTAL RANGE: Madagascar, Mascarenes, New Guinea, Singapore (cf. Tixier 1985).

**C. goebelii* (Gottsche ex Schiffn.) Schiffn.

Plants small, up to 1.0 cm long and 1.5 mm wide, leaves imbricate, leaf lobes elliptical, apex rounded, margins

somewhat denticulate; leaf lobules ovate, ca. 1/3–2/5 of lobe length, the first tooth 2 cells long, the second tooth small, unicellular, hyaline papilla situated at the inner surface of lobule; stylus composed of 1–3(–6) cells in a single row; gemmae numerous, discoid. — Illustration: Tixier 1985: 193 (fig. 1).

RANGE IN SINGAPORE: **2.** 520, Orchid Garden, on wood in *Bromelia* house. **5.** 613, on leaf.

TOTAL RANGE: China, Japan, Thailand, Philippines, Indochina, Malaysia, Singapore, Indonesia (Java), Australia (Queensland) (cf. Mizutani 1975, Tixier 1985).

**C. inflectens* (Mitt.) Benedix

This species has peculiar leaf lobules, of which the free margins are strongly involute and bear 3–10 ciliate or triangular teeth. — Illustration: Zhu 1995: 90 (fig. 5).

RANGE IN SINGAPORE: **8a.** 648, secondary growth forest, on trunk of *Rambutan*.

TOTAL RANGE: Sri Lanka, Indonesia (Java, Sumatra), Singapore, Papua New Guinea, Philippines, China, Vietnam, New Caledonia, Madagascar (cf. Zhu 1995).

**C. haskarliana* (Gottsche) Benedix

This species can be readily separated from other members of the genus by the parvicous plants, the leaf cells with spinose protrusions, the 2-lobule teeth typically crossing each other, the minute, unicellular stylus, and the angular gemmae on the ventral and dorsal surface of leaf lobes. — Illustration: Mizutani 1986: 444 (fig. 3).

RANGE IN SINGAPORE: **8c.** 675, secondary growth forest, on tree trunk; 687, on branch on brook side.

TOTAL RANGE: Himalaya, Bhutan, Sri Lanka, Malay Peninsula, Singapore, Indochina, Borneo, Indonesia (Java, Sumatra, Celebes), Philippines, China, Japan, Reunion, Seychelles, New Caledonia (cf. Tixier 1985, Mizutani 1986a, Long & Grolle 1990, Zhu 1995).

**C. minutissima* (Smith) Schiffn. subsp. *myriocarpa* (Nees & Mont.) R. M. Schust.

Plants very small, up to 0.6 mm wide, leaves distant, rarely contiguous, leaf lobes ovate, apex obtuse or rounded, margins crenulate with projecting cells; leaf lobules usually poorly developed, forming an ill-defined narrow fold; gemmae subcircular. — Illustration: Schuster 1980: 1248 (fig. 757).

RANGE IN SINGAPORE: **7.** 625, mature mangrove forest, “back mangrove”, on tree branch.

TOTAL RANGE: Widely distributed in North America, E Asia, Australia and Oceania (cf. Long & Grolle 1990).

**C. siamensis* (Steph.) Benedix

This species is distinctive in having densely papillose leaf lobes, crenulate and hyaline leaf margins, 1–2 rows of ocelli at the leaf bases, and long and falcate lobule tooth. — Illustration: Mizutani 1965: 118 (fig. VI: 12–17).

RANGE IN SINGAPORE: **5.** 578, 580, 612, on leaf of a climber; 595, on leaf of a palm; 613, on leaf; on trunk, 15.3.1998 *B. C. Tan* (H); Plot 27.3, 14.1.1999 *D. H. Murphy s.n.* (H). **7.** 623, 624, mature mangrove forest, “back mangrove”, on branch; 631, on trunk of *Bruguiera cylindrica*; 634, on fallen *Hibiscus*; 636, on trunk of coconut; 637, on tree trunk. **8c.** 687, secondary growth forest, on branch on brook side.

TOTAL RANGE: Vietnam, Borneo, Singapore (cf. Mizutani 1965, Menzel 1988).

**C. stoniana* Tixier

The species can be recognized by the often reduced lobules with long, acute cilia-like apex, and cordiform perianth. — Illustration: Tixier 1985: 110 (fig. 55).

RANGE IN SINGAPORE: **5.** 580, on leaf of a climber in full shade.

TOTAL RANGE: Malaysia, Singapore (cf. Tixier 1985).

**C. wightii* Steph.

This species is characterized by the lanceolate leaf lobes, entire leaf margins and pyriform perianths. — Illustration: Tixier 1985: 249 (fig. 31).

RANGE IN SINGAPORE: **2.** 518, Orchid garden, on tree trunk in *Bromelia* house. **3.** 525, Kent Ridge Hall, Block B, on tree base. **4.** 538, secondary growth forest, on tree trunk; 553, on base of rubber tree. **5.** 568, on rotten log; 613, on leaf. **6.** 614, primary forest, on tree trunk. **7.** 626, mature mangrove forest, “back mangrove”, on rotten *Hibiscus* sp.; 632, on branch of *Bruguiera*. **8b.** 660, secondary growth forest, on rotten log on brook side; 673, on rotten twig. **8c.** 679, secondary growth forest, on rotten log. **11.** 722, on decorticated log.

TOTAL RANGE: southern Indochina, Malaysia, Singapore, New Guinea, Micronesia (cf. Tixier 1985).

Dendrolejeunea fruticosa (Lindenb. & Gottsche) Lacout.

Plants large, up to 10 cm long and 4 mm wide, brown in dry condition; ventral merophytes 6–8 cells wide, leaves imbricate to contiguous, leaf lobes ovate-lanceolate, apex acute, margins with a few teeth; leaf lobules small, ovate to rectangular, compressed or slightly inflated, usually contiguous with incurved ventral margins of lobes; un-

derleaves imbricate, ovate-lanceolate, insertions straight to slightly arched. — Illustration: Thiers & Gradstein 1989: 72 (fig. 27).

RANGE IN SINGAPORE: 5. 598, on tree base; Chan Chu Kang, 30.10.1889 *H. N. Ridley 111* (SING-0017107, as *Thysananthus fruticosus*). — Staggmount (?), 1901 *Anonymous 11265* (SING-0017108, as *Thysananthus fruticosus*). Reported from Singapore as *Thysananthus fruticosus* (Lindenb. & Gottsche) Schiffn. in Turner & H. Tan (1994).

TOTAL RANGE: Throughout the Indopacific region (see Thiers & Gradstein 1989).

**Harpalejeunea filicuspis* (Steph.) Mizut.

Plants minute, up to 3 mm long and 0.4 mm wide, leaves contiguous to distant, leaf lobes triangular, apex acuminate, margins nearly entire, ocelli 2–3 at leaf base; leaf lobules large, ca. 1/2 of lobe length, ovate, slightly mammillose; underleaves small, distant, 2-lobed to 1/2 of their length, sinus wide, lobes linear, 3–4 cells long, and usually 1 cell wide at base. — Illustration: Mizutani 1973: 200 (fig. V, as *H. ridleana* (Steph.) Mizut.).

RANGE IN SINGAPORE: 8b. 667, secondary growth forest; 668, on tree base on brook side.

TOTAL RANGE: Philippines, Borneo, Singapore, New Hebrides (cf. Mizutani 1973).

**Lejeunea catanduana* (Steph.) H. A. Miller et al.

This species is characterized by the orbicular to subrhombic underleaves, with narrow, deeply bifid lobes. — Illustration: Mizutani 1961: 208 (fig. XX: 7–15, as *Lejeunea boninensis* Horik.).

RANGE IN SINGAPORE: 1. 492, secondary growth forest, on tree trunk. 2. 515, 516, National Orchid Garden, on base of *Melaleuca*; 519, on stone in *Bromelia* house; 700, Jungle Path, on decorticated log. 3. 525, 742, Kent Ridge Hall, Block B, on tree base. 4. 539, secondary growth forest, on stone; 554, on asphalt. 5. 565, on twig in full shade; 568, on rotten log. Plot 27.1, 14.1.1999 *D. H. Murphy s.n.* (H). 7. 633, 634, mature mangrove forest, “back mangrove”, on branch of *Hibiscus*.; Plot 27.3, 14.1.1999 *D. H. Murphy s.n.* (H). 8a. 638, secondary growth forest, on tree trunk in full shade; 639, on base of *Cinnamomum*. 8b. 654, secondary growth forest, on tree root; 662, on stump on brook side. 8c. 678, 690, secondary growth forest, on tree trunk. 10. 710, on stone. 11. 715, on twig on brook side; 718, on tree trunk. — Holland Park, on potted soil, 14.3.1998 *K. S. Peh 3* (H).

TOTAL RANGE: China, Japan, Borneo, Singapore, Samoa (cf. Mizutani 1961, as *Lejeunea boninensis*, Grolle & Schultze-Motel 1972, Menzel 1988, Piippo et al. 1998).

**L. flava* (Sw.) Nees

Plants small, up to 3 cm long and 1 mm wide, leaves imbricate, leaf lobes oblong-ovate to ovate, apex rounded or rarely obtuse, margins entire; leaf lobules small, ca. 1/4 of lobe length, inflated, oblong-ovate; underleaves imbricate, rarely distant, ovate-orbicular, subcordate at base. — Illustration: Mizutani 1961: 208 (fig. XX: 1–6).

RANGE IN SINGAPORE: 4. 557, secondary growth forest, in dense forest on tree trunk. 5. 590, 600, 610, Fresh water swamp forest, in full shade on tree trunk.

TOTAL RANGE: widely distributed in tropical and warm temperate regions of the world (cf. Long & Grolle 1990).

**L. parva* (Hatt.) Mizut.

Plants small, up to 2 cm long and 0.8 mm wide, leaves contiguous to loosely imbricate, suberect to obliquely spreading, leaf lobes ovate to oblong-ovate, apex rounded, margins entire; leaf lobules 1/3–1/2 of lobe length, triangular-ovate, inflated; underleaves small, distant, orbicular. — Illustration: Mizutani 1961: 204 (fig. XIX: 1–5, as *Lejeunea rotundistipula* (Steph.) S. Hatt.).

RANGE IN SINGAPORE: 2. 514, 499, on trunk of *Khaya senegalensis*; 515, National Orchid Garden, on base of *Melaleuca*; 521, on tree trunk in Bromelia House; 698, on trunk of *Ficus celebensis*. 4. 555, secondary growth forest, on tree trunk. 7. 628, mature mangrove forest, “back mangrove”, on trunk of *Excoecaria*; 627, 630, on trunk of *Hibiscus*. 8a. 646, secondary growth forest, on trunk of *Cassia*. 10. 709, on tree trunk.

TOTAL RANGE: China, Japan, Korea, Singapore (cf. Mizutani 1961, Piippo et al. 1998).

Lepidolejeunea bidentula (Steph.) R. M. Schust.

Plants up to 3.5 cm long and 2 mm wide, leaves imbricate, leaf lobes broadly ovate-falcate to obovate, apex obtuse, margins entire, often with marginal rhizoids; ocelli scattered in leaves and underleaves, female and male bracts and bracteoles and perianths; leaf lobules small, ovate-truncate, often with a short and obtuse apical tooth; underleaves usually contiguous, slightly wider than long, lobed to half of lobe length, margins entire, occasionally with rhizoids. — Illustration: Piippo 1986: 22–23 (figs. 4a–k, 5a–k).

RANGE IN SINGAPORE: 8a. 646, secondary growth forest, on trunk of *Cassia*. 8c. 683, secondary growth forest, on trunk of *Adinandra*.

TOTAL RANGE: SE Asia, Indonesia and Melanesia (Piippo 1986).

****L. borneensis* (Steph.) R. M. Schust.**

This species is distinctive in the very small-sized plants, the acute leaf apices, the entire margins of female involucreal leaves, and the male bracteoles only at base of male spike. — Illustration: Piippo 1986: 37 (fig. 10a–n).

RANGE IN SINGAPORE: **8b.** 671, secondary growth forest, on tree base on brook side. **II.** 717, on tree trunk.

TOTAL RANGE: Indonesia, Malaysia, Singapore, Caroline Is. (cf. Piippo 1986).

****Leptolejeunea elliptica* (Lehm. & Lindenb.) Schiffn.**

Plants minute, up to 1.0 cm long and 1.0 mm wide, leaves loosely imbricate or contiguous, obliquely spreading, leaf lobes elliptical, apex obtuse or subacute, margins entire, ocelli large, scattered at leaf lobes, basal ocellus conspicuously larger than others; leaf lobules oblong-ovate, ca. 2/5 of lobe length; underleaves distant, the basal portion trapezoidal in outline, lobes setose, widely or obliquely spreading, consisting of 3–4 cells in a row. — Illustration: Mizutani 1961: 232 (figs. XXVI: 1–15, as *Leptolejeunea subacuta* Evans).

RANGE IN SINGAPORE: **5.** 578, 591, 611, on leaf of a climber in full shade; 595, on leaf of a palm. Plot 27.1, 14.–15.1.1999 *D. H. Murphy s.n.* (H); on leaf, shaded, 3.2.1999 *B. C. Tan s.n.* (H). **8b.** 663, secondary growth forest, on tree base; 668, on tree base on brook side. **8c.** 674, secondary growth forest, on leaf; 680, on tree base; 684, on fallen log on brook side; 688, 689, on leaf of *Hoya*.

TOTAL RANGE: Widely distributed in tropical and subtropical Asia (cf. Long & Grolle 1990).

****Lopholejeunea nigricans* (Lindenb.) Schiffn.**

Plants up to 4 cm long and 1.4 mm wide, leaves imbricate to contiguous, leaf lobes ovate-oblong, apex rounded, obtuse or acute, margins entire; leaf lobules ovoid-oblong, up to 1/2 of lobe length; underleaves distant to subimbricate, entire, transversely ovate to suborbicular. — Illustration: Gradstein 1994: 113 (fig. 30).

RANGE IN SINGAPORE: **4.** 540, 561, secondary growth forest, on tree base on sand.

TOTAL RANGE: widely distributed in tropical regions of the world (cf. Gradstein 1994).

***L. subfusca* (Nees) Schiffn.**

This species is characterized by the rounded leaf apex, the strongly inflated proximal portion of leaf lobules, the

truncate leaf apex, and the immersed perianths hidden behind the bracteole, except for the large, crowded laciniatae. — Illustration: Thiers & Gradstein 1994: 40 (fig. 15).

RANGE IN SINGAPORE: **2.** 506, on brick, *ad arb. trunc. et viar. lat.*, ca. 20 m, 9.1930 *F. Verdoorn 250* (SING-0017092). **4.** 544, 548, secondary growth forest, on tree trunk. **8a.** 640, secondary growth forest, on branch; 647, on climber. — No locality, *ad arborum truncos secus vias, subphotophila*, ca. 20 m, 1894 *V. Schiffner* (SING-0017091). Reformatory Rd., 1900 *H. N. Ridley 52* (SING-0017111). *Prope lacum dictum* “Reservoir”, *in silvis*, ca. 50 m, 1930 *F. Verdoorn 241* (SING-001790).

TOTAL RANGE: widely distributed in tropical regions of the world (cf. Thiers & Gradstein 1989, Gradstein 1994).

****Microlejeunea punctiformis* (Tayl.) Steph.**

Plants very small, up to 1.0 cm long and 0.3 mm wide, leaves distant, erect-spreading, leaf lobes strongly convex, ovate, apex rounded or obtuse, margins entire; leaf lobules large, ca. 1/2–3/4 of lobe length, usually strongly inflated, ovate; underleaves distant, small, broadly ovate to orbicular, transversely inserted to stems, 2-lobed to about half of their length, margins somewhat crenulate due to projecting cells; monoicous. — Illustration: Mizutani 1961: 216 (figs. XXII: 1–10).

RANGE IN SINGAPORE: **3.** 532, near the Physics department, on tree trunk.

TOTAL RANGE: Himalaya (Nepal, Darjeeling, Bhutan), India, Sri Lanka, China, Japan, Thailand, Singapore (see Long & Grolle 1990).

***M. ulicina* (Tayl.) Steph.**

This species resembles *M. punctiformis*, but differs in its dioicous condition. — Illustration: Schuster 1980: 1069 (fig. 720).

RANGE IN SINGAPORE: **1.** 496, secondary growth forest, on trunk of *Samanea saman*. **4.** 545, 547, secondary growth forest, on tree trunk; 737, parking place, on tree trunk. **8b.** 651, on coconut trunk on brook side. Reported from Singapore as *M. lunulatiloba* Horik. in Turner & H. Tan (1994).

TOTAL RANGE: Widely distributed in tropical and warm temperate regions of the world (cf. Mizutani 1975).

***Pycnolejeunea contigua* (Nees) Grolle**

Plants small to medium-sized, up to 3.0 cm long and 1.5 mm wide, leaves closely imbricate, leaf lobes strongly convex, suborbicular, ovate or oblong-ovate, apex rounded, margins entire, ocelli basal, 1–8 per leaf lobe;

leaf lobules small, ovate, ca. 0.2–0.3 of lobe length, first tooth 1-celled, hyaline papilla proximal; underleaves closely imbricate to contiguous, strongly appressed, suborbicular to reniform, lobed to 0.2–0.5 of their length, lobes acute to obtuse, sinus often V-shaped. — Illustration: He 1999: 46–48 (figs. 13–15).

RANGE IN SINGAPORE: Kranji, on trees, 1920 *Chipp 6052* (SING-0017132). Reported from Singapore as *P. bancana* Steph. in Turner & H. Tan (1994).

TOTAL RANGE: Widely distributed in tropical regions of the world (He 1999).

Schiffneriolejeunea cumingiana (Mont.) Gradst.

This species is distinctive in the free margin of lobule involuted in the basal half, forming a sac, the 3–4 lobule teeth, and the underleaves 3–4 times the stem width. — Illustration: Gradstein & Terken 1981: 78 (fig. 2A–B).

RANGE IN SINGAPORE: 2. 699, on branch of *Melaleuca* sp. *ad arb. trunc.*, 20 m, 4.11.1893 *V. Schiffner* (SING-0017093, as *Ptychocoleus cumingianus*).

TOTAL RANGE: Indomalaysia and the Pacific (cf. Gradstein 1974a).

S. pulopenangensis (Gottsche) Gradst.

This species can be distinguished from other members of the genus by the plane free margin of lobule, with 2 teeth that are clearly visible *in situ*, the leaves not squarrose, the underleaves 3–5 times the stem width, and the denticulate apex of female bracteole. — Illustration: Thiers & Gradstein 1994: 59 (fig. 22).

RANGE IN SINGAPORE: 2. *Corticola, subskiophila*, ca. 20 m, 11.1893 *V. Schiffner* (SING-0017095, as *Ptychocoleus pulopenangensis*); *ad arb. trunc. et viar. lat.*, ca. 20 m, 9.1930 *F. Verdoorn 249* (SING-0017096, as *Ptychocoleus pulopenangensis*). — Jurong, 1896 *H. N. Ridley 469* (SING-0017101). *Prope lacum dictum* “Reservoir”, *in silvis*, ca. 50 m, 1930 *F. Verdoorn 242* (SING-0017094, as *Ptychocoleus pulopenangensis*). Reported from Singapore as *Ptychocoleus pulopenangensis* (Gottsche) Trevis. in Turner & H. Tan (1994).

TOTAL RANGE: Indomalaysia, Australia (cf. Gradstein 1974a, Gradstein & Inoue 1980, Thiers & Gradstein 1989).

S. tumida (Nees & Mont.) Gradst.

This species is characterized by the squarrose leaves when moist, the ventral margin and apex of leaves more

or less involuted, the free margin of lobule inrolled proximally, with 2 teeth often invisible *in situ*, the narrower underleaves, at most 1.5 times the stem width, and the entire apex of female bracteole. — Illustration: Gradstein & Terken 1981: 74 (fig. 1B–C, E).

RANGE IN SINGAPORE: 2. 1925 *R. E. Holtum 20994* (SING-0017130); *ad arb. trunc. et viar. lat.*, ca. 20 m, 1930 *F. Verdoorn 267* (SING-0017099, as *Ptychocoleus tumidus*). Reported from Singapore as *Ptychocoleus tumidus* (Nees & Mont.) Trevis. in Turner & H. Tan (1994).

TOTAL RANGE: Throughout the Indomalaysia and the Pacific region (cf. Gradstein 1974a, Gradstein & Terken 1981).

Thysananthus comosus Lindenb.

This species is recognized by the rounded-subtruncate underleaves, the strongly ciliate-laciniate keels of perianths, and the dioicous condition. — Illustration: Mizutani 1961: 154 (figs. VI: 24–26).

RANGE IN SINGAPORE: 6. *In silva primig., ad arb. truncos, corticola, subskiophila vel subphotophila*, 100–150 m, 11.1893 *V. Schiffner* (SING-0017104).

TOTAL RANGE: Widely distributed in Southeast Asia (cf. Gradstein 1994).

T. spathulistipus (Reinw. et al.) Lindenb.

The species is characterized by the dentate leaves and underleaves, the ovate-falcate leaves, the acute to apiculate leaf apex, the free margin of lobule with 1–2 blunt teeth, and the squarrose, spatulate underleaves with ventricose bases. — Illustration: Thiers & Gradstein 1994: 74 (fig. 28).

RANGE IN SINGAPORE: 5. Shaded, 3.2.1999 *B. C. Tan* (H). Chan Chu Kang, *H. N. Ridley 441* (SING-0017102, -0017109). — No locality, 1895 *H. N. Ridley 600* (SING-0017110).

TOTAL RANGE: Throughout paleotropics (cf. Thiers & Gradstein 1989).

Pallaviciniaceae Migula (by S. Piippo)

Pallavicinia lyellii (Hook.) Carruth.

Variable, dark and procumbent thalloid species, frond shoots usually 4–5 mm wide, almost flat, midrib prominent, frond margins with bicellular slime-hairs, otherwise usually entire. Androecia with scales dorsally on each side of the midrib; gynoecia cup-like, laciniate-dentate and ciliate. — Illustrations: Vanden Berghen 1972 (fig. 63),

Landwehr 1980: 221 (Af. 91).

RANGE IN SINGAPORE: **3.** 711, on clay (female). **5.** 608, on brook side on clay (female). **6.** 618, on brook side on sand (female). **8a.** 642, 643, on brook side on moist sand; 655, on brook side on clay (female). Mainly in secondary or primary tropical forests. The species is impossible to distinguish from *P. levieri* Schiffn. when it is without antheridia (cf. Grolle & Piippo 1986).

TOTAL RANGE: subcosmopolitan in warm temperate and subtropical areas (cf. Grolle & Piippo 1986, Long & Grolle 1990).

Podomitrium malaccense (Steph.) D. Campb.

Green, thalloid plants, ventral intercalary branching frequent, frond base usually wingless or almost so with only rhizoids, frond margins with bicellular, soon disappearing slime-hairs, midrib prominent. Gametoeidia and androecia are on short ventral branchlets. — Illustration: Grolle & Piippo 1986: 76 (fig. 7a–e).

RANGE IN SINGAPORE: **2.** 1895 *H. N. Ridley* 624 (SING-0017137). **5.** 573, on fallen tree branch; 576, on ground; 581, on tree stump; 597, on branch of tree. **6.** 725, primary forest, on sand. 1898 *H. N. Ridley* 356 (SING-0017136). **11.** 716, on brook side on stone.

TOTAL RANGE: Thailand, Indonesia, Malaysia, Singapore, Philippines, Oceania (cf. Grolle & Piippo 1986).

Aneuraceae Klinggr. (by S. Piippo)

Aneura pinguis (L.) Dumort.

Medium-sized to large, 2–5 cm long and 2–6 mm wide, fleshy plants, yellowish to green, thallus margins almost entire or plicate, sparingly branched, thallus 10–18 cells thick; gemmae absent. — Illustration: Furuki 1991: 314 (fig. VIII).

RANGE IN SINGAPORE: **3.** University greenhouse, 10.9.2000 *B. C. Tan s.n.* (SINU).

TOTAL RANGE: Cosmopolitan.

Riccardia graeffei (Steph.) Hewson

An extremely variable species; medium-sized to large, regularly pinnately to tripinnately branched, ultimate pinnules prostrate, winged at margins and characteristic unistratose portion 3–5 cells wide. — Illustration: Furuki 1991: 338, 340 (figs. XIX and XX).

RANGE IN SINGAPORE: **1.** 491, secondary growth forest, on sand; 498, on concrete wall. **2.** Jungle Path and

greenhouse, on humus, *B. C. Tan & D. H. Murphy* 98c (SINU). **3.** 526, Kent Ridge Hall, Block B, on moist clay; 712, on clay; 713, on stone. **4.** 559, dense secondary forest, on coconut. 1896 *H. N. Ridley* 433 (SING-0017059, with *Heteroscyphus succulentus*). Fern Valley, 19.2.1998 *B. C. Tan* 98A (SINU). **5.** 569, on rotten log; 570, 596, on clay; 601, on dry sand. Nearly dry swamp, 14.7.1998 *B. C. Tan s.n.* (SINU). **6.** 728, 732, primary forest in valley, on rotten log; 739, on stone. **8b.** 669, secondary growth forest, on brook side on rotten stump. **8c.** 676, 685, secondary growth forest, on decorticated log. **11.** 721, on concrete wall of artificial ditch. — Cluny Road, 1895 *H. N. Ridley* 588 (SING-0017057, with *Heteroscyphus zollingeri*).

TOTAL RANGE: Widely distributed in tropical Asia, Australasia and Pacific (cf. Furuki 1991).

Targioniaceae Dumort. (by S. Piippo)

**Cyathodium* sp.

Very delicate and thin plants, frond dichotomously branched, costa usually weakly developed, gynoecia terminal, becoming displaced ventrally beneath frond apex. — Illustrations: For *C. smaragdinum*, Schiffner 1938: 137 (figs. 2–8); 1939: 124 (figs. 9–14) as *C. griffithii* Schiffn., Hattori & Mizutani 1959: 133, 135 (figs. I–II); for *C. cavernarum*, Schiffner 1938: 133, 137 (fig. 1: 1).

RANGE IN SINGAPORE: **2.** 507, on concrete. The specimen is sterile and therefore it is difficult to tell with certainty whether the species is either *C. cavernarum* Kunze or *C. smaragdinum* Schiffn. Neither of the species has been reported from Singapore, but both are known from Java (Mehra & Sokhi 1972).

Marchantiaceae (Bisch.) Lindley (by S. Piippo)

**Marchantia acaulis* Steph.

Yellowish or bright green, 2–4 mm wide plants, with or without dark median band on dorsal surface, margins purplish or hyaline; epidermal pores bordered by 5–7 rings of cells, uppermost ring of (3–)4–5 cells; ventral surface and median scales purplish, but appendages usually yellow. Cross-section reveals mucilage cavities inside the thallus. — Illustration: Bischler-Causse 1989: 272, 274 (figs. 82 and 83).

RANGE IN SINGAPORE: **11.** 720, on concrete wall of artificial ditch.

TOTAL RANGE: Malaysia, Singapore, Indonesia, Philippines, Sri Lanka (cf. Bischler-Causse 1989).

Ricciaceae Reichenb. (by S. Piippo)

**Riccia treubiana* Steph.

Light green or bluish rosettes, 2–3 times forked, less than 2 cm long and 2–4 mm wide, dorsal surface like having reticulate stripes running against margins; ventral surface with numerous pale rhizoids, midrib deep and distinct; reproductive organs immersed in thallus along the midrib in two rows. — Illustration: Meijer 1958: 118 (fig. 9).

RANGE IN SINGAPORE: **2.** 505, 508, on clay; 517, National Orchid Garden, on stone. **4.** 535, 537, 541, 564, secondary growth forest, on sand. **9.** 705, Chinese Garden, on moist clay; 707, Bonsai Garden, on concrete.

TOTAL RANGE: Indonesia, Malaysia, and Singapore (cf. Meijer 1958).

Discussion

In the present study we considered the list of Singapore liverworts by Turner and H. Tan (1994) as the starting point with which to compare the species seen by us today. On the basis of 305 packets of specimens studied, we now documented 74 species in 37 genera for the hepatic and hornwort floras of Singapore. *Aneura*, *Cololejeunea*, *Cyathodium*, *Folioceros*, *Harpalejeunea*, and *Notothylas* are six new generic records. Thirty-eight species are reported new to the island. These are mostly epiphyllous species belonging to the family Lejeuneaceae. A few of them do have old specimens represented at SING that were not identified to the species level. Perhaps because of their minute plant size, these species were not collected in earlier surveys. It is also possible that these species are recent introductions to Singapore. The latter scenario is thought to be unlikely because of the lack of economic importance of liverworts as a plant group.

In spite of recent efforts to collect and study the local hepatic flora (Mishler *et al.* 1998), the number of collections per species indicates that this group of plants is still undercollected in Singapore. Of the 74 species, 23 are represented by one collection or known only from a single locality. Their continued survival in Singapore is rather critical.

Three species are considered endemic to Singapore: *Bazzania wallichiana*, *Ceratolejeunea singapurensis*, and *Jackiella singapuren-*

sis. Of these, *Bazzania wallichiana* is probably extinct today (see explanation below). *Ceratolejeunea singapurensis* has a questionable status as a full species. Our collections of *C. singapurensis* from Lasia Valley and MacRitchie (Juslén 664, 683) were made in 1998, exactly 153 years after the type was described in 1845. It is this kind of discovery that gives important value to the conservation of old growth forests in an island country crowded with four million people.

On the other hand, 21 out of the 74 species of Singapore liverworts have no recent collections. They may have become extinct locally due to heavy urbanization in the past 100 years. They are:

Acrolejeunea pycnoclada
Bazzania paradoxa
B. recurva
B. wallichiana
Cheilolejeunea ventricosa
Frullania apiculata
F. brotheri
F. gaudichaudii
F. hypoleuca
F. intermedia
F. nodulosa
F. sublignosa
Heteroscyphus succulentus
Plagiochila sciophila
Pycnolejeunea contigua
Radula borneensis
R. reflexa
Schiffneriolejeunea pulopenangensis
S. tumida
Thysananthus comosus
Trichocolea pluma

Seven of these belong to the genus *Frullania*, which may suggest a drastic change of tree composition in the vegetation of Singapore over the decades. Or, the extinct species of *Frullania* simply are overtly sensitive to a change of forest humidity and the quality of air and rainwater in Singapore.

The next genus that appeared to suffer significantly from extinction in recent time is *Bazzania*, mainly a ground dwelling group of liverworts. Of the four species recorded from the country, only one species, the very common *B.*

tridens, is still found in Singapore. The others were from river valleys now inundated as reservoirs.

In the case of Lejeuneaceae, only one of the three species of *Schiffneriolejeunea* reported for Singapore has a recent recollection. In spite of this, Lejeuneaceae still is the largest and most diverse family in the island's hepatic flora.

Lastly, there are 16 hepatic species listed in Turner and H. Tan (1994), Wee and Mohamed (1995) and others (*see below*) with no available voucher specimens to substantiate the claims. Their presence in Singapore therefore can only be accepted with doubt and these taxa are not counted in the total number of species reported for Singapore. Three of these, *Acromastigum echinatum*, *Cheilolejeunea tenella*, and *Cololejeunea pluripunctata* have their type locality in Singapore.

- *Acromastigum echinatum* (Gottsche) A. Evans
— The type of *A. echinatum* from Singapore is reportedly kept at NY (*see* Evans 1934), but all the specimens in SING identified as such were *A. inaequilaterum*.
- *Blepharostoma trichophyllum* (L.) Dumort.
— Reported from Bukit Timah by Wee and Mohamed (1995). This is a species common around the world and possibly occurs in Singapore.
- *Frullania ericoides* (Nees & Mont.) Nees & Mont. — This was reported from Singapore as *Frullania aeolotis* Schiffn. by Turner and H. Tan (1994), in which the species epithet was wrongly written as “acolotis”. According to Levier (1906) and Hattori and Lin (1985), *Frullania aeolotis* Nees & Mont. is a synonym of *F. ericoides*. This species is a common and widespread pantropical species, but its occurrence in Singapore needs confirmation.
- *Caudalejeunea cristiloba* (Steph.) Gradst. — Gradstein (1974b) reported this species from Burma, Andaman, Thailand and Singapore. It occurs also in Sri Lanka (Onraedt 1985), Indonesia, and Australia (Thiers & Gradstein 1989). We did not see any specimen among the old and new collections during this study that can be identified to this taxon.
- *Cheilolejeunea tenella* (Tayl.) Engel & B. C.

Tan — This species was first described from Singapore as *Lejeunea tenella* Tayl. (based on Wallich 6694) by Taylor in 1846; it was later reported also from Indonesia (Java) and Philippines as *Euosmolejeunea tenella* (Tayl.) Steph. (Stephani 1914). Tan and Engel (1986) transferred it to *Cheilolejeunea*. The type of this species was not available for the present study.

- *Cololejeunea floccosa* (Lehm. & Lindenb.) Steph. — This species was mentioned by Benedix (1953) from Singapore based on Verdoorn's material. We have not seen any collections of the species from Singapore.
- *C. pluripunctata* Benedix — Benedix (1953) described this species from Singapore based on Verdoorn's material. Even a new subgenus *Metalejeunea* Benedix was based on it. Benedix and Mizutani (1965) treat it closely related with *C. siamensis* and most probably they are synonyms.
- *Drepanolejeunea vesiculosa* (Mitt.) Steph. — Mizutani (1977) reported this species from Singapore, however, no specimen was seen by us in the present study. It is one of the most common species of the genus *Drepanolejeunea* in Southeast Asia (cf. Mizutani 1970).
- *Heteroscyphus splendens* (Lehm. & Lindenb.) Grolle (as *H. decurrens* (Nees) Schiffn.) — The occurrence of the species in Singapore cannot be verified, but is likely. No specimen of *H. splendens* is preserved at SING or SINU.
- *Jackiella javanica* Schiffn. — The occurrence of this species is possible in Singapore, but all the collections seen thus far have been *J. singaporensis*.
- *Jungermannia ariadne* Tayl. (as *Plectocolea ariadne* (Tayl.) Mitt.) — The only species of this genus collected locally in recent years is *J. truncata*. No specimen of *Jungermannia* was seen among the historical collections preserved at SING.
- *Mastigolejeunea auriculata* (Wilson) Schiffn. — This is reported from Singapore as *M. humilis* (Gottsche) Schiffn. by Turner and H. Tan (1994). It is a very widespread and common pantropical species (cf. Mizutani 1986b, Thiers & Gradstein 1989). However,

no specimen was seen by us to verify its occurrence in Singapore.

- *Pallavicinia levieri* Schiffn. — This species may occur in Singapore, but plants without antheridia are impossible to separate from *P. lyellii*. There are many female specimens in SING and those that have the male sex organs prove to be *Pallavicinia lyellii*.
- *Phaeoceros laevis* (L.) Prosk. — *Anthoceros validus* Steph. reported from Singapore was given as a synonym of *Phaeoceros laevis* (under *Anthoceros*) by Meijer (1957). No specimen from Singapore was seen. The genus *Phaeoceros* is very common and can be expected in Singapore.
- *Riccardia tenuicostata* Schiffn. — No specimen of this species was seen, but the species occurs in Java (Furuki 1991).
- *Wiesnerella denudata* (Mitt.) Steph. — The occurrence of this species in Singapore is probable, but no existing specimen is available to verify the claim in Turner and H. Tan (1994).

For the sake of argument, the original hepatic flora of Singapore could be taken to consist of 88 species including the above mentioned 14 taxa with no voucher specimens to substantiate their past presence on the island. Consequently, the number of taxa that have become extinct today would be 35, which represents a 40% extinction rate over a period of nearly two centuries of human activity in Singapore. This rate of extinction is lower than the 62% calculated for the forest vascular epiphytes in Singapore over the same period of time (Turner *et al.* 1994). Future and more careful collections in Singapore may increase the number of extant liverworts species. Yet, with continued urbanization of the island, there will be many more species becoming extinct.

The largest numbers of liverwort species in Singapore grow on tree trunks (26 species of still existing ones), secondly on soil, clay or concrete (22), tree bases and stumps (11), logs (8), leaves (8), rocks, boulders and stones (7), and wood (1). Some species grow on many substrates, which explains why the number of counts exceeds the actual species number. There is not enough data to tell which substrate has had

most of the extinct species, but it seems to have been the tree trunks.

Among Juslén's collection localities, Nee Soon is richest in species (21), followed by Bukit Timah and Singapore Botanical Gardens (both 20), then Pulau Ubin (18); the remaining localities have 7–13 taxa. The poorest sites investigated are Chinese/Japanese Gardens and Bukit Batok Nature Park with 2 and 3 species, respectively. By and large, the Singapore Botanical Gardens is also the best collected area, which has, additionally, eight previously recorded, but nowadays disappeared, taxa.

Synonymy, dubious and erroneous records

- *Bazzania stolonifera* (Swartz) Trevis. — Turner and H. Tan (1994) listed this for Singapore but the species occurs only in Central and South America and is known from Jamaica and Colombia (cf. e.g., Gradstein & Hekking 1979).
- *Marchantia geminata* Reinw. *et al.* — This record is most probably a misidentification of *M. acaulis*. No specimen of *Marchantia geminata* is available to verify the report of this species from Singapore.
- *Pallavicinia radiculosa* (Sande Lac.) Schiffn. — Synonym of *P. lyellii* (Grolle & Piippo 1986).
- *P. ridleyi* Steph. — Synonym of *P. lyellii* (Grolle & Piippo 1986).
- *Plagiochila densifolia* Sande Lac. — No specimen of this species was seen and most probably the report is erroneous due to its morphological similarity with *P. bantamensis*.

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