



Bryophytes of Two Peoples Bay Nature Reserve, Western Australia

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ABSTRACT

Context. Although the vascular flora of Western Australia is renowned for high species diversity and endemism, very little is known about the state's moss and liverwort flora. **Aims.** In 1984 we conducted surveys of bryophytes in Two Peoples Bay Nature Reserve. **Methods.** We searched comprehensively for bryophytes at seven major habitats on the Reserve, collecting voucher specimens subsequently identified with modern literature and with the help of Australian bryophyte experts. We updated the text to reflect modern taxonomy and considering modern literature on phytogeography and hypotheses associated with OCBIL (Old, Climatically Buffered, Infertile Landscapes) theory. **Key results.** A total of 38 species of mosses representing 25 genera from 13 families were identified along with 10 species of liverworts representing nine genera and six families. Two moss species (*Distichium inclinatum* and *Tortella dakinii*) were previously unknown from Western Australia. Another represented a new species (*Pleurophascum occidentale*) in a heretofore monotypic genus, family, and order. The Pottiaceae, with 11 species, was the most diverse family of mosses. The Lepidoziaceae, with three species, was the most diverse family of liverworts. **Conclusions.** Lower levels of endemism in bryophytes versus vascular plants may reflect the bryophytes' capacity for wide and long-distance dispersal of spores and fragments. Bryophyte diversity and endemism may be less than on extensive OCBILs because much of the Reserve emerged from the ocean as recently as the mid-Pleistocene. **Implications.** This, the first listing published of bryophytes on a Reserve in WA, indicates the potential rewards for further survey of mosses and liverworts.

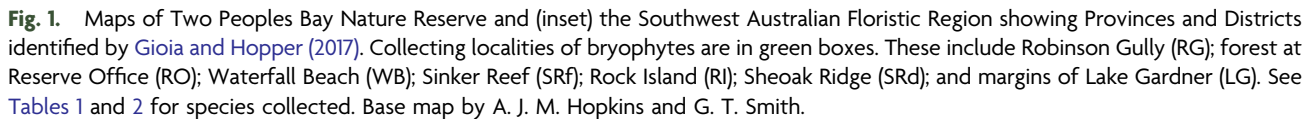
Keywords: ancient lineages, *Distichium*, herbarium studies, Lepidoziaceae, OCBIL theory, phytogeography, *Pleurophascum*, Pottiaceae, *Tortella*.

Introduction

Study of the bryophyte flora of Western Australia has been limited. According to Ramsay (1977), the flora is thought to be depauperate, with only about 100 species compared with more than 1200 species for the rest of Australia. In *The Mosses of Southern Australia*, Scott and Stone (1976) listed a total of 102 species documented for Western Australia. A census published in 1993, however, reported nearly twice as many: 192 species in 78 genera and 31 families (Stoneburner *et al.* 1993). Ramsay (1977) also predicted low levels of endemism in the bryophyte flora, in contrast to the high degree of endemism known among flowering plants (Beard 1981; Gioia and Hopper 2017). Ramsay suggested that the low incidence of rainforest habitat may explain why the bryophyte flora is not rich and diverse. From our own experience in the Southwest Australian Floristic Region (SWAFR, Fig. 1), it appears that this assumed low diversity may be attributed at least in part to a paucity of bryophyte collecting (Stoneburner *et al.* 1993).

On the other hand, it is probably true that endemism is low, as only four species of mosses and liverworts are known to be restricted to Western Australia. Note, however, that most of our collections were made in the SWAFR, which is famous for high levels of diversity and endemism in the vascular flora (Hopper and Gioia 2004; Gioia and Hopper 2017).

Collection: The Natural History of Two Peoples Bay Nature Reserve, Western Australia



At Two Peoples Bay Nature Reserve, the moderate Mediterranean climate with wet, mild winters and cool, dry summers (Hopkins *et al.* 2024) provides favourable conditions for establishment and growth of bryophyte colonies. The relative youth of much of the landmass of the Reserve, however, may have hindered development of a diverse bryophyte flora. However, the Mt Gardner headland has been above the sea for at least 250 million years (Kohn *et al.* 2002), likely as a nearshore island during high sea levels (González-Álvarez *et al.* 2016), thus forming a classic OCBIL (Hopper 2009, 2023), whereas with fluctuating Quaternary

Materials and methods

This survey should be considered a preliminary one. An attempt was made to visit different kinds of habitats in the relatively short time available. More time will be required

Table 1. List of moss species collected at Two Peoples Bay Nature Reserve.

Species	RG	RO	WB	SRf	RI	SRd	LG	Other
<i>Barbula calycina</i> Schwägr.	X	X	X					X
<i>Bryum chrysoneuron</i> Müll. Hal.		X						
<i>Campylopus australis</i> Catches. & J.-P. Frahm		X						X
<i>C. bicolor</i> (Hornsch ex Müll. Hal.) Wilson	X		X					X
<i>C. introflexus</i> (Hedw.) Brid.	X	X						X
<i>C. pallidus</i> Hook.f. & Wilson								X
<i>Codonoblepharon menziesii</i> Schwägr.		X						
<i>Dicranoloma diaphanoneuron</i> (Hampe) Paris	X							
<i>Didymodon australasiae</i> (Hook. & Grev.) R.H. Zander		X		X				
<i>D. torquatus</i> (Taylor) Catches.		X						
<i>Distichium inclinatum</i> (Hedw.) Bruch & Schimp.		X						
<i>Fissidens serratus</i> Müll. Hal.	X		X					
<i>Funaria hygrometrica</i> Hedw.		X						
<i>F. microstoma</i> Bruch ex Schimp.				X				
<i>F. salicicola</i> C. Müll.						X		
<i>Grimmia laevigata</i> (Brid.) Brid.								X
<i>Gymnostomum calcareum</i> Nees & Hornsch.			X	X				
<i>Hypnum cupressiforme</i> Hedw.								X
<i>Orthodontium inflatum</i> (Mitt.) Paris	X							
<i>Pleurophascum occidentale</i> R.E. Wyatt & A.H. Stoneb.	X						X	
<i>Pseudocrossidium crinitum</i> (Schultz) R.H. Zander		X						
<i>Racopilum cuspidigerum</i> (Schwägr.) Ångstr.	X	X			X		X	X
<i>Rhacocarpus purpurascens</i> (Brid.) Paris	X							
<i>Rosulabryum albolimbatum</i> (Hampe ex A. Jaeger) J.R. Spence	X	X			X			
<i>R. billardieri</i> (Schwägr.) J.R. Spence		X						X
<i>R. campylothecium</i> (Taylor) J.R. Spence		X						
<i>R. subtomentosum</i> (Hampe ex A. Jaeger) J.R. Spence	X	X						
<i>Sematophyllum amoenum</i> (Hedw.) Mitt.	X						X	
<i>S. contiguum</i> (Mitt.) Mitt.	X		X					X
<i>S. homomallum</i> (Hampe) Broth.	X	X	X		X		X	X
<i>Syntrichia princeps</i> (De Not.) Mitt.		X		X		X		
<i>Thuidiopsis furfurosa</i> (Hook.f. & Wilson) M. Fleisch.	X				X			
<i>Thuidium laeviusculum</i> (Mitt.) A. Jaeger	X	X						
<i>Tortella dakinii</i> J.H. Willis	X							
<i>T. rubripes</i> (Mitt.) Broth.				X				
<i>Tortula muralis</i> Hedw.		X						
<i>Trichostomum eckelianum</i> R.H. Zander				X				
<i>Triquetrella papillata</i> (Hook.f. & Wilson) Broth.		X	X			X		

Collection sites are: RG, Robinson Gully; RO, forest at Reserve Office; WB, Waterfall Beach; SRf, Sinkers Reef; RI, Rock Island; SRd, Sheoak Ridge; LG, margins of Lake Gardner. 'Other' represents reports of specimens collected subsequent to our study.

in the future to study in detail mesic habitats, especially the gullies and sclerophyll woodlands.

Mosses were identified using the manuals of [Catchside \(1980\)](#) and [Scott and Stone \(1976\)](#) and by comparison with

specimens from PERTH and the herbarium of the University of Western Australia (UWA, now incorporated at PERTH). Geographical distributions of the species were noted and compared for provinces within Western Australia, using

Beard’s (1980) classification, and within Australia and the rest of the world, as described in the aforementioned manuals and *Index Muscorum* (van der Wijk *et al.* 1959–1969). These data were then updated to conform to Gioia and Hopper’s (2017) classification of phytogeographic floristic regions, provinces and districts in the SWAFR. Liverworts were identified using keys made available and subsequently published by Scott (1985). Members of the genus *Riccardia* were identified using Hewson’s (1970) keys and descriptions. For some problematical specimens we enlisted the help of David G. Catcheside, Ilma G. Stone and George A. M. Scott. Using Tropicos, a plant database maintained by the Missouri Botanical Garden that links more than 1.38 million scientific names with more than 6.94 million specimens, the taxonomy and nomenclature of all the mosses were brought up to date. For liverworts we used the 828-page world checklist of hornworts and liverworts published by Söderström *et al.* (2016).

Results

Mosses

The 38 species of mosses listed in Table 1 represent 25 genera from 13 families. Two species are reported as new to Western Australia: *Distichium inclinatum* and *Tortella dakinii*. Most surprising of our discoveries, however, was a new species of *Pleurophascum* (Wyatt and Stoneburner 1989), a previously monotypic genus now treated as a separate family and order of mosses (Goffinet *et al.* 2001; Bechteler *et al.* 2023). *Pleurophascum* is estimated to have diverged from its nearest relative *Dicranella* at about 187 (157–216) million years ago (Bechteler *et al.* 2023). The Pottiaceae are the largest family represented in the bryophyte flora, with six genera and 11 species.

The habitats occupied by these taxa are not narrowly specific. Most are found on soil at the bases of trees or

boulders or on rocks in protected crevices or fissures. In more mesic sites, bryophytes grow on fallen logs or on the trunks and branches of trees and shrubs or over bare rock. Numerous species, although not strictly acidophilic, calciphilic or epiphytic, appear to favour particular habitats over others. Accordingly, granitic sites like Robinson Gully support a different set of bryophytes when compared with Sinker Reef, which is largely limestone. More than one-half of our collections came from just two of the seven sites: Robinson Gully and the forests adjacent to the picnic area at the Reserve Office.

Most of the moss and liverwort species collected at Two Peoples Bay Nature Reserve are found elsewhere in the Southwest Australian Floristic Region (Fig. 1), as defined by Hopper and Gioia (2004) and Gioia and Hopper (2017), notably from the Muir and Jarrah Floristic Districts. Except for *Pleurophascum occidentale*, all these species have been reported from elsewhere in Australia or New Zealand. The bryophyte flora of South Australia is especially close to that of south-west Western Australia. The greatest number of species (46%) are endemic to Australia and/or New Zealand; 24% demonstrate a Gondwanaland distribution; 27% can be described as nearly cosmopolitan; and only one species (*Sematophyllum homomallum*) shows an Australasian distribution (i.e. it occurs in Australia, New Zealand and parts of Asia).

Liverworts

Table 2 lists 10 species of liverworts in nine genera and six families, with site notes on their distribution. As with mosses, Robinson Gully supported the most abundant and diverse flora.

Discussion

Worldwide there are about 14,000 species of mosses and liverworts. Their origin is thought to be more ancient than

Table 2. List of liverwort species collected at Two Peoples Bay Nature Reserve.

Species	RG	RO	WB	SRf	RI	SRd	LG
<i>Riccardia crassa</i> (Schwägr.) C. Massal.	X		X				
<i>R. rupicola</i> (Steph.) Hewson			X				
<i>Symphyogyna interrupta</i> Carring. & Pearson	X		X				
<i>Cephaloziella exiliflora</i> (Taylor) Douin		X					
<i>Frullania probosciphora</i> Taylor			X		X		
<i>Heteroscyphus planiusculus</i> (Hook.f. & Taylor) J.J. Engel	X						
<i>Lophocolea semiteres</i> (Lehm.) Mitt.	X	X			X		
<i>Paracromastigum longiscyphum</i> (Taylor) R.M. Schust.	X		X				
<i>Neolepidozia disparata</i> (J.J. Engel & G.L.Sm.Merr.) E.D. Cooper							X
<i>Tricholepidozia tetradactyla</i> (Hook.f. & Taylor) E.D. Cooper	X		X				

Collection sites were: RG, Robinson Gully; RO, forest at Reserve Office; WB, Waterfall Beach; SRf, Sinker Reef; RI, Rock Island; SRd, Sheoak Ridge; LG, margins of Lake Gardner.

that of vascular plants (Bechteler *et al.* 2023). Except for local colonisations of newly available or disturbed sites, their present distributional patterns probably antedate the origin of flowering plants and the breakup of Gondwanaland in the Cretaceous (Crum 1972). A rich and diverse bryophyte flora would not be expected along that portion of the south-west coast that is of geologically recent exposure except where bedrock persists as elevated OCBIL uplands such as Mt Gardner. The genus to species ratio, 1:1.85, is nearly identical to that of mosses of the Hawaiian Islands (1:1.80), another landmass of geologically recent (though pyroclastic) origin (Crum 1972).

The Pottiaceae, the most common family occurring in the Reserve, constitutes a highly polymorphic group. Many of its members are adapted to semi-arid to arid conditions and are commonly thought of as small, tufted mosses of soil and typically basic rocks. There have been many recent changes

in the taxonomy of these plants, including recognition of many new genera, based on modern gene sequencing and phylogenetic reconstructions (Bechteler *et al.* 2023).

Regardless of family relationships, nearly one-half of the species collected in the Reserve have the capacity to occupy open, relatively dry habitats. The morphological adaptations to drought of several of these species have been described in detail by Scott (1982). Those sites with the greatest diversity and cover of bryophytes are the most mesic, especially Robinson Gully and the sclerophyll forests adjacent to the picnic area near the Reserve Office. The driest sites support a distinctly depauperate bryophyte flora, particularly 'Rock Island', the shores of Gardner Lake, and Sheoak Ridge.

The bryophyte flora of the Reserve is, as expected, similar to that of adjacent regions. Only three species (*Campylopus pallidus*, *Pseudocrossidium crinitum*, and *Funaria microstoma*) had not been collected previously from the Muir and Jarrah Districts, although they are known from other districts in the SWAFR. Most of the other collections from Two Peoples Bay Nature Reserve represent species that have also been reported from the Muir and Jarrah Districts. The Southeast



Fig. 2. *Racopilum cuspidigerum*, one of the most common mosses from Two Peoples Bay Nature Reserve, was collected from five sites. Photo taken in Porongurup, WA. Except as noted, all photos are courtesy of iNaturalist and used under the Creative Commons Attribution-Non-Commercial (CC BY-NC) license.



Fig. 4. *Sematophyllum homomallum* showing its distinctive red and gold colour, though new growth is often green. Photo taken in Denmark, WA.



Fig. 3. *Sematophyllum homomallum* is very common on acidic rocks, logs, and bases of trees and was collected from six sites in Two Peoples Bay Nature Reserve. Photo taken in Hazelvale, WA.



Fig. 5. *Pleurophascum occidentale* with its large, orange, obovoid capsules on very short setae. North-east of Esperance. Photo Michael Warren, iNaturalist.

Coastal Floristic Province appears to have a decidedly lesser overlap with the flora, and the Kalbarri Floristic Province and Boylya Floristic District have the least.

Some distinctive differences in substrate preferences can be identified based on our collections and field experience. Species found primarily on granite rocks, presumed to be acidic, include *C. bicolor*, *Dicranoloma diaphanoneuron*, *P. occidentale*, *Rhacocarpus purpurascens*, and *S. homomallum*. *P. occidentale* has, however, been found on a range of other substrates including quartzite,

spongelite and laterite subsequent to our work reported herein. On limestone rocks and soils derived therefrom, presumed to be basic, the following are commonly found: *Didymodon australasiae*, *Gymnostomum calcareum*, *Funaria salsicola*, *Tortella rubripes*, and *Trichostomum eckelianum*. An oddity on display near the Reserve Office of Two Peoples Bay is a partial skeleton of a '100-year-old right whale' (*Eubalaena australis*). The cranium and some of the vertebrae supported growth of several mosses including *Barbula calycina*, *Bryum chrysoneuron*, *Codonoblepharum*

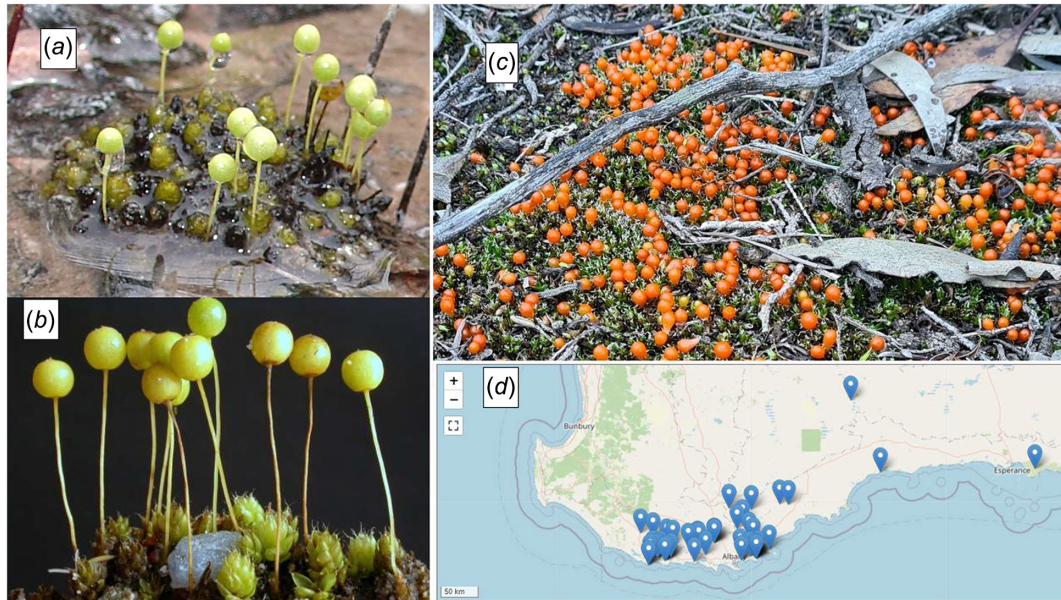


Fig. 6. *Pleurophascum grandiglobum* immersed in water *in situ* in Tasmania: (a) photo M. Brown, (b) photo David Tng. *Pleurophascum occidentale* north-east of Esperance: (c) photo Michael Warren iNaturalist. (d) *Pleurophascum occidentale* distribution (blue markers) from Florabase February 2024. *Pleurophascum occidentale* was a new species in a previously monotypic genus and family when first collected and described from Two Peoples Bay Nature Reserve. Its range is now known to extend east to the Esperance district, WA.



Fig. 7. *Riccardia crassa*, an impressive thalloid liverwort that grows on streambanks, was collected from two sites in Two Peoples Bay Nature Reserve. Photo taken in Walpole, WA.

menziesii, *D. australasiae*, *Syntrichia princeps*, and *Thuidium laeviusculum*. All of these appear to be species that prefer basic substrates (e.g. Duckett 2017), and recent study of blue (*Balaenoptera musculus*) and humpback (*Megaptera novaeangliae*) whale skeletons from Antarctica showed the pH ranges from 7.50 to 8.10 (Putzke *et al.* 2022).

The flora of south-west Western Australia and South Australia appear very similar, thereby making *Mosses of South Australia* (Catcheside 1980) an invaluable manual for



Fig. 8. *Lophocolea semiteres* is a leafy liverwort, often growing on bark at the base of *Eucalyptus* trees, collected from three sites in Two Peoples Bay Nature Reserve. Photo taken in Albany, WA.

collectors in Western Australia. Species collected at five or more sites show the following geographical affinities: *Racopilum cuspidigerum* (Fig. 2) is endemic to Australia and New Zealand; *B. calycina* and *C. bicolor* show a Gondwanaland distribution; *Campylopus introflexus* is cosmopolitan; and *S. homomallum* (Figs 3 and 4) is found in Australia, New Zealand, and parts of Asia.

Although the majority of species collected from the Reserve were not unexpected, several collections support the importance of continuing the bryophyte survey: *D. inclinatum* and *T. dakinii* had not been reported previously from Western Australia, and initially three species appeared to be new to science. Two of these taxa belonged to genera which are notorious for blurred species boundaries (*Bryum* and *Tortella*). With further study these taxa have been assigned to *Rosulabryum subtomentosum* and *T. eckelianum*. *P. occidentale* (Figs 5 and 6), however, differs distinctly from the one described species of the genus, *Pleurophascum grandiglobum* (Fig. 6), and represents a striking geographical disjunction of the genus from Tasmania and New Zealand, where the latter occurs (Wyatt and Stoneburner 1989). The new species differs in numerous characters from *P. grandiglobum*, described by Scott and Stone (1976) as a ‘famous bryological rarity’. It is a much larger plant overall with leaves 6 mm × 2.5 mm vs 2–3 mm × 1 mm, a

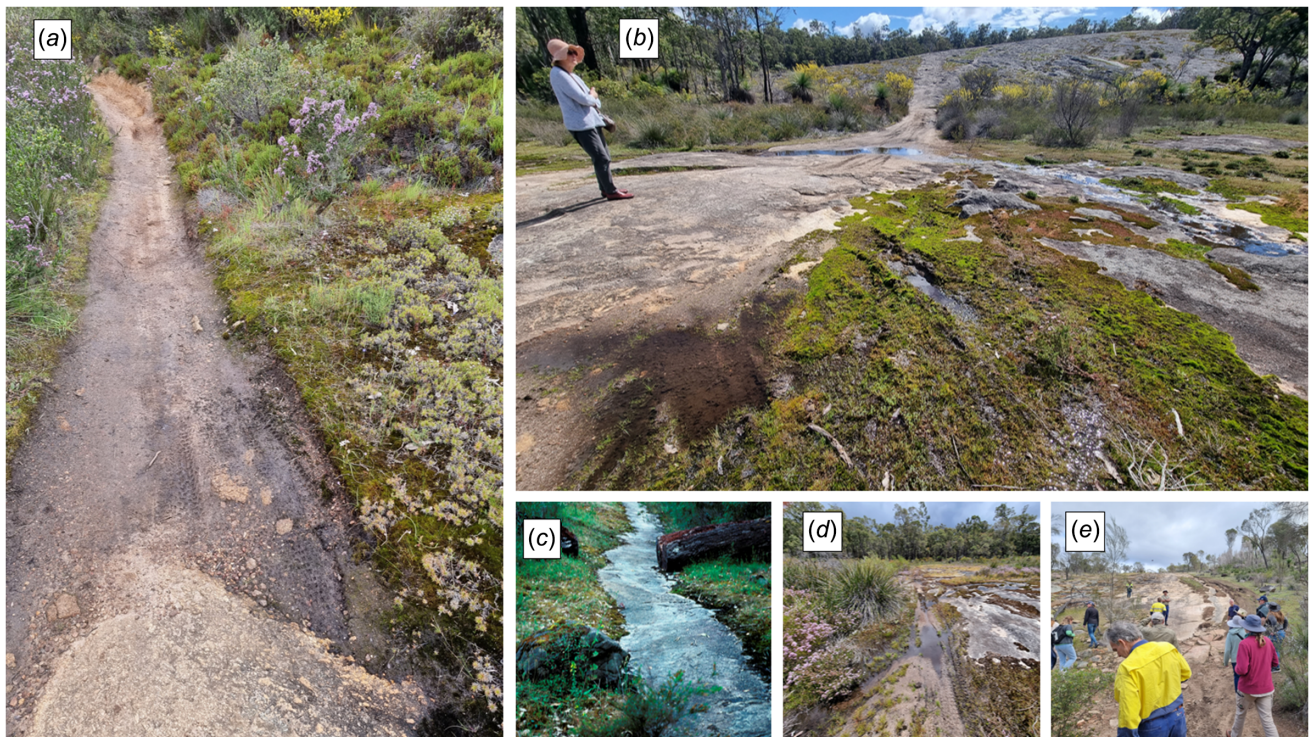


Fig. 9. Granite outcrop moss mats are particularly susceptible to erosion through off road vehicle use such as by mountain bikes, trail bikes, quad bikes and 4WD vehicles. Moss mats often provide habitat for threatened geophytes and annual plants, as well as resurrection plants such as *Borya nitida* (a). Photos by S.D. Hopper of damage caused to moss mats by: (a) mountain bikes at Mt Clarence Albany; (b) 4WD vehicles at Blue Rock SE of Perth; (c) pedestrian trail Mt Chudulup; (d) trail bikes at Blue Rock; (e) 4WD vehicles and trail bikes at Wandoo National Park east of Perth viewed by participants at a granite rock conservation conference.

flexuose, hoary, serrate vs rounded to bluntly obtuse leaf tip, and nearly sessile, large, orange, obovoid capsules vs longer-stalked, smaller, and lighter-coloured capsules (Figs 5 and 6). Since our original collection, searching west and east of Two Peoples Bay has significantly extended the range of the species (Fig. 6d). Clearly, it is important to continue floristic investigations of mosses in the SWAFR, a region unique in its geographical diversity and ecological amplitude. More thorough sampling of different habitats and substrates will undoubtedly add many new species of mosses and liverworts to the list of species in the region.

The hepatic flora of Australia is even less well-studied than the moss flora. Scott's (1985) manual has done much to remedy that situation for southern Australia, though he does not consider his manual exhaustive in scope. Distributional information available for Australian liverworts is especially incomplete. The list of species reported here should not be considered definitive, but rather an indication of the orders, families, and genera likely to be most common in the Reserve. Both thalloid (*Riccardia crassa*: Fig. 7) and leafy (*Lophocolea semiteres*: Fig. 8) growth forms are represented. For southern Australia, Scott (1985) lists 80 genera in 33 families and five orders.

Bryophytes play an important role in soil conservation (Moul and Buell 1955; Golding and Stanton 1972), vegetation development (Thieret 1956), and nutrient cycling (Brown 1982). A well-developed colony of a moss or liverwort may be decades in the making. It is well to remember 'that mosses are vulnerable ... and that indiscriminate or wasteful collecting is unethical, immoral and altogether to be deplored' (Scott and Stone 1976). Of even greater concern in terms of preserving the bryophyte flora is prevention of careless four-wheel driving and use of trail bikes and mountain bikes on granite outcrops and other sensitive habitats that support large colonies of mosses and liverworts (Fig. 9). Research on repair and restoration of such needless destruction of moss mats due to trail damage is only just beginning (e.g. Medeiros *et al.* 2023). Management policy at Two Peoples Bay Nature Reserve should continue with protection of the flora and fauna as its number one priority.

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