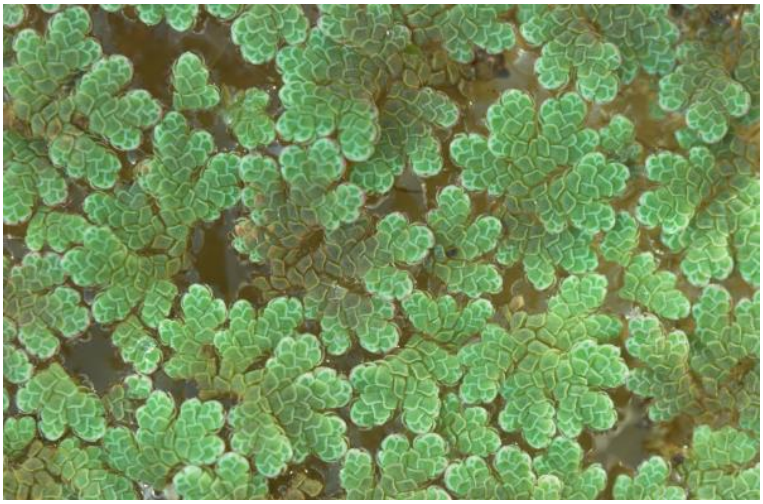
FLORA OF NEW ZEALAND

FERNS AND LYCOPHYTES

SALVINIACEAE



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Fascicle 10 – MARCH 2015

nzflora

CATALOGUING IN PUBLICATION

Brownsey, P.J. (Patrick John), 1948-

Flora of New Zealand [electronic resource] : ferns and lycophytes. Fascicle 10, Salviniaceae / P.J. Brownsey and L.R. Perrie. -- Lincoln, N.Z. : Manaaki Whenua Press, 2015.

1 online resource

ISBN 978-0-478-34779-1 (pdf)

ISBN 978-0-478-34761-6 (set)

1.Ferns -- New Zealand - Identification. I. Perrie, L.R. (Leon Richard). II. Title. III. Manaaki Whenua-Landcare Research New Zealand Ltd.

UDC 582.394.771(931)DC 587.30993

DOI: 10.7931/B1H59T

This work should be cited as:
Brownsey, P.J. & Perrie, L.R. 2015: Salviniaceae. *In*: Breitwieser, I.; Heenan, P.B.; Wilton, A.D. *Flora of New Zealand — Ferns and Lycophytes*. Fascicle 10. Manaaki Whenua Press, Lincoln. http://dx.doi.org/10.7931/B1H59T

Cover image: *Azolla rubra*, plants floating on the surface of standing water with irregularly branched stems bearing densely imbricate bilobed floating leaves

Manaaki Whenua PRESS

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Introduction

The family Salviniaceae is represented in New Zealand by two genera, *Azolla* and *Salvinia*. *Azolla* has one indigenous and one naturalised species, whilst *Salvinia* is represented by a single species which has been declared a noxious weed. *Azolla rubra* is indigenous, occurring in slow-moving streams and ponds throughout the North Island and the eastern half of the South Island. *Azolla pinnata* was first recorded in 1969, and is largely confined to the northern North Island, but is now spreading southwards, and has replaced *A. rubra* in some parts of Northland. *Salvinia ×molesta* is an extremely aggressive weed of lakes and ponds in Northland and Auckland. Both genera are free-floating, aquatic ferns with highly modified leaves adapted for flotation; they are characteristically heterosporous, producing mega- and microsporangia in hardened sporocarps. *Azolla* has small leaves and forms red carpets of growth on the water surface. *Salvinia* has dimorphic leaves arranged in whorls of three, and in *S*. ×*molesta*, characteristic egg-whisk-shaped hairs on the floating leaves for buoyancy.

Salviniaceae Martinov, *Tekhno-Bot. Slovar,* 559 (1820)

= *Azollaceae* Wettst., *Handb. Syst. Bot. 2,* 77 (1903)

Type taxon: *Salvinia* Ség.

Aquatic ferns, free-floating. Stems slender, branching, glabrous or hairy; roots either long and pendent, or absent. Leaves either monomorphic and bilobed, with the upper lobe aerial and green and the lower colourless and floating, or dimorphic and arranged in whorls of 3, with two floating and one submerged; not articulated, herbaceous, papillate or with very specialised hairs, non-circinate when young. Veins anastomosing, or absent. Sporocarps globose or conical, sessile or stalked, glabrous or hairy, either attached to the lower lobes of bilobed leaves, or to the submerged leaves, splitting open irregularly, each sporocarp bearing either mega- or microsporangiate sori. Annulus absent. Heterosporous, spores trilete, lacking chlorophyll; one megaspore in each megasporangium and 32–64 microspores in each microsporangium. Megaspores spheroidal, plain to tuberculate; microspores spheroidal, and plain to rugulate.

Taxonomy: A family of two genera and about 17 species. The Salviniaceae comprises floating aquatic ferns with highly modified leaves adapted for flotation, mega- and micro-sporangia borne in hardened sporocarps that give rise to mega- and micro-spores, and spores which germinate into greatly reduced gametophytes still attached to the parent spore.

Pryer (1999) and Pryer et al. (2004) showed that the heterosporous ferns, Salviniales, are one of three major lineages of “core leptosporangiate” ferns, along with tree ferns and polypod ferns. Nagalingum et al. (2008) subsequently confirmed that Salviniales is divided into two strongly supported families, the Marsileaceae and Salviniaceae, and that within Salviniaceae there is strong support for recognition of two genera, *Azolla* and *Salvinia*. Schneider & Pryer (2002) also demonstrated that the spores of Marsileaceae are markedly different to those of Salviniaceae and all homosporous ferns. The morphology of the reproductive structures in heterosporous water ferns has been critically examined by Nagalingum et al. (2006).

Some authors (Schneller 1990a; Chinnock 1998; Jones 1998) recognise two separate families, Azollaceae and Salviniaceae, on the basis of the significant differences in the morphology of the two groups, but we follow Smith et al. (2006) and Christenhusz et al. (2011) in recognising just one family.

It is represented in New Zealand by one indigenous genus (*Azolla*) and one fully naturalised genus (*Salvinia*).

Distribution: Widespread in tropical and temperate regions. One native and one naturalised genus with three species in New Zealand; none endemic.

Biostatus: Indigenous (Non-endemic).

Table 1: Number of species and named hybrids in New Zealand within *Salviniaceae* Martinov

Category	**Number**
Indigenous (Non-endemic)	1
Exotic: Fully Naturalised	2
Total	**3**

Azolla Lam., *Encycl. 1,* 343 (1783)

Type taxon: *Azolla filiculoides* Lam.

Etymology: From the Greek *azo* (to dry), and *ollyo* (to kill), a reference to the fact that plants are killed by drying out.

Aquatic ferns, free-floating. Stems short, branching, glabrous or sometimes hairy, bearing pendent roots. Leaves monomorphic, bilobed; the upper lobe aerial, green, papillate, containing the cyanobacterium *Anabaena* in a large cavity on the lower surface; the lower lobe colourless and floating; both lobes glabrous. Veins absent. Sporocarps usually absent in NZ; when present, borne on the first leaf of a lateral branch, in the axil of the lower lobe and protected by the upper lobe; megasporocarps oblong-conical; microsporocarps ovoid to globular, usually larger than megasporocarps. Megaspores solitary in each megasporangium, bearing hair-like filaments at the base and floats (massulae) at the apex. Microspores 32–64 in each microsporangium, mixed with massulae that bear hooked processes (glochidia). Megaspores spheroidal, coarsely tuberculate, perforate; microspores spheroidal, plain.

1	Plants regularly 2-3-pinnate; roots with fine lateral rootlets	*pinnata*
	Plants irregularly branched; roots simple	*rubra*

Distribution: Seven species widespread in tropical and temperate regions (Reid et al. 2006); four occur in North and South America, two in Africa and Asia, and two in Australia, one of which is also native to New Zealand and the other introduced. One naturalised and one native species in New Zealand.

Biostatus: Indigenous (Non-endemic).

Table 2: Number of species in New Zealand within *Azolla* Lam.

Category	**Number**
Indigenous (Non-endemic)	1
Exotic: Fully Naturalised	1
Total	**2**

Cytology: The base chromosome number in *Azolla* is x = 22 (Schneller 1990a).

Notes: Plants of *Azolla* are free-floating and capable of covering large areas of slow-moving or still water. They are easily recognised as a red carpet of growth on the water surface. In New Zealand, fertile plants are rarely found, and reproduction is usually vegetative by fragmentation of the lower branches of the plants. Only five collections with sporocarps have been detected in New Zealand herbaria (AK 284894, CHR 168181, 214754, WELT P002240, P024125).

Azolla is of considerable economic importance in Asian countries where crops such as rice are grown in flooded fields. *Azolla* contains the cyanobacterium *Anabaena* which fixes nitrogen and is a source of fertiliser when the parent plant dies.

The phylogenetic relationships of all seven species of *Azolla* have been investigated by Reid et al. (2006) and Metzgar et al. (2007). Spores are illustrated by Tryon & Lugardon (1991).

Azolla pinnata R.Br., *Prodr. Fl. Nov. Holland.,* 167 (1810)

Lectotype (selected by Brownsey & Perrie 2014): Patersons River [New South Wales], *R. Brown Iter Austral. No. 135*, Oct. 1804, BM 001048353!

Etymology: From the Latin *pinnatus* (pinnate), a reference to the regular pinnate branching of the plant.

Vernacular name: ferny azolla

Aquatic fern, free-floating, forming extensive red or green mats. Plants usually broadly triangular or pentagonal or occasionally ovate or elliptic, 5–25 mm long, 4–25 mm wide; stems branching regularly, usually 2-pinnate, or sometimes 3-pinnate in the distal half of the lower pinnae; roots with fine lateral rootlets, 10–60 mm long. Leaves densely imbricate; upper lobe of leaves ovate to elliptic, 0.5–1.5 mm long, 0.3–0.8 mm wide, red or green, papillate; apices acute to obtuse; margins membranous and translucent. Sporocarps rarely produced; megasporocarps not seen; microsporocarps ovoid to spheroidal, covered in a membranous indusium, 1.0–2.0 mm long, 0.8–1.5 mm wide, apiculate, glabrous.

Distribution: North Island: Northland, Auckland, Volcanic Plateau, Taranaki, Southern North Island.

Altitudinal range: 0–440 m.

A widespread species of tropical and warm temperate Africa, Asia, Australia and New Caledonia, now naturalised in ponds and lakes throughout Northland, Auckland, Waikato and the Bay of Plenty, south to Kāwhia and Lake Ohakuri near Atiamuri. There are also specimens collected since 2009 from New Plymouth, Wanganui, Turakina, Otaki and Pekapeka, near Waikanae, suggesting that the plant is spreading southwards. It occurs from sea level up to 440 m at Lake Rerewhakaaitu in the Rotorua region. In Northland, it appears to be replacing the native *A. rubra*.

Biostatus: Exotic; fully naturalised.

Habitat: Grows on the surface of farm ponds, ornamental ponds, lakes, sluggish stream margins and in dune swamps. It often occurs with *Spirodela*, *Wolffia*, *Lemna*, *Landoltia* and *Potamogeton cheesemanii*, and occasionally with *A. rubra*, sometimes amongst *Typha orientalis* or sedges, or on open water.

First record: NZ Weed & Pest Control Society (1969). Voucher: CHR 169486, 1969.

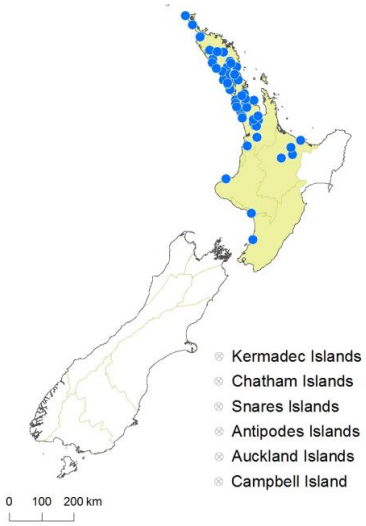

Fig. 1: *Azolla pinnata* distribution map based on databased records at AK, CHR and WELT.

Recognition: *Azolla pinnata* is readily distinguished from *A. rubra* by its more regular branching and by its roots with fine rootlets. It occurs only in the North Island.

Notes: Reid et al. (2006) and Metzgar et al. (2007) showed that *Azolla pinnata* and the African *A. nilotica* form a sister clade to *A. rubra*, *A. filiculoides* and the other American species.

Fig. 2: *Azolla pinnata*: plants floating on the surface of standing water with regularly branched stems bearing bilobed floating leaves.

Fig. 3: *Azolla pinnata*: plant floating on the surface of standing water with regularly branched stems bearing densely imbricate, ovate, papillate, floating leaves.

Fig. 4: *Azolla pinnata*: plants covering surface of standing water, tinged red in open sun.

Azolla rubra R.Br., *Prodr. Fl. Nov. Holland.*, 167 (1810)

≡ *Azolla filiculoides* var. *rubra* (R.Br.) Strasb., *Über Azolla,* 78 (1873)

Lectotype (selected by Brownsey & Perrie 2014): Budgery's Bridge [Badgery's Bridge, Nepean River, New South Wales], *R. Brown*, Apr. 1805, BM! (photo WELT E463/16)

Etymology: From the Latin *ruber* (red), a reference to the colour of the plant when growing in exposed habitats.

Vernacular names: Pacific azolla; kārearea; kārerarera; retoreto; returetu

Aquatic fern, free-floating, forming extensive red or green mats. Plants broadly ovate, elliptic or broader than long in outline, 6–30 mm long, 5–40 mm wide; stems irregularly branched; roots simple, 5–70 mm long. Leaves densely imbricate; upper lobe of leaves ovate, broadly ovate or broader than long, 0.5–2.0 mm long, 0.5–1.5 mm wide, red or green, papillate; apices obtuse to rounded; margins membranous and translucent. Sporocarps rarely produced; megasporocarps oblong-conical, c. 0.5 mm long; microsporocarps spheroidal, covered in a membranous indusium, 1.0–1.5 mm long, apiculate; both glabrous.

Distribution: North Island: Northland, Auckland, Volcanic Plateau, Taranaki, Gisborne, Southern North Island.

South Island: Western Nelson, Sounds-Nelson, Marlborough, Westland, Canterbury, Otago, Southland, Fiordland.

Altitudinal range: 0–800 m.

Azolla rubra occurs in scattered lowland areas of Northland, where it is being replaced by the naturalised *A. pinnata*. It is more common through Auckland, Waikato, the Bay of Plenty south to Lake Taupō, and in the southern North Island. On the east coast it has been collected as far north as Māhia, but is apparently absent from much of the East Cape district. It is also absent from much of Taranaki. It occurs most frequently in lowland areas up to c. 300 m but reaches almost 800 m in the Kaimanawa Mountains. In the South Island it is largely confined to lowland areas east of the main divide, extending westwards to near Karamea in the north, and Lake Manapouri in the far south. It extends from sea-level to c. 550 m near Lewis Pass.

Also Australia (all States), and probably Papua New Guinea, Indonesia and Japan (Reid et al. 2006).

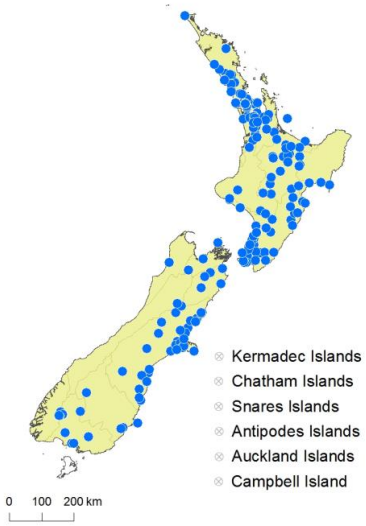

Fig. 5: *Azolla rubra* distribution map based on databased records at AK, CHR and WELT.

Biostatus: Indigenous (Non-endemic).

Habitat: Occurs on slow moving streams, ponds, lakes and swamps, and in farm ponds, ditches and drains where it forms extensive red mats of vegetation. It often occurs with species of *Spirodela*, *Wolffia*, *Lemna*, *Landoltia*, *Ludwigia* and *Potamogeton*, and occasionally with *A. pinnata*, sometimes amongst *Typha orientalis*, *Carex secta* or *Salix* species, or on open water.

Recognition: *Azolla rubra* is readily distinguished from *A. pinnata* by its irregular branching and by its roots that lack fine rootlets. *Azolla rubra* is currently the only species that occurs in the South Island, but the southward spread of *A. pinnata* into the Wellington region suggests that it may soon cross Cook Strait.

Cytology: No count has been made from New Zealand material of *Azolla rubra*, but 2n = 44 has been reported for Australian material (Tindale & Roy 2002).

Notes: In New Zealand, this plant was treated as *A. rubra* by Allan (1961) and by all previous Flora writers. However, following Svenson (1944), the name *A. filiculoides* was adopted for the New Zealand plant by Brownsey et al. (1985) and Brownsey & Smith-Dodsworth (2000), and for the Australian plant by Chinnock (1998). In a detailed investigation of the genus, Reid et al. (2006) showed that *A. filiculoides* and *A. rubra* can be distinguished on both morphological characters and molecular differences. Metzgar et al. (2007) confirmed that the two are closely related sister taxa that are themselves sister to a clade containing the remaining American species. The name *A. rubra* was therefore reinstated by Brownsey & Perrie (2013) as a species native to Australia and New Zealand, and sister to the American *A. filiculoides*.

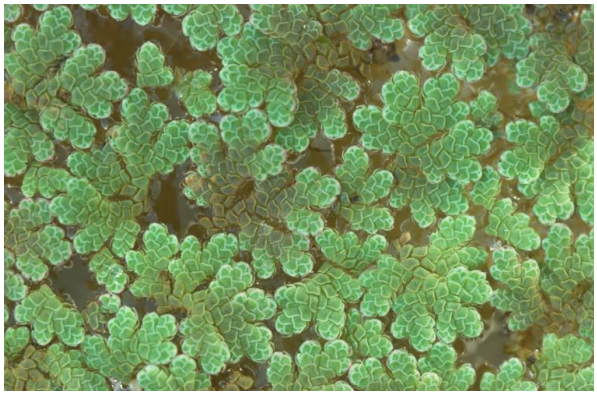

Fig. 6: *Azolla rubra*: plants floating on the surface of standing water with irregularly branched stems bearing densely imbricate bilobed floating leaves

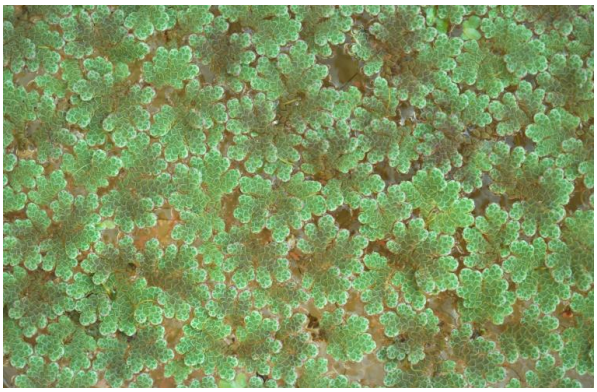

Fig. 7: *Azolla rubra*: plants floating on the surface of standing water showing the upper lobes of bilobed floating leaves, tinged red.

Fig. 8: *Azolla rubra*: simple roots hanging down from plants floating on the water surface.

Fig. 9: *Azolla rubra*: plants covering the surface of standing water, tinged red in the open sun.

Salvinia Ség., *Pl. Veron. 3,* 52 (1754)

Type taxon: *Salvinia natans* (L.) All.

Etymology: Named in honour of Professor Antonio Maria Salvini (1633-1722), botanist and Greek scholar from Florence.

Aquatic ferns, free-floating. Stems short, branching, hairy, lacking roots. Leaves dimorphic, arranged in whorls of 3; each group comprising two floating, green, entire, foliar leaves, and one submerged, highly divided leaf appearing root-like; upper surface of foliar leaves bearing specialised water-repellent hairs; lower surface of foliar leaves and the submerged leaves bearing multicellular hairs. Veins anastomosing without free included veinlets. Sporocarps attached to the submerged leaves, subsessile or stalked, globose to ovoid; each sporocarp bearing either mega- or microsporangia. Sporangia usually empty in NZ plants; when fertile (not NZ), megaspores solitary in each megasporangium; microspores 32–64 in each microsporangium. Spores absent or aborted in NZ plants; when formed (not NZ) megaspores spheroidal, plain, perforate; microspores spheroidal, plain to rugulate.

Distribution: 10–12 species widespread in tropical regions, extending also into temperate areas, with two centres of distribution in Africa, and in South and Central America (Schneller 1990b); some species have become tropical weeds. One naturalised species in New Zealand.

Biostatus: Exotic; fully naturalised.

Table 3: Number of species and named hybrids in New Zealand within *Salvinia* Ség.

Category	**Number**
Exotic: Fully Naturalised	1
Total	**1**

Cytology: x = 9 (Schneller 1990b), the lowest base chromosome number known in ferns (Smith et al. 2006).

Notes: The taxonomy of neotropical species was outlined by Mitchell & Thomas (1972) and adopted by Tryon & Tryon (1982). Following the initial investigation, *Salvinia ×molesta* was described as a new species (Mitchell 1972). It belongs to a small group of South American taxa, including *S. auriculata* and *S. biloba* (syn. *S. herzogii*, see de la Sota 1995), in which the hairs at the end of the leaf papillae are joined at their distal ends.

Based on analysis of five different genes, Nagalingum et al. (2008) showed that *Salvinia* comprises two Eurasian and American groups, although only the American clade, which includes *S. ×molesta*, is strongly supported.

Plants of *Salvinia* are free-floating and capable of covering large areas of slow-moving or still water. In New Zealand, sporocarps are rare and are usually empty when found, and reproduction is vegetative. Spores of American species are illustrated by Tryon & Lugardon (1991).

Salvinia ×molesta D.S.Mitch., *Brit. Fern Gaz.* 10: 251 (1972)

Holotype: Ruziruhuru River inlet, Lake Kariba, Rhodesia [Zimbabwe], *D.S. Mitchell 1330*, SRGH.

Etymology: From the Latin *molestus* (troublesome), a reference to its weedy and invasive nature.

Vernacular names: Kariba weed; salvinia

Aquatic fern, forming free-floating dense mats, with leaves tightly overlapping. Floating leaves broadly elliptic to orbicular when young, becoming broader than long at maturity, 12–30 mm long, 15–50 mm wide, often conduplicately folded along the midrib; apex emarginate; margins entire, sometimes inrolled; base cordate, shortly stalked; upper surface light or brownish-green, becoming darker on the margins, densely covered in papillae each bearing 2 or 4 uniseriate hairs united at their distal ends (shaped like an egg-whisk); papillae up to 3 mm long. Submerged leaves branched, 25–300 mm long, densely covered in brown septate hairs 1–3 mm long. Fertile axes on submerged leaves 15–70 mm long, bearing 4–20 pairs of sporocarps arranged in 2 rows. Sporocarps spheroidal or ovoid, 2–3 mm long, 1–2 mm wide, densely hairy, subsessile, containing sporangia that are usually empty or produce only aborted spores.

Distribution: North Island: Northland, Auckland.

Altitudinal range: 0–50 m.

A rampant weed of tropical and warm temperate regions, recorded as a naturalised plant in lowland areas of northern New Zealand from near Kaitaia to Hamilton. There are additional records of the plant from garden ponds as far east and south as Wairoa (AK 245013).

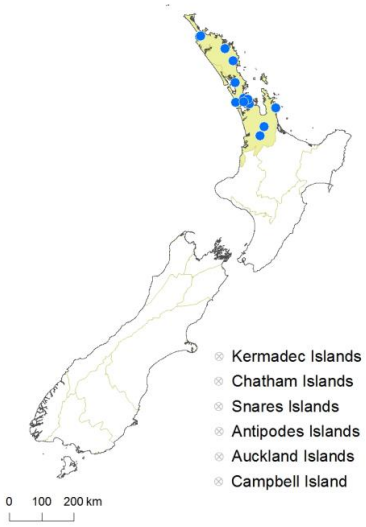

Fig. 10: *Salvinia molesta* distribution map based on databased records at AK, CHR and WELT.

Biostatus: Exotic; fully naturalised.

Habitat: Recorded as an aquatic weed on lakes and ornamental ponds, and in *Eleocharis sphacelata* swamp.

First record: Mason (1964, p. 235), Armiger (1964) – as *Salvinia natans*. Voucher: CHR 234901, 1961.

Recognition: *Salvinia ×molesta* is easily recognised by its floating habit, its dimorphic leaves arranged in whorls of three, and the presence of egg-whisk-shaped hairs on the leaves for buoyancy. When mature and opened out, the floating leaves are shaped like the wings of a butterfly. The plant is sterile, with sporocarps containing only empty sporangia, or aborted spores, and is probably of hybrid origin.

Notes: *Salvinia ×molesta* has been declared a noxious weed in New Zealand. It is believed to be a hybrid of horticultural origin from

South America, now widely distributed in Africa and other areas outside the neotropics (Mitchell 1972). It is a pentaploid with 45 chromosomes (Schneller 1981).

It is very similar to *S. biloba* (syn. *S. herzogii*) from South America (de la Sota 1962, 1995; Tryon & Tryon 1982). At least some forms of this latter species are also probably of hybrid origin (Schneller 1990b), and are distinguishable from *S. ×molesta* only by their chromosome number (Schneller 1980). However, there are no records of *S. biloba* in horticultural cultivation, and infestations outside South America all seem to be referable to *S. ×molesta*.

It has been proposed that the earlier name, *S. adnata* Desv., should replace *S. ×molesta* (de la Sota 1995). However, Moran & Smith (1999) argued that *S. adnata* is of uncertain application, possibly attributable to either *S. biloba* or *S. ×molesta*. Desvaux's type specimen is vegetative, and although de la Sota (2001) provided some characters for distinguishing *S. biloba* and *S. ×molesta*, he was unable to examine them in the type specimen itself. The name *S. ×molesta* should therefore continue to be used for the invasive plant of the Old World tropics.

Fig. 11: *Salvinia ×molesta*: plant showing tightly overlapping floating leaves with specialised water-repellent hairs on upper surface.

Fig. 12: *Salvinia ×molesta*: plant showing dimorphic leaves arranged in a whorl of three, with two floating green foliar leaves, and one submerged root-like leaf.

Fig. 13: *Salvinia ×molesta*: a single, conduplicately folded, foliar leaf with water-repellent hairs on upper surface.

Fig. 14: *Salvinia ×molesta*: plant showing fertile axes amongst the submerged leaves, each bearing up to 20 pairs of sporocarps.

Fig. 15: *Salvinia ×molesta*: a single fertile axis amongst the submerged leaves bearing pairs of sporocarps.

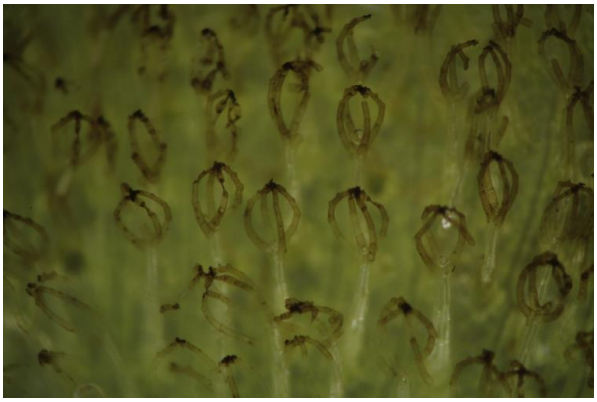

Fig. 16: *Salvinia ×molesta*: water-repellent hairs on the upper surface of a foliar leaf, each comprising a papilla with four uniseriate hairs united at their distal ends (shaped like an egg-whisk).

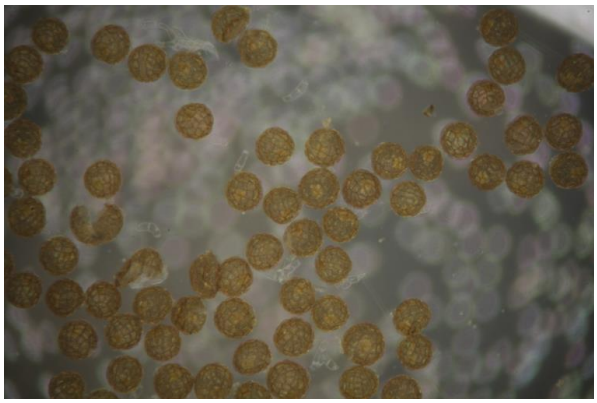

Fig. 17: *Salvinia ×molesta*: empty microsporangia released from the sporocarps.

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Acknowledgements

We thank the staff at AK, CHR and WELT for loans of specimens and for databasing and providing spreadsheets of collection data. We are grateful to staff at CHR for the preparation of maps and for assistance in editing and formatting the text, and to Nathalie Nagalingum for reviewing the manuscript.

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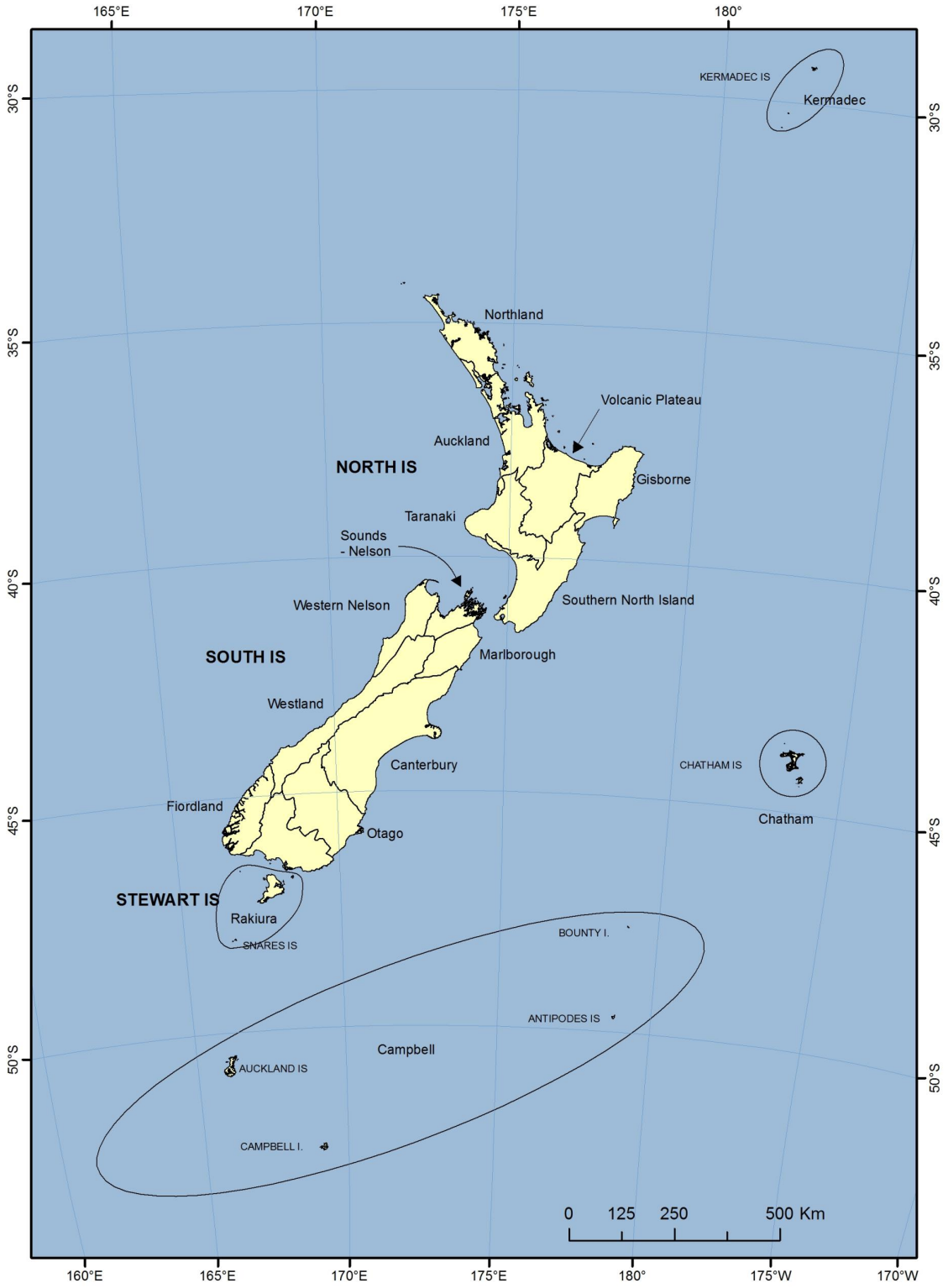
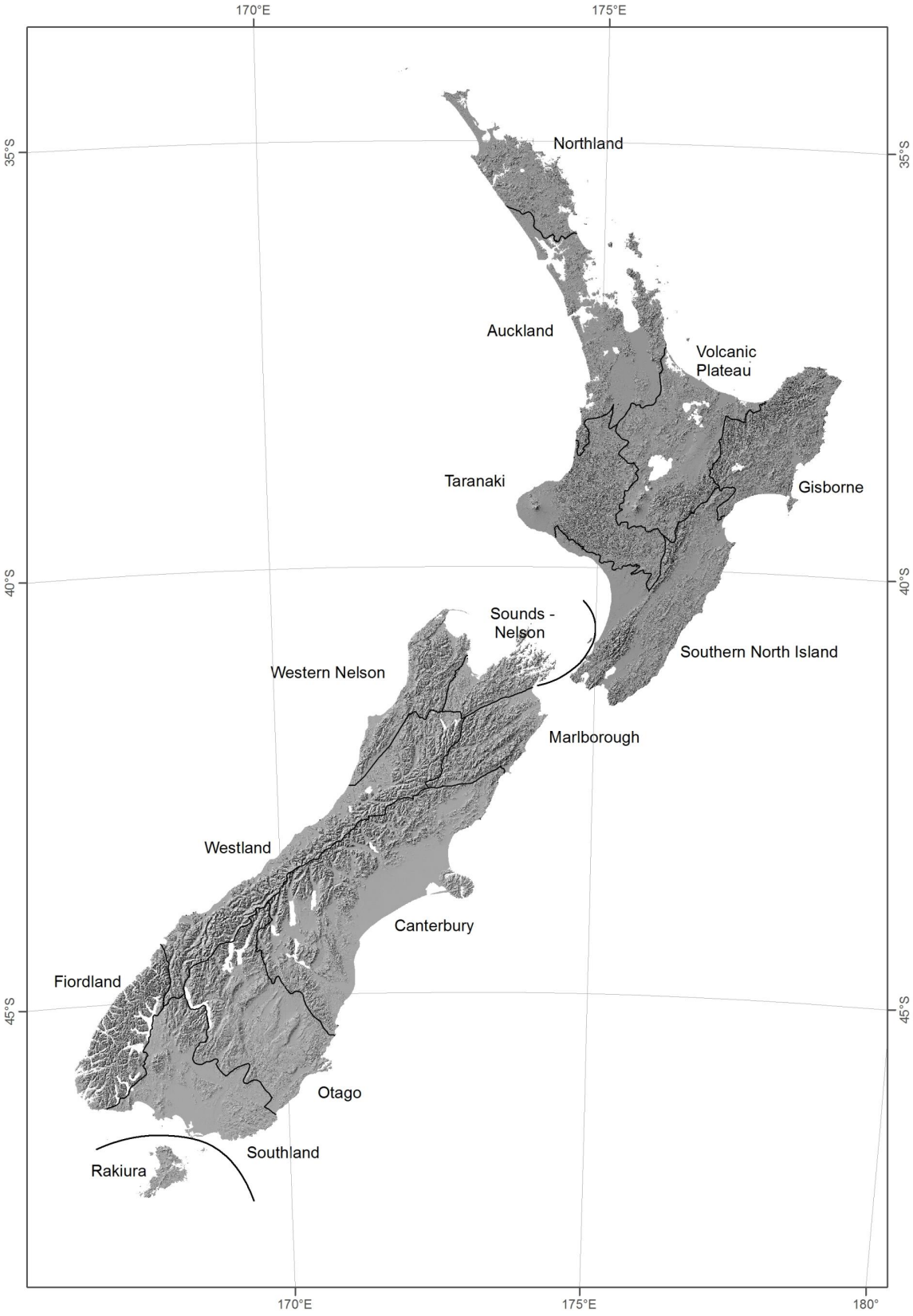


Map 1: Map of New Zealand and offshore islands showing Ecological Provinces



Map 2: Map of New Zealand showing Ecological Provinces

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