

# FLORA OF NEW ZEALAND

## SEED PLANTS

### NYMPHAEALES



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## Introduction

The Nymphaeales contains three plant families, Cabombaceae, Hydatellaceae and Nymphaeaceae, and is the most species-rich order of the early diverging angiosperms known as the ANA grade (Amborellales, Nymphaeales, Austrobaileyales). All three families are represented in New Zealand. Hydatellaceae is represented by only one species, the indigenous *Trithuria inconspicua*. Cabombaceae and Nymphaeaceae are represented by five naturalised species in the genera *Cabomba* (Cabombaceae), *Nuphar* and *Nymphaea* (Nymphaeaceae). All are freshwater aquatic herbs inhabiting ponds, lakes, and slow-flowing streams and rivers.

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## ***Nymphaeales* Salisb. ex Bercht. & J.Presl, *Prir. Rostlin* 270 (1820)**

= *Hydatellales*

Aquatic or sub-aquatic herbs; rhizomatous. Dicotylar; hypogeal germination. Arrangement of floral organs in whorls or irregular. Primary stem with  $\pm$  scattered vascular bundles; vascular cambium absent; vascular bundles lacking associated sclerenchyma; S-type sieve element-plastids present; aerenchyma present. Stomata anomocytic, hydathodes present. Anthers basifixed, tetrasporangiate and dithecal with longitudinal slits, endothecium present; pollen monocolpate or monoaperturate (*Nymphaea*), exine tectate-columellate. Carpels 1–many, apocarpic or syncarpic; ovules anatropous (rarely orthotropous), crassinucellate; embryo sac 4-nucleate, maternal perisperm abundant, a diploid few-celled haustorial endosperm. Seeds with thickened exotesta cells, operculate.

**Taxonomy:** The Nymphaeales is an order of three families with about 90 species in eight genera, *Barclaya*, *Brasenia*, *Euryale*, *Cabomba*, *Nuphar*, *Nymphaea* (incl. *Ondinea*), *Trithuria*, and *Victoria*. Although an early angiosperm lineage, most species display morphology in common with other plant groups of aquatic life-style. Cabombaceae and Nymphaeaceae in particular are macrophytes and have prominent specialised air-canals in vegetative parts and floating leaves on long petioles. The Hydatellaceae, however, differ considerably in that they are minute tufts with non-petiolate linear leaves with most species inhabiting ephemeral pools and wetlands. Characters shared (synapomorphies) by the three families include unusual embryological features, such as abundant maternal perisperm, a diploid few-celled haustorial endosperm, and a 4-nucleate embryo sac. Cabombaceae and Hydatellaceae share apocarpy and post-genital carpel closure, and Cabombaceae and Nymphaeaceae share solitary bisexual flowers, an undifferentiated perianth of tepals (Warner et al. 2009) and stellate parenchyma cells with crystals (astrosclereids).

The Nymphaeales are one of the first diverging branches of the flowering plant phylogeny, part of the ANA grade (Amborellales, Nymphaeales, Austrobaileyales). The order of these early lineages, however, is disputed (Borsch et al. 2003; Soltis et al. 2011; Drew et al. 2014; Goremykin et al. 2013, 2015; Gruenstaeudl et al. 2017). The oldest flowering plant fossil is identified as belonging to the Nymphaeales dating to the early Cretaceous, 115–125 Mya (Friis et al. 2001).

- 1        Plants minute, with simple non-petiolate linear leaves; perianth absent,  
          instead with hyaline bracts ..... *Hydatellaceae*  
          Plants not minute, with broad petiolate leaves, simple or divided; perianth petaloid ..... 2
- 2        Floating leaves lobed or non-lobed, when lobed sagittate or hastate; perianth  
          with six tepals in two trimerous whorls; gynoecium apocarpic ....  
          ..... *Cabombaceae*  
          Emergent or floating leaves lobed, cordate; perianth with numerous tepals  
          not in two trimerous whorls; gynoecium syncarpic or partially free ....  
          ..... *Nymphaeaceae*

**Distribution:** Almost cosmopolitan, temperate and tropical.

**Biostatus:** Indigenous (Non-endemic).

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## ***Cabombaceae* Rich. ex A.Rich. in Bory, *Dict. Class. Hist. Nat.* 2, 608 (1822)**

**Type taxon:** *Cabomba* Aubl.

Perennial herbs, aquatic; rhizomatous. Co-sexual. Stems with air canals, crystals present; indumentum of mucilage-producing trichomes, submerged parts, stems and petioles covered in mucilage (a thick sheath in *Brasenia* only). Leaves di- (*Cabomba*) or monomorphic (*Brasenia*), petiolate; submerged leaves (*Cabomba* only) opposite or whorled, non-peltate, palmately divided into di- and trichotomously dissected capillary segments; floating leaves, alternate, peltate, elliptic, linear, hastate or sagittate. Peduncles axillary or extra-axillary to a floating leaf. Flowers bisexual, solitary; perianth present, hypogynous, actinomorphic, in two whorls of trimerous petaloid tepals (rarely di- or tetramerous), the outer slightly connate at base. Androecium 3–36(–51) stamens; pollination syndrome entomophilous (*Cabomba*) or anemophilous (*Brasenia*). Gynoecium (1–)3–18(–22), apocarpic, placentation ascidiate, post-genital carpel closure incomplete, stigma capitate with multicellular papillae; ovules 1–3(–5) per carpel. Fruit follicle-like.

**Taxonomy:** A family of six species in two genera, the Cabombaceae is found across tropical and temperate areas of Australia, the Americas, eastern Asia and Africa. *Brasenia* with the single species *B. schreberi* has an unusually widespread and disjunct distribution, which Löhne et al. (2008) hypothesise as relictual, whereas the genus *Cabomba* with five species is restricted to the Americas. Bory (1822), who circumscribed the family, considered it belonged to the monocotyledons. Bentham & Hooker (1862) and Caspary (1878) treated the two genera within the Nymphaeaceae. Angiosperm Phylogeny Group (2009) treated it as optional within Nymphaeaceae or as a separate family (Angiosperm Phylogeny Group 2003). There is a general acceptance that *Brasenia* and *Cabomba* should be treated as a separate family based on morphological and molecular evidence (Ørgaard 1991; Löhne et al. 2007; Taylor 2008; Gruenstaeudl et al. 2017).

**Distribution:** Eastern Australia, North and South America, eastern Asia, and central to southern Africa.

**Biostatus:** Exotic; fully naturalised.

**Table 2:** Number of species in New Zealand within *Cabombaceae* Rich. ex A.Rich.

Category	Number
Exotic: Fully Naturalised	1
<b>Total</b>	<b>1</b>

**Recognition:** The flowers of the two genera appear very different owing to different pollination syndromes. *Brasenia* is wind-pollinated and *Cabomba* insect-pollinated, but both have a perianth with six tepals in two whorls of three (giving a monocot appearance) and a superior gynoecium with distinctive large free carpels relative to the flower. The carpels are elongated and tapered distally and the stigmatic area has conspicuous multicellular papillae.

## ***Cabomba* Aubl., *Hist. Pl. Guiane* 1, 321, t. 124 (1775)**

**Type taxon:** *Cabomba aquatica* Aubl.

Perennial, aquatic herbs; long, flexible, cylindrical, rhizomatous stems. Reproduction sexual or vegetative detachment and regeneration. Submerged leaves conspicuous, deeply and finely palmately divided. Floating leaves, linear, narrow-elliptic, trullate, orbicular, sagittate. Flowers emergent, solitary, actinomorphic, bisexual and protogynous, borne below the water surface on peduncles then elongating above the surface at anthesis; perianth hypogynous, 2-trimerous whorls of tepals (persistent on fruit) occasionally di- or tetramerous, pale yellow, white, occasionally purple-tinged or bright purple; inner tepals with auriculate nectaries. Androecium 3 or 6 stamens, when 3 opposite inner tepals; anthers on filaments of different lengths, dehiscence extrorse; pollen elliptic, monocolpate, tectum imperforate, exine surface mostly striate. Gynoecium 1–3(–4) carpels. Fruit follicle-like, coriaceous, maturation submerged, indehiscent. Seeds 1–5, dispersal hydrochory.

**Taxonomy:** *Cabomba* is a small genus (Ørgaard 1991; de Lima et al. 2014) found in tropical and warm-temperate America. Leaf dimorphism occurs in all species with peltate, entire, floating leaves and non-peltate, finely dissected, submerged leaves (Ørgaard 1991).

**Distribution:** A genus of five species, in the Amazonia region of South America but extending south and northwards from the tropics into the warm-temperate regions of southern South America and North America.

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**Biostatus:** Exotic; fully naturalised.

**Table 3:** Number of species in New Zealand within *Cabomba* Aubl.

Category	Number
Exotic: Fully Naturalised	1
<b>Total</b>	<b>1</b>

**Recognition:** Distinctly dimorphic between submergent and floating leaves. Profuse production of submerged leaves, which are finely and deeply divided into fragile capillary segments. Inconspicuous flowers are produced in the axils of the upper floating leaves.

Species of *Cabomba* have a floral arrangement of six tepals (3+3), three or six stamens and commonly three carpels, the same as a typical monocot. When there are six stamens *Cabomba* can be distinguished from most monocots by there being one whorl of six rather than two whorls of three (an exception is *Alisma*).

**Cytology:** Chromosome numbers  $2n = 26, 52, 39, c.78, c. 104$ .

### ***Cabomba caroliniana* A.Gray, Ann. Lyceum Nat. Hist. New York 4: 47 (1837)**

Lectotype (designated by Ørgaard 1991) U.S.A., Louisiana, *J. Hale* (GH barcode 217072).

**Etymology:** Named for the Carolinas: the states of North and South Carolina in the U.S.A.

**Vernacular names:** Carolina fanwort; cabomba; fanwort; green cabomba

Perennial, aquatic herb, repent rhizomes/stems tenuously attached to the substrate. Roots adventitious. Submerged vegetative parts thinly mucilaginous. Stems flexuose and fragile, terete, 1–5 m × 1–3 mm, branching and ascendant, with prominent nodes and internodes, green or reddish brown, with longitudinal striations; glabrescent with short white and longer red-brown mucilage-producing trichomes. Submersed leaves opposite and decussate, rarely a whorl of 3 (not NZ); lamina 20–50 × 25–70 mm, fan-shaped, dividing dichotomously and trichotomously into many fine segments; lamina segments 0.8–1.5 mm wide, linear or slightly spatulate, membranous, sparsely covered in minute trichomes; margin entire, minutely prickly-toothed; apex obtuse; petiole 2–30 mm long. Floating leaves (inconspicuous and present only with flowers), alternate, simple; lamina 12–20 × 1–3 mm, linear to narrow-elliptic, or trullate, tapering towards the ends, sometimes sagittate, coriaceous, glabrescent; margin entire; apex sub-acute to obtuse, peltately attached to petioles; petiole 7–20 mm long, terete. Flowers 6–20 mm in diameter, 5–12 mm long, solitary; 2 whorls of 3 petaloid tepals, oblong or obovate-elliptic with obtuse or emarginate apices, white or pale yellow, darker yellow towards the centre, sometimes margins purple-tinged; inner tepals with nectaries on 2 yellow auriculate basal appendages. Stamens 3 or 6; anthers approximately 1.5 mm long; pollination syndrome entomophilous. Carpels (2)–3–(4), ventricose, divergent at maturity, covered with red-brown trichomes; 2–3 ovules per carpel. Fruit indehiscent, 4–7 mm long, yellowish (not seen in NZ). Seeds 1–3, 1.5–3.0 × 1–1.5 mm, ovoid to ellipsoid, surface tuberculate in longitudinal rows. Dispersal hydrochory.



**Distribution:** North Island: Auckland – Auckland City, Point Chevalier, small spring feeding into Meola Creek, Aug 2009 (failed to persist – absent in 2016; PDC pers. obs.), Henderson, Paremu Lakes/storm water ponds (all three lakes, Feb 2016).

Occurs naturally in USA (Alabama, Arkansas, California, Connecticut, District of Columbia, Delaware, Florida, Georgia, Illinois, Indiana, Kansas, Kentucky, Louisiana, Massachusetts, Maryland, Michigan, Missouri, Mississippi, North Carolina, New Hampshire, New Jersey, New York, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, Washington State), Canada (Ontario), WC-Brazil (Mato Grosso), SE-Brazil (Rio Grande do Sul, Sao Paulo), Argentina (Buenos Aires, Cordoba, Corrientes, Entre Rios, Rio Negro, Santa Fe), Paraguay (Alto Paraguay, Central, Paraguari, Pres. Hayes), Uruguay (Soriano), Bolivia (Cochabamba).

Naturalised in Colombia, Australia, Sri Lanka, India, Austria, Netherlands, S- China, Japan, Korea, peninsular Malaysia, Vietnam, New Guinea (GBIF <https://www.gbif.org/species/2882443>), north-eastern and western USA (McCracken et al. 2013). Three phenotypes are recognised in the USA (Bultemeier et al. 2009), with most of the northern USA and Canadian populations dissimilar from native *C. caroliniana* in the south-eastern USA.

As an escapee of the aquarium trade, it is well established outside its native range of south-eastern USA and South America. Most likely the New Zealand incursions are from inappropriately discarded aquarium waste.

**Biostatus:** Exotic; fully naturalised.

**Habitat:** Sub-tropical to temperate, growing in stagnant or gently flowing waters of ponds, ditches, drains, lakes and streams.

**First record:** CHR 305927, P.J. de Lange 7940, 23 Aug 2009, Auckland City, Point Chevalier, small spring feeding into Meola Creek.

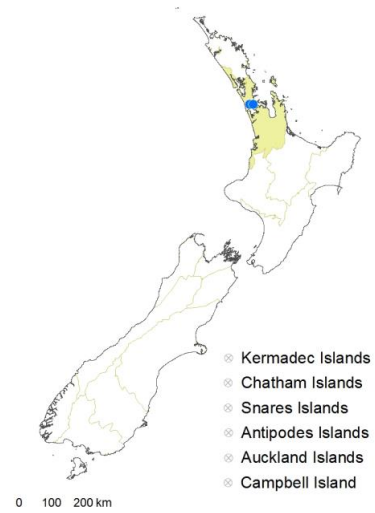
**Recognition:** The flowers are emergent above the water surface and in the axil of a linear, peltate leaf (sometimes arrow-shaped). The three inner tepals of the flower are distinctive, with two bright yellow nectaries on ear-like appendages at the base. The leaves are in opposite pairs, which distinguishes *Cabomba caroliniana* from other aquatic plants with finely divided leaves in New Zealand.

Following the detection of the Paremu storm retention ponds site, *C. caroliniana* was declared an unwanted organism in 2016 under the Biosecurity Act 1993. This prevents the sale and distribution of this species in the aquarium trade. Prior to this declaration, *C. caroliniana* was one of the most popular aquarium plants used by aquarists and had been traded for more than 40 years (Champion & Clayton 2001). Another is *Cabomba furcata* (red cabomba) and although not recorded naturalised in New Zealand is present in cultivation (Champion & Clayton 2001). In contrast to *Cabomba caroliniana* it has whorled submerged leaves and violet flowers.

**Phenology:** Flowering: late spring–early autumn (Schneider & Jeter 1982).

Dispersal by seed or vegetative detachment from readily fragmented stems or a leaf and node (Bickel 2015, 2017; Ørgaard 1991). Caging experiments indicate that apomixis and autogamy do not occur (Schneider & Jeter 1982). After fertilisation the petiole bends and the developing fruit is submerged underwater, maturing then disintegrating and releasing seeds (although fruiting not seen in New Zealand).

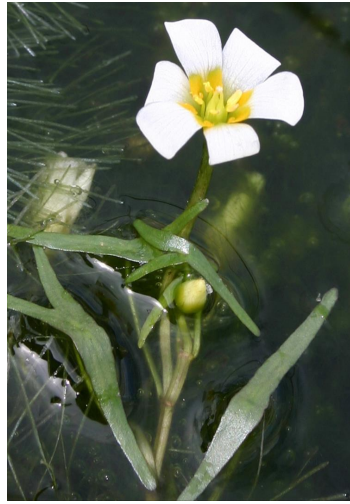
**Cytology:** 2n = c. 96 (Okada & Tamura 1981); 2n = 39, c. 78, c. 104 (Ørgaard 1991); 2n = 34 (Sen & Bhaduri 1971).



**Fig. 1:** *Cabomba caroliniana* distribution map based on databased records at AK, CHR & WELT.



**Fig. 2:** *Cabomba caroliniana*. Habit. Showing the submersed finely dissected leaves and the emergent leaves with both the narrow-elliptic and sagittate lamina forms.



**Fig. 3:** *Cabomba caroliniana*. A flower showing a perianth of two whorls of tepals with three pairs of nectaries (the bright yellow auriculate basal appendages) at the base of each inner tepal; the six stamens are in a single whorl, unlike most monocots.

## ***Hydatellaceae* U.Hamann, *New Zealand J. Bot.* 14: 195 (1976)**

**Type taxon:** *Hydatella* Diels = *Trithuria* Hook.f.

Annual or perennial herbs, sub-aquatic or aquatic; small tufts from short erect rhizomes. Co-sexual, dioecious, or apomictic. Stem crystals absent. Leaves spiral, lamina filiform-linear, margins entire, 1-veined. Peduncles scapose, axillary. Reproductive unit capitate, unisexual or bisexual (with carpels surrounding stamens), subtended by bracts in whorls; perianth absent. Stamens, with long, fine, cylindrical filaments, anther dehiscence latrorse; pollination syndrome anemophilous. Carpels, single stipitate, ascidiate; post-genital carpel closure incomplete; apex bearing 3–many apical multicellular, uniseriate stigmatic hairs (rarely absent), stigma absent; ovules 1 per carpel. Fruit an indehiscent achene or a capsule dehiscent via 3 ribs.

**Taxonomy:** A monotypic family of one genus *Trithuria*. Traditionally treated in the Centrolepidaceae (Diels & Pritzel 1904; Edgar 1966; Edgar 1970), until Hamann (1976) published the family Hydatellaceae to accommodate *Trithuria* (Hooker 1860) and *Hydatella* (Diels & Pritzel 1904), outlining the significant differences from the centrolepids in embryology, seed anatomy, and flower and pollen morphology (Bortenschlager et al. 1966; Hamann 1975, 1976), but he was not able to establish its affinities “...the affinities of *Hydatellaceae* are still obscure” (Hamann 1976).

Hydatellaceae had continued to be classified as a monocot in the Poales until multi-genic phylogenetic analyses placed it in the Nymphaeales and sister to Cabombaceae and Nymphaeaceae (Saarela et al. 2007). Embryological evidence, seed morphology and sieve-element plastids support this placement (Hamann 1976; Rudall et al. 2008; Friedman 2008; Tratt et al. 2009).

Species of Hydatellaceae are minute, tufted herbs with linear leaves and inconspicuous flowering heads with two to several bracts surrounding the carpels and/or stamens. They differ significantly from other Nymphaeales, which are broad-leaved with showy petaloid flowers. Particularly unusual is the arrangement of the bisexual “reproductive units”, where stamens are surrounded by carpels leading to early interpretations of the flowering head being a pseudanthium or inflorescence, an aggregation of unisexual perianthless flowers (Hooker 1860; Diels & Pritzel 1904; Edgar 1966; Hamann 1976). Also, they are described as having an “inside-out flower” and a “none-flower”, and not able to be recognised as a typical angiosperm flower due to secondary loss or a pre-floral condition (Rudall et al. 2007, 2009). Despite recent morphological and anatomical studies, there is still uncertainty about the nature of the flowering head, and whether it is a pseudanthium, a flower, or a flower homologue (Sokoloff et al. 2010). Therefore the term ‘reproductive unit’ (Rudall et al. 2007; Sokoloff et al. 2008) is used here for the flowering head, in place of capitula, pseudanthium or inflorescence.

Until recently, two genera, *Trithuria* and *Hydatella*, were recognised for Hydatellaceae (Diels & Pritzel 1904; Edgar 1966; Edgar 1970; Cooke 1987). Diels & Pritzel (1904) originally distinguished *Hydatella*

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from *Juncella* F.Muell. ex Hieron. (= *Trithuria*) based on separate male and female 'capitula', stipitate flowers, longer and more numerous stigmatic hairs and a lesser number of involucre bracts (two rarely four). Based on Diels' circumscription and the additional feature of indehiscent fruits, Cheeseman (1907) transferred the New Zealand species *T. inconspicua* to *Hydatella*, and this was followed by Edgar (1966) and Edgar (1970). Cooke (1981, 1983, 1987) recognised *Trithuria* and *Hydatella* based on the correlation of unisexual reproductive units and non-ribbed (indehiscent) fruits versus bisexual reproductive units and ribbed three-angled fruits (usually dehiscent). Sokoloff et al. (2008), with new insights and the discovery of additional species, demonstrated the non-correlation of these features and merged the two genera, with *Trithuria* Hook.f. having nomenclatural priority.

Biogeographical analyses date the stem lineage of Hydatellaceae to the early Cretaceous but the crown clade to the early Miocene, an indication that extant species mostly represent dispersal rather than vicariance (Iles et al. 2014). They infer an exception to the earliest split being vicariant and equating to tropical (northern Australia and India) versus subtropical/temperate lineages (South East Australia, Western Australia, New Zealand) and correlation with aridification of central Australia in the early Miocene. This may also correlate with differences in cotyledon morphology (Friedman et al. 2012; Iles et al. 2012; Sokoloff et al. 2008, 2013).

**Distribution:** Australia, India, New Zealand.

**Biostatus:** Indigenous (Non-endemic).

**Table 4:** Number of species in New Zealand within *Hydatellaceae* U.Hamann

Category	Number
Indigenous (Endemic)	1
<b>Total</b>	<b>1</b>

**Recognition:** Minute tufts with non-petiolate linear leaves. The inconspicuous flowering heads have two to several bracts surrounding the carpels and/or stamens. A variable sexual system, either co-sexual, dioecious, or apomictic. Crystals are absent. Fruit an indehiscent achene (NZ) or a capsule dehiscent via three ribs.

### ***Trithuria* Hook.f., Bot. Antarct. Voy. III. (Fl. Tasman.) Part II, 78, pl. 137, fig. 1 (1858)**

= *Juncella* F.Muell. ex Hieron. in Engler & Prantl, *Nat. Pflanzenfam.* II, 4, 15 (1888)

Type not designated

= *Hydatella* Diels in Diels & Pritzel, *Bot. Jahrb. Syst.* 35: 93, fig.7 (1904)

Lectotype: *Hydatella australis* Diels (≡ *Trithuria australis* (Diels) D.D.Sokoloff, Remizowa, T.D.Macfarl. & Rudall, *Taxon* 57(1): 193 (2008))

**Type taxon:** *Trithuria submersa* Hook.f.

**Etymology:** Three windowed (Greek), named for the pericarp valves in some species (not NZ).

Perennial (NZ & Tasmania) or annual herbs; tufted from an erect, shortly branching rhizome. Cotyledons free or united. Leaves spiral, 1-veined; lamina linear-filiform, air canals well developed. Reproductive unit an involucre of hyaline bracts 2–30 (NZ mostly 2 or 4). Stamens 1–17 per reproductive unit; anthers 0.3–2.8 mm long basifixed on filaments 1–5 mm long; pollen oblong or rounded, monosulcate, tectum perforate, exine surface microechinate. Carpels (2–)10–40 per reproductive unit, stipitate, on persistent stalks; uniseriate stigmatic hairs 0.2–5.0 mm long. Fruits dehiscent (2 or 3-valved) or indehiscent. Seeds sculptured or not.

**Taxonomy:** Most species are semi-aquatic annuals (of Australia) associated with seasonal ephemeral pools and wetlands, two species are fully aquatic perennials of permanent lakes, one in New Zealand and the other in Tasmania. Recent molecular phylogenetic analyses of *Trithuria* have resolved four lineages that Iles et al. (2012) have formerly classified into taxonomic sections, diagnosable by fruit and seed characters. *Trithuria inconspicua* is a sister species to *T. filamentosa* of Tasmania and both are classified in section *Hydatella* (Iles et al. 2012, 2014) along with *T. austinensis* and *T. australis* of Western Australia. This section is diagnosed on the basis of: an absence of pericarp ribs and papillae, a thick seed cuticle, and possibly the presence of leaf-sheath auricles (Iles et al. 2012).

*Trithuria* is adapted to wind pollination (Taylor et al. 2010) and not submerged hydrophily, despite flowers opening underwater (Edgar 1966). In *T. submersa* Taylor et al. (2010) showed that emergence was necessary for both pollen release and reception. Species of *Trithuria* have evolved both strong selfing and outcrossing breeding systems (Taylor & Williams 2012) and exhibit dioecy, autogamy and

apomixis. Evidence for apomixis in *T. inconspicua* and *T. filamentosa* is based on near permanent submergence of flowering plants below the water surface (Edgar 1966) and rarely emergent except during prolonged drought conditions; by pollen abnormalities (Hamann 1976, Remizowa et al. 2008); and by embryo development with an absence of pollen tubes (Rudall et al. 2008). Genetic population studies (Smitsen et al. 2019) have provided further evidence that *T. inconspicua* and its sister species *T. filamentosa* are apomictic, although possibly with a recent history of at least occasional sexual reproduction.

**Distribution:** *Trithuria* Hook.f. has 13 species; 11 endemic to Australia, and 1 endemic to each of New Zealand and India (Sokoloff et al. 2008).

**Biostatus:** Indigenous (Non-endemic).

**Table 5:** Number of species in New Zealand within *Trithuria* Hook.f.

Category	Number
Indigenous (Endemic)	1
<b>Total</b>	<b>1</b>

**Recognition:** The minute tufts with monocot-like linear leaves are very different to the macrophytes of Cabombaceae and Nymphaeaceae. *Trithuria* also differs significantly in flower morphology, with non-showy bracted 'reproductive units' (flowers or inflorescences) and with stalked, free carpels with multiseptate stigmatic hairs directly attached to the carpel apex. Most species are semi-aquatic (ex *T. filamentosa* and *T. inconspicua*) and inhabit ephemeral water-bodies that are flowering and fruiting above the receding waterline.

**Cytology:** *T. inconspicua* subsp. *inconspicua*  $2n = c. 24$  (de Lange et al. 2004); *T. submersa*  $2n = 56$  (Kynast et al. 2014).

### ***Trithuria inconspicua* Cheeseman, *Man. New Zealand Fl.* 756 (1906)**

≡ *Hydatella inconspicua* (Cheeseman) Cheeseman, *Trans. & Proc. Roy. Soc. New Zealand* 39: 434 (1907)

Holotype: AK 2889, Sandy shores of Lake Ngatu, Waipapakauri, between Rangaunu Harbour and the West Coast, *H. Carse s.n.*, Feb 1902

**Etymology:** Not easily visible.

Aquatic perennial herb, tufted 10–55 mm in height, from a shortly branching erect rhizome, trichomes present; copious adventitious roots. Apomictic or sexual. Plants in populations often female only, or plants cosexual with unisexual or bisexual reproductive units. Leaf-bases weakly dilated (not sheathing), hyaline, toothed auricles present or absent; leaves spreading, glabrous, 8.0–55 × 0.25–0.6 mm; lamina linear-filiform, adaxially faintly compressed below, terete above, apex rounded with a hydathode. Reproductive units (3.5–)4–5(–7) mm long, on glabrous scapes, 1–5 per plant; involucre bracts 2–4(–7), sometimes dimorphic. Stamens 1–8, anthers 0.8–1.4 mm long, filaments 1–5 mm long (only *T. inconspicua* subsp. *inconspicua*); pollination syndrome anemophilous or gravitational autogamy. Carpels (2–)8–25, white to reddish, with multicellular stigmatic hairs of unequal length or reduced to a knobby capitate head. Fruits 0.39–0.56 × 0.2–0.5 mm, beaked, deciduous from persistent stalks, pericarp thin and membranous, smooth, indehiscent. Seed faintly reticulate, yellow-brown to red-brown with a darker apical cap (formed by an operculum).

**Taxonomy:** *Trithuria inconspicua* is morphologically similar to *T. filamentosa* of Tasmania, its sister species in phylogenetic analyses with an estimated divergence of 0.5 Ma [0–1.1 Ma] (Iles et al. 2012, 2014). They share unique features in the genus such as: perennial life history (Pledge 1974), a fully aquatic habitat (Edgar 1966; Edgar 1970; Wells et al. 1998) and apomixis (Remizowa et al. 2008; Rudall et al. 2009; Smitsen et al. 2019). Gruenstaeudl et al. (2017) discovered a difference in length in the plastid genomes between the two species >15 kbp and hypothesised a single expansion in the IR region.

- 1 Stigmatic hairs approx. 1 mm long (Northland) .... *T. inconspicua* subsp. *inconspicua*  
 .....  
 Stigmatic hairs reduced to a capitate head (Otago, Southland) ....  
 ..... *T. inconspicua* subsp. *brevistyla*

**Distribution:** Disjunct between the South Island (provinces of Southland and Westland) and the North Island (province of North Auckland).

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The apparent absence of *Trithuria inconspicua sensu lato* in Lake Monowai may be due to the artificial raising of the lake level by 2.8 m in 1926 for power generation, since it is present in other nearby lakes. Recent surveys have not relocated *Trithuria inconspicua sensu lato* previously reported from Lake Moke near Queenstown in Otago and Lake Brunner in Westland. There are no specimens to verify whether these reports are of *T. inconspicua* subsp. *brevistyla*.

**Biostatus:** Indigenous (Endemic).

**Habitat:** Aquatic and growing in sediments in the shallows of permanent lakes, both warm-temperate coastal dune lakes (*T. inconspicua* subsp. *inconspicua*) and cool-temperate glacial lakes (*T. inconspicua* subsp. *brevistyla*).

**Recognition:** The minute tufts have narrow, linear leaves with a single mid-vein. The female inflorescence has mostly two or four bracts (sometimes more) that enclose a distinctive cluster of yellow to white or pinkish carpels, each attached to a stalk. *Trithuria inconspicua* is most similar vegetatively to *Eleocharis pusilla* if the creeping rhizome of the latter is buried in the substrate and missed in collection, but in that case *T. inconspicua* can be distinguished from it and species of *Isoetes* by having non-septate leaves. It differs from species of *Centrolepis* by having no leaf-sheaths, or if they are present they are very short and weak, whereas species of *Centrolepis* have a relatively well-defined leaf-sheath.

### ***Trithuria inconspicua* subsp. *brevistyla* K.A.Ford in Smissen et al., *Austral. Syst. Bot.* 32: 9 (2019)**

≡ *Trithuria brevistyla* (K.A.Ford) de Lange & Mosyakin, *Ukr. Bot. J.* 76: 97 (2019)  
Holotype: CHR 638456, Lake Hauroko, Mary Bay, east side,  
K.A. Ford kf448 & R.D. Smissen, 12 March 2015, isotype AK

**Etymology:** From *brevis* (Latin) brief and *stylus* (Latin) pencil or pen, referring to the short stigmatic hairs of the carpels.

Tufted, 10–40 mm in height. Apomictic, plants female only. Leaves 8–37 × 0.4–0.6 mm. Reproductive units 1–5 per tuft, on scapes 1–6 × 0.3–0.4 mm, terete, glabrous; involucre bracts 2–4(–7) ovate to broad-ovate or narrow-ovate. Female reproductive unit bracts 1.6–4.0 mm long, carpels 9–25, white to pinkish, with stigmatic hairs reduced to a knobby capitate head <0.2 mm long. Fruits 0.39–0.56 × 0.3–0.5 mm, ovoid to globose.

**Taxonomy:** Species delimitation in asexual or self-fertilising lineages is often problematic. We note that de Lange and Mosyakin (2019) have provided a combination at species rank for *Trithuria inconspicua* subsp. *brevistyla*. We reject their argument that species rank should be preferred over infraspecific ranks for threatened plants. They also stress a difference in breeding system between the two subspecies. However, both the subspecies of *T. inconspicua* and *T. filamentosa* exhibit apomixis, and Smissen et al. (2019) hypothesised a gradual transition from habitual self-fertilisation to apomixis. Smissen et al. (2019) also emphasised the subtle morphological differences between the two subspecies of *T. inconspicua* and described how similar *T. inconspicua* is to the Tasmanian *T. filamentosa*.

De Lange and Mosyakin cite Sokoloff et al. (2019), who utilised plastid DNA sequences (*rbcL*, *atpB*, *matK* and *ndhF*) in segregating species in the *T. australis* complex. Analysis of *T. inconspicua* subsp. *brevistyla* sequences for these loci (R.D. Smissen, unpublished: GenBank MN057954, MN057955, MN057956, MN057957) show that they are identical to those of *T. inconspicua* subsp. *inconspicua* (NC020372), and therefore plastid sequence diversity in *T. inconspicua* as circumscribed here is less than that in any of the groups proposed by Sokoloff et al. (2019) to be species in the *T. australis* complex.

**Distribution:** South Island: Southland – Lakes Pōteriteri, Hauroko, Manapōuri, Te Anau, and South Mavora Lake; Westland – Lake Sylvan.

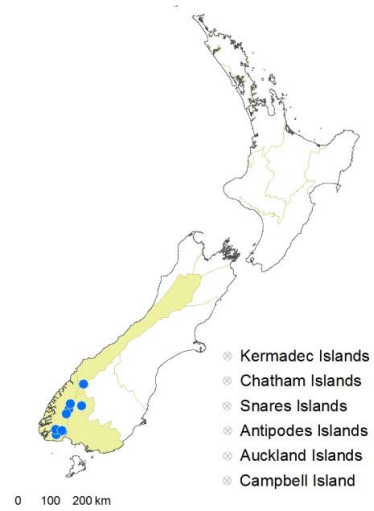
**Biostatus:** Indigenous (Endemic).

Nationally Endangered A (3/1). Reported to be declining in Lake Manapōuri and absent from the previously recorded locality of Brod Bay in Lake Te Anau.

**Habitat:** Shallows of glacial lakes to a depth of about 0.3–2 m (rarely exposed above the water in a dry season), between 35–600 m a.s.l. Growing in sand, silt, and gravel, sometimes almost completely buried in muddy silt. Often part of the aquatic turf community, particularly with short-growing, shallow water-species (Wells et al. 1998).

**Recognition:** Distinguished from *T. inconspicua* subsp. *inconspicua* by the carpels having stigmatic hairs reduced to a capitate head and the fruits ovoid to globose in shape compared with obvious septate hairs to 1 mm and fruits elliptic to ovoid in shape.

**Phenology:** Flowering from at least late Jan–Feb; fruiting Mar–May.



**Fig. 4:** *Trithuria inconspicua* subsp. *brevistyla* distribution map based on databased records at AK, CHR & WELT.



**Fig. 5:** *Trithuria inconspicua* subsp. *brevistyla*. Habit.



**Fig. 6:** *Trithuria inconspicua* subsp. *brevistyla*. A female reproductive unit with two hyaline bracts enclosing the carpels, and showing trichomes at the base of a glabrous scape.



**Fig. 7:** *Trithuria inconspicua* subsp. *brevistyla*. A female reproductive unit with four hyaline bracts in two whorls enclosing the carpels.



**Fig. 8:** *Trithuria inconspicua* subsp. *brevistyla*. Developing carpels from a female reproductive unit showing the uniseriate stigmatic hairs greatly reduced in length and coalesced to form a capitate head.

### ***Trithuria inconspicua* Cheeseman, *Man. New Zealand Fl.* 756 (1906) subsp. *inconspicua***

Tufted 15–55 mm in height. Apomictic or sexual, plants in populations often female only, or plants cosexual with unisexual or bisexual reproductive units. Leaves 14–55 × 0.25–0.4 mm. Reproductive units 1–4 per tuft, on scapes 20–40 × 0.3–0.4 mm; involucral bracts 2–4(–5) ovate to narrow-ovate. Male reproductive unit bracts 3.5–5.0 mm long; stamens (1–)3–8; anthers 0.8–1.4 mm long, bright red, filaments 1–5 mm long. Bisexual reproductive unit bracts 4–5 mm long; stamens 1–5; carpels 2–10. Female reproductive unit bracts 2.5–5.0 mm long; carpels 8–24, reddish, with 5–13 stigmatic hairs of unequal length, 0.3–1.0 mm long, red becoming hyaline. Fruits 0.4–0.56 × 0.2–0.4 mm, elliptic to ovoid.

**Distribution:** North Island: Northland – In dune lakes behind coastal dunes of the west coast between 34.9° and 36.5° latitude (Lakes Ngatu, Rotoroa, Waikare, Taharoa, Kai Iwi, Rotokawau).

**Biostatus:** Indigenous (Endemic).

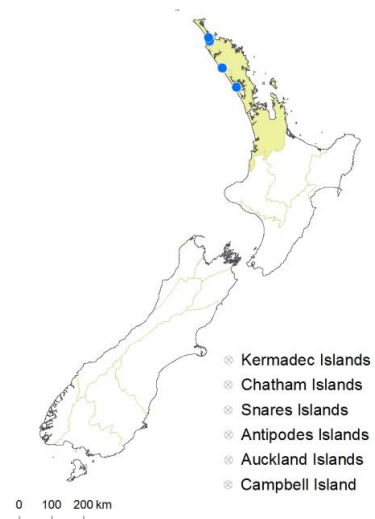
Nationally Critical B (3/1). Reported to have declined since 1998, with lake-wide extinction in seven of the thirteen lakes reported to have supported populations (Smitsen et al. 2019).

**Habitat:** In dune lakes to a depth of about 1 m (occasionally exposed above the water in a dry season, Edgar 1970); 20–70 m a.s.l. Growing in sand and silt, occasionally in peaty sediment, often part of the aquatic turf community and sometimes amongst taller sedges in the shallows.

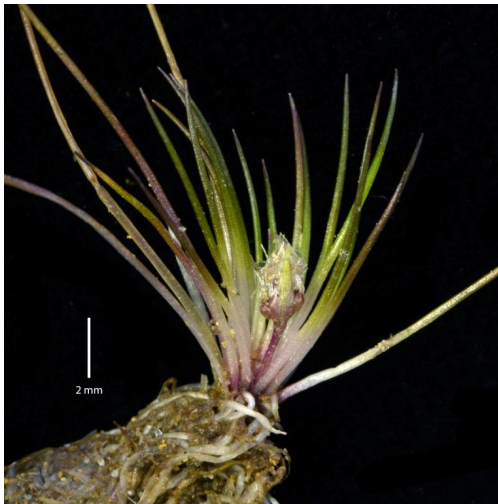
**Recognition:** Distinguished from *T. inconspicua* subsp. *brevistyla* by the carpels with obvious multiseptate stigmatic hairs to 1 mm long compared with a capitate head with much reduced stigmatic hairs and fruits elliptic to ovoid in shape rather than elliptic to globose.

**Phenology:** Flowering Oct.–Jan.; Fruiting from Jan. onwards.

**Cytology:** 2n = c. 24 (de Lange et al. 2004; AK 253948).



**Fig. 9:** *Trithuria inconspicua* subsp. *inconspicua* distribution map based on databased records at AK, CHR & WELT.



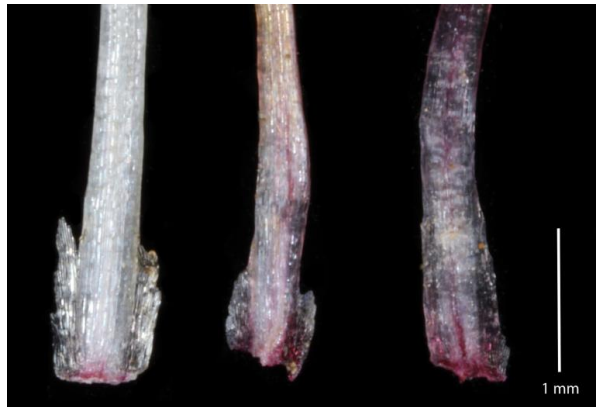
**Fig. 10:** *Trithuria inconspicua* subsp. *inconspicua*. Habit.



**Fig. 11:** *Trithuria inconspicua* subsp. *inconspicua*. Habit of a whole plant *in situ* at Kai Iwi Lakes, Northland.



**Fig. 12:** *Trithuria inconspicua* subsp. *inconspicua*. Erect rhizome with copious adventitious roots and decaying leaves.



**Fig. 13:** *Trithuria inconspicua* subsp. *inconspicua*. Variation in leaves showing some weak dilation and tothing of the leaf-base, or absent.





**Fig. 14:** *Trithuria inconspicua* subsp. *inconspicua*. A sequence of developing carpels (in female reproductive units) showing the elongation of uniseriate stigmatic hairs (left to right).



**Fig. 15:** *Trithuria inconspicua* subsp. *inconspicua*. A bisexual reproductive unit with mature fruits and one stamen.

## ***Nymphaeaceae* Salisb., *Ann. Bot. [König & Sims] 2: 70 (1805), nom. cons.***

Perennial (rarely annual) herbs, aquatic; rhizomatous with prominent petiole and peduncle scars. Many stout, fibrous, adventitious roots. Co-sexual. Stems and leaves with crystals. Leaves spiral, monomorphic or weakly dimorphic (strongly so in a few *Nymphaea*, not NZ); long petiolate; vernation involute; lamina floating or emergent, venation primarily palmate (*Nymphaea*) or pinnate (*Nuphar*); leaf bases cordate to sagittate; submerged leaves mostly similar to emergent. Peduncles, axillary or extra-axillary to an emergent leaf. Flowers, large and showy, bisexual, solitary, actinomorphic, with outer tetra-, tri- or pentamerous whorls of petaloid tepals; perianth parts free. Androecium with numerous stamens, whorled or spiralled (*Nuphar*?); pollination syndrome entomophilous. Gynoecium of 3–many carpels, partially to totally syncarpous, ascidiate or intermediate ascidiate/plicate (*Barclaya*), placentation laminar, post-genital carpel closure complete; stigmatic tissue, sessile, +/- flattened and radiate on an ovary disk (*Nuphar*) or stigmatic processes within a cup-shaped receptacle (*Nymphaea*); ovules many per carpel. Fruit berry-like.

**Taxonomy:** The Nymphaeaceae is the most species-rich and diverse family of the Nymphaeales. Of the five genera (*Barclaya*, *Euryale*, *Nymphaea*, *Nuphar*, *Victoria*), two are represented in New Zealand (*Nuphar* and *Nuphar*) (Garnock-Jones 1988). Molecular phylogenetic and morphological analyses (Borsch et al. 2008; Löhne et al. 2007; Taylor 2008; Gruenstaeudl et al. 2017) have shown that *Nymphaea* is paraphyletic with respect to *Euryale* and *Victoria*. The position of *Nuphar* is unresolved as to whether it is an early diverging lineage of Nymphaeaceae or closer to Cabombaceae (Gruenstaeudl et al. 2017); the traditional classification within the Nymphaeaceae is retained here.

Species of this family have established from ornamental plantings in ponds and lakes and from inappropriately discarded plant material into waterways.

- |   |  |                 |
|---|--|-----------------|
| 1 | Flowers globose, yellow; lvs. with pinnate primary venation and non-anastomosing veins; petiole air canals small .....                           | <i>Nuphar</i>   |
|   | Flowers non-globose, white, yellow, blue, red or pink; lvs. with palmate primary venation and anastomosing veins; petiole air canals large ..... | <i>Nymphaea</i> |

**Distribution:** About 70 aquatic species, almost cosmopolitan, temperate and tropical, exceptions include New Zealand and across the Pacific.

**Biostatus:** Exotic; fully naturalised.

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**Table 7:** Number of species in New Zealand within *Nymphaeaceae* Salisb.

Category	Number
Exotic: Fully Naturalised	3
Exotic: Casual	1
<b>Total</b>	<b>4</b>

**Recognition:** Macrophytes with floating leaves on long petioles and prominent, specialised air-canals in vegetative parts; crystals often obvious. Large, showy flowers which are apparently in whorls but appear more to be spiralled. The gynoecium is partially to totally syncarpic. Fruit berry-like.

## ***Nuphar* Sm. in Sibthorp & Smith, *Fl. Graec. Prodr.* 361 (1809)**

**Type taxon:** *Nuphar lutea* (L.) Sm.

**Etymology:** From *nouphar* (Greek), a general name for water lilies in medieval Europe, originally Sanskrit “nīlotpala” (blue lotus).

Perennial, rhizomes stout, horizontal, branching freely, deeply rooted. Leaves spiral, ex-stipulate; petioles terete to elliptical, plano-convex, winged, or trigonous with small air canals; lamina with primary venation pinnate and non-anastomosing lateral veins, emergent (not NZ), floating, or submerged, leaf-bases deeply cordate. Flowers subglobose, perianth hypogynous; outer tepals 4–7 petaloid (often persistent on fruit); inner tepals many, small and staminoid with abaxial nectaries, no transitions between tepals and stamens; flowers protogynous, diurnal opening. Stamens laminar, strap-like, yellow or red-tinged; anther dehiscence extrorse; pollen monocolpate, tectum imperforate, exine surface echinate. Ovary syncarpus, superior; carpels 4–36, sessile stigmatic rays on a hard-flattened disk, stigmatic tissue with secretory 1-celled papillae. Fruit follicle-like, coriaceous, maturation emergent, dehiscent. Seeds exarillate, numerous.

**Distribution:** Eleven species in temperate regions of the northern hemisphere: Eurasia, South East Asia, north Africa, North America as far south as Cuba and north-east Mexico. A conspicuous component of the northern hemisphere freshwater flora (Padgett et al. 1999).

**Biostatus:** Exotic; fully naturalised.

**Table 8:** Number of species in New Zealand within *Nuphar* Sm.

Category	Number
Exotic: Fully Naturalised	1
<b>Total</b>	<b>1</b>

**Recognition:** Species of *Nuphar* have subglobose-shaped yellow flowers (sometimes reddish tinged) and very distinctive, greenish, urceolate-shaped fruit capped by a hard-flattish disk that matures above the water surface, in contrast to species of *Nymphaea* where the fruits mature below the water surface.

**Cytology:** All species are  $2n = 34$  (Padgett 2007).

**Notes:** *Nuphar* is a northern hemisphere temperate genus (Padgett 2007) and the only genus in Nymphaeaceae with no tropical species. Features characterising the genus are a superior ovary, abaxial tepal nectaries, echinate pollen, and emergent fruit maturation. The group is divided into Old World/New World lineages (with one exception) based on molecular analyses and morphology (Padgett et al. 1999, 2007). The Old World Section *Nuphar* is characterised by flowers with five outer tepals, fruits with walls slightly furrowed, with elongated necks and narrow, stigmatic discs. The New World Section *Astylus* has flowers with more outer tepals (up to 14), fruits with walls deeply furrowed, lacking necks and with broader discs. All species have been recorded as self-compatible and protogynous, entomophilous with floral scents (Ervik et al. 1995). Although seeds have no aril as in *Nymphaea*, the slim pericarp has air-bubbles and serves the same. Recently well-preserved fossil seeds close to *Nuphar* described as *Notonuphar* (Fries 2017) have been recorded from the Eocene of the Antarctic Peninsula, the first record of Nymphaeales from Antarctica.

## ***Nuphar lutea* (L.) Sm. in Sibthorp & Smith, *Fl. Graec. Prodr.* 361 (1809)**

≡ *Nymphaea lutea* L., *Sp. Pl.* 510 (1753)

**Etymology:** Named for the flower colour *luteus* (Latin) or yellow.

**Vernacular names:** brandy bottle; yellow water lily

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Perennial, aquatic herb, with branching, spongy, tuberous rhizomes 20–150 mm in diam., firmly attached to the substrate, dense tangled hairs around leaf scars. Roots adventitious. Leaves weakly dimorphic, floating and submerged; floating leaves on long, stout, trigonous petioles; lamina 120–300 × 90–220 mm, broadly elliptic to ovate, cordate, coriaceous, green to dark purple below, glabrescent, margin entire; submerged leaves on thin, short petioles, lamina thin and semi-translucent (larger than emergent leaves). Flowers 30–65 mm in diameter, solitary, subglobose, with 2 whorls of tepals, outer whorl petaloid, inner whorl stamen-like, held above the water on stout terete peduncles 4–8 mm in diameter; stale alcoholic scented. Outer tepals 5(–6), 20–30 mm long, broadly obovate, apices rounded, yellow with green towards the base. Inner tepals 11–20, 7.5–23 mm long, obovate, apices rounded, with abaxial yellow nectaries. Stamens numerous, 11–12 mm long, anthers yellow. Ovary 26–45 × 20–35 mm, smooth to furrowed, neck prominent, capped by a slightly lobed to entire stigmatic disc 7–13 mm in diameter, 5–20 stigmatic rays. Fruit 26–60 × 20–35 mm, urceolate, neck prominent, glabrous, smooth to slightly furrowed, yellowish-green, dehiscent from the base. Seeds up to 400, 3.5–5 × 3–3.5 mm, ovoid, smooth, shiny, olive-green to pale yellow. Dispersal hydrochory.

**Taxonomy:** *Nuphar lutea* in the narrow sense of Padgett (2007) is followed rather than Beal's (1956) broad concept, which recognised nine subspecies encompassing all European and North American taxa.

**Distribution:** North Island: Southern North Island – Hawke's Bay, Horseshoe Lake, near Patangata (targeted for eradication, with no plants seen since 2013).

South Island: Canterbury – Hazelburn Creek, Tōtara Valley, near Pleasant Point (targeted for eradication).

Occurs naturally in Eurasia (sea level to approx. 850 m a.s.l.).

**Biostatus:** Exotic; fully naturalised.

**Habitat:** Growing in shallow waters of ponds, lakes, canals, wetlands and the margins of slow-flowing streams and rivers.

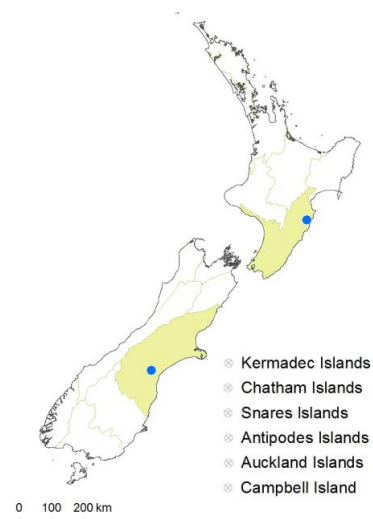
**First record:** CHR 119711, R. Mason, 21 Jan 1961, Horseshoe lake, near Patangata, Hawke's Bay.

**Recognition:** Distinguished from species of *Nymphaea* by more heart-shaped leaves, globose-shaped yellow flowers (with firm tepals) that appear half open, and a greenish, urceolate-shaped fruit capped by a hard, flattish disc that matures above the water surface rather than below. Also, *Nuphar lutea* has a distinctive, large, spongy rhizome compared with the rhizomes of *Nymphaea* species and also other attached-floating aquatics such as *Hydrocleys nymphoides* (water poppy) and species of *Nymphoides* (marshwort, fringed water lily). The flowers are said to smell of alcohol and *N. lutea* is sometimes known as brandy-bottle, a reference to the smell and the flask-shaped ovary (Garnock-Jones 1988).

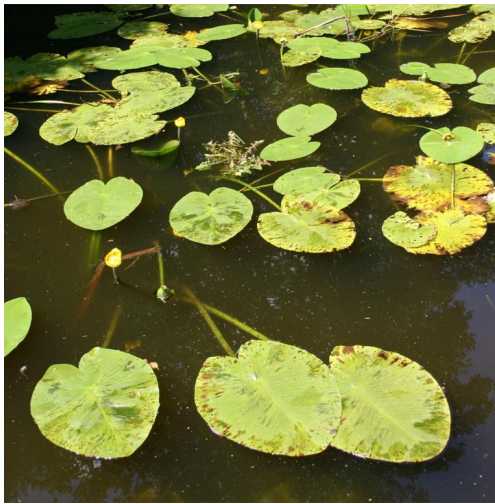
**Phenology:** Flowering: Nov.–Jan.; fruiting: Aug.

**Notes:** Large, tuberous rhizomes which overwinter, sending up new leaves in spring. Fruits develop above the water surface on decaying peduncles, with the outer tepal whorl often remaining attached to the mature fruit. According to Smits et al. (1989, 1990) the seeds are not buoyant, have a poor ability to withstand desiccation, and produce a transient seed bank whereby few viable seeds are present in the sediment between the end of the germination period and the next seed release. Evidence suggests (Schoelynck et al. 2014) that the larger, semi-translucent submerged leaves play a role in reducing flow velocities and promoting sedimentation.

Other species recorded in cultivation in New Zealand but not naturalised are: *N. advena*, *N. pumila* and *N. variegata* (Nichol 1997; Parsons et al. 1997).



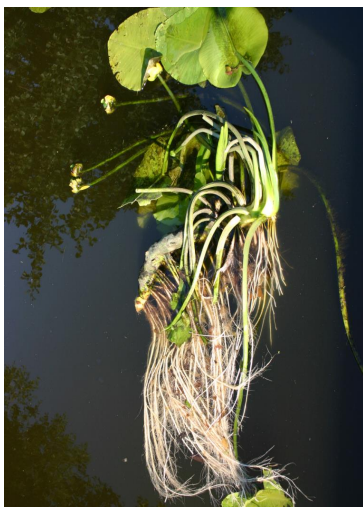
**Fig. 16:** *Nuphar lutea* distribution map based on databased records at AK, CHR & WELT.



**Fig. 17:** *Nuphar lutea*. Habit .



**Fig. 18:** *Nuphar lutea*. Exposed rhizomes.



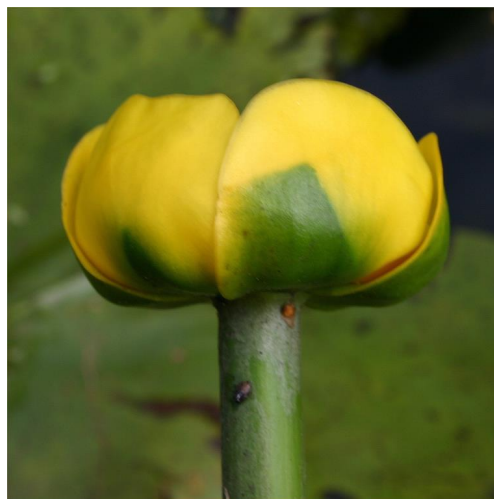
**Fig. 19:** *Nuphar lutea*. Fibrous, adventitious roots sprouting from the rhizome.



**Fig. 20:** *Nuphar lutea*. Leaf lamina and flower.



**Fig. 21:** *Nuphar lutea*. Prominent petiole scars on the spongy rhizome.



**Fig. 22:** *Nuphar lutea*. Side view of globose flower with the outer tepals in view only.



**Fig. 23:** *Nuphar lutea*. A partial side view of a flower showing the distinctive sessile stigmatic rays on a hard, flattened ovary disc and the recurving, strap-like stamens dehiscing pollen.



**Fig. 24:** *Nuphar lutea*. A flower from above showing two whorls of five outer tepals, numerous whorls of smaller inner tepals, numerous strap-like stamens, and a syncarpic ovary with sessile stigmatic rays on the ovary disc.

## ***Nymphaea* L., Sp. Pl. 510 (1753)**

**Type taxon:** *Nymphaea alba* L.

**Etymology:** *Nympe* (Greek) a female deity from Greek mythology; a nymph who haunts rivers, springs and forests.

Perennial, rhizomes short, thick, erect (caudex-like) or horizontal. Stolons present or absent. Leaves spiral, stipulate; petioles with large air canals; lamina with primary venation palmate and anastomosing lateral veins, submerged, floating or emergent; leaf bases deeply cordate to sagittate. Flowers broad, perianth perigynous; 4 outer green or reddish sepaloïd tepals; numerous inner tepals, often transitions between tepals and stamens, staminodes absent; nectaries absent; protogynous, diurnal or nocturnal opening. Stamens laminar; anther dehiscence introrse; pollen monoaperturate, tectum imperforate, exine surface echinate to smooth. Ovary syncarpic or partially free in a cup-shaped receptacle, semi-inferior, stigmatic processes covered with secretary multicellular, uniseriate papillae. Fruit berry-like, fleshy and spongy; submergent maturation, irregularly dehiscent. Seeds with inflated arils, numerous, dispersal hydrochory.

**Taxonomy:** *Nymphaea* is the most diverse group in the Nymphaeales, with five traditionally defined subgenera based on morphology (Conrad 1905). The subgenera are largely recovered within three major evolutionary lineages in analyses of molecular data (Borsch et al. 2008; 2011, Löhne et al. 2007). *Nymphaea* subgenus *Nymphaea* contains mostly northern temperate species from Eurasia and North America that are diurnal flowering, syncarpic, have un-appendaged anthers, ligulate carpellary styles, and flower colour mostly white, pink or red, rarely yellow. The northern water lilies are known as cold tolerant or 'hardy', and many cultivars grown in New Zealand are from this group as well as the two naturalised species. Species of *Nymphaea* subgenus *Brachyceras* are pan-tropical and close to the Australian and New Guinean endemic subgenus *Anecphyra* (Borsch et al. 2008, 2011; Löhne et al. 2007). These two subgenera also have diurnally flowering species, but they all have partly free carpels, appendaged anthers, thick, fleshy carpellary styles, and their flower colour is blue, mauve, pink, white and occasionally yellow. The two remaining subgenera are *Hydrocallis* (neo-tropical/sub-tropical) and *Lotos* (paleo-tropical/temperate); they are mostly nocturnal flowering species, are syncarpic, have un-appendaged anthers, but distinctive long stylar processes, and flower colour is mostly white to cream, pink, red and pale yellow. An evolutionary trend within the night bloomers is for large, broad flowers with more stamens and carpels, possibly associated with beetle pollination (Borsch et al. 2008; Löhne et al. 2007).

Two subgenera are represented in New Zealand by naturalised species, *N. alba* and *N. mexicana*, in subgenus *Nymphaea* and *N. capensis* in subgenus *Brachyceras*. The other subgenera are present in ornamental cultivations, both by species and hybrid cultivars (Champion & Clayton 2001). Hybridisation is mostly restricted between species within the same subgenus (Conrad 1905; Wood

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1959; Löhne et al. 2007). The cultivars of *Nymphaea* are many and diverse and the origins are generally unknown.

Names in brackets are species not naturalised but present in cultivation.

- 1      Flowers white, blue or pink; stolons absent ..... 2  
Flowers yellow; stolons present with brood bodies ..... *N. mexicana*
- 2      Flowers blue; stamens appendaged ..... *N. capensis*  
Flowers white, pinkish, red, occas. yellow; stamens non-appendaged ..... 3
- 3      Leaves crowded on rhizome; flowers faintly scented or odourless ..... *N. alba*  
Leaves scattered on rhizome; flowers often strongly scented ..... [*N. odorata*]

**Distribution:** About 40 species, almost cosmopolitan. Absent naturally in New Caledonia, New Zealand and across the Pacific Islands, but now naturalised in all these places.

**Biostatus:** Exotic; fully naturalised.

**Table 9:** Number of species in New Zealand within *Nymphaea* L.

Category	Number
Exotic: Fully Naturalised	2
Exotic: Casual	1
<b>Total</b>	<b>3</b>

**Recognition:** The species of *Nymphaea* have large, showy, wide-opening flowers (with diurnal or nocturnal opening/closing times) of various colours and a fleshy, globose, berry-like fruit, which matures below the water surface. The seeds are surrounded by inflated arils (unlike *Nuphar*).

**Cytology:** Chromosome counts indicate a base number of  $x = 14$  (Borsch et al. 2008).

**Notes:** The water lilies are rhizomatous and root in soft, organic sediments of still and slow-flowing waters. Flowers in *Nymphaea* are generally protogynous and insect pollinated, with copious stigmatic fluid on the stigmatic surface when functionally female on the first day or night of opening. The three New Zealand naturalised species are diurnal, opening during the day and closing at night (for three or four consecutive days), after which the flowers are pulled below the surface of the water on a bending or coiling peduncle. The fruits ripen and decay underwater, irregularly bursting and releasing seeds, which are within inflated, mucilaginous arils.

*Nymphaea odorata* (fragrant white water lily) type rhizomes are known from collections in New Zealand, and there are also other species in cultivation, including *N. candida* (dwarf white water lily). These species and hybrid cultivars have been deliberately introduced into natural waterbodies in New Zealand. In persistent plantings of *Nymphaea*, it is difficult to distinguish between a cultivated relic and naturalisation. In some hybrid cultivars and species, the former is likely, as they do not set seed or have detachable tubers, and although expanding clonally they are unable to spread between waterbodies and are reliant upon human-assisted establishment.

## ***Nymphaea alba* L., Sp. Pl. 510–511 (1753)**

**Etymology:** Named for the flower colour *alba* (Latin), white or pale.

**Vernacular names:** European white water lily; white lake rose

Perennial, aquatic herb with creeping, horizontal, sparsely branching rhizomes. Stolons absent. Brood-bodies absent. Roots adventitious. Leaves weakly dimorphic (submerged leaves broadly deltoid); stipules free; petiole terete, attachment narrowly peltate; floating lamina (60–)120–250 × 60–100(–220) mm, elliptic to suborbicular, deeply cordate (lobe margins usually overlapping), coriaceous, glossy, glabrous, upper surface dark-green; margin entire. Flowers (70–)100–140 mm in diameter, solitary, held on or above the water surface on peduncles 3.5–9 mm in diameter; slightly sweet-scented (on the first day) or odourless; outer tepals 4, 30–80 mm long, lanceolate to oblong or ovate, apex acute to subacute, inner surface white, outer surface green or reddish, obscurely veined. Inner tepals numerous, 40–90 mm long, outermost as long as outer tepals, lanceolate, ovate or oblong, usually white both sides or cream; rarely red or pink. Stamens numerous, 11–12 mm long, filaments and anthers yellow, appendages absent. Ovary syncarpic, globose with short triangular-ovate styler processes. Fruit globose or semi-globose. Seeds 2–3 × 2 mm, ellipsoid or ovoid, smooth, dark olive green, glabrous.

**Distribution:** North Island: Northland – Waitangi River, Waitakere River, Te Henga wetland (Bethells wetland); Auckland – Western Springs; Southern North Island – Hawke's Bay (Kakaponui Stream, Manhungaharuru Range), Manawatū–Wanganui (Lakes Waikato, Wairoa, Paui).

South Island: Western Nelson – Lake Rotoiti; Westland – Lake Kaniere, drain at Sponge Swamp, lower Kokatahi Valley, Lake Māhinapua, Pāringa River, roadside pond Waiatoto; Canterbury – near Motukārara; Southland – Stewart Island (Martins Creek, Freshwater River).

Occurs naturally in Europe, North Africa and Central Asia.

Water lilies have been planted in many locations (Garnock-Jones 1988).

Locations were recorded but not vouchered in herbaria. North Auckland: Lake Kereta, Waiti Stream, Mokoroa Stream.

Auckland: Lakes Ōkaihou, Paekawau, Pupuke. Waikato: Rotorua, Otamatearua, Mangakaware, Hakano, Waahi, Kimihia. Bay of Plenty: Lake Rotoiti. Manawatū–Wanganui: Lakes Westmere, Dudding, Virginia, Centennial Lagoon (Palmerston North), Ōhinetonga Lagoon. Wellington: Lake Waitawa (NIWA unpublished records).

**Biostatus:** Exotic; fully naturalised.

**Habitat:** Growing in a deep mud/silt substrate in stagnant waters of sheltered bays of lakes, ponds, drains and slow-flowing streams and rivers.

Recorded to depths up to about 3 m depending on water clarity and capable of tolerating a small degree of brackish water (Heslop-Harrison 1955).

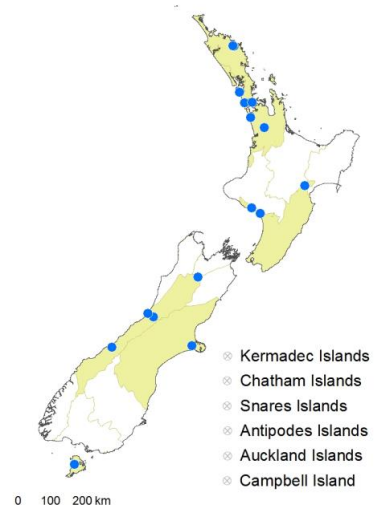
**First record:** AK 35855, CHR 69651, R. Mason, R. Cooper & N.T. Moar, 3 Dec. 1949, Waitangi River, Bay of Islands, (cited in Mason et al. 1950).

**Recognition:** Distinguished by white flowers (or sometimes red or flushed pink) compared with the blue and yellow flowers of *Nymphaea capensis* and *N. mexicana*, respectively. *Nymphaea alba* also has a branching, horizontal rhizome and glabrous seeds, whereas *N. capensis* and *N. mexicana* have a non-branching, erect, caudex-like rhizome and the seeds are hairy.

**Phenology:** Flowering: Nov.–Feb.

**Cytology:**  $2n = 48, 64, 96, 112$  (Heslop-Harrison 1955).

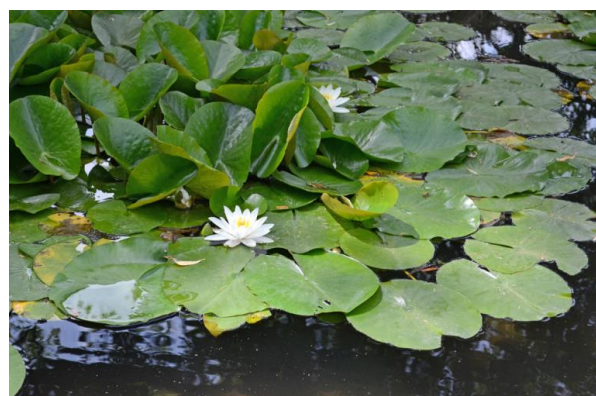
**Notes:** Many 'hardy water lily' cultivars fit into *Nymphaea alba* but are almost certainly of hybrid origin involving *N. alba*, *N. alba* var. *rubra* Lönnr. (Swedish red water lily), *N. mexicana* (yellow water lily) and other species of *N.* subgenus *Nymphaea*, particularly, *N. odorata* and *N. tetragona*, and their stabilised and fertile hybrid, *N. candida*.



**Fig. 25:** *Nymphaea alba* distribution map based on databased records at AK, CHR & WELT.



**Fig. 26:** *Nymphaea alba*. Habit.



**Fig. 27:** *Nymphaea alba*. Habit.



**Fig. 28:** *Nymphaea alba*. A rhizome with petiole scars and adventitious roots.



**Fig. 29:** *Nymphaea alba*. The hard rhizome split open lengthwise and showing the production of new leaves from the crown.



**Fig. 30:** *Nymphaea alba*. T.S. section of the peduncle showing air canals and astroclerids (calcium oxalate crystals).



**Fig. 31:** *Nymphaea alba*. A flower showing numerous tepals, stamens, and short stylar processes surrounding the stigmatic tissue on the top of the ovary.



**Fig. 32:** *Nymphaea alba*. L.S. of a flower showing tepals, stamens and the semi-inferior, syncarpic ovary with its incurved stylar processes, and the central apical residuum (receptacle stalk).



**Fig. 33:** *Nymphaea alba*. L.S. of the receptacle cup and apical residuum, showing the ovary with developing ovules and the apical stigmatic tissue (with secretory papillae), and surrounded by the incurved non-stigmatic stylar processes.



## *Nymphaea capensis* Thunb., Prodr. Pl. Cap. 92 (1800)

**Etymology:** Named for promontory of the Cape of Good Hope.

**Vernacular name:** Cape blue water lily

Perennial, aquatic herb, with non-branching, erect, tuberous, ovoid rhizomes. Stolons absent. Brood-bodies absent. Roots adventitious. Leaves weakly dimorphic; stipules partly adnate; petiole terete, attachment narrowly peltate; floating lamina 120–300 × 100–250 mm, suborbicular, deeply cordate to slightly sagittate (lobe margins overlapping), thin and soft, glossy, glabrous, upper surface bright green; margin irregularly sinuate, crisped. Flowers 60–200 mm in diameter, held 25–40 cm above the water; sweet-scented; outer tepals 4, 40–70 mm long, triangular-ovate, apex subacute, inner surface blue, outer surface green, obscurely veined. Inner tepals numerous, 35–55 mm long, shorter than the outer tepals, elliptic-lanceolate, ovate, sky-blue, deep blue, deep pink, mauve, rarely white. Stamens numerous, 15–35 mm long, filaments yellow, anther blue, appendages conspicuous (same colour as tepals). Ovary partly free, globose with short-tapered stylar processes. Fruit globose. Seeds 1.5–1.7 × c. 1 mm, ellipsoid to semi-globose, with rows of long, hair-like papillae, dull dark olive-brown.

**Distribution:** North Island: Southern North Island – Lake Wairua, near Paui Village south of the Whanganui River.

This species and several 'hardy' cultivars were planted into the southern arm of Lake Wairua by the landowner. These have persisted for many years (C.C. Ogle, pers. comm.).

Occurs naturally in Eastern and southern Africa.

**Biostatus:** Exotic; casual.

**Habitat:** Eutrophic dune lake, 60 m a.s.l.; generally in stagnant and slow-flowing waters of lakes, ponds and streams.

**First record:** CHR 518729, Ogle 3450, 31 Jan. 1999, Lake Wairua (cited in Heenan et al. 2002).

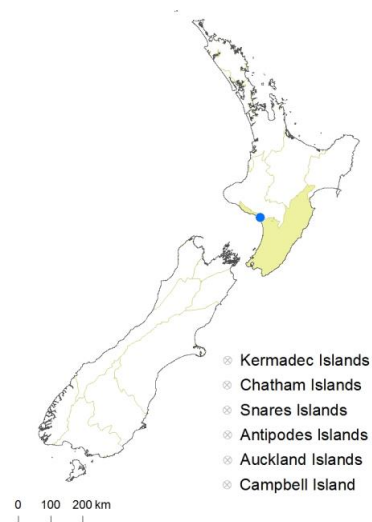
**Recognition:** Distinguished by having conspicuous anther appendages, which are absent in the other two naturalised species, *N. alba* and *N. mexicana*, and the many *Nymphaea* 'hardy' cultivars in New Zealand that are bred from species of *Nymphaea* subgenus *Nymphaea*. The flower colour in *Nymphaea capensis* is generally blue, pink or mauve (rarely white in New Zealand), whereas it is white, flushed pink or red in *N. alba* and yellow in *N. mexicana*. The seeds are also distinctive in having rows of hair-like papillae, which differ from the uniformly hairy seeds of *N. mexicana* and the glabrous seeds of *N. alba* (although seeds have not recorded for *N. capensis* in New Zealand). *Nymphaea capensis* also can be distinguished from *N. alba* and 'hardy' cultivars by having an erect, non-branching caudex-like rhizome rather than the branching, horizontal rhizome.

The striking anther appendages in *Nymphaea capensis* are blue, pink or mauve (the same colour as the tepals) and are characteristic of species from *Nymphaea* subgenus *Brachyceras*, although in some Central and South American species (and a few African species) they are white. Many hybrid cultivars involving species from this subgenus are also present in New Zealand (Champion & Clayton 2001).

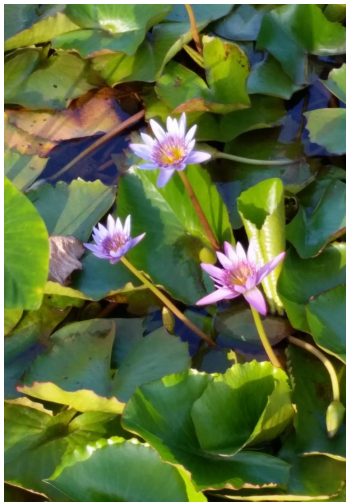
**Phenology:** Flowering: late Jan.

**Cytology:** 2n = 28 (Diao et al. 2006).

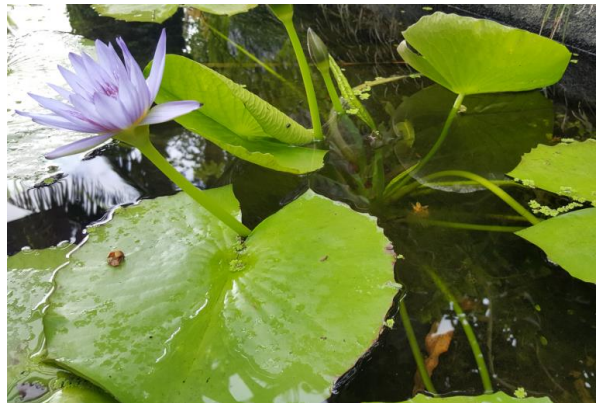
**Notes:** By using the name *Nymphaea capensis* Thunb., the traditional view of Conrad (1905) is followed rather than Verdcourt (1989), who treated this species and *N. caerulea* Savigny (Egyptian blue lotus) as conspecific with the Asian *N. nouchali* Burm.f. as *N. nouchali* var. *caerulea* (Savigny) Verdc.



**Fig. 34:** *Nymphaea capensis* distribution map based on databased records at AK, CHR & WELT.



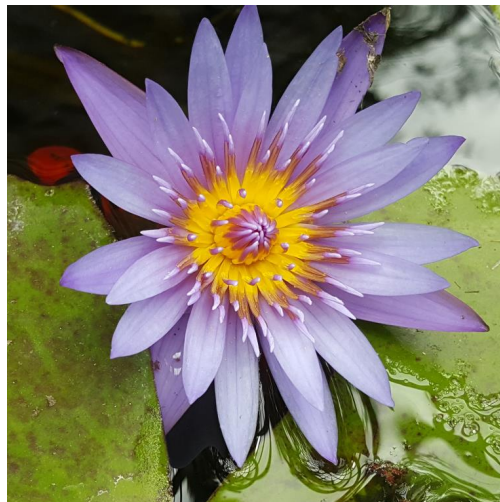
**Fig. 35:** *Nymphaea capensis*. Habit.



**Fig. 36:** *Nymphaea capensis*. Diurnal flower opening.



**Fig. 37:** *Nymphaea capensis*. Leaf-lamina with irregularly sinuate or crisped margin.



**Fig. 38:** *Nymphaea capensis*. Flower showing striking apical anther appendages the same colour as the tepals.

***Nymphaea mexicana* Zucc., *Abh. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. 1: 365–366 (1832)***

**Etymology:** Named for Mexico

**Vernacular names:** Mexican water lily; banana water lily; yellow water lily

Perennial, aquatic herb, with thick, erect, non-branching ovoid rhizomes, densely covered in long hairs between the leaf-base scars. Brood-bodies present. Stolons present. Leaves dimorphic (submerged leaves narrowly hastate); stipules adnate; petiole terete, attachment narrowly peltate; floating lamina (35–)110–220 × (35–)90–170 mm, suborbicular-elliptic, shortly cordate to slightly sagittate (lobe margins overlapping), smooth, glabrous, upper surface bright green, sometimes with red-brown or crimson blotching, lower surface red-brown or purplish-green; margin sinuate to crenulate or entire. Flowers 70–120 mm in diameter, flowers held above the water; faint tea-rose scented or odourless; outer tepals 4, 40–90 mm long, elliptic to lanceolate, apex obtuse, outer surface yellow-green, often red-tinted, inner surface yellow; veined. Inner tepals numerous, 25–65 mm long, outermost as long as outer tepals, elliptic to lanceolate, obovate, apex acute to subacute, bright yellow. Stamens numerous, 16–28 mm long, filaments and anthers yellow, anther appendages absent. Ovary syncarpic, globose with ridges, stylar processes oblong-tapered. Fruit spheroid or ovoid. Seeds 3–5 × 3–5 mm, covered in long, finely appressed, hair-like papillae, dull greenish-black.

**Distribution:** North Island: Northland – Waitakere River, Te Henga wetland (Bethells wetland); Auckland – Van Dammes Lagoon, Mt Wellington; Volcanic Plateau – Lakes Rotokaeo, Ohakuri (Waikato River).

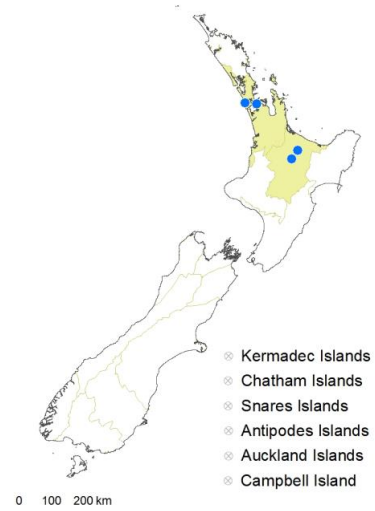
Occurs naturally in south-eastern USA and Mexico.

**Biostatus:** Exotic; fully naturalised.

**Habitat:** Growing around the edges of stagnant and gently flowing waters of lakes, ponds, wetlands, streams, canals and ditches.

**First record:** CHR 140394, L. Nicholls, 15 Jan. 1965, Waikato River, Broadlands end (cited in Johnstone 1982).

**Recognition:** Distinguished by yellow flowers rather than the white, blue, pink or reds of *Nymphaea alba* and *N. capensis*. The leaves are relatively short cordate compared with the latter, and also differ from those two species and many cultivars present in New Zealand by having long, spongy stolons with brood-bodies (a small cluster of buds and banana-like fleshy roots). In addition, the seeds are large, the largest seeds found in *Nymphaea*, with Johnstone recording them as being 2 × 3 mm and greenish-black when mature.



**Fig. 39:** *Nymphaea mexicana* distribution map based on databased records at AK, CHR & WELT.

*Nymphaea mexicana* is a designated unwanted organism in New Zealand under the Biosecurity Act 1993 and is banned from sale and distribution. It has been controlled in two of its locations, but regrowth from brood bodies and potentially seed has occurred at both sites.

**Phenology:** Flowering: Dec.–Jan.

**Cytology:** 2n = 56, 84 (Diao et al. 2006; Gupta 1980).

**Notes:** *Nymphaea mexicana* is a subtropical member in a generally temperate group of water lilies, *N.* subgenus *Nymphaea*. Popular as an ornamental for its yellow flowers, it is now listed as an invasive weed in a number of countries. It is the parent of some hybrid cultivars in ornamental collections. Unusual features are overwintering brood bodies that form on stolons in the muddy substrate (Wood 1959; Johnstone 1982; Garnock-Jones 1988), producing new plants which break off and establish elsewhere. This feature and the characteristic vertical rhizome are represented in the three documented New Zealand populations and are diagnostic of *N. mexicana*, although *N. ×thiona* D.B.Ward (Ward 1977), the natural sterile hybrid between *N. mexicana* and *N. odorata*, has been suggested as the likely origin of populations in New Zealand and naturalised populations elsewhere (J. Wiersema pers. comm., 2017). However, Johnstone (1982) considered the presence of brood-bodies and fruit (and seed) suggest the Ohakuri plant is not the natural hybrid *N. ×thiona*.

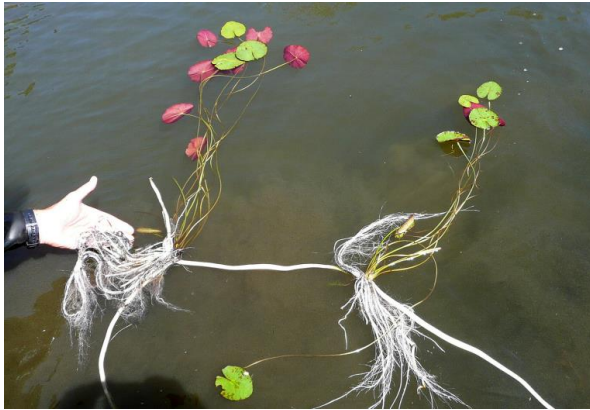
Hybrids with intermediate morphology between *N. alba* and *N. mexicana* have been recorded at Lake Ngātu north of Kaitiā (now eradicated, PDC) and at Bethells wetland, near Te Henga, Waitakere.



**Fig. 40:** *Nymphaea mexicana*. Habit.



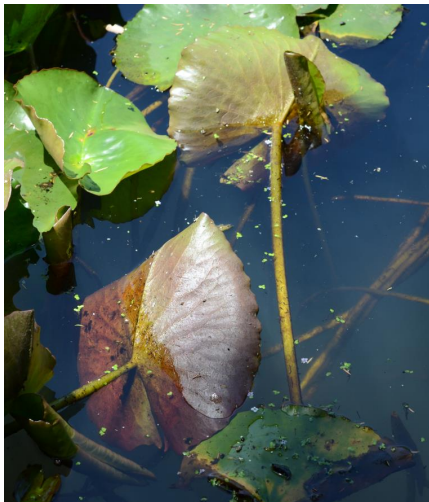
**Fig. 41:** *Nymphaea mexicana*. Showing leaf-lamina margins, which can vary from sinuate to crenulate to entire.



**Fig. 42:** *Nymphaea mexicana*. Stoloniferous habit.



**Fig. 43:** *Nymphaea mexicana*. L.S. of the erect rhizome showing a stolon and numerous adventitious roots.



**Fig. 44:** *Nymphaea mexicana*. Leaves, showing the red coloration of the underside of the leaf.



**Fig. 45:** *Nymphaea mexicana*. Open flower.



**Fig. 46:** *Nymphaea mexicana*. Four pinkish sepaloid outer tepals.



**Fig. 47:** *Nymphaea mexicana*. L.S. of a closed flower showing a compressed receptacle cup and the apical stigmatic tissue squashed into the central apical residuum, and with the terminating styler processors crumpled inwards.

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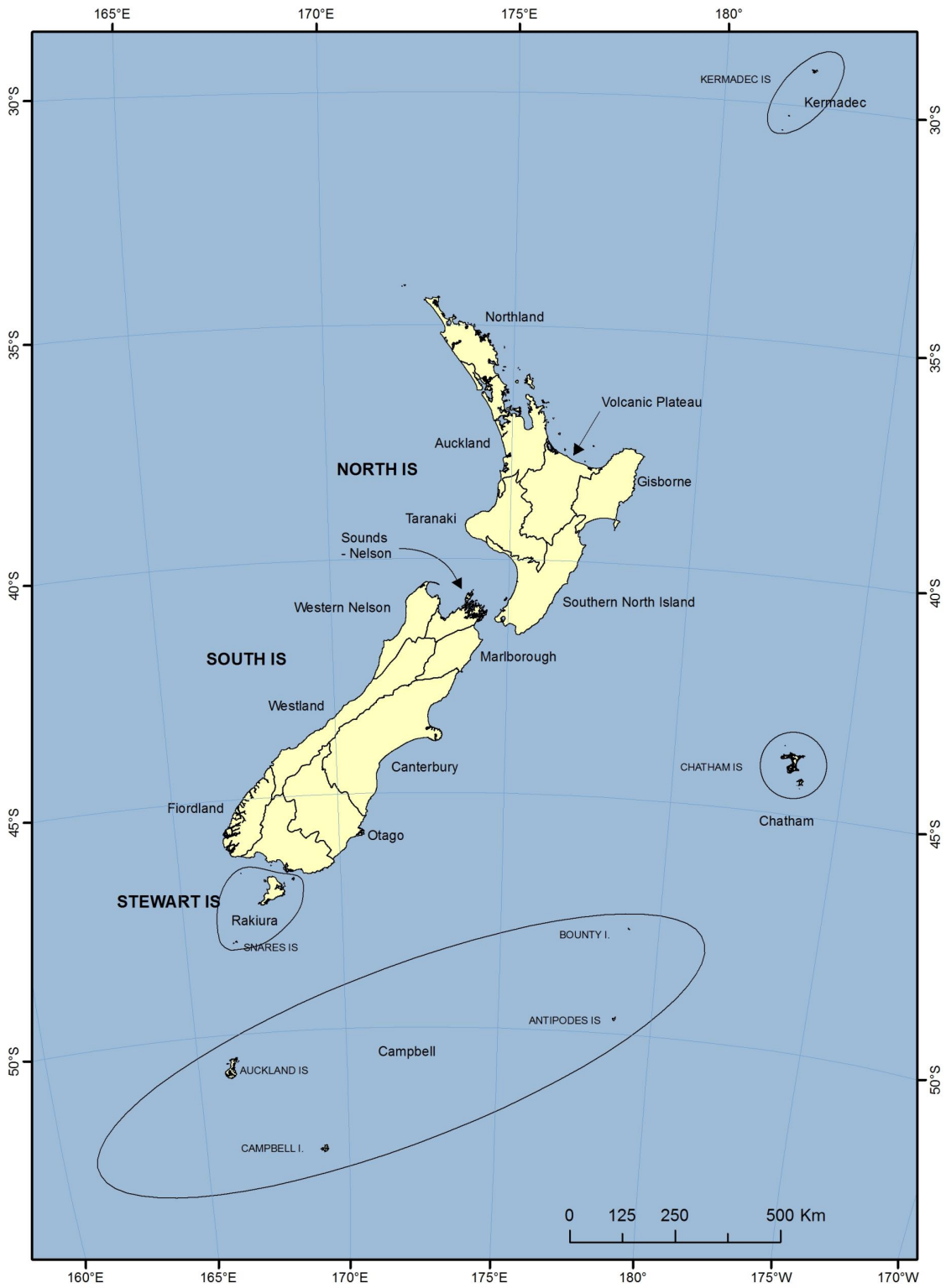
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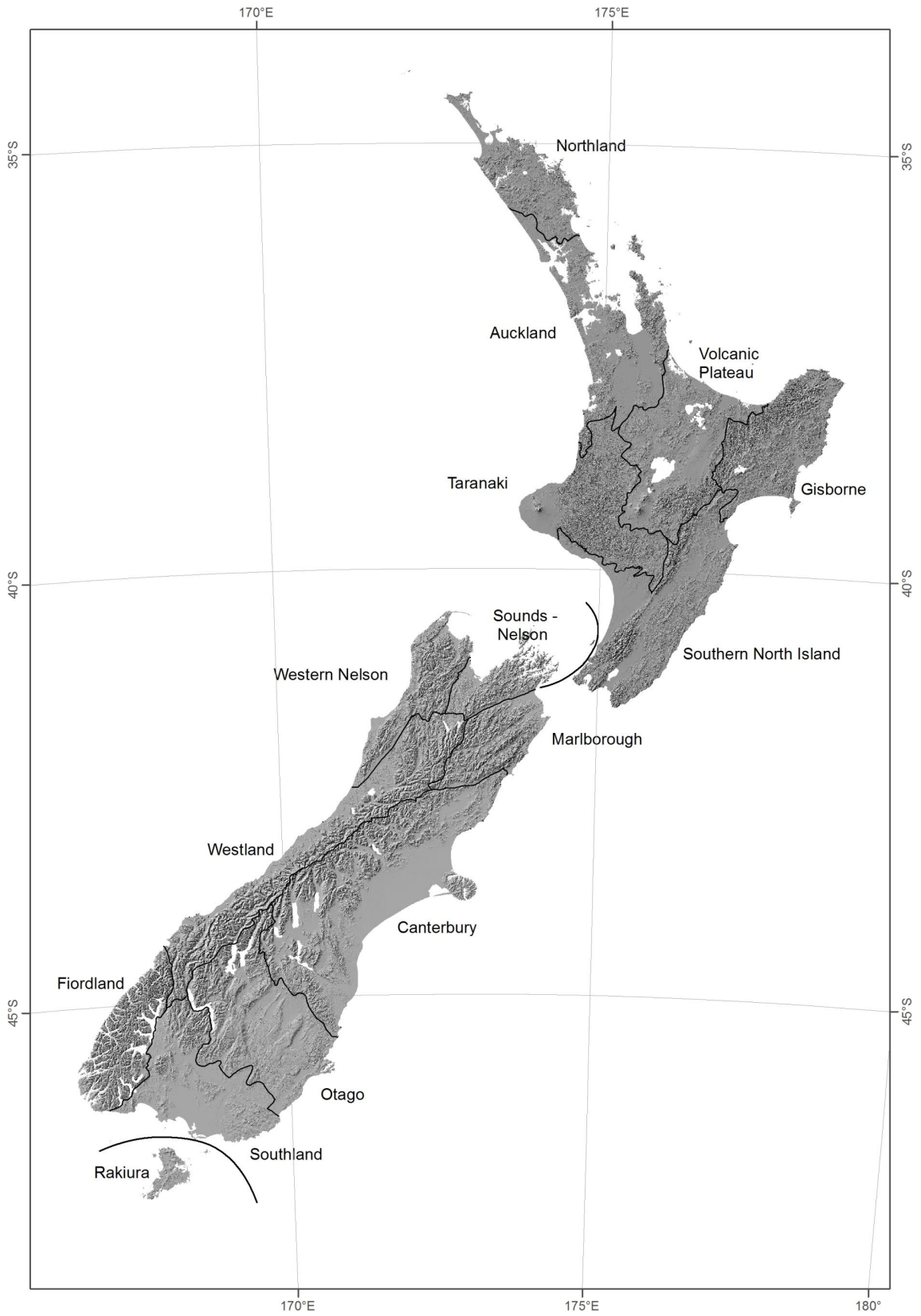
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**Map 1:** Map of New Zealand and offshore islands showing Ecological Provinces



**Map 2:** Map of New Zealand showing Ecological Provinces

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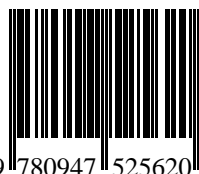
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