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WHORLED PENNYWORT, *HYDROCOTYLE VERTICILLATA* THUNB. (ARALIACEAE), A NEW RECORD OF A CASUAL AQUATIC MACROPHYTE IN SINGAPORE

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ABSTRACT. — *Hydrocotyle verticillata* (whorled pennywort) is an exotic aquatic macrophyte that is primarily planted in canals and water features in Singapore for aesthetics and phytoremediation. It has now been found in multiple localities in Singapore Island, having spread out of original planting zones into adjacent lawns. Additionally, several spontaneous populations have been found in housing estates which could have been introduced through the ornamental trade or dispersed propagules of planted individuals. This species is also often confused with *Centella asiatica* (Asiatic pennywort), a native species, which could be a reason for its widespread planting. A Weed Risk Assessment (WRA) was performed, and a score of 20 was obtained (the high risk threshold for aquatic plants is 19), indicating it as a high-risk species. A comparison table to distinguish *Hydrocotyle verticillata*, *Hydrocotyle sibthorpioides*, and *Centella asiatica* is included. We recommend for *Hydrocotyle verticillata* a status in Singapore of casual but with a high risk of naturalising, and also more stringent measures for the importation of this species. Replacement with a suitable native species is advisable, and a WRA should be undertaken for any future exotic species for introduction.

KEY WORDS. — Araliaceae, *Hydrocotyle verticillata*, whorled pennywort, casual, naturalising, new record, Singapore

INTRODUCTION

The genus *Hydrocotyle* L. is represented in Singapore by three species, namely the exotic *Hydrocotyle javanica* Thunb. and *Hydrocotyle umbellate* L., and the native *Hydrocotyle sibthorpioides* Lam. (Chong et al., 2009). A fourth species, *Hydrocotyle verticillata* Thunb., the whorled pennywort, has recently been found to be naturalising in the waterways and adjacent lawns from human-initiated plantings, and possibly through the ornamental aquatic plants trade. Specimens of *Hydrocotyle verticillata* were deposited in the Herbarium, Singapore Botanic Gardens (SING; collector's number: NIS-LH-12122013-1), and in the Herbarium, Lee Kong Chian Natural History Museum, National University of Singapore (SINU; accession number: 2007020265).

Description. — *Hydrocotyle verticillata* is a perennial, glabrous, creeping plant with slender stems (Fig. 1A) (Mathias, 1936; Wagner et al., 1990). Its leaves have 1.5–35 cm-long petioles and laminas that are orbicular-peltate, 5–60 mm in diameter, 8–14 nerved and shallowly 8–14 lobed (Fig. 1B, C). Its axillary inflorescences are made up of 1–4(–6) verticels along the peduncular axis in interrupted spikes between 1–22 cm long (Fig. 1D). The peduncle and rachis together may be longer than the petiole, but they are generally shorter. The pedicels are 5–40 mm long. Each spike bears 2–15 flowers with cream-coloured petals, each flower being c. 2 mm across. The fruits are acute, ellipsoid, and 1–3 mm long and 2–4 mm broad with distinct ribs (Fig. 1E). Flowering and fruiting occurs between Nov. and Jan., and between Mar. and May (Khatun et al., 2010). Plants encountered in Singapore were observed flowering and fruiting all year round.

It is native to North and South America, and is distributed from Massachusetts and South California in the USA to central Chile, Paraguay and northern Argentina (Mathias, 1936; Wagner et al., 1990). The generic name is derived from the Greek *hydro*, water, and *kotyle*, small cup, probably referring to the watery habitat and peltate leaves of certain species (Wagner et al., 1990). The specific epithet is derived from the Latin *verticillatus*, meaning whorled (Gledhill, 2008), probably referring to the inflorescence.

Ecology, Physiology and Use. — Whorled pennywort is common in wet places such as pond and stream margins, nutrient-rich pools, irrigation and drainage canals, seeps, and muddy sites from sea level to 1,600 m (Wagner et al., 1990; Rejmánková, 1992). It is a secondary species in floating vegetation mat communities in Grassy Lake, Arkansas, USA, sometimes making up to 25% of the mat (Huffman & Lonard, 1983). Aquatic macrophytes such as whorled pennywort, thrive in the littoral zone of lentic environments, and are important to maintain biodiversity and energy flow by being involved in the bio-geochemical processes within aquatic ecosystems (Bouchard et al., 2007; Theel et al., 2008). This is probably why it has begun to naturalise in Singapore through the waterways where it was planted for aesthetic and phytoremediation purposes, with observations of it creeping and proliferating onto lawns by the canals.

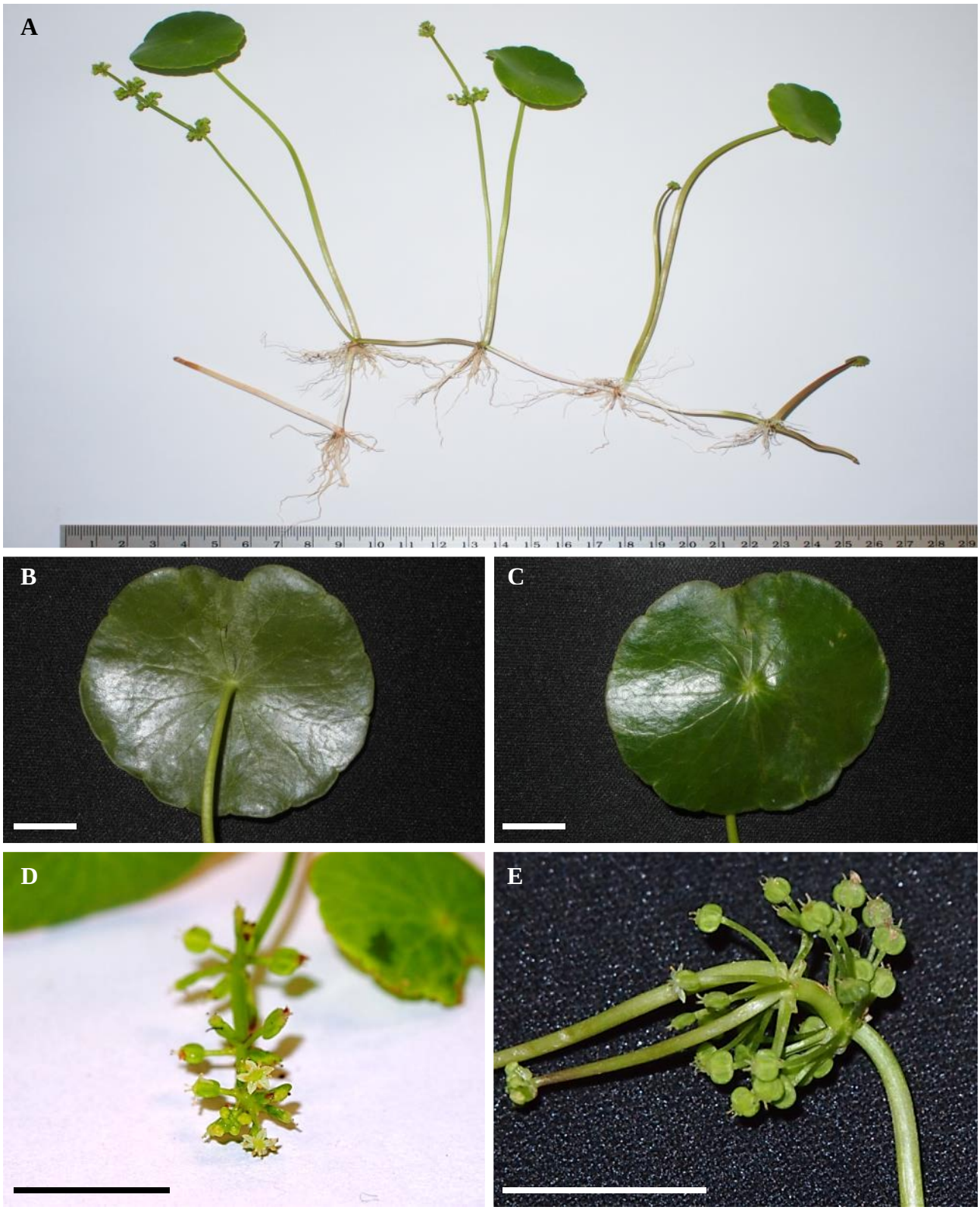

Fig. 1. *Hydrocotyle verticillata*. A, Section of the rhizome with five distinct nodes; B, underside of lamina to indicate how the petiole is attached; C, upperside of lamina ; D, inflorescence with open flowers at the tip (in focus) and young fruits further back; E, infructescence (Scale bar = 1 cm). (Photographs by: Alex Yee Thiam Koon [A, D, E] and Reuben Lim Chong Jin [B, C]).

As a creeping emergent, whorled pennywort roots in the substrate and sends out long prostrate rhizomes (horizontal stems) that freely root to create dense mats (Rejmánková, 1992). Its stems are not strong enough to grow vertically. Adventitious roots which develop on these stems are often without any direct contact with the substrate, and able to absorb nutrients directly from the water. It decomposes rapidly because of its low C:N ratio, generally around 10:1 (Godshalk & Wetzel, 1978). It has a high shoot to root area ratio, low tissue porosity, and possible diffusion barriers between the long petiole and lamina, which restricts uptake of sediment CO_2 (Winkel & Borum, 2009).

The whorled pennywort has been used in phytoremediation trials to treat various kinds of wastewater and runoff, such as acid-mine drainage and municipal wastewater (Rejmánková & Bayer, 1995; Strosnider et al., 2011), pharmaceutical and personal care products (Zhu & Chen, 2013), and eutrophic river water (Zhao et al., 2012). This plant is widely used in the aquarium trade as a foreground or mid-ground accent ornamental plant in tanks (The Planted Tank, 2000 onwards; Tropica Aquarium Plants, 2012) (Fig. 2). It can also be grown in ponds and indoors. It is best grown in temperatures between 10–25°C, pH 5.0–7.0, 15–25 mg l^{-1} of CO_2, and more than 1 W l^{-1} of light (The Planted Tank, 2000 onwards; Tropica Aquarium Plants, 2012).

It was probably a minor vegetable used as a condiment in pre-Columbian Mesoamerica, called amamalacotl or 'swirl of water' (Estrada-Lugo, 1987).The amamacotl was a marshy plant with round leaves abundant in Lake Texcoco that was aromatic, edible, and had medicinal properties as a stimulant (Picó & Nuez, 2000).

It is listed in the Global Compendium of Weeds as an environmental, naturalised, and noxious weed, along with possible invasive records for countries such as Australia, Japan, New Zealand and Spain (Hawaiian Ecosystems at Risk, 2007).

OBSERVATIONS

Waterways and Canals. — Within the last year, whorled pennywort was found to be planted in two canals in Singapore, Ulu Pandan Canal (27 Nov.2013) (Public Utilities Board,2013) and Punggol Waterway (12 Dec.2013) (Public Utilities Board, 2011), as part of a project to make canals look more natural and conducive for recreational and educational activities, as well as for phytoremediation of runoff. It was found to be spreading out from the canal below to grass lawns adjacent to the canal (Figs. 3, 4). This was repeated in several other waterways and water features in Bishan–Ang Mo Kio Park (5 Dec.2013) (Fig. 5), Lorong Halus Wetland (12 Dec.2013), MacRitchie Reservoir Park (4 Dec.2013), Punggol Park (15 Dec.2013), Sengkang Floating Wetland (12 Dec.2013) (Fig. 6), and Singapore Botanic Gardens (19 Jan.2014), where originally planted whorled pennywort was observed to have spread out of where it was intended. In Sungei Buloh Wetlands Reserve, this plant has also been planted in the freshwater pond by the outdoor classroom as well as in the pond outside the reserve's office building (Fig. 7).

In Sengkang Floating Wetland, there was a weathered sign (Fig. 6B) showing that the floating mat was made up of *Hydrocotyle asiatica* L. [= *Centella asiatica* (L.) Urban], the Asiatic pennywort, but upon inspection it was found that whorled pennywort was planted instead. It is likely that this was the case from the time when the floating mat was installed. About 20 m away from the floating mats, *Hydrocotyle verticillata* was found spontaneously growing on the sandy bank of Punggol River, below the Sengkang West flyover (Fig. 6C, D). This indicates that *Hydrocotyle verticillata* has escaped from the planted population and established spontaneously at a separate site nearby.

Fig. 2. A, Plastic versions of *Hydrocotyle verticillata* being sold in a local aquarium shop; B. Live plants of other *Hydrocotyle* species are also available. (Photographs by: Reuben Lim Chong Jin).

Fig. 3. Ulu Pandan Canal. *Hydrocotyle verticillata* growing: A, on lawn (red arrow) out of waterway where it was planted; B, in between planted heliconias and ixoras in planting bed (red arrow) by the cycling path. (Photographs by: Reuben Lim Chong Jin).

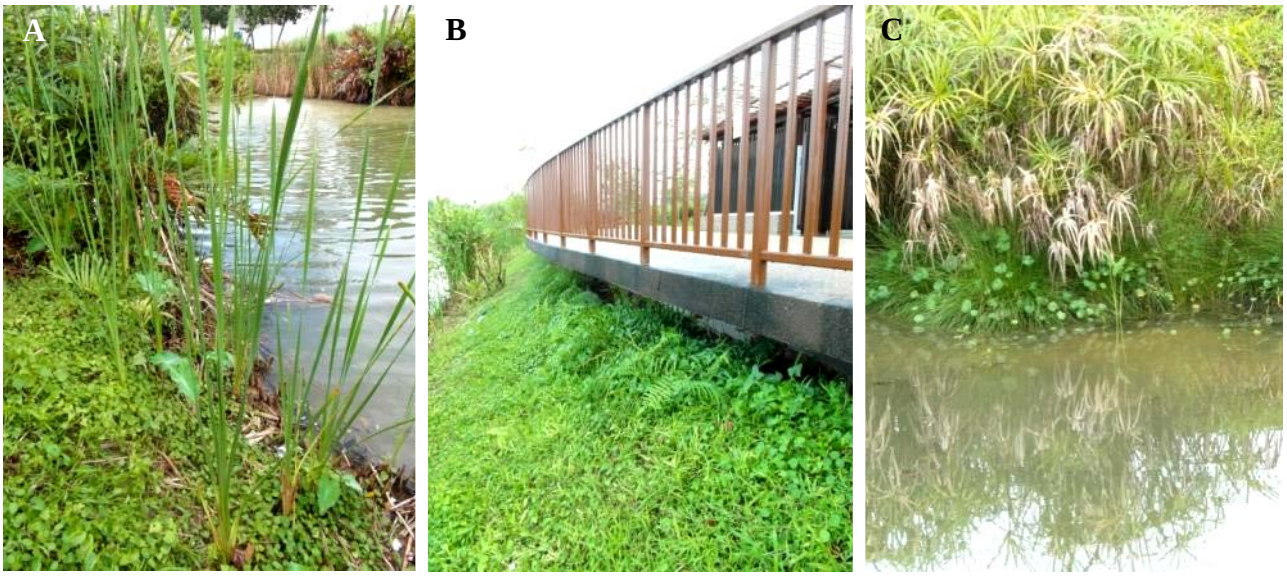

Fig. 4. Punggol Waterway. *Hydrocotyle verticillata* growing: A, densely on lawn by the river; B, up from the water up to below the concrete walkway; C, on the opposite riverbank. (Photographs by: Reuben Lim Chong Jin).

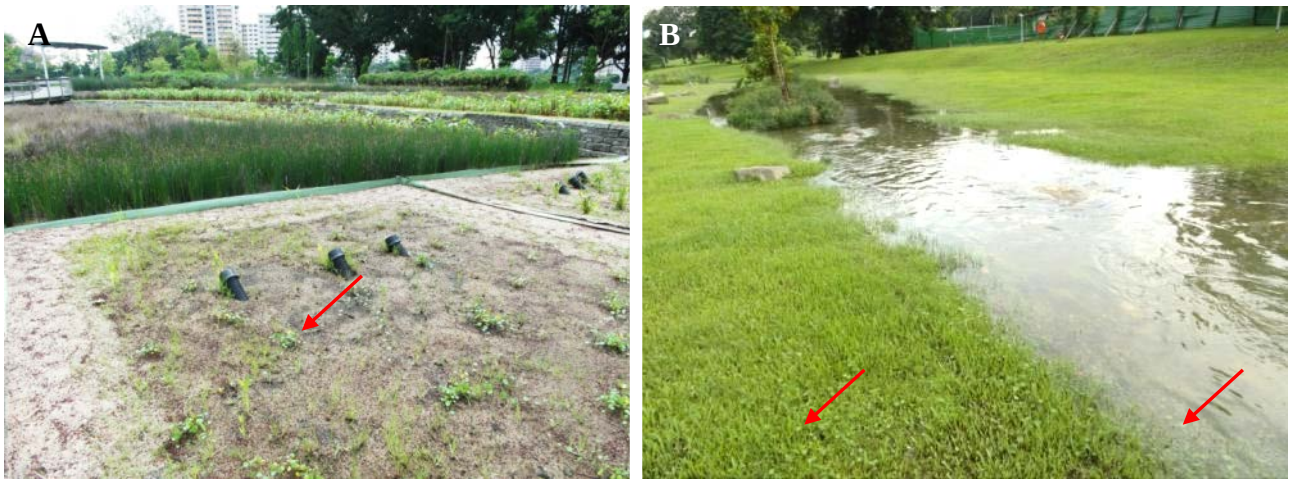

Fig. 5. Bishan–Ang Mo Kio Park. *Hydrocotyle verticillata*: A, planted (red arrow) as part of the Cleansing Biotope; B, growing in the the waters of Kallang River and on the lawn (red arrows). (Photographs by: Reuben Lim Chong Jin).

Housing Estates. — It was also found growing in the western lawn at Block 17 Ghim Moh quite abundantly (24 Nov.2013) (Fig. 8), and in roadside lawns of housing estates at West Coast Drive (20 Feb.2014) and Jalan Samarinda (20 Feb.2014).

Weed Risk Assessment. — To assess the invasiveness of whorled pennywort, a Weed Risk Assessment (WRA) was conducted (Table 1, Supplementary Material). The WRA used was adapted from the Australian-WRA (A-WRA) (Pheloung et al., 1999) with few questions modified to make the assessment more relevant to the tropics (Daehler et al., 2004). A-WRA is suitable because it was shown to be robust in different geographical regions (Gordon et al., 2008) and its scores were transferable within the tropical region (Chong et al., 2011).

DISCUSSION

Weed Risk Assessment. — In the WRA scoring system, any score greater than 6 indicates that a species should be rejected for import as it is likely to be of high risk of becoming invasive (Pheloung et al., 1999). The WRA score for the whorled pennywort that was obtained was high at 20. Aquatic plants undergoing the WRA would instantly receive a score of 5, and this might lead to the over rejection of non-invasive, aquatic plants since this score is already almost 6—the threshold score for rejection. To correct for this, Gordon & Gantz (2011) suggested increasing the threshold for rejecting aquatic plants from 6 to 19 to improve the accuracy of identifying non-invasive aquatic plants while not compromising the accuracy for detecting possible invasive aquatic species. In view of the higher suggested threshold, the whorled pennywort is still considered as high risk for invasiveness.

Other contributors to the high WRA score included the fact that it has naturalised outside its native range (score of 2), has a history of being a garden and environmental weed (score of 2 and 4, respectively), and has congeners that are weeds (score of 2). Congeneric species such as *Hydrocotyle bonariensis* and *Hydrocotyle ranunculoides* have been listed as invasive weeds outside their native range in parts of Australia (Pacific Island Ecosystems at Risk, 2013a; 2013b).

Alien aquatic plant species such as whorled pennywort have caused serious threats in the past or are suggested to cause economic and/or ecological impacts (Hussner, 2012). In general, 30% of all alien freshwater species have an ecological impact on ecosystems, while 24% have an economic impact (Vila et al., 2009). This high proportion can be attributed to the uniformity of most freshwater habitats, which allows aquatic plants to occupy very large ranges (Cook, 1985).

Misidentification. — We observed widespread use for planting in waterways and canals of Singapore. One possible reason is the inability of suppliers or landscapers to distinguish between whorled pennywort and the native *Centella asiatica* (Asiatic pennywort). *Centella asiatica* was formerly *Hydrocotyle asiatica*, until it was transferred to the genus *Centella* by Ignatz Urban in 1879 (Urban, 1879). This confusion between the two species and their names is the cause of the misidentification and subsequent planting of whorled pennywort instead of the native Asiatic pennywort (Fig. 6A, B). As the Asiatic pennywort was once of the same genus, and has a similar appearance and niche as whorled pennywort as a creeping aquatic macrophyte in shady, wet, grassy places and river margins, it is quite easy to confuse them for each other (She et al., 2005). Additionally, *Hydrocotyle* has traditionally been placed in the Apiaceae, but molecular analyses have shown that it is instead a member of Araliaceae, while *Centella* remains in Apiaceae (Plunkett et al., 2004).

A comparison table for characters that can be used to distinguish the exotic whorled pennywort from the native Asiatic pennywort and *Hydrocotyle sibthorpioides* is provided (Table 2). The main vegetative differences between the three species lie in the petiole length and leaf attachment; lamina shape, size, base and margin (Figs. 8, 9, 10). With flowers and fruits, characters such as number of flowers per inflorescence, length of peduncle and fruit size can provide better resolution. Generally, the whorled pennywort has the longest petioles and peduncles; the largest leaves, more than one vertical, and the most flowers in a verticil among the three.

Possible Introduction Methods. — The ornamental trade is a major pathway of introduction of alien aquatic plants throughout the world (Kay & Hoyle, 2001; Brunel, 2009). There is some possibility that whorled pennywort was established because of the ornamental trade, either through the aquarium or horticulture industry. Where there is no clear nearby areas intentionally planted with the whorled pennywort as in the cases of Ghim Moh Road (Fig. 8), West Coast Drive, and Jalan Samarinda, a possible method of introduction would be from the dumping of aquarium plants onto the lawn by a hobbyist, or from contaminated soil from new terrestrial ornamental plantings. Another possibility was that seeds and plant fragments could also have been dispersed by water along the waterways and drains.

Status in Singapore. — Given such a high WRA score, and a history of weediness in other countries, it was not surprising that whorled pennywort has escaped from cultivation in Singapore. Most of all populations of whorled pennywort surveyed in various localities around Singapore have been observed to be flowering and fruiting, indicating sexual reproduction capability. Moreover, it is likely that the spread of the whorled pennywort was quickened by its

Fig. 6. Sengkang Floating Wetland. A, Floating mats of *Hydrocotyle verticillata*; B, weathered plant sign, with degraded text, showing "*Hydrocotyle asiatica*", the former name of *Centella asiatica*, which is a different species; C, under Sengkang West Flyover, there is a population of *Hydrocotyle verticillata* (red arrow) growing spontaneously; D, *Hydrocotyle verticillata* (red arrow) growing inwards away from the Punggol River. (Photograph by: Alex Yee Thiam Koon).

ability to regrow from vegetative fragments. From our observations, we believe that this alien species has yet to cause significant negative ecological and economic impacts in Singapore. Therefore, although it has already been introduced into Singapore, much consideration should still be given before new stock is imported into Singapore. We also caution against planting them in large quantities along water canals and the edges of reservoirs in Singapore.

Based on the definitions of Chong et al. (2009) which were adapted from Pyšek et al. (2004), we suggest that the exotic whorled pennywort in Singapore is capable of growing spontaneously as they were observed to survive outside cultivation. We further suggest that it is starting to naturalise in Singapore as it has formed self-replicating populations, which were inferred from the numerous flowers and fruits in the Singapore populations. Thus a status of 'casual' is recommended, with a high risk of naturalisation.

Recommendations. — We recommend the planting of native alternatives such as *Centella asiatica.* There were spontaneous populations of *Centella asiatica* (Fig. 9) found in Punggol Park and Ghim Moh Road, Block 17, and numerous other sites. However, as the whorled pennywort was planted in abundance in many localities, their numbers far dwarfed the number of individuals of the Asiatic pennywort found. Thus, as this species was already found in the same localities and growing in the midst of the whorled pennywort plants, they have the same growth requirements. More horticultural research could be performed on the native species to make it more robust and develop better propagation techniques for large-scale plantings to replace the whorled pennywort. Another native species, *Hydrocotyle sibthorpioides*, was found in the Kallang River in Bishan–Ang Mo Kio Park (Fig. 10).

On a side note, we think that the spread and naturalisation of whorled pennywort in Singapore is a case study that highlights the need to strengthen the biosecurity of Singapore. A WRA program is needed at the pre-introduction stage to identify potentially invasive or high-risk plant species. These high-risk plants should then not be allowed to be imported into Singapore. If the high-risk species have properties that are highly desirable (i.e., phytoremediation), closely monitored small-scale trial plantings should be carried out to observe the possibility of invasiveness so as to minimise the risk of invasion, if introduced. Plant taxonomists or specialists should also be consulted to ensure the correct plant species is imported and planted large scale, hence minimising the risk of accidental introductions of invasive plant species into Singapore.

CONCLUSIONS

The prevalence of spontaneous, reproductive individuals of whorled pennywort in waterways, lawns, and built-up areas of Singapore indicates that it is likely to be starting to naturalise locally. Care should be taken when identifying plant species to ensure the correct species is used for landscaping. The WRA score and screening implies a very high risk of invasiveness, and caution should be practised when considering exotic plant species for import. We recommend doing a WRA for any exotic plant species being considered for import in the future or at the very least some research into whether the species has been a weed elsewhere, in the interest of Singapore's biosecurity. If the species has a history of weediness and invasiveness, it would be better to refrain from importing them. Hence, we would suggest an immediate stop to the importation and planting of whorled pennywort as it has started to naturalise in Singapore, and a focus on native aquatic species in its place for both the aquarium trade and planting in urban areas.

Fig. 7. Whorled pennywort was planted in the pond at the outdoor classroom at the Sungei Buloh Wetlands Reserve. (Photograph by: Riane Francisco).

Fig. 8. Ghim Moh Road, Block 17. Whorled pennywort growing: A, in a lawn by a drain (red arrow); B, flowering and fruiting; C, proliferating on a section of the lawn. (Photographs by: Hugh Tan Tiang Wah).

Fig. 9. *Centella asiatica* in Punggol Park. A, growing together with *Hydrocotyle verticillata;* B, closeup of *Centella asiatica* leaves (Scale bar = 1 cm). (Photographs by: Alex Yee Thiam Koon).

Fig. 10. *Hydrocotyle sibthopioides*. A, flowering and fruiting plants growing in a flower pot of a Singapore garden; B, closeup of dried specimen showing underside and upperside of the laminas (Scale bar = 1 cm). (Photographs by: Hugh Tan Tiang Wah [A] and Reuben Lim Chong Jin [B]).

Table 2. Characters that can be used to differentiate *Hydrocotyle verticillata* (whorled pennywort), *Centella asiatica* (Asiatic pennywort) and *Hydrocotyle sibthorpioides* (lawn pennywort) (Mathias, 1936; Deng, 2008).

Plant Part	Character	***Hydrocotyle sibthorpioides*** **(lawn pennywort)**	***Centella asiatica*** **(Asiatic pennywort)**	***Hydrocotyle verticillata*** **(whorled pennywort)**
Petiole	**Length (cm)**	0.5–3.0	1.5–15	1.5–35
	Hairiness	glabrous or sparsely hairy on the distal part	glabrous or sparsely hairy	glabrous
	Leaf attachment	marginal	marginal	peltate-central
Lamina	**Shape**	suborbicular or reniform	orbicular-reniform	orbicular
	Diameter (cm)	0.5–1.5	2.5–5.0	0.5–6.0
	Base	cordate	lobate	none
	Margin	shallowly 5–7 lobed	entire, crenate or lobulate	shallowly 8–14 lobed
Flower	**Number**	2–5(–10)	3–5	2–15 at each verticil
Peduncle	**Length (cm)**	0.5–2.0	0.2–0.8	8.0–22
Fruit	**Length (mm)**	0.8–1.5	3.0 × 3.0–4.0	1.0–3.0 × 2.0–4.0

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SUPPLEMENTARY MATERIAL

Table 1. Weed Risk Assessment (WRA) for *Hydrocotyle verticillata* Thumb. in Singapore. Questions and scoring system were obtained from US Forest Service, Pacific Island Ecosystems at Risk (2008), which are in turn, adapted from Pheloung et al. (1999). Species with a total score of less than 1 are of low risk; species with scores between 1−6 require further evaluation; and species with scores greater than 6 are of high risk. Link in the table is to Form A – Interpreting the questions in the WRA (Department of Agriculture, Government of Australia, 2013).

S/N	Category	Question	Scoring System	Answer	Score
1.01	Domestication/ Cultivation	Is the species highly domesticated?	y = −3, n = 0	n	0
1.02		Has the species become naturalised where grown?	y = 1, n = −1	NA	NA
1.03		Does the species have weedy races?	y = 1, n = −1	NA	NA
2.01	Climate and Distribution	Species suited to tropical or subtropical climate(s) (0 – low; 1 – intermediate; 2 – high) – If island is primarily wet habitat, then substitute "wet tropical" for "tropical or subtropical"	See link	high (Gonçalves, 1978)	NA
2.02		Quality of climate match data (0 − low; 1 − intermediate; 2 – high) see link		y	NA
2.03		Broad climate suitability (environmental versatility)	y = 1, n = 0	y (Gonçalves, 1978; USDA, 2014)	1
2.04		Native or naturalised in regions with tropical or subtropical climates	y = 1, n = 0	y (Gonçalves, 1978)	1
2.05		Does the species have a history of repeated introductions outside its natural range?	y = −2, ? = −1, n = 0	?	–1
3.01	Weed Elsewhere (depends on 2.01 and 2.02)	Naturalised beyond native range	y = 1*multiplier (see link), n = question 2.05	y (USDA, 2014; Nesom, pers. comm.)	2
3.02		Garden/amenity/disturbance weed	y = 1*multiplier (see link), n = 0	y (Scotts Lawn Service, 2013)	2
3.03		Agricultural/forestry/horticultural weed	y = 2*multiplier (see link), n = 0	No evidence	
3.04		Environmental weed	y = 2*multiplier (see link), n = 0	y (HEAR, 2007)	4
3.05		Congeneric weed	y = 1*multiplier (see link), n = 0	y (Invasive Species Scotland, 2014)	2
4.01	Undesirable traits	Produces spines, thorns or burrs	y = 1, n = 0	n	0
4.02		Allelopathic	y = 1, n = 0	No evidence	
4.03		Parasitic	y = 1, n = 0	n	0
4.04		Unpalatable to grazing animals	y = 1, n = −1	No evidence	
4.05		Toxic to animals	y = 1, n = 0	No evidence	
4.06		Host for recognised pests and pathogens	y = 1, n = 0	No evidence	
4.07		Causes allergies or is otherwise toxic to humans	y = 1, n = 0	No evidence	
4.08		Creates a fire hazard in natural ecosystems	y = 1, n = 0	n	0
4.09		Is a shade tolerant plant at some stage of its life cycle	y = 1, n = 0	No evidence	
4.10		Tolerates a wide range of soil conditions (or limestone conditions if not a volcanic island)	y = 1, n = 0	y	1
4.11		Climbing or smothering growth habit	y = 1, n = 0	n	0
4.12		Forms dense thickets	y = 1, n = 0	n	0
5.01	Plant type	Aquatic	y = 5, n = 0	y	5
5.02		Grass	y = 1, n = 0	n	0
5.03		Nitrogen fixing woody plant	y = 1, n = 0	n	0
5.04		Geophyte (herbaceous with underground storage organs – bulbs, corms, or tubers)	y = 1, n = 0	n	0
6.01	Reproduction	Evidence of substantial reproductive failure in native habitat	y = 1, n = 0	n	0

S/N	Category	Question	Scoring System	Answer	Score
6.02		Produces viable seed.	y = 1, n = −1	y	1
6.03		Hybridizes naturally	y = 1, n = −1	−1	0
6.04		Self-compatible or apomictic	y = 1, n = −1	−1	0
6.05		Requires specialist pollinators	y = –1, n = 0	n	−1
6.06		Reproduction by vegetative fragmentation	y = 1, n = −1	y	1
6.07		Minimum generative time (years) 1 year = 1, 2 or 3 years = 0, 4+ years =−1	See left	1	1
7.01	Dispersal mechanisms	Propagules likely to be dispersed unintentionally (plants growing in heavily trafficked areas)	y = 1, n = −1	y	1
7.02		Propagules dispersed intentionally by people	y = 1, n = −1	y (Weeds of Australia, 2011)	1
7.03		Propagules likely to disperse as a produce contaminant	y = 1, n = −1	No evidence	
7.04		Propagules adapted to wind dispersal	y = 1, n = −1	n	–1
7.05		Propagules water dispersed	y = 1, n = −1	y (Weeds of Australia, 2011)	1
7.06		Propagules bird dispersed	y = 1, n = −1	No evidence	
7.07		Propagules dispersed by other animals (externally)	y = 1, n = −1	No evidence	
7.08		Propagules survive passage through the gut	y = 1, n = −1	No evidence	
8.01	Persistance attributes	Prolific seed production (>1000/m2)	y = 1, n = −1	No evidence	
8.02		Evidence that a persistent propagule bank is formed (>1 yr)	y = 1, n = −1	No evidence	
8.03		Well controlled by herbicides	y = −1, n = 1	y (Department of Agriculture and Food, 2012)	–1
8.04		Tolerates, or benefits from, mutilation, cultivation, or fire	y = 1, n = −1	No evidence	
8.05		Effective natural enemies present locally (e.g. introduced biocontrol agents)	y = −1, n = 1	No evidence	
			Total Score		20