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Short Communication

Elodea najas (Planch.) Casp. and *Vallisneria natans* (Lour.) H.Hara (Hydrocharitaceae): Two Recently Naturalized Aquascape Plants in Java, Indonesia

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ABSTRACT
Aquatic ornamental plants are in high demand, driving market growth. The widespread importation of various aquascape species has led to the naturalisation of some taxa. During our field survey, we recorded two newly documented aquatic species in West and East Java from naturalized and cultivated populations: *Elodea najas* (Planch.) Casp. and *Vallisneria natans* (Lour.) H.Hara. Naturalized *E. najas* populations were found in Bogor and Sumedang, while *V. natans* proliferates along the Cilubang Tonggoh River in Bogor. The genus *Elodea* is often misidentified and sold as *Hydrilla*; thus, molecular analysis using the ITS sequence was conducted to confirm specimen identity.

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Aquatic ornamental plants have emerged as a significant element of high demand according to worldwide trends. Consequently, numerous aquatic plant species have been exchanged along various routes during the past few decades (Kadono 2006; Yakandawala et al. 2013; Nissanka et al. 2018). Several of these species are potentially invasive and have become important weeds in many different regions. Naturalisation has rendered them significant risks to emerging aquatic and semi-aquatic ecosystems (Kadono 2006; Nissanka et al. 2018). *Elodea*, a prevalent aquascaping plant, has been considered invasive in Croatia (Kočić et al. 2014), Italy (Buldrini et al. 2023), Ireland (Garland et al. 2022), Slovakia (Bubíková et al. 2021), and Southeast Europe (Lansdown et al. 2016). *Vallisneria spiralis* L., a neotropical aquatic species, has infiltrated freshwater ecosystems in Croatia (Rimac et al. 2020) and the Pannonian Basin (Anačkov et al. 2013).

The diversity of alien hydrophytes and their presence in aquatic habitats in Java are insufficiently studied. Conversely, our prior research demonstrated that newly naturalised aquascape plants remain on the island (Irsyam et al. 2022; Hariri et al. 2023). In 2022, two naturalised species of *Hydrocotyle*, *H. bonariensis* Comm. ex Lam., and *H. verticillata* Thunb., were initially reported (Irsyam et al. 2022). Additionally, we identified *Mayaca fluviatilis* Aubl., which has already evaded cultivation and established a spontaneous population in Sumedang (Hariri et al. 2023). Aquascape enthusiasts introduced these species to Java for decorative purposes, and the plants subsequently established themselves in the aquatic ecosystems. As part of the ongoing comprehensive study on the Alien Flora of Java, this research aims to document and to report the newly naturalised aquatic plant species in the region.

Field study was carried out in Jakarta, West Java (Bandung, Bogor, Sumedang), and East Java (Malang) from May 2023 to September 2024 (Figure 1). The fieldwork concentrated on both natural and artificial aquatic ecosystems, including natural rivers, artificial-canals, and reservoirs. Plant specimens were collected following the guidelines established by the Royal Botanic Garden Edinburgh (2017). The morphological observation was carried out at the Herbarium Bandungense (FIPIA), School of Life Sciences and Technology, ITB. A further herbarium examination was conducted at the Herbarium Bogoriense (BO), National Research and Innovation Agency (BRIN). The specimens were identified using taxonomic references such as Cook and Urmi-König (1985), McCullough (1997), Cook (1998), Haynes (2000), Haynes and Holm-Nielsen (2001), Mesterházy et al. (2021), and Martin and Mort (2023).

During our recent botanical exploration, we discovered two alien species belong to the genera *Elodea* Michx. and *Vallisneria* P.Micheli ex L. According to the previous study reports, these genera have a high potential to escape cultivation and become invasive in the future (Anačkov et al. 2013; Bubíková et al. 2021; Garland et al. 2022). The spontaneous populations of *E. najas* (Planch.) Casp. were discovered in Sumedang and Bogor, while *V. natans* (Lour.) H.Hara has naturalised in Bogor. Our finding increases the total count of Hydrocharitaceae in Java to 10 genera. An updated key to the family is included.

Taxonomic Treatment

Updated key to the Hydrocharitaceae in Java [modified from Backer and Bakhuizen van den Brink (1968) and den Hartog (1955)]

1. A. Fruit an achene ..... *Najas*

   B. Fruit capsule 2

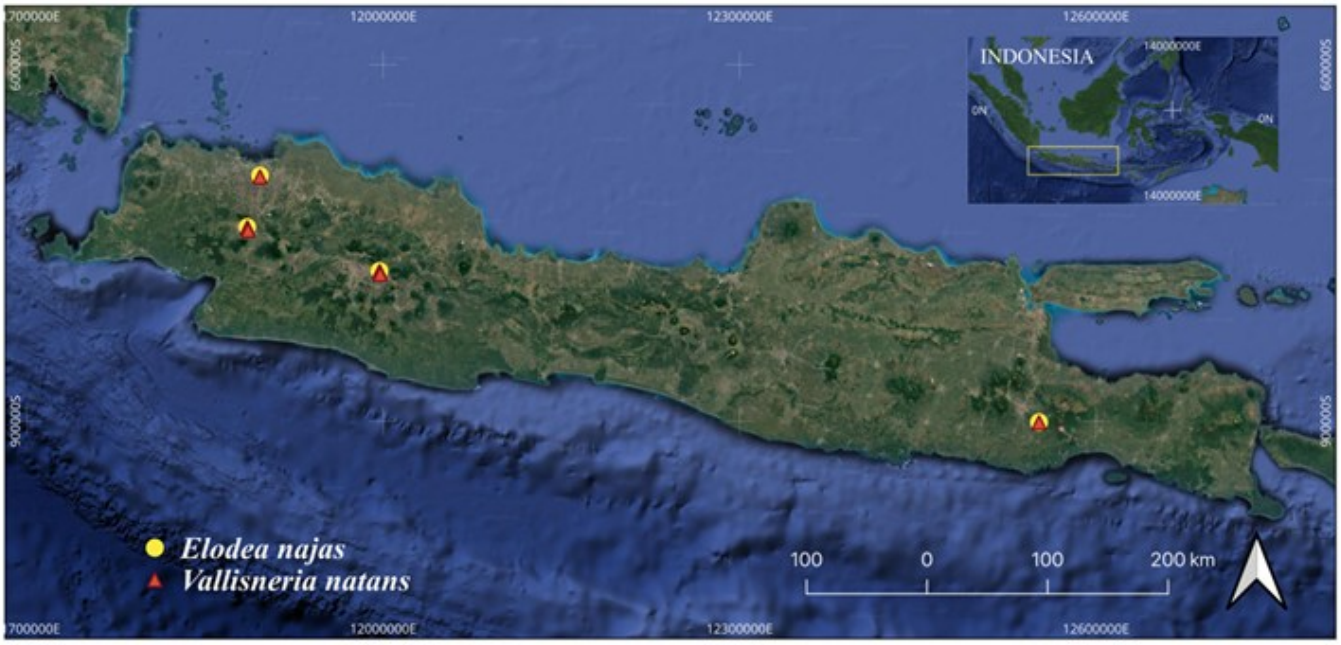

Figure 1. The occurrence of *Elodea najas* and *Vallisneria natans* during our observation (modified from the Google Satellite map).

2.	A.	Freshwater herbs	3
	B.	Marine herbs	8
3.	A.	Leaves sessile	4
	B.	Leaves petiolated	7
4.	A.	Stemless, leaves radical or in rosette, stoloniferous	5
	B.	Stems branched, leaves arranged in whorls or spiral, stolon absent	6
5.	A.	Stamens 3–9, ovary filiform, peduncle of female flower not coiling after anthesis	*Blyxa*
	B.	Stamens 1–3, ovary narrowly cylindric or triangular-cylindric, peduncle of female flower long, coiling after anthesis	*Vallisneria*
6.	A.	Prickles along midvein of the abaxial leaf surface present	*Hydrilla*
	B.	Prickles along midvein of the abaxial leaf surface absent	*Elodea*
7.	A.	Herb without stolons with submerged leaves and lack of aerenchym cushion beneath. Spathe with 6 ribs or 2–10 longitudinal wings	*Ottelia*
	B.	Stoloniferous herb with floating leaves and aerenchym cusion beneath. Spathe not ribbed or winged	*Hydrocharis*
8.	A.	Leaves longer than 5 cm long, tightly enclosed by a membranous sheath, styles deeply Bipartite	9
	B.	Leaves less than 3 cm long, sheath absent, styles entire	*Halophila*
9.	A.	Adult leaves ≥ 30 cm long, rootstock with persistent strands (fibres)	*Enhalus*
	B.	Adult leaves ≤ 30 cm long, rootstock without persistent strands	*Thalassia*

Elodea najas (Planch.) Casp., Monatsber. Königl. Preuss. Akad. Wiss. Berlin 1857: 49 (1857). – Figure 2.

Egeria najas Planch., Ann. Sci. Nat., Bot. , sér. 3, 11: 80 (1849).

Aquatic herbs, submerged, erect, without rhizomes or stolons. Stem elongated, green, glabrous; internodes ca. 1.5 mm long. Leaves simple, cauline, verticillate, 3–7 leaves per node, sessile; lamina linear, 5–13 × 1 mm, margin denticulate, apex acuminate, green. Inflorescences solitary, sessile; spathes not winged, 2–3 × 0.5–1 mm. Flowers unisexual, axillary, sessile, projected to the surface of the water by the extended floral tube base; floral tube base 2.1–2.5 cm long, white to pale green; petals 3, orbicular, 4–7 × 5–8 mm, white, thin to transparent. Pistillate flowers: ovary 1-locular; styles 3, 2–3 × 0.5 mm, bifid, white; staminodes 3, 0.4–1.3 mm long, white to pale yellow, cylindrical, papillose, papilla inconspicuous. Staminate flowers not observed.

Distribution: The species has a natural distribution in the northeastern region of Argentina, Bolivia, the southern region of Brazil, the southeastern region of Brazil, the west-central region of Brazil, Paraguay, and Uruguay (POWO 2024).

Ecology: The spontaneous populations have been found in sunny and muddy areas of the Situ II Lake (ITB Jatinangor Campus) and LSI Lake (IPB University). Situ II is situated at an elevation of 718 meters above sea level, while the LSI Lake at 174 m asl.

Specimens examined: INDONESIA, JAVA – **Jakarta** • East Jakarta, Jatinegara Subdistrict, Bali Mester; 6°12'54.0"S 106°51'56.7"E; 15 m asl, 19.VII.2023, *MR Hariri & ASD Irsyam s.n.* (FIPIA). – **West Java** • Bogor Regency, Ciomas Subdistrict, Ciherang Village, Jl. Bojong Sari, 6°35'32.1"S 106°44'49.4"E, 210 m asl, 27.V.2023, *MR Hariri 354–355* (FIPIA); Darmaga Subdistrict, IPB University, LSI Lake, 6°33'36.0"S 106°43'41.8"E, 174 m asl, 29.IX.2024, *ASD Irsyam 892* (FIPIA) • Sumedang Regency, Jatinangor Subdistrict, ITB Campus, Situ II, 6°55'56.7"S 107°46'08.5"E, 718 m asl, 25.VIII.2023, *ASD Irsyam 849* (FIPIA). – **East Java** • Malang Regency, Poncokusumo Subdistrict, Karanganyar Village, Lor Kali, 08°03'59.8"S 112°45'23.6"E, 614 m asl, 07.VI.2023, *MH Baidlowi 07* (FIPIA).

Vernacular name: *Egeria*, *Hydrilla*, *Ekor tupai* (Indonesian); *ganggeng* (Sundanese).

Note: *Elodea* is a genus of freshwater aquatic plants that are indigenous to America and consists of nine different species (Cook & Urmi-König 1985; POWO 2024). This species is distinguished by its elongated stem, which has cauline verticillate leaves or opposite leaves at the lower nodes. It also has a staminate spathe with a single flower, and the stamens can be glandular or eglandular. The pollen is found in either monads or tetrads (Cook & Urmi-König 1985; Haynes 2000; Haynes & Holm-Nielsen 2001).

In this study, we collected *E. najas* specimens from both cultivated and naturalized populations. The cultivated specimens were sourced from two distinct locations: Jakarta and Malang, where *E. najas* is primarily cultivated as an ornamental aquarium plant. The species is commonly grown and commercially sold under names such as *Egeria*, *Hydrilla*, or *ekor tupai* in local markets. However, our findings indicate that *E. najas* has successfully naturalized in Sumedang and Bogor, establishing spontaneous populations that have propagated independently in the environment without human intervention. These naturalised populations may have originated from plants discarded in Situ II Lake on the ITB Jatinangor Campus and the LSI Lake on the IPB University Darmaga Campus.

According to our observations, *E. najas* has been established through vegetative propagation, as no flowers were found. Previous studies showed that *Elodea* reproduces vegetatively through branching and fragmentation

(Matthews et al. 2012; Redekop et al. 2016). The stem is fragile and can break easily (Figure 2A), which helps plant fragments spread through water flows and establishes themselves in new areas of the campus lakes. It is important to evaluate the presence of wild populations of *E. najas* in campus lakes due to the potential for sedimentation and future spread to other areas.

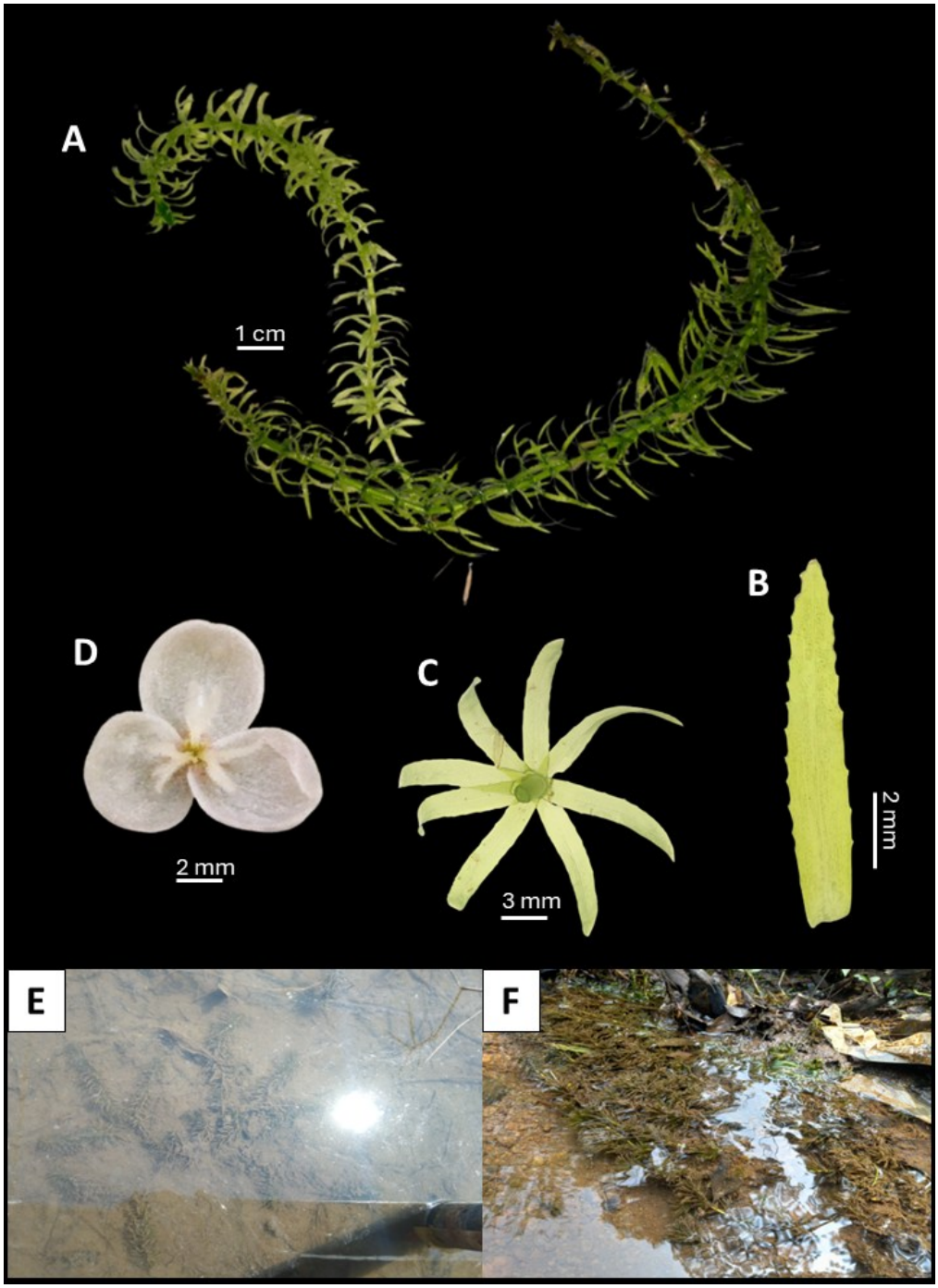

Figure 2. *Elodea najas*. A. Habit; B. Leaf; C. Whorled leaves on the node; D. Pistillate flower; E. Several individuals of the spontaneous population in Sumedang; F. Spontaneous population in Bogor.

In addition, certain species, like *E. canadensis* and *E. nuttallii*, could produce allelopathic chemicals, potentially enhancing their invasiveness (Fleming & Dibble 2015). According to a prior study, it has been observed that Mediterranean wetlands have been invaded by *E. najas* (Mayoral et al. 2018). Therefore, it is crucial for enthusiasts to be mindful of this to prevent inadvertently disposing of fragments into the sewer system while cleaning the aquarium.

Elodea najas is often erroneously identified as *Hydrilla* Rich. because of its similarities in possessing distinct branches and whorled leaves. *Elodea najas* is distinguished from the latter by the lack of tiny prickles on the midrib of the abaxial leaf surface (Figure 3).

DNA analysis was conducted in this study to verify the identity of the observed *Elodea*. The analysis was carried out in the Bogor Botanical Garden, the National Research and Innovation Agency (BRIN). The internal transcribed spacer (ITS) region of the DNA was subjected to barcoding analysis to support the species identification for *Elodea*. The contig-sequence was constructed, and the homology level was assessed using NCBI BLAST (https://blast.ncbi.nlm.nih.gov). The evolutionary history was deduced using the Maximum Likelihood approach and the Tamura-Nei model, employing 1000× bootstrap replications (Lemoine et al. 2018). All molecular analysis were performed using MEGA 11 software (Tamura et al. 2021).

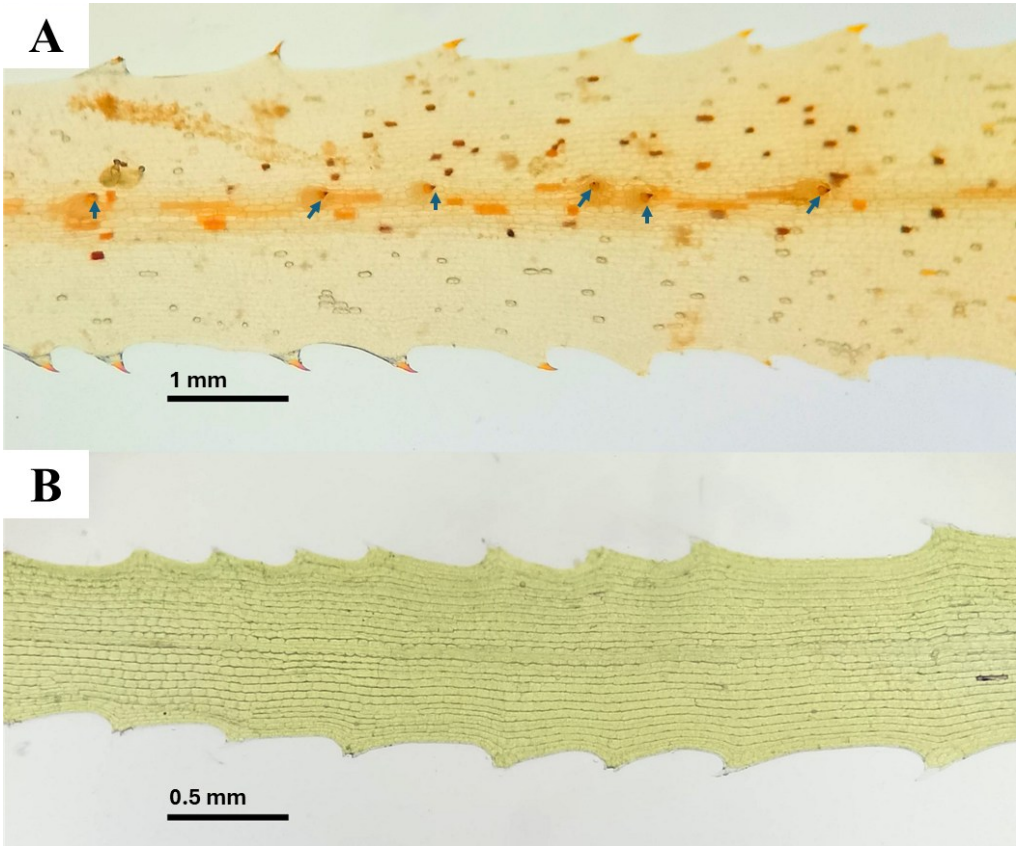

Figure 3. A. The abaxial leaf surface of *Hydrilla* (arrows= prickles); B. The abaxial leaf surface of *Elodea* lacks prickles.

In this study, the ITS sequences from one sample of *Elodea* (Bogor) were amplified successfully for 958 bp. The bulk of ITS sequences are approximately 700 base pairs in length (Susanti et al. 2015; Yang et al. 2016). The approximate length of the most frequently used ITS primers is around 600 base pairs (Hapsari et al. 2018). In this study, molecular identification was employed to evaluate the precision of species designation by conducting a comparative analysis of ITS sample sequences with those present in the NCBI databases. Seventeen sequences were employed in constructing the phylogenetic trees, consisting of five *Elodea* species obtained from the NCBI database.

The phylogenetic tree derived from the ITS region suggests that each species of *Elodea* is expected to exhibit monophyly. The analysis of the ITS sequence topology tree indicated that the *Elodea* specimen we examined has a high degree of similarity to the entries in the database corresponding to *E. najas* (Figure 4).

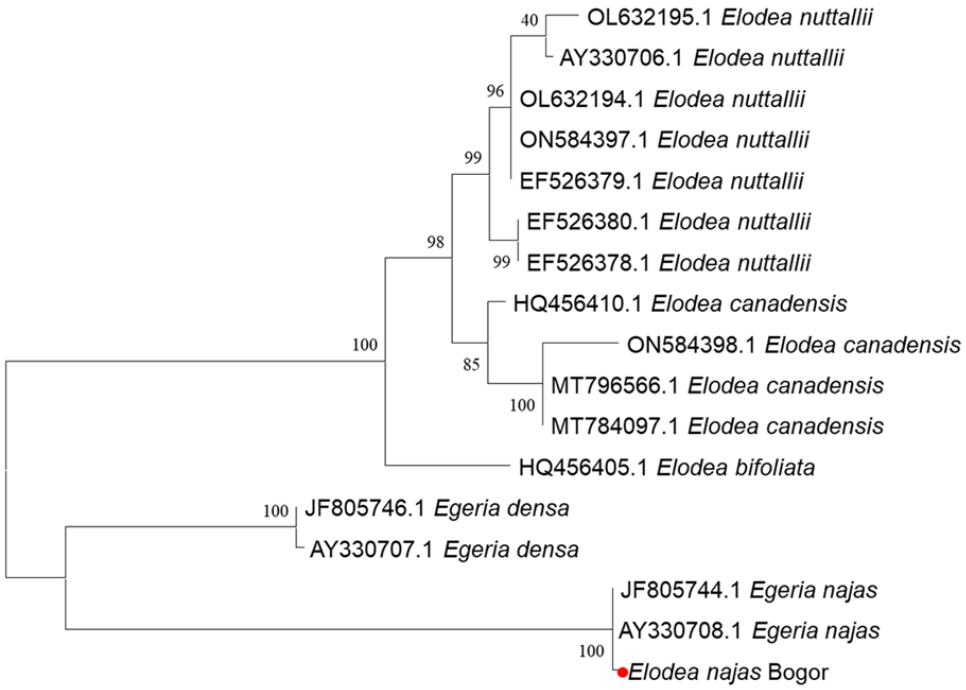

Figure 4. Phylogenetic tree of *Elodea* built using maximum likelihood method and Tamura-Nei parameter with 1000× bootstrap replications.

Vallisneria natans (Lour.) H.Hara, J. Jap. Bot. 49: 136 (1974). – Figure 5.
Physkium natans Lour., Fl. Cochinch. : 663 (1790).
Aquatic herbs, submerged, stoloniferous, dioecious. Stolon slender, up to 6.7–8.9 cm long, brownish green, rooting at nodes; internodes 3–4 cm long. Leaves basal, sessile, linear or spiral shape, 6.6–29.4 × 0.5–1 cm, margin denticulate, apex acute, veins 5, yellowish-green or green, with or without brown pigmented leaf striae. Flowers unisexual. Male spathes ovate-conical, up to 9 × 2 mm, transparent; peduncle up to 5 mm, pale green, emerge on mature and juvenile nodes; spadix oblong, up to 3 × 2 mm, pale yellow, with irregular flower arrangement; staminate flowers numerous; sepals convex; stamen 1. Female spathes not observed.
Distribution: The species is naturally found in Russia, India, Nepal, East Asia, Vietnam, and Australia (Wang et al. 2010).
Ecology: The naturalised population of *V. natans* has been discovered in Cilubang Tonggoh, West Bogor. It is commonly found in a small stream with a stony substrate, where it thrives under the exposure of sunlight at an elevation of 178 m above sea level.
Specimens examined: INDONESIA, JAVA – Jakarta • East Jakarta, Jatinegara Subdistrict, Bali Mester, 6°12'54.0"S 106°51'56.7"E, 15 m asl, 08.VII.2023, *ASD Irsyam, MR Hariri & MH Fadhil s.n.* (FIPIA). – West Java • Bogor City, West Bogor Subdistrict, Situgede, Jl. Cilubang Tonggoh, 6°33'22.4"S 106°44'44.0"E, 178 m asl, 17.VIII.2023, *MR Hariri & MH Fadhil s.n.* (FIPIA). • Sumedang Regency, Jatinangor Subdistrict, Sayang Village, 6°56'03.3"S 107°46'11.7"E, 718 m asl, 30.V.2023, *ASD Irsyam 809* (FIPIA). • Sumedang Regency, Jatinangor Subdistrict, Mekargalih, Jl. Nasional III, 6°57'22.6"S 107°46'30.7"E, 676 m asl, 22.VIII.2023, *ASD Irsyam 845* (FIPIA). – East Java • Malang Regency, Poncokusumo Subdistrict, Karanganyar Village, Lor Kali, 08°03'59.8"S 112°45'23.6"E; 614 m asl, 07.VI.2023, *MH Baidlowi 06* (FIPIA).
Vernacular name: *Rumput belut* (Indonesian).

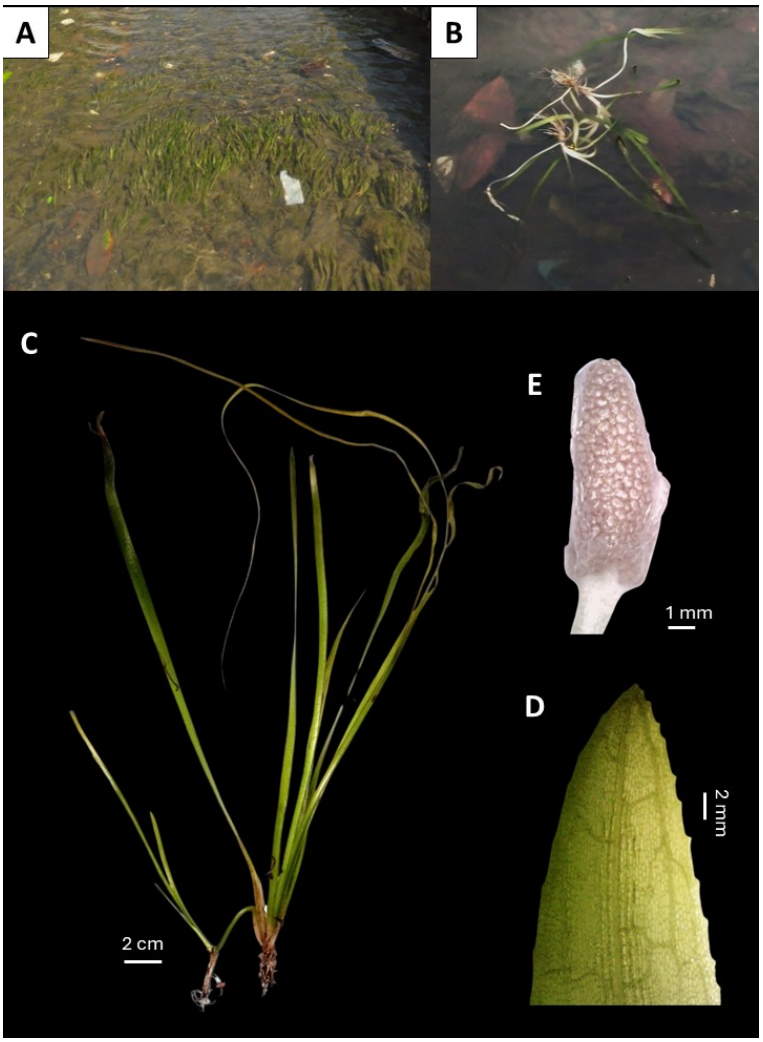

Figure 5. *Vallisneria natans*. A. The spontaneous population in the Cilubang Tonggoh river; B. Floating detached individual stolons; C. Habit; D. Leaf apex and margin; E. Male spathe.

Note: The genus *Vallisneria* in Malesia is represented by *V. nana* R.Br., which is exclusively found in the Philippines and New Guinea (den Hartog 1955; McCullough 1997). *Vallisneria* is distinguished from other freshwater plant genera by its linear radical leaves, staminate flowers that detach and float on the water's surface, and pistillate flower peduncles that coil post-fertilization (den Hartog 1955). *Vallisneria natans* is distinguished by its acute leaf apex in mature leaves (Figure 5D). Furthermore, Mesterházy et al. (2021) observed that *V. natans* differs from *V. spiralis* by possessing a maximum fruit length of 16–27 cm, a flat or linear fruit cross-section, hairs at the base of the androecium, Y-shaped filaments, and a free staminode arising at the upper edge of adjacent stigma margins.

In this study, we collected *V. natans* specimens from both cultivated and naturalized populations. Cultivated specimens were obtained from three locations—Jakarta, Sumedang, and Malang—where the species is primarily grown as an ornamental aquarium plant. It is commonly marketed under its genus name or referred to as *rumput belut* in local markets. However, our findings indicated that *V. natans* has successfully naturalised in Bogor, forming self-sustaining populations that propagate independently in the environment without human interference.

An unexpected occurrence of naturalised *V. natans* has been found in a small river at Jl. Cilubang Tonggoh, Situgede Village, West Bogor. The potential origin of the source material may involve plants cultivated in aquatic environments. A comparable occurrence has been documented in Japan,

where naturalised populations of *Vallisneria* have been identified and are believed to have originated from aquaria (Wasekura et al. 2016). Prior study showed that *Vallisneria*, for example, *V. spiralis*, only flourished in captivation through stolons since seeds never formed in aquaria (Matthews et al. 2012). The stolon fragments thrown from aquaria can be dispersed by water flow and developed into new individuals in suitable habitats.

In our study area, V. *natans* exhibited a high population density, forming a visually cohesive mat of green vegetation on the Cilubang Tonggoh river floor (Figure 5A). The species is found within a 660-meter river segment, predominantly occupying areas with stony terrain (Figure 6). The root and stolon of *V. natans* exhibited vulnerability to fracture, potentially leading to the transportation of plant fragments to different locations through water currents (Figure 5B). Its population is expected to increase and spreads widely in the future, requiring further study of its distribution and ecological effects.

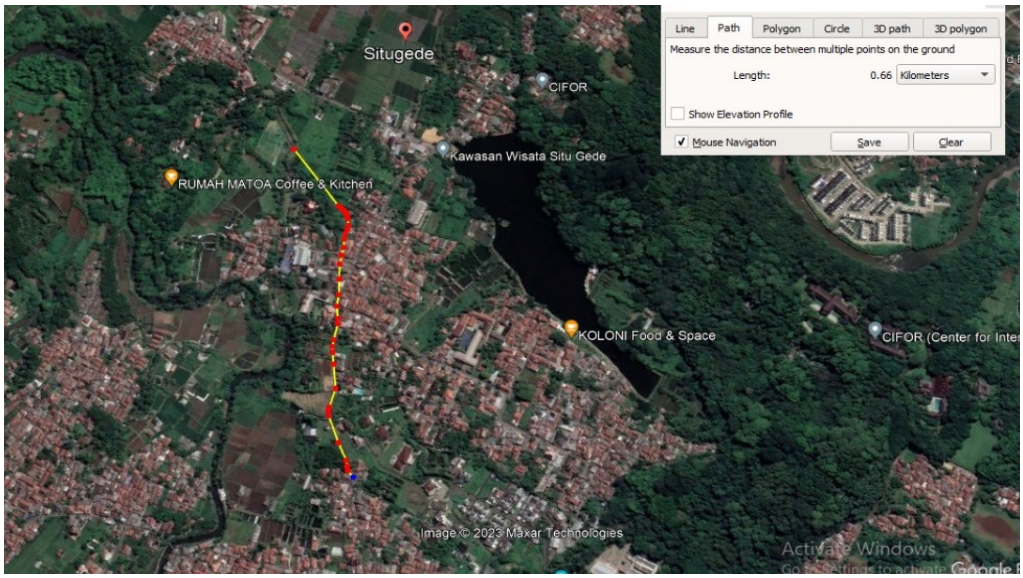

Figure 6. The area of Cilubang Tonggoh river that occupied by *V. natans* (modified from the Google Satellite map).

AUTHOR CONTRIBUTION

ASDI and MRH designed the research. ASDI, MRH, MHF, MHB, ER, and PP collected the plant materials, observed the specimens, and analysed the data. ASDI, MRH, and MHB wrote the original draft. ASDI and MRH validated the data. DR and MM reviewed the manuscript. All author agreed to the final manuscript.

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CONFLICT OF INTEREST

All authors declare no conflict of interests.

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