Taiwania 62(1): 99–104, 2017
DOI: 10.6165/tai.2017.62.99

NOTE

New Additions of the Bladderworts (Lentibulariaceae) in Taiwan

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(Manuscript received 5 May 2016; accepted 18 November 2016; online published 20 Febrauary 2017)

ABSTRACT: Wild populations of three bladderworts (*Utricularia*, Lentibulariaceae) were newly recognized in Taiwan. *Utricularia heterosepala* is newly recorded in Hualien, and two naturalized species, *U. smithiana* and *U. tricolor*, are found in northern Taiwan. Morphology, ecology and conservation status of these species are described. A renewed key for all *Utricularia* species ever recorded in Taiwan and Kinmen is also presented.

KEY WORDS: Lentibulariaceae, Naturalized species, New record, Taiwan, *Utricularia*.

INTRODUCTION

The bladderwort genus *Utricularia* L. is the largest genus of the carnivorous family Lentibulariaceae comprising ca. 235 cosmopolitan species (Fleischmann, 2015) characterized by the absence of roots and the presence of small bladder-like traps that actively capture and digest small organisms. In Taiwan, seven species (*U. aurea* Lour., *U. australis* R.Br., *U. bifida* L., *U. caerulea* L., *U. gibba* L., *U. striatula* Sm. and *U. uliginosa* Vahl) were confirmed in the latest taxonomic treatments (Chao, 2003; Li *et al.*, 2011), and two more species, *U. graminifolia* Vahl and *U. livida* E.Mey., were found naturalized in northern Taiwan (Lin, 2009; Liu *et al.*, 2011). In addition, *U. minor* L. and *U. inflata* are considered as doubtfully recorded in Taiwan (Chao, 2003), and *U. minutissima* Vahl was recently recorded in Kinmen (Lu, 2011) but has not been found in the geographic range of Taiwan.

During our recent field investigation, three uncertain bladderworts were discovered from northern and eastern Taiwan. The species found in Hualien by the second author in 2014 was at first identified as *U. uliginosa*, a very rare species in Taiwan which's wild population has not been reported since 1960s (Chao, 2003). However, after a detailed specimen and literature examination, this Hualien bladderwort is comfirmed as *U. heterosepala* Benj., a species previously recorded in the Philippines and India (Fleischmann, 2012) and hence a new record for Taiwan. The other two uncertain taxa were observed by the first author as early as in 2009, and more wild populations were then found around the border region of Taipei, New Taipei and Keelung. They are here recognized as *U. smithiana* Wight and *U. tricolor* A.St.-Hil. after consulting the monograph of *Utricularia* (Taylor, 1989). Since both species have been traded in horticulture markets in Taiwan, and all their wild populations occur in easily accessible area around the Taipei metropolis, they are presumed as naturalized species.

Herein, morphological description, color plates and brief notes on ecology and taxonomy of *U. heterosepala*, *U. smithiana* and *U. tricolor* are presented. Their conservation status based on IUCN Red List categories (IUCN, 2012) are evaluated as well. A revised key of all *Utricularia* species ever recorded in Taiwan is provided to contribute to their identification. Altogether nine native species, four naturalized species, two doubted species are so far recorded in Taiwan and Kinmen. Including *U. heterosepala*, six among the nine native *Utricularia* species in Taiwan are of conservation concerns (Wang *et al.*, 2012), and protection measures are thus urgently needed. On the other hand, for those naturalized species, careful monitoring of their population expansion is also necessary considering the cases that alien bladderworts could reproduce rapidly and pose a threat to local aquatic vegetation (Urban *et al.*, 2006; GISD, 2006).

Key to the *Utricularia* species recorded in Taiwan

1a. Leaves divided into narrowly linear or capillary segments……...2
1b. Leaves simple, entire ……..……..……...6
2a. Leaves palmately or dichotomously divided into 2–11 ultimate segments, with few or no traps …...…….3
2b. Leaves pinnately divided into numerous ultimate segments, with many traps ……..……4
3a. Turions never developed; ultimate segments capillary; scale 0–1; seeds lenticular, obviously winged ….…..……..***U. gibba***
3b. Turions developed in winter; ultimate segments flattened; scale 2–4; seeds prismatic, scarcely winged ….…...…….……***U. minor***
4a. Leaves unequally bifid; floats many, floating ……...***U. inflata***

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4b. Leaves subequally bifid; floats absent or if present then few (1–4) and ±submersed ……..…..……..……..5
5a. Turions never developed; segments not displaying on the same plane, margin entire; scale absent; persistent style often equaling or exceeding capsule ……..……..…….. ***U. aurea***
5b. Turions developed in winter; all segments displaying on the same plane, margin toothed; scale present; persistent style much less than 1/2 as long as capsule ……..……..……..***U. australis***
6a. Corolla yellow; leaves linear to linear-oblanceolate……***U. bifida***
6b. Corolla white, violate, purple or blue, sometimes tinged with yellow at throat; leaves various ……..…..……..7
7a. Leaves broadly obovate to subreniform, 0.8–1.5 cm wide; petiole 1–4 cm long ……..……***U. tricolor***
7b. Leaves various, up to 6 mm wide; petioles inconspicuous or shorter than 3 mm …..……..8
8a. Pedicel 0.5–2.0 mm long; spur appressed to lower corolla lip ...9
8b. Pedicel 1–20 mm long; spur widely divergent from lower corolla lip ……..……..……..11
9a. Leaves 1–5 mm wide, with branched veins; corolla 7–15 mm long; spur about as long as lower corolla lip ……..……***U. livida***
9b. Leaves 0.4–1.6 mm wide, with simple veins; corolla 3–7 mm long; spur much longer than lower corolla lip ……..……..…10
10a. Leaves 0.8–1.6 mm wide; peduncle 0.3–1.3 mm thick; bracts and bracteoles basisolute (Taiwan and Kinmen)……..***U. caerulea***
10b. Leaves 0.4–0.8 mm wide; peduncle 0.2–0.4 mm thick; bracts and bracteoles basifixed (Kinmen) ……..……***U. minutissima***
11a. Leaves rosulate at the peduncle base, suborbicular; upper calyx lobe obtuse at apex; bracts and bracteoles basisolute ....***U. striatula***
11b. Leaves not rosulate, linear, oblanceolate or obovate; upper calyx lobe acute at apex; bracts and bracteoles basifixed ……....……12
12a. Pedicel much longer than calyx; corolla 7–20 mm long ……...13
12b. Pedicel shorter than or as long as calyx; corolla 3–11 mm long …..……..……14
13a. Inflorescence erect, never twining; corolla 7–15 mm long; seeds ovoid to ellipsoid, with elongate reticulations ……***U. graminifolia***
13b. Inflorescence sometimes twining; corolla 15–20 mm long; seeds globose, with isodiametric reticulations ……..……***U. smithiana***
14a. Leaves oblanceolate to obovate; bracteoles absent; calyx lobes narrowly ovate, the upper one smaller than the lower one; anticlinal walls of seed testa cells finely sinunate ……...***U. heterosepala***
14b. Leaves linear to oblanceolate; bracteoles present; calyx lobes ovate to ovate-orbicular, the upper one slightly larger than the lower one; anticlinal walls of seed testa cells straight .....***U. uliginosa***

TAXONOMIC TREATMENTS

Utricularia heterosepala Benj., Linnaea 20: 310. 1847; Taylor, Kew Bull. Add. Ser. 14: 397–399, f. 116. 1989. **Type:** PHILIPPINES, Manila, *Cuming 1117* [lectotype: K photo!, designated by Taylor (1989); isolectotypes: B (destroyed), BM photo!, C, F, G, MEL, P, W photo!].

異萼挖耳草 Figs. 1–2.

Perrenials or *annuals*, terrestrial, subaquatic. *Rhizoids* capillary, up to 2 cm long. *Stolons* very numerous, capillary, 0.2–0.3 mm thick, frequently branched. *Leaves* very numerous, solitary at each stolon node, 5–15 × 1.5–2.5 mm, petiolate; lamina obovate or oblanceolate, apex rounded, 3-veined. *Traps* on leaves and stolons, globose, stalked, 0.7–2.0 mm long; appendages 2, dorsal, subulate, stalked glandular. *Inflorescence* erect, solitary, 2–8 cm long, 0.3–0.5 mm thick, glabrous. *Scales* 1–3, similar to the bracts. *Bracts* basifixed, narrowly ovate-deltoid, apex acute, 2–3 mm long. *Bracteoles* always absent. *Flowers* 2–8, laxly arranged; pedicels erect, 3–6 mm long. *Calyx lobes* unequal, narrowly ovate, the upper lobe 2.5–4.0 mm long, apex acute; the lower lobe constantly larger, up to 6 mm long in fruit, apex acute or minutely bidentate. *Corolla* 6–11 mm long, pale blue or violat, upper lip slightly constricted below middle; the superior part oblong, apex rounded or truncate; the inferior part broadly ovate; lower lip limb suborbicular, galeate, apex rounded or emarginate, base with a prominent swelling; palate with a ciliate marginal rim; spur subulate, apex acute, curved, longer than and widely diverging from the lower lip. *Filaments* ca. 1 mm long, straight; anther thecae distinct. *Ovary* ovoid; style short but distinct. *Capsule* ovoid, 2–3 mm long. *Seeds* globose or depressed globose, ca. 0.4 mm in diam., with isodiametric reticulations; anticlinal walls of seed testa cells finely sinunate.

Distribution: *Utricularia heterosepala* is recorded in India (the Western Ghats), the Philippines (Luzon, Sibuyan and Palawan) and Taiwan (Hualien).

Ecology: *Utricularia heterosepala* is found in sunny coastal wetlands around sea level. Accompanied plants include *U. bifida*, *Eriocaulon truncatum* Buch.-Ham. ex Mart., *Dimeria ornithopoda* Trin., *Eleocharis geniculata* (L.) Roem. & Schult., *Drosera burmannii* Vahl, *Hypericum japonicum* Thunb., *Centaurium japonicum* (Maxim.) Druce, *Fimbristylis cymosa* var. *spathacea* (Roth) T.Koyama, *F. macassarensis* Steud., *F. schoenoides* (Retz.) Vahl. and *Schoenoplectus tabernaemontani* (C.C.Gmel.) Palla. Flowering and fruiting are observed from March to June.

Conservation status: VU [D2]. So far only 2 subpopulations of *U. heterosepala* are located in Taiwan. Although numerous mature individuals exist in each subpopulation, and no immediate threat is so far observed, a careful monitoring of its population dynamics is still needed since the area of occupancy is very small (< 1 km^2) and easily disturbed by human activity and affected by climate change.

Voucher specimens: **TAIWAN**: Hualien County, Fengbin Township, Fengping (豐濱), *T.-C.Hsu 7797, 7801* (TAIF).

***Note*:** As listed in the key, *Utricularia heterosepala* is similar to *U. uliginosa* in gross outlines but significantly different in leaf shape, absence of bracteole, calyx structure and seed morphology. The finely sinuate anticlinal walls of seed testa cells, noted by Taylor (1989) as a unique character in the genus, are also clearly observed from Taiwanese specimens (Fig. 2). *U. heterosepala* was thought as endemic to the Philippines (Taylor, 1989), but recently Fleischmann (2012) treated *U. janarthanamii* S.R.Yadav, Sardesai & S.P.Gaikwad, described from the Western Ghats of India (Yadav *et al.*, 2000), as a synonym of *U. heterosepala* and thus extends its distribution range. Cleistogamous flowers are reported from the Indian population (Yadav *et al.*, 2000; Sardesai and Yadav, 2008) but not observed in Taiwan so far.

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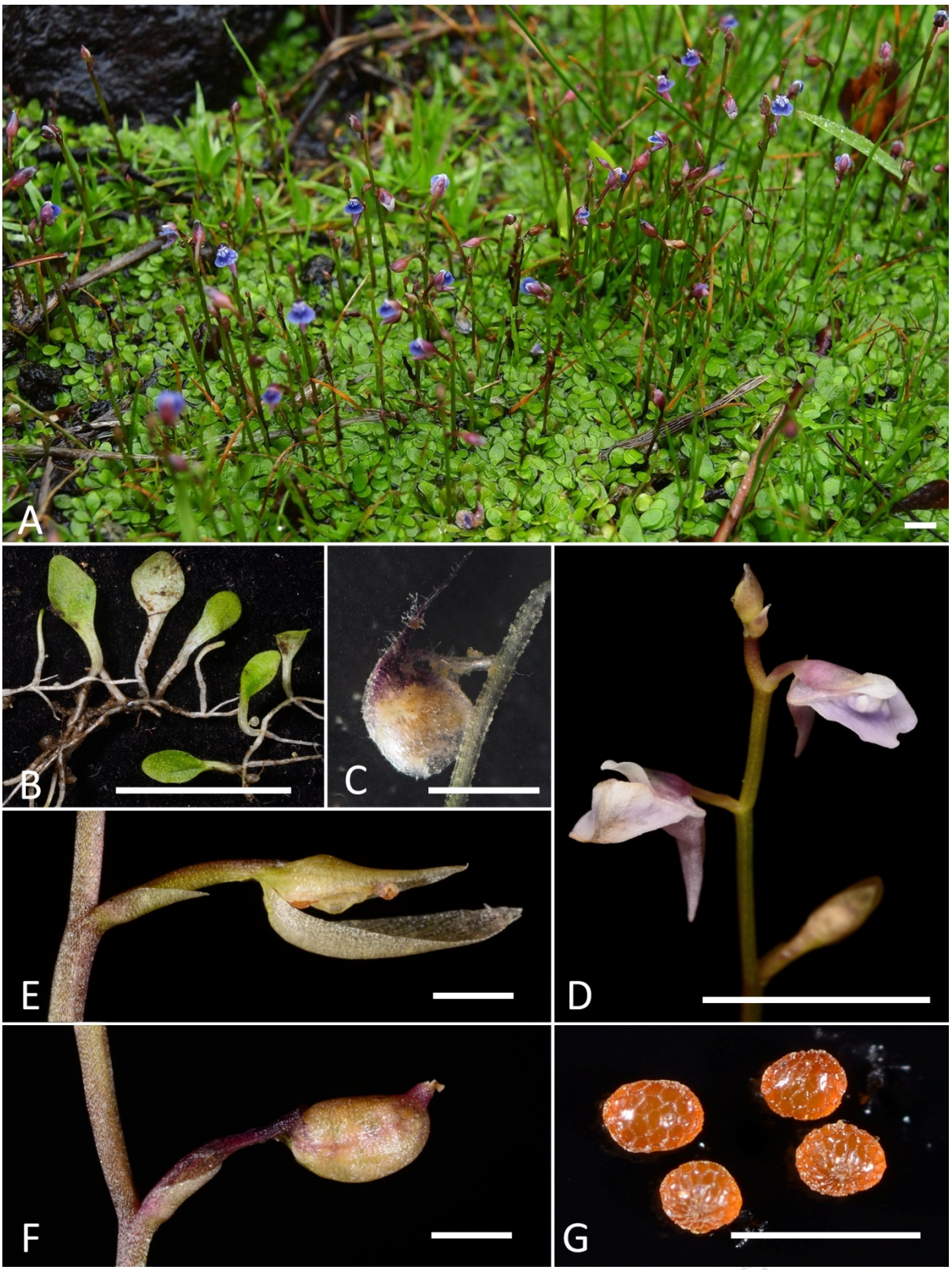


Fig. 1. ***Utricularia heterosepala*** Benj. (from *T.-C.Hsu 7797*). **A**: Habitat and habits. **B**: Stolons, leaves, rhizoids and traps. **C**: Trap. **D**: Inflorescence and flowers. **E**: Immature capsule with persistent calyx. Note the obviously smaller upper calyx lobe and the absence of bracteole on pedicel. **F**: Capsule with calyx removed. **G**: Seeds. Note the isodiametric reticulations. Scale bars: **A**–**B** & **D** = 1 cm; **C** & **E**–**G** = 1 mm. Photographed by Z.-H.Chen (**A** & **C**) and T.-C.Hsu (**B** & **D**–**G**).

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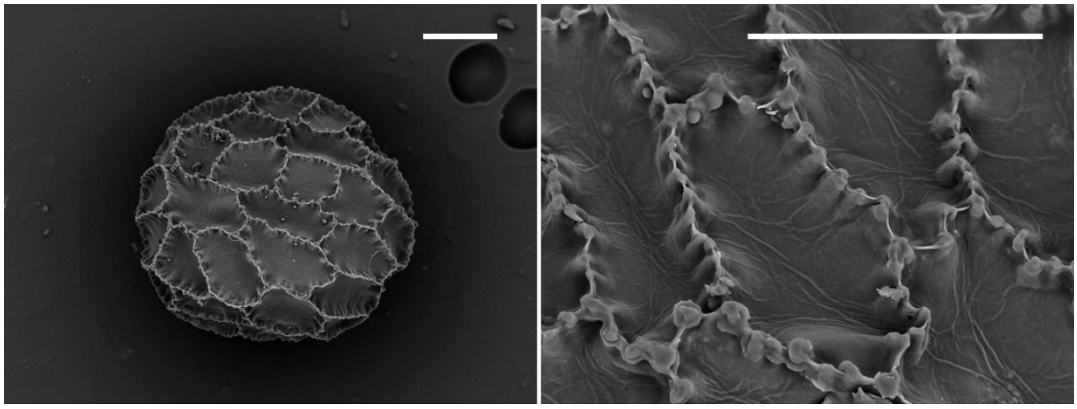


Fig. 2. SEM micrographs of the seeds of ***Utricularia heterosepala*** (from *T.-C.Hsu 7797*). Note the finely sinunate anticlinal testa walls. Scale bars = 100 μm. Photographed by Y.-S.Chao.

Utricularia smithiana Wight, Hooker's J. Bot. Kew Gard. Misc. 1: 373. 1849; Taylor, Kew Bull. Add. Ser. 14: 338–340, f. 93. 1989.. **Type:** INDIA. "Malabar or Coorg.", *Herb. Wight s.n.* (holotype: K)

史氏挖耳草 Fig. 3(A–D)

Perrenials, terrestrial or occasionally lithophytic, subaquatic. *Rhizoids* numerous, capillary, up to 3 cm long. *Stolons* very numerous, capillary, 0.2–0.4 mm thick, frequently branched. *Leaves* very numerous, solitary at each stolon node, 1.5–5 cm × 1–3 mm, petiolate; lamina linear, apex rounded, 3-veined. *Traps* on leaves and stolons, globose, stalked, 0.5–1.0 mm long; appendages 2, dorsal, subulate, stalked glandular. *Inflorescence* erect or ascending, sometimes twining distally, solitary, simple, 10–20 cm long, 0.5–1.5 mm thick, glabrous. *Scales* few, similar to the bracts. *Bracts* basifixed, ovate, apex acute, ca. 2 mm long. *Bracteoles* basifixed, subulate, ca. 2 mm long. *Flowers* 1–6, laxly arranged; pedicels ascending, 5–15 mm long. *Calyx lobes* slightly unequal, ovate, 4–5 mm long, the upper lobe acute at apex; the lower lobe usually slightly smaller, obtuse or minutely bidentate at apex. *Corolla* 1.5–2 cm long, mauve, violat or bluish, upper lip slightly constricted near the base; the superior part obovate-oblong, apex retuse; the inferior part quadrate; lower lip limb suborbicular, galeate, apex rounded, base with a prominent swelling; palate with a ciliate marginal rim; spur subulate, apex acute, curved, about as long as and widely diverging from the lower lip. *Filaments* ca. 2 mm long, straight; anther thecae distinct. *Ovary* ovoid; style short. *Capsule* and *seeds* not seen.

Distribution: *Utricularia smithiana* is native in India and naturalized in Taiwan (New Taipei).

Ecology: *Utricularia smithiana* grows on semi-open wet grassy slope and roadside concrete cliffs with dripping water at the elevation of 300–600 m. Accompanied plants include *U. bifida*, *U. livida*, *Eriocaulon truncatum*, *E. sexangulare* L., *Drosera spatulata* Labill., *Dimeria ornithopoda*, *Eleocharis tetraquetra* Nees, *Eragrostis atrovirens* (Desf.) Trin. ex Steud. and *Ischaemum barbatum* Retz. Flowering is observed from April to July; no fruit set is observed.

Conservation status: NA. *Utricularia smithiana* is not native in Taiwan.

Voucher specimens: **TAIWAN**: New Taipei City: XiZhi District, Mt. Wuchih (五指山), *T.-C.Hsu 2230* (TAIF); XiZhi District, Chepingliao (車坪寮), *T.-C.Hsu 7080* (TAIF).

Note: The identification of above collections is somewhat difficult because capsules and seeds, which are very important in diagnosing *Utricularia* species (Taylor, 1989), are not observed in Taiwan so far. Even so, *U. smithiana* is adopted here since it is the only known species with a combination of long linear leaves with three longitudinal veins, sometimes twining inflorescences, and 1.5–2 mm long, mauve or violate corolla with spurs widely divergent from the lower lobes (Taylor, 1989; Fleischmann, 2012; 2015). This species is indeed displayed in flower and aquarium markets in Taiwan and also cultivated by some enthusiasts, although the plants are mostly labeled as *U. reticulata*, *U. graminifolia* or "*Utricularia* sp." (Hsu, personal observation). Such confusion is possibly due to the lack of fruits and seeds in ornamental races and the great floral similarity among these species. However, even when lacking fruits and seeds, *U. reticulata* could still be distinguished from *U. smithiana* by its constantly 1-veined leaves and more aggressively twining inflorescences (Taylor, 1989), while *U. graminifolia* is also distinguished by its constantly erect inflorescence and slightly smaller flowers (Taylor, 1989; Li *et al.*, 2011; Liu *et al.*, 2011).

Utricularia tricolor A.St.-Hil., Voy. Distr. Diam. 2: 418. 1833; Taylor, Kew Bull. Add. Ser. 14: 294–298, f. 79. 1989. **Type:** BRAZIL. Rio de Janeiro, S. Joao de Barra, *St.Hilaire s.n.* (holotype: P photo!; isotype: MPU).

三色挖耳草 Fig. 3(E–H).

Perrenials, terrestrial, subaquatic. *Rhizoids* few, capillary. *Stolons* few, capillary, 0.4–0.6 mm thick,

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Fig. 3. Naturalized bladderworts in Taiwan. **A**–**D**: ***Utricularia smithiana*** Wight (from *T.-C.Hsu 2230*). **A**: Habitat and habits. Note the slightly twining inforescences. **B**: Leaves. **C**: Flower, front view. **D**: Flower, side view. **E**–**H**: ***U. tricolor*** A.St.-Hil. (from *T.-C.Hsu 4719*). **E**: Habitat and habits. **F**: Leaves. **G**: Flower, oblique front view. **H**: Flower, side view. Scale bars: **A**–**H** = 1 cm. Photographed by T.-C.Hsu.

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sparsely branched. *Leaves* 1–3 rosulate at the base of peduncle, distinctly petiolate; petioles 1–4 cm long; lamina broadly obovate, suborbicular or subreniform, apex rounded, 0.8–1.3 × 0.8–1.5 cm, with numerous anastomosing veins. *Traps* on rhizoids and stolons, broadly ovoid, stalked, 1.5–2 mm long; appendages 2, dorsal, narrow-deltoid, acute, inner sides densely glandular hairy. *Inflorescence* erect or ascending, sometimes twining distally, solitary, 10–30 cm long, 0.3–1.5 mm thick, glabrous. *Scales* few, basifixed, ovate-deltoid apex acute, ca. 2 mm long. *Bracts* basifixed, deltoid to ovate-deltoid, apex acute, ca. 1.5 mm long. *Bracteoles* much narrower than bracts but as long. *Flowers* 1–4, laxly arranged; pedicels ascending, 0.5–1.5 cm long. *Calyx* lobes unequal, convex, the upper lobe broadly ovate to suborbicular, 5–6 mm long, apex rounded; the lower lobe much shorter, transversely elliptic, apex emarginate. *Corolla* 1–2 cm long, violet to lilac, marked with white and yellow at the base of the lower lip, minutely papillose and wit sessile and stipitate glands; upper lip broadly ovate; lower lip limb transversely elliptic, base with a prominent bilobed swelling; apex rounded, entire or shallowly 3-crenate; palate papillose; spur narrowly conical, apex acute, slightly curved, about as long as or slightly longer than the lower lip. *Filaments* ca. 2 mm long, curved; anther thecae distinct. *Ovary* globose, glandular; style distinct. *Capsule* and *seeds* not seen.

***Distribution*:** *Utricularia tricolor* is native in S America, including Argentina, Brazil, Bolivia, Colombia, Paraguay, Uruguay and Venezuela (Taylor, 1989), and it is naturalized in Taiwan (Keelung and New Taipei).

***Ecology*:** *Utricularia tricolor* grows on wet roadside grassy slopes and on concrete ditch walls with dripping water. Accompanied plants include *U. bifida*, *Drosera spatulata*, *Eriocaulon truncatum*, *E. sexangulare*, *Dimeria ornithopoda*, *Juncus prismatocarpus* R. Br., *Ischaemum barbatum* and *Emilia praetermissa* Milne-Redh. Flowering is observed in September; no fruit set is observed.

***Conservation status*:** NA. *Utricularia tricolor* is not native in Taiwan.

***Voucher specimens*:** **TAIWAN**: Keelung City, Qidu District, Chifenliao (七分寮), *T.-C.Hsu 4719*, *8130* (TAIF). New Taipei City: Xizhi District, Mt. Wuchih (五指山), *T.-C.Hsu 8129* (TAIF).

***Notes*:** *Utricularia tricolor* is easily distinguished from other species in Taiwan by its relatively very large, broadly obovate to subreniform leaves with 1–4 cm long petioles. The flowers are also large and quite attractive although rarely seen in field. This species is relatively easier cultivated and has long been traded in horticultural markets in Taiwan (Hsu, personal observation).

ACKNOWLEDGEMENTS

The authors thank Dr. Shih-Wen Chung for his kind assistant in field work and literature consulting.

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