# Postprint: New Plant Records from the Alpine Periglacial Zone in Northwestern Yunnan

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## Abstract

The alpine ice-edge zone represents the highest-altitude vegetation belt on land, characterized by harsh natural conditions and difficult accessibility. The flora of the alpine ice-edge zone in northwestern Yunnan exhibits rich species diversity and high endemism. This study conducted a plant diversity survey in the alpine ice-edge zone of northwestern Yunnan, investigating morphological characteristics through specimen collection and consultation of references including floras and type specimens. One genus new to Yunnan was discovered, namely *Thylacospermum* Fenzl, along with five new record species: *Thylacospermum caespitosum* (Camb.) Schischk, *Silene rubricalyx* (Marq.) Bocquet, *Solms-laubachia angustifolia* J. P. Yue, Al-Shehbaz & H. Sun, *Oxygraphis endlicheri* (Walp.) Bennet & S. Chandra, and *Leontopodium haastioides* (Hand.-Mazz.) Hand.-Mazz. These discoveries not only enrich the flora data of the alpine ice-edge zone in northwestern Yunnan, but also indicate that plant diversity surveys in alpine ice-edge zones remain inadequate. For the alpine ice-edge zone of the Qinghai-Tibet Plateau, particularly in regions where plant diversity surveys are weak or lacking, detailed and in-depth survey work urgently needs to be implemented and improved.

## Full Text

## New Records from the Alpine Subnival Belt of Northwest Yunnan

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## Abstract

The alpine subnival belt represents the highest terrestrial vegetation zone, characterized by harsh natural conditions and extreme inaccessibility. The alpine subnival flora of Northwest Yunnan harbors abundant species diversity and exceptionally high endemism. This study investigated plant diversity in this region through specimen collection and morphological analysis based on floristic references and type specimens. We report one genus new to Yunnan—*Thylacospermum* Fenzl—and five species new to the province: *Thylacospermum caespitosum* (Camb.) Schischk, *Silene rubricalyx* (Marq.) Bocquet, *Solms-laubachia angustifolia* J. P. Yue, Al-Shehbaz & H. Sun, *Oxygraphis endlicheri* (Walp.) Bennet & S. Chandra, and *Leontopodium haastioides* (Hand.-Mazz.) Hand.-Mazz. These discoveries enrich the floristic documentation of the alpine subnival belt in Northwest Yunnan and reveal that plant diversity surveys in this zone remain incomplete. Comprehensive and intensive investigations are urgently needed for the alpine subnival belt of the Qinghai-Tibet Plateau, particularly in regions where biodiversity surveys have been weak or absent.

**Keywords:** Northwest Yunnan, alpine subnival belt, plant diversity investigation, flora, new record

## Introduction

Yunnan Province has conducted relatively comprehensive biodiversity inventories at the national scale, producing works such as *A Catalogue of Seed Plants of Yunnan* and *Flora of Yunnan* that have clarified the patterns of plant diversity, distribution, and floristic characteristics. However, research by Chen et al. (2013) on the diversity and distribution of higher plants in Yunnan demonstrates that intensive surveys remain essential, especially in historically underinvestigated regions. In the high-altitude zones of the Hengduan Mountains in Northwest Yunnan, the combination of high elevation, complex topography, harsh climate, and oxygen deficiency makes detailed plant diversity surveys exceptionally challenging, resulting in scarce herbarium specimens. More than half of plant species from this region are represented by only 1–2 specimens, with average collection numbers decreasing progressively with altitude (Zhang & Sun, 2008). The alpine subnival belt, situated at the apex of the montane vertical vegetation spectrum, presents even more severe conditions, limited accessibility, and greater logistical difficulties, rendering plant diversity surveys particularly weak and constraining our understanding of its botanical diversity.

Building upon references including *Vascular Plants of the Hengduan Mountains*, *Flora of Tibet*, *Flora of Yunnan*, *Flora of Qinghai*, and *Flora of China*, and examining major herbarium collections from the Hengduan region, Xu et al. compiled *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains* through extensive field investigations. This work confirmed that the subnival flora possesses rich seed plant diversity, exceptionally high endemism, and diverse specialized adaptive structures and resource types (Xu et al., 2014). Notably, the alpine

subnival belt does not form a continuous vegetation zone; rather, isolated peaks within mountain systems create distinctive "sky islands" where climate, vegetation, and species composition differ markedly from surrounding lower-elevation areas (Heald, 1951; He & Jiang, 2014). These heterogeneous low-elevation habitats simultaneously impede species migration and dispersal, fostering a pattern of narrow endemism whereby many subnival species are restricted to specific individual peaks, exemplified by genera such as *Solms-laubachia* (Brassicaceae) and *Corydalis* (Papaveraceae) (Xu et al., 2014). The prevalence of narrowly endemic species necessitates broad-scale, intensive biodiversity surveys.

Although previous subnival plant diversity surveys covered most areas of the Hengduan Mountains, deficiencies persist due to variations in survey timing, slope aspect coverage, and taxonomic expertise among investigators. Some mountain ranges remain inadequately surveyed, with numerous remote areas still inaccessible, leaving significant gaps and even complete blanks in our knowledge. In recent years, many new taxa have been described from the Hengduan Mountains subnival belt, including *Bupleurum baimaense* from Baima Snow Mountain along National Highway 214 in Deqin County, Yunnan (Ma et al., 2013), *Meconopsis uniflora* from the same locality (Yoshida et al., 2019), *Solms-laubachia tianbaoshanensis* from Tianbao Snow Mountain in Shangri-La City, Yunnan (Chen et al., 2018), *Saussurea sunhangii* from Daxue Mountain in Geza Township, Shangri-La (Raab-Straube, 2017), and *Saussurea balangshanensis* from Balang Mountain Pass along National Highway 318 in Xiaojin County, Sichuan (Zhang et al., 2019). It is important to emphasize that the subnival belt growing season is brief (June–October), creating a narrow window for fieldwork. Flowering periods are asynchronous—some taxa bloom in June (e.g., Brassicaceae), while others flower as late as September (e.g., Gentianaceae, Apiaceae). Furthermore, species composition varies dramatically among different slope aspects of the same mountain at the same time. These unique characteristics of the subnival environment substantially increase the difficulty of fieldwork and biodiversity inventory. The authors maintain that thorough and intensive investigations of under-surveyed and blank areas in the alpine subnival belt will undoubtedly yield new discoveries, a conviction that has sustained our continuous research on Qinghai-Tibet Plateau subnival plant diversity since 2006.

## 1. Study Area Overview

The alpine subnival belt represents the transition between the upper alpine ecosystem and the permanent snow zone (Nagy & Grabherr, 2009) and comprises the total assemblage of plant species inhabiting the highest vegetation band adjacent to the snow line within the alpine vertical spectrum (Li et al., 1981; Xu et al., 2014). Due to the relatively low latitude of the Hengduan Mountains, many peaks lack permanent snow cover. However, near summits, intense freeze-thaw weathering breaks surface rocks into gravel of various sizes, with minimal soil development in crevices, creating a sparsely vegetated habitat also classified as subnival [Figure 1: see original paper]A. As the highest-elevation

vegetation zone on land, the subnival environment represents an extreme limit for terrestrial plant diversity distribution, characterized by thin air, low mean annual temperatures, large diurnal temperature ranges, strong winds, intense solar radiation, and dramatic short-term climate fluctuations that may include high winds, intense sun, rain, snow, or hail within hours. These harsh conditions restrict most species, allowing only a few with specialized biological traits to colonize the habitat. The subnival flora represents an evolutionary adaptation to extreme environments, dominated by cold-xerophytic or cold-mesoxerophytic perennial tap-rooted herbs and cushion plants adapted to snow and severe cold. Key features include extremely sparse vegetation, low cover, small populations, simple community structure, short growing seasons, patchy discontinuous distribution, pioneer community characteristics, and small-cluster distribution patterns (Li et al., 1981; Liu et al., 1984; Wu et al., 1987).

Northwest Yunnan, located in the southern Hengduan Mountains, harbors some of the world' s richest biodiversity resources and is recognized as the most species-rich region within the Indo-Burma biodiversity hotspot (Myers et al., 2000; Boufford et al., 2004). It is also exceptionally rich in alpine subnival plant diversity. Our survey sites include: (1) Daxue Mountain Pass (facing Sichuan, left side) subnival belt, located in Geza Township, Shangri-La City, Diqing Tibetan Autonomous Prefecture, approximately 84 km north of the city center and 2 km left of Provincial Highway 217, at 4,295–4,879 m elevation; (2) Balagezong Pass subnival belt in Nixi Township, Shangri-La City, approximately 70 km northwest of the city center at 4,314–4,687 m; and (3) Zhugu Snow Mountain subnival belt in Mingyin Town, Yulong Naxi Autonomous County, Lijiang City, approximately 62 km north of the city center at 4,125–4,312 m. None of these locations have climate monitoring stations. All three sites are remote with poor accessibility, have received weak botanical survey attention, and feature sparse vegetation characteristic of alpine gravel meadows and scree slopes —typical subnival vegetation.

## 2. Research Methods

During field surveys, we prioritized remote and under-investigated subnival areas, emphasizing repeat visits. Plant diversity surveys at each site followed the principle of multiple visits during the same season across different slope aspects, as well as across different seasons and slope aspects, covering both flowering and fruiting periods. We collected specimens from healthy individuals bearing flowers or fruits, along with seeds and molecular materials for future cytological and molecular biological studies. Specimens were pressed using newspaper, corrugated paper, and warm-air drying for rapid processing. Initial species identification referenced *Flora of Yunnan*, *Vascular Plants of the Hengduan Mountains*, *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains*, *Flora of China*, *Flora of Tibet*, and online databases (e.g., https://plants.jstor.org) to examine type specimens and conduct comparative morphological studies for final determination.

### 3.1.1 New Record Genus–*Thylacospermum* Fenzl [Figure 1: see original paper]B

**Thylacospermum caespitosum** (Camb.) Schischk. in Sched. ad Herb. Fl. Ross 9: 90. 1932; *Flora of Tibet* 1: 704. Pl. 224: 7–12. 1983; *Vascular Plants of the Hengduan Mountains* (Vol. 1): 414. 1991; *Flora of China* 26: 251. 1996; *Flora of China* 6: 40–41. 2001; *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains* 240. 2014.

**Morphological characteristics:** Perennial cushion-forming herb, often spherical, reaching 30 cm or more in diameter, glabrous throughout. Stems strongly branched at base, woody. Leaves densely arranged, imbricate; blades ovate-lanceolate, 2–4 mm long, ca. 2 mm wide, apex mucronate, rigid, glossy. Flowers solitary at stem apex, subsessile; sepals lanceolate, ca. 2.5 mm long, ca. 1 mm wide, apex obtuse or acuminate, with three green veins; petals 5 or 4, ovate-oblong, apex slightly rounded, base slightly narrowed, entire; disc circular, fleshy, yellow; stamens 10, shorter than sepals; styles 3 or 2, filiform, often exserted beyond calyx. Capsule globose, 2.5–3 mm in diameter, yellow, glossy, 6- or 4-toothed; seeds reniform, ca. 1.5 mm in diameter, with spongy testa (Lu & Gilbert, 2001).

**Distribution:** Xinjiang, Qinghai, Gansu, Sichuan (south to Muli, Daocheng), and Tibet (east to Leiwuqi, Basu) in China. Grows on scree slopes, rock crevices, and cushion vegetation at (3,600–)4,300–6,000 m. Also occurs in Kazakhstan, Kyrgyzstan, northwestern India, Nepal, and Sikkim, India. Type specimen from northwestern India (Lu & Gilbert, 2001).

**New record for Yunnan, China.**

**Voucher specimens:** 16 September 2011, Xu Bo et al. SunH-07ZX-3530 (KUN); 6 July 2012, Xu Bo, Luo Dong XU Bo-517 (KUN); 4 October 2017, Xu Bo, Ye Fazhi, Lü Shenglin, Zhou Aiting, Li Dong Tsui-1024 (KUN); left side of Daxue Mountain Pass, Geza Township, Shangri-La City, Yunnan, at 4,365 m on alpine scree; coordinates 99°48 23.93" E, 28°34 17.46" N. Associated species include *Allium forrestii*, *Anaphalis* sp., *Corydalis calcicola*, *Cremanthodium smithianum*, *Saussurea sunhangii* (Raab-Straube, 2017), *Saussurea spathulifolia*, *Solms-laubachia xerophyta*, etc.

### 3.1.2 New Record Species in *Silene* L. [Figure 1: see original paper]C

**Silene rubricalyx** (Marq.) Bocquet, Candollea 22: 15. 1967; *Vascular Plants of the Hengduan Mountains* (Vol. 1): 422. 1991; *Flora of China* 26: 322–323. 1996; *Flora of China* 6: 92–93. 2001.—*Melandrium rubricalyx* (Marq.) Pax & Hoffm., *Flora of Tibet* 1: 724. 1983.

**Morphological characteristics:** Perennial herb, 5–15 (–20) cm tall. Roots robust, woody, often with stolons. Stems laxly cespitose, erect, unbranched, densely purple glandular-pubescent. Basal leaves spatulate or narrowly oblanceolate, 2.5–5 cm long, 7–13 mm wide, apex acute or subacute, midvein conspic-

uous abaxially, pubescent; cauline leaves 1–2 pairs, smaller, elliptic, 1–2 cm long. Flowers 1–3, slightly nodding, becoming erect after anthesis; pedicels 2.5–3 cm, glandular-pubescent; bracts lanceolate, glandular-pubescent; calyx campanulate or tubular-campanulate, membranous, sac-like, 13–17 mm long, 8–10 mm wide, mouth open, inflated in fruit, densely glandular-pubescent, longitudinal veins brown or purple-black; calyx teeth broadly triangular, ca. 4 mm long, finely pubescent, margin ciliate; androgynophore ca. 3 mm long, lanate; petals exserted ca. 7 mm beyond calyx, claw exserted 2–3 mm, cuneate, 13–14 mm long, 5–6 mm wide, upper portion with triangular-ovate auricles, pale red; limb spreading, broadly ovate in outline, ca. 5 mm long, purple or deep purple, 4-lobed; stamens slightly exserted from corolla throat, filaments basally pubescent. Capsule globose or ellipsoid, shorter than persistent calyx, 5-toothed; seeds subglobose, slightly compressed, ca. 1.5 mm long, brown, shiny, raphe with inconspicuous tubercles (Zhou et al., 2001).

**Distribution:** Eastern Tibet (Zayü, Medog) and southwestern Sichuan in China. Grows in dwarf willow thickets on alpine meadows, limestone rubble, and granite steep rock crevices at 3,400–3,600 (–4,300) m (Zhou et al., 2001).

**New record for Yunnan, China.**

**Voucher specimens:** 16 September 2011, Xu Bo et al. SunH-07ZX-3543 (KUN); 14 October 2015, Xu Bo, Chen Guangfu, Zhang Yukun, Wang Hongbin Tsui-311 (KUN); left side of Daxue Mountain Pass, Geza Township, Shangri-La City, Yunnan, on scree at 4,335 m; coordinates 99°48 23.12” E, 28°34 12.83” N. Associated species include *Allium forrestii*, *Anaphalis rhododactyla*, *Corydalis calcicola*, *Pedicularis verbenaefolia*, *Rhododendron* sp., *Salix* sp., *Saussurea spathulifolia*, etc.

### 3.2 New Record Species in Brassicaceae [Figure 1: see original paper]D

**Solms-laubachia angustifolia** J. P. Yue, Al-Shehbaz & H. Sun in Ann. Missouri Bot. Gard. 95(3): 532. 2008; *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains* 210–211. 2014.

**Morphological characteristics:** Perennial, cespitose herb, 2–6 cm tall; stem base with persistent petioles. Leaves in basal rosettes; blades linear, 2.0–7.7 cm long, 0.3–1.3 mm wide, eciliate, adaxially grooved, sparsely pilose, margin entire; petioles 0.4–1.5 cm, thickened, eciliate; cauline leaves absent. Flowers blue-purple, fragrant, broadly elliptic to broadly obovate. Fruiting pedicels solitary from basal leaf rosettes, 1–1.7 cm long. Ovary with 14–22 ovules. Fruits linear to narrowly elliptic, 1.6–4.8 cm long, 4–8 mm wide, smooth, with inconspicuous reticulate veins; septum complete; style 1–1.6 mm long; stigma entire to slightly 2-lobed; seeds in two rows, broadly ovate to suborbicular (Yue et al., 2008).

**Distribution:** Southwestern Sichuan (Muli, Daocheng) in China. Grows on gravel meadows, scree slopes, and cliffs at 3,800–5,200 m (Yue et al., 2008; Xu

et al., 2014).

**New record for Yunnan, China.**

**Voucher specimen:** 8 June 2017, Xu Bo, Peng Jiansheng et al. Tsui-834 (KUN); Balagezong Pass, Nixi Township, Shangri-La City, Yunnan, on gravel meadow and scree at 4,314 m; coordinates 99°26 49.33" E, 28°23 56.38" N. Associated species include *Aletris pauciflora* var. *khasiana*, *Anaphalis* sp., *Chesneya polystichoides*, *Euphorbia stracheyi*, *Pedicularis elwesii*, *Salix* sp., *Viola* sp., etc.

### 3.3 New Record Species in Ranunculaceae [Figure 1: see original paper]E

**Oxygraphis endlicheri** (Walp.) Bennet & S. Chandra, Indian Forester 108: 374. 1982; *Flora of China* 6: 434. 2001.—*Oxygraphis polypetala* J. D. Hooker & Thomson. Fl. Ind. 27. 1855; *Flora of China* 28: 331–334. 1980; *Flora of Tibet* 2: 109–111. 1985.

**Morphological characteristics:** Plants 4–8 cm tall, cespitose. Fibrous roots long. Basal leaves 2–5, glabrous; blades subpapery, orbicular, reniform, or ovate, 5–20 mm long, 7–22 mm wide, base subcordate or truncate, margin with 5–13 shallow rounded teeth, apex obtuse or rounded; petioles 3–5 cm long, with membranous broad sheaths at base. Scapes 1–4, longer than 1.5 cm, extending to 6 cm in fruit, glabrous; bract 1 or absent, linear or obovate-cuneate, entire or 3-lobed. Flowers solitary, 1.2–2 cm in diameter; sepals 5, glabrous, subcoriaceous or thick-papery, ovate or elliptic, 3–8 mm long, enlarged and persistent after anthesis; petals yellow or white adaxially, 10–15, oblong-spatulate, 6–10 mm long, 1.2–4 mm wide, apex acute, base attenuate into claws, nectar pit cup-shaped; anthers elliptic, ca. 0.5–0.8 mm long; receptacle glabrous. Aggregate fruit ovoid, 8–10 mm in diameter, with numerous dense, glabrous achenes; achenes rhomboid-cuneate, ca. 2 mm long, ca. 1 mm wide, with four longitudinal ribs, apex with straight beak ca. 0.5 mm long (Wang et al., 2001).

**Distribution:** Southern Tibet (Yadong) in China. Grows on alpine meadows or forest margins at 3,600–5,000 m. Also occurs in Bhutan, northern India, Nepal, Kashmir, and northern Pakistan (Wang et al., 2001).

**New record for Yunnan, China.**

**Voucher specimens:** 6 July 2012, Xu Bo, Luo Dong XU Bo-526 (KUN); 4 October 2017, Xu Bo, Ye Fazhi, Lü Shenglin, Zhou Aiting, Li Dong Tsui-1022 (KUN); 19 June 2019, Xu Bo, Wang Junwei, Liu Yun Tsui-1289 (KUN); Daxue Mountain Pass, Geza Township, Shangri-La City, Yunnan, on gravel meadow and scree at 4,355 m; coordinates 99°48 26.10" E, 28°34 16.32" N. Associated species include *Amitostigma tibeticum*, *Anemone* sp., *Cardamine franchetiana*, *Cyananthus formosus*, *Pedicularis delavayi*, *Phlomis rotata*, *Saussurea spathulifolia*, *Solms-laubachia xerophyta*, etc.

### 3.4 New Record Species in Asteraceae [Figure 1: see original paper]F

**Leontopodium haastioides** (Hand.-Mazz.) Hand.-Mazz. in Beih. Bot. Centralbl. 44(2): 84. pl. II, 7. 1928; *Flora of Tibet* 4: 676. 1985; *Vascular Plants of the Hengduan Mountains* (Vol. 2): 2013. 1994; *Flora of China* 75: 115. 1979; *Flora of China* 20–21: 778–781. 2011; *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains* 343. 2014.

**Morphological characteristics:** Perennial herb forming dense cushions up to 10 cm in diameter. Rhizomes slender, much-branched. Numerous leaf rosettes 1.5–3 cm tall, leaves densely imbricate, with persistent old leaves at base, overall short-cylindrical. Leaves spatulate or elliptic, 2–6 × 1–2 mm, base appressed, thin, dry-membranous, abaxially sparsely arachnoid-pilose, upper portion spreading, thickened, herbaceous, densely gray-tomentose, apex rounded. Capitula solitary, dioecious, or mostly female, 3–4 mm in diameter; involucre absent, capitulum hidden among apical leaves of rosettes, without peduncle. Phyllaries lanceolate to oblanceolate, 4–6 × 0.6–2 mm, apex acute or obtuse; corolla 3–4 mm long. Achenes ca. 1.2 mm long, papillate or smooth; sterile ovary glabrous or sparsely pilose. Pappus white, ca. 4 mm long (Chen & Bayer, 2011).

**Distribution:** Tibet (Dinggyê, Nagarzê, Yadong, Comai, etc.) and Sichuan (Muli) in China. Grows on alpine gravel meadows, scree slopes, barren ground near snow lines, and glacial alluvium at 4,300–5,300 m. Also occurs in Bhutan, India (Sikkim), and Nepal (Chen & Bayer, 2011).

**New record for Yunnan, China.**

**Voucher specimens:** 1 October 2017, Xu Bo, Ye Fazhi, Lü Shenglin, Zhou Aiting, Li Dong Tsui-1005 (KUN); 2 July 2019, Xu Bo, Wang Junwei, Liu Yun Tsui-1399 (KUN); Zhugu Snow Mountain, Mingyin Town, Yulong County, Lijiang City, Yunnan, on scree at 4,229 m; coordinates 100°17 55.50” E, 27°24 52.06” N. Associated species include *Androsace alchemilloides*, *Arenaria smithiana*, *Arenaria weissiana*, *Meconopsis venusta*, *Paraquilegia microphylla*, *Solms-laubachia* sp., etc.

## Discussion

Taxonomy depends on taxonomists, field exploration, specimen collection, and systematic research (Wilson, 2004). This study confirms that five subnival species—*Thylacospermum caespitosum*, *Silene rubricalyx*, *Solms-laubachia angustifolia*, *Oxygraphis endlicheri*, and *Leontopodium haastioides*—represent new records for Yunnan Province, with *S. rubricalyx* and *O. endlicheri* also constituting new records for the Hengduan Mountains subnival flora. Based on literature and herbarium records combined with these new distributions, *Thylacospermum* exhibits a Central Asian–Hengduan Mountains distribution pattern, *S. rubricalyx* an East Himalayan–southern Hengduan pattern, *S. angustifolia* is endemic to the southern Hengduan Mountains, *O. endlicheri* shows a central/western Hi-

malayan–Hengduan disjunct pattern, and *L. haastioides* a central Himalayan–Hengduan disjunct pattern. These new records from three remote subnival areas in Northwest Yunnan expand the known distribution ranges of these species and underscore the inadequacy of current subnival plant diversity surveys, necessitating continued research.

*Thylacospermum caespitosum* is among the highest-elevation seed plants (Lu & Gilbert, 2001; Xu et al., 2014) and represents a quintessential alpine cushion plant with exceptional drought and cold tolerance (de Bello et al., 2011). Research demonstrates that cushion plants not only adapt well to alpine environments but also provide "nurse effects" for other non-cushion plants through their specialized morphological structures (Yang et al., 2010). Some species can only survive or reproduce in subnival habitats by establishing on or near cushion plants, making these keystone species crucial for maintaining alpine plant diversity (Cavieres et al., 2014). *Thylacospermum caespitosum* exhibits two phenotypes: flat, loose cushions and dome-shaped, compact cushions, with the former providing stronger nurse effects for surrounding alpine plants (Dvorský et al., 2013; Michalet et al., 2016). Floristically, *Thylacospermum* represents a Central Asian distribution type, and its presence in the southern Hengduan Mountains indicates that Central Asian floristic elements remain significant in the subnival flora (Wu et al., 2006). A parallel example is *Biebersteinia odora*, initially recorded only from western Tibet (Ali) to Central Asia but later discovered in Zuogong County of the Hengduan region (Xu et al., 2014).

The Yunnan record of *Silene rubricalyx* was collected at 4,335 m—700 m higher than documented in floras—and can extend into the subnival belt. It was not included in *Seed Plants of the Alpine Subnival Belt from the Hengduan Mountains*, making it also a new subnival record. Additionally, *Oxygraphis endlicheri* had no herbarium records from the Hengduan Mountains, and our new specimens from the subnival belt were similarly omitted from the aforementioned work, constituting both a Yunnan and a Hengduan subnival record.

*Solms-laubachia angustifolia*, described as a new species in 2008 (Yue et al., 2008), flowers early, but the original description lacked flowering specimens. Our June subnival survey first collected specimens in flower, confirming blue-purple corollas and completing the morphological description. Morphologically, *S. angustifolia* resembles *S. xerophyta* in its narrow, grooved leaves and thickened petioles, but differs in having longer leaves, glabrous petioles and blades, and narrowly elliptic to linear fruits (versus shorter leaves [0.7–2 cm], ciliate petioles, pubescent blades, and lanceolate to linear-lanceolate fruits in *S. xerophyta*). At the time of description, *S. angustifolia* was known from only eight specimens including the type. Given its narrow distribution and preliminary conservation assessment, it was designated Critically Endangered (CR) (Yue et al., 2008). This discovery expands its range and provides new material for studying the systematics of *Solms-laubachia*. Notably, *S. rubricalyx*, *S. angustifolia*, and *O. endlicheri* all exhibit showy flowers with excellent ornamental potential as floricultural resources.

*Leontopodium haastioides* has a relatively wide distribution, likely attributable to its cushion growth form and dense woolly indumentum—important ecological adaptations for subnival extremes (Xu et al., 2014). Its central/western Himalayan–Hengduan disjunct distribution pattern is shared by numerous subnival species, including *Aletris nana*, *Allium phariense*, *Arenaria szechuensis*, *Aster prainii*, *Lagotis pharica*, and *Salix flabellaris* (Xu et al., 2014). These species extend eastward to the Hengduan subnival belt and westward to the Xigazê region or even the western Himalaya, yet are largely unrecorded from Chamdo, Nyingchi, and Shannan in Tibet due to weak baseline surveys and collection gaps. For example, aside from surveys led by Wu Zhengyi in the 1970s and the joint Kunming Institute of Botany–Harvard University Hengduan biodiversity expedition in the early 2000s, Chamdo has lacked systematic subnival investigations.

While the inventory of subnival seed plant diversity in the Hengduan Mountains is largely complete, the continuous discovery of new species and records reveals persistent survey gaps. Subnival investigations require strengthening, particularly in the adjacent Qinghai-Tibet Plateau, with emphasis on repeated, multi-seasonal, multi-aspect surveys at fixed locations. Biodiversity inventory forms the foundation for conservation planning and represents a core component of biodiversity protection (Smith & Figueiredo, 2010). Detailed biodiversity data help identify priority areas and taxa for conservation, and effective acquisition of distribution data is key to sustainable utilization and management decisions (Sousa-Baena et al., 2014). Therefore, intensifying species diversity surveys in weak and blank areas of the Qinghai-Tibet Plateau subnival belt is critically important for biodiversity conservation. Since biodiversity is unevenly distributed and conservation resources are limited, systematic and scientific approaches to identifying priority taxa and regions are urgent and essential (Ma, 2001). Many nations and international organizations have developed species endangerment evaluation systems to determine conservation priorities and establish criteria for protected areas (Olson & Dinerstein, 1998; Myers et al., 2000; Jiang & Luo, 2012).

Species threat assessment is considered an essential tool for implementing biodiversity priority protection (Mace & Lande, 1991) and is particularly important for developing conservation management policies. Following completion of the Qinghai-Tibet Plateau subnival seed plant inventory, priority species could be identified based on endangerment status (distribution range and threat level), endemism (subnival or Chinese endemics), specialized adaptive structures (glasshouse plants, woolly plants, cushion plants), medicinal resources, ornamental value, special cold-resistant germplasm, and community service functions. Priority regions could be determined based on numbers of endemic species, species diversity, community representativeness, and counts of rare/endangered or "plant species with extremely small populations" (PSESP). Furthermore, future subnival surveys should establish permanent plots at selected sites as long-term monitoring stations to obtain dynamic data and develop regional or plateau-wide monitoring networks for subnival plant diversity.

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*Note: Figure translations are in progress. See original paper for figures.*