Postprint: Endangered Status and Priority Conservation Ranking of Gesneriaceae in Guangxi

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Abstract

Based on literature review and field investigations, the endangerment status and priority protection ranking of Gesneriaceae species currently known to be distributed in Guangxi were determined using their 'endangerment coefficient' and 'priority protection value'. The results indicate that among the 236 Gesneriaceae species in Guangxi, there are

Full Text

Preamble

Study on Endangered Degree and Priority Conservation Sequence for Gesneriaceae Plants in Guangxi

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Abstract: Based on data collection and field investigation, 236 species belonging to 24 genera of Gesneriaceae known to be extant in Guangxi (as of the end of 2018) were selected as research objects. Through quantification of evaluation indicators and weight allocation, the "coefficient of endangerment" and "value of priority conservation" were calculated for each species, thereby determining their endangered levels and conservation priority rankings. The results showed that among the 236 Gesneriaceae species in Guangxi, 58 were critically endangered (CR), 70 were endangered (EN), 72 were vulnerable (VU), 31 were near threatened (NT), and 5 were of least concern (LC). The priority conservation values ranged from 0.952 to 0.429, with 107 species classified as Grade I protection plants, 75 as Grade II, 28 as Grade III, and 26 as Grade IV. While these results differ somewhat from national and provincial plant protection categories and from endangered levels synthesized from literature and the IUCN Red List

for certain species, they are generally consistent with the current protection status and destruction patterns observed for Gesneriaceae plants in Guangxi. The threat level to most Gesneriaceae plants in Guangxi is intensifying and warrants serious attention.

Keywords: Guangxi, Gesneriaceae, evaluation, endangered degree, priority conservation

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Introduction

Biodiversity conservation has received increasing attention from the international community, with governments and scientists implementing various protective measures through multiple channels. However, from the perspective of conservation efficiency, protection actions should have clear targets or priority objects (regions or taxa) (Ma, 2001). Therefore, assessing the endangered status and protection levels of species is a prerequisite for effective species conservation in a country or region and represents a focal issue in current conservation biology research (Cao et al., 2012). In recent years, scholars have conducted extensive quantitative research on priority conservation evaluation of rare and endangered plants (Rana & Samant, 2010; Shi et al., 2011; Safont et al., 2012; Wang et al., 2013; Chen & Zhang, 2015; Peng et al., 2017). These studies typically focus on plants within specific nature reserves, designing different evaluation systems based on actual conditions for quantitative research on priority conservation of rare and endangered plants. Studies targeting specific taxonomic groups are relatively rare, with Liu et al. (2011) conducting a quantitative evaluation of priority conservation for rare and endangered bamboo species in Yunnan Province, providing relevant references for the conservation of rare bamboo germplasm resources in Yunnan.

Gesneriaceae plants are mostly perennial herbs, comprising approximately 150 genera and 3,500 species worldwide (Weber et al., 2013), widely distributed from tropical to temperate regions in eastern and southern Asia, Africa, southern Europe, Oceania, and South America to Mexico. China is one of the distribution

centers for Gesneriaceae, with extremely rich species diversity. According to the latest research data, as of March 2020, China has recorded 44 genera and 757 species (including infraspecific taxa) of Gesneriaceae (Xu et al., 2017; Wen et al., 2019, 2020). In China, this family is mainly distributed south of the Yangtze River, with Guangxi in South China and adjacent limestone areas in the southwest representing distribution and diversity centers. Most species exhibit narrow distribution ranges and small populations, making their habitats vulnerable to anthropogenic threats. Among Gesneriaceae plants, five species are listed as national first- or second-level key protected wild plants in the "List of National Key Protected Wild Plants (First Batch)" (State Forestry Administration, 1999). The "China Species Red List (Volume 1)" assessed the endangered status of 38 Gesneriaceae species (Wang & Xie, 2004), while the "Threatened Species List of China' s Higher Plants" evaluated 496 Gesneriaceae species, with 73 classified as threatened (Qin et al., 2017). However, these evaluations mostly considered national-scale situations and were largely qualitative. Based on our continuous multi-year field tracking surveys, the endangered status of many Gesneriaceae plants in Guangxi and even South and Southwest China differs considerably from these documented assessment results. Conducting more precise assessments of the threatened status of Gesneriaceae in Guangxi holds important practical significance for effective conservation of Gesneriaceae and future expansion to other rare plant families and genera.

This study focuses on Gesneriaceae plants distributed in Guangxi Zhuang Autonomous Region (hereinafter referred to as Guangxi), including new taxa published between the publication of *Flora of China* (English edition) in 1998 and December 31, 2018. Through quantitative analysis and comprehensive evaluation of their threatened degree, this research aims to determine their endangered status and priority conservation ranks within Guangxi, providing a scientific basis for relevant scholars and departments to formulate specific conservation measures and laying a research foundation for future implementation of conservation measures from multiple perspectives including genetic diversity, *in situ* conservation, and *ex situ* conservation.

1 Natural Overview

Guangxi is located between 104°26'–112°04' E and 20°54'–26°24' N, with a total area of 236,700 km^2. Situated on the southeastern edge of the Yunnan-Guizhou Plateau and the western part of the Guangdong-Guangxi hills, it faces the Beibu Gulf to the south and spans north tropical, south tropical, and mid-subtropical zones. Guangxi features mountains exceeding 2,000 m in elevation as well as low-altitude plains, terraces, valleys, and hills. The region has extensive karst landforms, with exposed carbonate rocks covering approximately 40% of the total area, forming spectacular peak clusters, peak forests, caves, karst plains, and valleys (Wang, 1986). As a low-latitude region, Guangxi is rich in heat resources. Due to a latitudinal span of approximately 5°, temperatures vary significantly across different regions, with annual average temperatures ranging

from 18–23°C from south to north, and even lower temperatures in high-altitude areas. The $ $10°C annual accumulated temperature ranges from 8,300–5,600°C. Guangxi has a monsoon climate with abundant rainfall, generally 1,300–1,800 mm annually, though considerable regional variation exists with distinct rainy and dry seasons. Main soil types include latosol, lateritic red soil, red soil, yellow soil, limestone soil, purple soil, and coastal saline soil. Guangxi' s complex topography, varied landforms, and diverse climatic conditions provide favorable conditions for various plants, nurturing an extremely rich flora. According to incomplete statistics, Guangxi has 8,565 vascular plant species belonging to 285 families and 1,819 genera, including 845 fern species in 56 families and 153 genera, and 7,720 seed plant species in 229 families and 1,666 genera, ranking second nationally after Yunnan (Su et al., 1996; Huang et al., 2006; Wei, 2008).

2 Methods

2.1 Determination of Gesneriaceae Species in Guangxi

Based on relevant literature (Xu et al., 2017; Wen et al., 2019), recent survey data from the Guangxi Native Plant Full Coverage Project (Wei et al., 2019), and all new taxa literature published from 1998 to December 31, 2018, we compiled a list of 237 rare and endemic Gesneriaceae species known to be distributed in Guangxi (including 236 extant species; the monotypic genus *Gyrogyne* W.T.Wang with its single species *Gyrogyne subaequifolia* W.T.Wang has been assessed as extinct in the wild (EW)). The determination of rarity and endemism for Guangxi Gesneriaceae primarily followed these principles: rare and endangered species distributed in Guangxi that are assessed in the "List of National Key Protected Wild Plants (First Batch)" (State Forestry Administration, 1999), "China Species Red List (Volume 1)" (Wang & Xie, 2004), and "Threatened Species List of China' s Higher Plants" (Qin et al., 2017), as well as species with narrow distribution and small populations, including Chinese endemics and Guangxi endemics, and all IUCN endangered levels except Least Concern (LC) and Data Deficient (DD) as determined by authors when new taxa were published.

2.2 Establishment and Calculation of Evaluation Indicators

Based on reference to other scholars' quantitative research on priority conservation of rare and endangered plants (Zhou, 2006; Cao et al., 2012; Wang et al., 2013; Chen & Zhang, 2015; Peng et al., 2017), and according to the biological characteristics of Gesneriaceae, indicators were modified to suit the specific actual conditions in Guangxi. Priority conservation values were calculated through evaluation indicator assignment for rare and endemic plants, including endangered coefficient, utilization value coefficient, conservation status coefficient, and reproduction difficulty coefficient.

2.2.1 Endangered Coefficient The endangered coefficient represents the endangerment degree of rare and endemic Gesneriaceae populations in their natural distribution in Guangxi. Indicators are shown in Table 1.

After quantitative evaluation of the six indicators in the above table, the endangered coefficient (C_ 濒) for each species was calculated using the formula:

$$C_{濒} = \frac{\sum_{i=1}^{6} X_i}{\sum_{i=1}^{6} MaX_i}$$

where X_i is the actual score for each evaluation indicator and MaX_i is the maximum possible score for each indicator.

Based on the endangered coefficient (C_ 濒) values and new international endangered species criteria (Shan et al., 2019), species endangered levels were classified as: Critically Endangered (CR) C_ 濒 > 0.90, Endangered (EN) C_ 濒 = 0.80-0.90, Vulnerable (VU) C_ 濒 = 0.60-0.79, Near Threatened (NT) C_ 濒 = 0.40-0.59, and Least Concern (LC) C_ 濒 < 0.40 (Wang & Xie, 2004; Wang et al., 2013).

2.2.2 Utilization Value Coefficient The utilization value coefficient represents the value of Gesneriaceae plants in scientific research, economy, society, and ecology, primarily referring to recognized and utilized value or potential development value in ornamental, scientific research, greening, medicinal, edible, and other aspects. The maximum score is 5 points: 5 points for species with high ornamental, edible, and medicinal value and important breeding materials; 4 points for species with good ornamental, edible, and medicinal value; 3 points for species with general ornamental, edible, and medicinal value; 2 points for species with poor ornamental, edible, and medicinal value; and 1 point for species with no special use or currently only known to have gene conservation value. The utilization value coefficient (C_ 价) is calculated as:

$$C_{价} = \frac{X}{5}$$

where X is the actual score for each evaluation indicator.

2.2.3 Conservation Status Coefficient The conservation status coefficient represents the degree of protection achieved for rare and endangered plants under current conservation measures, primarily divided into *in situ* and *ex situ* conservation status. *In situ* conservation status is scored based on the protected population size of Guangxi Gesneriaceae at their original locations under natural conditions, with a maximum of 4 points: 4 points for no *in situ* protection or known distribution points not within any protected area or reserve, or known distribution points currently affected by various factors (natural and

anthropogenic); 3 points for small populations or less than 1/4 of the population within protected habitats such as nature reserves or national forest parks; 2 points for partial individuals or 1/4-1/2 of the population within such protected habitats; and 1 point for adequate protection with sufficient individuals or more than 1/2 of the population within nature reserves. *Ex situ* conservation status has a maximum of 4 points, scored based on the number of species under *ex situ* conservation or expanded cultivation over the years. Species with no *ex situ* conservation measures, or those that are difficult to complete a life cycle from seed to seed after introduction, or those that fail to survive are scored 4 points; those that can be introduced and survive, completing a life cycle from seed to seed under special conditions, or with propagation of less than 100 individuals through seed or vegetative propagation are scored 3 points; those relatively easy to introduce and survive, relatively easy to complete life cycle replacement in greenhouse protected conditions, or with propagation of 100-500 individuals are scored 2 points; and those extremely easy to introduce and survive, able to complete the entire life cycle without special care, with total propagation exceeding 500 individuals through vegetative or seed propagation are scored 1 point.

The conservation status coefficient (C_ 保) is calculated as:

$$C_{保} = \frac{\sum_{i=1}^{2} X_i}{\sum_{i=1}^{2} \mathrm{MaX}_i}$$

where X_i is the actual score for each evaluation indicator and MaX_i is the maximum possible score for each indicator.

2.2.4 Reproduction Difficulty Coefficient The reproduction difficulty coefficient primarily represents the difficulty of *ex situ* conservation and propagation for rare Gesneriaceae plants in Guangxi. The maximum score is 3 points: 3 points for difficult reproduction (mainly seed propagation with germination rate not exceeding 50%, and cutting propagation very difficult); 2 points for moderate reproduction difficulty (germination rate generally below 20%, moderate cutting difficulty); and 1 point for relatively easy reproduction with various methods and high survival rates. The Gesneriaceae Conservation Center of China (GCCC), based at Guangxi Institute of Botany and Guilin Botanical Garden, has established a low-temperature seed bank that has collected seeds of over 70% of Gesneriaceae species in Guangxi. Partial germination experiments were conducted at the genus level before seed storage, such as for *Petrocodon lui* and *Petrocodon jingxiensis* (Wu, 2017). Additionally, relevant research results on seed germination and germination rates of Gesneriaceae plants in China and Guangxi were referenced, such as for *Paraisometrum mileense* (Hu et al., 2020), *Briggsia longipes* and *Lysionotus pauciflorus* (Zhao et al., 2010). Based on comprehensive estimation of seed germination difficulty from the perspective of known congeneric species, combined with leaf and stem cutting propagation methods used in daily work at GCCC, this coefficient was calculated.

The reproduction difficulty coefficient (C_ 繁) is calculated as:

$$C_{繁} = \frac{X_i}{3}$$

where X_i is the actual score for each evaluation indicator.

2.3 Calculation and Classification of Priority Conservation Values

Based on the relative importance of the above 10 evaluation indicators, weight allocation was determined through repeated discussion of various materials (Zhou, 2006; Cao et al., 2012; Chen & Zhang, 2015; Peng et al., 2017; Wei, 2019): endangered coefficient 55%, utilization value coefficient 15%, conservation status coefficient 20%, and reproduction difficulty coefficient 10%. Priority conservation levels were assessed based on the priority conservation value (V_ 优):

$$V_{优} = 55\% \times C_{濒} + 15\% \times C_{价} + 20\% \times C_{保} + 10\% \times C_{繁}$$

Priority conservation levels are classified as: V_ 优 > 0.80, urgently requiring protection, recommended as Grade I priority conservation; $0.70 <$ V_ 优 ≤ 0.80, requiring protection, recommended as Grade II; $0.60 <$ V_ 优 ≤ 0.70, appropriate protection recommended as Grade III; and V_ 优 ≤ 0.60, considered to have not yet suffered serious threats to population size or habitat, recommended to maintain current status for now, listed as Grade IV.

3 Results

3.1 Endangered Status of Rare and Endemic Gesneriaceae in Guangxi

As shown in Table 2 , based on endangered coefficient (C_ 濒) values, rare and endemic Gesneriaceae in Guangxi were classified as follows: 58 species were assessed as Critically Endangered (CR), accounting for 24.57% of the total, including *Petrocodon huanjiangensis*, *Primulina debaoensis*, *Primulina leprosa*, *Petrocodon fangianus*, *Primulina cardaminifolia*, *Primulina debaoensis*, *Oreocharis dayaoshanioides*, and *Petrocodon guangxiensis*; 70 species as Endangered (EN), accounting for 29.66%, including *Primulina crenulata*, *Primulina spinulosa*, *Hemiboea rubribracteata*, *Allocheilos guangxiensis*, *Paraisometrum mileense*, and *Oreocharis stewardii*; 72 species as Vulnerable (VU), accounting for 30.51%, including *Primulina medica*, *Primulina subulata*, *Oreocharis sinohenryi*, *Paraboea angustifolia*, *Primulina diffusa*, and *Primulina parviflora*; 31 species as Near Threatened (NT), accounting for 13.14%, including *Oreocharis boehica*, *Aeschynanthus austroyunnanensis* var. *guangxiensis*, *Oreocharis argyreia*, *Petrocodon dealbatus*, *Primulina gueilinensis*, and *Raphiocarpus begoniifolia*; and 5 species as Least Concern (LC), namely *Chirita fimbrisepala*, *Hemiboea follicularis*, *Hemiboea gracilis*, *Hemiboea cavaleriei*, and *Primulina eburnea*.

3.2 Priority Conservation Level Evaluation for Gesneriaceae in Guangxi

Based on priority conservation value classification, Table 2 shows that 107 species were rated as Grade I priority conservation plants, accounting for 45.34% of the total, including *Petrochema iodioides*, *Oreocharis cotinifolia*, *Primulina wuae*, *Primulina bipinnatifida* var. *zhoui*, *Primulina debaoensis*, *Primulina gueilinensis*, *Primulina leprosa*, *Primulina wangiana*, *Primulina cardaminifolia*, *Primulina rongshuiensis*, *Primulina tribracteata* var. *zhuana*, *Petrocodon guangxiensis*, *Primulina davidioides*, and *Primulina gigantea*. These species share characteristics of extremely small populations and limited individual numbers. Seventy-five species were classified as Grade II priority conservation, accounting for 31.78%, including *Primulina lutea*, *Paraboea peltifolia*, *Beccarinda minima*, *Primulina guigangensis*, and *Primulina cordifolia*. Twenty-eight species were Grade III, accounting for 11.86%, including *Oreocharis boehica*, *Paraboea velutina*, *Primulina medica*, *Primulina subulata*, and *Gyrocheilos retrichum* var. *oligolobum*. Twenty-six species were Grade IV, accounting for 11.02%, including *Primulina hochiensis*, *Anna mollifolia*, *Oreocharis xiangguiensis*, *Oreocharis argyreia*, and *Hemiboea follicularis*.

4 Discussion and Conclusions

Guangxi is located in the distribution center of Gesneriaceae plants in China, with 24 genera and 236 species of rare and endemic Gesneriaceae currently known from this region. Based on endangered coefficient (C_ 濒) classification, there are 58 critically endangered species, 70 endangered species, 72 vulnerable species, 31 near threatened species, and 5 least concern species. Based on priority conservation value (V_ 优) assessment, four priority conservation levels were established: 107 species as Grade I, 75 as Grade II, 28 as Grade III, and 26 as Grade IV. Among the 38 rare and endangered Gesneriaceae species assessed in the "China Species Red List (Volume 1)" , 16 are distributed in Guangxi, with 14 assessed as critically endangered (Wang & Xie, 2004). The "Threatened Species List of China' s Higher Plants" assessed 21 rare and endangered Gesneriaceae species distributed in Guangxi, with 8 classified as critically endangered (Qin et al., 2017). In this study' s endangered status evaluation, 58 species were assessed as critically endangered, far exceeding the number included in the Red Lists. Currently, few endangered Gesneriaceae species are included in the "List of National Key Protected Wild Plants (First Batch)" for priority protection, with only *Oreocharis boehica*, *Oreocharis dayaoshanioides*, and *Primulina crenulata* listed as national first-level key protected wild plants in Guangxi. However, except for *Oreocharis dayaoshanioides*, the other two species have fallen below the critically endangered standard based on surveyed population sizes, distribution ranges, and degrees of natural and anthropogenic impact. Therefore, this study maintains *Oreocharis dayaoshanioides* at Grade I priority conservation while downgrading the other two species accordingly. Additionally, with time and increasingly thorough investigations, many other

species distributed in Guangxi have been upgraded in priority conservation level, providing a more realistic assessment of the living environment and endangered status of Gesneriaceae in Guangxi.

Our research team has conducted investigations for over 20 years, covering detailed surveys of all known Gesneriaceae distribution sites in Guangxi, accumulating massive amounts of information, and comprehensively referencing evaluation methods. The accuracy and reliability of our evaluation results are scientifically grounded and generally consistent with the current protection status and destruction patterns of Gesneriaceae in Guangxi. However, differences exist between our evaluation system results and national and provincial plant protection categories and levels for some species. For example, *Primulina subulata* was listed as critically endangered in the China Species Red List (Wang & Xie, 2004), but actual surveys revealed relatively large populations, ranking 185th in our evaluation results, while *Primulina spinulosa* ranked 60th due to having only one distribution point. Similarly, *Petrochema iodioides* was found at only one site in Guangxi with fewer than 20 individuals, and despite larger populations in Yunnan, this study must consider only the quantity limited to Guangxi, resulting in a very high ranking. The same phenomenon applies to species such as *Paraisometrum mileense* and *Paraboea* species. This fully demonstrates that, except for some Guangxi endemics, certain species may be endangered to critically endangered from a Guangxi perspective but may not be endangered from a South China, Southwest China, or national perspective.

With in-depth investigation of special habitats in southern karst and Danxia landforms by botanists, 191 new taxa and 3 new national distribution records of Gesneriaceae have been published in China from January 2005 to December 2018, with 90 new taxa published from Guangxi, accounting for 46.39% (Xin et al., 2019). Most newly published taxa belong to the broadly defined genera *Primulina* and *Petrocodon*, with the vast majority having narrow distribution ranges, small populations, and extreme dependence on specialized microhabitats, consistent with the endangered conservation status of most *Primulina* and *Petrocodon* species in this evaluation.

For new taxa published after 1998 and distributed in Guangxi, except for assessed species with direct population statistics from field surveys, main evaluation data were derived from IUCN endangered levels and related data provided in the original publication articles. For example, *Petrocodon fangianus* was reported to have only 43 individuals (Wei, 2004), *Paraboea guilinensis* had only about 20 individuals remaining in the wild (Xu & Wei, 2004), and *Hemiboea rubribracteata* was found at only one site with a total of fewer than 100 individuals (Li & Liu, 2004). These data are continuously updated with further field investigations of target species, which may affect evaluation results, but the data from publication time still provide valuable references for assessing current endangered status. In previous research, we fully utilized the latest IUCN Red List criteria (Version 3.1) (Wei et al., 2010) and referenced the China Red List evaluation system, but this study' s conclusions show that the three systems do

not fully agree. While this is partly due to continuously updated baseline data from field investigations, it also indicates the need for further in-depth research and analysis in future studies.

Biodiversity conservation depends on harmonious coexistence between humans and the environment. Field surveys have revealed that many Gesneriaceae populations are gradually declining, with some even extinct (e.g., *Gyrogyne subaequifolia*) (Li & Wang, 2005; Wei et al., 2019, 2010). Most Gesneriaceae species are adapted to specialized microhabitats, primarily growing in tropical-subtropical rainforests, monsoon forests, and evergreen broad-leaved forests, as well as in limestone caves, gorges, rock crevices, cliffs, and waterside areas (especially rocky sections). However, current rock desertification and anthropogenic destruction have impacted many Gesneriaceae habitats, making population recovery difficult. Over-collection of traditional medicinal plants in an exhaustive manner has threatened many Gesneriaceae species with medicinal value (e.g., *Primulina longgangensis*, *Primulina hochiensis*, *Primulina guilinensis*) (Li & Wang, 2005; Huang et al., 2010; Weber et al., 2011a; Qin et al., 2013), directly causing severe population decline or even death. Repeated and duplicate collection of experimental materials by different research institutions and universities has caused population destruction, degradation, exhaustion, and extinction, primarily through over-utilization and collection of type specimens from type localities (Wen, 2008). Insufficient understanding of the biodiversity and importance of Guangxi Gesneriaceae, lack of active science popularization and education for local people, and long-term absence of effective protection measures are also important reasons for the continuous reduction of Gesneriaceae resources (Li et al., 2018). Therefore, sufficient attention should be paid to the conservation of Gesneriaceae resources in this region, with increased publicity to enhance protection awareness, strengthened scientific research on endangerment mechanisms, implementation of *in situ* and *ex situ* conservation, and scientific and rational resource utilization for effective plant protection.

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