

A Review of Studies on the Medicinal Endangered Mangrove Plant *Acanthus ebracteatus*

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Abstract This study, integrating both domestic and international literatures as well as field research findings, presents a comprehensive review of the geographical distribution, ecological and physiological characteristics of *Acanthus ebracteatus*. It further delves into the factors leading to its endangered status and proposes corresponding protection strategies. The main reasons for the endangered of *A. ebracteatus* are as follows: illegal harvesting of whole plants, habitat destruction, reproductive obstacles, and competition or interference from invasive or noxious plant species. To address these threats, a series of conservation strategies are proposed. Firstly, in-depth research on the artificial propagation techniques of *A. ebracteatus* should be conducted to surmount reproductive barriers. Secondly, habitat restoration initiatives need to be carried out to create a suitable ecological setting. Thirdly, in-situ protections should be enhanced while the implementing *ex-situ* conservation measures. Meanwhile, continuous monitoring of *A. ebracteatus* seedlings should be conducted to strengthen subsequent management and conservation efforts. Finally, it is recommended to rationally explore and utilize the medicinal properties of *A. ebracteatus*.

Key words *Acanthus ebracteatus*, Ethnomedicinal plant, Endangered mangrove plant, Ecological characteristics, Protection strategy

0 Introduction

Acanthus ebracteatus, a species within the genus *Acanthus* of the Acanthaceae family, is recognized as a true mangrove plant and holds considerable ecological significance^[1]. *A. ebracteatus* naturally occurs in the middle and high intertidal zones of estuaries characterized by relatively low salinity^[2]. Its distribution spans regions including southern Asia, Southeast Asia, and northern Australia^[2]. Within China, it is confined to the estuaries of Hainan, Guangdong, and the Guangxi Zhuang Autonomous Region (hereinafter referred to as "Guangxi")^[3-5]. *A. ebracteatus* is a traditional ethnic medicinal plant both domestically and internationally^[6]. Since 1980, its global distribution has declined due to anthropogenic activities and climate change. The International Union for Conservation of Nature (IUCN) currently classifies the species as Least Concern (LC)^[2]. However, in countries such as China^[7] and India^[8], *A. ebracteatus* is considered endangered (EN). Furthermore, recent studies have revealed that the seed setting rate of *A. ebracteatus* is exceedingly low^[5]. Consequently, research focused on the rescuing protection of the endangered mangrove species *A. ebracteatus* is of critical urgency.

Based on both domestic and international researches, as well

as the author's field investigation results accumulated over several years, this study reviews the biological and ecological characteristics, geographical distribution, and environmental adaptability of *A. ebracteatus*. It further explores the factors contributing to its endangered status and proposes protection strategies, with the aim of providing references for the protection and ecological restoration of *A. ebracteatus*.

1 Biological and population characteristics of *A. ebracteatus*

1.1 Biological characteristics *A. ebracteatus* is a true mangrove species belonging to the genus *Acanthus* in the family of Acanthaceae, with an estimated divergence time of approximately 32 million years ago^[9]. The leaves are arranged oppositely and characterized by a truncate or slightly rounded apex (Fig. 1A) and a cuneate base^[3,10-11]. They exhibit high succulence and a relatively low specific leaf area^[12], reflecting adaptation to saline environments. Leaf epidermal cells are polygonal with nearly straight anticlinal walls, and stomata are of the straight-axis type, situated with a compound epidermis. The vascular bundles are of the ectophloic type. These morphological traits reflect typical halophytic adaptations, including a well-developed cuticle, a prominent wax layer, functional salt glands, and palisade parenchyma organized into up to three layers^[13]. The stem is erect and cylindrical, with diameters ranging from 0.5 to 2.8 cm. Thorn-like structures at the nodes are directed downward, and aerial roots are highly developed. The inflorescence is a raceme bearing small flowers with corollas that are white or pale blue at the tips (Fig. 1B). The fruit is an oblong-elliptic capsule with a persistent stigma resembling a mouse's tail (Fig. 1C). Field observations and empirical studies

Received: September 22, 2025 Accepted: December 15, 2025

Supported by Special Innovation Projects for Regular Institutions of Higher Education in Guangdong Province (2023KTSCX071); Zhanjiang Science and Technology Bureau Project (2023A01018); Colonel-level Project (LY2207). Danfeng LI, doctoral degree, lecturer, research fields: mechanisms of conservation and endangerment of endangered mangrove plant germplasm resources.

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have consistently documented substantial flower and fruit abscission (Fig. 1C), along with a high incidence of embryos abortion. These reproductive limitations strongly suggest the presence of sex-

ual reproductive disorders, underscoring the necessity of employing artificial breeding techniques to enhance and expand germplasm conservation efforts.



NOTE A. Leaf; B. Flower; C. Capsule.

Fig. 1 Morphological characteristics of *Acanthus ebracteatus*

1.2 Population characteristics The population of *A. ebracteatus* typically demonstrates an aggregated distribution pattern. Its populations have been documented to display clumped spatial arrangements in multiple locations, including Palawan Island and the Aurora mangrove forests in the Philippines^[14], the Segara Anakan Cilacap mangrove forest in Java, Malaysia^[15], the Jiangshan Peninsula in Fangchenggang, Guangxi^[4], and the Jiuzhou River estuary tidal flats on the Leizhou Peninsula in Guangdong^[5] (Table 1). However, in areas where habitats are degraded or under anthropogenic pressure, populations tend to adopt a scattered or patchy distribution^[16–17], as observed in the Batangas mangrove forest in the Philippines^[18] and in the Hainan populations of *A. ebracteatus* in China (Table 1). The population density of *A. ebracteatus* is generally high across its range. For instance, in the Jiangshan Peninsula mangrove forest, Guangxi, the average density reaches 2.62 individuals/m²^[4]; in the Jiuzhou River estuary, Guangdong, it rises to approximately 14 individuals/m²^[5]; and in the mangrove forests of Java, densities peak at 14.8 individuals/m²^[14]. While wild populations of *A. ebracteatus* demonstrate vigorous vegetative reproduction, natural seedling recruitment remains limited^[4], indicating potential constraints in sexual regeneration.

1.3 Community structure *A. ebracteatus*, a shrub species, is commonly found in the lower strata of mangrove ecosystems^[4,15] and frequently coexists with other mangrove species. For example, on the floodplain of the Adelaide River in northern Australia, approximately 25 km from its estuary, *A. ebracteatus* occurs alongside *Acanthus ilicifolius* at the forest margins dominated by *Avicennia marina*, *Rhizophora stylosa*, *Lumnitzera racemosa*, *Ceriops australis*, *Bruguiera exaristata*, and *Bruguiera gymnorhiza*^[19]. In the mangrove forest of Yensawai Village on the Raja Ampat Islands, Indonesia, *A. ebracteatus* commonly grows in the understory beneath *B. gymnorhiza*^[20]. In certain regions, it forms co-dominant species communities with other mangrove species. Specifically, in Aurora and Palawan in the Philippines, *A. ebracteatus* co-dominates with *Kandelia obovata* and *Excoecaria agallocha*, respectively^[14]. It also establishes co-dominant associations with *A. ilicifolius* or *Derris trifoliata* within canopy gaps of the Segara Anakan Cilacap mangrove forest on Java Island, Malaysia^[15,21]. Under fa-

vorable environmental conditions, *A. ebracteatus* can form dense, monospecific stands independently. Notably, at the Jiuzhou River estuary on the Leizhou Peninsula, Guangdong Province, it forms a monospecific community characterized by high density and canopy coverage. The dominance of this species suppresses the growth of other plant species within the community, with only a few species, including *Sonneratia apetala*, *A. ilicifolius*, *Acrostichum aureum*, *Volkameria inermis*, *Pluchea indica*, and *D. trifoliata*, occurring sporadically in the surrounding area^[5]. In terms of vertical community structure, *A. ebracteatus* typically occupies the lower stratum. For instance, in the Rhin River estuary in Nghe An Province, Vietnam, *A. ebracteatus* and *A. ilicifolius* form a co-dominant understory layer beneath dispersed individuals of *Sonneratia caseolaris*^[22]. In Fangchenggang, Guangxi, communities structured as *E. agallocha*—*A. corniculatum*—*A. ebracteatus* and *E. agallocha*—*A. corniculatum* + *L. racemosa*—*A. ebracteatus* have been observed, exhibiting distinct vertical stratification^[4]. In contrast, in the mangrove ecosystems of Batangas, Philippines, *A. ebracteatus* is sporadically distributed in the lower stratum of the *Rhizophora apiculata* + *Rhizophora mucronata* community^[14].

1.4 Reproductive biological characteristics The full blooming period of *A. ebracteatus* predominantly occurs during spring and summer, although distinct temporal variations were observed across different geographic regions. In the mangrove forest of Bhitarkanika National Park, Odisha, India, the flowering period spans from May to June^[17], with fruiting primarily concentrated in September^[11]. Conversely, in the Jiuzhou River mangrove forest of the Leizhou Peninsula, Guangdong, flowering extends from June to March of the following year, peaking in December^[5]. This study reveals that in Qinglan Port, Wenchang, Hainan, flowering spans from late October to late July of the following year, while in Fangchenggang, Guangxi, it ranges from late September to late June of the following year. Notably, seed-setting rates in Hainan and Guangxi populations are higher than those recorded in Guangdong. The primary pollinators of *A. ebracteatus* are insects such as bees and ants^[11,17]. While *A. ebracteatus* employs both vegetative and seed-based propagation methods^[17], wild populations rely predominantly on vegetative reproduction^[4–5].

Table 1 Population characteristics and community structures of *Acanthus ebracteatus* in selected locations

| Country | Location | Longitude ° | Latitude ° | Population characteristics | | | Community type | Data source |
|-----------------|--|----------------|---------------|----------------------------|------------------------|---|---|------------------------------------|
| | | | | Distribution pattern | Area m ² | Population density plants/m ² | | |
| China | Jiangxin River, Wanning, Hainan | 18.595 6 | 110.017 9 | Scattered | 90 | 0.67 | <i>Pluchea indica</i> + <i>A. ebracteatus</i> | Field investigation |
| | Boaonangang Village, Qionghai, Hainan | 19.155 1 | 110.577 4 | Scattered | 1 | 2 | <i>P. indica</i> + <i>Excoecaria agallocha</i> | Field investigation |
| | Danchang Village, Wenchang, Hainan | 19.621 4 | 110.809 | Patchy | 256 | 1.12 | <i>Bruguiera gymnorhiza</i> + <i>Bruguiera sexangula</i> — <i>P. indica</i> + <i>A. ebracteatus</i> | Field investigation |
| | Danzhou Bay, Hainan | 19.785 7 | 109.294 | Scattered | 16 | 0.69 | <i>Acanthus ilicifolius</i> + <i>A. ebracteatus</i> | Field investigation |
| | Dongzhai Harbor, Hainan | 19.993 3 | 110.809 7 | Scattered | 70 | 0.6 | <i>Sonneratia caseolaris</i> + <i>Sonneratia ovata</i> | Field investigation |
| | Jiuzhou River, Lianjiang, Guangdong | 21.461 2 | 109.987 9 | Aggregated | 9 083 | 14 | <i>A. ebracteatus</i> monospecific community | Lin Guangxuan <i>et al.</i> , 2022 |
| | Jiangshan Peninsula, Guangxi | 21.516 4 | 108.226 2 | Aggregated | 686 | 2.62 | <i>E. agallocha</i> — <i>Aegiceras corniculatum</i> — <i>A. ebracteatus</i> <i>E. agallocha</i> — <i>A. corniculatum</i> + <i>Lumnitzera racemosa</i> — <i>A. ebracteatus</i> | Huang Liyan <i>et al.</i> , 2021 |
| The Philippines | Huangzhu River, Guangxi | 21.646 3 | 108.193 2 | Scattered | 80 | 0.44 | – | |
| | Batangas | 13.735 3 | 121.057 7 | Scattered | – | – | <i>Rhizophora apiculata</i> + <i>Rhizophora mucronata</i> | Replan <i>et al.</i> , 2017 |
| | Palawan | 9.490 3 | 118.481 8 | Aggregated | – | – | <i>E. agallocha</i> + <i>A. ebracteatus</i> | |
| | Aurora | 15.390 6 | 121.444 9 | Aggregated | – | – | <i>Kandelia candel</i> + <i>A. ebracteatus</i> | |
| Indonesia | Segara Anakan Cilacap mangrove forest on Java Island | –7.734 6 | 108.928 6 | Aggregated | – | – | <i>Aegiceras corniculatum</i> + <i>Nypa fruticans</i> + <i>Rhizophora apiculata</i> — <i>A. ilicifolius</i> + <i>A. ebracteatus</i> | Nordhaus <i>et al.</i> , 2019 |
| | Raja Ampat Islands | –0.800 7 | 130.682 | – | – | – | – | Yulianda <i>et al.</i> , 2019 |
| | Kapuas River, Pontianak, West Kalimantan Province | 0.239 4 | 109.165 | – | – | – | – | Nakamura <i>et al.</i> , 2019 |
| India | Andaman Islands | 11.613 92 | 92.689 5 | – | – | – | – | Ragavan <i>et al.</i> , 2014 |
| | Nicobar Islands | 11.799 6 | 92.717 56 | – | – | – | – | |
| | Pondicherry | 11.874 748 | 79.805 904 | Segmented | – | – | – | Saravanan <i>et al.</i> , 2008 |
| | Bhitarkanika mangrove forest, Odisha | 20.407 602 | 86.713 316 | – | – | – | <i>S. caseolaris</i> | Pradhan <i>et al.</i> , 2016 |
| Vietnam | Rhin River, Nghe An Province | 18.689 7 | 105.760 56 | Aggregated | – | – | <i>A. ilicifolius</i> + <i>A. ebracteatus</i> | Takahashi <i>et al.</i> , 2020 |
| Myanmar | Avicennia mangrove forest of Rakhine State | 20.4 | 93.470 6 | – | – | – | <i>Avicennia</i> | Kyaw, 2012 |

2 Distribution characteristics of *A. ebracteatus*

2.1 Geographical distribution of *A. ebracteatus*

A. ebracteatus is naturally distributed in the intertidal zones of tropical coasts (21.646 2° N – 12.415 3° S) (Table 1). Previous studies have documented its presence in the mangrove forests of Pondicherry^[23], the Andaman and Nicobar Islands^[16], and Bhitarkanika National Park in Odisha^[11,17], in India. It is also found in the *Avicennia*-dominated mangrove forest of Rakhine State, Myanmar^[24]. A dense population has been recorded outside the shrimp ponds at the estuary of the Rhin River in Nghe An Province, Vietnam^[22]. In Thailand, *A. ebracteatus* is primarily distributed along the southern coast,

with notable occurrences in the mangrove forests of Rayong^[25], Samut Songkhram^[26], Surat Thani^[27], Songkhla^[28], and Pattani Province^[29]—regions recognized as major collection areas for the Thai medicinal herb *A. ebracteatus*. The species is present in the mangrove forests of Aurora, Batangas, and Palawan in the Philippines^[14], as well as in Mori, Selangor, Malaysia^[30]. Additionally, *A. ebracteatus* occurs in the mudflats along the Kapuas River, Pontianak, West Kalimantan Province, Indonesia^[31]; the Segara Anakan mangrove forest in the Port of Cilacap, Java Island^[15]; and the Yensawai mangrove forest in the Raja Ampat Islands^[20]. Ball *et al.*^[19] reported a small population of *A. ebracteatus* in the floodplain of the Adelaide River in northern Australia.

In China, *A. ebracteatus* has been recorded in the Jiangshan Peninsula and along the Huangzhu River bank in Fangchenggang, Guangxi^[4]; on tidal flats of the Anpu River and Yingzhai River, where the Jiuzhou River meets the sea on the Leizhou Peninsula, Guangdong^[5]; and at Qinglan Port in Wenchang, Hainan^[32]. Field investigations further identified populations in the estuary of the Jiangxin River in Hainan, Boaonangang Village, Danzhou Bay, and Dongzhai Harbor (Table 1). Collectively, these findings indicate that the distribution of *A. ebracteatus* in China is confined to estuarine tidal flats located at the northern margin of the tropics.

2.2 Environmental adaptability characteristics of *A. ebracteatus* The habitat of *A. ebracteatus* is primarily located in the middle and lower reaches of estuarine tidal flats and high tide zones. The pH of its distribution range varies from 5.61 to 7.92, with a mean of 6.4. Soil salinity ranges from 8‰ to 29‰^[15], while soil organic matter content fluctuates between 14.5‰ and 31.97‰, averaging 23.42‰. Total nitrogen content ranges from 16.53‰ to 35.07‰, with an average of 24.41‰ and total phosphorus content ranges from 2.68‰ to 7.00‰, with averaging 4.36‰^[5,15].

Throughout its long-term evolutionary history, *A. ebracteatus* has developed morphological adaptations to the high-salinity conditions of the intertidal environment. Studies have demonstrated that the salt glands in the leaves are well-developed, with frequent observations of salt secretion^[13], indicating that the species maintains internal ion homeostasis through active salt excretion. Additionally, *A. ebracteatus* adapts to periodic tidal inundation producing well-developed aerial roots, which enhance gas exchange under waterlogged conditions.

Ion regulation, osmotic adjustment, and photosynthetic efficiency are key physiological mechanisms underlying salt tolerance in halophytes^[33]. In *A. ebracteatus*, the concentrations of Na, Cl, and N in the leaves are relatively high, whereas specific leaf area is comparatively low^[33]. These traits suggest that this species employs osmotic regulation by accumulating inorganic ions to reduce cellular water potential, while elevated nitrogen levels may contribute to the stabilization of cellular structures and increased tissue density^[34].

The expression of salt-tolerant genes plays a critical role in enabling mangrove species to thrive in saline habitats. Transcriptomic studies have identified gene sequences in *A. ebracteatus* associated with salt tolerance, antioxidant defense, osmotic regulation, ion homeostasis, and detoxification processes^[30,35–36], indicating a genetically regulated adaptive capacity to high-salinity environments. Furthermore, *A. ebracteatus* possesses multiple vacuolated H⁺-ATPase enzymes that are involved in stress response and cellular compartmentalization^[37]. Notably, the introduction of a salt-tolerant gene from *A. ebracteatus* into *Oryza sativa* significantly has been shown to significantly enhance the salt tolerance of transgenic rice lines^[38–39]. This functional evidence further confirms that the expression of salt-tolerant genes in *A. ebracteatus* is a fundamental mechanism supporting its survival and growth in saline habitats.

3 Current protection status of *A. ebracteatus*

3.1 Resource status of *A. ebracteatus* The global distribution range of *A. ebracteatus* has undergone a significant decline^[2,8]. According to IUCN Red List criteria, *A. ebracteatus* in Bhitarkanika National Park, Odisha, India, is classified as endangered (EN)^[17]. Furthermore, *A. ebracteatus* has been extirpated from the mangrove forests of Pondicherry, with no recent records of its presence^[8,23]. In China, wild populations of *A. ebracteatus* are experiencing severe habitat loss due to anthropogenic activities and are currently listed as Endangered (EN)^[7]. For instance, the population in the Sanya mangrove forest has become locally extinct^[32]. Currently, *A. ebracteatus* is included in the *List of Key Protected Wild Plants of Hainan Province*^[32] and the *National China Biodiversity Red List—Higher Plants Volume (2020)*, reflecting its conservation priority at both regional and national levels.

3.2 Causes of resource degradation of *A. ebracteatus* Human poaching and habitat destruction are the primary drivers of the endangered status of *A. ebracteatus*. This threat manifests in three major aspects: (i) *A. ebracteatus* possesses multiple pharmacological properties, including anti-inflammatory, anti-cancer, and hepatoprotective effects, making it one of the most heavily targeted mangrove species for illegal harvesting in local regions^[5,7,40]. For instance, the population in Yulin Port, Sanya, Hainan Province, was declared locally extinct after being entirely uprooted and removed by collectors^[32]. (ii) Unsustainable development and improper utilization of coastal resources, particularly through aquaculture expansion, have led to widespread habitat degradation. In Jiangshan Town, Fangchenggang, Guangxi, fishermen have constructed shrimp ponds adjacent to mangrove forests and built embankments that disrupt natural tidal flows—critical for maintaining healthy mangrove ecosystems—thereby threatening the survival of *A. ebracteatus*^[41]. (iii) Infrastructure development and land reclamation projects have resulted in direct habitat loss, fragmentation, and physical barriers such as road construction and vegetation clearing, further isolating populations^[5].

Sexual reproductive impairment is another significant factor contributing to the species' decline. While *A. ebracteatus* reproduces both sexually and asexually^[17], its sexual reproduction faces substantial challenges at multiple developmental stages^[5]. On the Leizhou Peninsula, flowering is prolonged and asynchronous, with sparse and weak floral production, leading to extremely low fruit set. As a result, natural regeneration and population expansion via seed are severely limited^[5]. Furthermore, our research team observed a high incidence of embryo abortion in *A. ebracteatus*. Despite high adult density, there is virtually no seedling recruitment beneath the forest canopy^[4–5]. Although vegetative reproduction is vigorous, the species has limited capacity for long-distance dispersal due to habitat fragmentation caused by human activities, restricting its ability to colonize new areas.

Competition from harmful or invasive plant species also contributes to the endangerment of *A. ebracteatus*. *D. trifoliata* frequently grow around these populations^[5,15]. These vines climb and

envelop the canopy of mangrove plants, inhibiting photosynthesis, which can ultimately causing lead to plant mortality^[42]. Additionally, the exotic mangrove species *S. apetala* poses strong competitive pressure on *A. ebracteatus* due to its rapid growth, tall stature, and well-developed pneumatophore system. Under the *S. apetala* canopies, *A. ebracteatus* individuals are sparsely distributed, exhibit stunted growth, and show reduced flowering and fruiting rates compared to those growing in open or non-invaded areas^[5]. The negative impact of *S. apetala* on *A. ebracteatus* occurs through two primary mechanisms: first, its dense network of aerial roots encroaches upon and displaces the rooting space of *A. ebracteatus*; second, its canopy creates deep shade, significantly reducing light availability and thus photosynthetic efficiency in understory *A. ebracteatus* plants.

4 Protection strategies

The *Mangrove Ecological Restoration Manual* advocates adhering to the principles of "ecological priority and natural restoration" in mangrove restoration initiatives. It underscores the importance of protecting and restoring natural mangroves ecosystems and native species, particularly rare and endangered mangrove species. To effectively conserve the germplasm resources of the endangered true mangrove species *A. ebracteatus* and promote the ecological recovery of its populations, the following conservation strategies are proposed in response to the key threats contributing to its endangered status.

First, comprehensive research should be conducted on artificial breeding technique for *A. ebracteatus* to overcome challenges associated with sexual reproduction. (i) The *Technical Standard for Ecological Restoration of Mangrove Wetlands* (hereinafter referred to as the *Standard*) recommends "restoring the habitats of rare and endangered mangrove species and implementing suitable artificial assistance measures to facilitate their natural regeneration". Artificial pollination technique has successfully increased the seed setting rate of the endangered mangrove species *Nypa fruticans*^[33] and the nationally first-class protected mangrove species *Lumnitzera littorea*^[43], playing a crucial role in its conservation. Applying such techniques to *A. ebracteatus* can help overcome reproductive limitations including low fruit set, poor seed development, and high rates of embryo abortion, thereby enhancing its sexual reproductive capacity. (ii) Cuttings represent one of the most widely used of artificial propagation. Traditionally, semi-woody branches are used for *A. ebracteatus*^[44], which may cause significant damage to parent plants. In contrast, our research group has utilized leaf cuttings, significantly reducing harm to mother plants. These leaf cuttings are readily available, exhibit high rooting success, and enable rapid seedling development with a short propagation cycle^[45]. (iii) Plant tissue culture enable the mass production of healthy, genetically uniform plantlets from small tissue samples under controlled conditions^[46]. However, tissue culture in true mangrove plants remains technically challenging, with callus induction achieved only from the leaf tissues of *Kandelia*

candel^[47]. Advancing the tissue culture protocols for *A. ebracteatus* would not only support large-scale seedling production for ecological restoration but also provide sustainable sources of medicinal material, facilitating the scientific and ethical utilization of its therapeutic properties.

Second, habitat restoration efforts must be strengthened to establish favorable ecological conditions. (i) In response to illegal harvesting, public education campaigns should be intensified to raise awareness of the legal protections afforded by the *Wetland Protection Law of the People's Republic of China*. Local governments should enforce effective measures to safeguard mangrove wetlands and mitigate anthropogenic disturbances. (ii) To address competition and interference from invasive or harmful species, active management interventions—such as removal of climbing weeds and eradication of invasive mangroves like *S. apetala* should be implemented. These actions can restore degraded habitats, enhance biodiversity, and promote natural regeneration of *A. ebracteatus* population. (iii) For fragmented habitats, restoration should follow the guidelines outlined in the *Standard*, including enclosure of tidal flats for afforestation, installation of debris-blocking nets, remediation of polluted waters, restoration of tidal channels and exposed mudflats, maintenance of appropriate elevation gradients, pest and disease control, and improved forest management practices.

Third, *in-situ* conservation should be enhanced, complemented by *ex-situ* conservation and continuous monitoring and tracking to ensure effective post-intervention management. (i) The *Standard* emphasizes "expanding populations of rare and endangered mangrove species through artificial cultivation". *A. ebracteatus* exhibits rapid growth in canopy gaps within degraded mangrove forests^[15], indicating strong potential for use in mangrove restoration projects. Moreover, studies have demonstrated that reseeding endangered mangrove species, such as *L. littorea*, *Sonneratia ovata*, and *Dolichandrone spathacea*, within their native distribution regions leads to higher survival and adaptability^[40]. In protected areas where wild populations of *A. ebracteatus* are small, seedlings produced by sexual and asexual propagation and meeting nursery release criteria should be introduced. By optimizing planting density and spatial arrangement, the success rate of population recovery can be significantly improved. (ii) A long-term monitoring system should be established within protected sits of *A. ebracteatus* to continuously track seedlings growth, survival rates, and environmental responses. Where survival is low, timely replanting should be conducted to maintain population viability. (iii) *Ex-situ* conservation programs for *A. ebracteatus* should be developed based on comprehensive ecological assessments. These include detailed characterization of climatic conditions, tidal regimes, soil properties, vegetation composition, and benthic communities in the natural habitat of *A. ebracteatus*. Integrating these data with the known optimal conditions for germination and seedling establishment will enable the identification of suitable sites for translocation and conservation nurseries.

Fourth, the medicinal potential of *A. ebracteatus* should be

systematically explored and sustainably utilized, with raw materials sourced through artificial asexual propagation. The *Special Action Plan for Mangrove Protection and Restoration (2020 – 2025)* promotes market-driven conservation mechanisms and encourages the development of value realization pathways for mangrove ecological products. All parts of *A. ebracteatus* (roots, stems, leaves, fruits, and whole plants) possess documented medicinal properties and are used in traditional treatments for various ailments. If the public is permitted to rationally and scientifically utilize artificially propagated individuals (*e. g.*, from leaf cuttings or tissue culture) for producing liver-protective, skincare, beauty, and haircare products, this approach could generate socioeconomic benefits while fostering public engagement in conservation. Furthermore, such sustainable utilization models may enhance community stewardship and reduce illegal harvesting of wild *A. ebracteatus* populations.

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