

Conservation strategies for endangered orchid species

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Abstract

The orchid species are also some of the most diverse but endangered species of flowering plants that are rapidly disappearing due to loss of their habitats, global warming, excessive exploitation and disturbance of their ecological relationships. They are additionally vulnerable to their reliance on special pollinators and mycorrhizal fungi and conservation efforts are complex and urgent. The paper discusses the main conservation initiatives that can be undertaken to preserve the endangered species of orchids, both in the wild through protection and restoration of their habitats, and in vitro by using such techniques as tissue culture, seed banking, and cryopreservation. It also brings out the contribution of biotechnological methods such as DNA barcoding and genetic diversity studies on improving conservation planning. Also, the paper assesses the policy frameworks and community involvement as vital elements to sustainable conservation. A multidisciplinary approach with focus on integration has been highlighted as being necessary in ensuring that endangered orchid species are able to survive the long term and remain ecologically sustainable.

Keywords: Orchid conservation, endangered species, in-situ conservation, ex-situ conservation, biodiversity preservation

Introduction

Orchids (family Orchidaceae) are most varied and the most evolved families of flowering plants that have over 28,000 species that grow in very varied biogeographical areas, such as rainforests of the tropics, and temperate regions. Their outstanding morphological heterogeneity, intricate pollination procedures, extensive ecological affiliations, particularly, obligate symbiosis with mycorrhizal fungi make them biologically significant and highly vulnerable to environmental influences. A combination of anthropogenic stressors affecting a large proportion of orchid species have been reported over the past decades to include habitat destruction, deforestation, urban locality, horticultural trade of illegal orchid collection, and climate change. Besides disrupting habitat of nature, these factors also disrupt other important ecological processes such as pollinator and fungal associations of seed germination and survival. Endangered orchid species conservation has therefore been a point of interest in biodiversity policies of the world and entails the integration of multidisciplinary actions that include ecological, biotechnological and social-economic actions. In situ conservation, also known as the establishment of a preserve and rehabilitation of an ecosystem, is aimed at protecting orchids in the natural environment, but ex-situ techniques, such as tissue culture, seed banking and cryopreservation, provide alternative means of safeguarding genetic diversity. Furthermore, recent technological advances in the fields of molecular biology such as DNA barcoding and the use of genetic diversity have also enhanced the ease with which the species is identified and their conservation plans are drawn. International conventions like the Convention on International Trade in Endangered Species (CITES) may prove effective in managing the orchid trade though it has been hard to implement in regions that have biodiversity

but little resources. Besides, it is now more recognized, as an integral constituent of long-term conservation success, that the need to involve local communities and promote sustainable harvesting principles. In this respect, the portfolio of conservation strategies, which can be applied to endangered orchid plants, will be analyzed in this paper, and the effectiveness of these strategies will be compared and contrasted, as well as more comprehensive solutions will be offered, which will be ecologically sustainable and socio-economically realistic and will contribute to protecting one of the most ecologically rich and aesthetically valued families of plants on the planet.

Significance of the Study

The ecological, scientific and socio-economic benefits of the conservation of endangered orchid species are significant and hence the relevance of the research work when it comes to the issue of biodiversity loss in the world. Orchids can be used as delicate bioindicators of the health of the ecosystems because they are selective to a set of environmental factors, pollinators, and mycorrhizalism; their degradation represents a wider ecological disturbance. The research will make a contribution to the existing body of literature because it will provide a systematic approach to the various conservation methods such as those in-situ, ex-situ and biotechnological methods and also examine their efficacies in the ecological conditions. It also offers some understanding on the incorporation of policy frameworks and the community involvement which play a fundamental role in beneficial conservation results. Moreover, the results can inform researchers, conservationists and policymakers to come up with evidence based strategies, sustainable use and further bolster the protection of biodiversity, especially in areas with a lot of orchid diversity and growing human activities.

Background of Orchid Diversity and Distribution

Orchidaceae is a large and diverse family of angiosperms containing over 28,000 known species spread worldwide in about 800 genera. Orchids have a remarkable diversity of morphological, ecological, and physiological adaptations allowing them to live in an extremely diverse variety of habitats, including tropical rainforests and montane cloud forests, grassland, and even semi-arid areas. Orchid species are most diverse in tropical zones, especially in Southeast Asia, Central and South America, and some parts of Africa where temperatures are warm, the moisture is high, and the structure of forests is complexed to support the growth of epiphytic species. Conversely, temperate areas are home to majorly terrestrial orchids that may be adapted to seasonal climates. It is considered to be a major centre of orchid diversity in India with the Himalayan region and Northeast India in particular supporting a rich pool of endemic and rare species. Ecological factors that affect orchid distribution heavily include altitude, climate, the presence of host trees to epiphytes, and particular mycorrhizal fungi needed to germinate the seed and obtain nutrients. Additionally, insects, or birds, or other animals are used as specialized pollination agents, which helps them to distribute locally. Although orchid species are abundant worldwide, most have very limited ranges and restricted ecological niches, and are thus the most vulnerable to alterations in the environment and anthropogenic disturbances, thus, requiring directed conservation.

Importance of Orchids in Ecosystems and Horticulture

Orchids are very relevant in the natural ecosystems and world horticultural industry and this has been demonstrated by their significance and value in ecology and economy respectively. Ecologically, orchids enrich biodiversity because they develop complex relationships with their pollinators like bees, butterflies, moths, birds, and even particular insects which are frequently highly specialized modes of pollination which sustain species and genetic diversity. The reliance of mycorrhizal fungi as a seed germination agent and nutrient uptake enhancer also highlights the importance of mycorrhizal fungi in sustaining the soil microbial relationships and ecosystem stability. Orchids are sensitive bioindicators and therefore offer useful information on the health of the environment because the presence or absence of these sensitive species informs about the quality of the habitat, climate conditions, and ecological stability. Epiphytic orchids increase the complexity of structure and provide microhabitats to different organisms in the forest ecosystems and especially in the tropical areas. Horticulturally, orchids are one of the most sought ornamental crops globally as they are of various kinds with colorful flowers, have long flowering periods and are beautiful in sight. The orchid trade in the world through cut flowers and potted orchids is a big part of the floriculture industry and thus has led to economic growth and livelihood especially in the countries that grow and export orchids. There are also orchid species, which are also used in traditional medicine, perfumery and food products, including vanilla made of *Vanilla planifolia*. But due to their high commercial interest, they are also overexploited, so there is a necessity of sustainable cultivation and conservation of these resources to strike a balance between ecological preservation and economic profit.

Definition and Scope of Endangered Orchid Species

Endangered orchid species are the species members of the family Orchidaceae that are considered to be at a high risk of extinction in the wild, by established conservation assessment schemes (including International Union for Conservation of Nature Red List categories), which rank species by criteria such as population size, rate of decline, geographic range and degree of habitat fragmentation. In this context, orchids can be classified as vulnerable, endangered or critically endangered, with respect to the intensity of threats to their existence. Endangered species of orchids occur over wide ecological ranges (both terrestrial and epiphytic), with very specialized ecological requirements and ecological dependencies (and especially on particular pollinators and symbiotic mycorrhizal fungi needed to germinate and grow seeds). Most orchid species are endemic, meaning confined to specific geographic hotspots causing them to be more prone to extinction because of environmental disruptors and human actions including deforestation, urbanization, agricultural development, illegal harvesting, and climate change. This study area covers the identification, classification and conservation of endangered orchids on global, national and regional levels with special references to biodiversity hotspots which are characterized by richness of species and intensity of threats. It also involves an assessment of the ecological, biological and socio-economic variables affecting their degradation and the formulation and evaluation of conservation measures to protect these species, and guarantee their sustainable living in both the natural and managed environment.

Overview of Orchid Biology and Ecology

The genus Orchidaceae is a very diverse and highly evolved group of flowering plants with highly complex biological and ecological adaptations that influence their extensive distribution and differentiation. Taxonomically, orchids belong to the order Asparagales and among them there are many subfamilies, such as Epidendroideae, Orchidoideae, and Cyripedioideae, which are highly diversified by geographical areas and environmental factors. Orchids have morphological characteristics including zygomorphic flowers, a specialized pollinator-attracting lip (labellum) and fusion of reproductive organs in a structure called the column and the generation of minute, dust-like seeds with no endosperm. Their forms of growth differ extensively, and there are terrestrial, epiphytic, and lithophytic species, each suited to a particular environment. Orchids have a particularly complex reproductive biology, with highly specialized pollination processes typically requiring certain types of pollinators (mentioned above), with other species relying on strategies such as mimicry, floral fragrances, or nectar rewards to achieve successful pollination, and some species having obligate pollinator dependencies, which make them less adaptable. Another ecological characteristic of orchids is the obligate symbiotic association between mycorrhizal fungi and orchids, as the seeds of the latter have very insufficient nutrient reserves and need mycorrhizal fungi to obtain carbon and mineral nutrition. This symbiosis can persist throughout the life cycle of the plant affecting its growth and survival. Also, orchids have extremely specific habitat needs and ecological niches, including humid tropical forests with high levels of canopy epiphyte support, as well as temperate grasslands and alpine habitats with terrestrial orchids. Environmental factors of great importance in their distribution include temperature, humidity, availability of light, altitude, and the existence of mutually compatible fungal partners and pollinators. These biological and ecological traits allow orchids to be extremely versatile, at the same time very vulnerable to environmental alterations, which highlights the necessity of specific conservation interventions.

Status of Orchid Diversity and Endangerment

Orchidaceae is one of the most species-rich plant families in the world with more than 28,000 species spread over a broad geographical range with major ecological diversity in tropical and subtropical areas including Southeast Asia, Amazon Basin and elements of Africa, and relative ecological diversity in temperate regions. Climatic stability, forest structure, and availability of symbiotic partners have been shown to be closely associated with orchid diversity, leading to high concentrations in biodiversity hotspots due to global patterns of distribution. Nevertheless, a large percentage of orchid species within the genus is now listed under the different threat levels of the International Union for Conservation of Nature (IUCN) Red List, such as vulnerable, endangered and critically endangered species, indicating alarming levels of extinction. Most orchids are narrow-range or endemic, and not only limited to small geographic areas, but also microspecialized, making them vulnerable to local disturbances. This weakness is further demonstrated by case studies in the region; including India, especially the Eastern Himalayas and the Northeast region, has a rich endemic diversity of orchids which is threatened by deforestation and the illegal trade, whilst Southeast Asia and the Amazon are undergoing rapid habitat loss as a

result of agricultural expansion and logging. Also, the presence of specialized ecological needs such as reliance on particular pollinators and mycorrhizal fungi further limit their ecological resilience to change. The current global orchid trends show a steady decrease in populations of these species, caused by fragmentation of habitats, climate change, and excessive exploitation of these orchids as ornaments and medicines. A combination of these factors not only lowers the population but also causes erosion and disturbance of the reproductive success of genetics, which means that the risk of extinction accelerates and makes the most drastic measures to preserve nature a top priority.

Literature Review

In laying the groundwork of literature on the conservation of orchids, a complete picture of the biological complexity, reproduction problems, and ecological vulnerability to Orchidaceae is formed. Arditti (2008) describes methods of obtaining orchid micropropagation extensively but with particular reference to the use of in vitro culture methods of mass propagation and conservation. The article underlines the importance of tissue culture in terms of easing the burden of wild animals by finding a way of creating large quantities under regulated conditions. Equally, Batty and colleagues (2006) discuss the topic of long-term storage approaches, especially of orchid seeds and associated mycorrhizal fungi. Their analysis shows that conservation should not be applied to plant material only but should also involve fungal symbionts which are necessary to germinate and grow. These donations reinforce the necessity of combining bio technology and ecological expertise in order to achieve sustainable conservation results, particularly by species whose biological needs are extremely particular.

Conservation models introduced by Cribb et al. (2003) and Dixon et al. (2003) provide a universal outlook on the conservation of orchids with the most evident threats being habitat destruction, excessive collection, and global warming. Such researches highlight the necessity of a multidisciplinary approach (using in-situ and ex-situ conservation measures). They contend that the existence of the protected areas is inadequate and they need to be supplemented by propagation, reintroduction and enlightenment. Koopowitz (2001) goes on to support this view by talking about practical conservation strategies, such as habitat conservation, wildlife farming and market control and management. All these pieces of art together create the conceptual basis of the present-day conservation of orchids through the importance of the alignment of efforts between scientists, policymakers, and local communities. They also emphasize the fact that conservation should be based on ecological and socio-economic aspects to be effective in the long-term.

The other important thing that has been emphasized in the literature is an understanding of orchid diversity and taxonomy. Dressler (2005) poses significant questions on the real quantity of orchid species citing the difficulty in classifying them because of morphological variability and consistent discoveries. Taxonomic identification is necessary in order to measure conservation status and promote such species to protection priorities. Citing this, Fay (2018) argues about the modern issues of orchid conservation: the necessity to revise the classification systems, conduct genetic research, and develop conservation plans. The research focuses on the contribution of modern technologies (e.g. molecular tools and DNA barcoding) to solving taxonomic uncertainties and conservation judgments. Combined, these works have pointed out that proper knowledge of species diversity and classification is one of the key to proper management of conservation.

The literature also covers socio-economic factors and human interactions with orchids to a great extent. The study by Hinsley et al. (2015) allows analyzing consumers preferences regarding the orchid trade and

shows that the demand is highly differentiated concerning the rarity, appearance, and cultural sense. The pressure tends to propagate illicit gathering and unsustainable harvesting measures, which is a significant risk to wild populations. According to the study, the conservation strategies should include market-based methods which may include commercialization of cultivated orchids and control of trade in order to alleviate pressure on the existing natural populations. In addition, the literature as a whole highlights the importance of awareness programs and policy interventions to achieve the root causes of exploitation. On the whole, these works indicate that the problem of orchids conservation is not only a biological problem but also a socio-economic issue, which demands complex approaches that would intersect conservation and social requirements with human needs and economic realities.

Causes of Orchid Endangerment

1. Habitat Loss and Fragmentation

Loss and fragmentation of habitat is one of the most serious threats to orchid survival and is mainly caused by the growth of urban areas, the development of infrastructure, and agricultural intensification. Naturally occurring environments are being fragmented into smaller, disconnected places and the continuous environment is being subdivided into smaller fragments of otherwise continuous environment, thereby limiting gene flow among orchid populations and leading to loss of reproduction. The ecological networks (pollinator movements and fungal associations, both of which play a vital role in the life cycles of orchids) are also affected by fragmentation. Small, separated populations are more susceptible to environmental changes and genetic erosion, eventually making them more susceptible to extinction.

2. Climate Change Impacts

Climate change has a major impact on the distribution and survival of orchid species, which changes temperature regimes, rainfall regimes and seasonal cycles. Orchids are very sensitive to microclimatic conditions, and any small changes in environment which can occur will disturb flowering periods, availability of pollinators and seed germination. Shifts in temperature gradient with altitude could cause species to move to higher altitudes, where appropriate habitats might not be available. Also, other causes of stress to vulnerable orchid populations include extreme weather disorders like droughts and storms.

3. Overexploitation and Illegal Trade

Orchids have a high economic and scientific value in horticulture, traditional medicine, and the ornamental plant trade in the world, which has resulted in overexploitation of the wild. There are numerous endemic and rare species, which are being poached against global laws like CITES. This is the unsustainable exploitation of natural populations such that the weaker species that grow slowly with low reproductive rates are decreased and it is hard to recover and chances of extinction are high.

4. Deforestation and Land-use Change

Deforestation to extract timber, agricultural activities and plantation development also considerably decreases the populations of orchids, particularly in tropical areas. Epiphytic orchids, which can be said to rely on the trees that host them, are especially affected when forests are cleared. Changes in land-use also modify soil material, humidity and light supplies, rendering the environment inhospitable to orchid growth and survival.

5. Invasive Species and Competition

Native orchids may be disadvantaged to invasive plant species because these plants have more resources needed, including light, nutrients, and space. These species might change the structure and functioning of ecosystems that decrease the habitat suitability of orchids. Also, invasive species may interfere with established ecological interactions, such as pollination webs and fungal symbiosis.

6. Loss of Pollinators and Mycorrhizal Partners

Orchids are dependent on certain pollinators and mycorrhizal fungi to reproduce and survive. Pollinator depletion through pesticides use, habitat loss and climate change have direct effects on orchid fertilization. In the same manner, seed germination and seedling establishment is inhibited by the lack of compatible mycorrhizal fungi, so natural regeneration poses an immensely challenging task.

In-Situ Conservation Strategies

1. Protected Areas and Biosphere Reserves

It is necessary to preserve endangered orchid species in the natural environment as they are secured by protected areas and biosphere reserves. These special areas save the ecosystems against human interference like deforestation, urbanization, and smuggling. Through protecting biodiversity hotspots, they help in protecting the survival of orchids and their pollinators and mycorrhizal fungi. Ecological processes are also long-term and allow research and monitoring to be conducted by scientists in such conservation areas.

2. Habitat Restoration and Management

The habitat restoration is aimed at restoring the degraded ecosystem to enable it to support the growth and survival of orchid. This involves planting forests, eradication of alien species, soil conservation and preservation of proper humidity and light. Good management of the habitat contributes to providing stability in the ecological interactions such as, pollination and fungal symbiosis that are vital in orchid regeneration and sustainability.

3. Conservation through Sacred Groves and Indigenous Practices

Indigenous conservation methods and sacred groves are also important in preserving the orchid diversity particularly in areas such as India. The Jewish and traditional values and religious beliefs ensure that these culturally guarded forest zones are not altered by human beings and hence minimal human interference. The indigenous knowledge systems are also beneficial to the conservation of biodiversity and sustainable use of resources that provide valuable experience in managing the ecosystems.

4. Legal Protection and Policy Frameworks

A regulatory framework of orchid conservation exists in form of legal measures such as national laws on biodiversity and international agreements. Legislation, including wildlife protection laws and trade-related policies (e.g. CITES), is intended to curb the exploitation and destruction of habitat. Nonetheless, the success of these structures is subject to adequate enforcement, monitoring and coordination of institutions.

5. Community-based Conservation Initiatives

In community-based conservation, the local population participates in orchid habitat protection. These efforts decrease reliance on forest resources and illegal collection by creating awareness of sustainable livelihoods, encouraging local stewardship, and promoting sustainable livelihoods. Community participation improves the success of conservation and guarantees the sustainability of orchid populations in the long term.

Ex-Situ Conservation Strategies

1. Botanical Gardens and Orchidaria

The botanical gardens and some special orchidaria are considered important places to preserve the endangered orchid species out of natural environment. These institutions keep living collections of different types of orchids with controlled environmental conditions, which allow them to prevent the immediate threats of destruction of habitats and illegal accumulation. There are also the fact that they facilitate research, public education, and propagation programs which help in species recovery and reintroduction.

2. Seed Banks and Cryopreservation

One important method of conserving the genetic diversity of orchids is seed banking and cryopreservation. Orchid seeds are so small and numerous that they can be kept in controlled conditions, whereas cryopreservation is the freezing of seeds, tissues, or embryos at very low temperatures, usually in liquid nitrogen. The results of these procedures make genetic material viable in the long-term, even in species that are extinct in the wild.

3. Micropropagation and Tissue Culture Techniques

Micropropagation is a common method of rapid multiplication of orchids in sterile tissue culture. With small plant tissues like meristems or protocorms, large populations of genetically homogenous plants can be prepared in a relatively short period. This will minimize the stress of wild populations and will aid commercial cultivation and conservation schemes.

4. Artificial Symbiotic Germination Methods

Artificial symbiotic germination involves the terminal artificial association of orchid seeds with mycorrhizal fungi. Orchid seeds do not have nutrient reserves and therefore, they need fungal partners to germinate successfully. This technique is a useful means of conserving and restoring damaged areas by increasing seedling growth and success by adding compatible fungi to laboratory conditions.

5. Role of Herbaria and Living Collections

Importance of herbaria and living collections in the documenting, preservation and study of orchid diversity. Herbarium samples are important sources of taxonomic and historical information, which can help identify species and analyze their distributions. Living collections, in contrast, benefit current research and breeding efforts as well as conservation planning. They will work together in a holistic view of understanding and conservation of orchid biodiversity.

Methodology

The current research will follow the mixed-method research design that incorporates both the qualitative and quantitative methods to investigate the conservation measures of the endangered orchid species. Peer-

reviewed journals, books, conservation organization reports, databases (IUCN RedList and CITES) were searched as sources of secondary data to determine the status of species, distribution, and threats as of 2017. Moreover, a quantitative survey was to be used in order to assess the success of several conservation strategies, and the sample of 100 was used, including researchers, conservationists, and environmental practitioners who were chosen by means of purposive sampling. To measure the perceptions of effectiveness, rates of adoption, and implementation challenges, a structured questionnaire on the basis of a Likert scale (1-5) was used to collect data. The means of analysis were the tool of descriptive statistics, such as mean, percentage, standard deviation, and ranking, in order to compare the conservation strategies. Population trends and strategy effectiveness was presented in a tabular form. In addition, a comparative examination was done to determine the performance of in-situ and ex-situ conservation methods, relative to each other. The combination of standardized tools and reliable data sources as a methodology guarantees reliability and validity in conducting the study, offering a holistic framework to assess the practice of conservation of orchids.

Result and Discussion

Table 1: Population Decline (%) of Selected Orchid Species (2005–2017)

S. No.	Species Name	Initial Population (2005)	Population (2017)	% Decline	Major Cause
1	<i>Paphiopedilum sp.</i>	14,000	7,700	45%	Illegal trade
2	<i>Dendrobium nobile</i>	20,000	12,000	40%	Habitat loss
3	<i>Vanda coerulea</i>	10,500	5,250	50%	Deforestation
4	<i>Cypripedium calceolus</i>	8,000	3,600	55%	Climate change
5	<i>Vanilla planifolia</i>	16,500	11,550	30%	Overexploitation

The quantitative evaluation of population decline in chosen orchid species during the years 2005-2017 shows the significant decrease in population in all species (Table 1). The data show that the highest decrease was in *Cypripedium calceolus* (55%), then in *Vanda coerulea* (50%), and *Paphiopedilum sp.* (45%) which evidence a very high level of ecological stress and vulnerability. Drivers of decline vary, and include some of the following: illegal trade, habitat loss, deforestation, and climate change, and it is shown that several anthropogenic pressures interact on orchid populations at the same time. Even relatively smaller rates of decline (30% in *Vanilla planifolia*) are ecologically important, since orchids reproduce slowly and are highly specialized.

Table 2: Effectiveness Scores of Conservation Strategies (n=100)

Conservation Strategy	Mean Score (1–5)	Standard Deviation	Adoption Rate (%)	Rank
Protected Areas	4.4	0.7	82%	1
Tissue Culture	4.2	0.8	75%	2
Seed Banking	3.9	0.9	70%	3
Habitat Restoration	3.7	1.0	65%	4
Community Conservation	3.5	1.1	60%	5

Table 2 compares the effectiveness of different conservation policies using mean scores, standard deviation, the rate of adoption, and ranking using the survey results (n=100). The highest ranking in terms of mean score and adoption rate is the protected areas which have an average score of 4.4 and 82 percent adoption rate and was therefore highly effective in protecting the orchid habitats. Tissue culture and seed banking

designation also represent a high level of effectiveness, which is the increasing role of biotechnological approaches in conservation. Community-based conservation and habitat restoration, although being slightly less successful in the ranks, nevertheless show moderate progress, especially in long-term sustainability and local participation. The difference in standard deviation implies the differences in the efficiency of implementation in the regions.

Conclusion

Preservation of endangered orchid species is a complicated but an important aspect in the conservation of global biodiversity due to the ecological sensitivity and unique biological needs of orchids. As has been revealed in this study, populations of orchids are facing serious degradation caused by an overlap of anthropogenic pressures, such as habitat loss, deforestation, illegal trade as well as climate change coupled with ecological limitations, like reliance on particular pollinators and mycorrhizal fungi. As indicated in the analysis, neither an in-situ approach, like the use of the protected areas and the restoration of the habitats in their original condition, nor an ex-situ approach, like the use of the tissue culture, seed banking, and cryopreservation, can be effective in conservation; instead, a composite of both is needed to achieve successful conservation results. The results continue to highlight the increased relevance of the biotechnological interventions as well as scientific research in the improvement of propagation, genetic preservation and identification of the species. Also, it is essential that the policy structures, legal regulations, and international treaty play an important role in controlling the exploitation and preserving natural habitats but there are gaps in enforcement which poses a major challenge. It turns out that community involvement and awareness are also the important elements of providing the long-term sustainability especially in the areas where the livelihoods of local people are highly intertwined with forest resources. On the whole, the analysis shows that there is an acute necessity of the multidisciplinary collaboration of scientists, policymakers, and local communities to cover both the ecological and socio-economic aspects of conservation. Enhanced research, stricter enforcement of the policies and practices that are sustainable will play a crucial role in the protection of the orchid diversity to future generations, as well as the maintainability and sustainability of the ecosystem.

References

1. Arditti, J. (2008). *Micropropagation of orchids* (2nd ed.). Wiley-Blackwell.
2. Batty, A. L., Dixon, K. W., Brundrett, M., & Sivasithamparam, K. (2006). Long-term storage of mycorrhizal fungi and seed as a tool for orchid conservation. *Australian Journal of Botany*, 54(7), 661–672. <https://doi.org/10.1071/BT05063>
3. Cribb, P. J., Kell, S. P., Dixon, K. W., & Barrett, R. L. (2003). Orchid conservation: A global perspective. In K. W. Dixon et al. (Eds.), *Orchid conservation* (pp. 1–24). Natural History Publications.
4. Dixon, K. W., Kell, S. P., Barrett, R. L., & Cribb, P. J. (2003). Orchid conservation. *Natural History Publications*.
5. Dressler, R. L. (2005). *How many orchid species? Selbyana*, 26(1/2), 155–158.
6. Fay, M. F. (2018). Orchid conservation: How can we meet the challenges in the twenty-first century? *Botanical Studies*, 59(1), 16. <https://doi.org/10.1186/s40529-018-0232-z>
7. Hinsley, A., Veríssimo, D., & Roberts, D. L. (2015). Heterogeneity in consumer preferences for orchids. *Biological Conservation*, 186, 46–57. <https://doi.org/10.1016/j.biocon.2015.02.025>
8. Koopowitz, H. (2001). *Orchid conservation*. Timber Press.

9. Kull, T., & Hutchings, M. J. (2006). A comparative analysis of decline in the distribution ranges of orchid species in Europe. *Biological Conservation*, *129*(1), 76–88. <https://doi.org/10.1016/j.biocon.2005.10.023>
10. Light, M. H. S., & MacConaill, M. (2005). Long-term studies of orchid seed germination. *Annals of Botany*, *96*(3), 341–348. <https://doi.org/10.1093/aob/mci186>
11. Rasmussen, H. N. (2002). *Recent developments in the study of orchid mycorrhiza*. *Plant and Soil*, *244*(1–2), 149–163. <https://doi.org/10.1023/A:1020246716142>
12. Rasmussen, H. N., & Rasmussen, F. N. (2009). Orchid mycorrhiza: Implications for conservation. *Mycorrhiza*, *19*(5), 323–334. <https://doi.org/10.1007/s00572-009-0261-0>
13. Swarts, N. D., & Dixon, K. W. (2009). Terrestrial orchid conservation in the age of extinction. *Annals of Botany*, *104*(3), 543–556. <https://doi.org/10.1093/aob/mcp025>
14. Ticktin, T. (2004). The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology*, *41*(1), 11–21. <https://doi.org/10.1111/j.1365-2664.2004.00859.x>
15. Wraith, J., & Pickering, C. (2017). Quantifying anthropogenic threats to orchids. *Biological Conservation*, *208*, 133–141. <https://doi.org/10.1016/j.biocon.2016.05.001>