Status Survey and Conservation Action Plan

Orchids

Edited by Eric Hágsater
and Vinciane Dumont

Compiled by Alec M. Pridgeon

IUCN/SSC Orchid Specialist Group

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Foreword

The goal of this Action Plan is to document the diversity and suggest conservation strategies for orchids in general. We cannot protect all species of one of the largest plant families in the world, and this is not our intent. Our approach therefore is quite different from other Action Plans. We will not address the question of what the most endangered species are, but rather how to protect habitats with high diversity and important orchid populations. To do so, we asked experts from all over the world to contribute their knowledge and interpretations based on their particular circumstances. As a result, this Orchid Action Plan reflects very different opinions on orchid conservation strategies, making it a most useful and helpful document.

Eric Hágsater
Chair, IUCN/SSC Orchid Specialist Group
Mexico

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Eric Hágsater
Chair, IUCN/SSC Orchid Specialist Group
Mexico

Vinciane Dumont
Deputy Chair, IUCN/SSC Orchid Specialist Group
Switzerland

Executive Summary

For centuries orchids have gripped the imagination, inspiring mass-collection in the latter half of the nineteenth century and extending to certain genera such as *Paphiopedilum* in recent times. Although CITES legislation offers protection to the most endangered species by placing them on Appendix I, the remaining 20,000 or so orchid species are included in Appendix II either because they might become threatened by trade so monitoring is needed, or because they look like other orchid species listed in the Appendices. However, the greatest threat to orchid diversity is habitat loss; for orchids this can occur on a very small scale as a single tropical tree can bear hundreds of epiphytic orchid species. The scale of threat to orchid diversity then reaches frightening proportions as millions of hectares of habitat are lost annually to ranching, monocrop agriculture, mining, logging, and urban development. Even when fragments of the original habitat are left, gene flow and number of pollinators are significantly reduced. Biologists now agree that we are entering a period of extinction not experienced since the end of the Cretaceous Period. Although we have the technology to reverse most of the trends, the commitment to do so regardless of the costs involved simply is not there on a worldwide scale when the pressures caused by overpopulation command different priorities.

The Orchid Action Plan chronicles the threats to certain critical species, but more importantly to critical habitats that host extraordinarily high orchid diversity and endemicity. It explores and recommends specific ways that national and local government legislators, scientists, and orchid conservationists and growers can all help to reverse present trends. The facts and viewpoints presented in this comprehensive document update and supplement the information available to conservation organizations and agencies throughout the world so that they can lobby their appropriate government offices more effectively.

The first half of the Plan discusses 1) the unique biology of the orchid family; 2) threats posed by habitat loss and overcollecting; 3) *in situ* strategies of habitat conservation and management; 4) *ex situ* strategies of artificial propagation and seed banking; and 5) the desperate need for more research and education from the international level down to the local orchid society. The second half of the Plan details the present status of knowledge, diversity, threats, and case histories in many of those countries or regions richest in orchid species: Mexico, Costa Rica and Panama, Ecuador and neighbouring countries, the Guayana region, the United States and Canada, Caribbean Islands, Europe, North Africa, the Near East, North Asia and Japan, India, Africa, Madagascar and surrounding islands, Australia, south-east Asia, and the south-west Pacific islands.

This Action Plan advocates dual strategies to conserve orchid diversity: establishing *in situ* protection of natural habitats and promoting trade of artificially propagated plants and cut flowers. Among the specific priority actions recommended at the close of the Plan are the following:

- Preparation of global checklists of orchid species and identification of areas of high biodiversity;
- Legislation and funding to protect, research, and properly manage and monitor such areas;
- Availability of propagation material of rare and new species for commercial development, preferably in those countries where the species are native, thereby reducing demand for wild-collected plants;
- Responsible salvage of orchid plants from areas of deforestation where appropriate, followed by artificial propagation and distribution;
- Preparation of educational programmes on orchids and their role in biodiversity by orchid societies and botanical gardens for the general public;
- More active registration of *bona fide* herbaria and scientific institutions belonging to CITES party countries to enable freer movement of pressed and liquid-preserved plant materials for scientific purposes;
- Sharing of plants, seeds, and pollen among orchid growers and botanical gardens.

Alec Pridgeon, Royal Botanic Garden, Kew, UK

Résumé

Depuis toujours, les orchidées ont éveillé l'imagination, inspirant de grandes collections dês la seconde moitié du dix-neuvième siècle et perpétuant certaines espèces comme le *Paphiopedilum* jusqu'à nos jours. Alors que la réglementation de la CITES permet la protection de la plupart des espèces menacées en les plaçant en Annexe I, le reste des 20'000 espèces d'orchidées sont inscrites en Annexe II, soit parce qu'elles risquent d'être menacées par le commerce (rendant donc un contrôle nécessaire), soit parce qu'elles ressemblent à des espèces figurant dans ces annexes. Toutefois, la plus grande menace qui pèse sur la diversité des orchidées est la perte de leurs habitats. Ceci est vrai même à une très petite échelle puisqu'un seul arbre tropical peut contenir des centaines d'espèces d'orchidées épiphytes. L'impact de cette menace atteint des proportions effrayantes lorsque des millions d'hectares d'habitats disparaissent chaque année. En effet, la croissance démographique engendre le développement de l'élevage, de l'agriculture, de l'exploitation minière ou forestière et des villes. Même si quelques fragments de l'habitat original sont préservés, la diversité du patrimoine, les sources génétiques et les variétés de pollinisateurs sont sérieusement réduites. Les biologistes s'accordent actuellement pour dire que nous entrons dans une époque d'extinction, comme il n'en est plus arrivé depuis la période du Crétacé. Malgré le fait que nous maîtrisons la technologie pour inverser la plupart de ces processus, le budget nécessaire à l'échelon mondial n'est pas accordé, car les pressions causées par la surpopulation imposent d'autres priorités.

Le Plan d'Action des Orchidées répertorie certaines espèces menacées de façon critique, mais aussi ce qui est plus important, les habitats contenant des degrés de diversité et endémicité en orchidées extraordinairement élevés. Il recommande également des règles spécifiques aux représentants de gouvernements, locaux ou nationaux, aux scientifiques, et aux cultivateurs d'orchidées qui peuvent aider à renverser les tendances actuelles. Les faits et les points de vue énoncés dans ce document, accessible à tout un chacun, complètent et mettent à jour les informations disponibles pour les organisations de conservation et agences à travers le monde, de telle sorte qu' elles puissent aussi transmettre plus efficacement leurs connaissances à leur gouvernement respectif.

La première moitié du Plan détaille 1) la spécificité biologique de la famille des orchidées; 2) les menaces représentées par la perte de l'habitat et la surcollection; 3) les stratégies *in situ* de préservation et de gestion d'habitat; 4) les stratégies *ex situ* de propagation artificielle et de banque de graines; 5) le besoin urgent de recherches et d'éducation depuis le niveau national jusqu'aux sociétés d'orchidophiles.

La seconde moitié du Plan répertorie l'état des connaissances actuelles, de la diversité, des menaces, et les cas historiques de pays ou régions riches en espèces d'orchidées tels que: le Mexique, le Costa Rica et Panama, l'Equateur et les pays voisins, le bassin de l'Amazone et la Guyane, les Etats-Unis et le Canada, les Caraïbes, 1' Europe, l'Afrique du Nord, le Proche-Orient, le nord de l'Asie et le Japon, l'Inde, l'Afrique de l'ouest et de l'est, Madagascar et les îles environnantes, l'Australie, le sud de l'Asie et les îles du sud-ouest Pacifique.

Le Plan d'Action présente la dualité de la stratégie pour conserver la diversité des orchidées: 1) en préconisant la préservation des habitats naturels, 2) en promouvant la propagation artificielle et le commerce des plantes cultivées et des fleurs coupées. Les actions spécifiques prioritaires recommandées dans le Plan sont les suivantes:

- Préparation de listes d'inventaire des espèces d'orchidées et identification des régions à haute biodiversité;
- Réglementation et récolte de fonds pour la protection, la recherche et la gestion saine de tels espaces;
- Mise à disposition d'espèces rares ou nouvelles, pour la reproduction à but commercial, en favorisant les pays d'où ces espèces sont originaires, réduisant ainsi la demande de récoltes sauvages;
- Si approprié sauvetage efficace de plantes d'orchidées des aires de déforestation, puis propagation artificielle et distribution;
- Préparation de programmes d'éducation sur les orchidées et leur rôle dans la biodiversité par des sociétés orchidophiles et des jardins botaniques à l'intention du grand public;
- Enregistrement plus actif des herbiers et des institutions scientifiques de confiance des pays signataires de la CITES, afin de faciliter l'échange, à des fins scientifiques, de plantes conservées sous forme séchées ou dans du liquide;
- Partage de plantes, graines et pollens entre les cultivateurs d'orchidées et les jardins botaniques.

Trad. Madame Anne Taub, and Vinciane Dumont
Société Suisse d'orchidophilie, Switzerland

Resumen Ejecutivo

Las orquídeas han inspirado la imaginación durante siglos, esto ha sido causa de su sobrecolecta masiva durante la segunda mitad del siglo diecinueve, misma que se ha prolongado en ciertos géneros como *Paphiopedilum* hasta nuestros días. Aunque la legislación CITES ofrece protección a las especies más amenazadas colocándolas en el Apéndice I, las 20,000 especies de orquídeas restantes se consideran amenazadas por la pérdida de su hábitat debido al desarrollo y a la deforestación y están incluidas en el Apéndice II. Un solo árbol tropical puede sostener cientos de especies de orquídeas epífitas y literalmente miles de especies de plantas y animales conjuntamente. El alcance de la deforestación por lo tanto toma proporciones pavorosas al perderse millones de hectáreas de bosques anualmente para la ganadería, plantaciones, el corte de madera, la agricultura, el desarrollo urbano, y la minería. Aún cuando se dejen fragmentos del hábitat original, el flujo genético y el número de polinizadores se ven significativamente reducidos. Los biólogos están de acuerdo ahora en que estamos entrando en un período de extinciones no visto desde el final de Cretáceo. Aunque tenemos la tecnología para revertir la mayoría de estas tendencias, la voluntad de hacerlo, tomando en cuenta el costo, simplemente no existe a escala mundial pues las presiones causadas por la sobrepoblación demandan prioridades diferentes.

El Plan de Acción para Orquídeas, más que una crónica de las amenazas a ciertas especies críticas, lo es respecto de los hábitats con gran diversidad y endemicidad de especies de orquídeas. También explora y recomienda formas concretas mediante las cuales los legisladores gubernamentales locales, científicos y cultivadores de orquídeas pueden ayudar a revertir las tendencias actuales. La información presentada en este documento pone al día y complementa información para que organizaciones y agencias conservacionistas en todo el mundo puedan cabildear a sus gobiernos de manera más efectiva.

La primera parte del plan discute 1) la biología singular de la familia de las orquídeas; 2) las amenazas representadas por la pérdida del hábitat y la sobrecolecta; 3) estrategias *in situ* para la preservación y manejo del hábitat; 4) estrategias *ex situ* para la propagación artificial y bancos de semillas; y 5) la necesidad impostergable de mayor investigación y educación desde el nivel nacional hasta las sociedades orquidófilas locales. La segunda mitad del plan detalla el estado actual del conocimiento, la diversidad, las amenazas y ejemplos de casos concretos en muchos de los países o regiones más ricas en especies de orquídeas: México, Costa Rica y Panamá, Ecuador y los países vecinos, las Guayanas, los Estados Unidos y Canadá, los Islas del Caribe, Europa, el Norte de Africa, Medio Oriente, Asia del Norte y Japón, la India, Africa del Sur y Oriental, Madagascar y las islas circundantes, Australia, Asia suroriental, y las islas del Pacífico suroccidental.

El Plan de Acción está a favor de una estrategia doble para conservar la biodiversidad en orquídeas — conservar los hábitat naturales y fomentar la propagación artificial y comercio de plantas propagadas y flor cortada. Entre las acciones concretas prioritarias que se recomiendan al final del Plan están las siguientes:

- Preparar listados globales de especies de orquídeas e identificación de las áreas de alta biodiversidad;
- Legislar y financiar la proteción, investigación, manejo y monitoreo apropiado de áreas de alta biodiversidad;
- Fomentar la disponibilidad de especies raras y nuevas para los propagadores comerciales, preferentemente en los países de donde las especies son nativas, de manera que se disminuya la demanda de plantas silvestres;
- Rescatar responsablemente las plantas de orquídea de áreas de deforestación, seguido de su propagación artificial y distribución;
- Preparar programas educativos sobre orquídeas por parte de sociedades orquidófilas y jardines botánicos para el público en general;
- Un registro más activo de los herbarios e instituciónes científicas de CITES para el intercambio de material prensado y conservado en líquido para uso científico;
- Fomentar y compartir plantas, semillas y polen entre orquidófilos aficionados y jardines botánicos.

Traduc. Eric Hágsater, Asociación Mexicana de Orquideología, México

Chapter 1

Introduction

1.1 Interest for Conservation

Orchids are some of the best known and loved plants by amateurs and scientists alike, although sadly many species are being driven to extinction by either direct or indirect human activities. The preparation of a conservation Action Plan for the Orchidaceae, a family comprising some 20,000 species, therefore seemed a daunting task, but this compilation of views and experience from many experts in the field has provided underlying principles which can be used to further orchid conservation. Although orchid conservation must be undertaken at a local level, the strategies discussed in this Action Plan are general enough that they can provide a conceptual framework for actions, irrespective of the species concerned.

The orchid family displays a wide variety of unique morphological and anatomical adaptations, a diversity which few other plant families match. Their distribution ranges from desert and semiscrub, rain forest and cloud forest, to tundra ecosystems. This ecological complexity, coupled with their popularity worldwide, inspires an urgency for orchid conservation while the pressure on the natural environment increases daily.

Orchids are pollinated mainly by insects or birds which are attracted to the shapes, colours, and/or a great variety of fragrances of the flowers. Most species provide only nectar or oils as a reward, and in fact many advertise false rewards, achieving pollination through deceit. The pollinator-plant relationship is often species-specific. Most members of the family rely heavily on intimate association with one or several species of mycorrhizae (fungi that associate with plant roots in a symbiotic relationship) which plays a major role in nutrient acquisition and is especially important for seed germination. Since mycorrhizae are adapted to very specific substrate chemistry and conditions, orchids which are their obligate associates are also strictly limited to those specific habitats. This helps to explain why some orchids occur in very limited ecological niches.

1.2 The Action Plan

The main goal of this Action Plan is to ensure that orchid conservation is promoted by a wide array of people and organizations. It is recommended that all members of the IUCN/SSC Orchid Specialist Group (OSG) (listed at the end of this publication) be used as focal points for regional orchid conservation activities. These individuals then need to liaise with the Chair of the OSG (which we hope will have a small Secretariat as a result of this Action Plan), who will then be able to disseminate the experiences gained from field projects to others, as well as highlight areas of conservation concern. While most orchidologists bemoan the loss of habitat and species, there is not enough action being undertaken on the ground to halt the loss of orchid biodiversity, and any actions helping to reverse the trend must be highlighted and supported politically, technically, and financially.

To guide the reader, a review of the taxonomy and biogeography of the family is presented in chapter 2 which, along with this introduction, provides background helpful to the reader while considering the conservation strategies presented in this Action Plan. The third chapter is a report on the threats to orchids worldwide. While there are numerous threats to orchids, many (e.g. invasive alien species, wood-cutting) endanger other plant or animal species as well. Therefore, conservation actions directed to the habitat level will protect a myriad of other species as well as orchids. However, some threats are specifically aimed at individual species (e.g. overcollecting), and require specific conservation strategies (e.g. artificial propagation, better enforcement of legislation).

The fourth chapter gives an overview of some of the existing and possible conservation strategies that have local or global applications. The chapter begins with an explanation of some of the international protection conventions that are presently in place. Although little used, some of these conventions and regulations could have a significant impact on orchid conservation. The dual strategies of *in situ* and *ex situ* conservation are addressed separately in this chapter while the importance of the tools of research and education are also stressed.

The bulk of the Action Plan is composed of regional accounts of the status of orchid distribution and conservation. This chapter as a whole illustrates the enormous diversity and range of orchids worldwide while highlighting the need to develop systematic orchid checklists, conservation status reviews, and conservation programmes for species or habitats under threat. Each regional account discusses the threats to local orchid diversity, current conservation measures, and some site-specific recommendations. Case histories of exemplary orchid taxa of each region are presented to illustrate the urgency for conservation action.

The final chapter of the Action Plan opens with a general summary of the needed actions and is followed by an outline of specific priority projects that should be implemented. It is hoped that this Action Plan will be completely revised six years following publication, and that the recommended activities presented here will be completed so that other activities aimed at helping orchid conservation will then be able to be undertaken. Conservation work (from basic ecological research to hands-on management) is an ongoing process and must build on previous work, all with the common goal in view: that no more species should be allowed to disappear, and conditions that allow species to evolve to the constantly changing world must be maintained.

Chapter 2

The Orchid Family (Orchidaceae)

2.1 Patterns of Diversity

The Orchidaceae is among the largest families of flowering plants. Species counts range from 17,500 (Mabberley 1990) to 30,000-35,000 (Garay and Sweet 1974; Gentry and Dodson 1987); well-documented reports estimate c. 20,000 species (Atwood 1986; Dressier 1993b). Although the largest number of genera and species may be attributed to another group of plants (Asteraceae or Compositae, the sunflower family), few would doubt the pre-eminence of the Orchidaceae in beauty and in the complexity of its flowers and pollination mechanisms. The orchids also excel in colours, fragrances (Kaiser 1993; Senghas 1993), and vegetative size range, from microscopic plants in *Platystele* and *Bulbophyllum* to long vines in *Vanilla* and gigantic plants in *Grammatophyllum* and *Cyrtopodium.* Orchids grow in all terrestrial ecosystems except the poles and extremely dry deserts, but their greatest diversity is found in the tropics. They can grow on the ground on many soil types (the ancestral substrate; Benzing and Atwood 1984), on rocks, and many species have an epiphytic growth habit, that is they grow on other plants or structures (e.g. telephone wires) using them for physical support. There are also well-documented cases of fully subterranean orchids in Australia (Dixon *et al.* 1990).

Several factors confound a precise species count of the Orchidaceae. Some orchids with extensive geographical ranges tend to have different names for each floristic region or country, and horticulturally important orchids are often redundantly described because of the disproportionate attention they receive from orchid growers. This trend has led to accusations that "... far too often new names have been given to plants already described and named; the synonymy in the Orchidaceae is probably higher than in any other group" (Seidenfaden and Wood 1992). On the other hand, many 'superspecies', encompassing a myriad of synonyms, have been shown to have too large a circumscription, and many of the former synonyms are currently treated as valid species (e.g. Romero 1994). It is difficult to make a prediction, but it would appear that careful revisionary work may show that there are many more species than we had anticipated (e.g. Luer 1986-1993; Gentry and Dodson 1987; Hágsater 1993a, b; Bennett and Christenson 1994). Another factor, the few professional botanists working on Orchidaceae compared to the number working on Asteraceae (c. 12 orchid taxonomists versus c. 200 in the Asteraceae, *fide* Gentry and Dodson 1987) may also contribute to the limited number of comprehensive revisions in the Orchidaceae and therefore to reliable estimates of the number of orchid species.

2.1.1 Distribution

Orchids are far more diverse in the tropics than in any other ecosystem. Dressier (1993b) recognised 803 genera with a total of 19,501 species for the entire family. Thirty-six genera, each with 100 or more species, comprising 10,849 species (56% of the total) are found in the tropics. Of these 36 genera only a few also occur marginally in subtropical regions (e.g. *Epidendrum, Habenaria*), and 13 are exclusively neotropical. These include two of the most diversified genera: *Pleurothallis,* which with an estimated 1120 species constitutes the largest genus of Orchidaceae, and *Epidendrum* (800 species). The second largest genus, *Bulbophyllum* (1000 species), has a pantropical distribution with a large proportion of the species in tropical Asia (Vermeulen 1991). *Dendrobium,* the third-largest genus, is found in India and tropical and subtropical Asia (Bechtel *et al.* 1992). In general, the epiphytic flora of tropical Africa and Australasia is impoverished compared to that of the Neotropics (Madison 1977; Gentry 1982a, 1988), but the lack of comprehensive checklists of the orchids of the Paleotropics makes accurate comparisons impossible.

The recent availability of a checklist of the orchids of the New World in a database format (Dodson, unpublished) allows further study of the distribution of the orchids within this hemisphere. The database contains 10,967 accepted names (i.e. not thought to be synonyms of other species). Distribution of these orchids within the Neotropics is by no means even as seen in Table 2.1. Southern Central America and north-west South America (Costa Rica, Panama, Colombia, Venezuela, Ecuador, Peru, and Bolivia) have the highest number of species. Ecuador (3270 species) and Colombia (2899 species) have the most diverse orchid floras. Costa Rica and El Salvador have the largest number of species per km^2.

Several factors appear to influence the distribution pattern of orchid species. Gentry and Dodson (1987) proposed that epiphyte orchid diversity increases along moisture and latitudinal gradients (see also Gentry 1988). In their analysis, the neotropical site with the largest number of species was La Selva, Costa Rica (with 4000 mm of annual rainfall); the one with the lowest was Capeira, Ecuador (804 mm). The peak in epiphyte diversity appears to be between 1000 and 2000 m elevation, somewhat lower in Costa Rica and Panama (Gentry and Dodson 1987). This elevational range is perhaps important because of the greater microsite differentiation there (Gentry and Dodson 1987). Other explanations put forward to explain high plant diversity in the northern Andes are the 'evolutionary explosion' hypothesis of Gentry (1982a), generated by the relatively recent uplift of the Andes; founder events associated with shifts in pollinators (Gentry and Dodson 1987); and the colonisation of habitats left vacant by retreating glaciers (Hirtz 1993).

Figures of local endemism are invariably cited in most recent orchid floras and monographs. Rather than reviewing these figures, however, it should be emphasised that current knowledge of orchid floristics is highly uneven. Ecuador, for instance, has had a disproportionately high number of professional botanical collectors compared to Colombia, Peru, and Bolivia, and Costa Rica and Panama more than other Central American countries. The unevenness is detectable even within countries. In Venezuela the 'Cordillera de la Costa' is floristically better known than the Venezuelan Andes, and the tepui summits are better sampled than the surrounding lowland forest. Although many 'hot spots' of orchid endemism have been identified (New Guinea, Madagascar, the Chocó region of Colombia and Ecuador, coastal Brazil, and the Guayana highlands), we need to compile a global checklist of orchid species (such as Dodson's for New World orchids) to make realistic assessments of endemism and, most important of all, to identify areas/countries that possibly have received little attention from plant collectors.

Orchidaceae is a rapidly evolving pollinator-oriented family (Darwin 1862; Benzing 1987; Dressier 1981b). Large numbers of small seeds that favour the expression of genetic variability and high dispersal rates across geographical/ecological barriers, relatively rapid life cycles, high plasticity in floral architecture and fragrance, and preadaptation for epiphytism may account for the high diversity found in the orchids (Gentry and Dodson 1987, 1991; Burns-Balogh and Bernhardt 1988). Most plants have evolved incompatibility between stylar tissue and pollen of closely related species that function as a hybridisation barrier. Orchids rely instead on mechanical and/or ecological factors for barriers to hybridisation, such as different pollinator, different microsites on the same pollinator, and different phenologies (van der Pijl and Dodson 1966; Bechtel *et al.* 1992). As a result, orchid growers have been able to make a multitude of intrageneric and intergeneric hybrids. From the time the first hybrid was flowered and named in 1856, more than 100,000 hybrids have been registered (Bechtel *et al.* 1992), over three times the number of species accepted in Dressier (1993b). Just the 1986-1990 Addendum to *Sander's List of Orchid Hybrids* (Royal Horticultural Society 1991) has 779 pages and weighs nearly two kilograms! It should be emphasised, however, that crossability is usually confined to genera within a subtribe (Dressier 1981b), and that "the majority of commercially important genera involved in hybridisation can almost be counted on two hands" (Bechtel *et al.* 1992).

2.1.2 Known status of orchids

Knowledge has evolved rapidly in the field of orchidology in the last ten years. The publication of Dressler's *The Orchids: Natural History and Classification* (1981b) and *Phylogenyand Classification of the Orchid Family* (1993) were major landmarks in the field. Much work on phylogenetic relationships is currently in progress, some based on plastid DNA (Chase and Palmer 1992; Cameron *et al.* 1994), others on morphological characters (Freudenstein and Rasmussen 1994; Freudenstein and Rasmussen, in progress), others combining both types of data (Albert 1994). Anatomical studies have flourished as well (see H. Kurzweil bibliography in Dressier 1993b; Judd *et al.* 1993; Stern *et al.* 1993a, b). We need, however, more systematic studies of species (Freudenstein and Doyle 1994) and generic complexes (Albert and Pettersson 1994). These studies, whether or not they are widely accepted, provide new perspectives on the species and generic concepts currently employed in orchid systematics. Finally, there is a wide gap in our knowledge of orchid ecology, particularly in highly diverse groups (i.e. Pleurothallidinae and Bulbophyllinae). The lack of ecological research is also acute in areas with highly diverse orchid floras (i.e. montane forests of New Guinea, Costa Rica, and the Andes of Ecuador and Colombia). We should encourage both the protection of some of these areas and ecological studies in those facing imminent destruction.

Acknowledgements

I am grateful to P.L. Beer-Romero for useful comments, to J. Freudenstein for providing references, to C. H. Dodson for kindly providing a copy of his electronic checklist of the orchids of the New World, and to the American Orchid Society, the Eastern Orchid Congress, and the Massachusetts Orchid Society for their financial support.

Gustavo A. Romero, Oakes Ames Orchid Herbarium, Harvard University, USA

Table 2.1.1 **Area and number of orchids in countries of the continental New World (except the USA and Canada).**

Country	Area[1]	Orchids[2]	Orchid index[3]
Brazil	5,256,992	2,291	0.44
Argentina	1,715,584	107	0.06
Mexico	1,218,240	1,008	0.83
Peru	793,752	1,625	2.05
Colombia	703,392	2,899	4.12
Bolivia	678,480	1,032	1.52
Venezuela	563,280	1,429	2.54
Chile	464,200	51	0.11
Ecuador	285,008	3,270	11.47
Paraguay	251,208	121	0.48
Guyana	132,768	490	3.69
Uruguay	115,448	28	0.24
Surinam	101,176	431	4.26
Nicaragua	91,408	639	6.99
Honduras	69,224	478	6.91
Guatemala	67,248	669	9.95
French Guiana	56,200	358	6.37
Panama	48,488	1,030	21.24
Costa Rica	31,440	1,446	45.99
Belize	14,184	279	19.67
El Salvador	13,216	432	32.69
Total	12,670,936	20,113	

1 Area in km^2 calculated from The Diagram Group (1993).

2 Number of orchid species from Dodson's database. Only 'valid names' are considered.

3 Orchid Index was calculated as the ratio of number of orchids: area multiplied by 1000.

Chapter 3

Conservation Threats

Many orchid species are now considered to be at risk of extinction as a result, directly or indirectly, of two types of human activities: habitat alteration or destruction derived from change in the use of land, and extraction of wild plants for trade. However, not all taxa are equally threatened by these factors. On one hand, collecting for trade affects mostly those few taxa that either produce very showy flowers or provide certain edible products (e.g. salep, vanilla). On the other hand, habitat loss is by far the main threat to most orchids.

The degree to which these threatening factors affect each orchid species varies according to geographical distribution, habitat specificity, and population size. These criteria provide a basis for estimating the relative rarity of orchids and other plant species (Rabinowitz *et al.* 1986). Generally it can be assumed that the smaller its geographical distribution and population size and the more specific its habitat preferences, the rarer the species.

Many of the known orchid species would qualify as rare by one or more of the criteria mentioned above. For instance, most of the several hundred species of the neotropical genus *Lepanthes* have restricted geographical distributions and are obligate inhabitants of montane cloud forests. In the Antilles most *Lepanthes* species are found on only one island (Tremblay and Ackerman 1993), and 52 of the 60 species recorded in Mexico are restricted to a single mountain range (Salazar and Soto Arenas 1994), although their populations are usually formed by large numbers of individuals. A good example of extreme rarity is provided by the recently discovered *Phragmipedium* (=*Mexipedium*) *xerophyticum* (Soto Arenas *et al.* 1990). A careful search in the only known locality turned up only seven plants. The species thrives in a very specialised habitat — dry scrub with *Agave, Beaucarnea,* cacti, and several other xerophytes on limestone outcrops in an evergreen tropical forest. The habitat itself is very rare, and further exploration is required to determine whether additional, similar patches containing *P. xerophyticum* exist in the region.

Both intuition and experience suggest that rare plants are intrinsically more prone to extinction that those which are 'common,' with or without the intervention of man. For instance, species with small populations and occupying narrow geographical areas may perish as a consequence of natural catastrophes (e.g. volcanic eruptions, large forest fires, or unusually severe mesoclimatic variations). The latter is exemplified by the Floridian populations of several epiphytic orchid species (e.g. *Epidendrum floridense,* Hágsater 1993a, b), which appear to be nearly extinct as a consequence of severe frosts affecting southern Florida in recent years, although most of the species in question are also found elsewhere.

Human activities usually have more drastic consequences for rare species than for the common ones, although even relatively common species may be threatened as a consequence of extensive habitat destruction and/or immoderate collecting. Exceptions may be those species that qualify as rare by the above criteria but are found in inaccessible locations, areas that are unsuitable for agriculture or other types of human development, or effectively protected nature reserves.

3.1 Habitat destruction, modification, and fragmentation

Habitat alteration, including total destruction, modification, and fragmentation, is widely recognised as the main threat to biodiversity. Although this problem has worldwide dimensions (Ayensu 1975; Senghas 1980), it reaches dramatic levels in the tropics, where orchid diversity is greatest (Dressier 1981b) and where conservation of biodiversity is usually rated low among the national priorities. An estimate of the deforestation rate (including both modification and complete destruction) for 87 tropical countries between 1981 and 1990 is a mean of 0.9% a year, with a mean annual loss of 170,000 km^2 of forest (World Conservation Monitoring Centre 1992). The rate increased from that estimated in 1980 and is expected to continue increasing as the pressure for more open land grows in order to satisfy the needs of an increasing population. Highly diverse habitat types with many endemic taxa, such as the coastal wet forest of Ecuador, have been nearly completely destroyed (Gentry 1977), and comparable situations can be witnessed throughout the tropics. Along with their habitats, countless orchid plants, many of them representing taxa not yet known to science, are irrevocably lost.

Most tropical orchids are found exclusively in primary forests that are largely undisturbed, although a lesser number of species thrive in marginal or disturbed sites, such as forest edges or 'gaps.' Species belonging to the latter group, including the so-called 'twig epiphytes' (plants growing on other plants for support, Chase 1987), are more tolerant of modification and fragmentation of the original forest and are, in fact, favoured by disturbance, successfully colonising secondary or introduced vegetation (e.g. citrus and coffee plantations). However, populations of many of the less-tolerant taxa associated with mature forests usually decline as a result of disturbance, apparently being unable to cope with the increased insolation and reduced relative humidity, among many other potentially adverse factors. The destruction of the forest (i.e. the complete removal of the original tree cover and its substitution by another habitat type) results in the loss of the whole biota associated with the forest, although a minor portion of it may be able to remain in relictual forest patches along streams and in ravines or irregular terrain that is unsuitable for any other land use. How many of the species originally present in an undisturbed forest habitat will survive in the long run in such relics cannot be predicted *a priori*, as their persistence will depend on a number of factors such as the size of the patch and autecological features of the populations.

Phillip Cribb

Clear-cutting on Mt. Kinabalu, Sabah

Clearing of the tree cover results mainly from lumbering and from the opening of new spaces for agriculture and livestock. Additionally, in the less developed regions of the world deforestation also results from gathering of firewood by the local people. Since many tropical soils are rather poor once the plant cover has been cleared, rendering the productivity of either pasture grass or crops low, large extensions of cleared land are required for the livestock, usually one to three hectares for each animal. Very few or no trees are left standing in the pastures. Only a few orchids are able to survive in isolated trees, although in some wet, higher areas these may host an unexpectedly high number of orchid taxa. However, the substitution of a tropical forest environment by a pastureland unquestionably impoverishes the native orchid flora.

3.1.1 Logging

Selective logging of valuable timber species in a forest often significantly modifies light intensity, humidity, and other microclimatic factors affecting the survival of the epiphytes and may also alter soil ecology and disturb the mycorrhizal relationships of terrestrial species. Also, poor logging practice can inflict damage to the remaining tree stock. Tree deaths result in further increase in the light levels that enter the understory, a further decrease in relative humidity, and the invasion by sun-loving, secondary species which in turn affect many of the most delicate, shade-loving forest orchids that may not have died directly as a result of the felling of their supports or their protective tree cover.

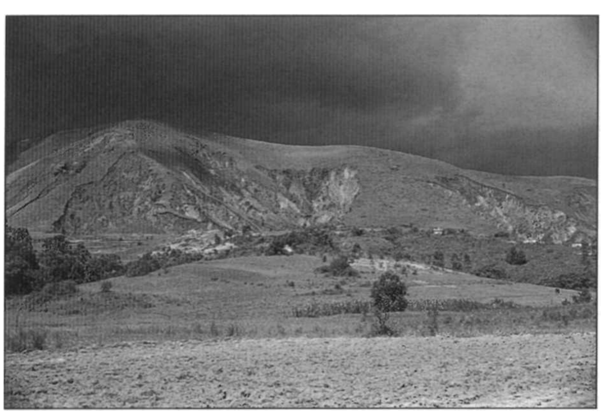
Alec Pridgeon

Deforestation to produce charcoal in Costa Rica

3.1.2 Agriculture and plantations

There are agricultural practices that do not necessarily involve the total removal of the original tree cover with its load of epiphytic orchids, or at least under certain conditions, permit a rapid recolonisation of introduced trees by a considerable sample of the native orchids. One of these is the establishment of traditional coffee plantations, in which the original trees are removed but substituted by a few other trees that provide controlled shade to the coffee plants. Other such practices are the establishment of plantations of cocoa, citrus, and other arboreal crop species growing intermingled with trees of the original forest. Although all these forms of land use usually reduce orchid diversity, experience from several areas that have long been devoted to traditional coffee production (e.g. central Veracruz, Mexico) shows that these areas retain a significant portion of the native orchid flora. It is apparent that the impact of these practices on the soil, the landscape, the microclimate, and consequently the orchids inhabiting the area is much lower than other forms of land development that involve the complete elimination of the tree cover over large areas. Few data are available concerning the proportion of an original orchid sample that is able to subsist in areas subject to such utilisation regimes, but a significant insight in the issue was provided by Catling and Catling (1987) who surveyed the orchids present in 75 trees of three age classes (13, 20, and 30 years) in a grapefruit orchard in Belize. They recorded a total of 3583 orchid plants representing 21 species. Several of the 10 most abundant species undoubtedly are twig epiphytes (*Campylocentrum fasciola, Ionopsis utricularioides, Notylia barkeri,* and *Psygmorchis pusilla*), but most of the remaining taxa do not belong in that category and are commonly found in well-developed forests elsewhere in Central America. As could be expected, the greatest diversity was found on older trees (30 years old), with an average of 7.8 (range 4-12) orchid species per tree.

Shifting cultivation, in which a given area of forest is slashed and burned, used for sowing food crops for two or three years, and then abandoned for a number of years before being reutilized, is a rather common practice in all the tropical regions of the world. Because most tropical forest soils rapidly lose their productivity (most of the forest's nutrients are restricted to its biota), new plots have to be opened constantly. This method of production results in the alteration of extensive forest areas and, according to a report by Lanly (1982, cited by World Conservation Monitoring Centre 1992), accounts for 70% of the forest loss in Africa, 50% in Asia, and 35% in the Americas. This is a sustainable form of forest utilisation in areas where population density is low, i.e. five or less inhabitants per km^2 (Myers 1980, cited by World Conservation Monitoring Centre 1992); but in densely populated areas, as many tropical countries are, more land is continuously opened and allowed to recover for successively shorter periods, so that the soil progressively loses fertility. Consequently, the forest can no longer recover, and the areas become unproductive grasslands or erode to bare earth.


Phillip Cribb

Erosion gulleys in Madagascar

Introduction of extensive monocultures of exotic trees may have a detrimental effect on native diversity. Wherever monocultures are found in the tropics they contrast dramatically with the diverse native forest and the rich assortment of potential supports for the epiphytes and appropriate substrates for terrestrial species. Introduction of Mexican pines in New Zealand and Brazil and indiscriminate use of Australian *Eucalyptus* in commercial plantations and reforestation projects everywhere in Latin America are well-known examples. Aside from the immediately evident loss of diversity caused by the substitution of a native habitat by a plantation, alien species often are highly invasive and can displace native species unable to compete with the higher growth rate and sometimes allelopathic effects of the invaders; it is not uncommon to see the land occupied by invaders virtually devoid of understory and competing trees. The odds that a native orchid species will recolonise an area occupied by the introduced species are negligible.

3.1.3 Habitat fragmentation

Habitat fragmentation (i.e. the transformation of a comparatively large expanse of habitat into a number of smaller patches that account for a smaller total area) has two main components that adversely affect populations. On one hand, it reduces the population size by reducing the total habitat area; on the other hand, it affects dispersal and gene flow among the subpopulations remaining in disjunct habitat fragments (Wilcove *et al.* 1986). Further, habitat fragmentation exposes orchids to unsuitable environmental conditions (mostly in marginal situations) and to competition, predation, or parasitism by alien organisms. It can also produce other deleterious, though indirect, effects, e.g. the reduction or elimination of orchid pollinators. Euglossine bees are responsible for pollination of about 55 genera and at least 625 species of neotropical orchids (Dressier 1982a). Experimental studies carried out in forest patches of different sizes as compared with continuous, undisturbed Amazonian forest in Brazil showed a decrease in visitation rates at chemical baits (an indirect indicator of abundance) of male euglossine bees in three patch size-classes after their isolation from continuous forest (Powell and Powell, cited by Lovejoy *et al.* 1986). For several species of *Euglossa* the visitation rates were positively correlated with patch size. It seems that a landscape of very small forest patches might not maintain viable populations of forest-dwelling euglossine bees and may consequently experience a decline in euglossine bee-pollinated orchids.

3.1.4 Urban development

Urban expansion is perhaps a major threat to orchid populations in densely populated areas such as central Europe, but also represents a problem in undeveloped countries where there is little or no control on the growth of cities and other human settlements. Road construction has an adverse effect on orchid populations not only because of the direct habitat alteration resulting from the construction process itself (although under certain favourable conditions road cuts can be soon colonised by a number of orchid species), but also because they often open the way to invasion of previously uninhabited areas by landless people who clear the forest and found new settlements.

3.1.5 Mining

Mining may cause devastating direct effects on certain orchid habitats, at least at the local level. Miranda (1990) reported that *Laelia milleri,* a rupicolous Brazilian species limited to iron ore outcrops, is in serious, imminent risk of disappearing from the wild because of mining. Also, pollutants resulting from the mining and separation processes are usually dumped directly into the environment, poisoning the surrounding land and rivers.

3.2 Collecting

Removal of unsustainable levels of plants from wild populations for trade is a major cause for the decline of many showy orchids. Commercial collectors usually are very selective with regard to the taxa they gather, choosing those species that are in high demand for the beauty of their flowers; rarity certainly adds to their appeal.

3.2.1 Horticultural trade

Well known examples of taxa menaced by commerce of wild-collected specimens are the slipper orchids in the genus *Paphiopedilum,* which have long been a main target for orchid collectors in south-east Asia. Many of the species of this genus have been overcollected, and populations have been extirpated even from protected areas, such as national parks and nature reserves. Most *Paphiopedilum* species are naturally rare by having restricted geographical distributions and narrow habitat preferences. Cribb (1987a) estimates that 25 (over 40%) of the 60 species recognised are seriously endangered in the wild. A similar situation prevails in species of the genus *Phragmipedium* distributed throughout the American tropics. The critical situation of some species in both these genera led to their complete inclusion in Appendix I of CITES (7th Conference of the Parties, Lausanne, Switzerland, Oct. 9-20, 1989).

Data from CITES records on the international orchid trade show that, excluding flasks and cut flowers, the average annual number of orchid plants traded internationally during the 1983-1989 period amounts to nearly five million individuals (World Conservation Monitoring Centre 1992). It must be pointed out, however, that approximately 80% of the orchids traded are reported to be artificially propagated hybrids, although there is still significant demand for wild-collected species.

Aside from the pressure imposed on native orchid populations to satisfy the international trade, demand for ornamental plants at the local level also may result in a severe load for some species. A very harmful practice in some tropical countries is that a trader offers the local people money for the orchids they gather, encouraging them to strip entire forests of orchids including juveniles and species of no commercial value which will be discarded and thrown away by the trader.

A well documented case of an orchid species threatened by collection for the local market is *Laelia speciosa,* a Mexican endemic restricted to the southern limits of the Central Plateau. Although its geographical distribution is relatively extensive, populations are mostly local and strictly associated with a very specific habitat, a low, very dry forest of *Quercus deserticola.* Every year many thousands of plants are collected wholly or in part when in flower and sold in the streets of Mexico City and several other cities and towns. Most of these plants are discarded after the flowers fall or die slowly as a consequence of inadequate culture. A demographic study showed that in a population that is heavily harvested every year recruitment of new individuals is non-existent, and the population will apparently become extirpated as the remaining old plants die (Hernandez 1992; Soto Arenas 1994). There is evidence that controlled collecting is possible by allowing the damaged plants to recover and by hand-pollinating a certain number of flowers to compensate for the lower rate of pollination due to fewer flowers. However, to date no effective measures for sustainable collecting have been instituted to control the exploitation of this species.

3.2.2 Amateur collection

An issue that is often cause of debate is whether or not amateur orchid-collecting constitutes a significant threat to wild orchid populations. Many orchid hobbyists are primarily interested in hybrids, which exceed by far the number of species available and often surpass the original species in both flower size and colour intensity, although undoubtedly there are species devotees, too. Conscientious, well-informed hobbyists are for the most part respectful of nature and, if offered the opportunity to collect plants directly in the wild, are usually highly

Phillip Cribb

Selling collected plants of *Angraecum sororium* by the roadside in Madagascar

selective in looking for the most horticulturally outstanding specimens. In this way they contribute to the improvement of the orchid stock in cultivation, which will serve as the basis for future production of high-quality progeny either through careful selection and inbreeding of the species or through hybridisation. However, some hobbyist, especially those new to orchids, are excessively enthusiastic and may be tempted to take more plants with the hope of selling or exchanging some of them. Even in these cases, and as long as no truly endangered taxa are involved, the damage caused to a population should be much less than that caused by clearing of the forest or wholesale collection by unscrupulous commercial interests. Unfortunately, when groups of orchid amateurs organise collecting field trips to the same locality over several years, the orchids will slowly become depleted there, even if only a few plants are taken each time. Addressing these issues, the Orchid Specialist Group of the IUCN has produced a code of conduct for orchid growers and collectors (Hágsater and Stewart 1986).

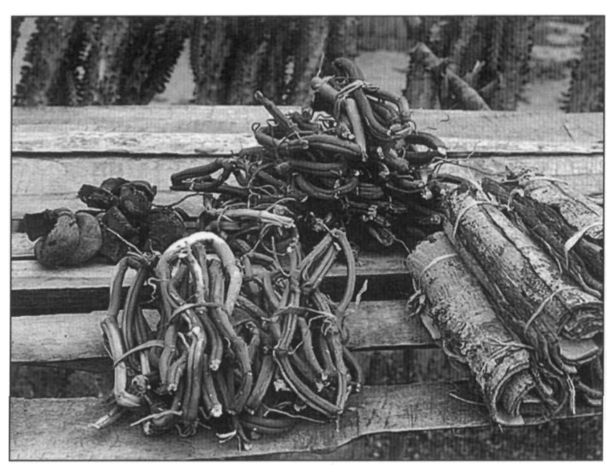
3.2.3 Consumable orchids

Orchids are sometimes collected for purposes other than trade as ornamentals, sometimes on a large scale. The best example is the collection of a number of species for the production of salep in Turkey and other eastern Mediterranean countries (see Sections 5.7.3 and 5.7.4). Salep, a jelly or mealy starch made of the dried tubers of wild-collected terrestrial orchids, is used for flavouring a popular hot drink and for ice cream texturing. Traditionally it has been consumed (for centuries now) as a food, restorative, tonic, and aphrodisiac (Arditti 1992). Recent data provided by the Flora and Fauna Preservation Society (1994) show that in Turkey alone over 16 million orchid plants, involving at least 38 species, are collected each year for the production of salep. Estimates of the amount of past exports of tubers from several countries are presented by Arditti (1992), who argues that salep production may eventually endanger the orchids used for it.

In some areas of Mexico, such as the Chinantla region of Oaxaca, the peasants collect any plants of *Vanilla* that they happen to find in the forest and take them to their coffee plantations for cultivation to obtain the pods for the flavouring agent. Many such plants, however, do not prosper and die within a short span of time since coffee plantations usually do not provide the conditions required by *Vanilla* vines (Soto Arenas, pers. comm.). Such an indiscriminate collecting system results in loss of genetic diversity of a valuable natural resource that, if properly utilised, would yield considerable profits for the local people without exhausting the natural populations.

There are a number of orchid species that are locally collected and used in traditional or folk medicine (García Peña and Peña 1981; Lawler 1984; Handa 1986; Arditti 1992), but no data are available concerning the numbers of plants collected or whether any of the species are endangered by this sort of utilisation, with the exception of salep.

Gerardo A. Salazar, Herbario Nacional,
Instituto de Biologia, UNAM, Mexico



Phillip Cribb

Stems of *Vanilla madagascariensis* being sold as an aphrodisiac

Chapter 4

Conservation Strategy

4.1 International Protection

4.1.1 Background

Many countries have national legislation under which a number of orchid species are protected. While some protected species may be rare on a national level, they may not be rare globally. Within the context of this action plan it has not been possible to evaluate national legislation, although one can generally state that the number of orchids protected under such legislation is often very limited.

Some Conventions do provide possibilities for the protection of orchids (see also Lyster 1985). With the exception of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, see Section 4.1.2), the primary conservation benefit of these agreements is the protection of habitat. Examples of such measures are:

1) The African Convention on the Conservation of Nature and Natural Resources (the African Convention) entered into force in 1968. Its main concern is the protection of animals and their habitats. However, the protection of habitats favours the protection of orchid species occurring in the areas concerned.
2) The Convention on the Conservation of European Wildlife and Natural Habitats (the Berne Convention) became effective in 1982. It is mainly directed at Europe, although its scope is currently extending into North Africa. This Convention itself deals with habitat protection but also has an Appendix of species which may not be collected at all. This list, however, contains very few orchids. (See also van Vliet and Grimm 1994.)
3) The Convention concerning the Protection of the World Cultural and Natural Heritage (The World Heritage Convention), which came into force in 1975, protects certain natural and man-made features considered part of the heritage of all peoples.
4) The Convention on Wetlands of International Importance, especially as Waterfowl Habitats (the Ramsar Convention), effective in 1975, seeks to stem the loss of wetland habitats which, beyond their value to waterfowl, are home to many orchid species.
5) The Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (the Western Hemisphere Convention), became effective in 1942. This broad but little-used measure has as its purposes the protection of species from man-induced extinction, wildlife trade regulation, the identification and protection of important habitat, and international co-operation.
6) The Convention on Biological Diversity (the Biodiversity Convention), was adopted at the United Nation Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. This convention is a far-reaching measure that seeks to establish common requirements and procedures for the use of living natural resources. It is meant to fill the gaps between existing laws dealing with the use of biological resources and provide a foundation for future national and international measures. It urges participating Parties to identify their biodiversity, to establish relevant *in situ* and *ex situ* conservation projects, and patronise the sustainable use of these resources. They are also asked to promote research programmes and to improve the education of people about dynamic conservation of the biodiversity.

The Orchid Specialist Group (OSG) of the Species Survival Commission of IUCN has never been closely involved with the workings of these Conventions, and it will have to decide whether increased participation in the near future is desirable.

4.1.2 CITES

Many species of orchids have been subject to international trade since the 18th century, the period when people started to develop an interest in this family. In the present century, however, the trade in wild-collected specimens has increased to such an extent that a number of species have almost been collected to extinction. This threat to the survival of species has not been limited to orchids but has involved many other plant and animal species. In the 1960s several organizations including IUCN took the initiative to create an international convention that would ensure the conservation of species in international trade through control of that trade. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was signed in 1973 and entered into force on the first of July 1975. As of June 1995,128 nations are Parties to the Convention. This Convention was created to regulate international trade of wild species that are or may become threatened with extinction because of this trade. CITES permits trade in species which are less endangered but could become threatened if trade is not controlled. Those species are included in Appendix II.

CITES was never meant to prohibit completely trade of wild fauna and flora; its goal is to regulate trade to prevent any extinction due to unsustainable exploitation of the species. Obviously the wild species of Appendix I cannot be traded internationally for commercial purposes. But this does not affect the species from Appendix I which are artificially propagated or those from Appendix II, as long as the country of origin issues a valid export permit, or the country of re-export issues a re-export certificate. The whole system is dynamic. It means, for instance, that when severe measures have been taken to prevent further decrease of a species and guarantees have been given that trade is now supervised, a species can eventually be downlisted or even deleted from the Appendices. On the other hand, if a species is found to be heavily traded without any conservation consideration, proposals can be made to include or uplist those species. These proposals of inclusion, deletion, or other amendments to the Appendices must be made by the Parties to the Convention in order to be discussed and possibly approved at the Conferences of the Parties, which is held every two-and-one-half years.

Since its entry into force, CITES has had the whole family of Orchidaceae included in its Appendices. The whole family was included because it is very difficult to distinguish the threatened species from the non-threatened ones in the form in which they are traded; that is, without flowers. Nine species (*Cattleya skinneri, C. trianaei, Didiciea cunninghamii, Laelia jongheana, L. lobata, Lycaste skinneri* var. *alba, Peristeria elata, Renanthera imschootiana,* and *Vanda coerulea*) were included in Appendix I in 1975; the genera *Paphiopedilum* and *Phragmipedium* were added to this Appendix at the seventh meeting of the Conference of the Parties in 1989. All other Orchidaceae were included in CITES Appendix II in 1975.

Many amendments to the Appendices were approved at the ninth Conference of the Parties (COP9) in Fort Lauderdale, Florida. Some of those directly affect the orchids. *Cattleya skinneri, Lycaste skinneri* var. *alba,* and *Didicea cunninghamii* were downlisted to Appendix II, whereas *Dendrobium cruentum* was uplisted to Appendix I. Thus, since going into effect 90 days after the closing of the COP9, Appendix I includes the following orchids: *Cattleya trianaei, Dendrobium cruentum, Laelia jongheana, L. lobata, Peristeria elata, Renanthera imschootiana, Vanda coerulea,* and the genera *Paphiopedilum* and *Phragmipedium.* All other species of the orchid family are still included in Appendix II. This measure allows monitoring of trade via the annual reports both from the country of export and from the country of import. It is then possible to determine those species that are significantly in trade and seem to be threatened. More investigations can eventually be started for a possible uplisting. Because all orchids are already included in Appendices I and II, none are included in Appendix III.

The regulations for the trade in artificially propagated specimens are less strict than the regime for the specimens of wild origin. Trade in artificially propagated specimens is possible but is subject to the issuance of CITES documentation by the country of export.

All orchid hybrids are covered by CITES. In 1979, at the second meeting of the Conference of the Parties, it was decided that when higher taxa have been included in the Appendices because of problems with the identification of the specimens in trade, the trade in hybrids should be controlled also. To omit documentation requirements for hybrids would undermine the purpose of the listing because it has been recognised that hybrids as well as the species are often even more difficult to identify solely from the vegetative state. While discussing the facilitation of the trade in hybrids during the sixth, seventh, and eighth meeting of the Conference of the Parties, the Parties have not changed their position regarding the need for control of the trade in hybrids. Consequently, the international trade in hybrids is also covered by the Convention. See Wijnstekers (1992) for more detailed information about the history and implementation of CITES.

4.1.3 Activities of the Orchid Specialist Group (OSG) related to CITES

Although the number of plant species covered by CITES has always been much higher than the number of animal species, the main focus of the Convention has been on the international trade in animals. Plant issues have received little attention, and it must be admitted that orchids did not receive adequate attention in plant-trade issues in the CITES forum. From the second half of the 1980s (i.e. after the OSG formed in 1984), and in particular after the appointment of a Plants Officer at the CITES Secretariat in 1990, the plant issues have received more attention. This involvement relates to a number of aspects of the purpose and implementation of the Convention:

"Appendix I species"

Phillip Cribb

Phragmipedium besseae

Phillip Cribb

Vanda coerulea

Emil Lückel

Laelia jongheana

Phillip Cribb

Paphiopedilum sanderiamim

Royal Botanic Gardens, Kew

Renanthera imschootiana

"Appendix I species"

Alec Pridgeon

Peristeria elata

Royal Botanic Gardens, kew

Cattleya trianaei

Joyce Stewart

Dendrobium cruentum

Ene Hágsater

Phragmipedium
(=*Mexipedium*) *xerophyticum*

Plate 2

1) *Analysis of the listing of Orchidaceae in Appendix I* The nine species and two genera included in Appendix I since 1975 were listed on the basis of undocumented information available at that time. The OSG should consider assisting the Plants Committee in its work of evaluation of the Appendices by providing, through the network, information about the current distribution, possible demand in international trade, and the amount of artificial propagation of the species concerned.

2) *The conservation of orchid species threatened by international trade* The current information on distribution and population status of many orchid species is very limited. The OSG should seek to stimulate research in this area not only for its own conservation programmes (see Chapter 6), but also to assist countries of origin and the CITES Plants Committee to determine whether the trade in wild specimens of certain species is detrimental to their survival.

3) *Orchid checklist* Development of a checklist, providing updates on the current taxonomic status and nomenclature, is important for adequate implementation of CITES. Although the OSG is not in a position to finance and develop this work, individual members are involved in the development of a checklist of the most commonly traded orchid genera. This project is coordinated through the Royal Botanic Gardens, Kew (United Kingdom).

4) *Improvement of the CITES regulations for the trade in artificially propagated orchid species and their hybrids*

   a) The greatest part of the international trade in orchid specimens is the trade in artificially propagated plants, hybrids in particular. Because these plants are propagated *ex situ*, the specimens have no value for the conservation of the species from which they are derived. Through its contacts with the orchid traders and organizations the OSG should encourage orchid growers to learn more about CITES regulations (see also under 6) and also obtain information on aspects of trade control which can be further approved. The OSG should bring this information to the attention of the CITES Plants Committee and, in cooperation with this Committee and the CITES Secretariat, should search for solutions acceptable within the legal framework of the Convention. The OSG has already strongly supported some proposals to facilitate trade in flasked seedlings and hybrids. These proposals were adopted at the eighth meeting of the Conference of the Parties (COP8).

   b) Another very important decision that has been made by COP9 was nursery registration. This resolution (9.30) urges the Parties to register their nurseries which artificially propagate and export Appendix I plants. After a control, where their mother-stock plants are identified and the origin of their artificially propagated plant certified, the Management Authorities should facilitate the issuing of the still-needed export permits. This resolution has been accepted with the assumption that the trade of artificially propagated plants is one of the measures that could help the conservation of wild populations and reduce the threat to them. The OSG has supported such a proposal because it believes that such a registration will stimulate the artificial propagation of the species concerned.

   c) As a direct consequence of this resolution, nurseries that are registered may serve as rescue centres for salvaged plants. They can use those as parental stock and may trade all the propagated plants arising therefrom. This is a very positive step toward plant rescue. The OSG hopes that this resolution will be better publicised and that many countries will implement it.

5) *Stimulation of artificial propagation* While recognising the right of each country to trade sustainably in specimens of wild origin, the OSG also believes in stimulating artificial propagation. This artificial propagation should be developed in countries that traditionally exported only wild-collected specimens, and more particularly in those countries that have a ban on the export of wild-collected orchids. In this respect particular attention should be given to the CITES definition of artificial propagation (see also 6a). Artificial propagation will reduce the pressure on wild populations because fewer plants will be taken from them. It will provide an additional source of income in the countries concerned. Also the quality and quantity of the specimens on the international market will increase, making competition with the trade in wild-collected specimens economically more feasible.

6) *Educating and informing organizations dealing with conservation (e.g. botanic gardens), trade (nursery and trade associations), and collecting (national and international orchid associations)*

   a) One important element that needs to be brought to the attention of all involved in the plant trade is the definition of 'artificially propagated/ as used by CITES. This definition, as adopted by the meeting of the Conference of the Parties in Resolution Conf. 8.17, paragraph a), clearly describes how the term 'artificially propagated' should be interpreted: referring "only to plants grown from seeds, cuttings, divisions, callus tissues or other plant tissues, spores, or other propagules under controlled conditions (in a non-natural environment that is intensively manipulated by human intervention for the purpose of producing selected species or hybrids"). Plants not grown or propagated in accordance with this definition should be regarded as being of wild origin. The OSG should help to make clear to all involved that the term artificially propagated refers to the source of the specimens. For CITES the only possible sources are artificially propagated or wild-collected. The terminology artificially propagated should not be confused with the use of the words 'cultivated' or 'propagated' which have a bearing on the techniques used by nurseries (although elements of these techniques are part of the definition).

b) Botanic gardens can play an important role in the conservation of orchids, particularly in relation to the propagation and reintroduction of rare orchid species, as well as for purposes specifically related to the implementation of CITES (BGCI 1994). The OSG should, where possible, stimulate the active participation of botanic gardens in CITES implementation and orchid conservation.

c) Through its contacts with national and international orchid associations, the OSG should disseminate detailed and accurate information regarding the purpose and workings of CITES. At the moment too many of these associations still have a negative opinion about CITES, based on incomplete information and inaccurate understanding about its purpose and the various aspects of the implementation.

d) Individual collectors should also be encouraged to buy only wild-collected plants after they have assured themselves that these have been imported legally.

Bertrand von Arx, Canada

Box 4.1 Definition of IUCN Red Data Book (old) categories (IUCN 1980).

Extinct (Ex) This category is only used for species which are no longer known to exist in the wild after *repeated* searches of the type localities and other likely places. This category includes species extinct in the wild but surviving in cultivation.

Endangered (E) Taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating. Included are taxa whose numbers have been reduced to a critical level or whose habitats have been drastically reduced that they are deemed to be in immediate danger of extinction.

Vulnerable (V) Taxa believed likely to move into the Endangered category in the near future if causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range.

Rare (R) Taxa with small world populations that are not at present Endangered or Vulnerable but are at risk. These taxa are usually localised within restricted geographical areas or habitats or are thinly scattered over a more extensive range.

A capital letter is used for the IUCN threatened status category when referred to in this Action Plan.

4.2 *In situ* conservation

The single most important aspect of orchid conservation is believed by many (e.g. Dressier 1981b) to be the conservation of habitats. Many habitats cannot be conserved without management; thus management is a major conservation issue. While the large mammals in an extensive African park can be effectively managed only by full-time experts with expensive and specialised equipment, orchid populations can and have been effectively managed within small areas by landowners, teachers, horticulturists, and members of natural history clubs. Their success has been based on the popularity of orchids, certain aspects of orchid ecology, and detailed observations. Increasingly it is being realised that at least a small commitment to management will be necessary if certain natural values are to be maintained within protected sites other than national and provincial parks where professional full-time managers are only occasionally feasible. The management of orchids and certain other popular plants on private lands and other kinds of protected sites or semi-protected sites will be increasingly important if biodiversity is to be adequately protected.

The following brief review is based largely on experience in North America and Central America but is intended to apply worldwide. The intent is to provide a reference for professional managers and to increase the involvement of non-professionals.

4.2.1 An information deficit

Since orchids are one of the most popular groups of plants and have been featured in thousands of books and magazines, it may come as a surprise that relatively little is known of their ecology. Good general introductions to orchid ecology are provided by Dressier (1981b) and Sanford (1974), but as noted by their authors these are superficial considering the size and complexity of the group. Regional orchid manuals invariably contain little ecological data, some exceptions being the exemplary works on the Flora of the mid-west of the United States by Case (1987), Smith (1993), and Homoya.(1993) that do provide ecological data that is very useful for management purposes. Sheviak's (1974) *An Introduction to the Ecology of the Illinois Orchidaceae* is a classic study that set the stage for similar works, but in fact relatively little has been done. This deficiency is a worldwide phenomenon.

Although information is limited and often inadequate, quick and decisive action may often be necessary to maintain a rapidly declining orchid population. Bratton and White (1980) noted that the academic tendency toward infinite data collection is a severe burden to management, and overstressing the lack of information may easily become an excuse for doing nothing when a positive management alternative already exists.

An outstanding example of the first steps in solving the information deficit problem is provided by the recovery plans prepared for the US Fish and Wildlife Service. Recovery plans have been prepared for several North American orchids which have been listed as threatened or endangered. The recovery plan determines threats and limiting factors and on this basis delineates reasonable actions necessary for recovery, the objective being to remove species from 'endangered' or 'threatened' categories. The recently released draft recovery plan for the Western prairie fringed orchid (*Platanthera praedara*), for example, recognises the need for appropriate regimes of fire, hay mowing, grazing, and particularly the need for research to determine these regimes (Sather 1991; US Fish and Wildlife Service 1994). Often up to half of the cost of the recovery plan involves research leading to implementation of habitat management.

4.2.2 Orchid survival strategies

Disturbance

Many authors have drawn attention to the fact that the occurrence of many temperate orchids is associated with disturbance. Case (1983, 1987) noted that many species are potentially long-lived, but their ideal habitats are fleeting. "Hence, orchids are noted for their brief and irregular appearance in many of their stations. Yet when special conditions continually recycle the factors favourable to seed germination and growth without competition, remarkable stands can develop and endure" (Case 1983).

Case's (1983) list of 18 species responding positively to human disturbance represents about 27% of the orchids of the Great Lakes region and does not include a consideration of a potentially positive response to activities such as tree cutting, grazing by livestock or trampling. When these are considered, it is clear that most of the orchids of the Great Lakes region respond positively, at least sometimes, to certain human activities, and indeed this may be true on a much broader scale. If so, one might imagine that management of orchid habitats would be a simple matter. It is often complex, however, requiring common sense, astute observation, and/or extensive research into timing, degree, and interaction of management approaches.

Ecological strategy

In ecological terms, Case's observations relate to the theory of r- and K-selection (MacArthur and Wilson 1967; Pianka 1970). The theory prompts ecologists to think of two extreme strategies. K-selected organisms have a long life expectancy and devote proportionately less energy to reproduction, whereas r-selected organisms have a short life expectancy and a large reproductive effort. In fact there is a continuum from the r- to the K-extremes with many organisms, sometimes closely related species or even populations within species, occupying different positions along the continuum. The recognition of a continuum led to the recognition of three strategies: 1) the r-selected group of short life expectancy and poor competitive ability but high reproductive effort; 2) a group of longer-lived successful competitors with lower reproductive effort; and 3) a group of stress-tolerators (Grime 1977, 1979). These strategies may be viewed as the points of a triangle, with different taxa occupying different positions within the triangle.

Despite the fact that they are perennial, orchids in general have a short life expectancy because: 1) they inhabit niches which are in successional flux, and 2) they are subject to numerous catastrophic events. They are characterised by a relatively large investment in reproduction, with large inflorescence, large, attractive flowers, and/or large numbers of small seeds that can be dispersed over long distances. Their strategy appears to be to colonise new, temporary patches of habitat quickly. In one of the earlier North American studies documenting population changes, Curtis and Greene (1953) referred to the changes in orchid populations as 'explosions' which in many cases were followed by extinction. Thus they are largely in the r-selected group, which, because of the tendency to die out and move around continually, are probably among the most difficult plants to manage. Nevertheless some (e.g. Dressier 1981b) have considered that the orchids are generally closer to the stress-tolerator group. Perhaps orchids are generally best regarded as within the 'stress-tolerant ruderals' category, i.e. between the r-selected group and the group of stress-tolerators. The stress-tolerant ruderals occur in habitats where opportunities for growth and reproduction are limited and where stress is more or less restrictive to annual production (Grime 1977, 1979).

Extent of reliance on pristine habitats

Often it is assumed that the threatened or endangered orchids are not in the mobile, disturbance-related, r-selected group, but rather in the group associated with enduring, pristine, and climax conditions. Interestingly this is generally untrue. For example, none of the five North American orchids officially listed under the US Endangered Species Act is associated with pristine, climax growth. All are species associated with a certain amount of disturbance and intermediate stages of succession. One is auto-pollinating, and another is apomictic; both are features that reduce pollinator-dependence, improving the plant's ability to move around and rapidly colonise new habitats.

The Eastern prairie fringed orchid (*Platanthera leucophaea*) provides an interesting example of a species once associated with climax prairie. It declined and vanished over large areas of its range due to the conversion of prairie to agricultural land, but with recent changes in land use and increasing old field habitats (previous corn fields or pastures), it has reappeared with such uninspiring associates as red-osier dogwood and Canada bluegrass. This old-field habitat has been reported in Ohio (Homoya 1993) and observed also in southern Michigan and south-western Ontario (pers. obs.) and includes vigorous populations of hundreds of plants.

The important point here is that when faced with the problem of protecting a rare orchid, one should generally ask what kinds and levels of disturbance are required, rather than allow succession to proceed to climax or promote a mature, high-competition environment. Therefore, a knowledge of natural disturbances is useful (White 1979) along with a general understanding of management issues (see Bratton and White 1980 for a useful overview).

4.2.3 Terrestrial orchids: threats, limiting factors, solutions

Although largely based on the Great Lakes region of North America, Case's (1987, 1990) discussions of critical factors in terrestrial orchid environments are useful and generally applicable to orchids around the world. They also provide the valuable perspective of a leading horticulturist.

Wood-cutting and openings in forests

Recently one of the larger stands of Showy lady's-slipper (*Cypripedium reginae*) in Ontario, a stand including 16,000 plants, was purchased for protection. A management plan was requested from a botanical consultant who specialised in plant ecology. It was discovered that the semi-open fen habitat had been maintained over many years as a result of winter wood-cutting by the previous landowner. It was also found that a large portion of the habitat had been flooded out by the activity of beavers. It was recommended that vegetation management including removal of white cedar and tamarack trees be continued and that flooding caused by beavers be controlled as it had been over many years by the previous owner (Mosquin 1986). This provides a good example of how historical conditions which led to impressive orchid occurrences are often the key to maintaining them.

The recommended control of beaver activity in this case demonstrates the need for management on a small scale that may not be necessary in a larger reserve (a minimum dynamic area, see Pickett and Thompson 1978) where the plants could move around as habitats were created and destroyed. Considering their activity over a broad area, beavers are important in renewing the wetland succession cycle, and their tree-felling activity creates open patches in otherwise closed canopy woodlands. The patches and patch edges may be colonised by a number of terrestrial orchids.

Roadcuts, gravel pits, and quarries

Along shorelines where sand and gravel are continuously being deposited by wind and water, various early- and mid-successional habitats are maintained and have impressive orchid populations. Case (1983) listed 18 species in the Great Lakes region of eastern North America which invade man-made habitats such as abandoned quarries and roadsides, which are characterised by raw sand and gravel and successional communities similar to those of shorelines. In many areas open habitats have to be maintained along roads for reasons of safety. This provides an excellent opportunity for orchid colonisation and habitat management, but unfortunately roadside banks are often planted with weedy introduced aliens which prevent native vegetation from ever establishing and even spread to smother adjacent native flora. The kudzu vine (*Pueraria lobata*) is a good example of a serious weed in the south-eastern United States initially introduced and planted along roads to control erosion. Erosion invariably does not have to be controlled to the extent that it is, and netting with or without seeding of native species could be used in most cases to control erosion adequately.

The effects on orchids of herbicides used to control tree and shrub growth along roads and power lines are not well documented, although some herbicides are more or less specific to woody vegetation. Stuckey (1967) described a power right of way in Rhode Island that had been sprayed with 2, 4-D to control woody vegetation, resulting in a solid stand of *Platanthera blephariglottis*, which later declined as the woody growth regained a foothold. Stuckey also reported some successful stimulation of orchid growth at this site with experimental herbicide application in November when the orchid plants were dormant.

Tropical roadsides are rarely seeded or planted to prevent erosion, and a rich native flora frequently becomes established. Dressier (1981b) lists several tropical orchids that are found on steep, open slopes of rockslides which are often scarce in the natural landscape and quickly become reforested. The habitat is created and to some extent maintained along steep roadcuts, where the otherwise rare species have become locally abundant. In some respects roads are useful in creating and maintaining a certain amount of habitat diversity, but they can also be detrimental by 1) promoting access to (and destruction of) habitats in remote areas, and 2) causing changes in hydrology.

Grazing

Many authors have noted that heavy grazing and trampling in pastures eliminates orchids and other unusual plant species, reduces plant diversity, and often leads to soil erosion (Rawes and Welch 1972). However, the same authors have invariably noted that certain levels of grazing may simulate natural disturbance regimes, reduce competition, and promote certain rare species. The importance of grazing in maintaining high biodiversity is probably best known through work on British chalk grasslands (Wells 1969), but it is a widespread phenomenon. Case (1987, 1990) and Sheviak (1974) have noted that limited grazing promotes species of *Spiranthes* in the Great Lakes region of North America. Case (1987) also noted a situation where regulation of pasturing was used to control competition of shrubs and young trees in a colony of *Cypripedium reginae* and was successful over two generations.

Browsing by white-tailed deer in a balsam fir-white cedar swamp maintained sunny glades where the orchids thrived, only to decline when the deer population crashed (Case 1987, 1990). Other wildlife may similarly have beneficial or detrimental effects. For example, Stuckey (1967) noted a devastating effect of a dense population of rabbits on a stand of *Platanthera blephariglottis* on Rhode Island. Clearly, grazing and other influences of large animals can often be a important component of a management plan.

Mowing

An article that had substantial impact in publicising the need to manage orchid habitats was Curtis's (1946) paper in the *Journal of Wildlife Management* which demonstrated the beneficial effect of April mowing on populations of the Small white lady's-slipper (*Cypripedium candidum*). This orchid is shade-intolerant, and annual mowing reduced shrub encroachment. Although there have been few detailed studies since Curtis's paper, references to mowing as an important process at significant orchid stations are fairly numerous. For example, Keenan (1986) described the largest station of *Platanthera flava* in Vermont (more than 2000 plants in

15 x 30 m) as a wet meadow "maintained as a meadow by periodic, but not annual, mowing." Case (1983) noted that *Spiranthes lucida* occurred in places that were disturbed by mowing for marsh hay. Mowing is also an important management consideration in the case of the North American prairie fringed orchids (US Fish and Wildlife Service 1994).

Perhaps some of the most interesting discussions of the stimulatory effects of mowing on North American orchids are related by Stuckey (1967, under 'competition'). She noted, for example, that between 1870 and 1920, when hay was extensively cut for draft animals in Rhode Island, some of the hay meadows were purple with *Arethusa bulbosa* in June, and the orchid was plentiful enough for bunches of it to be sold on the streets of Providence. In 1950, when automobiles had largely replaced draft animals and natural hay meadows were converted to other uses, Harvard botanist and regional flora expert Merritt Lyndon Fernald commented that the orchid was becoming extinct south of Canada.

Trails

There are disturbance gradients along trails that depend on the frequency of trampling (or other kinds of damage). Within a few metres visitors step off the trail accidentally to pass, to photograph, etc. Beyond a few metres from the edge of a trail, disturbance is little and more or less equivalent to the average for the surrounding landscape. Animals use the same trails or their own trails also resulting in disturbance gradients. Although trails have to be planned in such a way as to protect natural features, the disturbance gradient associated with them may be a niche occupied by many species. In the Great Lakes region of North America, the increased frequency of orchids along nature trails over that away from the trails is very clear (pers. obs.). In some cases the same applies to car tracks, old logging trails, snowmobile trails, cross-country ski tracks, and all-terrain-vehicle trails. However, trails make orchids accessible with the result that conservationists, photographers, and educators may trample orchid seedlings and other rare plants surrounding a blooming individual. At one location I found everything thoroughly trampled within 10 m of a fine flowering clump of *Cypripedium reginae.* There is no such thing as a non-consumptive user (Wilkes 1977).

Substrates and microclimates

Certain substrates appear to be particularly attractive to orchids. In an Ontario pine plantation, *Cypripedium acaule* was most likely to be found near tree bases where large masses of decaying cone scales had accumulated as a result of the gathering and feeding behaviour of red squirrels. Elsewhere in the same plantation the orchids appeared to be growing in buried food caches of red squirrels, where both cones and fungi may have been stored. The needle litter and debris from cones in pine plantations of the Great Lakes region of North America have produced some very impressive orchid displays including species such as *Cypripedium acaule, Corallorhiza odontorhiza, C. maculata, Goodyera pubescens, G. tessellata, G. repens,* and *Spiranthes lacera.* In Rhode Island, Champlin (1976) found that populations of the locally rare *G. tessellata* were increasing because of its ability to colonise plantations of the introduced Scots pine (*Pinus sylvestris*). Orchid populations peak as the plantations reach middle age and maturity but decline as soon as shrubs and deciduous trees begin to invade.

In a pineland preserve in north-central Florida, *Calopogon multiflorus* occurred primarily in decaying wood chips along the edges of a wood-chip path. Whereas 24 plants were located along path edges, only two were located more than one metre away from the path growing without wood chips (pers. obs.).

The importance of substrate and microclimate characteristics, including perhaps the mycorrhizal environment, is suggested by instances of co-occurrence 'hot spots' where two to several species exist in close proximity. Where *Cypripedium passerinum* was found on the north shore of Lake Ontario, *Listera borealis,* an equally rare disjunct, occurred with it. Where *Spiranthes lacera* grows on granitic rock barrens of eastern Ontario, *S. casei* is often present as well.

Sheviak (1983) made a very interesting observation that many orchids occur in either acid or alkaline, but not neutral, soils; he related this to the effect of soil pH in regulating the vigour and pathogenicity of mycorrhizal fungi. Although many questions remain unanswered, orchids are generally associated with nutrient-deficient substrates. Improving the ground with fertilizer as done routinely for many gardens is not likely to improve the situation for many rare orchids. Additional information on soil characteristics associated with orchid occurrences may be found in articles by Case (1987, 1990) and Stuckey (1967).

Hydrology

Changes in water tables are particularly important to wetland habitats such as bogs, fens, and moist savannas. A reduction in the water table can result from nearby quarrying, roadside ditches, and from reducing the water table catchment (through urban sprawl for example) or tapping the ground water excessively. Flooding can result from road building with inadequate bridges and culverts. Water levels are not easily controlled, but when impacted they may have to be managed if natural values are to be maintained. As far as water is concerned the best management appears to

Orchid diversity

Phillip Cribb

Phalaenopsis gigantea

Eric Hágsater

Epidendrum pfavii

Alec Pridgeon

Cyrtopodium andersonii

Phillip Cribb

Orchis simia

Eric Hágsater

Epidendrum ilense

Alec Pridgeon

Platystele microglossa

Eric Hágsater

Rossioglossum spendens

Eric Hágsater

Epidendrum pseudepidendrum

Habitat diversity


Alec Pridgeon

Calopogon tuberosus in a sphagnum bog in New Jersey, USA


Marc Dumont

Orchis laxiflora in France


Eric Hágsater

Epidendrum elongatum


Alec Pridgeon

Epiphytic orchids and other plants in the Colombian Andes


Phillip Cribb

Angraecum sororium growing on granite inselbergs in Madagascar


Xavier Garreau de Loubresse

Paphiopedilum rothschildianum on Mt. Kinabalu be to maintain the buffer zones necessary to maintain the past hydrological regimes. Water-level fluctuations are essential for some species since succession cycles, where certain species occupy a niche, are renewed. Case (1987) describes high water levels in the 'beach bogs' of the upper Great Lakes region, destroying competing grasses, sedges, and shrubs and thus creating a temporary habitat (until the next flood or until competition becomes excessive) for several species of native orchids. Both annual and perennial fluctuation cycles are important, the former especially to species of wooded bottomland shores, such as *Cypripedium kentuckiense* (Case 1990) and *Platanthera flava* (pers. obs.).

Invasive alien species

The most obvious cases of alien species invading orchid habitats with evidently deleterious results have occurred in wetlands and particularly fens. In the Great Lakes region, the introduced glossy buckthorn (*Rhamnus frangula*) has invaded open grassy fens, converting them to dense thickets with almost complete elimination of the original flora, apparently due to both competition for nutrients and light. Stands of *Cypripedium candidum* have disappeared following replacement of their open habitat with dense thickets of buckthorn. Other species of open and semi-open fen such as *Cypripedium reginae* and *Calopogon tuberosus* have substantially declined following invasion of buckthorn. The best way of controlling buckthorn appears to be with fire (Heidorn 1991), and this may well apply to other aggressive alien species. On a broader scale, biocontrol is potentially valuable.

Serious concern over invasive aliens in natural habitats is largely a recent phenomenon associated with widespread recognition of the biodiversity crisis. Invading alien animals may also pose threats to rare plant species and require management as part of the plant protection plan. Although an extensive literature concerning the control of weeds in agricultural landscapes is available, appropriate methods of controlling aliens in natural habitats have not been extensively researched. However, articles on the subject are being published with increasing frequency in journals read by landscape managers (Heidorn 1991).

Fire

In most, if not all, grassland, scrub, or savanna ecosystems, fires are a natural phenomenon and many plants found there, including various species of orchids, are adapted to fire. Essentially fire releases nutrients, allows light penetration in otherwise dense graminoid cover, and creates patches of bare ground (where shrubs or fallen trees burned at high temperature). In Central American savannas, the pseudobulbs of *Cyrtopodium* can resist fire to a large degree, whereas other species are protected underground. Wherever savannas burn with a frequency of once every few years, large orchid populations establish and create impressive displays (Catling 1989), and plant diversity in general is high (although insect diversity may be reduced).

In the pineland savannas of the south-eastern United States, fire is important in the maintenance of *Cleistes divaricata, Cleistes bifaria, Calopogon barbatus,* and *Calopogon multiflorus,* as well as several species of *Platanthera* and *Spiranthes* (pers. obs.). In Central America species such as *Sacoila lanceolata* are virtually absent from old, unburned savannas (pers. obs.). Similar reports are available for South Africa (Schelpe 1970) and Australia (Stoutamire 1974b).

Savanna protected by fire breaks such as roads or ditches often becomes dominated by a few graminoids and/or is invaded by woody growth. The only way to maintain orchids in certain isolated savannas is to manage them with fire. Timing is important, and some research is often necessary. The use of fire in management of North American prairie orchids and to control aliens is noted above.

4.2.4 Limiting factors for epiphytes

The occurrence of epiphytes can only be explained by a complex interaction of numerous factors that are generally difficult to comprehend. There are some obvious trends, however, that provide a useful, if not fully adequate basis for management. One of the best general summaries of epiphyte biology is that of Benzing (1990), but the references noted above specifically dealing with orchid ecology are also useful.

The resilience of orchids in orchards

Although there are clearly limiting factors, many epiphytes are remarkably resilient. After original forests have been destroyed, they often colonise the plantations that are established on the cleared lands. Twenty-one species of orchids and 3597 individual plants were reported on 75 grapefruit trees in Belize (Catling *et al.* 1986; Catling and Catling 1987). The older trees (30 years) had more individual plants and the highest diversity with an average of 7.8 species per tree. Within a tree the medium-sized branches contained the most species. Two of the orchid species present in this orchard are rare in Belize, making the area a significant habitat.

Other kinds of plantations also sometimes contain impressive orchid populations. The orange orchards in Belize are similar to the grapefruit orchards in their orchid flora. Four species were reported on coffee trees on a Puerto Rican finca, and several other native species were found on the shade and ornamental trees in and around

Box 4.2 Influence of fire on management of Australian orchid habitats.

Fire is a predominant factor influencing the biotic and abiotic character of Australian ecosystems and has a wide and pervasive influence upon the regeneration and composition of adult plant populations (see Gill 1981; Pate and Hopper 1993) as it impacts factors such as microclimate, edaphic conditions, pathogens and predator abundance, reproductive effort, pollination biology, and germination.

For epiphytic species, fires at any time of the year can cause a drastic change in plant abundance by scorching of plants, degrading or removing the support substrate, and altering the microclimate resulting from fragmentation of the canopy. Management for optimisation of abundance and persistence of epiphytes in a habitat needs to address these issues. Fire in tropical and subtropical Australia is a matter of chance or, in fire-prone areas such as the monsoon savannas and forests of northern Australia, is used for fodder improvement and protection of property. In Western Australia, changes in fire frequency, due to fire management practices such as controlled burning, are thought to be responsible for the rapid contraction in the number and area of vine thickets in the Kimberley region (Dixon *et al.* 1989). These thickets are not only important ecological and evolutionary remnants, but are home to a number of orchids including the epiphytic species *Dendrobium affine.*

Fire responses by Australian terrestrial orchids are complex and can be broadly grouped into three categories:

(a) *Flowering dependent on fire:* Species in the genera *Caladenia, Diuris, Eriochilus, Leptocems, Microtis,* and *Lyperanthus* have an obligate requirement for fire to flower. Although soil disturbance can result in flowering in some of these fire-promoted species, others such as *Lyperanthus nigricans, Pmsophyllum fimbria,* and *Eriochilus scaber* have the impressive habit of synchronised flowering only after fire. The exact nature of the stimulus leading to the response is not known, but can be duplicated under pot conditions by exposing dormant tubers to ethylene (Dixon *et al.* 1989). For these taxa the additional nutrients required for flowering and seed development are a significant drain on the plant. Therefore, fires at high frequency could lead to decline or even death of plants.

(b) *Flowering/growth enhanced by fire:* Increased growth and flowering occurs in many taxa of most terrestrial genera in response to fire in the previous summer. The nature of the response appears to be related to increased availability of phosphorus, nitrogen, and possibly other nutrients; altered mycorrhizal status in the plant; and/or decreased competition by other vegetation for light and moisture. For species in this response category, increasing the fire frequency may have limited impact since the stimulus is nutrient-based and the vegetative expression directly related to the nutrients available from the fire.

(c) *Flowering/growth unaffected or depressed after fire:* A wide suite of terrestrial species from many genera are unaffected by fire, most of which flower annually and require nutrient-rich sites. Many species, particularly in the genera *Pterostylis, Corybas,* and some *Diuris,* show depressed or irregular growth after fire. Species most affected are those that have tubers close to the surface where there is a high frequency of fire.

A predominant effect of fire on orchid management is the influence that burning has on the composition of non-orchid species and on weed invasion. In many southern Australian habitats, introduced grass weeds often choke out bushland which has been exposed to high-frequency fires. In Western Australia, the introduced South African grass *Ehrharta calycina* has followed in the path of fires and significantly diminished the conservation values of many bushland reserves. This weed alone has resulted in a decline in terrestrial orchid species in several significant urban bushland reserves in the Perth region by the effects of direct competition, reduction in the organic layer, and increased susceptibility to fire.

Fire is now used in many parts of Australia as a management tool for the reduction in flammable biomass and is applied in some states to all classes of reserves and national parks. The procedure is now being actively canvassed as a key procedure for protection of people and property, but in almost all instances there is little or no consideration of the impacts on plant diversity, in particular the potentially irreversible changes in understory composition. Paradoxically, fuel loads are calculated on the abundance of flammable biomass, yet most of the moist temperate species of terrestrial orchid depend on a substantial organic or leaf mulch for seed germination and plant establishment. For fire-susceptible species with transient seed banks the timing of controlled fires (usually spring in Western Australia) leads to localised extinction of even common shrub elements (Meney *et al.* 1994). The subsequent impact of altered community structure on the orchid populations can only be surmised. Equally, for epiphytic species there needs to be a guarantee that actions to suppress wildfires result in a lengthy fire-free period to ensure adequate re-establishment of adult, fully reproductive plants.

Orchids are intimately tied to the presence of a stable, diverse, and functioning ecosystem. Since orchids depend heavily on the organic components of a functioning ecosystem, any alteration in these components, however subtle, is likely to have a substantial and often permanent impact on orchid populations. The tuber reserves of most terrestrial species enable the plants to survive for up to three seasons without addition of new nutrients, which makes it difficult to identify when plant health is declining as a result of poor management practice. In the absence of critical indicators of orchid population fitness or of the essential parameters on which to structure an orchid population management plan, prudent planning to minimise intrusive management is advocated.

Kingsley Dixon, Kings Park and Botanic Garden, Australia the plantation (Nir 1988). Nine species of orchids were reported from a rubber plantation in Sarawak (Madison 1979). Although documentation is scanty, orchids are a characteristic feature of orchards in many parts of the tropics. In many cases, the orchards can be managed by not removing plants, not cutting heavily laden branches, and by restoring fallen branches to maintain high orchid populations. Orchard orchid populations have proven useful for research, teaching, and tourism.

Adaptation to different substrate ages and hosts

Despite the resilience of some, many epiphytic orchids are more or less host-specific (Benzing 1990), either locally or generally, and do not occur in plantations. Some species occur only on specific portions or ages of host substrate such as dead branches, lower trunks or twigs in the uppermost canopy. Variations in microclimate and light as well as substrate characteristics could be implicated in this specificity. A locally high diversity of hosts and host ages can lead to a locally high diversity of species. This may be an important consideration on certain semi-protected lands where selective removal of timber may lead to the removal of certain species of epiphytes, including orchids.

Open patches in closed canopy forest bring high light intensities to the moister lower levels of the forest, thus creating a niche essential to some species. This niche may be a natural result of windfalls, flooding, or herbivory but may become very scarce as extensive tracts of forest are reduced to tiny remnants. Epiphyte diversity in tropical forests is often greater in areas subject to limited patch-forming disturbances (gaps), either natural or human-induced (such as tree-cutting).

Effects of exposure

In a case where the objective is to manage overall diversity of epiphytic orchids, some consideration should be given to the localised effects of variation in exposure to wind, fog, and rain. The effect of exposure is well illustrated by Benzing (1990, Fig. 7.15) with regard to bromeliads in rugged terrain. Protection of a natural range of exposures within a reserve design may reduce the need for management to maintain essential microsites.

Biological interactions

Animals may promote orchid epiphyte diversity by increasing the niches available. Some orchid epiphytes such as species of *Coryanthes axe* confined to the carton (cardboard-like material) nests of arboreal ants. Management of the often locally rare *Coryanthes* would require consideration of the limiting factors influencing the ants which create the essential substrate. Animals frequently influence plants in many ways other than as pollinators. Perry (1978) found that bat excrement created luxuriant and distinctive epiphyte loads on trees inhabited by bats. Mycorrhizal associations are obligate for many terrestrial orchid species.

4.2.5 Considerations for management

Reserve design and management

Management considerations such as the establishment of corridors connecting fragmented natural landscapes (Fahrig and Merriam 1985) may not be as important for orchid plants as they are for animals (Järvinen 1982), but an effect may still exist through influence on pollinators such as bees, various lepidoptera, and hummingbirds. Although it may be well established that larger reserves located close to others can hold more species (Diamond 1975) and that reserves should be considered in terms of minimum dynamic areas (Pickett and Thompson 1978), there is no reason to dispense with the concept of small isolated reserves for rare plants (Reznicek 1987). Small isolated sites have in some cases contained significant plant assemblages for many decades, and their loss can mean the local extirpation of valuable, healthy, and sometimes genetically distinct populations. The smaller the protected site, the more important and the more intensive management is likely to be. Small reserves offer many advantages, including the protection of more species per unit area (Higgs and Usher 1980) at lower costs, more choices of sites to protect, and more protected sites to resist catastrophic events (Järvinen 1982; Reznicek 1987).

Managing pollination

Pollination biology of orchids has been relatively well studied (Pijl and Dodson 1966; Dressier 1981b; Catling 1990; Catling and Catling 1991) compared to other aspects of their ecology, but it is still not well documented considering the size of the family. Since limited pollinators will often lead to limited seed production, it is important to consider the factors limiting pollinators (see Catling and Catling 1991 for references to pollinator-limitation to seed production in North American orchids).

High local floral diversity (providing an abundance and continuity of food) and landscape diversity (providing bee nesting sites) may enhance orchid seed production through its effect on the abundance and diversity of pollinators (Catling and Knerer 1980; other references noted in Catling and Catling 1991). Plowright *et al.* (1980) found significantly lower levels of pollination in portions of New Brunswick forest sprayed with the insecticide fentrothion to control spruce budworm than in forests that were not sprayed. This was a result of the non-specific insecticide reducing the populations of bumblebees.

Private lands

Since it is often impossible to protect, through acquisition, all of the landscape within a region that needs to be protected to ensure the survival of certain species, other means have to be considered. One important method is to secure protection through agreements with private landowners. Rare orchids are a source of interest and pride to many landowners (more so than rare mosquitoes that are less easily appreciated or nocturnal rodents that are less easily observed). Sometimes landowners may be persuaded to allow management plans to be implemented on their property or even to implement management themselves. This is a very desirable situation because management is a step toward increasing participation in protection on the part of the landowner, and the later steps may involve lease, easement, or purchase. Among the potential incentives for landowners to protect and manage are awards, participation in volunteer biologist groups, education kits, and property tax rebates. Stewardship programmes are becoming an increasingly popular means of protecting and managing valuable natural resources.

Transplantation, re-establishment, restoration

Transplanting is not a reliable method of conserving rare species (Fahselt 1988). It is certainly less reliable than the protection of flora in its natural positions within dynamic natural ecosystems. The major problem with transplantation as a conservation tool is that costs are generally high, and success rate is generally low. Transplantation and re-establishment should be practised with caution and an understanding of the limitations; however, given the present and anticipated rates of biodiversity depletion, they will definitely be practised, and in some cases they have already met with a certain amount of success (Rawes and Welch 1972).

Management may involve re-establishing fallen epiphytes, salvaging plants from destroyed forest, or even propagating material with transplantation and re-establishment in mind. Such practices may be important in increasing genetic diversity within existing populations, or increasing population sizes to the point where a species is no longer threatened. Although increasing a population is a way of managing it, the issue of re-establishment is a topic on its own. Here we need only point out that success will often depend on ecological observations and experimentation. Epiphytes, for example, should be placed in the same positions on the same host trees that they normally occupy. For example, in the threatened coastal rain forest of Brazil, *Laelia crispa* grew much better at low positions on dead trees and when the roots reached the ground, rather than at higher positions on living trees (Warren and Miller 1992).

When re-establishment involves plant associations and communities, it is often referred to as 'restoration'. One of the North American leaders in restoration of natural plant communities and ecosystems has been the University of Wisconsin-Madison Arboretum which publishes the informative newsletter *Restoration and Management Notes*. At the early stages of restoration of orchid habitats, monitoring and management are necessary. With the intent to re-establish an endangered orchid species within an area where it once occurred, it may be necessary to restore the habitat first. Although this may prove very difficult, very expensive or even impossible, in some cases it may be worthwhile.

Components of a management plan

The most successful management plans (also called stewardship plans) involve consideration of several components. A lack of attention to one or more of these can result in failure to implement the plan effectively. The major components as outlined, for example, by Foster (1984) are:

1) Well-conceived goals and objectives;
2) Determination of the simplest and easiest management techniques;
3) A clear definition of roles, responsibilities, and boundaries;
4) A consideration of local landowners and public concerns;
5) Determination of the extent to which use including recreation, research, and education can be accommodated, and intent to maximise use without negative impacts;
6) Development of a clear visitor policy;
7) A plan for monitoring and periodic evaluation;
8) Use of specialists, working groups, reviewers, and advisory boards.

Monitoring

Monitoring of the status of natural values and periodic evaluation of management practices are important components of management plans, in order to determine the extent to which an implemented management plan is achieving success. Some useful recent examples of monitoring orchid populations include the work of Stuckey (1967), Tamm (1972), Wells (1981), Hutchings (1987), and Mehrhoff (1989).

Although very long periods of dormancy alleged for some terrestrial orchids are unlikely to be true,

In situ conservation

Marc Dumont

Orchids in the American tropics

Marc Dumont

Cypripedium calceolus in Switzerland

Xavier Garreau **de Loubresse**

Paphiopedilum godefroyae
in Asia

Joyce Stewart

Satyrium membranaceum
in Africa

Joyce Stewart

Cyrtorchis arcuata
in Africa

Ex situ conservation

Royal Botanic Gardsns, Kew

Protocorms of *Orchis militaris* growing on nutrient agar

Royal Botanic Gardens, Kew

Flasked orchid seedlings

Joyce Stewart

Nursery-raised seedlings of *Miltoniopsis*

Xavier Garreau de Loubresse

Paphiopedihim delenatii

Max Thommen

Orchis militaris

Phillip Cribb

Seedlings of various *Cypripedium* species transplanted into separate pots terrestrial orchids do fluctuate in above-ground appearance from year to year in response to variation in rainfall and periods of drought (Tamm 1972). Consequently, apparent population declines can be a consequence of a 'bad year,' or a few 'bad years,' instead of an indication of ineffective management. In many cases, reliable conclusions regarding population trends can only be made over a period of several years.

4.2.6 Conclusions

Perhaps the most important point to be summarised from the preceding discussion on *in situ* conservation is that many orchids are generally stress- and disturbance-adapted plants. First, managing orchid populations is not necessarily a matter of maintaining pristine conditions or very old forest growth but often encouraging certain kinds of disturbance so as to maintain a successional or at least patchy habitat. Second, regardless of the very scanty information available on habitats and ecology, effective management can be achieved in many cases through 1) a familiarity with the basic principles of orchid ecology, 2) astute observations of plants under natural conditions, and 3) limited experimentation and data analysis. Monitoring is necessary following legal or cooperative protection, and with monitoring, active management will usually be necessary (if only to regulate visitation). A strictly hands-off, preservationist attitude is, in most cases, no longer possible (Bratton and White 1980). Finally, management actions often involve trade-offs: for example, management for orchids may be fatal for insects, and management for duck production may be fatal for orchids. However, more is likely to be gained overall when the management of a species or a group of species is incorporated into a broader ecosystem management plan.

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Paul M. Catling, Canada

4.3 *Ex situ* conservation

4.3.1 Sharing species (amateurs, commercial growers, botanic gardens)

Regulatory measures for conservation primarily designed for animals, most of which are highly mobile, fail for the most part to take into account the different needs for plants. Orchids have the advantage over some other plant families in being extremely fecund; one capsule is capable of producing hundreds or thousands of seeds. The earth would be overrun with orchids if all those seeds germinated and grew to maturity, but in the wild a relatively low percentage of seed survives to germinate, and even then they are often restricted to a very small area. It is this, along with widespread habitat loss, that makes orchids particularly vulnerable in the wild but which, conversely, makes them excellent candidates for conservation *ex situ*. In most cases, the technology exists to grow seed to maturity and to produce subsequent generations artificially, but this expertise is under-utilised, with most artificially propagated material comprising hybrids for the flower trade.

Meanwhile, orchid species remain in danger of extinction in the wild as their habitat is destroyed. From the standpoint of public relations if nothing else, conservationists must address the problems of salvaging plants from destroyed habitats, and making plants and/or seed from highly endangered species available to qualified commercial breeders. The presently perceived schism between science (conservation) and commercial interests is reflected in the wording of CITES permits for scientific collecting; the same attitude is indicated in the conditions under which an institution can qualify as a rescue centre for plants confiscated under the terms of the CITES agreement. Obviously, neither a collecting permit nor a license as a rescue centre should be a cover for mass commercial degradation of plant populations. However, agreements could be made whereby scientific collections and salvage operations could also encourage the responsible commercial propagation of rare species.

From the standpoint of mass circulation of species material, the commercial species growers are already in a position to reach the broadest possible market with their plants. They have invested time and money to reach the involved and dedicated amateur growers and are prepared to invest their considerable expertise in propagating new and rare plants successfully. It is in their own best interest to do so. Certain nurseries have been propagating species for decades, depending on the availability of collected material. However until recently, none of these commercial growers has limited their stock to artificially propagated material only, and few will do so in the immediate future because the collection of Appendix II wild material is not forbidden by international treaty.

However, some countries have decided to prohibit collection of Appendix II orchid species on a national basis. This is considered by many commercial growers as unhelpful for conservation, as often the country in question is unable to provide habitat protection for all the species within its boundaries, and does not have the facilities to propagate all of its native species artificially.

By the prohibition of collection and trade, orchids in that country may be destroyed along with their habitats, and the opportunity of *ex situ* propagation lost. There is no reason (other than that the privilege will be abused) to prohibit the salvage of plants from destroyed habitats. A system of licensing and management that is not open to corruption would make salvage a desirable option to acquire plants for artificial propagation that would otherwise die. Ideally this would reduce the collecting pressure on those still in the wild by flooding the market with artificially propagated specimens.

At present, there is little opportunity for plants of new or rare species, especially those on Appendix I of CITES, to be obtained legally as stud plants for artificial propagation. Part of the reason lies in the common traditional perception of the three groups of individuals that play major roles in the introduction and continued propagation of rare orchid species, as well as in the realistic limitations of each of these groups: a) orchid scientists or taxonomists with 'tunnel vision'; b) the 'rapacious' collector/importer; and c) the 'greedy' hobbyist. In reality, the present roles of these three are quite different and becoming more so all the time.

Scientists and botanic gardens

Scientists, no longer concerned solely with the narrow aspect of pure science, and botanic gardens, for which many scientists work, are often active partners in orchid conservation. Most orchid scientists are acutely aware of the desperate state of plant conservation, and many became interested in the Orchidaceae as a result of being amateur growers, or interested in native plant conservation. Scientists often obtain research material from orchid collections of commercial importers or the sophisticated amateur.

To serve conservation, botanic gardens with their scientific associates should serve as repositories for living speciality orchid collections. A comprehensive collection limited to a genus or a larger taxonomic rank should be the goal of each botanic garden with the personnel and equipment to do so. Each should specialise in a different group of orchids, that grow well under their climatic conditions, so that it serves as an *ex situ* gene pool.

To improve their collection, they should interact more with both commercial growers and amateurs specialising in the same genera, each receiving and sharing redundant plant material and new clones. Gardens should routinely outcross their plants to increase their genetic base, giving the seeds to commercial growers with the facilities to grow and distribute them to a large number of orchidists. Amateurs specialising in the same genera should routinely share their clones with the appropriate botanic garden collection with reciprocation from the botanic garden.

A common misunderstanding is that a botanic garden is the safest repository for rare plants. Botanic gardens have limitations which the dedicated amateur does not, and vice versa. The most obvious is that a botanic garden is usually funded by the public and that its function is dictated to some extent by the will of the public, expressed in political ways. The politicians in office influence the garden's policies, in response to the public's perception of what the priorities of the garden should be. A large part of the funds received by the garden are used for high-profile, public relations-oriented activities, but an *ex situ* collection of orchids would, for the most part, be out of the public eye.

A collection of this kind is also dependent on the interests and horticultural abilities of its curator and horticultural personnel. Personnel in public institutions have a rapid rate of turnover due to budget cuts, changes of emphasis, and personal decisions. For a collection such as this to be maintained well, it requires specialised knowledge and dedication. Over a long period of time, it is difficult to maintain both funds and appropriate personnel.

One way to accomplish this could be for societies dedicated to specific genera to contribute funds annually toward the maintenance of the position of curator for the speciality collection of those genera, wherever it is located. This would give the society some leverage in the designation of the appropriate personnel to care for the collection properly. Presently, a number of such world-wide societies exist, each dedicated to a different group, e.g. Odontoglossum Alliance, Phalaenopsis Alliance, and Pleurothallid Alliance. Through these and similar activities, these single-interest societies could have a positive impact on the long-term maintenance of living gene-bank collections for conservation and scientific purposes. At least two of these societies now are funding research in their fields of interest. These groups are the logical catalysts in the interaction among botanical institutions, individual growers, and commercial, species-oriented nurseries. It is logical to assume that most, if not all, people with a high level of involvement in this orchid group would gravitate naturally to this society and would be among its policy-makers. Because of long-term association and high degree of involvement with the orchid genus, subtribe, or tribe on which they are focused, the interactions are positive and effective.

Some among them undoubtedly stand out as better growers of that orchid alliance, and it is to these (commercial or amateur) that very rare species collected under the aegis of botanical institutions should be given. Only when the plants are sufficiently large and well established should divisions be made, one for the botanical institution as a herbarium specimen. Because conservation of the species is the primary goal when few clones exist, the goal should be to make additional divisions first, then make either sibling- or self-pollinations of one of the two divisions, leaving the other unstressed by the development of capsule or capsules. The seed should then be sown by a qualified laboratory or commercial firm and the seedlings disseminated on the open market for widest dispersal. If there are few seedlings resulting from the capsule, then these seedlings should be sown or given only to those other growers with the expertise to bring them to maturity and to breed them successfully.

Commercial nurseries

Commercial nurseries are often tainted by the past performance of some when conservation consciousness was not a factor in their actions. Today most species-oriented nurseries, while still importing material from the wild when it is feasible, supplement this supply by buying and trading flasked material with each other. These nurseries range across the spectrum, from those that deal in nothing but artificially propagated species to those that deal in nothing but imported, wild-collected species. Public pressure is strong in favour of the former, sometimes to the point of being unrealistic in its condemnation of a nursery for importing stock plants of new species with which to breed. The informed public condemns only those nurseries which repeatedly import wild-collected stock with no effort made to breed any of it. Since legal salvage operations are not yet a major factor, the simplistic view now prevails that all importation of collected plants is wrong. The public in general does not understand what controls CITES and other national legislation placed on the export and import of orchid species between nations. Depending on their agenda, people wishing to ship plants internationally regard existing legislation either as obstructionist or ineffectual, and it also colours their views on nurseries themselves. Nurseries make a living from selling plants: the better the plants, both in diversity and condition, the more money they can make. Ultimately, except for stud plants of new species and plants salvaged from destroyed habitats, nurseries should be limited to selling artificially propagated species only.

Those nurseries that do not wish to propagate plants already in cultivation can establish links with individuals, laboratories, or nurseries in countries of origin for trade in seed or artificially propagated plants. Persons in an exporting country should be able to profit from commerce in artificially propagated specimens of their own native plant material. As the shift from collecting to a propagating economy occurs, those who collect in bulk will shift to a different livelihood, perhaps searching for new species to propagate, or doing some of the propagating themselves. Current emphasis is on teaching propagation techniques in countries of origin and making sources of supplies available. Nurseries in the importing countries must also take an active part in this process. Many commercial growers already have relationships with qualified amateurs and routinely share divisions of rare plant material as insurance. Commercial growers of orchid species have at their disposal a painstakingly compiled network of customers, other nurseries, propagation laboratories, collectors in the countries of origin, and other sources of plants, as well as contacts within the scientific community.

The amateurs

Qualified amateurs, in contrast to casual hobbyists, are committed growers who spend much time, money, and effort in the pursuit of their interest. Most commercial growers and taxonomists started as amateurs. The difference between qualified amateurs and casual hobbyists is one of degree in commitment to the proper care of plants, responsibility for the long-term upkeep of the collection, and motivation to learn new information necessary for the successful pursuit of the hobby. Qualified amateurs are involved in conservation as a natural extension of their interest, whereas casual hobbyists are not orchid conservationists except in the most perfunctory way, if at all. Qualified amateurs naturally will express a preference toward one or more genera or subtribes as their knowledge of orchids increases. Eventually, their collection will reflect this focus of interest, and if this interest is pursued the collection will acquire horticultural and taxonomic value in proportion to the degree of expertise and education of the owner. The amateur becomes part of a broader network of amateurs, commercial growers, and scientific personnel sharing interests and plant material in that specialised field. The amateur can contribute to this triangle of orchid conservation *ex situ* by amassing and maintaining a collection of significance and being willing to share seeds, pollen, and divisions with others involved with the same genera or alliance. Just as important, the amateur can help by becoming fully committed, realising the worth of the orchid collection to orchid conservation *ex situ* and expending whatever time, care, and funds are necessary to maintain the collection in optimum condition. An amateur's policy decisions are based on what sacrifices he or she is willing to make to accomplish a set goal regardless of political or personnel changes. An amateur can spend far more attention on a rare plant in precarious condition to restore it to health or even just grow it than can an institution or even a commercial grower.

4.3.2 The role of growers

Briefly, the strengths and weaknesses of each part of the *ex situ* conservation triangle are these. Botanical gardens, educational institutions, and scientists working within them can be subject to budgetary, personnel, and policy fluctuations, hampering consistent administration of long-term goals. Needs to achieve spectacular, large-scale results on low budgets can have deleterious effects on relatively inconspicuous but important projects, especially those that are labour-intensive. However, for projects requiring large amounts of expertise and equipment, such as the construction of a laboratory capable of highly sophisticated technologies or the replication of habitat conditions otherwise difficult to reproduce, such institutions have no peer. The housing of a specialty collection of one or more genera or subtribes, especially some not particularly horticulturally desirable, is a contribution to *ex situ* conservation that botanical gardens should be asked to undertake. Such a collection in conjunction with laboratory facilities and a herbarium would give students and taxonomists easy access to all study material and equipment as well as serving as educational material for the public at large.

Commercial growers must make a profit to survive. They are limited to following commercially effective horticultural practices. They cannot expend unlimited amounts of time and effort on plants that will not survive under most growing conditions or are not horticulturally desirable. Nurseries can keep and propagate only a few such plants for the sake of conservation. They can try raising the 'delicate' horticulturally desirable species from seed, where optimally they will self-select for artificial growing conditions, or they can give these species to individuals willing to expend the time to grow them. The latter can then share the plants with botanical institutions having the appropriate growing environment, which can sib-cross them and return the capsules to the donor nursery. The commercial species nursery is expert in the growing of species in quantity, maintaining adult plants, and raising seedlings to maturity. The most successful species nurseries are those that have first access to new species and can grow and propagate them well prior to marketing the artificially propagated plants widely and rapidly. These are the same steps necessary for effective *ex situ* conservation as well. Nurseries doing this should be aided and encouraged to continue.

Qualified amateur growers, as individuals, have few support systems in place, especially in personnel. They may involve their families, another grower or friend to some extent, but quite often there is no set arrangement for personnel to assist in case of absence or emergency. Amateurs may have spent much money and effort on duplicating optimum growing conditions, but the effectiveness of the results rarely approaches that of botanical institutions or the more complex systems of advanced commercial growers. However, the advanced amateur can and will expend large blocks of time on the individual care of plants. This is particularly valuable to the *ex situ* conservation process, because the rare plants are often in small quantities and require specialised care that commercial and botanical facilities are unable to provide for very long. For this reason, commercial growers and scientists routinely give their rare species in precarious condition to individuals experienced in growing the plants in question.

There are two factors that have been mentioned previously but not detailed: the role of the speciality collection and the necessity of redundancy in all steps. The specialty collection usually evolves from gradually focused interest by the collector. At some point the grower realises that the value of the whole collection supersedes the value of any individual plant, that it has a scientific significance or a role in conservation. The focus can be defined by geographic limits, such as those orchids native to a particular area, or it can have a taxonomic structure such as a genus, subtribe or tribe. That collection is then more than a simple, random assemblage of species and hybrids; it should be considered a unit and not be broken up. The owner of such a collection should make arrangements, temporary and permanent, for appropriate continued care and transfer of the collection in case of emergency or disability of the caretaker. Legal prototype documents can be obtained to do this in a number of countries. This is only one of the many backups desirable in *ex situ* conservation.

The concept of redundancy is that divisions of every plant in such a collection should exist in at least one other collection elsewhere to minimise risk of loss of the clone. From the moment the division is made, each clone should carry a clonal name which identifies it throughout its life and subsequent propagations. This clonal name serves dual functions. First, it allows a prospective propagator to know whether the plant is desirable outcross material or simply a division of the plant already in the collection. Second, it gives some indication of how many different clones exist in cultivation at any one time. Other forms of backup are duplications of support systems maintaining the collection: warm and cool temperature systems, humidity systems, ventilation and air movement systems, watering systems, all controls and thermostats, all alarm systems and paging units, and personnel. The last backup necessary is duplication of record-keeping. All data should be kept in duplicate and on separate sites. Information for each plant should include the binomial and clonal name, locality (as detailed as possible, including elevation), date of collection or date of acquisition, and name of donor or seller if applicable. At least the binomial and clonal information should be on the individual plant label, with complete records located elsewhere.

The concept of *ex situ* conservation involves several steps: 1) removal of only a few plants of a species from the wild (preferably from destroyed habitat); 2) growing the plants until they are large enough to divide; 3) exchange of divisions with qualified growers to insure against loss of the clone; 4) sib-crossing one of each pair of divisions; and 5) dissemination of progeny among proficient and interested growers for continuance of the breeding programme. When enough plants exist to satisfy market demand, there will be little reason other than for purpose of salvage to go to the trouble to remove more plants of the same species from the wild.

Ann Lauer Jesup, USA

4.3.3 Propagation for genetic diversity

Minimal viable populations

The smallest number of individuals that can make up a population and allow it to retain its genetic integrity over succeeding generations is sometimes referred to as the minimal viable population or MVP (Soulé 1987). This number is not a hard and fast rule but depends on the nature of the species in question. Not only must the genetic structure of the gene pool be known, but the life history and demography of the population is also important. Very few orchid species are known in sufficient detail to allow a rational assessment of the optimum MVP. When dealing with unknowns it is usually assumed that a randomly selected 50-100 individuals from a population will contain 95% of the genetic diversity of the gene pool (Marshall and Brown 1975). But many of the rarer genes, which might be important for the long-term survival of the species, would be missed if only 50 individuals were collected or used for breeding. With small founding populations, genetic drift, i.e. the stochastic loss or acquisition of genes, can cause important changes in the genetic make-up of the population. In addition, inbreeding depression, i.e. the expression of deleterious alleles, can be a real problem when small interbreeding populations are composed of related individuals. In order to avoid those effects, much larger founding populations are recommended. For vertebrate animals 250 to 500 individuals is usually considered to be the lower limit for such a sustainable population (Seal 1985). One can identify two strategies for orchid species conservation: *in situ* conservation, which refers to conservation of a species in its natural environment, and *ex situ* conservation which refers to species that are maintained and managed under conditions of cultivation. The reproductive capacity of orchids is, however, very great, so by deliberate breeding one can build up populations very rapidly. While deliberate artificial propagation is often easily accomplished for most epiphytic orchid species, it is recommended it be used primarily for *ex situ* species conservation and only resorted to as a last resort for *in situ* conservation strategies.

When species and populations occur in the field they are under continuous selection pressure. It is this selection pressure that determines the nature of the species through evolution. As soon as man interferes with a wild species he also interferes with the selection pressures and starts to change the nature of that species.

Box 4.3 *Catalogue of Artificially Propagated Orchid Species.*

Given that nursery-raised plants are showier, easier to grow, and more ecologically sound than wild-collected plants of the same species, how can orchid growers be sure that they are purchasing artificially propagated plants? Equally important, where are such plants available? Currently the best source of such information is the *Catalogue of Artificially Propagated Orchid Species.* In 1992 horticulturists from 26 countries were asked to provide a listing of their orchid species grown from seed, tissue culture, or divisions from a parent plant that remains in the nursery for further use. The third edition, updated and available in the autumn of 1995, lists over 3000 orchid species and varieties as well as the nurseries propagating them.

It is difficult to assess what impact the *Catalogue* has had on buying habits of growers. Many use the book to locate rarely available orchids, while the book has introduced the concept of artificial propagation to other growers. Certainly several of the small but dedicated nurseries have attracted more customers. Another bonus for the nurseries is that the *Catalogue* offers free advertisement for professional growers with orchid conservation in mind.

New computer technologies such as CD-ROM and the Internet are ideal vehicles for relaying this information to a larger number of hobbyists and encouraging them to purchase only artificially propagated orchid species and support those nurseries specialising in them.

Jean-Jacques Beguin, Switzerland

This is particularly true when artificial methods of propagation are used. Therefore, *ex situ* propagation interferes with the natural evolution of the species in many ways. Normally in the wild there are very few survivors of the many propagules that are produced. A single orchid seed capsule can produce hundreds of thousands of seeds, and a mature plant can produce many capsules each season. The great majority of the seeds never germinate or else they die off in the first season. During early growth and development, the death rates of the progeny act as a very strenuous and restrictive filter, allowing only a very small percentage of genotypes to survive. Under nursery conditions those restrictions are relaxed and large numbers of plants survive. Most of these would not have succeeded under normal 'wild' conditions.

Pollination strategies

Artificial pollination should be the last recourse in saving a species, used only when populations are so small in number that just a few individuals are still alive and there is no other alternative to maintaining the species. The resulting population will have been altered compared to what might have existed in the wild. However, when species are maintained *ex situ* in horticultural cultivation, most selective pressures are relaxed anyway, and then these matters are of less concern. There are many negative points to be considered if artificial pollination is used in *in situ* conditions. If the decision is made to use this to bulk up populations, then one needs to be aware of the following.

Artificial selection - When plants are selected for pollination there may be unexpected biases caused by the person acting as the vector. For example, brighter-coloured flowers or larger-than-normal flowers might be selected in preference to dull-coloured or smaller-flowered plants. Or, only those flowers open on the particular day that the site is visited may be pollinated. Such biases may be deliberate or unconscious. People pollinating flowers must try to avoid these inclinations because they introduce an unnatural and artificial selective element to the genetic composition of the progeny to be produced. One way to reduce unconscious bias is to collect the pollinia from several or many flowers at the same time and mix them up. The pollinia to be placed on the stigma are then selected arbitrarily from the mixed group. Pollinia collectors should try to collect pollinia from a wide spectrum of flower and plant types of the species being considered. The vegetative characteristics should be considered and sampled as well as the floral traits.

Accidental hybridisation - Natural hybrids are found in the wild but are relatively rare. Orchid species, however, are renowned for their promiscuity. Not only will related species within a particular genus interbreed and produce viable and fertile offspring, but even species from related but different genera will often interbreed. It is important, therefore, to take extra care to avoid making mistakes when artificially pollinating flowers in the field. Sometimes orchids occur as mixed populations of species, often of the same or related genera. The person carrying out the pollinations must be aware of subtle differences that can exist between species so that hybridisation will be averted.

Inbreeding problems - Self-pollinating a flower leads to reduction in the genetic variability within individual progeny that result from such a selfing. This is expressed as increasing homozygosity. With succeeding generations of self ings, genetic diversity of the population may be lost as the gene pool becomes more restricted. In addition, increasing homozygosity increases the possibility that lethal or sub-optimal alleles within the genome will be expressed; the resulting plants may become weak growers, or lose vigour and even fertility.

Changes in gene-flow patterns - Natural populations receive immigrants in the form of seed or pollen from other populations of the same species. In return they also export genes in the form of pollen and seeds. The rates of immigration determine changes in the gene pool frequencies of the population. Artificial pollination from plants collected from other populations would change the natural gene-flow patterns within the population. But this may be needed if only a few plants remain in a single population.

Potential for spreading viral diseases - With artificial pollination, the potential exists for infecting orchid plants with a variety of diseases. In particular, viruses are readily transmitted through contaminated pollinia and can infect 'clean' pod parents. This is a particular problem if one is attempting to make an outcrossing between a cultivated plant and a wild clone. Cultivated collections of orchids are notorious for their high levels of viral infection. Seedlings produced from virus-infected plants may also be infected with the virus, however, the incidence of virus-infected seed is reduced if the seed is carried to full term and only harvested as 'dry seed' once the capsule has dehisced. If 'green pod' seed is used for embryo culture, there is usually a higher incidence of infected individuals.

Reproductive costs - Whenever a plant produces seed there is a cost to that plant that can be expressed as reduced growth and vigour the following growing season. This cost is variable from species to species. If the population to be propagated is small and fragile, excessive seed production could stress the plants and jeopardise their ultimate survival. Therefore, only a few flowers per inflorescence should be pollinated, and it may be advisable to allow plants a chance to recover for several seasons after seed production and before attempting to pollinate them a second time. It should be mentioned that some species do not appear to be affected by reproductive costs, but unfortunately few data are available. If seed is to be used for *ex situ* propagation, very few seed capsules are needed. But success rates even for artificial pollination can be quite low, and at least five times the number of flowers should be pollinated for the number of seed capsules needed. In the wild, success rate varies with species, ranging from 1.2% to 49.5% in different species (cited in Rodriguez-Robles *et al.* 1992).

In most orchid flowers, there is normally only a single stamen which is combined with the style and stigma to form a single central structure, the column. The pollen is carried at the apex of the column and is packaged into units called pollinia. One to eight pollinia may be united to form a pollinarium. Pollination is effected when one or more pollinia are deposited in the stigmatic cavity of the column. As a pollinium can carry hundreds to thousands of pollen grains, usually one pollinium is sufficient to produce a very large number of seeds.

Optimising effects of artificial pollination

Merely pollinating a flower is not sufficient. There are several parameters that should be considered before embarking on an artificial pollination programme in order to rescue a species.

Expanding populations - One way to promote genetic diversity is to expand the population size as rapidly as possible. One must assume that the founding population contains the only genetic variation available. Genes in that generation which are not passed on to the next generation will be lost. In order to maximise the variety of genotypes, as many offspring as possible need to be produced. In situations where only a few offspring are produced and maintained in each generation, the population will rapidly slide into genetic uniformity, and most alleles will become homozygous (Barrett and Kohn 1991).

Promote outcrossing - If a plant is to be pollinated by its own pollinia, i.e. self-pollination, a proportion of the genes in the offspring population will be expressed in the homozygous condition. If selfing is carried through several generations, one finds the rapid occurrence of inbreeding depression where deleterious genes occur in the homozygous expression and are expressed. This not only often results in loss of vigour but also the appearance of vegetative and/or reproductive abnormalities. Inbreeding depression also occurs where related individuals are mated. One way of avoiding inbreeding is by outcrossing, i.e. mating two individuals which are not related.

Where the founding population is very small we recommend that pollinia be pooled. If the stigmatic cavity is large enough to accommodate several pollinia or pollinaria, then it should receive pollen from a number of different individuals. This will increase the variety of genetic combinations that can be effected and also reduces the need to mate plants with different parents in following seasons. This cuts the reproductive cost effects. After pollination the column walls grow over to enclose the pollen in the stigmatic cavity. But if there are too many pollinia then some may be pushed out and voided. Careful observation is needed to be sure that multiple pollinia are actually retained by the developing column.

Select parents from within the same population - Local populations of orchid species often differ from one another in minor ways. For conservation purposes one should try to maintain these differences. To do this, both parents should be from the same local group. It may be useful to compile a pollen bank especially when flowering is not synchronised. This allows one to maximise the genetic variation in the propagated population. Details for setting up a pollen bank are given below. In extreme cases, one might self-pollinate flowers. This should only be done when a single plant remains or there is no available chance of cross-pollinating that plant and maintenance of the genetic integrity of the local population is desired.

Repairing inbreeding depression - If the population is showing signs of inbreeding depression, then it is sometimes possible to effect repairs. This can be done by using pollinia from a different geographical locality to reintroduce vigour into the local population. One problem is that one could also be introducing genes that were not selected for that particular region. The resulting plants will not be the same as the original population.

Use fresh flowers - Despite the fact that many orchids have flowers that last on the plant for extended periods of time, sometimes even months, the chances of succeeding with seed production is usually improved if one places the pollinia on freshly opened flowers. Likewise, if pollen from a bank is used, then freshest pollen is often the most effective.

Data management - There are several ways that data on pollinations can be managed. It is useful to be able to keep records of both parents and also dates of pollination. The former is needed to keep records that can be referred to in succeeding years for determining the reproductive success of individual clones. The latter data is needed to determine the time when capsules should be harvested. Flowers should be tagged following pollination, and under ideal conditions data should be kept on the performance of the parents and their progeny. If several flowers are to be pollinated, each with pollinia from different parents, then the position of the flower on the inflorescence should be noted. Flowers should be counted from the base of the inflorescence and can be numbered, proceeding in a distal direction. Paper tags or labels are not recommended, as the label will often need to be legible for a period of more than six months. Small tags made of metal foil and tied to the inflorescence by small wires are ideal provided that the plants are not in a very windy position. If the plants are in the wild, then some co-ordinate system may be needed so that the plant can be refound at later times. If the plants are under cultivation, then the details of the cross and its location on the inflorescence as well as date of pollination can be written on plastic plant labels and inserted into the pot.

Protect developing ovaries - For some orchids there seems to be little capsule predation even in the field. Nevertheless, it is a wise precaution to protect developing ovaries on plants in the wild. Once the ovary has started to swell the capsules can be fitted with loose sleeves of gauze that exclude insects and molluscs but will allow air and light to the developing organ. The time that it takes ovaries to ripen and produce viable seed varies from species to species. Tables listing those times can be found in Arditti (1992). Usually six to nine months are sufficient to mature embryos to the point where they can be extracted from the capsule for successful tissue culture.

Seed sowing - Orchid seed is normally grown under aseptic conditions which require sterile laboratory facilities. The seedlings are grown *in vitro* on artificial media. Two methods are often used — 1) dry seed which is harvested from capsules that have dehisced, and 2) green-pod where embryos are excised.

Dry seed is routinely used where the pod-parent plant is virus-infected. Many plants seem able to exclude virus from seeds. This is not always a reliable method of clearing stock from virus, but usually a substantial percentage of the seedlings that result are uninfected. Growing from dry seed requires that the seed be disinfected before planting. The solutions used for disinfecting dry seed can be toxic to the seed if applied incorrectly. Using green-pod techniques allows one to disinfect the outside of the capsule and makes it easier to maintain sterility without damaging the seed. Consequently, most laboratories prefer to use green pods. Pods are usually harvested just before maturity, which varies depending on the species. Usually embryos are ready to culture a month or two before the pod would normally dehisce. It can take from several months to longer than a year to harvest a mature seed capsule; experimentation may be needed to determine the correct amount of time required.

Typically two types of media are used, one to effect germination and a different medium on which the seedlings are grown until the stage when they can be released from the sterile container. Seed sowing should be performed by laboratories with professional tissue culture experience. There are many books available on tissue culture techniques, but a very useful starting place for beginners is a small booklet by Thompson (1977) which explains simple methods succinctly. A good reference source for the variety of media used is to be found in Arditti *et al.* (1982); however, many of the modern media used are proprietary secrets. Thus it may be more economical to farm out the laboratory work to a reputable firm than initiate research to find out how to culture particular species from scratch.

Germination of terrestrial orchids - Unlike most epiphytic orchid species which can be grown aseptically on defined media, terrestrial species present problems. In particular most of the orchidoid species appear to be reluctant to grow unless a symbiotic fungus is also supplied. Techniques are now available for Australian terrestrial species (Clements and Ellyard 1979) and European terrestrial species (Clements *et al.* 1986; Stewart 1993b). Successful germination can involve pairing the orchid species with the correct and appropriate strain or species of fungus (Hadley and Pegg 1989). Consequently, mass propagation of terrestrial species from seed can be a very difficult proposition. It is not as routine as that for epiphytic taxa, but it can be achieved.

Seed banks

For many agricultural plants, very long-term storage of seed is possible, and special gene banks have been set up in many countries for that purpose (Plucknett *et al.* 1987). Normally orchid seed has a very short life span, and viability can be lost in a matter of weeks. The longevity of orchid seed is dependent on both ambient temperature and water content of the seed (Thornhill and Koopowitz 1992). Methodologies have been worked out for non-orchid seed for extended periods of time (Harrington 1972; Chin *et al.* 1989). But reliable methodologies have not been worked out for most orchids (Pritchard and Seaton 1993), for which seed-banking is still at the experimental stage. Long-term seed-banking does, however, seem possible for orchids. *Encyclia vitellina* seed has been stored for 10 years at

-25°C with almost no loss in viability (Koopowitz and Thornhill 1994).

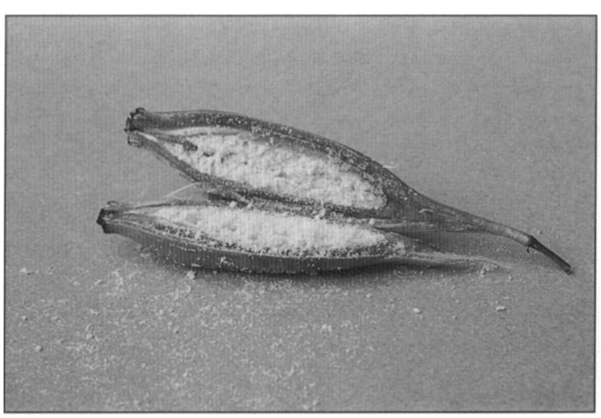
Seed banking has great potential for orchid conservation because long-term seed-storage will allow one to maintain an enormous array of species very economically.

Pollen banks

Where individual plants in a small population are not synchronised in their flowering, it may be necessary to store pollen so that one can cross different individuals. Pollen storage has been used by many orchid hybridisers in a routine fashion. Pollen or pollinia are removed from the flower and air-dried over a desiccant. Empty gelatine capsules such as those used by pharmacists are useful for this. The capsule should be labelled with the contents and dated. These can then be stored, usually in the presence of a desiccant in a refrigerated unit at temperatures slightly above freezing. Pollen viability is usually of the order of a year or longer. Storing air-dried pollen at subfreezing temperatures is more effective than storing it with cryo-protectorants (Pritchard and Prendergast 1989).

Seed distribution schemes

One conservation strategy is to have a species widely distributed and grown in horticulture. It is recommended that if this policy is to be followed that such species be distributed by seed and not wild-collected plants. Orchid seed exchange programmes are known from various parts of the world. The Australian Orchid Foundation is one well-known example. These kinds of orchid seed banks require that seeds be stored in refrigerators at temperatures as close as possible to 0°C without freezing. Such banks are usually only effective for short time periods.



Seed capsule

Propagation for selected horticultural clones

Much of the collection pressure on wild species can be obviated by using micropropagation techniques to multiply either seedlings or selected superior clones of a particular species. Some clones such as *Polystachya pubescens* 'Orchidloft' CBR/AOS have been tissue-cultured and are now widespread in both the USA and Japan, with the result that there seems to be little interest in bringing additional material from the wild into cultivation (pers. obs.).

There is a great deal of variation in the ease with which individual species or even cultivars of a species can be propagated by tissue culture. Even some entire genera such as *Paphiopedilum* and *Phragmipedium* appear to be very recalcitrant to the techniques. Therefore, it can take a considerable amount of experimentation with media and techniques before micropropagation will succeed. Nevertheless, this has proven itself to be a useful method of mass propagation. Many different orchid cultivars are routinely propagated in this fashion, but there are clonal differences, and even siblings can differ in the ease by which they can be multiplied.

Several practical texts on tissue culture exist which discuss both media and techniques for tissue culture (Arditti and Ernst 1993; Kyte 1987). However, it is recommended that where it is deemed necessary to use these techniques such services be contracted out to laboratories that are already proficient in these abilities. This will save on the costs of purchasing, training the personnel, and staffing the facility. However, if much experimentation is necessary to devise new media or techniques to save one or several species, then it may be necessary to set up an independent facility. In some developing countries it may be very difficult or even impossible to get some of the components or repair equipment when necessary for *in vitro* multiplication. It may be more cost efficient to contract the laboratory services to countries where there is experience or where these techniques are routine.

Vegetative division

Vegetative division can be carried out for many orchid species which are either sympodial or are monopodial but have basal branching systems. Here different parts of the plant can be physically isolated from each other and potted up separately. Where plants have clusters of pseudobulbs the older growths can be removed to stimulate new growth.

Physically breaking the plants apart and potting up the resultant pieces separately is a traditional way of propagating orchids that has been carried out for over 150 years. There are, however, some potential problems that can arise if the propagator is naive, leading to losses or weakening of the plant stocks. The propagator should be aware of the following factors.

Season - Some orchid plants are quite specific about the time of the year that they can be divided and re-potted. This varies from species to species, and there are plants which may die or deteriorate if they are divided at the inappropriate time. Usually the best time to divide a plant is at the beginning of the growing season as the new roots start to emerge. Timing is critical; the new roots are fragile and can be damaged if they elongate too much before re-potting. If the division is made before the roots are ready to emerge, the separated piece may go into 'shock' and fail to produce new roots for that season. There are, however, some species that appear insensitive to disturbance, but knowing how a species will react is usually a matter of experience.

Size of the division - With monopodial orchids, side branches or offsets termed keikis should have produced sufficient aerial roots to maintain the plant once it has been severed from its parent. Unfortunately, the minimum amount of root needed is usually learned by experience. Without sufficient roots the division may not grow. If the plant is sympodial, divisions should be of no less than three pseudobulbs or growths excluding the lead growth if that is immature. Some orchids such as the larger *Cymbidium*, *Lycaste*, and *Zygopetalum* species can be propagated from single growths, but most species appear to require a minimum of at least three. Often the smaller the growth and the thinner the pseudobulb the greater the number of individual growths needed to support a new plant.

Disease - The major problem in vegetative propagation is the spread of infectious diseases by means of the knives or other instruments used to separate the portions of the plant. Virus diseases are of major concern here. Only sterile instruments should be used to separate the pieces of the plants. Blades can be sterilised by immersing them in a strong bleach solution or heating the blade in a strong flame. The entire blade and not merely the cutting edge must be sterilised. Small droplets of sap on the flat of the blade can infect otherwise healthy materials. There are few long-term orchid plant collections in which virus-infected plants do not make up a major portion of the collection. Such plants lose their vigour and require special precautions if they are to be used for sexual propagation.

Harold Koopowitz, Ecology and Evolutionary Biology, University of California, USA

Box 4.4 OrchidNet, an *ex situ* global propagation network.

OrchidNet is the only organization in the world focused on linking together orchid growers to enable *ex situ* conservation in their own homes and greenhouses. We collect inventory listings of orchid collections to allow orchid growers to set up seed, pollinia, plant, and information exchanges. Once plants are obtained, grown, and outcrossed, we provide free flasking of species to ensure that non-commercial species will also be propagated. To allow timely sharing of text and graphical information related to conservation and propagation of orchids, we maintain an on-line site on the World Wide Web.

There are several advantages to orchid conservation by OrchidNet. By distributing orchid plants among thousands of growers we avoid the potential problems of site vulnerability. If a hurricane destroys a collection in Florida, the same plants can exist in Brazil, Botswana, or India. The same is true for funding. Growers who are part of our World Collection are dedicated to maintaining their plants and are not subject to fluctuations in bureaucratic funding. We can have thousands of the same species propagated to help prevent genetic bottlenecks. Using computer databases it is possible to track lineages of plants and ensure that outcrossing occurs.

Those most actively involved in conservation are most likely to enjoy its benefits. Hobbyist and commercial growers (as well as botanic gardens) are enlisted to do what they do best — grow orchids. This approach empowers non-scientists to participate in conservation as opposed to letting governments and international agencies "take care of the problem." Concern for the planet grows from a perceived ability to help as well as having a stake in the outcome of environmental actions.

To date OrchidNet lists over 10,000 different orchid species resources and connects over 1200 growers. We are expanding continuously. We have flasked and distributed over 40 different species, some Appendix I species and others as yet unnamed, totalling thousands of plants. Currently, we are growing our first plants for reintroduction and extend an open offer to any organization needing this service.

Orchid conservationists must continuously re-evaluate international conservation opportunities and challenges. OrchidNet sees one unified world interconnected by telephone, computer lines, and postal carriers and invites orchid conservationists to participate.

Jonathan Titus and Jonathan Driller, OrchidNet, USA; DB4Orchids@aol.com, http://Orchid.Org.

4.4 The importance of research

Humans have destroyed approximately 44% of the world's tropical forests (WRI 1990). Eighty per cent of the total of 20 million hectares of deforestation per year is due to the conversion of forests to agricultural lands (Pimentel *et al.* 1986). The effects of this destruction may very well lead to a mass extinction of plant and animal species.

In order to preserve orchid diversity it is necessary, among other things, to undertake research to know, first, <u>which</u> taxa are endangered and require urgent action, and second, <u>how</u> to preserve them. The answer to the first question can be drawn mainly from floristics, biogeographical studies, and inventories of threatened species. The second question involves three different strategies in conservation (Frankel 1983): 1) provide the space required for survival and continued evolution; 2) accept extinction and removal (for *ex situ* conservation) when space demands cannot be satisfied, with unknown but perhaps drastic consequences to the community; and 3) manage population size and population structure of selected species presumed to be threatened. To implement any of these strategies, especially the third, requires substantial data, much of which has not been gathered.

When our aim is to preserve the diversity of orchids in the world, we actually want to preserve their ecological and evolutionary processes, including speciation and natural extinction. When we preserve a species *ex situ*, we are not preserving the genetic pool of the taxon, i.e. the diversity of allelic frequencies among individuals within a population and among populations, and consequently we are not preserving the potential for long-term evolution. Therefore, I will focus on the maintenance of orchids *in situ* rather than *ex situ.*

It is currently realised that the protection, management, and restoration of natural habitats is the best and cheapest method of preserving biological diversity and the stability of the global ecosystem. Propagation of endangered species in cultivation can contribute significantly to the maintenance of orchid diversity; this alone, however, is not a viable alternative because limited resources and facilities (laboratories, greenhouses, trained horticulturists, etc.) and inevitable genetic changes from random genetic drift and selection in artificial environments may make it difficult for cultivated strains to be re-established in the wild.

4.4.1 Studies needed to determine what to conserve

Floristics

Floristic studies are extremely important not only for identification and correct nomenclature of plants but also for compiling a global inventory of orchid species to make realistic assessments of endemism and to identify areas that should be preserved because they contain rare species or a great variety of species. In the last decade excellent floristic works have appeared, resulting in much more detailed knowledge about distribution of orchid species, especially for Central America, southern Africa, Australia, south-east Asia, some South Pacific islands, and even Andean South America, although it is understandable that the last, the richest orchid flora of the world, is less well known when compared with the floras of less diverse areas.

We have a much better understanding of the distribution of the common orchid species. However, there are so many species with such specialised habitats, low population numbers, and narrow geographical distributions that some of them, terrestrials and small epiphytes in particular, will remain unknown. The incredible number of new species of pleurothallids, *Bulbophyllum*, and *Epidendrum* described in the last few years suggest that many yet unrecorded orchids remain in tropical forests. Perhaps 10-25% of Mexican orchids will remain unknown (unrecorded, undescribed, or unrecognised as distinct taxa) after completion of a synopsis of orchids of Mexico now in preparation by Soto, Salazar, and Hágsater. There are also many unknown species in Venezuela, notwithstanding that both these countries are often regarded as well botanised, and that is true when compared with Honduras, Bolivia, and Peru. Similar situations can be found in the African and Asian tropics.

Floristic works must continue and be encouraged in many areas, including those supposedly well botanised. Furthermore, monographic studies on certain groups are also important and have produced new orchid species, even in the United States (e.g. Hágsater 1993c). It is sad that current trends in orchid systematics often do not consider monographic projects a research option.

Biogeography

Like other organisms, orchids frequently are concentrated in obvious 'diversity centres,' 'diverse habitats,' or 'centres of endemicity'. These centres have been known by orchid collectors and taxonomists for some time, but there is very little objective or systematic information about them. Despite the fact that a strong correlation between rainfall and plant diversity has been

Box 4.5 The problems associated with botanical sampling and study.

In order to plan for the conservation of orchids, we need to know what kinds there are, where they occur, and something of their ecology and frequency. One can learn something about the more popular horticultural species from the orchid growers in a given area. Unfortunately, this information is rarely written down and documented by museum specimens, so that we cannot be sure of the species involved.

Ideally, we would study living orchid plants, but no single living collection is large and varied enough for our needs. Then, too, many living collections fail to keep accurate records on the geographic origin of their plants (when known). In practice, we must depend on pressed and dried museum specimens, supplemented where possible by living plants and flowers preserved in liquid. Most pressed plant specimens have been gathered by general collectors, who press specimens of any plants they find in flower, though some, of course, specialise in trees or particular groups. Most orchids specimens that are preserved without flowers are of limited utility, and the most efficient way to collect orchids for study is to press specimens of those species found in flower and to gather living plants of other species to be cultivated until they flower and specimens can be pressed. Most orchid growers do not label their plants as to geographic origin and are reluctant to prepare pressed specimens. In most cases, though, one can prepare quite useful specimens by pressing an inflorescence and the oldest vegetative parts, without harming the plant.

One must emphasise that, in general, orchid species are not well represented by museum specimens. Many species (and especially the larger-flowered taxa) are poorly represented in museum collections, and some problems simply cannot be resolved with the available material. In the preparation of the orchid manuscript for the Costa Rican Manual, I studied material from the following herbaria where Costa Rican material is relatively well represented: Oakes Ames Orchid Herbarium, Duke University, Field Museum of Natural History, Missouri Botanical Garden, Marie Selby Botanical Gardens, Museo Nacional, and the Herbarium of the Universidad de Costa Rica. Of some 300 species studied so far, 28 species have been represented by more than 25 Costa Rican collections. All of these are common or widespread species (see Table 5.4.1). Much more than 10% are represented by few or inadequate specimens, including even some species that are relatively common (Table 5.4.2), and some species were represented in only one herbarium. It is therefore clear that orchids are poorly represented in Costa Rican collections. For example, in my recent revision of *Dimerandra*, two species were reported for Costa Rica, and another is to be expected. *Dimerandra* is generally a common and weedy plant at lower elevations, yet from the herbaria listed above I have seen seven specimens with only two very battered flowers.

Conservation and botanical study Although the authors of the CITES legislation expressed a desire not to interfere with botanical research, these good intentions seem to have been lost in the succeeding bureaucracy. Many general botanical collectors will not press a single orchid, as the presence of a pressed orchid makes their pressed material much more difficult to import into the United States or Europe. It would help greatly if pressed material and material in liquid preservative could be deregulated, as there is no real commerce in either type of material.

Sampling problems In tropical areas in particular, degradation of the forests occurs soon after roads are built, so that accessible areas are generally of little interest. Sampling, therefore, poses a number of logistical problems. There are several ways to study the forest canopy, but none of them would be economical for large-scale sampling. In too many cases, settlement by foot and horseback moves well ahead of passable roads, so the habitat is degraded, if not destroyed, before botanists even enter the area. Unfortunately, I can offer no real solution to this problem.

Robert L. Dressier, USA

stressed (Gentry 1982b), centres of orchid diversity must be identified because there are other factors such as historical events that have created these 'diversity pockets'. Identification of such centres, which are of great importance for the conservation of a significant number of orchid species, must be a priority.

As an example, I have estimated that six very diverse areas in Mexico (each less than 100,000 ha), located in different floristic provinces, contain about 50% of the total recorded orchid flora for the country. The advantages of this clustered distribution can be seen when we realise that these areas represent only 0.003% of the territory of Mexico, and they correspond with other centres of diversity identified for other groups such as birds and reptiles.

Endangered species lists

An important and urgent goal not yet fulfilled for most regions is the determination of the degree of threat that particular species are facing. This is necessary in order to dedicate more efforts to critical taxa. Most of the available information about threatened taxa is extremely fragmentary and in many cases inaccurate. Correct information will help us to focus our time and resources on those taxa which are truly endangered or threatened. However, care must be taken in the preparation of such lists, because some of them are based on uncritical information, which has exaggerated the number of species in endangered categories with negative consequences. Endangered species lists should be prepared only by teams which are acquainted with the status of the populations in the field and the pressures that those populations are facing.

Propagated species lists

An outstanding contribution has been the preparation of a record of species that are being successfully propagated in commercial nurseries (Beguin 1993). We hope that this kind of contribution will continue to be available in the future, since it allows us to plan *ex situ* efforts and potentially reduce the pressure of collecting in wild populations.

4.4.2 Studies needed to determine how to conserve

Extinction — natural and otherwise

In general, it has been said that the factors contributing to the extinction of local populations are low density, small and infrequent suitable patches, limited dispersal ability, inbreeding, low heterozygosity, founder effects, hybridisation, successional loss of habitat, environmental variation, long-term environmental trends, catastrophes, extinction or reduction of mutualist populations, competition, predation, disease, collecting, habitat disturbance, and habitat destruction (Soulé 1983). Translate these subjects to orchid conservation, and a terrible lack of information about them is immediately evident, especially with regard to tropical taxa.

There are several general estimates about the magnitude of extinction due to human activities; however, data suggest that there are more orchid species than those expected in certain managed areas. The absence of extinct orchid species in densely populated countries such as Mexico is also rather surprising. This could mean that orchid species have mechanisms that enable them to survive at very low densities or with very small population sizes. However, studies in this area are not available.

Orchids of economic importance

There are several orchids of economic importance, like some *Vanilla* species and the wild relatives of species in the flower trade. Although many orchid cultures comprise genetically uniform populations, either of strains or clones, eventually the hybridisers have to return to wild populations for desirable features that they want to add to their cultivars. As far as I know, there are no programmes for the maintenance of the genetic diversity of the wild populations of these economically important orchids.

The case of *Vanilla* is noteworthy, since cultures are very probably formed by only a few clones. Diseases, especially systemic rots, are a major problem for *Vanilla* growers and have discouraged plans to expand commercial cultivation in new areas or in those where pathogens occur. Obviously, the search of disease-resistant clones in wild populations and their inclusion in breeding programmes can help solve this problem.

Natural history

Orchid flowers are fascinating subjects, and they have attracted the attention of biologists in such a way that many other aspects of orchid biology remain relatively little studied (Benzing 1986). Even relatively basic information on habitat preferences, soil type, light environment, associated vegetation or phenology is largely unknown for tropical orchids. Probably the most noticeable difference between temperate and tropical orchids is the amount of knowledge on the natural history available for the former and the scarcity of information for the latter. When a maintenance, restoration, or reintroduction programme of orchid populations is attempted, this kind of information, either systematically collected or not, is much appreciated. Very useful data can be collected by amateurs without formal training in botany or ecology. Relationships among amateurs and trained botanists have produced outstanding contributions to orchidology. It cannot be over emphasised that one should gather some knowledge about the species before attempting to manipulate either a given species or its habitats.

Demography

Orchid population sizes and densities -Although there are some ideas about the possible sizes of orchid populations, we need much more accurate estimates of the numbers of the wild populations to design conservation strategies. Some orchid species have population densities of thousands of individuals per hectare, both in temperate and in tropical communities. For example, maxillarias are usually extremely abundant in neotropical forests. On the other hand, individuals of *Teuscheria, Coryanthes,* and surely many other genera occur at very low densities. For mammals and large tropical trees there is an inverse relationship between survival and area; perhaps this can be applied as well to orchid species with low density populations. If the population density of one of these 'rare' species is 1 individual per 5 ha, a 500-ha reserve (approximately the size of Los Tuxtlas reserve in Veracruz, Mexico) can support a population of only 100 individuals. This is a very low number for the successful long-term conservation of a population, and consequently it is very probable that a species with these density characteristics will disappear.

Populations declining to low numbers experience diminished viability and reproduction for non-genetic reasons, and there may be a threshold density or number of individuals below which the population cannot recover (Alle's effect). In very sparse populations, the probability that an orchid stigma will receive pollinaria from another individual may be so low that individual fitness can drop dangerously, with negative consequences for the whole population.

How long do orchids live under natural conditions? Our knowledge about longevity in orchids comes mostly from experiences on cultivated plants, but there are surprisingly few studies which describe the age structure of orchid populations. Demographic information is indispensable for the proposal of sound management plans and utilisation of wild populations, and it also permits us to make predictions about the fate of the populations. More elaborate demographic studies can indicate those stages of the life cycle with higher mortality that can be manipulated in order to maintain the wild population.

Maintenance of orchid species with special life-histories - Orchids are members of almost all the major types of plant communities, have different systems that function in very different ways, and also play different roles in the community. Many orchids seem to be specialised for certain stages of the dynamics of the community. For example, many species in the subtribe Catasetinae are found only in lightgaps of humid forests left by fallen trees, and rely on relatively rapid growth and efficient dispersal to succeed in a continually shifting mosaic of suitable habitats. Critical factors affecting the persistence of a subdivided population include the number, size, and spatial distribution of patches of suitable habitat and dispersal rates between them; a dynamic balance between local extinction and colonisation. Species with this life-history strategy, in which there are explosions of population numbers and extinctions in a particular site, are difficult to manage and represent a challenge for conservationists (Soto 1994).

The disappearance of the 'dove orchid' (*Peristeria data* Hook.) on Barro Colorado Island, Panama, can be attributed to a change in the disturbance regime of the vegetation. Frequency of fires in savannas and chaparral, landslides in mountain rain forests, other successional processes, and effects related to herbivory and competition are all factors that maintain or exclude orchid populations from the communities. Of course, it is impossible to accumulate information on how vegetation dynamics and other species affect every orchid population, but much more information is needed in order to serve as models. It is obvious that research is essential to determine what kinds and levels of disturbance (fire, mowing, grazing) are required if we attempt to maintain or reintroduce orchids in their habitats.

Effects of isolation and fragmentation on the population genetics - The establishment of reserves is undoubtedly an important factor for the maintenance of orchid diversity. It is sufficient for the preservation of many species but not for all of them. Nature reserves are usually small when compared with the original habitat that we want to conserve. In countries with a very high human population density, as in most tropical countries, it is fortunate if even small reserves of a few hundred hectares can be established. Are those areas enough for the maintenance of orchids? For which species is it sufficient and for which is it not?

A crucial question is whether the conditions in nature reserves facilitate, restrict, or inhibit the essential ecological and evolutionary processes. In contrast to populations in undisturbed habitats, many species in nature reserves are small, disconnected, and subject to inbreeding, genetic drift, and random fixation of alleles, resulting in a gradual weakening and genetic impoverishment. Even if an orchid species has a large population and a wide distribution, it is very probable that it will face fragmentation or isolation of some of its populations along its range. Orchid populations seem to have survived severe fragmentation during periods of climatic change in the Tertiary and Pleistocene (the presence of 'series' of sister species along the mountain chains in the Neotropics seem to support this hypothesis). The question is whether they will survive the much more rapid and extreme fragmentation caused by humans.

It is well known that isolation predisposes small populations to extinction, especially in inflexible taxa. Many orchids are probably inflexible species because of their particular habitat preferences and complex symbiosis with other organisms (hosts, mycorrhizal fungi, and pollinators). Isolation promotes the divergence between populations and eventual speciation, but it has been suggested that for every small population that survives extreme isolation, many more probably become extinct. The genetic factors contributing to the extinction of the populations include population inbreeding and genetic drift. We still do not know how isolation and fragmentation of suitable habitats affect orchid populations. Because most tropical species are epiphytes, and this life form has some very contrasting life-history features when compared to terrestrials (e.g. potentially long-distance dispersal of seeds and pollen transport), one is tempted to suppose that some genetic flux can occur among populations located far apart.

Edge effects and survival of orchid populations - Another important point in conservation in nature reserves is that they experience deterioration of habitat quality near their boundaries. This fact is usually known as the edge effect. In orchids and other epiphytes that are very sensitive to slight changes in available humidity, edge effects or desiccation by logging should have severe impact. No research has been conducted to evaluate the consequences of this environmental deterioration.

Effective population size - This is an important concept developed by conservation biologists, defined as the population size that could maintain typical amounts of heritable variation in selectively neutral quantitative characters (see Section 4.3.3). Franklin (cited in Lande 1988) has proposed that a number of 500 (reproductive) individuals for any species can meet this requirement. However, management of particular species should incorporate details of a species' ecology, especially its life-history and demography, which may require larger populations than those that have been suggested on genetic grounds alone (Lande 1988). Therefore, each case must be carefully evaluated to determine which population numbers could maintain this genetic variation. This is probably the field of research in orchid conservation about which most information is needed.

Genetics - The concept of minimum viable populations has been approached from two different perspectives. The first is a demographic approach already stressed. The second approach has focused on genetic aspects of the population, but it suggests equally the existence of critical factors — population size and structure — below which inbreeding and loss of selectable variation become a problem for the continued survival of the population (Gilpin and Soulé 1986). In small populations, inbreeding can greatly reduce the average individual fitness, and loss of genetic variability from random genetic drift can diminish future adaptability to changing environments.

The orchids probably have slower adaptative genetic divergence when compared with other plants, since the dust-like seeds have a bigger chance of long-distance dispersal. Also, pollinaria attached to insects can permit a larger genetic flux among relatively distant populations. Although floral biology of orchids has been developed to a larger extent than other fields of orchid biology, the information about genetic fluxes is fragmentary and inconclusive, and research has been more focused toward its role in speciation than its relevance in keeping populations genetically connected.

Many other aspects of the genetic structure of orchid populations are unknown. Does the majority of the species' genetic variation reside within the population or does most of it occur among populations? In other plants the disturbance regime, sexual mode of reproduction, self-pollination, animal-dispersed seeds, and characteristics associated with early stages of the succession have been correlated with higher allelic diversity among their populations than in species with other combinations of life-history strategies. This kind of information is almost absent in studies dealing with orchids.

Maintenance of orchid diversity in managed systems - Enhancement of survival does not necessarily mean protection in formal reserves, at least for orchids. Pimentel *et al.* (1992) have estimated that only 5% of the land surface of the Earth is unmanaged and uninhabited. Managed areas contain most of the biodiversity, so major efforts should be made to conserve the many species that now exist in the extensive, managed environments. The role of small suitable habitats such as riparian forests, remnant trees in pasturelands, orchards, coffee plantations, and other similar habitats is very important for the conservation of other groups of plants and animals, and their importance for the orchid populations must be evaluated. Grapefruit orchards in Belize hold a significant proportion (21 species; Catling *et al.* 1986) of the total orchid flora of the area (c. 80 epiphytic species) (see Section 4.2.4). Similar or even higher numbers of orchid species can be found in other plantations of tropical, perennial crops such as coffee, vanilla, and cocoa. As the remaining natural areas become smaller and more fragmented, it is increasingly important to understand the ecological and evolutionary dynamics of small populations in managed systems in order to preserve them for a time when future restoration of natural areas may allow expansion of their ranges (Lande 1988).

Ex situ conservation

Today there is a considerable amount of information about maintenance of orchids *ex situ*. Most epiphytic orchids and some terrestrials are easily cultivated in artificial environments. It is not unusual to have hundreds or even thousands of species being grown in a limited space.

The viability of orchid seeds stored in seed banks may be lost after a short time, and special methods to extend longevity have not been developed for most orchids. Seed banking is very important for *ex situ* conservation because it permits long-term storage of a very large number of taxa at relatively low costs. At present, relatively little attention has been paid to this field of research.

Germination of orchid seeds by asymbiotic techniques is a common practice in commercial nurseries, botanic gardens, and even by amateur growers. There are excellent manuals about the subject (Arditti and Ernst 1988; Arditti *et al.* 1982) as well as a voluminous bibliography in which information about germination media, suitable temperatures, management of seedlings, and other relevant topics can be found. New information on difficult species is continually published.

In some species in which asymbiotic germination techniques have been largely unsuccessful, symbiotic germination has produced excellent results (Clements 1982; Smreciu and Currah 1989). Symbiotic germination has been attempted mainly on temperate terrestrial orchids and promises valuable information directly related to management, restoration, and *ex situ* conservation of orchids.

Summary of research needs for orchid conservation

1) More monographic and floristic work, especially in those genera or areas which have not been covered by modern treatments;
2) Precise recognition of particular areas of high diversity and endemicity, based on accurate information;
3) Precise recognition of habitats and species which are facing critical conservation situations, based on objective field work and data;
4) Collection of information on the natural history and ecology of selected orchid species;
5) Demographic research on orchids with different life-histories, so that models can be established for the management of other species;
6) Demographic and genetic effects of habitat fragmentation;
7) Kinds of management necessary to enhance the preservation of orchid diversity in agrosystems.

Miguel Soto Arenas, Herbarium, Asociación Mexicana de Orquideología, Mexico

4.5 Commercial trade

Orchids have been collected from the wild and grown in cultivation as pot plants for at least 2000 years. Orchid growing began in the Far East and was popular at the time of Confucius. It can be said to have started in Europe toward the end of the 18th century. The first tropical epiphyte flowered in the Royal Botanic Gardens at Kew in 1782. In the first half of the 19th century there were introductions from around the world as botanical exploration and collecting expanded. Growers, too, became more adventurous in breeding from wild stock, and the first artificial hybrid flowered in 1856. Raising plants was erratic until 1899 when the French botanist Noel Bernard demonstrated the need for a fungus to aid germination. In the 1920s the American plant physiologist Lewis Knudson showed that the fungus could be eliminated and that a complex sterile mixture of mineral salts and sucrose incorporated in agar provided a suitable medium for the germination of the seeds of many species and hybrids. From this moment the modern orchid industry has its origin. Research for improving artificial propagation techniques was undertaken in many nursery laboratories. Methods for seed germination are simple, inexpensive, and feasible from either the home kitchen or the sophisticated laboratory. Since so many seedlings can be produced from a single seed capsule the main problems encountered in artificial propagation are 1) finding adequate space for cultivating the plants and 2) distributing and marketing these large quantities. The advent of techniques of tissue culture in the 1960s further enhanced the multiplication of plants throughout the world and contributed greatly to the development of the commercial cut-flower industry in Asia (Stewart 1993a).

Trade in seedlings, young plants, flowering pot plants, cut flowers, and vanilla pods constitutes a significant contribution to the economy of many countries. Artificial propagation reduces the demand for wild-collected plants for hobbyists by increasing the availability of desirable species, especially if better clones have been selected. Therefore the collection of wild plants, whether for commercial gain locally or in distant countries, has greatly diminished compared with the 'trade' in these plants a century ago. The fact that more and more endangered species are artificially propagated is a great step in orchid conservation and should be encouraged at all levels.

Here we present information selected from the *Review of Significant Trade in Species of Plants Listed on Appendix II of CITES, 1983-1989* (Oldfield 1991) prepared by the Wildlife Trade Monitoring Unit, Cambridge, England, for presentation to the CITES meeting in 1992. The information was obtained from the CITES annual

Commercial trade

Marc Dumont

Cattleya forbesii

Marc Dumont

Epidendrum radicans

Marc Dumont

Cymbidium hybrid

Marc Dumont

Dendrobium onosmum var. *album*

Phillip Cribb

Cut-flowers of *Dendrobium* hybrids in the Bangkok Flower Centre

Commercial trade

Marc Dumont

Odontocidium Tiger Hambühren

Marc Dumont

Vuylstekeara Etna Stamperline

Marc Dumont

Masdevallia coccinea

Alec Pridgeon

Phalaenopsis hybrid in trade

Phillip Cribb

Mt. Fujiyama made out of *Phalaenopsis* hybrids at the 12th World Orchid Conference, Tokyo

Phillip Cribb

Vanda Miss Joachim

reports for the seven-year period. It should be noted that figures refer only to international trade and that in certain countries there is extensive collection and sale of plants for local use in addition to the export trade. The information has been selected and rearranged for this chapter in Tables 4.5.1 and 4.5.2.

There are major difficulties in collecting and collating figures relating to orchid production and trade. They stem from the inaccuracy of the published reports and the frequent failure to report wild-collected and artificially propagated plants separately. Furthermore, the reports and figures that are available derive from CITES-related information, which is concerned only with species. If an exporter or importer is dealing with orchid hybrids, these must be recorded as 'spp.' because there is no space on the form for dealing with hybrids (which do not occur in animal trade). Compilers of statistics, who do not understand this difficulty, usually include the figures recorded as spp. as if they are unnamed species in their totals for each genus. In the data used in this chapter, the numbers included in the figures for the family Orchidaceae as a whole refer to intergeneric hybrids (Inskipp, pers. comm.), which are entirely artificially propagated and a unique feature of the orchid family.

4.5.1 Countries involved in international orchid trade

The figures quoted in Table 4.5.1 are selected from the , *Review of Significant Trade in Species of Plants Listed on Appendix I of CITES 1983-89* (Table 4 in Oldfield 1991). More recent figures are not yet available. In all the figures the data are derived from "all sources," i.e. a combination of wild-collected plants and artificially propagated material.

The average number of plants traded annually during this period as recorded in the CITES statistics was 4,996,508. Eighty percent were recorded as artificially propagated (Oldfield 1991). If these figures are accurate, nearly four million of the plants in trade each year were artificially propagated, and almost one million had been collected from the wild.

The largest exporters of orchid roots were China, Japan, and Taiwan. These 'roots' may in many cases be pseudobulbs. No indication of the difference between roots and live plants is given, and it would seem safer to combine these figures to learn how many specimens were actually exported during this period.

The major exports of orchid plants during this period were confined to 20 countries, although an additional 19 countries exported more than 1000 plants each year. Thailand appears to have been the largest exporter, with more than two million plants exported during this period, 83% of which are recorded as artificially propagated. Six countries exported more than 100,000 live plants during this five-year period — China, Japan, the Netherlands, Taiwan, United Kingdom, and the USA. For the United Kingdom, the figure for artificially propagated was given as 96%, but for China it was as low as 16%. In addition, 13 countries exported more than 10,000 plants per year — Australia, Brazil, France, Germany, Guatemala, India, Italy, Malaysia, Mexico, New Zealand, Peru, the Philippines, and Singapore. Of these, Brazil, Guatemala, Mexico, Peru, and Singapore recorded that less than 50% were artificially propagated. Surprisingly few orchids were exported as seeds during the period reviewed, but the figures given presumably refer to packets of seeds or capsules rather than individual seeds. Seeds are not subject to CITES controls.

Flasks and cultures, exempted since 1985, were exported by those countries known to have modern laboratory facilities for orchid production. Taiwan, Thailand, Brazil, the Netherlands, and the USA all exported more than 1000 flasks per year. Significant numbers were also exported by Malaysia (877) and Japan (486), and smaller numbers (more than 50) by Australia, the United Kingdom, Venezuela, and Australia.

Cut flowers, also exempt from CITES controls, were a major export from Thailand and Singapore, and large numbers were also exported from Australia, New Zealand, Taiwan, and USA. The figures given for the Netherlands for this period seem to be extraordinarily low, perhaps because their major production is exported to countries within the European Union and therefore are not recorded as exports for CITES purposes.

4.5.2 Major orchid genera in international trade

For each genus or group of genera listed below, we record the approximate numbers of species and hybrids and comment on their cultivation. These remarks are followed by some comments on the international trade in each of the groups. The figures extracted from the CITES reports already cited are presented in Table 4.5.2.

1. *Cattleya, Laelia,* and related genera and hybrids - These orchids in subtribe Laeliinae are distributed chiefly in the New World tropics. The huge number of hybrids, particularly those resulting from intergeneric crosses, greatly exceed the number of wild species in cultivation. The approximate numbers of species currently accepted according to Pridgeon (1992) are: *Cattleya* (48), *Brassavola* (17), *Epidendrum* and *Encyclia* (1,300), *Laelia* (60), *Rhyncholaelia* (2), *Sophronitis* (7), and *Schomburgkia* (17).

Approximately 5450 hybrid grexes (i.e. hybrids which have been officially registered) had been produced in the genera of this subtribe by 1991, and there is also a considerable number of intergeneric hybrids within the subtribe. They are traded nationally and internationally as seedlings, tissue-culture propagations, young plants, and mature ones. They are also grown in great quantities for trade as cut flowers, but this is largely local, particularly in the USA, because of the fragility of the large flowers.

2. *Cymbidium* - *Cymbidium* is a genus of about 50 species, distributed throughout the Old World tropics, through the Himalayan region to China and south to Australia where there are three species. Many plants have been grown in the Orient for more than 2000 years and are still treasured plants in connoisseurs' collections. Hybrids bred over the last century from the larger-flowered species have become very popular in the West, partly as pot plants for room decoration, as cut flowers, and also as highly prized specimens when they receive prestigious horticultural awards. More than 7500 hybrid grexes have been registered to date.

The Netherlands produced 1.36 million flowering pot plants of cymbidiums in 1986 in addition to 45 million flowers and 27 million cut inflorescences (Post 1990). Similarly, in Japan the annual production of pot plant orchids in 1991 was 17 million, 43% of which were cymbidiums (Sinoda 1994). Cymbidiums are also propagated and maintained for cut-flower production in New Zealand and Australia (many of which are exported to Japan and North America), South Africa (for exports to Japan and Europe), and California (for the domestic market). Tissue culture was an important tool in the 1960s for the rapid multiplication of uniform plants and has made *Cymbidium* cut-flower production possible.

The figures given in Table 4.5.2 for named species include very large numbers each year for five Chinese species: C. *goeringii* (average 48,073), C. *kanran* (19,497), C. *ensifolium* (9830), C. *sinense* (8980), and C. *faberi* (7165). These species have been cultivated in China and Japan for centuries. If these figures for plants in trade (93,545) are deducted from those given in the table, then the figures supplied for other *Cymbidium* species total 9,583 plants among 31 species, an average of 309 plants per species per annum.

3. *Cypripedium* - About 50 species of temperate terrestrial orchids comprise the genus *Cypripedium*. They are distributed around the Northern Hemisphere, extending as far south as Mexico and Honduras. Only one species, C. *calceolus*, is circumboreal, the others confined to a single continent. Nearly 20 hybrid grexes have been raised to date since 1990. The number of plants recorded in the trade (Table 4.5.2), all presumably wild-collected, is therefore alarming. Figures for live plants and roots have been totalled because plants of this genus are normally traded in the dormant state. They include 4377 plants of North American species exported per year and 51,621 plants of Asiatic species.

4. *Dendrobium* - *Dendrobium* is one of the largest orchid genera in the Old World, with approximately 1000 species. More than 6000 hybrid grexes have been registered. *Dendrobium* has two main lines of breeding and development in horticulture. Plants are developed by the millions and grown in hundreds of hectares for the cut-flower trade in any parts of south-east Asia. Plants are very floriferous, some of them producing up to 30 inflorescences per year at regular intervals. The central plains of Thailand, north of Bangkok, is the main centre. More than half of the Thai exports go to Japan; the rest go to Europe and USA. In 1991 Thailand exported about $80 million worth of flowers, most of which were dendrobiums, and sold an additional $40 million worth locally (Handley 1992). Singapore exported S$23 million worth in 1993, 62% of which went to Japan (Anonymous 1993b). Japan recorded imports of more than 124 million cut orchids in 1992, most of which were phalaenopsis-type dendrobiums (Sinoda 1994).

Dendrobiums bred from a different set of species, the so-called soft-cane or *nobile-type* dendrobiums, are widely grown as pot plants, particularly in Hawaii, Japan, and Brazil. Many of these are for domestic use, but other plants are traded, particularly among these three areas.

5. *Masdevallia, Dracula,* and other Pleurothallidinae - This group of New World epiphytic orchids is enjoying a renaissance of interest in the 1990s. However, there is also considerable interest in their conservation, and many of the plants in trade are known to be seed-raised. They can be raised from seed to flowering size in a few months (pers. obs.). More than 300 species of *Masdevallia* and about 100 species of *Dracula* are known. Many of them are currently in cultivation in specialist collections. About 100 hybrid grexes have been registered so far.

6. *Miltonia, Miltoniopsis, Odontoglossum,* and *Oncidium* - This group of New World orchids in subtribe Oncidiinae is largely found along the Andes of South America, the coastal mountains of Brazil, and in Central America. Major genera in cultivation and approximate number of species in each according to Pridgeon (1992) are: *Miltonia* (10), *Miltoniopsis* (6), *Cochlioda* (5), *Odontoglossum* (60), *Oncidium* (600), and *Brassia* (29). More than 5000 hybrid grexes within and among several of these genera have been registered.

The genera *Odontoglossum* and *Miltonia* grow best in cool climates, and these have been traditional pot plants for greenhouses in Europe and North America. One of the intergeneric hybrids, *Vuylstekeara* Cambria *(Cochlioda* x *Odontoglossum* x *Miltonia)*, is probably the most commonly cultivated orchid in the world. Many millions of plants have been obtained by tissue culture in the Netherlands and exported all over Europe, USA, Australia, and South Africa.

Oncidium is another genus from which several species and hybrids are cultivated in great numbers in Singapore, mostly for the cut-flower trade, but also to supply young plants to other farmers.

7. *Paphiopedilum* - The tropical slipper orchids comprise the largest single group of orchids in horticulture. Although there are only about 70 species in the wild, more than 12,000 hybrid grexes have been bred from them, in a variety of combinations, over the last 140 years. Modern prize-winning hybrids may be up to 16 generations away from their wild origin. Large numbers of wild-collected plants were traded until the genus was placed on Appendix I in the late 1980s. Each new discovery changed hands for high prices when it first appeared, even in the 1980s. The excitement is quickly superseded by another novelty or by new hybrids of various shapes or colours. The trade is largely in seedlings, flasks, or bare-root mature plants. New crosses and awarded hybrids account for most of the trade, most of which is domestic. International trade in this genus occurs between major breeders of new hybrids in UK and USA with Japan, Australia, and elsewhere. Trade in cut flowers of the genus is largely within Europe.

8. *Phalaenopsis* - About 50 species of mainly epiphytic orchids have been recorded in this genus from India east to China and south-east to northern Australia. They are easy to grow in warm, humid conditions where there is a drop in temperature at night. More than 11,000 grexes had been registered by 1991. The trade in wild-collected plants is still significant.

The species and hybrids of *Phalaenopsis* flower on small plants; they can be raised from seeds to flowering size in two years or less. There is a huge industry in their production in Taiwan and especially in Japan where they are second only to cymbidiums in orchid pot-plant production. Plants are also produced in California and several European countries. To grow and flower well they require high temperatures and high humidity, so they can be raised cheaply only in areas where heating fuel is inexpensive or unnecessary.

9. *Pleione* - About 16 species of these rather attractive dwarf orchids occur in the Himalaya region and extend into Taiwan. About 40 hybrids had been registered to 1991. Some species are easily propagated vegetatively from small bulbils which develop at the base or apex of the old pseudobulbs and also from seed. Wild-collected material, especially from China and India, is still a significant proportion of the international trade. Plants are usually traded as dormant pseudobulbs, which may be recorded as 'roots.' Although they are not usually hardy under temperate conditions, pleiones are very popular among alpine plant enthusiasts. Few are regularly cultivated by traditional orchid growers.

10. *Vanda* and related genera - The monopodial orchids in the genera often described as vandaceous occur throughout south-east Asia. Major genera and estimated species in each (Pridgeon 1992) are: *Arachnis* (7), *Papilionanthe* (10), *Renanthera* (15), *Vanda* (50), and *Vandopsis* (5). There are at least 4000 registered hybrid grexes. Hybrids of *Vanda* and related species are grown very easily in many parts of tropical Asia, either in the open air or under inexpensive shade cloth. Orchid farming in Singapore began with vandas and intergeneric hybrids such as *Aranda, Mokara,* and *Holttumara,* the last two each having three different genera in their parentage. The inflorescences are easy to pack, and the flowers are long lasting and brightly coloured. The export trade from Singapore was worth US$14 million in 1991, and the government there aims to triple this figure by 1995. This will be achieved by coordinating the work of university laboratories, botanical gardens, and commercial growers. There will also be some expansion into neighbouring territories of Malaysia where more land is available. These hybrids have come a long way from the wild species such as *Vanda coerulea* and *Vanda suavis,* which are themselves propagated in great numbers and available as selected cultivars superior, at least horticulturally, to the wild forms.

11. Species and hybrids attractive to hobbyist growers - Orchid plants are grown by hobbyists on a different scale today compared with one hundred years ago. Although there are probably more growers than ever before, they usually have small greenhouses with perhaps a few hundred plants or grow plants on windowsills or in the basement of the home. Many growers have become quite selective and concentrate on a particular group or subfamily of orchids. In Great Britain, for example, the Paphiopedilum Society has about 100 members, and the Pleurothallid Alliance has 35. Nurserymen have also become specialists in these and other groups in order to meet the demand. Most species today are raised from seed in the laboratory, and techniques are improving all the time. Equatorial Plants of County Durham, UK, has raised over 600 species from seed in the last 10 years and have no difficulty selling their products in flasks or as weaned seedlings for a few pounds sterling each. No other nursery in UK has such a large number of species for sale today.

12. *Vanilla* - Until 30 years ago the only orchid of economic importance (other than ornamental) was *Vanilla*. Three species are grown for their fruits, known as 'pods' or 'beans/ but the majority of commercial vanilla farms use *V. planifolia.* It is an important crop in tropical areas where labour is cheap, land is available, and the climate is suitably humid for most of the year. The greatest production is in Madagascar, Reunion, and the Comoro Islands.

Joyce Stewart, UK

4.6 Ecotourism

Our experience of conservation management and ecotourism is in a series of remote river headwaters and contiguous valley and mountain complexes situated some 160 km north-east of Rio de Janeiro, Brazil. The area of approximately 15,000 hectares is situated within the coastal mountain barrier range. The elevations vary between 900 and 1800 m, and the terrain is rugged. Four thousand hectares of the area are undisturbed primeval high mountain Atlantic Rain Forest, whereas the remainder comprises regrowing native forest in various stages of development, interspersed with pasture and some *Eucalyptus* and pine plantations. Due to the efforts of both the Rio de Janeiro Botanic Garden and ourselves, the region has been given the official status of a Municipal Ecological Reserve. However, at present such status has little practical meaning as the municipality has neither the funds nor the expertise to manage such an area.

Ten years ago, together with like-minded friends, we bought a 4000-ha tract of primeval forest. The area is uninhabited. Approximately two-thirds was purchased with full title, and the remainder with 'precarious title' known as 'the right of possession' because the occupant is living on and earning a living from such land. In traditional terms this implies, of course, cutting down the forest, planting bananas, and making pasture. Obviously, this was not our aim, so we set about occupying the area in a different way.

We called in botanists from the Rio de Janeiro Botanic Garden, who were then setting up a major study of the Mata Atlantica (Atlantic Forest). They chose our area as their main base and, nine years on, are still carrying out sub-studies derived from their original census of woody plant species (Martinelli *et al.* 1990). We convinced a number of botanists and biologists that the area provides valuable baseline data and support in which to undertake field work for doctoral theses and other research. We ourselves took a census of the Orchidaceae in the area and published a book describing over 230 orchid species from 56 genera (Miller and Warren 1994). We have written dozens of popular articles, published in various magazines, describing aspects of flora and fauna of the region. Through our liaison with the municipality's Environment Secretary, we appear frequently on television to demonstrate the fauna and flora, particularly the orchids, to highlight and illustrate discussions on conservation. These programmes have been received very favourably. We also give lectures and slide programmes to orchid societies, schools and other committed and interested groups, describing the area, its resources and especially its vulnerability. Included in our work is a 'vulnerability assessment' of each orchid species, which predicts its fate should the ecosystem be radically altered. Finally, we conduct tours for periods ranging from one day to three weeks. These are designed for botanists, principally orchid enthusiasts, but also for ornithologists, biologists, schoolchildren, and lay people interested in ecology and conservation. At present, this activity is our main money-earner and justifies our 'right of possession' title, enabling us to continue living in the area.

The activities outlined above have a threefold purpose: 1) To emphasise the importance of these magnificent primeval forested mountains and valleys to the local population and general public. The local population is ultimately responsible for conservation, but the people cannot be expected to adopt an active role until they know what they are conserving and why they are conserving it. 2) To prevent the encroachment of undesirable visitors such as hunters, plant collectors and clandestine lumbermen by bringing in scientists. In a legal sense, the scientists occupy the whole study area and significantly help our legal defence when our precarious title is threatened, as it often is, by dishonest real estate agents. 3) To expand knowledge of other significant and interesting plant families in this area, about which there is no popular literature in Brazil. Visitors, in particular the horticulturists and growers, are able to see the plants they grow professionally in their natural habitat, helping them to improve their growing methods. In addition, most of these visitors will later go on lecture circuits in their home countries, so creating a ripple effect of our work.

Ecotourism in the region managed this way can bring only benefits. Because of the rugged nature of the terrain it is virtually impossible for visitors to stray from the cut paths which run up the river valleys and along mountain ridges. As such, less than 1% of the total area is accessible for practical purposes, though all can be surveyed from the mountain ridges. When a tree falls, orchidists can often identify over 50 orchid species from its branches. It is always our practice to accompany visitors along these paths. In this way we prevent fire, litter, plant collection, snakebite, and lost visitors. The day-long treks we make are strenuous but completely rewarding for the incredible variety of plant genera and

Table 4.5.1 Exports of orchids, averages per annum for 1983-1989 (from Oldfield 1991)

Country	Roots	Plants	Seeds	Flasks/Cultures	Flowers
Australia		20,094		158	38,463
Brazil		62,404		3,659	
Canada		4,587			
China	20,782	156,132			1,199
Colombia		9,524	15		
Costa Rica		3,702	5	9	5,417
Denmark		154			
Ecuador	2	3,412			
France	1	25,598		33	59
Germany		19,814	63	68	312
Guatemala	9	10,238			4
Hong Kong		1,458			
India	712	65,919		1	
Indonesia	14	5,852		2	9
Italy		12,592			
Jamaica		5,482		3	
Japan		850,909	857	486	5,809
Kenya		1,551			1,438
Korea		8,153			
Madagascar		3,648			1
Malaysia		16,562		877	5,061
Mauritius	428				
Mexico		32,844			
Nepal		6,546			
Netherlands		554,681		1,172	864
New Zealand	61	22,548		20	34,151
Panama		2,109			
Papua New Guinea		1,260			
Paraguay		1,334			
Peru		20,164		1	
Philippines		53,348	3		2
Poland		3,493			
Singapore		84,427		3	1,074,252
South Africa	9	2,590	124	7	28
Sri Lanka		5,943			39
Suriname		3,608			
Sweden		2,249			
Switzerland		67			
Taiwan	69,406	852,772	40	6,174	62,928
Thailand	27	2,334,468		4,348	4,877,544
United Kingdom	3	157,025	1	151	
United States	2,525	248,586		1,131	16,930
Venezuela		3,481		123	

Genus	Hybrids and unnamed	Named species	No. species named	Average no. of individuals per species
Cattleya	56,004	12,811	46	278
Cochlioda	104	176	5	35
Cymbidium	310,176	103,128	36	2,864
Cypripedium[a]	24,173	55,998	17	3,294
Dendrobium	1,706,074	85,595	364	235
Encyclia	1,690	10,870	120	90
Epidendrum	3,171	3,960	199	20
Laelia	1,955	16,086	48	3351
Masdeoallia	3,981	3,639	286	12
Miltonia/MiHoniopsis	16,609	1,356	15	90[2]
Odontoglossum	49,022	2,985	79	37
Oncidium	175,227	24,594	250	98
Paphiopedilum	97,518	304,370	65	4,682[3,4]
Phalaenopsis	389,440	13,380	41	326
Pleione[a]	57,534	181,181	12	15,098
Vanda	90,468	3,769	30	125
Orchidaceae[b]	1,146,591			

Table 4.5.2. Orchid plants in international trade, averages per annum for 1983-1989 (from Oldfield 1991)

Notes

[a] Including 'roots'

[b] Including intergeneric hybrids and unnamed plants

[1] The figures include 2683 plants of Mexican species and 13,403 plants of Brazilian species.

[2] These genera are listed together because many suppliers do not recognise them as separate genera.

[3] The figures include 2624 plants of *P. delenatii*, which must be artificially propagated because the species was not rediscovered in the wild until 1993.

[4] Largely because of these high trade figures, the whole genus was transferred to Appendix I in 1989 (effective 1990).

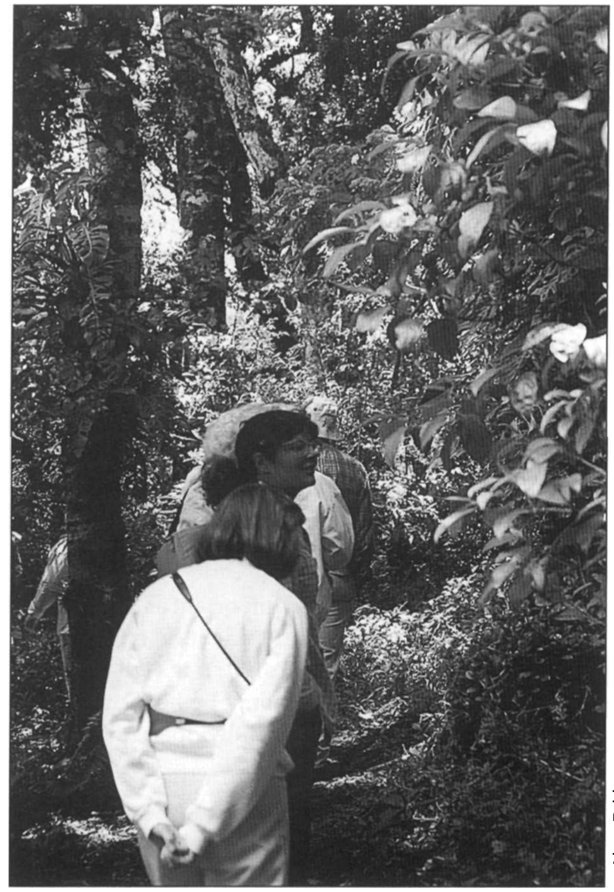
species we see, the half-dozen distinct ecosystems, and the spectacular views of this untouched fragment of the original Mata Atlantica.

Obviously regions such as this should not be available for mass ecotourism but only for small enthusiastic groups and always by appointment. We generally handle groups of three to twelve people but have had one school field trip with 24, studying for their higher school exams and carrying out legitimate scientific projects. For these numbers we have adequate, comfortable living facilities, and even this volume of supervised on-site ecotourism presents no threat whatsoever to the resilience of the ecosystem. We have also given day-tours for schoolchildren and will be offering many more, for it is our view that it will be the next generation that will tackle the conservation problem in Rio de Janeiro State; our role is to hold on to what exists and broadcast and explain it by all means possible. We have concentrated heavily on divulging information, rather than on education in the more formal sense, recognising that we have an important role as interpreters between the scientists who carry out research in the forest and the general public who need to be informed of research results.

The most dangerous threats to our conservation programme are the pressures by dishonest real estate agents. This means that we must always be present in the area and have sufficient funds available to pay legal expenses for the defence of the property. None of the ecologically involved international non-governmental agencies, at both national or international levels, will offer to help finance the purchase and management of primeval forest if the title is 'precarious'. This is curious because we suspect that most of the remaining untouched mountain Atlantic Rain Forest in the State of Rio de Janeiro is still without definitive title, and consequently at the mercy of dishonest real estate agents.

The costs of setting up and running these operations are substantial. Because of the enlarging size of our managed area and the increasing intrusions resulting in rising costs, we have established the Rio Atlantic Forest Project to raise funds directly from the public and have applied for charitable status.

The 11,000 ha of buffer zone property which comprises the remainder of the Municipal Ecological Reserve is a valley inhabited by a small local population who mostly watch over the property of 'weekenders'. In our view it is inevitable that, as the middle class increases in numbers and the demand for weekend cottage properties grows, this part of the reserve will become more intensely populated and lose many of its 'ecological reserve' characteristics. Nevertheless, in the last 10 years we and the Friends of the Macaé Valley have effected major decreases in hunting, the trapping of birds, and the collection of plants. The evidence for this is in the frequent reappearance of the rarer animal and bird species, in particular the puma (*Felis concolor*) and monkeys.



Alec Pridgeon

Orchid tour along the trails of Braulio Carrillo National Park, Costa Rica

What we have described is obviously not a typical conservation approach toward remaining primeval forest in the Mata Atlantica, nor is this a typical ecotourism situation. However, it has worked without external funding until now. The main problem is that we are not immortal; so organizing the perpetual conservation of the Upper Macaé and surrounding area is the next phase we must tackle.

David Miller and R. C. Warren,
Rio Atlantic Forest Project, UK

4.7 Education

4.7.1 Botanic gardens

Botanic gardens are in the best position to offer formal training and disseminate information to the greatest number of people, including those not already involved in orchids. It is important that botanic gardens use their position to advantage in spreading the conservation message to the widest audience in various ways: formal classes on the culture, ecology, physiology, and taxonomy of Orchidaceae; greenhouse displays to show the diversity of the family along with approximations of the natural habitat; outdoor wildflower gardens to show local orchid species in simulations of their habitats; educational exhibits at local orchid shows, illustrating the botanic garden's role in conserving endemic and/or threatened species.

Botanic gardens are also important as repositories and disseminators of important scientific information, particularly through their herbaria. It is vital to orchid conservation that orchid taxonomy be kept up to date and that herbaria allow qualified individuals full and free access to their collections.

4.7.2 Orchid societies

Orchid societies play an important part in conservation education and ethics. They are fortunate in having members already interested in expanding their knowledge of orchids. The typical orchid society member is more or less familiar with the basic idiosyncrasies of the orchid family and is eager to learn more about the hobby, including how to improve growing techniques by approximating the conditions of the natural habitat. Tremendous opportunities for information exchange exist in the larger national and smaller local societies and on a one-to-one basis in society workshops, publications, and monthly meetings.

All societies should hold at least one meeting each year dedicated solely to orchid conservation matters and should keep the membership informed about important conservation-related events. Society workshops can be short discussions before the regular monthly meetings or day-long symposia covering a wide range of subjects. Correct plant culture is an important aspect of *ex situ* conservation, and workshops should cover the ways to recognise and control viruses in addition to basic cultural information. Societies should encourage their members to share rare species so that a plant is not lost through neglect, poor culture, or accident.

Field trips to local nature reserves to see orchids in the wild, to botanic gardens, and to sites of local rescue operations are valuable educational experiences. Societies may also present programmes on the maintenance and management of unprotected habitats and assist biologists who do so. Adoption of local and/or foreign reserves and raising funds for their maintenance can be achieved by auctions and raffles. Volunteers from nearby societies can provide the physical labour necessary for habitat maintenance.

Finally, societies can offer programmes about the conservation status of local orchid species as well as about defining and reinforcing ethical practices and behaviour, such as abstaining from collecting and taking precautions when walking in orchid habitat.

4.7.3 Orchid nurseries

The orchid nursery also has many means of sharing conservation information with a broad group of people, from beginner to advanced grower, interested in the Orchidaceae and eager to learn more. First and foremost, a nursery should offer cultural information, which is the best means of *ex situ* conservation. This should be self-evident to the reputable nursery, because giving detailed cultural hints along with the sale ensures the survival of the plant and repeat business for the nursery. This information can be passed along at the time of the sale with cultural sheets or can be included in lecture programmes to societies. Notes on the conditions of the natural habitat — rainfall, temperature ranges, elevation, etc. — should be shared. Nurseries should also offer clonal information. Divisions should be identified by clonal names, and the importance of properly labelling plants should be emphasised to the customer.

Nurseries should act as role models, showing how conservation can be practised and how it can be economically feasible at the same time. Among nurseries themselves, peer pressure is the best form of self-policing.

4.7.4 Nature reserves

One of the roles of the nature reserve is to educate visitors. This can be achieved by 1) exhibits of local orchids to illustrate biodiversity and their interactions with the rest of the ecosystem, and 2) exhibits in foreign shows to encourage ecotourism. It is necessary that people living around the reserve are educated in orchid conservation and sustainable use of the plants. Nature reserves should encourage cottage industries outside the reserve, such as small nurseries selling propagations of local plants. This will in turn offer visitors seeking souvenirs an alternative to removing plants from the wild.

4.7.5 Authorities

Authorities must maintain timely contact with individuals and representatives of organised societies within their jurisdiction so that all are aware of pending legislation that might affect orchids and orchid conservation. Involving local orchid society members as a resource in data-gathering and decision-making benefits both the society and the authorities. It is important for authorities to know the intent of CITES. Excessively strict legislation has been enacted too often when CITES regulations are misinterpreted. Local authorities must understand that the intent of CITES for Appendix II species is not the prevention of trade, but the monitoring of trade to ensure that conservation objectives are met.

4.7.6 Non-government organizations

Non-government organizations (NGOs) must work with all other conservation groups, local societies, and authorities to educate each other on the peculiarities of orchids and their requirements. It is very important that they formulate consistent viewpoints, explain the reasoning behind these viewpoints, and work toward a mutual consensus with NGOs representing other conservation groups. Finally, NGOs should work with their local nature reserves and help to establish new ones.

Cordelia Head, J & L Orchids,
USA, and Ann Lauer Jesup, USA

Box 4.6 ***Orchid Research Newsletter***

Now entering its 15th year of publication at the Royal Botanic Gardens, Kew, the *Orchid Research* Newsletter has two functions: 1) maintaining communication among orchid scientists and listing new research publications from the wide variety of scientific and horticultural journals, and 2) publishing the minutes of IUCN/SSC meetings of the Orchid Specialist Group. The *Orchid Research Newsletter*, produced semi-annually, is the primary vehicle through which all are made aware of recent publications, completed and current research projects of orchid scientists, specific taxa needed for research, and announcements of upcoming conferences.

The *Newsletter* is free to subscribers and is also available on the Internet at http://www.rbgkew.org.uk:80/herbarium/orchid. Those without access to the Internet may request subscriptions for hard-copy versions by writing to Sarah Thomas or Phillip Cribb, Royal Botanic Gardens, Kew, Richmond, Surrey TW9 3AB, UK.

Chapter 5

Regional Accounts

5.1 United States and Canada

Canada and the United States comprise the main body of the North American continent, extending from the southernmost point of the continental United States at Key West, Florida, to the ice pack surrounding the North Pole. In addition, the state of Hawaii, a series of volcanic islands, lies almost at the centre of the northern Pacific Ocean. As a geographic unit, the two countries cover an area of 19,495,756 km^2, with climate ranging from temperate to arctic. Tropical and/or subtropical climates are found in the states of Florida and Hawaii and the coast of California.

The islands of Hawaii are of volcanic origin and host a tropical flora. Florida is composed of podzolic soils on a limestone of compacted ancient corals and shells. The dominant vegetation of the areas of higher elevation is oak-pine-palmetto-scrub palmetto, while that of the lower-lying areas is cypress-oak-willow in the freshwater areas and mangroves in the saltwater marshes along the shores. Climatically, Florida is divided roughly in half, with the southern region approaching tropical and the northern region subtropical. Periodically the southern half is exposed to brief periods of frost, which are usually not severe enough to kill the native epiphytic and terrestrial orchids. In the northern half of the state frosts can be more severe and persist longer. Epiphytic orchids which are not growing in sheltered microclimates may be killed outright in harsh winters.

The Atlantic coastal plain from Georgia to New York is characterised by podzolic soil; from there northward to the Gaspé Peninsula and Nova Scotia in Canada the substrate is glacier-scoured bedrock of the Canadian Shield (Bell 1985). The Eastern Deciduous Forest covers the eastern third of the continent between southern New England and Georgia until it gives way to the Prairie to the west, which extends over the centre third of North America. In Canada, these two zones penetrate only slightly north of the Great Lakes, where they yield to the dominant Northern Coniferous Forest stretching from the eastern coast of Canada to the western province of British Columbia and northward from there to the interior of Alaska.

Weather on the prairie is more extreme than in the eastern section of the continent. Summers are often hotter and drier, the winters harsher with more snow and wind. Flooding is common, keeping woody vegetation to a minimum. The dominant vegetation is forbs and grasses, and much of the land used for agriculture and pasture.

The Western Mountain Forests follow the Rocky Mountains and coastal range south out of Canada to southern California and northern Arizona where they are ringed by the South-western Desert ecosystem. In the southern portions of the ranges the forests retreat higher and higher on the mountains until at the southern tip they are to be found only on the high mountaintops where a moist, cool climate prevails.

5.1.1 Present status of knowledge

Native orchids in the United States and Canada have been studied closely since the 19th century. Linnaeus named 24 native North American species, and more were added in later editions of *Species Plantarum* (Luer 1975). Britton (1901) listed 26 genera and 70 species in *Manual of the Flora of the Northern States and Canada.* Through the early 1900s interest in native North American orchids as wildflowers was reflected in several books (e.g. Niles 1904; Gibson 1905; Morris and Eames 1929), which detailed habitat conditions and often provided taxonomic descriptions for field identification.

Correll's (1950) *Native Orchids of North America* covered all species north of Mexico, the most comprehensive work on the subject at that time. It served both as a field guide and scientific reference work for more than 20 years, being then updated by two books by Luer (1972, 1975). The first, *Native Orchids of Florida,* covers the 102 species that occur in the state. The second, *Native Orchids of the United States and Canada,* deals with the remaining 108 species elsewhere on the continent, together with an additional 25 species occurring in both Florida and the rest of the continent.

As the extensive list of references in Luer's volumes and others in this Action Plan indicate, the orchidaceous flora of the United States and Canada has been studied extensively, yet discoveries are still being made. For example, being a new *Piperia* was recently described from California (Morgan and Glicenstein 1993). Taxonomic tinkering also continues, especially in the genera *Cypripedium* (Reed 1981), *Epidendrum,* and *Encyclia* (Hágsater 1993a,b).

5.1.2 Diversity

Generally, the largest numbers of terrestrial orchid species on the North American continent occur at those locations where there is an acidic layer of vegetative material overlying a limestone base with enough moisture to allow the two to mix; the wide range of pH can accommodate many orchid species. The most species-rich areas are along both coasts, the Appalachian ridge, and Florida. Florida is of special interest because of its subtropical climate and high biodiversity, and because so many of its orchid species are shared by Cuba and cannot be found elsewhere in the United States and Canada. A similar situation exists in the Alaskan peninsula, as many of its species have migrated across the Aleutian Island chain from Asia and are not found elsewhere in North America.

Some species are highly restricted in distribution. *Cypripedium califomkum* is endemic to the common corner of north-eastern California and south-eastern Oregon. *Piperia maritima* is endemic to the coastline of California and Oregon. *Triphora latifolia* is found in a relatively small area of Florida. The two species native to Hawaii, *Anoectochilus sandwicensis* and *Liparis hazvaiensis,* are found only on the Hawaiian archipelago. *Isotria medeoloides,* on the other hand, exists in small, disjunct populations, mostly in one to five sites in each of 16 US states and Ontario, Canada *(Federal Register* 59: 50852-50857). *Cypripedium fasciculatum* has a similar distribution pattern in the north-western United States. A management plan for this species has been established by the Oregon Natural Heritage administration.

Distribution of Orchidaceae on the North American continent (Table 5.1.1) follows several patterns. The orchids of Florida, especially the epiphytic ones, are most closely allied to those in the Caribbean. Of the 102 species occurring naturally in Florida, 63 do not extend past the northern boundary of the state. An equal number are found in Cuba as well as Florida (Luer 1972). Of the 39 species found in Florida whose distribution extends north of the state, 18 are found all the way up the Atlantic coast into New England. No species native to Florida are found west of the Rocky Mountains, but a few are found in the mountains themselves. The 500+ mile north-south length of Florida serves as a transition zone and barrier between the temperate species occurring along the coastal plain to the north and the tropical ones found in the Caribbean area. The northern third of the state harbours the temperate, mostly terrestrial genera (*Calopogon, Cleistes, Corallorhiza, Goodyera, Habenaria, Isotria, Liparis, Malaxis, Platanthera, Spiranthes,* and *Triphora*), species of which extend northward along the coastal plain. The southern third of Florida is dominated by members of the tropical genera (*Bletia, Brassia, Bulbophyllum, Cranichis, Cyrtopodium, Encyclia, Epidendrum, Erythrodes, Galeandra, Harrisella, Ionopsis, Leochilus, Lepanthopsis, Macradenia, Oncidium, Pleurothallis, Polyradicion, Polystachya, Tctramicra, Triphora,* and *Vanilla*).

The terrestrial species in the northern third of Florida extend in varying degrees north along the coastal plain and piedmont behind it up into Canada. In Georgia and the Carolinas another dominant genus, *Cypripedium,* is added to the list. As the coastal plain, warmed by the Gulf Stream offshore, provides a pathway for warmer-growing species to infiltrate northward, so the Appalachian Mountain chain, with its higher, cooler terrain, is an avenue for the southward migration of cooler-growing orchids. Northern species such as *Platanthera orbiculata,* ranging mainly in Canada, extend down the Appalachian ridge into North Carolina and Tennessee. *Platanthera psycodes, Platanthera grandiflora,* and other species follow the same pattern.

The prairie serves as a natural barrier to the east-west movement of orchid species, extending south almost to Mexico through Texas and well into Canada to the north. Relatively few orchid species occur in the prairie, partly because of the historic extensive use of the rich

Joan Cooper

Cypripedium kentuckiense

grasslands for agriculture and cattle grazing. Attempts are being made to conserve and restore portions of the original vegetation (Madson 1992). The Canadian government is working on a five-year Prairies Conservation Action Plan to identify, protect, and establish orchid habitat in each of four major prairie ecoregions.

In the Western Mountain region there is generally less rainfall than in the eastern forests, explaining the lower diversity of orchid species. In this region orchids only occur on the high mountaintops where a moist, cool climate prevails and where the soil is rich, as along streambanks. Two endemic species are severely restricted in habitat by their need for moisture: *Cypripedium californicum* grows along shaded streams in south-western Oregon and northern California, and *Piperia maritima* grows along the dwarfed vegetation forming the beachhead along the foggy Pacific coast (Luer 1975).

In the South-western Desert zone, where scrub oaks, cacti, mesquite, and sage comprise the dominant vegetation, few orchids are found. Where there is water, some orchids will grow, most of them outliers of the Mexican flora. *Epipactis gigantea* will grow at lower elevations, whereas species of *Spiranthes* are found higher up.

The Northern Coniferous Forest is dominated by slow-growing, hardy conifers such as tamaracks, cedars, balsams, and firs. One common feature of this forest is the quaking bog, a thick layer of sphagnum moss carpeting the surface of a shallow pond. In the sphagnum are orchids which require cool temperatures at their roots. Because the bedrock of these ponds is often limestone and the sphagnum peat acidic, a wide range of pH is found allowing niche partitioning to occur which accounts for a diversity of orchid taxa. *Arethusa bulbosa, Calopogon tuberosus, Pogonia ophioglossoides,* and many species of *Spiranthes* flourish in this habitat (Luer 1975; Case 1989). Small knolls of conifers have patches of cold sphagnum and mud at their bases, providing ideal habitat for populations of such orchid species as *Cypripedium arietinum, C. calceolus, C. reginae, Goodyera repens, Listera cordata, Calypso bulbosa, Corallorhiza trifida,* and several species of *Platanthera* (Luer 1975).

5.1.3 Threats

There are three main threats to the orchids of North America: increasing natural resource needs of an expanding human population, industrial and residential development, and pollution. Other threats include overcollection of orchids, introduction of invasive exotic plant species, successional change in disturbed sites, and agriculture and grazing.

Large-scale clearcut logging threatens the survival of plants on the North American continent as much as it does in South America. Left with no shade, no pollinators, no parent stock, little ground cover protection against erosion, and a lack of favourable microclimates, orchids in a large clearcut area cannot regenerate. Presently large-scale clearcutting is practised in the north-western United States and Canada, northern Maine, and south along the Appalachian Mountain range. In Florida cypress wood is logged and large pine plantations in many of the southern states serve the paper industry. Epiphytic orchids in Florida are threatened because bald cypress and pond cypress are typical host species.

Many large-scale earth-moving operations, such as development and surface-mining, are detrimental to the survival of native orchid populations. Suburban development continues to pose a major threat to native orchids because of the scale on which it occurs. After clearcutting and bulldozing for houses and roads, erosion from construction sites fouls watercourses and buries plants. The permanent removal of habitat or potential habitat by covering it with buildings and paved parking lots is most detrimental. Surface-mining operations are widespread in some regions. A large parcel of land is surface-mined and, if required by law, 'restored,' such that soil and vegetation are replaced over the remaining topography (Raven *et al.* 1993), although recolonisation is not necessarily with the same species that previously occupied the area.

As many terrestrial orchids are opportunistic colonisers, one of the most favourable environments for some species is on roadcuts and verges, which in the United States and Canada are mown periodically during the growing season. The less-often mown edges, or 'roughs' of golf courses have proven to be excellent habitats for many terrestrial species in genera such as *Calopogon,Habenaria, Platanthera, Pogonia,* and *Spiranthes.* These are the same species that prefer the infrequently mown edges of roads. Ecological succession is a serious threat to opportunistic terrestrial orchids. Many types of changes to an environment can create unfavourable conditions for these orchids, such as allowing the vegetation on road edges to grow, natural succession in marshes and pastures, and the death of forest overstory trees from pests or disease.

In some areas introduced exotic plants crowd out native orchids. *Lythrum* and *Phragmites* species in moist areas of the north-east United States are causing declines in the numbers of orchids that normally are found in this habitat and have now spread widely from the site of their original introduction (Koopowitz and Kaye 1983). In the southern Appalachians kudzu (*Pueraria lobata*), a rampant exotic vine, threatens all native vegetation, including terrestrial orchids (Zettler 1994).

The overuse and misuse of chemical herbicides on open sites pose a serious threat to native orchids. Local road crews have found that spraying these road edges with non-selective herbicides reduces costs and time, but kill many desirable wildflowers. Most herbicides used kill the orchids, either outright or because they are sprayed when the plants are at the peak of their growing season and can build no reserves for the following year's growth. In South Dakota herbicides are also being used as weed control on federal grazing lands over the objections of the lessees who wish to protect *Platanthera leucophaea* growing there. An alternative to herbicide use in these situations is controlled burning early in the season before the orchids appear above ground. This method was previously used on these lands (Wall, pers. comm.) and has been used as a habitat management tool by the Nature Conservancy since 1985 (Krause 1985).

Collecting orchids has long been discouraged by conservationists and wildflower enthusiasts, and generally the public has responded by buying desirable plants from nurseries. However, collecting has continued, often in considerable quantities, despite protective legislation in some states. These plants are sold to foreign orchid nurseries and domestic wildflower nurseries (Anon. 1993a). In Florida's Fakahatchee Swamp preserve, members of a local Indian tribe were apprehended removing quantities of native orchids for sale to dealers (Rozsa 1994). Populations of *Cypripedium acaule* have been removed in Pennsylvania for sale to nurseries abroad (Glicenstein, pers. comm.). In Michigan, a German national was apprehended and fined for the removal of approximately 85 plants of *Goodyera oblongifolia* from a national park (Anon. 1992a). In Tennessee, *Platanthera integrilabia* has been collected and sold in quantities to wildflower nurseries for many years (Zettler and Zettler 1992).

Agro-pastoral practices have negatively affected native orchids through grazing of terrestrials (Zettler 1994; Glicenstein, pers. comm.), monoculture, erosion, and fertilising. However, there are benefits as well: elimination of vegetative competition by the burning of pastures and the exposure of soil by plowing at regular intervals.

5.1.4 Current conservation actions

Many research projects dealing with the problems encountered in propagating terrestrial orchids are now in progress, ranging from the isolation and propagation of the appropriate mycorrhizae (Zettler and Mclnnis 1992, 1993, 1994) to studies of pollinators, seed harvest, media, and germination (Anon. 1990; Plaxton 1983). Researchers in several botanic gardens and educational institutions within and outside the United States and Canada are studying aspects of the life cycles and propagation of North American terrestrial orchids (Anon. 1990; Katz *et al.* 1993; Zettler and Mclnnis 1993).

Legislation protecting orchids ranges from the federal Lacey Act, which only protects plants being transported over state lines, to legislation in effect for individual states, which varies in the amount of protection afforded. Unfortunately, loopholes have been written into most trade laws, so that nurseries legally sell wild-collected plants to an unsuspecting public by terming them 'nursery-grown' after they have been in cultivation in the nursery for as little as one year. The American Orchid Society Conservation Committee published a summary of state protection measures (Gade 1987), which has been updated every few years. Most of these measures arise as a result of studies made for the Nature Conservancy's Heritage Program.

Federal legal protection for endangered orchids in the United States is afforded by the Endangered Species Act; individual states may have additional legislation in place (Gade 1987; World Conservation Monitoring Centre 1992). Canadian federal protection has been through legislation on forests (World Conservation Monitoring Centre 1992). Responses to threats to native orchids have been met in the United States by more comprehensive state legislation and in Canada by a proposed new set of more stringent regulations, by continuing efforts at education of the populace through media coverage, and by the efforts of the American Orchid Society in the form of articles in the *American Orchid Society Bulletin,* slide programmes, educational exhibits, and lecturers. In addition, the American Orchid Society has funded research on many projects related to native orchids, and encourages its local affiliates in the United States and Canada to volunteer their efforts on Nature Conservancy projects. Efforts to protect native orchids arise also from wildflower interest groups, nature photographers, local nature centres, local orchid societies, and educational institutions (Anon. 1992b; Katz *et al.* 1993). Individuals from these organizations are motivated to continue working in habitat protection, propagation research, conservation education, species population studies, and monitoring. Articles in newspapers exposing poor conservation practices and abuses appear regularly.

5.1.5 Case histories

1) ***Cypripedium acaule*** - One species particularly impacted by collecting is the highly desirable and showy *Cypripedium acaule* Aiton, which cannot be established long-term outside its habitat. Although concentrated efforts to propagate this species from seed are progressing (Ling *et al.* 1989; Glicenstein, pers. comm.), it has not been artificially propagated past the community-pot stage (Koopowitz and Kaye 1983; Anon. 1990). C. *acaule* has a horticulturally desirable flower which appeals to both the unsophisticated and the knowledgeable collector. It is the state flower of many states. Many plants are killed every year because the entire growth is removed by many people picking wildflowers. It is particularly at risk because of its wide distribution and apparent commonness, and those unaware of its peril regard it as expendable. It is collected in quantity for resale in the horticultural market and sold for use in folk medicine (Anon. 1993a). Newspapers as notable as the *Wall Street Journal* have printed articles to inform the public that any plants they see for sale have been taken directly from the wild (Hagan 1991). It is difficult for accurate population counts to be made because *C. acaule* has been known to respond to declining conditions by going dormant for as long as 14 years and then reappearing (Anon. 1990).

2) ***Platanthera integrilabia*** - *Platanthera integrilabia* (Correll) Luer is a modest white-flowered terrestrial with a natural range restricted to the south-western Appalachian slopes and the Cumberland Plateau. Its description in 1950 triggered a spate of collecting which resulted in the attrition of viable sites. Two of these few remaining sites are presently threatened by encroaching housing developments; one is being grazed in a cattle pasture; one is threatened by kudzu. In a national forest site the largest population is being decimated by collectors, feral pigs, and logging operations (Zettler 1994). However, unlike *Cypripedium acaule, P. integrilabia* has been successfully propagated artificially. Zettler (1994) has isolated the mycorrhiza necessary for the survival of the species, propagated the strain, and grown seedlings on inoculated medium. He is now using the same method successfully on *Spiranthes cernua* and is attempting to propagate *Isotria medeoloides* (see below) in a similar manner.

3) ***Isotria medeoloides*** - Popularly known as the small whorled pogonia, *Isotria medeoloides* (Pursh) Raf. was described in 1814 and as a result soon had the reputation as the rarest orchid east of the Mississippi River. An inconspicuous orchid, its growth habit resembles that of cucumber-root (*Medeola virginiana*) and bunchberry (*Cornus canadensis*), often growing among them. Several of the authors of the floras of the eastern United States in the early 1900s had not seen the species in the wild, but in 1924, Oakes Ames listed 17 stations where the species had been reported (Luer 1975). One colony in eastern Virginia has been continuously monitored since its discovery in 1920 until Luer (1975) reported it threatened by encroaching housing development. *I. medeoloides* was listed in 1975 by Luer as having small populations in 13 states. In 1982, when federally listed as endangered, there were still only 17 known populations (Anon. 1985). Five years later it was listed as endangered in the states of Illinois, Michigan, North Carolina, and South Carolina (Gade 1987). From censuses in connection with state Heritage Programs, biologists located 20 new populations in New Hampshire and Maine (Anon. 1985). With 104 sites now known and 46 of these protected, *I. medeoloides* was downlisted in 1994 from endangered to threatened (*Federal Register* 59: 50852-50857).

5.1.6 Recommended actions

1) Continue research on artificial propagation of commercially important species;
2) Manage mid-successional habitats for opportunistic orchid species;
3) Seek alternatives to herbicide use on roadsides;
4) Assure recolonisation with native species on restoration sites, i.e. surface-mining areas;
5) Continue orchid distribution studies.

Ann Lauer Jesup, USA

Table 5.1.1 Diversity of orchids of the United States and Canada.

Higher taxon	No. genera	No. species
Angraecinae	3	3
Arethusinae	2	5
Bletiinae	4	9
Bylbophyllinae	1	1
Corallorhixinae	5	10
Corymbidinae	1	1
Cranichidinae	3	3
Cypripedioideae	1	12
Crytopodiinae	4	5
Goodyerinae	3	7
LaeHinae	4	13
Limodorinae	2	3
Liparidinae	2	12
Listerinae	1	8
Maxillariinae	1	1
Onddiinae	5	8
Orchidinae	7	37
Pleurothallidinae	3	3
Pogoniinae	4	9
Polystaehyeae	1	1
Spiranthinae	2	30
Thtmiinae	1	1
Vaillinae	5	7
Total	65	189

5.2 Mexico

Mexico is located in the southernmost part of North America and northern Central America. The country has an area of 1,972,576 km^2 and is divided by the Tropic of Cancer into two halves. The northern region is mostly arid, temperate, with its climate strongly influenced by the continentality of North America. In contrast, southern Mexico is humid and tropical due to its lower latitude and the maritime influence, and has a more rugged topography. These varied conditions have created an extremely diverse mosaic of vegetation.

The geologic history of Mexico is complex, but it is well documented that the northern part is Laurasian in origin, while the southern half, together with Central America and the West Indies, was formed by the combined movement of the North American, South American, Cocos, Farallon, and Caribbean plates (Ferrusquía-Villafranca 1993). The present-day topography of Mexico is also complicated, with six principal mountain ranges: 1) Sierra Madre Occidental, 2) Sierra Madre Oriental, 3) Trans-Mexican Volcanic Belt, 4) Sierra Madre del Sur, 5) Central Plateau of Chiapas, and 6) Sierra Madre de Chiapas. These mountains are surrounded by plains or plateau, the most important being the Mexican Altiplano (which is bordered by the first three mountain ranges), the Gulf Coast Plain, the North-western Plain, and the peninsulas of Yucatan and Baja California. Essentially the northern plains and plateau are deserts dominated by xerophyllous scrub, prairies, thorn forests, and other xeric vegetation types; the northern highlands support grasslands, chaparral (where Mediterranean climate dominates), oak-juniper woodlands, coniferous forest, and scattered patches of temperate deciduous forests.

The southern lowlands support mainly tropical vegetation, with a more humid climate on the Atlantic side (tropical evergreen forest), than on the drier Pacific side (tropical subdeciduous, deciduous, or thorn forests). The highlands of the southern part of the country are characterised by pine-oak forests, with juniper-oak scrub in the drier parts and cloud forests in the wet sites. Savannas are largely restricted to soils with very special features, like sandy areas or damp, clay soils. On the other hand, alpine meadows are confined to the highest mountains (mostly volcanic cones), which occupy a small area and have a depauperate flora when compared to similar communities of Andean South America and the Rocky Mountains. Detailed descriptions of the vegetation of Mexico can be found in Miranda and Hernandez X. (1963) and Rzedowski (1978).

The Mexican human population is estimated to be 91 million. Notable demographic features are the uneven population distribution (with most people living in the temperate, subhumid, central-southern zone, while the arid region in the central northern zone is scarcely populated) and the 2.3% annual population growth rate. Furthermore, it is estimated that 27% of the total population lives in rural areas. In southern Mexico, mostly in the states of Oaxaca, Chiapas, Guerrero, and Puebla, a large proportion of the rural population is Indian, amounting to 29% of the total population of the country.

5.2.1 Present status of knowledge

Floras and checklists - The orchid flora of Mexico is relatively well known; many European collectors have travelled in Mexico since the end of the 18th century, and local and North American botanists have also worked in the country since that time. The most comprehensive study of orchids is that of Williams (1951), *The Orchidaceae of Mexico*, in which he synthesised all the knowledge accumulated up to 1941. This work was largely based on the orchid herbarium of Erik Oestlund, notable for his systematic collections made in all parts of the country. Additional sources of information are the many papers published in *Orquídea* (*Méx.*), the journal of the Mexican Orchid Association. The most outstanding recent publications on the subject include the volume of Orchidaceae in *Flora Novo-Galiciana* (McVaugh 1985) and *Icones Orchidacearum, Orchids of Mexico I* (Hágsater and Salazar 1990). An updated checklist was published by Soto (1988), recording about 918 species and subspecies. Soto, Salazar, and Hágsater are preparing a synopsis of the Mexican Orchidaceae, to be published in 1996, which includes more than 1100 taxa. This unpublished synopsis is the source of information about the family in Mexico used in this account.

The following genera have been monographed or carefully studied: *Amparoa, Arpophyllum, Artorima, Aulosepalum* (*Deiregyne sensu* Burns-Balogh 1988), *Barkeria, Bletia, Calanthe, Catasetum, Cattleya, Clowesia, Coelia, Corallorrhiza, Cuitlauzina, Cypripedium, Dichaea, Dignathe, Dimerandra, Dracula, Elleanthus, Encyclia, Epidendrum, Erycina, Eurystyles, Hagsatera, Laelia, Leochilus, Lepanthes, Lophiaris, Lycaste, Macroclinium, Meiracyllium, Mexipedium, Mormodes, Oncidium, Palumbina, Pachyphyllum, Papperitzia, Physogyne, Phragmipedium, Platystele, Ponera, Restrepia, Rhynchostele, Rodriguezia, Rossioglossum, Stelis,* and *Trichosalpinx*. In contrast, the following groups need much more work because they have been traditionally neglected by botanists: *Cyclopogon, Habenaria, Isochilus, Malaxis, Myrmecophila, Platanthera, Polystachya, Ponthieva, Sarcoglottis* sect. *Potosia, Schiedeella,* and *Sobralia*.

Besides taxonomic research, little work has been done on other aspects of orchid biology in Mexico, although anatomical, morphological, or ecological studies have been conducted for some small groups and particular species.

Information on endangered and threatened orchids - In the last few years it has been possible to identify the endangered and threatened orchids of Mexico thanks to the field work of our team and relationships with amateur orchid growers, amateur botanists, commercial growers, and Mexican conservation authorities. In 1990, Soto and Hágsater published the first list of endangered and threatened Mexican orchids. With other orchidologists we have updated and continuously amended that list, and a modified version is now used by the Mexican Government Office of Ecological Conservation (SEDESOL 1994).

National legislation protecting wild orchids - The official Mexican regulation that lists the species of plants and animals, terrestrials and aquatics considered rare, threatened, endangered and/or needing special protection must be strictly observed during the collection or capture of any wild species. It also regulates the possession, use, and management of wildlife. At present about 180 orchid species have been included in the official conservation status list as follows: 16 endangered, 57 vulnerable, 103 rare, and 4 species under special protection. Removal of wild specimens of those species in the categories of endangered or vulnerable from their habitats is permitted only when they are necessary for propagation programmes, and in every case, a justification and plan for the activity must be presented for evaluation. A remarkably good relationship exists between Mexican authorities and conservation biologists that permits the exchange of information, ideas, and concerns resulting in a continuous updating of the lists of species at risk.

5.2.2 Diversity

Number of taxa - The Mexican orchid flora basically falls into three distinct groups: southern, northern, and endemic (Rzedowski 1965, 1978, 1993), comprising 1106 species and subspecies, distributed in 159 genera and 38 subtribes (Table 5.2.1). Several genera account for the majority of species: *Epidendrum* (101), *Encyclia* (86), *Specklinia* (72), *Lepanthes* (60), *Habenaria* (50), *Malaxis* (47), *Oncidium* (39, excluding 15 species of the *Lophiaris* group), *Maxillaria* (30), *Stelis* (26), *Cyclopogon* (25), *Schiedeella* (22), and *Bletia* (21), while a much larger number of smaller genera account for the remainder. Similar to other countries located with at least a portion in the tropics, the terrestrial orchid flora of Mexico is very well developed, particularly the Spiranthinae (mainly *Aulosepalum, Cyclopogon, Schiedella*), and the genera *Bletia, Govenia, Habenaria,* and *Malaxis*.

Numerically the most important group is the southern, which includes many well-known genera such as *Epidendrum, Oncidium,* and *Specklinia* whose centres of diversity are in South America. Many other genera are in this group, having centres of distribution also outside Mexico. The southern element is present in both warm and temperate habitats. The northern element is relatively small and includes such typical holarctic genera as *Corallorhiza, Epipactis, Goodyera, Piperia, Platanthera,* and *Spiranthes,* most of them confined to habitats ranging from temperate to subalpine habitats.

Endemicity - One of the most outstanding features of the Mexican orchid flora is the high proportion of endemic species. There are 444 endemic species or subspecies (Table 5.2.1), which corresponds to about 40% of the total taxa recorded in the country. This feature makes the Mexican orchid flora proportionally one of the richest in endemics among the neotropical, mainland countries, perhaps surpassed only by Brazil.

Mexico is the centre of distribution for several small subtribes of the family — Goveniinae, Chysiinae, Arpophyllinae, Meiracylliinae, and Coeliinae — which, together with such genera as *Bletia, Calanthe, Hexalectris, Isochilus, Mexipedium,* and *Ponera,* could represent relictual Laurasian megathermal lineages which now occur only in northern Latin America but not elsewhere in the Neotropics or in other regions of North America (see Wendt 1993 for a biogeographic explanation of this type of distribution).

The rich endemic element of the Mexican orchid flora is probably the result of evolution of lineages that arose very early in Mexican territory, although they can be ultimately either of southern or northern origin. *Alamania, Artorima, Cuitlauzinia, Dignathe, Erycina, Hintonella, Phragmipedium* (=*Mexipedium*) *xerophyticum, Papperitzia, Physogyne,* and *Pseudocranichis* are strictly endemic. On the other hand, the following genera, although not strictly endemic, have their distribution centred in Mexico but extending to south-western US, Mesoamerica, or both: *Amparoa, Aulosepalum, Barkeria, Dichromanthus, Dithyridanthus, Galeottiella, 'Prescottia' tubulosa* (Lindl.) L.O.Williams (an undescribed, distinct genus belonging in the Cranichidinae, not Prescottiinae), *Hagsatera, Hexalectris, Kionophyton, Meiracyllium, Microthelys, Ocampoa, Osmoglossum, Rhyncholaelia, Rhynchostele,* and *Rossioglossum.*

Species-rich areas and centres of endemism - The orchids are very unevenly distributed in the country. It has been estimated that as many as 50-60% of the total orchid flora thrive in the cloud forest (which originally covered less than 2% of the territory) concentrated in the high-rainfall areas on the foothills of the mountains, although this does not mean that the species are confined to this type of vegetation. Other species-rich habitats, in order of importance, are the evergreen tropical forests, the pine-oak forest, and the subdeciduous and deciduous tropical forests. In contrast, few orchids are known from the xeric formations, and it has been estimated that about 50% of the Mexican territory is too dry to support any orchid species.

The general distribution of the Mexican orchids is Y-shaped. The base of the Y comes into Mexico from Central America, following the highlands of Chiapas. The stem of the Y continues in a west-north-westerly direction up into the state of Oaxaca. Somewhere east-south-east of the city of Oaxaca the 'stream of orchids' bifurcates. One branch extends north-north-east to the states of Veracruz, Puebla, Hidalgo, and San Luis Potosi. The other main branch of the Y continues almost westward through the states of Guerrero, Michoacan, Jalisco, Nayarit, and Sinaloa, with a subsidiary branch toward Mexico and Morelos (Williams, 1951).

The areas of endemism detected for the genus *Lepanthes* (Salazar and Soto 1994) are strongly associated with areas of overall high orchid species richness: 1) the Teotepec System, Guerrero, 2) the region of Teoxomulco, Oaxaca, 3) the Sierra Mixe, Oaxaca, 4) the Sierra de Juarez, Oaxaca, 5) the Montebello area, Chiapas, and 6) Volcan Tacana and adjacent mountains of Guatemala. Additionally, lowland endemism centres and species-rich areas are located near 7) Puerto Vallarta, Jalisco, 8) Pluma Hidalgo, Oaxaca, 9) Uxpanapa, Veracruz-Oaxaca, and 10) the Selva Lacandona, Chiapas. Another zone, subhumid and rich in endemics is 11) the region of Temascaltepec, Mexico. Apart from these areas, each of which has several endemics, most Mexican orchids are widely distributed inside each of the approximately 19 floristic provinces. An analysis of the distribution of Mexican orchids was made by Soto (unpublished), but it was relatively incomplete because it was based on the author's 1988 checklist, which missed almost 200 species now well documented for the country.

5.2.3 Threats

The majority of the human population is concentrated in the more humid southern half of the country, where most of the orchids are found, which has had a negative impact on orchid conservation. The Mexican population has been high historically, and the temperate, intermountain valleys, like that of Mexico City, have supported a large population since before the arrival of the Spaniards in the 16th century. About 27% of the Mexican population practise subsistence farming and live in small settlements and villages. Since the landscape of southern Mexico is very rugged, the only available areas for agriculture are the hillsides, frequently too steep for efficient agricultural practices. It has been said that the major industry in southern Mexico should be forestry rather than agriculture, although modern technical forestry is relatively poorly developed in the country. The impact of human activities has been so severe that some floristic provinces were devastated before they were botanised, particularly the Coastal Plain of Chiapas, the southern part of which must have been rain forest which is now totally destroyed. What kind of vegetation once dominated the densely populated valleys, such as those of Mexico, Tehuacan, Puebla, and Oaxaca, is unknown.

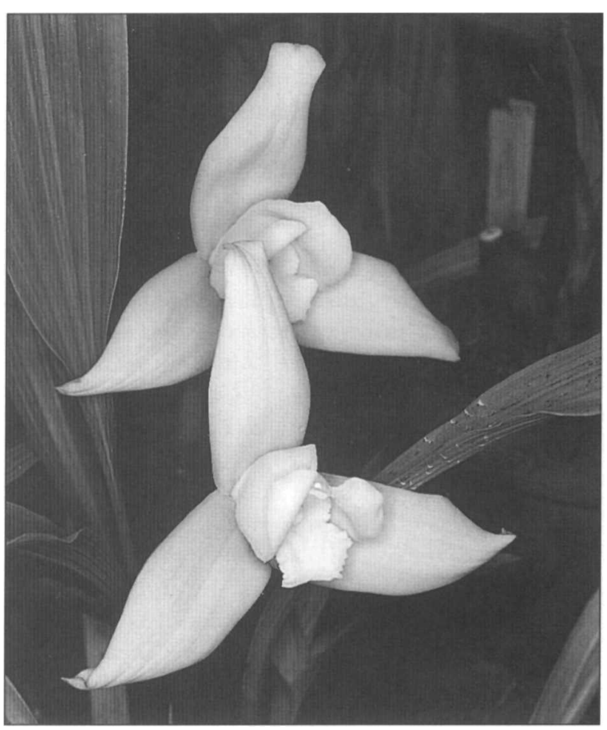
Probably the greatest threat to Mexican orchids continues to be the destruction and/or transformation of the cloud forest to pasture or agricultural fields. Toledo and Ordonez (1993) have estimated that about 60% of the original cloud forest areas are still forested, although they do not distinguish among primary, secondary (which can be very extensive in shifting agriculture areas), and coffee plantations. The lower cloud forest is suitable for coffee growing, and extensive areas were transformed into plantations. Although coffee plantations do not entirely destroy the original vegetation, they do produce major changes in the environment and especially in microclimates, with the most dramatic changes in open-grown coffee plantations (Barradas and Fanjul 1986). A typical coffee plantation in Mexico contains only a very small proportion of the original diversity of the primary cloud forest.

The other serious problem in Mexico is extensive cattle raising. Livestock farming has been one of the most profitable activities in the country, and many original forests were completely destroyed during conversion to pastureland. About 22% of the original cloud forests are now livestock grasslands; similar proportions of the subdeciduous and deciduous (20%) and evergreen (19%) tropical forests have been converted. Cattle raising has also altered or degraded open woodlands, scrubs, native grasslands, and savannas.

Shifting agriculture is practised over much of Mexico, especially in mountainous areas and regions with primarily Indian populations. Although many orchid populations have been affected by this land use, rarely do species become extinct due to the common practice of leaving a few trees, forested ravines, and other small patches of original vegetation among the cultivated plots. On the other hand, modern agriculture was developed extensively in the coastal plains and inner basins of the arid north, where few orchids, if any, thrive. For this reason its impact on orchid populations has been much smaller than that of shifting agriculture, although both practices have influenced the original plant formations to different degrees. The most affected ecosystems are the tropical deciduous or subdeciduous forests (24%) and the temperate, subhumid forests of pines and/or oaks (15%).

Mexican orchids are of great cultural importance among rural and Indian communities; numerous species of *Laelia,* in particular, have been collected and grown by peasants for centuries. Other very showy orchids are collected today and sold in Mexican markets. These activities have had a negative impact on some populations, and there are cases of particular populations completely destroyed by collecting. However, the only orchid actually threatened with extinction by this kind of collecting is *Laelia speciosa* (H.B.K.) Schltr. (Hernandez 1992). This activity is now illegal but continues because of inadequate surveillance.

Some Mexican orchids have been appreciated in horticulture since the 'orchid fever' in Europe in the 19th century. Large quantities of plants were exported to satisfy the great demand, and the practice continued almost to the present. Today few orchids collected in the wild are exported illegally from the country, although occasionally some shipments of ostensibly propagated plants are thought to be of wild provenance. In the past some species were brought to the verge of extinction because of international trade, such as *Laelia anceps* subsp. *dawsonii* (J.Anderson) Rolfe, *Lycaste skinneri* (Bateman ex Lindl.) Lindl., *Phragmipedium exstaminodium* Castano, Hágsater & Aguirre, and *Rossioglossum grande* (Lindl.) Garay & Kennedy. The rest of the endangered orchids in Mexico have been put in that situation by other causes, mostly habitat destruction by change of land use.



Phillip Cribb

Lycasteskinneri

Extinct species - As far as we know the only orchid that seems to be Extinct in the Wild in Mexico is *Laelia gouldiana* Rchb.f. This orchid has never been known in a wild state; all the specimens have been found growing on private property in the state of Hidalgo. The species is appreciated by the local people, who occasionally sell inflorescences and small pieces of plants to supplement their income.

Marc Dumont

Laeliagouldiana

Most threatened species - A summary of the conservation problems of the most endangered Mexican orchids may be found in Soto (1994). Table 5.2.2, which summarises the population features and causes of risk of these species, is extracted from that source. This study concluded that some orchids reported by authors as Endangered should be removed from the list and transferred to other categories of risk. These species are *Bletia urbana* Dressier, *Cattleya skinneri* Bateman, *Palumbina Candida* (Rchb.f.) Lindl., *Laelia superbiens* Lindl., and *Rhynchostele* (=*Mesoglossum*) *londesboroughianum* (Rchb.f.) Salazar & Soto Arenas. On the other hand, species such as *Encyclia kienastii* (Rchb.f.) Dressier & G.E. Pollard and *Phragmipedium (=Mexipedium) xerophyticum* Soto Arenas, Salazar & Hágsater apparently have no viable populations and cannot be successfully conserved *in situ. Galeandra greenwoodii* Warford, *Mormodes sotoana* Salazar, and *Trichopilia galeottiana* A.Rich. & Galeotti, widely distributed with sparse individuals, have good probabilities of success in large reserves, but at least the first two require additional habitat management. In addition, *Laelia anceps* subsp. *dawsonii* (J.Anderson) Rolfe, *Rhynchostele* (=*Lemboglossum*) *majale* (Rchb.f.) Salazar & Soto Arenas, *R. uroskinneri* (Lindl.) Salazar & Soto Arenas, *Mormodes uncia* Rchb.f., *Rossioglossum grande* (Lindl.) Garay & Kennedy, and *R. williamsianum* (Rchb.f.) Garay & Kennedy, all with restricted distribution in the country, require both habitat and *ex situ* conservation. Probably the only way to maintain populations of *Phragmipedium exstaminodium* in the field is by reintroducing nursery-propagated plants (Soto 1994).

All the species classified as Endangered are desirable plants in horticulture. Although many of them are being propagated abroad, it is now difficult to obtain propagated plants in Mexico, and certainly there is a demand for them among orchid growers. Special support must be given to propagation programmes conducted by Mexican commercial growers. This would be the only way to maintain wild populations at safe levels, especially for those species with beautiful flowers, such as *Lycaste skinneri* and *Rossioglossum grande*.

Areas at risk - Three species-rich areas are severely threatened at present. One of them, the mountain rain forest of the Teotepec System in Guerrero, is one of the areas richest in endemics and is undoubtedly a relict habitat. The lower part of the area has been transformed into coffee plantations; the mid-elevation zone is being cleared for maize milpas, and the upper zone is being heavily logged. Another area at risk is the region of Pluma Hidalgo, Oaxaca. It is a small patch of lower montane rain forest, unique in its type on the Pacific slope. At present we have been unable to locate any patch of intact vegetation. The entire area has been transformed into coffee plantations, and species endemic to it have become extremely rare or have not been located recently. A third area in great risk is the region of Montebello in Chiapas. This is currently a national park, but there is still disturbance because of inadequate surveillance. The region holds the richest cloud forest in Mexico, a *Podocarpus-Clusia* forest that has disappeared almost completely. With as many as 200 orchid species per hectare of primary forest, this area also has more Endangered orchids than any other in the country, although most of them can be found also in the cloud forests of Alta Verapaz and Quiche (Guatemala). The park is surrounded by settlements of Guatemalan refugees and poor Mexican peasants who collect wood in the park for construction and fuel. The current political problems and the presence of guerrillas in the zone have complicated the situation.

Local response - At present, the majority of the Endangered species are being propagated (flasked) by Mexican commercial orchid growers from seed, sometimes supplied by Asociación Mexicana de Orquideología. They hope to make these species widely available at reasonable prices in a few years. A programme of propagation of threatened species of Veracruz is starting at the Botanic Garden 'Javier Clavijero' in Xalapa, but no species in the Endangered category is included as none are native to Veracruz.

5.2.4 Proposed urgent actions

Specific urgent actions for the conservation of orchid diversity in Mexico are:

1) Promote the establishment of responsible nurseries for the artificial propagation of desirable and threatened species. This action will

Table 5.2.1 Subtribes, number of genera and species, and endemics in Mexican Orchidaceae. Classification according to Dressier (1993b).

Taxon	Genera	Species	Endemic species
Angraecinae	1	7	0
Arpophyllinae	1	6	2
Bletiinae	3	29	15
Bulbophyllinae	1	5	3
Calypsoeae	1	7	3
Catasetinae	4	29	20
Chysiinae	1	5	1
Coeliinae	1	5	0
Cranichidinae	5	24	7
Cryptarrheninae	1	1	0
Cypripedioideae	3	5	3
Crytopodiinae	2	3	1
Eriopsis	1	1	0
Eulophiinae	1	1	0
Goodyerinae	6	13	2
Goveniinae	1	11	8
Habenariinae	1	50	25
Laeliinae	23	285	119
Limodorinae	1	1	0
Lycastinae	3	13	2
Malaxideae	2	55	29
Maxillariinae	3	32	5
Meiracyllinae	1	2	1
Oncidiinae	26	120	54
Orchidinae	2	6	1
Ornithocephalinae	2	7	3
Pleurothallidinae	15	201	72
Polystachyinae	1	4	1
Prescottiinae	1	2	0
Sobraliinae	2	14	3
Spiranthinae	24	108	51
Stanhopeinae	6	25	9
Telipogoninae	1	1	0
Triphoreae	2	4	1
Tropidieae	2	2	0
Vanillinae	1	7	1
Wullschlaegeliinae	1	1	0
Zygopetalinae	6	14	2
Total	159	1106	444

Table 5.2.2 Mexican orchids that have been reported as being endangered in recent years. A geographic range (km^2), B number of known populations, C population density, D occurrence in cultivation, E habitat disturbance, F being propagated, G number of known plants (genets), H probable abundance (order of magnitude). (Source: Soto Arenas 1994).

Species	A	B	C	D	E	F	G	H
Bletia urbana	410	3	low	-	++	+	>20	3-4
Cattleua skinneri	1650	n	high	+++	++	+	n	6-8
Encyclia kienastii	1	1	low	+	+	+	30	2
Galendragreenwoodiana	1260	4	low	+	++	+	>100	3
Galeottiagrandiflora	1740	1	low	-	+	-	3	2
Laelia anceps subsp. *dawsonii*	300	2	low	+	+++	-	11	2-3
L. gouldiana	0	0	0	+++	?	+	1	0
L. speciosa	1240	20	high	+	+++	-	n	6-8
L. superbiens	790	1	medium	++	+	-	n	4-5
Lycastelasioglossa	540	1	low	+	+++	+	c.10	2
L. skinneri	720	4	medium	+++	+++	+	c.100	3-4
Mormodes sotoana	270	2	low	-	+++	-	6	2-3
Mormodes uncia	230	3	low	-	+	-	5	2-3
PalumbinaCandida	150	2	medium	+	++	-	>n	5-6
Phragmipedium exstaminodium	85	5	low	+	+++	+	39	2-3
P. xerophyticum	1	1	low	+	-	-	7	2
Rhynchastele londesboroughinana	35	4	high	-	-	-	c.100	4-5
R. majalis	140	1	low	+	-	+	<10	3
R. uroskinneri	140	1	low	+	+++	-	>20	3-4
Rossioglossum grande	150	2	low	+	+++	-	>20	3-4
R. williamsianum	540	1	low	+	+++	-	3	2
Trichopiliagaleottiana	780	2	low	-	+	-	c.20	2-3

reduce the collecting pressure on natural populations. This implies giving permits and facilities for the importation/exportation of propagated plant material.

2) Stop the local trade of flowers and plants collected in the wild. This could be done easily by stopping the distribution network.

3) Establish protected areas along the cloud forest belt, especially in isolated, endemic-rich regions or species-rich areas (Teotepec System, Sierra de Juarez, Sierra Mixe, Mountains of the Soconusco, and region of Teoxomulco). Those sites now protected are too few or do not include important tracts. This does not mean the establishment of large areas, since many small patches of forest remaining in ravines and similar places can play a very important role in conservation; however, the present agricultural practices and policies promote the disappearance of these 'pockets of diversity.'

4) Provide adequate surveillance of those areas already protected and stabilisation of the land tenure of these areas.

Miguel Angel Soto Arenas,
Asociación Mexicana de Orquideología, Mexico

5.3 Caribbean Islands

The Caribbean region as defined here comprises several island groups and includes the Bahamian bank, the Greater Antilles, and the Lesser Antilles, but excludes the continental islands of Trinidad and Tobago whose affinities are clearly South American. The total land area under consideration is approximately 229,694 km^2. Physiography of the region is quite diverse. Many of the Lesser Antilles are relatively young volcanic islands with abrupt, steep topography. Other small islands, such as those of the Bahamian bank, are composed largely of limestone, are relatively flat, and seemingly featureless. The present-day Greater Antilles (Cuba, Hispaniola, Jamaica, and Puerto Rico) are a product of complex geological processes involving the movement of a number of small continental plates. Floristically, the islands have similar elements, a consequence of similar latitudes and habitat types. For example, each of the four major islands is mountainous (reaching 3000 m in Hispaniola), with dry and wet regions and a karst area. Each is also unique due to differences in size, elevational amplitude, distance from source areas, and oceanic isolation. The large islands are bordered by mangroves, sandy beaches or rocky shores, and have alluvial plains, limestone karst hills, and substantial mountain ranges.

The climate of the Caribbean region is oceanic, subtropical at higher latitudes and tropical in the lower latitudes. The region is seasonally subjected to hurricanes and lesser tropical storms during summer and fall months with often devastating effects on the vegetation. Consequently, forest canopies rarely reach the heights of forests with equivalent temperature/moisture regimes at similar, climatologically more benign latitudes on the mainland. Where moisture is abundant, broadleaf forests are dominant from low to high elevations. Dwarf cloud forests occur along the ridges of the highest and wettest mountains (as low as 1200 m in Puerto Rico). In drier locations, principally at low elevations, cactus thorn scrub forests exist. Extensive serpentine areas occur on the larger islands and typically support sclerophyllous vegetation, regardless of rainfall. Parts of Cuba, Hispaniola, and the Bahamas have open pine forests with grassland understories.

5.3.1 Present status of knowledge

The orchid flora of the Caribbean region is well known in certain areas but incomplete in others. The first comprehensive floristic work in the region was the *Flora of the British West Indies* (Grisebach 1864), and the last was Urban's *Symbolae Antillianae* written by Cogniaux and Urban (1909-1910). Modern treatments exist for the Lesser Antilles (Garay and Sweet 1974; Fournet 1978), Puerto Rico, and the Virgin Islands (Ackerman and Del Castillo 1992; Ackerman 1995), Bahamas (Sauleda and Adams in Correll and Correll 1982), Cayman Islands (Proctor 1984), and Jamaica (Adams 1972). The orchid Flora of Cuba is outdated (Acuña Galé 1939; Sauget and Barbier 1946), but a revision is currently underway (M. Diaz and collaborators) as is the Flora of Hispaniola (D. Dod). Furthermore, J. Ackerman and collaborators are working on the orchid treatment for the *Flora of the Greater Antilles* project.

Apart from floristic studies and alpha-level taxonomy (such as the numerous papers of H. Dietrich and D. Dod), very little work of systematic or monographic nature has been published on the orchids of the region. Withner and Stevenson (1968) and Withner (1976) studied putative examples of introgressive hybridisation. Ackerman and Galarza (1991) described morphological variation within and among populations of *Tolumnia variegata* and suggested mechanisms for its maintenance. Using largely typological approaches, Braem (1986) revised the equitant oncidiums; Sauleda (1988) monographed *Psychilis;* and Sauleda and Adams (1984) revised the *Broughtonia* alliance.

Some work on the ecology and evolutionary biology of Caribbean orchids, primarily from Puerto Rico, has been published recently. Parrilla and Ackerman (1990) correlated root characteristics of Puerto Rican orchids with habitat type; Moya and Ackerman (1993) examined floral fragrance variation within and among Puerto Rican populations of *Epidendrum ciliare;* Meléndez and Ackerman (1993, 1994) described ecological and evolutionary consequences of a fungal disease in an orchid population; epiphyte host specificity of *Psychilis krugii* was studied by Ackerman *et al.* (1989); and the distribution and abundance of orchids and their phorophytes were presented by Migenis and Ackerman (1993) in the context of rain forest management of biodiversity. Pollination and population studies have been the focus of several works (Nierenberg 1972; Gonzalez-Diaz and Ackerman 1988; Rodríguez-Robles *et al.* 1990, 1992; Ackerman *et al.* 1994), and many have emphasised the limitations to reproduction (Calvo 1993; Ackerman and Montero Oliver 1985; Montalvo and Ackerman 1987; Ackerman 1989; Ackerman and Montalvo 1990). Although these studies are usually presented in a ecological or evolutionary context, they do have implications for the conservation and management of species.

5.3.2 Diversity

There are approximately 645 species in 110 genera and 32 subtribes (following Dressier 1993b) comprising approximately 10% of the region's vascular flora. Factors contributing to species richness in the Caribbean include a remarkable diversity of habitats from mangroves, lowland dry forests, karst and serpentine regions, pine woodlands, rain forests, and high-elevation dwarf cloud forests. A number of species have dispersed from Central and South American species pools, and considerable autochthonous speciation has occurred in a number of widespread genera such as *Encyclia, Epidendrum, Lepanthes, Lepanthopsis,* and *Pleurothallis.* In addition, many genera are either endemic or have their centres of diversity in the region: *Basiphyllaea, Broughtonia, Dendrophylax, Dilomilis, Domingoa, Psychilis, Quisqueya,* and *Tolumnia.*

Orchid species richness in the Caribbean seems somewhat associated with island size, topographic diversity, and distance from the tropical mainland, but the species/area relationship is not a simple one. The smaller islands have a higher species/area ratio than the larger ones. For example, I estimate that the Cayman Islands with an area of 259 km^2 have 0.73 species/km^2 and the Virgin Islands (US and British) with a combined area of 505 km^2 have 0.57 species/km^2. The Caymans are much closer to the mainland than the Virgin Islands, which may explain the discrepancy. However, estimates of species per unit area from the major islands of the Greater Antilles are much lower. Jamaica (11,396 km^2) has approximately 0.21 species/km^2; Puerto Rico (8897 sq km) has 0.017; Hispaniola (76,484 km^2) has 0.005; and Cuba (114,524 km^2) has only 0.003. Clearly, species/area relationships are strongly affected by scale.

Species-rich areas in the Caribbean are in the montane regions of the islands, generally at middle elevations in moist to wet habitats. A thorough study of endemism and areas of richness has yet to be conducted for the Caribbean as a whole and must await the completion of floristic projects currently underway. I estimate that endemism in the Lesser Antilles and Puerto Rico is a modest 10-11% of the orchid flora (Garay and Sweet 1974; Ackerman 1995). The other islands of the Greater Antilles are substantially richer in endemics. Jamaica has approximately 25% endemic orchids; Cuba has roughly 30% endemics; and Hispaniola has about 45% (D. Dod, pers. comm.).

5.3.3 Threats

The immediate threats to orchid populations of the Caribbean are simply development and agriculture, both large-scale and subsistence cultivation. The long-term threats to Caribbean orchids rest with overpopulation and the accompanying demands to house and feed people. Most of the lowland forests have been converted to sugar cane, banana, or tobacco cultivation or to cattle production. Even rough montane areas, including karst regions, have been subjected to extensive deforestation. A few islands have reversed this trend, and Puerto Rico is one of the best examples. Forested areas on this island have been increasing due to the shift from an agrarian economy to an industrial one. Forest reserves are well protected, and most of the native species occur within them. However, not all orchid habitats are protected, and many of them are threatened by urbanisation. The situation on other islands is much different. For example, Hispaniola suffers severe deforestation at a rapid rate, and the few forest reserves are not well protected (D. Dod, pers. comm.). On the other hand, existing forests of Cuba, primarily in montane regions, are not heavily exploited, but under the current economic crisis there are pressures to cut fuel wood (M. Diaz, pers. comm.). Throughout the Caribbean, orchid collecting has been a problem to varying degrees. Commercial exploitation has been curbed somewhat, but private collectors, both local and foreign, continue to exert pressures on orchid populations.

At present it is not known whether any Caribbean species have become extinct. However, several species are clearly threatened. There is no organised attempt at *ex situ* conservation of threatened species, although the Fairchild Tropical Garden in Miami, Florida, USA, serves as the Centre for Plant Conservation's germplasm depository for the Caribbean region.

5.3.4 Case histories

1) *Lepanthes caritensis* - Puerto Rico is relatively well known floristically, yet there continue to be new discoveries. Typical of such discoveries is that the species are often geographically confined and populations quite small. The epiphytic *Lepanthes caritensis* Tremblay & Ackerman is no exception. It exists within the state-run Carite Forest Reserve in a remnant 'tabonuco' (*Dacryodes excelsa,* Burseraceae) forest. In one census, 196 individuals were scattered on eight host trees within a small watershed near the border of the reserve (Tremblay and Ackerman 1993). Less than half the plants showed signs of reproductive effort. Only 18% had flowers, and just 11% had fruit. Any major disturbance of the watershed will certainly threaten the existence of these plants. Although the population persists in a forest reserve, it is not immune to clandestine charcoal production, squatters, or from legislative-mandated forest management practices. *Lepanthes caritensis* is currently under consideration for listing on the US Federal Endangered Species Act.

2) *Broughtonia cubensis* - The genus *Broughtonia* (*sensu lato*) is composed of a number of attractive species, and collecting pressures undoubtedly threaten some, particularly *B. domingensis* (Lindl.) Rolfe. In the case of

B. cubensis (Lindl.) Cogn., a Cuban endemic species, few plants are known from a very few places. Habitat destruction has been the primary threat to its populations. One population has been completely destroyed at Loma de la Coca. Another population is near an area of tourism development and is seriously threatened. Only in the Peninsula de Guanahacabibes are plants safe because the region is a protected area (M. Diaz, pers. comm.).

5.3.5 Recommended actions

1) Environmental education is an important general action that will provide hope for maintaining biodiversity in the face of increasing basic needs of a growing human population. Unfortunately, such programmes are either lacking on a large scale or are in their infancy.
2) Conduct thorough studies of endemism and areas of richness for the Caribbean region, using floristic projects in progress.
3) Increase protection of the habitat of threatened or endangered species.
4) Botanic gardens within the Caribbean should take a more active role in *ex situ* conservation of orchid species.

James D. Ackerman, Department of Biology, University of Puerto Rico, USA

5.4 Costa Rica and Panama

5.4.1 Present status of knowledge

The orchids of Costa Rica have been relatively well sampled, as Costa Rica has a long tradition of resident orchidists and naturalists who prepare material for study. In an ongoing data base of Western Hemisphere orchids, Dodson listed 1020 orchid species for Costa Rica in a 1982 printout. At present, Dodson and Escobar (1994) estimate 150 genera and 1600 species for Costa Rica. The orchids are being revised for the Manual project of Museo Nacional, Missouri Botanical Garden, Field Museum, and Marie Selby Botanical Gardens. To date, Dressler's revision of about 300 species has resulted in about 65 additions to the Flora (new records and new taxa, some still unnamed), while about 13 old records are found to be misidentifications or undocumented. In general, the mountains of central Costa Rica and Guanacaste and the Pacific coast have been well sampled, whereas the Atlantic coast and south-eastern Costa Rica are still poorly sampled.

In Panama there are much larger areas that are inaccessible and relatively undisturbed. Dodson and Escobar (1994) estimate 1050 species for Panama. The Atlantic slope, many mountainous areas, and the mountains of Darién are poorly sampled, but new records are likely to appear in all areas.

5.4.2 Orchid genera and species

Acineta **—** This is one of the most problematic genera in our area. The plants are very large, and the large flowers are thick and fleshy. There is very little preserved material available for study. Schlechter revised the genus in 1917, but, alas, too many species were from 'Unknown, probably Central America.' Three species are generally cited for Costa Rica, but there is virtually no study material. Horich (1992a) tells of finding *A. gymnostele* Schltr. in Costa Rica, but I doubt that any specimens were preserved. The *Acineta* of Cerro Campana and El Valle de Anton, Panama, is thought to be *A. superba* (Kunth) Rchb.f., but I know of no good specimens. This species occurs at least in the national park of Cerro Campana, where it should be fairly safe. Andres Maduro suggests that he sees three different species of *Acineta* in the area of Cerro Punta, but I do not know what they might be.

Brachionidium — These bizarre little plants usually grow on mountain tops, where the delicate flowers seem to be infrequent and short-lived. Mountain tops are, fortunately, relatively undisturbed (barring a proliferation of microwave and TV towers), so these species are probably safer than most. The species that occur at lower elevations tend to be more widely distributed. *B. folsomii* Dressier and *B. kuhniarum* Dressier were described from north of El Copé (Coclé prov., Panama; Dressier 1982b), where B. *folsomii* was known from a small colony and B. *kuhniarum* from a single plant. We now know that *B. folsomii* ranges westward to Veraguas, where it is relatively frequent on Cerro Arizona, and southward to Ecuador. B. *kuhniarum* has been found in both Ecuador and Bolivia.

Brassavola acaulis Lindl. — Restricted to north-western Panama and adjacent Costa Rica. I have seen no specimens from Costa Rica. I would guess that the species is vulnerable or threatened in both countries because of the limited area of distribution.

Cattleya aurantiaca (Bateman) P.N.Don — Known from Mexico to Nicaragua, this species was recently found in Costa Rica along the Río San Juan by members of the Asociación Sancarleña de Orquideología. Though it may be very local in Costa Rica, it is, as noted by Hágsater and Salazar (1990), not threatened. It is widespread and locally abundant, growing as a weed in towns in El Salvador (Bernhardt 1977).

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Cattleyaaurantiaca

Cattleya dowiana Bateman, 'Guaria de Turrialba' — This species is restricted to moist, lowland forests on the Atlantic slope of Costa Rica and Panama and is highly prized by orchidophiles, though difficult to maintain in cultivation. Its habitat is shrinking, and the plants are collected for sale. This species is becoming quite scarce and seems truly threatened.

***Cattleya patinii* Cogn.** — Widespread in Panama and Atlantic lowland Costa Rica, this species is less desirable as a garden plant than its relative, C. *skinneri,* but it is vulnerable to habitat destruction.

Cattleya skinneri Bateman, 'Guaria morada' — Southern Mexico to Costa Rica, where it is the national flower. Once common in central and north-western Costa Rica, it is now relatively scarce due to habitat destruction and collection for sale and gardens. The gene pool in cultivation may be greater than that in the wild. Possibly the best strategy would be to produce good-quality seedlings of this species and make them available to the Costa Rican public at a low price.

Chysis — This is another real problem genus. There are, according to Fowlie (1971), two species in Costa Rica, but he made no specimens. His C. *tricostata* Schltr. is presumably C. *costaricensis* Schltr., but I have seen no specimens of his 'C. *maculata* (Hook.) Fowlie,' and cannot dissect his photographs. There is a *Chysis* in central Panama, of which there is said to be an herbarium specimen somewhere, but I have seen no flowers. *Chysis* appears to be uncommon everywhere.

Cochleanthes aromatica (Rchb.f.) R.E.Schult. & Garay and C. *discolor* (Lindl.) R.E.Schult. & Garay — Both are attractive species and much appreciated in cultivation. They are reasonably widespread and perhaps not endangered.

Coryanthes — Another problem genus, the plants are scattered in nature and hard to find. When found, they are difficult to cultivate. Generally restricted to mature forests, especially along rivers. Gerlach and Schnell (1993) offer a revision, but it is clear that the sampling is poor, and the identity of C. *powellii* Schltr. remains uncertain. Highly vulnerable to deforestation.

Cycnoches warscewiczii Rchb.f. — In western Panama the plants are usually collected by loggers. Possibly vulnerable.

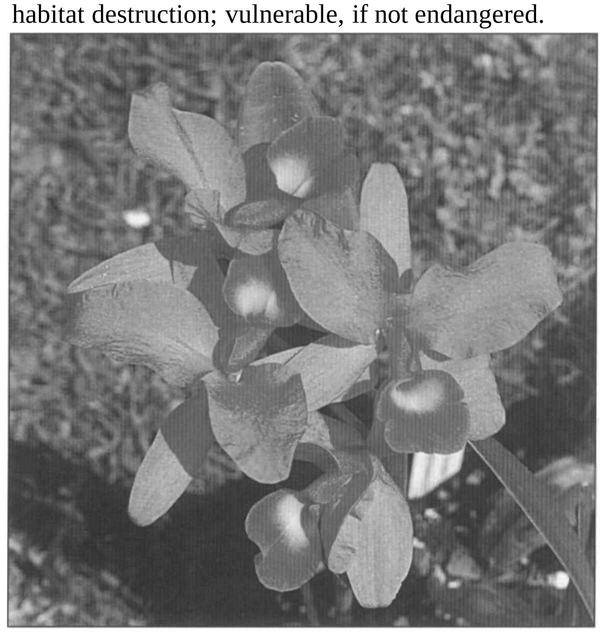
Encyclia cordigera (Kunth) Dressier, 'Semana Santa' in Panama — A showy and much sought species with distinct colour forms (or species?) in Costa Rica and Panama. It grows in seasonally dry forest and brushland on the Pacific slope and is probably not in great danger.

Encyclia sima Dressier — Known only from the cloud forests on Cerro Jefe and above El Valle de Anton (Dressier 1969). Vulnerable, because it is so local.

Epidendrum pendens L.O.Williams — Once occasional above El Valle de Anton, and collected once or twice in Costa Rica. Unless there are other populations in remote areas, this species is endangered by habitat destruction above El Valle.

Epidendrum pfavii Rolfe — A large and showy plant whose horticultural interest is restricted by its large size. This also restricts the species to large trees (Fowlie 1964), so the species is vulnerable to forest clearing.

Epidendrum pseudepidendrum Rchb.f. — Another large species that is much sought for the bright orange-red lip. This species is restricted to north-western Panama and adjacent Costa Rica and has been greatly reduced by habitat destruction; vulnerable, if not endangered.



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Cattleyaskinneri

Erythrodes bimentata Dressier — *Erythrodes* is usually an inconspicuous terrestrial, of little horticultural interest at best. Only two rather poor specimens were known of a relatively large-flowered species in the Monteverde reserve, each of these with lax, few-flowered inflorescences. Because it is so unlike all other Central American species and the Monteverde area is well sampled, it was decided to go ahead and publish the species (Dressier 1993a). Shortly after submitting the manuscript, I was in Monteverde with John Atwood, and we dedicated most of a day to searching along the Pantanoso and Chomogo trails without seeing so much as a leaf of *Erythrodes bimentata*. A few days later we found a single tall plant with an erect, many-flowered inflorescence along the Río Negro (near the Reserva Santa Elena). The flowers, however, are typical of E. *bimentata*. I believe that the plants collected by Dryer and Zuchowski near the Chomogo trail were weak plants that had sprouted up after the trailside vegetation had been cut. By now, *E. bimentata* probably has been eliminated as a trailside plant in the Monteverde Reserve, though it might yet be found on a river terrace. It is common to find remnants of orchid plants on road cuts and trailsides after the work crew has gone through. How we manage roadside vegetation may be an important factor in the survival of orchids in protected areas.

Houlletia odoratissima Linden ex Lindl. & Paxton — In Panama known only from Cerro Jefe, where it occurs as a terrestrial, scattered in the cloud forest. The plants are inconspicuous when not in flower, so the species is fairly safe unless the forests are destroyed.

Houlletia tigrina Lindl. & Paxton — Once occasional above El Valle de Anton, this species is now scarce in most areas but is still frequent on Cerro Pirre (Darién, Panama).

Kegeliella — This genus seems to be limited to moist, lowland, primary forests, where the plants are never very abundant. The localities where they used to occur in Panama are largely cut or badly degraded, though there may be large areas on the Atlantic slope where the species still occurs. *Kegeliella atropilosa* L.O. Williams ranges from Guatemala to Panama, while *K. kupperi* Mansf. is known only from Costa Rica and Panama.

Koellensteinia kellneriana Rchb.f. or ***K. lilijae*** Foldats — This species was once occasional in brushland along the road between Cerro Azul and Cerro Jefe. There is also one collection cited from north of El Valle de Anton (Williams and Allen 1949). The Cerro Azul locality is now converted to chicken farms, and the *Koellensteinia* may be extinct in Panama.

Maxillaria insolita Dressier — So far known only from a single collection along the ridge east of Cerro Jefe (La Eneida or Altos de Pacora, Dressier 1981a). Nevertheless, there are extensive forests to the north-east of the locality, and plants without flowers would easily be overlooked. Probably not endangered.

Miltoniopsis roezlii (Rchb.f.) God.-Leb. — In Panama this showy species is best known from near El Valle de Anton, where it must now be very rare, but the species also occurs in Veraguas (slopes of Cerro Arizona), in Altos de Pacora and near the El Llano-Cartí road. Probably not threatened.

Neomoorea wallisii (Rchb.f.) Schltr. —A very large plant that is found in Panama only in moist or wet forests in the Atlantic lowlands. Its size restricts it to primary forest. It is certainly scarce in accessible areas and may be threatened or endangered.

Oerstedella pseudoschumanniana (Fowlie) Hágsater — This showy species occurs above El Valle de Anton but is difficult to cultivate even in El Valle. Still, it is common and nearly weedy locally in the remaining cloud forests above El Valle. In addition, it occurs near Cerro Arizona in Veraguas and has been found near sea level along the Río Guanche. Probably not threatened.

Oncidium powellii Schltr. — Known from low elevations on the Atlantic slope of Panama, this species appears to be scarce. Possibly vulnerable or threatened.

Paltnorchis — One of the most poorly known orchid genera in tropical America. The plants resemble forest grasses or palm seedlings, and the ephemeral flowers, produced at irregular intervals, are usually wilted by noon. *Palmorchis nitida* Dressier was published from Barro Colorado Island, where it is known from less than a dozen plants (Dressier 1983). Since then, herbarium specimens without flowers suggest that it occurs in eastern Panama and Colombia. Three named species are known from Costa Rica, and we have poor specimens of three others. As indicated by Seidenfaden (1978), many of these terrestrial orchids are far more vulnerable than most epiphytes. If the forest is logged but some trees left in place, many epiphytes will survive, but the terrestrials may be shaded out by weedy secondary growth. In this case, *Palmorchis* has never, to my knowledge, been cultivated and is of no commercial interest. Nonetheless, these species can be wiped out by habitat destruction.

Paphinia 'clausula' Dressier — A plant that appears to be very scarce in wet, lowland Atlantic forests. There is a good specimen now in the University of Costa Rica Herbarium. It is said to be more common in some remote areas (Rodolfo Dodero, pers. comm.).

***Paphinia* species** — With the publication of the revision by Dodson and Neudecker (1990), it is clear that the plant found in central Panama is not *P. cristata* Lindl. There is little herbarium material, but the species is locally frequent near Caño Sucio (Coclé).

Peristeria elata Hook., 'Flor de Espíritu Santo' — This species, which is listed in Appendix I mainly because it is the national flower of Panama, is an interesting case. It appears to be at home on steep or rocky slopes, a habitat that is much more common now than in pre-Columbian times. One finds seedlings growing on road cuts, but when the plants reach flowering size, they are sure to be stolen for cultivation. Unfortunately, most people do not know how to grow them, so there is continuous pressure on all accessible plants. Such pressure is little affected by legislation.

***Peristeria* species**—An epiphytic *Peristeria* with spotted flowers was once locally common above El Valle de Anton. The plants require very wet conditions and usually die in cultivation. The expanding chicken farms have now overrun most of the population above El Valle. Gregorio Ruíz tried to save the plants, but he cannot cultivate, nor hope to sell many of them. The species ranges west to Chiriquí and may be locally frequent somewhere in the mountains, but it is nearly extinct above El Valle.

Phragmipedium caudatutn (Lindl.) Rolfe — The Central American form of *P. caudatutn* (often incorrectly called *P. warscewiczianum*) is known from few localities. At one time it could be found in the tops of tall trees on Cerro Pando (Dunn 1948). It is now frequent on the south rim of the Fortuna Valley. When the area was first accessible, the lady-slippers were found on stumps and trees in pastures. Now, I am told, they are growing well on the road cuts. It probably occurs elsewhere in the Fortuna Valley in the treetops. I do not know of any localities in Costa Rica. The Fortuna Valley is protected to some degree, though the plants along the road are very vulnerable to collectors.

Phragmipedium longifolium (Rchb.f. & Warsz.) Rolfe — This species is widespread, occurring usually near streams and sometimes on steep slopes. Greatly reduced in accessible areas but not threatened.

Schlimia jasminodora Planch. & Linden ex Lindl. & Paxton — Only one plant has been reported from Costa Rica (Horich 1992b). Apparently very rare.

Selenipedium chica Rchb.f. — In the early 1800s Berthold Seemann found this species to be common enough "in dark woods in the Provinces of Panama and Veraguas," that the plant had a common name ('Vainilla chica') and the fruit was used for flavoring. The Pacific slope of Panama has been heavily settled since before the conquest, and the primary forests are virtually gone. At the present, I know of a small colony of three or four adult plants on Cerro Campana (Dressier 1989a). There may still be some along the upper Chagres River, where it was collected by Paul Allen, but it must be considered one of Panama's rarest orchids. It is difficult or impossible to cultivate. In May 1993 I found the plants on Cerro Campana to be weaker than ten years earlier and without sign of having flowered that year. The trees at the site should probably be pruned or thinned to let more light in to the *Selenipedium* colony. I suspect that this is really a species of old secondary forests, with the plants normally dying out as the forest matures.

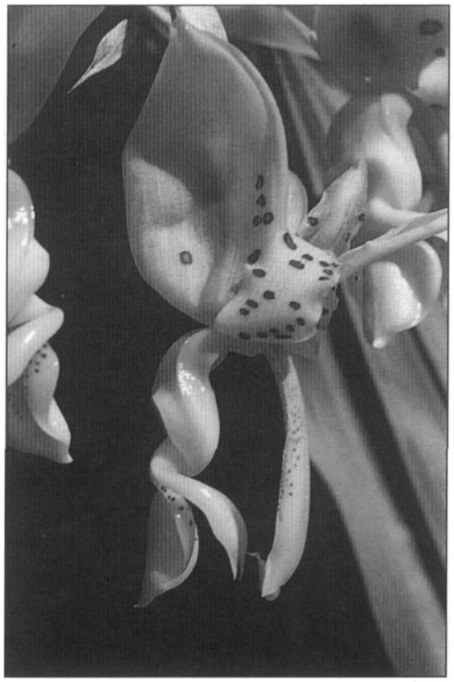
Sievekingia butcheri Dressier — Known only from very few plants found near El Valle de Anton (Dressier 1979). Unless there are other colonies of the species somewhere in the mountains, it is rare and vulnerable. An effort should be made to collect seed and distribute seedlings of this species.

Sievekingia fimbriata Rchb.f. — Horich (1966) has made much of the rarity of this species, but it is widespread in suitable habitats in Costa Rica and Panama, though rarely abundant. The population on Cerro Campana in Panama is well protected.

Sievekingia species — We have found the pollinaria of an unknown *Sievekingia* on the males of *Euglossa ignita* near Portobelo, on the Atlantic coast of Panama. We know nothing else of the plant or its flowers. Considering the rapid habitat destruction in the area of Portobelo, the species may well be threatened.

Sanhopea, 'Toritos' — The larger-flowered species of *Stanhopea* are popular garden plants, and they usually occur in moist forests at relatively low elevations. None of them is common in accessible areas. Their survival in nature depends on the protection of forest habitats. At the same time, when forests are cleared, the toritos are often saved and planted on trees near houses (Horich 1974). Such plants may survive for years, flowering and setting seed, surely a better fate than to be burned along with their host trees. The smaller, twin-flowered species are also scattered in the appropriate forests but seem to be less rare than the larger species, though *S. avicula* Dressier is little known because of its remote range (Dressier 1989b).

Trichopilia leucoxantha L.O.Williams — Known only from the area near El Valle de Anton, this species is now very scarce and surely endangered.



Stanhopeagraveolens

Trichopilia suavis Lindl. — An attractive and popular species but fairly widespread.

5.4.3 Areas of special interest in Panama

Cerro Pirre — This is an interesting mountain peak in one of several mountain ranges in eastern Panama (Bagre, Darién, Jungurudo, Pirre, Sapo). All are poorly known and need to be studied. These are part of the park system and are protected by their isolation. On C. Pirre were found: *Chondrorrhyncha anatona* (Dressier) Senghas, *Miltoniopsis* sp. (not *M. roezlii), Ophidion pleurothallopsis* (Kraenzl.) Luer, *Polycycnis lehmannii* Rolfe, P. *ornata* Garay, and an unnamed *Scaphyglottis.*

El Llano-Cartí road — A relatively new highway that crosses the low mountain range north of El Llano. This area had a very rich forest, though this has been largely cut near the road on the Pacific side. Similar forests are probably to be found to the east and west of the road. The Cuna Indians are controlling access to the Atlantic slope, which should be better conserved. *Miltoniopsis roezlii* (Rchb.f.) God.-Leb., *Platystele calymma* Luer, *Uleiorchis ulei* (Cogn.) Handro, *Vanilla pauciflora* Dressier, and *Wullschlaegelia calcarata* Benth.

Santa Rita Ridge to Portobelo — The Santa Rita Ridge is now largely logged, but had a really fascinating tropical forest. There is still a good deal of very wet forest on Cerro Bruja and on the upper Río Guanche. There has been much disturbance near the coast. *Jacquiniella pedunculata* Dressier, *Platystele dressleri* Luer, *P. ortiziana* Luer, and *Sievekingia* sp. (pollinaria only).

Cerro Jefe — Low-elevation cloud forest, probably due to edaphic conditions. The orchid distribution in the cloud forest is markedly spotty, and some of the most interesting areas have been cleared, but there is still extensive cloud forest. It is supposedly being protected as part of the watershed. *Dresslerella pertusa* (Dressier) Luer, *Encyclia sima* Dressier, *Koellensteinia* sp., *Masdevallia pelecaniceps* Luer, *M. pleurothalloides* Luer, *Maxillaria insolita* Dressier, and *Otoglossum chiriquense* (Rchb.f.) Garay & Dunst. below 1000 m elevation.

El Valle de Anton — The mountains north of El Valle had a very rich cloud forest, but chicken farms have destroyed much of the cloud forest, and the accessible areas are now much degraded. One of the areas most deserving of protection. *Chondrorrhyncha eburnea* Dressier, *Cycnoches* sp., *Epidendrum pendens* L.O.Williams, *Oerstedella fuscina* Dressier, *Sievekingia butcheri* Dressier, *Trichopilia leucoxantha* L.O.Williams, and *Trichosalpinx pergrata* (Ames) Luer.

Alto del Calvario — There was, for a time, a sawmill north of El Copé (Codé). The site appears to be a low gap in the mountains, so that the area is constantly wet during the 'dry' season and only a bit drier during the rainy season. While the operations of the sawmill destroyed some of the very rich cloud forest and some of the wet forests at lower elevations, it did maintain the road and open up the area for study. At present, the roadsides have grown up in secondary growth and it is difficult to find many orchids. Still, the bulk of the vegetation is intact, even if inaccessible. *Brachionidium folsomii* Dressier, *B. kuhniarum* Dressier, *Chondrorrhyncha crassa* Dressier, *Epidendrum insolatum* Barringer, *E. tenuisulcatum* (Dressier) Hágsater, *Kefersteinia auriculata* Dressier, *Polycycnis tortuosa* Dressier, *Maxillaria rodrigueziana* J.T.Atwood, and *Salpistele brunnea* Dressier.

Cerro Arizona — A mountain above Santa Fé, Veraguas. The peak was apparently a small army radar station during the war. There is a trail to the peak, recently improved by the National Guard. This mountain has rich very wet forests and something approaching cloud forest near the peak. It is, at the present, protected by distance. There was an attempt to build a road past the Cerro to Calovébora on the Atlantic coast, but I believe the road has been abandoned, though there is some foot traffic along it and some settlement along the lower portion. An exceedingly rich area, some of which should be protected. *Kefersteinia maculosa* Dressier, *Myoxanthus balaeniceps* (Luer & Dressier) Luer, *M. pan* (Luer) Luer, *Oerstedella lactea* (Dressier) Hágsater, *Pleurothallis* *peculiaris* Luer, *Scaphosepalum viviparum* Luer, and *Scaphyglottis arctata* (Dressier) B.R.Adams.

Cerro Colorado — An exceedingly rich area north of San Felix. Roads were built to support a proposed copper mine, but the project has fortunately been abandoned. Another area that deserves protection but for now is protected by virtue of its remote local. *Acrorchis roseola* Dressier, *Lacaena* sp., and *Sobralia undatocarinata* C.Schweinf.

Fortuna Valley — A hydroelectric plant has been built on the upper Rio Chiriquí, and a paved road was built through the Valley and over to the Atlantic coast. This is a very rich, very wet forest that has already yielded a great many botanical surprises. For now, at least, the Valley itself is protected to maintain the watershed. *Chondrorrhyncha crassa* Dressier, *Cischweinfia* sp., *Encydia fortunae* Dressier, *Lycaste schilleriana* Rchb.f., *Phragmipedium caudatum* (Lindl.) Rolfe, *Trichopilia* sp., and *Warreopsis parviflora* (L.O.Williams) Garay.

5.4.4 Factors influencing vulnerability of plant populations

Restricted area - Species that are limited to small areas or localised habitats, as the cloud forests on Cerro Jefe and above El Valle de Anton, are especially vulnerable. When the habitats are being converted to summer homes or chicken farms, then no amount of well-intentioned legislation will halt the disappearance of the plants involved. If a well-protected reserve cannot be created above El Valle de Anton, then we should try to distribute remaining plants of rare species to botanic gardens, where there might be some chance of their survival.

Wide range, but sparse population - This is the other end of the spectrum, but sparse populations are also very vulnerable to habitat destruction. This is especially the case of moist lowland forests. These are being logged heavily in most areas. The rain forest does not do well as little bits and pieces, and unless there are sizeable reserves, the species of this habitat are very vulnerable, as, for example, *Cattleya dowiana, Coryanthes, Kegeliella, Neomoorea wallisii*, and *Stanhopea.*

A special case where small forest parcels are worthy of protection may be where a species is sparsely dispersed in semi-cleared areas or other special local habitats, such as *Erythrodes bimentata* or E. *tuerckheimii.* The latter ranges from Guatemala to Panama but seems always to be found as isolated plants, rather than colonies. E. *bimentata* is much more localised (on present evidence) but occurs in a mountainous area where there are several reserves. It is probably not threatened, even though it may have disappeared from the trailsides in Monteverde.

Lowland forests versus mountain areas - By now, it is clear that the lowland forests are much more vulnerable to large-scale logging than mountainous areas. In the mountains there are usually cliffs, steep slopes, and narrow canyons where it is impractical to cut the trees or to extract the logs. Furthermore, steep slopes, rocky areas, and even road cuts supply an alternate habitat for many epiphytes at higher elevations.

Collecting pressure on commercially valuable species - This is clearly a contributing factor for some species. In many cases, though, these species are collected for commerce only where trees are being cut. In other words, restrictions on commerce without habitat protection accomplish little and may even be harmful. Even though international commerce in *Cattleya dowiana* and *Peristeria elata* is prohibited, the plants are so popular in their countries of origin that they are still being collected avidly and sold to local tourists and gardeners.

At the same time, it should not be forgotten that the species of special commercial interest comprise probably less than one-tenth of the orchid family. Many species are of very limited commercial interest. This is especially true of many small-flowered terrestrial orchids that have virtually no interest even for the amateur orchidophile. These, however, are especially vulnerable to habitat destruction. Most of the smaller-flowered epiphytes can survive very well if samples of their habitat remain. Indeed, in forested areas these species are usually collected, whether for horticulture or for study, only where the trees are being cut for one reason or another.

5.4.5 Summary and conclusions

Some orchid species are threatened by both commercial exploitation and habitat destruction, while some are threatened only by habitat destruction, and many others are relatively widespread in habitats that are not widely threatened. The most endangered species are those of restricted habitats or of habitats that are being destroyed at a rapid rate (especially lowland moist and wet forests). Orchids in montane habitats are much less vulnerable than those of lowlands. Terrestrial orchids as a class may be much more vulnerable than epiphytic species.

5.4.6 Recommended actions

1) It is desirable to keep orchid species viable in their natural habitats, but this is doomed to failure unless reasonable plots of habitat are protected.
2) The careful botanical study of the orchids in the wild should be conducted.
3) We need to improve our museum and herbarium collections for study purposes.
4) Cooperation between botanists, local growers, and naturalists should be promoted.
5) Critical habitats of threatened and endangered species should be protected.

Robert L. Dressier, USA

Table 5.4.1 Costa Rican orchid species represented by more than 25 collections in the five herbaria sampled. Only about 300 species already borrowed and reviewed for the Manual manuscript were sampled, so about 10% of the species sampled were represented by more than 25 collections.

Species	No. specimens
Elleanthus aurantiacus (Lindl.) Rehb.f	39
E. cynarocephalus (Rchb.f.) Rchb.f	28
E. glaucophyllus Schltr.	60
E. hymenopohorus Rchb.f.	38
E. poiformis Schltr.	33
E. tonduzii Schltr.	48
Erythrodes killipii Ames	26
Habenaria monorrhiza (Sw.) Rchb.f.	56
Hexisea imbricata (Lindl.) Rchb.f.	34
Isochilus linearis (Jacq.) R.Br.	27
Nidema boothii (Lindl.) Schltr.	49
Oncidium bracteatum Warsz. & Rehb.f.	26
O. heteranthum Poepp. & Endl.	39
O. obryzatoides Kraenzl.	40
O. obryzatum Rchb.f.	38
O. pusillum (L.) Rchb.f.	26
Scaphyglottis acostaei (Schltr.) C. Schweinf.	44
S. crurigem (Lindl.) Ames & Correll	26
S. densa (Schltr.) B.R. Adams	43
S. mesocopis Hemsl.	31
S. micrantha (Lindl.) Ames & Correll	33
S. prolifera Cogn.	41
Sobralia amabilis (Rchb.f.) L.O. Williams	72
S. macra Schltr.	53
Ticoglossum oerstedii (Rchb.f.) Halb.	30

Table 5.4.2 Costa Rican orchid species that are represented by less than five collections in the five herbaria sampled. Species not represented in these herbaria are known from other herbaria or were described from Costa Rica from specimens later destroyed by war. This list does not include 24 distinct species of which the available material is too poor for their description. An * denotes species known to be fairly common.

Species	No. collections
Baskervilla leptantha Dressier	3
Bletia companulata La Llave & Lex.	0
**B. purpurea* (Lam.) DC.	2
Brassavola acaulis Lindl.	0
Bulbophyllum vinosum Schltr.	0
Cattleya aurantiaca (Lindl.) P.N. Don	0
**C. patinii* Cogn.	1
Chysis maculata (Hook.) Fowlie	0
C. tricostata Schltr.	3
Cleistes costaricana Christenson	3
**Cranichis muscosa* Sw.	3
C. sylvatica Rich. & Galeotti	1
Crossoglossa eustachys (Schltr.) Dressier & Dodson	0
Elleanthus longibradeatus (Griseb.) Fawc.	3
Erythrodes bimentata Dressier	0
E. epiphytica Dressier	0
E. roseoalba Dressier	2
E. stictophylla (Schltr.) Ames	0
E. tuerckheimii (Schltr.) Ames	1
E. utriculata Dressier	0
E. venustula (Ames) Ames	1
Goodyera bradeorum Schltr.	0
G. micrantha Schltr.	0
G. modesta Schltr.	0
G. turrialbae Schltr.	0
Habenaria novemfida Lindl.	1
H. rodeiensis Barb. Rodr.	1
H. strictissima Rchb.f.	2
Malaxis adolphii (Schltr.) Ames	0
M. aurea Ames	1
M. carpinterae (Schltr.) Ames	0
M. crispifolia (Rchb.f.) Kuntze	0
M. lagotis (Rchb.f.) Kuntze	0
M. pandurata (Schltr.) Ames	1
M. talamancana Dressier	2
M. tanduzii (Schltr.) Ames	0
M. unifolia Michx.	0
M. *wendlandii* (Rchb.f.) L.O.Williams	1
M. woodsonii L.O.Williams	1
Myrmecophila brysiana (Lem.) Kennedy	0
**M. tibicinis* (Bateman) Rolfe	3
Oncidium isthrni Schltr.	2
Palmorchis silvicola L.O.Williams	2
Polystachya lineata Rchb.f.	1
Prescottia oligantha (Sw.) Lindl.	0
**Pterichis habmarioides* (Lehm. & Kranzl.) Schltr.	3
P. leo Gómez & Gómez	2
Reichenbachanthus reflexus (Lindl.) Brade	1
Rhynchostek (Lemboglossum) bictoniensis (Bateman) Soto Arenas & Salazar	0
R. cordata (Lindl.) Soto Arenas & Salazar	2
R. hortensiae (R.L. Rodr.) Soto Arenas & Salazar	3
R. maculata (La Llave & Lex.) Soto Arenas & Salazar	0
Scaphyglottis geminata Dressier & Mora-Retana	0
S.gigantea Dressier	1
S. modesta (Rchb.f.) Schltr.	1
S. pulchella (Schltr.) L.O.Williams	4
S. spathulata C.Schweinf.	4
Sobralia allenii L.O.Williams	3
Triphora nitida (Schltr.) Schltr. ex Mansf.	0
T. ravenii (L.O.Williams) Garay	1
Vanilla helleri A.D.Hawkes	1
V. odorata Presl	3
V. pautiflora Dressier	1
V. pfaviana Rchb.f.	4

5.5 Ecuador and neighbouring countries

(Adapted with authors' permission from Dodson, C. H. and R. Escobar R. 1994. *Native Ecuadorian Orchids,* Vol 1. Hola Colina, Medellín, Colombia)

5.5.1 Western Ecuador

Geography

The boundaries of western Ecuador have been established as the Pacific Ocean to the west, the Colombian border to the north, the Peruvian border to the south, and the 900 m contour line on the Andean mountains to the east. With this definition, western Ecuador has a land area of approximately 80,000 km^2, about a third of the total 263,000 km^2 of continental Ecuador. The majority of western Ecuador consists of a series of peneplains extending westward from the base of the abruptly rising western Cordillera of the Andes. There is also a low range of coastal hills seldom exceeding 800 m in elevation.

Major ecosystems

Of the 12 life zones reported in western Ecuador, 10 have been studied with varying degrees of intensity. Five have been intensively sampled by using the florula approach. These include the *Flora of Rio Palenque* (Dodson and Gentry 1978) in tropical wet forest, the *Flora of Jauneche* (Dodson *et al.* 1985) in tropical moist forest, the *Flora of Capeira* (in press) in tropical dry forest, the *Flora of Centinela* (in prep.) in premontane pluvial forest, and the *Flora of Tenefuerte* in premontane wet forest. The Santa Elena Peninsula, with three very dry life zones (tropical desert, tropical desert scrub, and tropical thorn scrub) was studied by Svenson (1946) and Tazan and Valverde (1979). Valverde (1991) has continued with studies of the Cerros de Colonche. This region of the dry coastal mountains has tropical thorn scrub, premontane thorn scrub, tropical dry forest, very dry tropical forest, premontane dry forest, and tropical moist forest.

The prolonged dry season in the south and west results in desert, desert scrub, tropical thorn scrub, and a cover of very dry to dry tropical forest on the plains progressively inland and away from the cold waters along the coast. The coastal hills are clothed with thorn scrub at the base, premontane dry forest on the slopes, and moist or wet forest on the higher crests.

Finally, a narrow strip of perhumid cloud forest on the lowermost Andean slopes is included in western Ecuador as here defined. This region has a forest cover that is an extension of the Colombian Chocó pluvial forests, generally characterised by extremely high annual rainfall. These conditions extend southward in increasingly narrow elevational bands along the flanks of the Andes. Pluvial forest with 8800 mm of annual rainfall reaches south only to Tobar Donoso, at the Colombian border, at about one degree north latitude. However, premontane pluvial forest reaches nearly to the Peruvian border where it is reduced to a strip only a few hundred metres wide near the 900 m contour. In general, each of the moist vegetation types forms a broad extension near the Colombian border but are reduced to narrow bands between the 300 and 900 m elevational lines near the Peruvian border.

5.5.2 The Sierra

Geography

The Sierra consists of about 102,000 km^2, all of which is above 900 m elevation. Ecuador is split north and south by the Andes mountains (the Sierra) that constitute its main geographical structure. Two chains are generally recognised, while both to the north and south of Ecuador the Andes are composed of three chains. In Ecuador, the Andes resemble a ladder with the western range forming one side while the eastern range forms the other. Between the ranges are inter-Andean valleys separated by rungs or 'nodes.' Each valley is on average 2500 m in elevation and 60 to 70 km wide with a river that exits either to the west or east. Those valleys with westward-exiting rivers tend to be drier. A series of high, mostly snow-capped volcanoes, some of them active, characterise the two parallel ranges.

Major ecosystems

The Holdridge system divides the vegetation formations occurring from the 900 to the 3000 m contour into an extensive series of life zones developed in bands that are often narrow due to the abruptness of the slopes. This band contains lower montane and premontane dry forest, lower montane and premontane moist forest, lower montane and premontane wet forest, and lower montane and premontane pluvial forest. Above the 3000 m contour the life zones are montane dry, montane humid, montane wet, montane pluvial, subalpine dry tundra, subalpine humid tundra, subalpine pluvial tundra, alpine pluvial tundra, and finally, the perpetual snow zone.

5.5.3 The Oriente

Geography

The Oriente occupies about one third of the country with about 81,000 km^2 below and east of the 900 m contour of the Andes. Approximately half of the Oriente, 40,000 km^2, consists of the lower eastern slopes of the Andes from the 300 to the 900 m contour. This region is heavily broken but tends to slope gradually to the east. Most of the area is very wet and forms the head waters of very large rivers such as the Napo, the Pastaza, the Santiago, etc., which feed into the Amazon to the east. The three eastern ridges — the Guacamayo, the Cutucu, and the Condor — form the third range of the Andes and tend to emerge from the base of the eastern slope. Each of the ranges reaches little more than 2400 m elevation.

The Amazon basin, as defined here, begins at the 300 m contour and extends to the Colombian and Peruvian borders. This area constitutes about 40,000 km^2, roughly half of the Oriente, and tends to have meandering rivers, ox-bow lakes, relatively flat lands, and agriculturally poor soils.

Major ecosystems

The Cañadas map lists relatively few Holdridge life zones in the Oriente region as defined here. A substantial majority of the region from the 300 m contour line eastward lies within the tropical moist forest life zone, whereas the area close to the base of the Andes has broken bands of premontane moist forest, premontane wet forest, and premontane pluvial forest. A substantial number of forest types occur within each of the life zones based on differences in soils, inundation periods, rainfall, cloud intrusion, slope facing, etc.

5.5.4 Present status of knowledge

The earliest known collections were made by Thaddaus Haenke when he stopped at Guayaquil in 1790 during his voyage along the Pacific coast of South America. Alexander von Humboldt and Aime Bonpland visited what was the Audiencia de Quito, from late 1801 to early 1803, and collected and described about 20 orchid species from the region. The later collections of Jameson, Hartweg, and Hall were forwarded to England and described by John Lindley at Chiswick (Horticultural Society of London), with the origin of the collections cited as 'Peru.' Lindley was either confused in his geography, or he considered most of western South America as 'Peru.' In 1854 Joseph Warscewicz visited southern Ecuador and northern Peru and collected a significant number of orchid species which were described by Lindley and H. G. Reichenbach.

One of the most important early collections of Ecuadorian orchids was made by a mining engineer and German Consul to Popayán, Colombia, Friedrich C. Lehmann, who visited Ecuador several times between 1872 and 1890. Reichenbach described and identified many of Lehmann's collections, while Lehmann, together with F. Kränzlin, described and identified many more.

A very significant collection of plants was made by the priest Luis Sodiro from 1870 to 1908 and many species were described by Reichenbach, Cogniaux, and Schlechter. Unfortunately, collections were poorly maintained in a Jesuit high school in Quito, widely dispersed and mostly destroyed during the bombing of the Berlin Herbarium in 1944. After his death, Sodiro was replaced by the priest Luis Mille who made some orchid collections described by Schlechter. Rudolf Schlechter (1921), published a checklist of the orchids known from Ecuador. He listed 93 genera and 746 species of which 124 were described as new.

Beginning in 1952 and building on the collections made by Eric Asplund in 1939 and 1940, the Swedish botanists Gunnar Harling and Benkt Sparre began extensive general collecting in Ecuador and initiated the *Flora of Ecuador* project. The Flora is designed to provide a professionally prepared, standardised treatment of the whole flora of Ecuador. The efforts of the Scandinavian botanists over the past several decades in the collection of flowering plants, and orchids in particular, have provided a remarkably complete survey of the orchid flora of Ecuador. In 1976 and 1977, Bemt Løjtnant of the Botanical Institute at the University of Aarhus, a member of the second expedition, published four papers on the orchids collected during those two expeditions. Løjtnant listed and discussed 93 species based on the specimens collected. Many were reports of species new to Ecuador, and six new species were described.

The orchids collected by the Swedish botanists and their Danish colleagues provided the basis for the start of the treatment of the Orchidaceae by Leslie A. Garay, the first volume of which was published in 1979. That first volume treats the primitive members of the family (the subfamilies Cypripedioideae, Orchidoideae, and Neottioideae in the classification used by L. A. Garay) often termed the 'terrestrials,' though some species grow as epiphytes. It includes 49 genera and 255 species and describes 48 new species. The same group included 23 genera and 83 species in Schlechter's list of the orchids of Ecuador in 1921. Since the publication in 1978, of Garay's treatment, 56 additional species in this group have been encountered. Most are new records for Ecuador, and some are undescribed species.

During the years from 1957 to 1963, Calaway Dodson, Grady Frymire, and Leonard Thien made approximately 2000 orchid collections throughout most of the country on the existing access roads and trails. From 1966 to 1992 Dodson and various collaborators made approximately 5000 additional orchid collections. Beginning in 1974, Carlyle Luer has made more than 5000 collections of orchids in Ecuador, primarily members of the Pleurothallidinae.

Schlechter listed 746 species of orchid for Ecuador, whereas we now list 3259 species of which about one-third (1112) have been described in the last three decades. The difference of 900 species between the number listed by Schlechter, the species recently described from Ecuador, and the total number we report here, are those that have been encountered in Ecuador but which were originally reported from neighbouring countries.

During the last decade, monographs and treatments of large genera have resulted in a proliferation of segregate genera, e.g. L. A. Garay's treatment of the genera surrounding *Spiranthes* and *Erythrodes*, Halbinger's treatment of the Middle American *Odontoglossum* complex, and Luer's treatment of the Pleurothallidinae. In addition, substantial exploration of tropical regions by orchid taxonomists and highly motivated enthusiasts, particularly concerning the relatively inconspicuous plants with small flowers that are adapted to living as twig epiphytes in guava and citrus trees, has resulted in the recognition of many new genera. Some conservative botanists have been critical of such treatment but have also commented that classical generic alignments such as those of the *Oncidium-Odontoglossum-Miltonia* series, the *Spiranthes-Sarcoglottis-Pelexia* alliance, and the *Pleurothallis* complex are strictly artificial and unsatisfactory.

5.5.5 Diversity

As with the flora in general, the distribution of the orchids in the Andean countries tends to be regional. Table 5.5.1 summarises the regional distribution of species throughout Ecuador. The larger genera tend to be widespread throughout tropical America. Small genera tend to be local and often concentrated in the Andes. The orchids of the coastal plain of western Ecuador are most closely associated with those of Central America. The Andean orchids tend to be distributed from Bolivia to Venezuela and north to Costa Rica. Those orchids of the lower elevations of the Amazon drainage of eastern Ecuador are associated with the species occurring throughout the Amazon Basin.

Detailed comparison of the orchid floras of neighbouring countries of Ecuador is difficult due to lack of an adequate data base. The only tropical South American country whose orchid flora is reasonably well known is Venezuela. No list of the species of orchids of Colombia has been published since Schlechter's list of 1920, and that list is very incomplete with only 138 genera and 1293 species. In 1924 Schlechter published additions to the Colombian orchid flora including eight genera and 197 species new to Colombia, making a total of 146 genera and 1490 species. The *Orchids of Peru* by C. Schweinfurth (1958-1961) in some respects misrepresents the orchid flora by including a substantial number of species that were cited from 'Peru' but actually occur only in Ecuador. It also suffers from an inadequate collection base, as can be attested to by anyone who has collected extensively in Peru and attempted to use Schweinfurth's flora for identification. Nearly one-half of the orchid species which occur in Peru are not listed in the *Flora of Peru*. Schweinfurth listed 120 genera (= about 150 genera in this treatment) and 900 species, whereas Schlechter (1921)

Table 5.5.1 Distribution of orchids in Ecuador

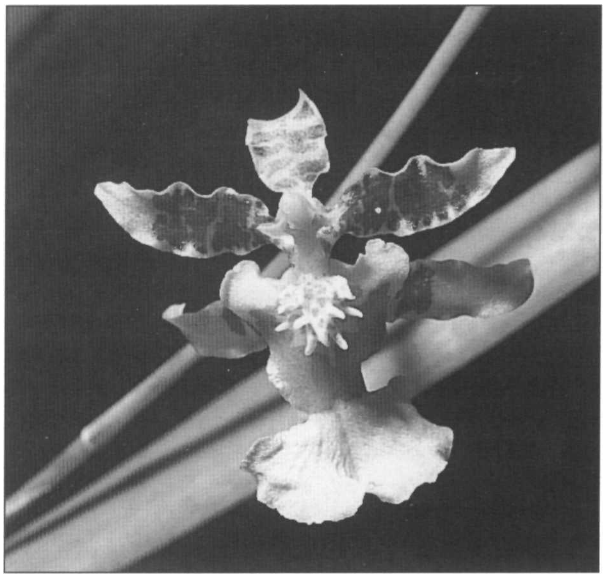
Region	No. of species	Area (km^2)	Elevation (m)	Type of forest
Eastern Ecuador below 300 m	138	60,000	125-300	tropical moist
Eastern Ecuador 200-900 m	465	83,000	100-900	5 life zones
Western Ecuador below 300 m	156	60,000	0-300	tropical dry to pluvial
Western Ecuador 0-900 m	501	80,000	0-900	12 life zones
Western Ecuador 0-3700 m	1,303	102,000	0-3,700	16 life zones
All of Ecuador below 300 m	291	120,000	0-300	
Montane Ecuador above 3000 m	588	20,000	3,000-4,400	Upper montane to alpine
Ceja de la Montana 300-3000 m	2,659	133,000	300-3,000	Premontane to montane

listed 111 genera and 838 species. In 1970 Schweinfurth published a supplement to the *Orchids of Peru* adding four genera and 118 species for a total of 150 genera and 1018 species.

Of the 2223 species reported for Brazil by Pabst and Dungs (1977), 651 are found in Andean countries, with 1556 occurring in Brazil, Argentina, Paraguay, and Uruguay.

The combination of the treatments of the orchid flora of Venezuela by Foldats (1969-1970) and Dunsterville and Garay (1979) provides a reasonably adequate data base for comparison with the known Ecuadorian orchid flora. Foldats listed about 1100 species, whereas Dunsterville illustrated 1055 species for Venezuela. The difference between the number of species listed in the two treatments (including those not found and illustrated by Dunsterville) would provide a total of about 1420 species. By extrapolation of the generic status of the orchids of Venezuela and those of Ecuador, reducing some generic names to synonymy and recognising others as mentioned above, there are 161 genera in common with 198 genera in Venezuela and 214 in Ecuador. At present we can estimate that about 1600 species occur in Venezuela and more than 3500 in Ecuador.

Forty genera of orchids have been found in Ecuador which have not been found in Venezuela. Seven of these are endemic to Ecuador and 33 are Andean in distribution; six are monotypic and only *Dracula* has more than ten species. One the other hand, 15 genera are known for Venezuela that have not been found in Ecuador; 12 are Amazonian in distribution and may still be found in the largely unexplored forest of lowland eastern Ecuador.



Paul & Jenne Davies

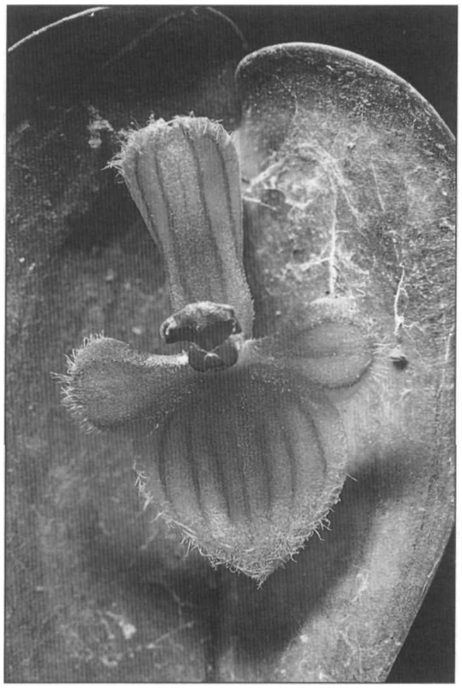
Oncidium baueri

At the generic level, the orchid floras of Venezuela and Ecuador are comparable, 198 vs. 211, but the difference in number of species is substantial, c. 1600 vs. c. 3500. The orchid flora of Colombia has not been treated, but total numbers of genera and species should be similar to those of Ecuador. The Peruvian orchids will probably not exceed 2000. Bolivia should have about 119 genera and 1200 species, based on the recent collections of R. Vasquéz, but it still has the least known flora in the Western Hemisphere.

Only seven genera (2.5 %) are endemic to Ecuador. The additional factors of extreme diversity of habitats and microclimates in Ecuador resulting from the high Andes mountains, the meeting of the cold Humboldt current and the warm Nino currents off the coast, and the wet eastern slope of the Amazon drainage have provided easily isolated and highly varied conditions. Species have proliferated with an estimated 700 species (over 20%) endemic to Ecuador. This is particularly true of species in large genera such as *Pleurothallis, Masdevallia, Stelis, Lepanthes, Epidendrum, Maxillaria,* and *Oncidium.*

Though the data are incomplete, it becomes immediately evident that the majority of orchid species are to be found between the 300 and 3000 m contours (Table 5.5.1). Below 300 m, 138 species occur in eastern Ecuador and 153 in western Ecuador. Of the 291 species occurring in Ecuador below the 300 m line, only 10 species are in common on both sides of the Andes, leaving 281 orchid species occurring below 300 m (or 8% of the total orchid flora). Species occurring above 3000 m, conversely, total 588 (or 18% of the total). Therefore, 879 species occur below 300 m or above 3000 m (or 26% of the total of 3259 species reported in Ecuador), leaving 2659 species (81% of the species) between the 300 and 3000 m contours. The land area occupied below 300 m and above 3000 constitutes about 140,000 km^2 while the remaining 133,000 km^2 forms the flanks of the Andes between 300 and 3000 m.

Comparison of the orchids of western and eastern Ecuador below 900 m indicates that 504 species occur in the 80,000 km^2 of western Ecuador, whereas 465 species are found in eastern Ecuador below the same elevation. Only 89 species are in common on both flanks, leaving 872 species not occurring on both sides below 900 m. Therefore, 31 % of the orchid species occurring in Ecuador are found below 900 m. Curiously, 194 species (40%) are considered endemic to western Ecuador (from 0-900 m), while 163 species (35%) are endemic to eastern Ecuador (from 200-900 m). However, the significant number is that only two of the Amazonian species (or 2%) occurring below 300 m are thought to be endemic, whereas 45 of the western species occurring below 300 m (or 29%) are judged to be endemic.



Pleurothallis perryi

The explanation for the lack of commonality between the orchids of the eastern and the western lowlands can be explained by the predominantly Amazonian nature of the flora of the lowlands of the east, whereas the relationships of the lowland western orchids are with Central America and the Chocó of Colombia. The Andes are a very important isolation factor, suggesting that much of orchid speciation has taken place since their emergence.

5.5.6 Threats

The senior author arrived in Ecuador in September of 1957 to study orchid populations in their natural state. Ecuador then had a human population of under four million. Access to the back country was limited with a total of about 10,000 km of primary road, of which less than 100 (or 1%) was paved. Secondary roads probably did not exceed 3000 km at that time. A single, unpaved road from Baños to Puyo provided limited access to the Amazon drainage of Ecuador. Three unpaved roads led from the coast into the Andes. Vast expanses of untouched forest were present in the western lowlands and western slopes of the Andes. The eastern slopes and lowlands were essentially untouched. The effects of what little forest conversion that existed were minimal, and the forests of Ecuador were little changed from colonial times. Of the approximately 80,000 km^2 considered by geographers to constitute western Ecuador, about 63% was still covered by forest (Dodson and Gentry 1991).

By September of 1991, 34 years later, the human population of Ecuador exceeded 10 million. More than 40,000 km of primary and secondary roads existed with 3300 km completed between September of 1984 and September of 1987. The forests of western Ecuador constitute less than 6.5% of their original cover with only two sizeable (contiguous) reserves in the extreme north-west totalling less than 3000 km^2, a few patches of inaccessible hilltop forests in Manabi and Esmeraldas, and a few tiny reserves of a few hundred hectares total in the rest. The forests of the Andean valleys are gone, and both slopes are under extreme pressure due to the development of penetration roads throughout. The forests of north-eastern Ecuador have been reduced drastically as a result of accessibility provided by petroleum exploitation. Oil-well drilling in the large Yasuni National Park, on the eastern border with Peru, has been successful, and new roads are under construction. Some parts of south-eastern Ecuador are still reasonably virginal, but new primary roads are under construction there as well.

Since natural populations of many orchid species require fairly extensive stands of undisturbed forest for reproductive success, the future of the orchids of Ecuador appears grim. As seen in Table 5.5.2, which list the status of the forests of Ecuador by region, there are a large number of threatened species. Even in the relatively extensive forest reserves declared by the government and managed by the forestry department of the Ministry of Agriculture, control has hardly been effective.

One positive, yet tragic, effect of opening up the country with an extensive network of roads has been to make nearly all regions available for collection and study of the orchid flora. In recent years, nearly continuous collecting trips have greatly affected the collection base, changing it from poorly known to one of the better-known orchid floras in the Neotropics. Unfortunately, with access came forest destruction so that it is impossible to return and restudy areas of interest.

Calaway H. Dodson, Ecuador; and
Rodrigo Escobar R.,
Jardín Botánico Joaquín, Colombia.

5.6 The Guayana Region

The Guayana Region is located in north-eastern South America and consists of a highly characteristic complex of neotropical flora and vegetation types that occur on the periphery of the Precambric Guayana crystalline shield. The orchid flora of the Guayana region is also highly characteristic in the region's floristic composition and the variety of orchid communities encountered (see for example Romero 1993a,b). The term Guayana, derived from an Amerindian word (Berry *et al*,. in press), should be distinguished from 'Guiana' and 'Guyana'. Guiana, or the Guianas, an English derivation of Guayana, apparently first published by Raleigh (1596), is currently used to designate the area occupied by French Guiana, Surinam, and Guyana. Early English language accounts of exploration of the former British portion of the Guianas called it 'British Guayana' (R. H. Schomburgk 1836, 1837a,b), but it was later known as 'British Guiana' (e.g. R. H. Schomburgk 1840). British Guiana became an independent country in 1966 and was renamed Guyana.

5.6.1 Geography

The Guayana region is defined here following the phytogeographical concepts of Huber (1987, 1988a, 1988b, 1994). It is bordered by the Caribbean region to the north including the llanos of Venezuela and Colombia, the Atlantic Ocean to the east, and the Amazon region to the south and west (Huber 1994). Guayana includes the central and eastern areas of French Guiana, the countries of Surinam and Guyana, the northern sections of the States of Roraima and Amazonas in Brazil, the Venezuelan States of Delta Amacuro, Bolívar, and Amazonas, and the Departments of Vichada, Guainía, and Vaupés in Colombia. Combined, these areas cover an extension of c. 1,000,000 km^2. The area is defined by a combination of geographical, ecological, and floristic criteria (Huber 1994). The Guayana region is characterised by a distinctive montane physiography, composed mainly of ancient highlands of variable elevations ranging from 200 to 3000 m, including isolated sandstone tablelands Ctepuis') and granitic inselbergs. The Guayana region mountains are surrounded by lowlands covered by savannas and rain forests and are isolated from other mountainous areas in the Neotropics, such as the Andes, the coastal range of Venezuela, and the Brazilian Shield.

Following Huber (1994), the Guayana region can be divided in four provinces. The Eastern Guayana Province includes the macrothermic lowlands of French Guiana, Surinam, Guyana, the delta of the Orinoco, and the extreme north-east of the Bolivar State in Venezuela. In this account, it also includes the granitic outcrops (locally known as 'lajas') along the southern rim of the middle Orinoco. These granitic outcrops have a distinctive orchid flora that has been described by Romero (1993a) and includes Guayanan, Amazonian, and Caribbean floristic elements. The Eastern Guayana Province is covered mainly by tropical rain forests or semideciduous forests.

The Central Guayana Province spreads irregularly across the Guayana region and includes uplands and mountain slopes at elevations ranging from 300 to 1500 m in north-western Guyana, the Venezuelan States of Bolivar and Amazonas with outliers in Surinam and northern Brazil. This province is characterised by a mosaic of vegetation types, the montane forests and the shrublands being the two most distinctive. Here, interesting edaphic communities dominate the landscape, and many endemic plant species occur.

The Pantepui Province includes all the high montane ecosystems of the Guayana Highlands, starting

Table 5.5.2 Regional status of forests and species at risk in Ecuador.

Region	Original coverage (km^2)	Present coverage (km^2)	% remaining	No. of species	Species at risk
Western Ecuador	80,000	5000	6	5,400	1,260
Dry forest	20,000	200	1	1,000	190
Moist forest	40,000	1500	4	1,000	140
Wet forest	12,000	<90	<0.1	1,700	340
Pluvial forest	8,000	3200	40	2,300	590
The Sierra	102,000	26,000	25	10,500	2,625
Flanks	61,000	18,000	30	8,500	2,125
High Sierra	40,000	8000	20	2,000	500
The Oriente	81,000	41,700	51	8,200	1,230
Base of Andes	39,000	11,700	30	6,000	1,000
Amazon Basin	42,000	30,000	70	2,200	230
Total	263,000	72,000	27	25,000	5,215

at elevations of approximately 1500 m (Huber 1987). This province is restricted to north-western Guyana and southern Venezuela, and consists of isolated, raised 'islands' ('tepuis'), formed mainly of sandstone emerging from the lower-lying Central Guayana Province. This province is characterised by montane shrublands, tepui meadows, and open rock communities, the most distinctive assemblages of vegetation types in the Guayana region. It also has the largest proportion of endemic plant taxa, including orchids (Carnevali, in prep.).

The Western Guayana Province consists essentially of the Río Negro Basin and includes the upper Orinoco lowlands, the peneplains, hills, and lower plateaux or mesetas of south-eastern Colombia (e.g. serranías de Araracuara and Chiribiquete, the 'Colombian tepuis'; Huber 1994), and the north-western Amazonas State of Brazil. This region is covered by an assemblage of several types of forests, particularly tall to medium sized sclerophyllous lowland forests ('Amazon Caatinga') intermixed with flooded and 'terra firme' forests. Shrublands (called 'banas' or 'caatingas') are also locally frequent and irregularly distributed, as well as savanna-like meadows dominated by such plant families as Rapateaceae, Eriocaulaceae, and Xyridaceae.

5.6.2 Present status of knowledge

The orchid flora of the Guayana region has been relatively well studied. Jean B. C. F. Aublet (1775: 815-825, t. 320-322) and Louis C. M. Richard (1792) described some of the earliest orchids collected in French Guiana. A few other species from Surinam were described by George F. W. Meyer (1819: 258-261). Karl S. Kunth described additional orchid species from the area based on A. von Humboldt and A. Bonpland's collections from the Central and Western Guayana Province (Humboldt, Bonpland, and Kunth 1816). John Lindley later described many new taxa based on collections made by M. R. and R. H. Schomburgk in the Eastern Guayana Province and by R. Spruce in the Western Guayana Province (e.g. Lindley 1843). Reichenbach also described taxa based on collections made by the Schomburgk brothers, Spruce, and other collectors (e.g. Reichenbach 1849,1859,1877). The first floristic treatment of the orchids of the Guayana, however, was completed by C. Schweinfurth (1967), who dealt with the orchids of the Guayana Highlands, although he included many lowland species. Partial treatments or checklists were completed by Lemée (1955) and Cremers and Hoff (1992) for the orchids of French Guiana; Pulle (1906: 116-138) and Werkhoven (1986) for Surinam; M. R. Schomburgk (1848: 904-916, 1068-1069, 1122-1124), Ridley (1887), and Graham (1934: 121-125) for Guyana; Schweinfurth (1948) and Christenson and Boggan (1992) for the Guianas; and Cogniaux (1893-1906, 1907), Hoehne (1940-1953), and Pabst and Dungs (1975-1977) for Brazil. The Venezuelan portion of the Guianas was covered by Humboldt, Bonpland, and Kunth (1825), Ames and Schweinfurth (1931), Foldats (1969-1970), and Dunsterville and Garay (1958-1976). Since then, current efforts toward a Flora of the Venezuelan Guayana has resulted in an as yet unpublished, more detailed and comprehensive treatment for the Orchidaceae (Carnevali *et al.*, in prep.) that should be published by the end of 1996. Several authors have already contributed unpublished treatments of Orchidaceae for the Flora of the Guianas Project, and many other are forthcoming (Christenson *et al.*, in prep.). All these treatments, especially the last two, provided some of the information presented here. Several orchid specialists are currently focusing all or part of their research efforts in the Guayana region such as G. Carnevali, E. A. Christenson, E. Foldats, G. A. Romero, and M. C. M. Werkhoven.

Current orchid research in the Guayana region focuses primarily on systematics or floristic research. Some phytogeographical research, however, is being completed for the region. Carnevali (1995) has analysed the phytogeography of the highland orchids in the Guayana region. Romero (1993a,b) published a series of papers dealing with the ecology and floristics of orchids growing in edaphic association in Amazonas State, Venezuela. Werkhoven (1992) analysed the altitudinal distribution of orchid species in Surinam, and Veyret (1982) studied the incidence of apomixis in some members of the *Epidendrum nocturnum* L. complex in French Guiana.

Since the orchid flora of the Guayana region is a composite of several floristic elements, including an endemic one, no monographic work has been carried out that dealt only with orchids. Exceptions are the revision of *Habenaria* Willd. by Renz (1992) for the Guianas and by Snuverink (1980) for Suriname and articles that deal with the Guayanan species of a particular genus, such as *Encydia* Hook. (Carnevali *et al.* 1994) and *Mormodes* Lindl. (Salazar and Romero 1994).

5.6.3 Diversity

Based on accounts from several ongoing floristic treatments for the area, (Carnevali *et al.*, in press; Christenson *et al*,. in prep.), c. 810 species in 154 genera are known to occur in the Guayana region (Table 5.6.1). Of these, c. 130 species (28%) are restricted in their distribution to the region, and nine of the genera (6%) are considered endemics at this time. These genera are *Aganisia* Lindl., *Aracamunia* Carnevali & I. Ramírez, *Chamelophyton* Garay (probably only a distinct subgenus of *Pleurothallis* R.Br.), *Cheiradenia* Lindl., *Degranvillea* Determann, *Duckeella* Brade, *Helonoma* Garay, *Polyotidium* Garay, and two undescribed genera in the Zygopetalinae and Lycastinae (Carnevali and G. Romero, ined.). Other genera, such as *Cleistes* Lindl., *Koellensteinia* Rchb.f., *Octomeria* R.Br., and *Habenaria* are centred or have secondary centres of diversity in the Guayana region. In common with most Neotropical areas, the largest genera are *Pleurothallis* R.Br. (c. 75 spp.), *Epidendrum* L. (c. 68 spp.), and *Maxillaria* Ruiz & Pav. (c. 60 spp.). Differing from other such Neotropical regions, however, and showing an affinity with south-eastern Brazil, the next largest genera are *Habenaria* Willd. (c. 40 spp.), *Octomeria* R.Br. (c. 30 spp.), *Encyclia* (c. 25 spp.), and *Catasetum* Rich. (c. 25 spp.). Genera that are usually well represented in Andean or Central American floras such as *Cranichis* Sw., *Stelis* Sw., *Odontoglossum* H.B.K., *Oncidium* Sw., *Masdevallia* Ruiz & Pav., and *Lepanthes* Sw., are poorly represented in the Guayana region.

At the suprageneric level, the Guayana region is characteristic of most tropical orchid floras in being dominated by members of the subfamily Epidendroideae. In common with other Neotropical regions, the subtribes Pleurothallidinae (c. 180 spp.) and Laeliinae (c. 135 spp.) are the most speciose, accounting together for close to 38.5% of the species in the region. The region is also characterised for its unusually high representation of members of the primitive Epidendroideae, since genera such as *Cleistes* (10 spp.) and *Epistephium* Kunth (7 spp.) are diverse here.

Next to the Epidendroideae, the Spiranthoideae is the largest subfamily with 53 species. This subfamily includes three of the endemic genera. The Orchidoideae comes next with 39 species, all in the genus *Habenaria*. Finally, the Cypripedioideae has four species in two genera, *Selenipedium* Rchb.f. and *Phragmipedium* Rolfe.

The orchids of the Eastern Guayana Province are mainly lowland forest epiphytes. The genera *Cheiradenia* and *Degranvillea* are endemic to this province, whereas some other genera such as *Psychopsis* Raf. and *Caluera* Dodson & Determann are found only in this province within the Guayana region. The 'lajas' have an orchid flora that, although small, is interesting for its adaptations to the dry season and high temperatures that the black granitic rocks reach during daytime (Romero 1993a). Several taxa are endemic here, including *Catasetum bergoldianum* Foldats and *Schomburgkia heidii* Carnevali.

The orchid flora of the Central Guayana Province is also dominated by epiphytes, but there are many interesting terrestrial and lithophytic species associated with the unique edaphic communities of the area. The Central Guayana Province contains close to 400 species of which close to 35% are endemic to the province (the genus *Chamelophyto*, for example).

The Pantepui Province is characterised by lithophytic orchids adapted to pioneer rock communities or to tepui swamps. Approximately 250 species are known to occur in this province of which close to 40% are endemics. Endemism increases with elevation; approximately 60% of the orchids that occur at elevation in excess of 2000 m are endemic to Pantepui. The genera *Aracamunia*, *Helonoma*, and an as yet undescribed genus in the Zygopetalinae are endemic to the Pantepui Province, all three primarily associated with the bogs and meadows of the tepui summits. The genus *Octomeria*, centred in south-eastern Brazil, has suffered a radiation in the Guayana region, but is particularly interesting in the province since all of the species known to occur there are endemics. The Pantepui Province is noteworthy because of its relationships with the Andean montane flora. This relationship is distinctly displayed by orchids such as *Pterichis acuminata* Schltr. and *Scelochilus ottonis* Klotzsch, which are known elsewhere only from the high Andes.

The Western Guayana Province is characterised by its typical epiphytic orchid flora which shows an affinity with the Amazonian region, although many of the taxa occurring in this province are endemics. Many interesting orchid taxa associated with the scrubby vegetation growing over white sands such as *Duckeella pauciflora* Garay, *Octomeria gemmula* Carnevali & I.Ramírez, *Paphinia dunstervillei* Dodson & Neudecker, and the genus *Polyotidium* are endemic to the Western Guayana province.

5.6.4 Threats

The areas at risk are fortunately few, since most of the species occur in mountainous or inaccessible areas. These areas of high diversity are generally unsuitable for agriculture or are included in National Parks or other types of reserves. In general, the large, populated centres in the region are concentrated toward the coastal belts in the Guianas or along the major rivers inland and almost always at elevations below 200 m. In the Venezuelan Guayana, all major cities (Ciudad Bolívar, Ciudad Guayana, Caicara del Orinoco, and Puerto Ayacucho) are concentrated in a narrow band along the southern rim of the Orinoco, leaving the southern section largely uninhabited, except for a few scattered hamlets and many small Amerindian settlements. In Guyana (Georgetown, Corriverton), Surinam (Paramaribo, Marienburg), and French Guiana (Cayenne, Sinnamaary), the largest population centres are all located along the coast, which runs roughly NW-SE from the Orinoco Delta to the delta of the Amazon. Although it is difficult to make an accurate estimate, it is possible that c. 90% of the human inhabitants in the Guayana region live in this coastal section of the region. Roads are few and mostly concentrated along this narrow coastal belt, with the exception of the highway that leads to the village of Santa Elena de Uairén in south-east Bolivar State in Venezuela and that crosses the easternmost section of the Gran Sabana. Fortunately, the most interesting areas along the road, those on the Gran Sabana Plateau, are protected within the Canaima National Park.

Venezuela has seven national parks within the Guayana region, which combined cover 95,437 km^2. This park system includes the Canaima National Park (c. 30,000 km^2) which protects most of the tepuis of eastern Bolivar State and great portions of the Central Guayana Province and of Pantepui. Brazil has recently established Monte Roraima National Park ,which covers 1160 km^2 in the state of Roraima. Surinam has nine nature reserves covering an area of 5741 km^2, which protect several types of ecosystems including the areas of highest orchid diversity in the country such as the Tabelberg. Aside from the national parks, Venezuela has also declared 29 natural monuments and two biosphere reserves, including the Alto Orinoco-Casiquiare Biosphere reserve with an area of 83,830 km^2, the largest reserve in the tropics (Huber, in press).

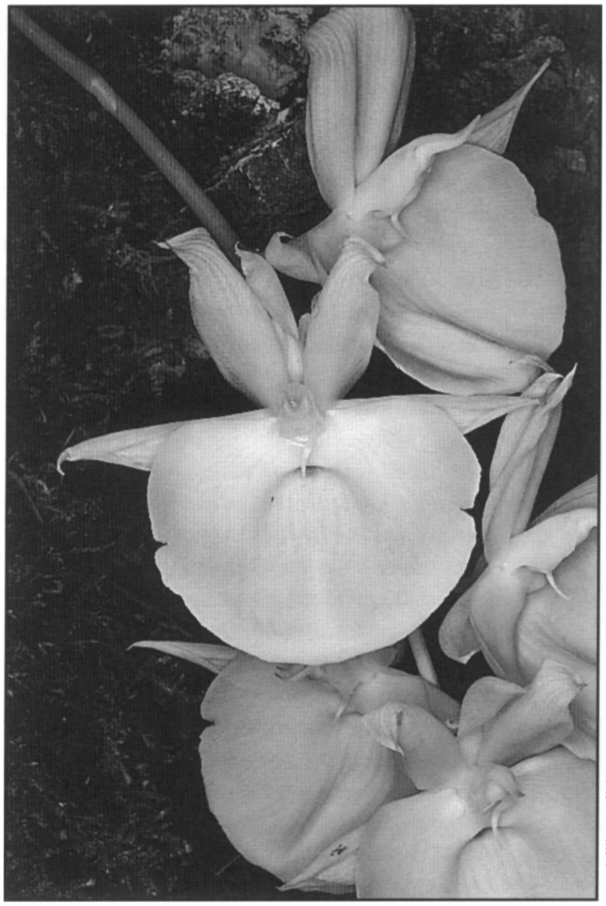
Specific threats to the Guayanan orchids are logging, clearings for agricultural developments, fires, mining, disturbances associated with tourism, construction of roads, and collecting by amateurs and commercial collectors. Some logging is being conducted in Guyana and the eastern section of the Venezuelan Guayana. These activities affect mostly the lowland forests (but see Colchester 1994). Most of the orchids of these forests are widespread in the whole Guayana region, but development could eventually affect some species that have restricted distributions. Agricultural developments in the Guayana region are mostly of the slash-and-burn type, which are essentially carried out in the lowlands and affect only small areas, thus leaving the areas of high diversity and endemism largely unaffected. Relatively major agricultural developments are being conducted close to the bigger cities, which are mainly in areas of low diversity. Cattle-raising is being conducted in restricted zones, mainly in areas with *Trachypogon* savannas which are low in diversity and endemisms. Fires, often anthropogenic in origin, affect the savannas and other open vegetation types of the Guayana region and, in some areas close to human settlements, can pose specific threats to some of the orchid species that specialise in this type of vegetation. Again, most of the interesting species grow in inaccessible places and are not directly affected by fires.

Gold mining is particularly damaging in the Venezuelan Guayana. Mining has evolved from simple panning for placer gold to extensive deforestation followed by the use of heavy-duty water pumps and hoses. Environmental damage is usually confined to areas along water courses, but quasi-permanent mining settlements may cause considerable damage to the surrounding vegetation. Disturbances by miners is equally confined to lowland forests, but in the last ten years it has affected the slopes of some tepuis, particularly Yapacana in Venezuela and Neblina on both sides of the Venezuelan-Brazilian border posing a threat to these orchid habitats.

Collecting pressure is most intense along the few roads that penetrate the region or along the rivers that serve as major highways of communication in areas not served by roads. Collecting affects primarily the showier orchids of the area, but also some of the more common species found along the roadsides and in populated centres. Many showy orchids have been already stripped or at least grossly overcollected, e.g. *Cattleya lawrenceana* Rchb.f., C. *jenmanii* Rolfe, C. *violacea* (H.B.K.) Rolfe, *Oncidium lanceanum* Lindl., and *Catasetum pileatum* Rchb.f. These species are mostly lowland taxa, and many have wide distributions within the Guayana region. Other showy orchids that occur at higher elevations are fairly inaccessible to most collectors or are considered difficult to cultivate because they grow at very high elevations or over specialised substrates (such as tepui bogs or meadows, or white sand associations), and thus are not subject to major collecting pressures. In general, the Guayana region has poor representations of many of the traditionally horticulturally-desirable orchid genera such as *Lycaste* Lindl., *Masdevallia*, *Miltoniopsis* Godf.-Leb., *Odontoglossum*, and *Oncidium* Sw., and hence it is poor territory for orchid commercial collectors. However, with the current trend toward the specialty orchid amateur collection that concentrates on species or particular genera, some of the rare or unique orchid taxa are being subjected to restricted collecting pressure.

No orchid species can be documented as extinct from the Guayana region at this time, although some of the showier species can be considered severely threatened or even locally extinct, particularly along the main highways or near the major human settlements. Species such as the three *Cattleya* species that occur in the region exemplify this threat. C. *lawrenceana* Rchb.f., which is endemic to the Central Guayana Province, was once common along the gallery forests and patches of submontane forests in the Gran Sabana. Recently, however, it has become very rare along the Ciudad Bolivar-Santa Elena de Uairén highway due to overcollecting.

No efforts in the *ex situ* conservation of threatened species of the Guayana region are now being made. Many of the showiest species are currently cultivated by orchid amateurs in the Guayana region and elsewhere, and some of them are being commercially reproduced by nurseries in the international trade (e.g. *Cattleya jenmanii* Rolfe, *Oncidium lanceanum* Lindl., *Psychopsis papilio* (Lindl.) H.G.Jones, and *Psychopsis veerstegiana*



Catasetum pileatum

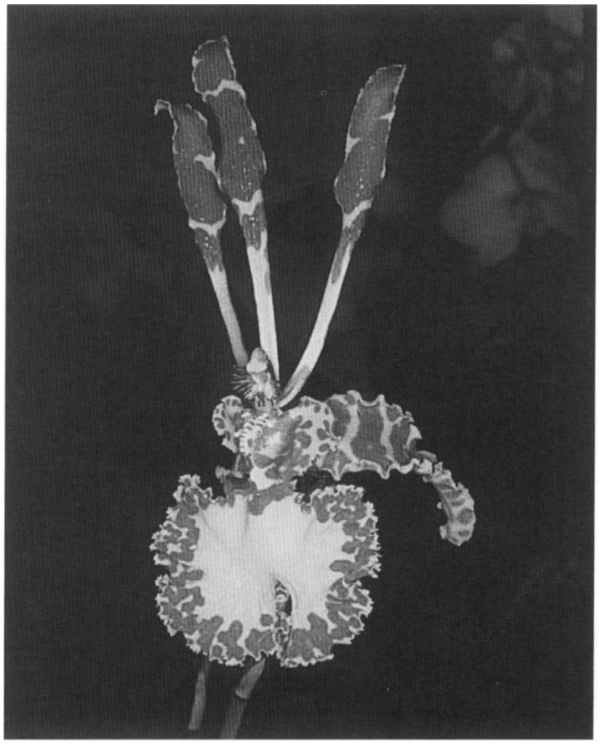
(Pulle) H.G.Jones, etc.). Many of the showy endemics are edaphic specialists and are usually difficult to cultivate, a situation that usually discourages orchid growers from collecting them, but this limitation, on the other hand, allows little hope for their *ex situ* conservation.

5.6.5 Case histories

1) Catasetum pileatum - *Catasetum pileatum* Rchb.f. has been in high demand from orchid growers since the time it was introduced to horticulture in 1886 (as C. *bungerothii* N.E.Brown). It is confined to the upper Orinoco and upper Rio Negro river basins in Venezuela, Colombia, and Brazil. This species is frequently cultivated by the local inhabitants (particularly in Venezuela, where it was the national flower between 1942 and 1949), and populations near settlements are usually reduced to a few isolated individuals. Furthermore, overcollection for commercial greenhouses, in particular searching for red varieties (Couret 1973, 1977, 1982), has severely stripped populations of the species in its northernmost range in Venezuela (southern Apure, western Bolívar, and north-eastern Amazonas states), where it should be considered seriously threatened. C. *pileatum,* however, remains in good conservation status in its southernmost range (southern state of Amazonas in Venezuela, northern state of Amazonas in Brazil, and south-eastern Department of Vichada and Department of Guainía in Colombia).

2) Cattleya jenmanii - *Cattleya jenmanii* Rolfe is a showy orchid endemic to the Pakaraima range in south-eastern Venezuela and south-western Guyana at elevations between 400 and 900 m. It has not been reported from Brazil, but known localities for the species are only a few kilometres away from the Brazilian Territorio do Roraima. In southern Venezuela, the species is apparently confined to one dense but restricted population that has lately been decimated by commercial overcollecting and by habitat fragmentation due to agricultural developments by transcultured Pemón Indians. Although C. *jenmanii* was described in the late 1880s, it was 'lost' to science (and horticulture) until the 1970s when a few plants of this species started arriving to the horticultural centres, following the opening of the El Dorado-Santa Elena de Uairén road. Soon plants that were evidently field-collected were offered by commercial nurseries in the US and Europe. Pemón Indians once commonly sold plants of C. *jenmanii* along the Santa Elena de Uairén road. Although there is not much deforestation going on in the area, since population pressure is not great, the attractiveness of the species and the high prices that its plants command have reduced drastically the sizes of the few populations known. Recently, some commercial nurseries in the US have made available seed-raised plants to orchid growers, so collecting pressure for export is expected to diminish. In the meantime, this species should be considered seriously threatened.

3) Cattleya lawrenceana - *Cattleya lawrenceana* Rchb.f. is endemic to the Guayana Highlands in Venezuela and Guyana. It was once frequent along the Santa Elena de Uairén road in gallery forests and patches of forests surrounded by savanna. Nowadays it has become very rare along the road due to overcollecting by amateurs and commercial collectors and by the Pemón Indians, who used to sell the plants along the road. The species is still found in fair numbers away from the road and from riverways, and it may be common on the slopes of the tepuis in Estado Bolivar. A large portion of the natural range of the species is protected by the Canaima National Park in Venezuela, and many populations are in remote or inaccessible sectors of the Venezuelan Guayana and Guyana. Despite its beauty, C. *lawrenceana* never seemed to be very popular with orchid growers outside of Venezuela, perhaps because it is considered difficult to grow. If the Canaima National Park remains in good conservation status as it has been to date, the future of the species looks bright, although populations along the



Phillip Cribb

Psychopsis sandeae

roads inside and outside the Park and along riverways are likely to become extinct.

4) Phragmipedium lindleyanum - This showy slipper orchid is widespread but rare and local from Surinam to south-eastern Venezuela and in the Brazilian Territorio do Roraima. It occurs at elevations between 200 and 2000 m and is usually found over granitic or sandstone substrates. Most populations of the species are in remote or inaccessible sites in the Guayana region, and the species, as a whole, seems well preserved. In Venezuela, a population of *Phragmipedium lindleyanum* (R.H.Schomb. ex Lindl.) Rolfe known from the Piedra de La Virgen area, at the beginning the ascent of the El Dorado-Santa Elena de Uairén road, was discovered in the mid-1960s when the road was built. Collectors stripped the population in the 1970s. In the mid-1980s, a few individuals of *P. lindleyanum* were found again in the same general area, and now it is extremely rare along the first five km along the El Dorado-Santa Elena road.

5) *Schomburgkia heidi* - This recently described species is restricted to granitic outcrops, locally known as 'lajas', in the immediate vicinity of the village of Puerto Ayacucho, Estado Amazonas, Venezuela. The area has a well-defined dry season, and many laja species are deciduous. The lajas are covered by a distinctive flora that includes many endemic taxa (Steyermark 1982), among them some orchids (Romero 1993a). *Schomburgkia heidi* Carnevali grows generally in lightly shaded spots on the bare granite rock. Pressure from the ever-increasing human population in the area has resulted in the local destruction of the vegetation of the lajas due to the extraction of fire wood, disturbance due to the overturning of trees and bushes for the collecting of earthworms (for fish bait), and an increasing number of fires. *S. heidi* is still locally common in the lajas around Puerto Ayacucho but should be considered threatened.

Germán Carnevali, Fundación Instituto Botánico, Caracas, Venezuela; and Gustavo A. Romero, Oakes Ames Orchid Herbarium, Harvard University, USA.

Table 5.6.1 Orchidaceae of the Guayana Region.

Subtribe	Genera	Species	Endemic
Angraecinae	1	8	2
Bletiinae	1	1	0
Bulbophyllinae	1	10	6
Catasetinae	4	37	15
Cranidichidinae	4	6	1
Cryptarrheninae	1	4	1
Cypripedioideae	2	4	4
Cyptopodiinae	3	16	8
Eulophiinae	2	2	0
Gastrodiinae	1	2	1
Goodyerinae	1	13	4
Habenariinae	1	39	10
Laeliinae	15	133	44
Lycastinae	5	14	3
Malaxidiinae	2	6	3
Maxillariinae	3	63	10
Oneidiinae	28	83	22
Ornithocephalinae	5	10	1
Palmorchidinae	1	6	4
Pleurothallidinae	17	180	70
Pogoniinae	2	14	11
Polystachyinae	1	4	1
Prescottiinae	2	7	4
Sobraliinae	3	29	8
Spiranthinae	13	24	8
Stanhopeinae	11	25	11
Telipogoninae	1	1	0
Triphoreae	2	4	1
Vanillinae	2	15	4
Vargasiellinae	1	1	1
Wullschlaegeliinae	1	2	0
Zygopetalinae	18	48	23
Total	155	811	281

5.7 Europe, North Africa, and the Near East

This region of about 17,820,000 km^2 includes 54 countries and corresponds approximately to the Western Palearctic; it is bounded on the north by the Arctic Ocean, on the west by the Atlantic (Canary Islands, Madeira, Azores, Faeroes, and Iceland are included), on the south by the Sahara and the Arabian Desert, on the east by the Urals, the Caspian Sea, and the Iranian deserts. The vegetation of this area is extremely diverse. Five major floristic regions can be distinguished: Mediterranean, sub-Mediterranean, temperate, boreal, and arctic, which can be subdivided into Alpine, Atlantic, Caucasian, Macaronesian, and Pontic zones.

Major habitats for orchids in the area are evergreen sclerophyllous bush and scrub (e.g. 'garigue', 'matorral', 'phrygana')- These are dominant in the meridional and submeridional regions, dry calcareous grassland, wet grassland, bogs and marshes of the lowlands, hills and mountains of the temperate and boreal regions and of the Alpine zones (up to 3000 m above sea level), neutrophilous and calciphilous forests and woodlands of native coniferous or deciduous trees, particularly Mediterranean and supra-Mediterranean Scots pine, black pine and aleppo pine forests as well as beech forests dominated by *Fagus sylvatica* L. in medio-European, Atlantic, and mountains of the sub-Mediterranean zones. For a catalogue of recognisable communities formed by the Palearctic flora, see Devillers and Devillers-Terschuren (1994).

5.7.1 Present status of knowledge

Since ancient times, European orchids have captured the attention of scientists. Between 1753 and 1771, Linnaeus published 58 orchid names relating to taxa from the region (Baumann *et al.* 1989). Since that time, several comprehensive works have been devoted to relevant monographs and Floras (Reichenbach 1851; Camus and Camus 1921-1929; Keller *et al.* 1930-1940; Landwehr 1977). Some genera have been monographed: *Dactylorhiza* (Nelson 1976; Averyanov 1988), and *Ophrys* and *Serapias* by Nelson (1962, 1968) and Baumann and Künkele (1986, 1989).

Over the last 25 years the subject has been researched extensively, principally owing to associations of amateur botanists specifically interested in European orchids, who organise symposiums and publish journals. Numerous papers and some monographs devoted to a province or a country are now published every year, and catalogues are regularly produced (Willing and Willing 1977, 1985). Various field guides intended for an enthusiastic public have been published recently (Williams *et al.* 1978; Baumann and Künkele 1982, 1988a,b; Delforge and Tyteca 1984; Buttler 1986, 1991; Mossberg and Nilsson 1987; Davies *et al.* 1988) as well as numerous distribution maps drawn up for islands, provinces, or whole countries; an ambitious cartography of orchids in the Mediterranean basin, prepared by numerous contributors, has not yet been published (Baumann and Künkele 1980).

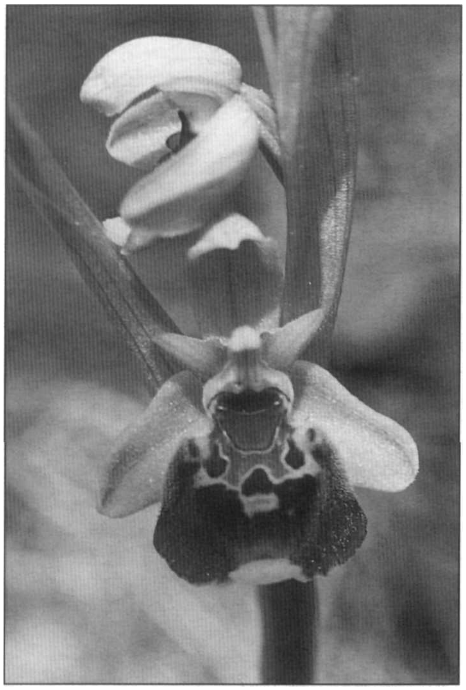
However, these recent investigations have led to the description of many new taxa, resulting in discrepancies in taxonomy and nomenclature as well as, paradoxically, confusion concerning the distribution and population dynamics of many species. In the case of the Mediterranean genus *Ophrys*, for example, it is only recently that mechanisms of pollinator attraction by sexual deception have been explained (Kullenberg 1961). Studies of specific bee pollinators (e.g. Paulus and Gack 1986, 1990a,b, 1992a,b) have shown that this genus comprises many taxa, sometimes cryptic, isolated by efficient pregamic mechanisms, so that what was regarded some time ago as one widespread species now turns out to be in fact a group of connected species, each existing in a limited area. *Ophrys arachnitiformis* Gren. & Philippe (Devillers-Terschuren and Devillers 1988), *O. bertolonii* Moretti (Delforge 1990), and *O. fusca* Link (Paulus 1988; Delforge 1994) are cases in point. As a result, the number of *Ophrys* species has quadrupled in 25 years. Several investigations have led to similar conclusions for *Dactylorhiza* and *Serapias, Nigritella,* and *Epipactis.* These taxonomic developments have been integrated in a new field guide (Delforge 1994). Such developments make the evaluation of the status of the rarer species of European orchids quite difficult, though an updated attempt at appraising their vulnerability has been made for the European Union by Devillers (1986). Therefore, the information conveyed in this paper should be considered as work in progress.

5.7.2 Diversity

The tribe Orchideae comprises the bulk of the European orchid flora in number of species and endemics (Table 5.7.1). The genus *Ophrys*, with more than 140 species, and the genus *Orchis*, with 55 species, include between them more than half of the species of the region.

The Mediterranean zone is by far the most species-rich. *Barlia, Ophrys, Serapias,* and *Limodorum* may be regarded as Mediterranean endemics. Most of the Orchideae and Epidendroideae are found primarily in the temperate region; the genera *Chamorchis* and *Nigritella* are Boreo-Alpine endemics.

The main centre of endemism seems to be in the eastern Mediterranean region, in the Aegean basin, with important secondary centres in the Alpine zones, Sicily, the Balkan peninsula, and the Caucasus. In fact, each



Ophrys holoserica

large island, archipelago, and big massif possesses endemic orchids, but a comprehensive study delimiting the areas of endemism is still lacking.

5.7.3 Threats

Unfortunately, for historical reasons a large part of the European region must be regarded as an area at risk. Prehistoric humans followed the northward movement of the glaciers after the end of the last glaciation (10,000 B.C.) and contributed to the diversification of habitats by slow but omnipresent agro-pastoral activities, which resulted in semi-natural biotopes favourable to orchids. The dispersal and growth of may species depend on human activities, e.g. clearing for pastures, grazing of livestock on waste land and forests, and mowing of meadows.

In the course of two centuries, population growth, industrialisation, and urbanisation have strongly increased human domination over the landscape. The agricultural revolution altered the environment so quickly that the capacity of orchid species to adapt could not keep pace. At the same time, the decline in farming in some areas as well as the evolution of agricultural practices have reduced the area of the remaining semi-natural biotopes, many of them disappearing progressively, often as a consequence of spontaneous afforestation. However, this has not restored the diversity of the environment. Orchids growing in wet biotopes and thermophilous grasslands have particularly suffered (Table 5.7.2).

In north-western Europe the deterioration has begun to slow down due to appropriate legislation and to numerous initiatives with a view to creating nature reserves. The situation is more worrying in southern Europe and in the Mediterranean basin because of delayed awareness of problems of biodiversity conservation, progressive modernisation of agriculture, and especially to a widespread urbanisation of the seaboard for the sake of tourism, precisely in areas which are particularly rich in endemic species with very limited distribution. Moreover, serious damage is sometimes caused by plundering by horticulturists, both amateurs and professionals. In Turkey, Syria, and Lebanon, the situation is even more grim because tubers of many terrestrial orchids are used as food products (see Section 3.2.3 and case study (1) below).

All European orchids are terrestrials and need endotrophic mycorrhizae to germinate and grow. At this stage of technical development, cultivation of seedlings on asymbiotic media does not always yield satisfactory results, and *ex situ* conservation of endangered species is not often conceivable. It is thus necessary to protect habitats suitable for orchids by reinstituting traditional farming practices that have fallen into disuse or managing habitats to mimic traditional management methods; this necessity is now well understood and is finding expression in national legislation (Duvigneaud 1983; Devillers *et al.* 1990).

5.7.4 Case histories

1) *Comperia comperiana* - *Comperia comperiana* (Steven) Asch. & Graebn. was described in 1829. Its large flowers make it especially conspicuous. It is restricted to calcareous, thermophilous pinewoods, between 400 and 1800 m above sea level. It is mainly prevalent in southern Anatolia (Renz and Taubenheim 1984; Sezik 1984), although some isolated stations exist in Iraqi and Iranian Kurdistan, in Lebanon, and in four Eastern Aegean islands, where it is Endangered (IUCN 1983). Among 32 Anatolian localities published in the past, Taubenheim (1980) noticed that C. *comperiana* is now to be found virtually only in burial places; recent observations confirm this trend (Coulon 1992; Ettlinger unpubl.; Kajan *et al.* 1992; Rückbrodt *et al.* 1992). During a journey of 12,000 km in Anatolia in 1990, I did not observe more than seven plants in bloom in an old cemetery near Ibradi (Antalya) (Delforge 1994).

This catastrophic decline is principally caused by the gathering of tubers. The tubers, which are dried and ground up for salep, were formerly used as aphrodisiacs or expectorants. Tubers are now removed from plants in flower, dried, and reduced to powder in order to prepare ice cream and stimulating milk drinks. They are harvested and converted by locals and sold to dealers and then wholesalers who market or export them. In Turkey, about 45 tons of salep are collected every year, out of which 15 tons can be exported later. It takes from 1000 to 4000 tubers to make 1 kg of salep (Sezik 1984, 1990); in Syria, the crop has been estimated at 1,500,000 orchids per annum (Arnold and Arnold 1985). The trade generates sizeable profits at each stage of the process, which makes it difficult to replace salep with a synthetic substitute.

The pressure exerted on orchids by such exploitation explains why C. *comperiana* is now virtually to be found only in some ancient cemeteries, where the harvest of tubers is viewed as baneful. This situation affects other rare terrestrial orchids as well.

2) Ophrys tardans - The case of *Ophrys tardans* O. & E. Danesch (pro. hybr.) exemplifies the emphasis that recent studies have put on species with limited distributions. Described as an occasional hybrid (Danesch and Danesch 1972), *O. tardans* is now recognised as a valid species, endemic to the area of Lecce (Apulia, Italy) (Baumann and Künkele 1988a,b; Liverani 1991; Delforge 1994). In 1970,418 specimens in bloom were counted on four sites (Danesch and Danesch 1972). In 1984, five new stations were reported, some including one hundred plants or so (Baumann and Künkele 1988a). In 1991, I was able to observe about 500 specimens in bloom, often grouped, on five sites. All sites seem to be situated in the suburbs of Lecce or a little to the south, on littoral fallow lands or grounds already completely enclosed by urbanised villages. The species is directly threatened today by illegal dumping and probably before long by the urban development of Lecce and the extension of coastal tourist facilities.

3) Goodyera ntacrophylla - *Goodyera macrophylla* Lowe is a Macaronesian relict species, an endemic of the island of Madeira and restricted to cliffs and ravines, growing in the shade of the hyper-humid evergreen acidiphilous laurel forest (laurisilvas) between 1000 m and 1400 m above sea level. Described as early as 1851, it was present in the north and north-west of the island. As it flowers very sporadically, it was not observed in bloom in recent times until 1973, at a time when the agricultural development of the island had already confined it to a few sites (Frey and Pickering 1975; Frey 1977). It is now located in only two inaccessible sites in the north of the island and in the Ribeiro Frio Botanical Garden (Rückbrodt and Rückbrodt 1990), where three specimens flowered in 1987 (Salkowski 1988), others in 1991 (Delforge 1994), and one in 1992 (Tyteca and Tyteca 1994). This species is regarded as Endangered (IUCN 1983).

Pierre Delforge, Section Orchidées d'Europe des Naturalistes Beiges, Belgium

Table 5.7.1 Subfamilies, subtribes, number of genera and species, and endemics in the European, North African, and Near Eastern orchid flora. Classification after Dressier (1981b), modified in Delforge (1994).

Taxon	Genera	Species	Endemics
Cypripedioideae	1	3	0
Neottioideae			
Limodorinae	4	48	36
Listerinae	2	3	0
Spiranthinae	1	4	1
Goodyerinae	1	2	1
Epidendroideae			
Corallorhizinae	2	2	0
Liparinae	3	3	0
Orchidoideae			
Gymnadeniinae	10	28	20
Serapiadinae	12	284	258
Total	36	377	316

Table 5.7.2 Most threatened European species and the nature of their threats. Classification after Delforge (1994). *Red Data Book* status (old categories) is indicated in square brackets.

Cypripedioideae

Cypripedium calceolus L. Populations decreasing, many populations extinct. Risk medium. Flower-pickers; collectors for horticulture. [vulnerable]

C. guttatum Sw. Populations decreasing, many populations extinct. Risk high. [endangered]

C. macranthos Sw. Populations decreasing, many populations extinct. Risk high. [endangered]

Neottioideae

Cephalanthera cucullata Renz & Taubenheim. Some populations with few plants known, restricted to three small areas. Risk high. Habitat destruction, critically low populations. [endangered]

C. kotschyana Renz & Taubenheim. About twenty populations very scattered known, with few plants. Risk high. Probably critically low populations.

Epipactis cretica Kalop. & Robatsch. Several populations with few plants, restricted to two small areas. Risk high. Habitat destruction, critically low populations.

E. danubialis Robatsch & Rydlo. Restricted to one area, poorly known. Risk medium.

E. dunensis (T. & T.A.Stephenson) Godfery. A few populations known, also taxonomically problematic. Risk medium. [rare]

E. leutei Robatsch. Single population known in a beech forest. Risk high. Forestry.

E. nordeniorum Robatsch. A few stations known in a riparian oak forest. Risk high. Agriculture.

E. renzii Robatsch. Some populations known, restricted to one small area. Risk medium.

E. troodii H. Lindb. Several populations, restricted to one area. Risk medium. [vulnerable]

E. youngiana A.J.Richards & A.F.Porter. Five populations known. Risk medium. Taxonomically problematic.

Goodyera macrophylla Lowe. Two small populations and about twenty plants in a botanic garden. Risk high. Critically low populations. [endangered]

Spiranthes romanzoffiana Cham. Several small populations known, restricted to two countries. Risk medium. Critically low populations. [rare]

Epidendroideae

Calypso bulbosa (L.) Oakes. Some populations known, scattered. Risk medium. [vulnerable]

Hammarbya paludosa (L.) Rich. Populations decreasing, many populations extinct. Risk medium. Land drainage and afforestation. [vulnerable]

Liparis loeselii (L.) Rich. Populations decreasing, many populations extinct. Risk medium. Land drainage and coastal urbanisation. [vulnerable]

Orchidoideae

Barlia metlescisiana W.P.Teschner. Some small populations known, restricted to one area. Risk high. Critically low populations.

Comperia comperiana (Steven) Asch. & Graebn. Some small populations known, very scattered. Risk high. Gathering of tubers for salep. [vulnerable]

Dactylorhiza ebudensis (Wiefelspütz) P.Delforge. Two large populations known, restricted to one area. Risk medium. Change in arable farming.

D. foliosa (Sol. ex Lowe) Soó. Some populations known, restricted to one area. Risk probably high. Collectors for horticulture. [neither rare nor threatened]

D. graeca H.Baumann. Some populations known, restricted to one area; also with taxonomic problems. Risk medium.

D. maculata (L.) Soó var. *elodes* (Griseb.) Hunt. Populations decreasing, many populations extinct; also with taxonomic problems. Risk high. Land drainage.

D.ochroleuca (Wüstnei ex Boll) Holub. Populations decreasing. Risk medium. Land drainage.

D. traunsteineri (Saut. ex Rchb.) Soó. Populations decreasing, also with taxonomic problems. Risk high. Land drainage.

H. affine (Boiss.) Schltr. Some small populations known, scattered. Risk high. Gathering of tubers for salep.

Table 5.7.2 cont.

H. formosum (Steven) K.Koch. Poorly known, not seen for many years. Probably extinct.
Neottianthe cucullata (L.) Schltr. Several populations known. Risk medium. Forestry. [rare]
Nigritella archiducis-joannis Teppner & E.Klein. Three populations with few plants known, restricted to one area. Risk medium. Critically low populations.
N. stiriaca (K.Rechinger) Teppner & E.Klein. Five populations known, restricted to one area. Risk medium. Critically low populations.
N. widderi Teppner & E.Klein. Some populations with few plants known, restricted to three small areas. Risk medium. Critically low populations.
Ophrys aegea Kalteisen & H.R.Reinhard. Some populations known, restricted to one area. Risk medium. Overgrazing, tourist development.
O. amanensis (E.Nelson ex Renz & Taubenheim) P. Delforge, Several populations known, restricted to one area. Risk probably high. Gathering of tubers for salep.
O. andria P.Delforge. Some populations known, restricted to one area. Risk medium. Overgrazing, coastal tourist development.
O. aurelia P.Delforge, J. & P.Devillers-Terschuren. Several populations known, restricted to two areas. Risk high. Coastal tourist development, urbanisation.
O. aveyronensis (J.J.Wood) P.Delforge. Some populations known, restricted to one area. Risk medium. Agriculture.
O. aymoninii (Breistr.) Buttler. Some populations known, restricted to one area. Risk medium. Agriculture.
O. balearica P.Delforge. Several populations known, restricted to one area. Risk high. Coastal tourist development.
O. basilissa Alibertis & H.R.Reinhard. Some populations known, restricted to two areas. Risk high. Overgrazing, agriculture.
O. benacensis (Reisigl) O.Danesch, E.Danesch & Ehrend. Several populations known, restricted to one area. Risk high. Inland tourist development, urbanisation.
O. carduchorum (Renz & Taubenheim) P.Delforge. Some populations known, scattered. Risk high. Gathering of tubers for salep.
O. castellana J. & P.Devillers-Terschuren. Some populations known, often small, restricted to three areas. Risk high. Land draining, agriculture.
O. cephalanica (H.Baumann & Künkele) J. & P.Devillers-Terschuren. Several small populations known, restricted to three areas. Risk high. Agriculture, tourist development.
O. chestermanii (J.J.Wood) Gölz & H.R.Reinhard. Some populations known, restricted to one area. Risk medium. Destruction of habitat.
O. dlicica H.Fleischm. & Soó. Some small populations known, restricted to one area. Risk high. Gathering of tubers for salep.
O. elegans (Renz) H.Baumann & Künkele. Some populations known, restricted to one area. Risk medium. Forestry, tourist development. [vulnerable]
O. flavicans Vis. Some populations known, restricted to one area. Actual status uncertain.
O. icariensis Hirth & Spaeth. Some populations known, restricted to one area. Risk medium. Overgrazing, coastal tourist development.
O. isaura Bornm. & H.Fleischm. Some small populations known, restricted to one area. Risk high. Gathering of tubers for salep.
O. khuzestanica (Renz & Taubenheim) P.Delforge. Some populations known, scattered. Risk high. Gathering of tubers for salep.
O. kotschyi H.Fleischm. & Soó. Several large populations known, restricted to one area. Risk medium. Tourist development, [vulnerable]
O. lacaitae Lojac. Some small populations known, very scattered. Risk probably high. Agriculture, collectors, critically low populations.
O. lesbis Gölz & H.R.Reinhard. Some populations known, restricted to one small area. Risk high. Overgrazing, tourist development.
O. lycia Renz & Taubenheim. A single large population known. Risk high. Overgrazing, gathering of tubers for salep.
O. mirabilis Geniez & Melki. Some small populations known, restricted to two areas. Risk high. Overgrazing, agriculture, critically low populations.

Table 5.7.2 cont.

O. montenegrina (H.Baumann & Künkele) J. & P.Devillers-Terschuren. Some populations known, restricted to one small area. Risk probably high.
O. pallida Raf. Some populations known, restricted to two areas. Risk medium.
O. parvimaculata (O. & E.Danesch) Paulus & Gack. Some populations known, restricted to two areas. Risk medium. Forestry.
O. saratoi E.G.Camus. Several populations known, restricted to one area. Risk high. Coastal tourist development, urbanisation.
O. schulzei Bornm. & H.Fleischm. Some populations known, scattered. Risk high. Gathering of tubers for salep.
O. sipontensis R.Lorenz & Gembardt. Some populations known, restricted to one area. Risk medium. Urbanisation, tourist development.
O. sitiaca Paulus & Alibertis. Some populations known, restricted to one area. Risk high. Overgrazing, forestry.
O. splendida Gölz & H.R.Reinhard. Several populations known, restricted to one area. Risk high. Tourist development, urbanisation.
O. tardans O. & E.Danesch. Some large populations known, restricted to one area. Risk high. Urbanisation, coastal tourist development.
Orchis brancifortii Biv. Some populations known, restricted to two areas. Risk medium.
O. israelitica H.Baumann & Dafni. Some large populations known, restricted to two areas. Risk medium.
O. ligustica Ruppert. A few populations known, restricted to one area. Risk high. Urbanisation.
O. patens Desf. Some populations known, restricted to two areas. Risk high in one area, uncertain for the moment in the other. Urbanisation.
O. prisca Hautz. Thirteen small populations known, restricted to three small areas. Risk high. Overgrazing, forestry. [vulnerable]
O. punctulata Steven ex Lindl. Some populations known, often small, scattered. Risk medium. Gathering of tubers for salep.
O. robusta (Stephenson) Gölz & H.R.Reinhard. A few populations known, restricted to three areas. Risk high. Agriculture.
O. scopulorum Summerh. Some populations known, restricted to one area. Risk medium. [endangered]
Platanthera azorica Schltr. Some populations known, rarer than *P. micrantha*. Risk medium.
P. micrantha (Hochst. ex Seub.) Schltr. Some populations known, restricted to one area. Risk medium. [vulnerable]
P. oligantha (Hochst. ex Seub.) Schltr. Some populations known. Risk medium. [vulnerable]
Serapias aphroditae P.Delforge. Some populations known, restricted to one area. Risk probably high. Overgrazing, tourist development.
S. ionica E. Nelson ex H.Baumann & Künkele. Some large populations known, restricted to three areas. Risk medium. Coastal tourism development.

5.8 North Asia and Japan

This region comprises eastern Siberia, Korean Peninsula, Japan Islands, Ryukyu Islands, and the eastern part of mainland China, roughly north of the Tropic of Cancer and east of the Qinghai-Xizang (Tibet) Plateau and Mongolia Plateau. Climatically it extends over cold, temperate, and subtropical zones. The annual precipitation ranges from 500 to 2000 mm, particularly in its subtropical zone, where many orchids, including some epiphytes, occur.

5.8.1 Present status of knowledge

The antiquity of civilisation in Eastern Asia is well known. Cultivation of orchids there has a long history, especially the cultivation of cymbidiums in China, Japan, and Korea. Since the *Flora of the U.S.S.R.* (Nevski 1935) and *Flora of Japan* (Ohwi 1978) were published, the orchid floras of eastern Siberia and Japan have become better known. Japan is rather rich in orchids, on which many important works have been published recently, such as those by Maekawa (1971) and Hashimoto (1987). Compared to Japan, the orchid flora of the Korean Peninsula is rather poor, estimated at less than 50 species. That of China is still poorly understood. The chief difficulty is that China is rich in orchids, but it has not been botanised thoroughly, particularly in its south-western parts, e.g. Sichuan, Guizhou, north-west Yunnan, and east Xizang (Tibet). T. Tang and F. T. Wang made a comprehensive study on Chinese orchids in the 1930s, visiting many European herbaria to examine the type specimens of Chinese orchids and publishing several articles after they returned to

China. Since that time, more works on this family have appeared, among which *Iconographia Cormophytorum Sinicorum V* (Anon. 1976) and *A General Review of the Orchid Flora of China* (Chen and Tang 1982) are most helpful to those who want to understand Chinese orchids. The compilation of the *Orchid Flora of China* commenced a few years ago, and publication is expected within five years.

Apart from its alpine and northern parts, northern and eastern Asia is afforested, though the destruction of forests in some places is rather serious because of the demands placed on them by the dense population and agricultural expansion. Phytogeographically this region encompasses the Eastern Asiatic Region and part of the Circumboreal Region (Takhtajan 1978). The Eastern Asiatic Region is well known for its very broad subtropical areas, extending from the north edge of the tropics to the temperate zone; in North America and northern Africa there is no such range of areas because of interruption by either ocean or desert.

5.8.2 Diversity

An estimated 400 species in 106 genera are indigenous to the region. Hashimoto (1987) listed 253 species and 33 infraspecific taxa of Japanese orchids, of which 29 taxa in 14 genera are epiphytic. If *Chondradenia, Dactylorhiza,* and *Ponerorchis* are treated as congeneric, there is a total of 84 genera. Recently the generic and specific numbers rose to 85 and 254, respectively, due to the discovery of *Archineottia japonica* M.Furuse ex M.Furuse & S.C.Chen (1988) in Honshu.

There are fewer orchids in the Korean Peninsula than in Japan. According to recent information, 45 orchid species, including five epiphytic ones, in 32 genera occur on the peninsula. Most have a wide distribution through the area. Eastern Siberia is also relatively poor in orchids with 58 species of terrestrials in 30 genera (Nevski 1935). If *Neolindleya, Pseudodiphyllum, Lysiella,* and *Limnorchis* are reduced to synonyms of *Platanthera,* and *Galeorchis* and *Chusua* to synonyms of *Orchis,* the generic number will decrease to 24, less than that in the Korean Peninsula.

It is regrettable that there are few precise statistics on Chinese orchid species. I estimate that in subtropical and temperate China (east of the Mongolian Plateau) there are about 98 genera and 320 species, of which about 70 species in 30 genera are epiphytic.

Endemism is high in the Eastern Asiatic Region. Notable examples of endemic and subendemic genera are *Stigmatodactylus, Changnienia, Ephippianthus, Hemipilia, Amitostigma, Bletilla, Oreorchis, Ischnogyne, Pleione,* and *Neofinetia.* According to Hashimoto (1987), there are 74 species endemic to Japan, amounting to nearly one-third of the total number there. The percentage is much higher if we expand the endemism phytogeographically from Japan to the Eastern Asiatic Region. For example, Japan has five taxa of *Listera* with two endemics, whereas the Eastern Asiatic Region possesses 15 taxa with nine endemics. Another example is *Cymbidium.* Japan has nine taxa with only one endemic, whereas the Eastern Asiatic Region possesses 22 species with twelve endemics. It is estimated that in the Eastern Asiatic Region endemics would account for nearly half of all orchid species.

Eastern Asia is, as mentioned above, the only part of the Northern Hemisphere with a wide range of subtropical areas where the ranges of some tropical and temperate orchids overlap. Epiphytic orchids extend northward to the Qingling Mountains of central China, the southern tip of the Korean Peninsula, and southern Honshu of Japan, as well as up to an elevation of 3600 m in the Hengduan Mountains in south-west China. For example, *Hippeophyllum pumilum* Lin described from Taiwan was recently found in southern Gansu; *Liparis fargesii* Finet, *Pleione bulbocodioides* (Franch.) Rolfe, *Dendrobium hancockii* Rolfe, and *Ischnogyne mandarinorum* (Kraenzl.) Schltr. extend to south slopes of the Qingling Mountains; *Bulbophyllum drymoglossum* Maxim. ex Okubo, *Cleisostoma scolopendrifolium* (Makino) Garay, *Taeniophyllum aphyllum* (Makino) Makino, *Dendrobium moniliforme* (L.) Sw., and *Sedirca japonica* (Linden & Rchb.f.) Garay & Sweet are found in southern Korean Peninsula and southern Honshu of Japan; many species of *Pleione* can reach an elevation between 3200 and 3600 m in north-west Yunnan and south-east Xizang (Tibet). Although the plants there are rather small and grow only in specific microclimates, they survive and grow very well. There is no example of such northward and elevational migration of epiphytic orchids in either North America or Africa. Obviously, their cold-tolerance is of great ecological and physiological interest.

Marc Dumont

Dendrobium moniliforme

The distributional patterns of some orchids, as in most other angiosperms, show close floristic relationships between eastern Asia and North America. Chen (1983) listed eight closely related species-pairs disjunctively distributed in these two continents and illustrated a series of transitional patterns of distribution from continuous ranges of the same species to disjunctive ones of closely related species-pairs. It is interesting to note that the Asian taxa of these species-pairs are mainly found in the subtropical zone, whereas almost all their American counterparts occur in the temperate zone; the former are generally of narrower distribution than the latter. A biosystematic study of their genetic relationships and evolutionary trends, as well as migration times and routes, would be extremely valuable.

5.8.3 Threats

In eastern Siberia there has been little threat to orchid survival, for orchid habitats there have been well protected. However, increased logging activities and commercial orchid collecting have characterised the last five years and will undoubtedly increase. The Korean Peninsula is roughly the same, where there is little collection of orchids for trade. Orchid markets in Japan do brisk business, but only a few ornamental species occur there. Many forests there are privately owned and are also well protected. Some botanical gardens in Japan, such as the Hiroshima Botanical Garden and Atagawa Tropical and Alligator Garden, are notable for their orchid collections, though most are imported from tropical countries.

The main problem in Japan and also in the Republic of Korea is that importers there often receive large consignments of wild orchids from Hong Kong and Taiwan. Almost all of these orchids are native to mainland China and were smuggled through Hong Kong and Taiwan. It is estimated that over 100,000 cypripediums are smuggled from Yunnan and Sichuan into Hong Kong each year, of which only one-third survive the warmer climate before export to Japan. Wild cymbidiums are exported to Japan and Republic of Korea by the same route.

China is rather rich in ornamental orchids. Many species of *Paphiopedilum, Cymbidium, Calanthe, Pleione, Dendrobium,* and *Vanda* have commercial value, some of which, however, have become endangered due to destruction of their habitats and uncontrolled collections for commercial gain. In 1985 over 60,000 plants of *Paphiopedilum micranthum* Tang & Wang and *P. armeniacum* S.C. Chen & F.Y. Liu were illegally transported to Hong Kong and then exported to other countries (Stewart 1987; Chen 1989). Cymbidiums have been cultivated in China for over 1000 years but now face a crisis. In some areas of south-west China, for instance, collectors removed every cymbidium plant to sell in the markets. It is very difficult now to find either paphiopedilums or terrestrial cymbidiums in the places near towns or villages. Some species have become seriously endangered, and others are quite rare.

5.8.4 Current government and folk efforts for conservation

In eastern and northern Asia, as mentioned above, one of the problems that face us is the smuggling of orchids from mainland China through Hong Kong to Japan, the Republic of Korea, and other countries. In order to control the orchid trade scientifically an advisory body of the administrative office of CITES of China, the Endangered Species Scientific Commission, was set up in China in 1978. A short course for customs officers has been conducted three times (to date) in the fight against orchid smuggling.

There are over 400 nature reserves established in China. Orchids are known from many of them, such as Wo Long Nature Reserve of north-west Sichuan, Fan Jing Shan Nature Reserve of north-east Guizhou, and Wu Yi Shan Nature Reserve of north Fujian. Orchids are well protected in the reserves, but management is poor in some due to a shortage of funds and lack of experts. In the first volume of *The China Plant Red Data Book* (Fu 1992), seven endangered orchids are listed: *Archineottia gaudissartii* (Hand.-Mazz.) S.C.Chen, *Diplandrorchis sinica* S.C.Chen, *Changnienia amoena* Chien, *Dendrobium candidum* Wall, ex Lindl., *Gastrodia elata* Blume, *Phalaenopsis aphrodite* Rchb.f., and *Tangtsinia nanchuanica* S.C.Chen. More orchids, including some paphiopedilums and cypripediums (e.g. *Cypripedium subtropicum* S.C. Chen & K.Y. Lang and C. *segawii* Masam., will be included in the second volume, which will be published in the next few years. How to protect them scientifically, however, is still a problem because we know little of the ecology, physiology, reproductive biology, and other aspects of most orchids. At present nearly 50 genera and 200 species of orchids are cultivated in Chinese botanical gardens. Among them, the Wuxi Orchid Conservation and Research Center ranks first; no less than 40 genera and 140 species have been grown there. This is only the first step. Many more remain to be introduced, and there is still much to be learned about their conservation biology.

5.8.5 Problems and proposed recommendations

Although efforts have been made to improve orchid conservation in eastern and northern Asia, we still face many problems:

1) At present orchid smuggling in this region is still serious, particularly from mainland China through Hong Kong and/or Taiwan into Japan and the Republic of Korea. It is suggested that China strengthen the customs and frontier inspections in the fight against orchid smuggling, and that at the same time Japan and the Republic of Korea stop importing those plants native to mainland China from both Hong Kong and Taiwan, though the Republic of Korea is not a signatory party to CITES. In the meantime, all the countries concerned should not restrict import and export of the flasked products of tissue culture or other artificial propagation, and also relax the restrictions on import and export of common orchids artificially propagated. These measures would help to reduce orchid smuggling.

2) Orchid markets should be controlled to stop free trade of rare and endangered species, particularly wild paphiopedilums. Recently nearly a dozen species of Chinese paphiopedilums, some of which were newly described or even undescribed, were smuggled in large quantities into the Western countries. There is a great need to investigate the orchid resources of China thoroughly and to publish the *Orchid Flora of China* as soon as possible. From that point we could set up a data bank of rare and endangered species, containing information on their status, distribution, ecology, biological features, cultivation, artificial propagation, conservation measures, etc.

3) The protection of rare and endangered species, whether wild or introduced, should be better organised. The authorities concerned should establish or encourage orchid nurseries to raise orchid plants from seed or to produce ornamental orchids by tissue culture for export. Japan has succeeded very well in this respect, but China has just begun to propose a plan.

Chen Sing-chi, Laboratory of Systematic and Evolutionary Botany, Institute of Botany, Academia Sinica, P. R. China

5.9 India

The Indian region comprises India, Nepal, Bhutan, Bangladesh, Sri Lanka, and Pakistan, covering an area of 4,489,130 km^2 north of the Equator (Kumar 1993) and extending from 8°N to 37°N and from 61°E to 97°E. The Indian subcontinent is characterised by the tropical monsoon climate. In winter trade winds blow overland and in most areas provide scanty rain except for certain parts like Tamil Nadu. In summer, lasting from June to October, moisture-laden winds from the sea bring rainfall throughout the region. Where the monsoon comes in contact with the high mountains and ranges in the coastal belt the rainfall is heavy. In contrast, areas over which winds blow for great distances receive little rain.

The dominant vegetation is tropical monsoon forest, but the area is so large that the natural vegetation varies tremendously according to variation in soil, elevation, and the amount of precipitation. Areas with over 2000 mm of rainfall have a luxuriant vegetation of evergreen forests. These forests have tall trees and creepers, lianas, and dense undergrowth capable of supporting a variety of epiphytic flora including orchids. The dominant species of these forests are sal, teak, rosewood, and bamboos. Where the annual precipitation is between 120 and 200 cm, broad-leaved deciduous trees such as teak, ebony, sandalwood, and deodar are common and commercially used. Pines and bamboos grow here also. Scrub and acacias are found in areas with rainfall of 50-120 cm, mainly in north-west India and the Central Deccan Plateau. Xerophytes and scrub dominate the Thar Desert in north-west India, where rainfall is less than 50 cm. The harsh nature of the terrain makes this area almost barren. Mountain areas are covered with deciduous trees and mixed coniferous forest. The coastal areas are inhabited by tidal forests of mangroves (Nigam 1984).

5.9.1 Present status of knowledge

The orchid flora of the vast Indian region is yet to be well studied. J. D. Hooker (1890) made the first compilation of Indian orchids in the *Flora of British India*, followed by an illustrated anthology, *A Century of Indian Orchids*, in 1895. King and Pantling (1898) produced an exquisitely illustrated account of one of the richest orchid areas in the region, the Sikkim-Himalaya. This was followed by an equally excellent work along the same lines by Duthie (1906) on the orchids of Western Himalaya. Works on neighbouring orchid floras have been written by Grant (1895), Holttum (1953), Seidenfaden and Smitinand (1959-1965), Santapau and Kapadia (1966), Tuyama (1966, 1971, 1975), Banerji and Thapa (1969-1973). Using these main works, U. C. Pradhan (1976, 1979) compiled the illustrated account, *Indian Orchids: Guide to Identification and Culture*, in two volumes. These volumes formed the basis for concentrated research on the subject at national and international levels, resulting in numerous publications on the subject. Several local orchid Floras have since appeared. Of note among them are Seidenfaden and Arora (1982), Raizada *et al.* (1981), Hegde (1984), Kataki (1986), Joseph (1987), Banerji and Pradhan (1984), Jain and Mehrotra (1984), and Jayaweera (1981).

There have also been detailed cytological studies documented by Pradhan (1979). This study addressed the problems of generic limits, especially in subfamilies Epidendroideae and Orchidoideae.

The pollination biology of Indian Orchidaceae is grossly unknown, though some cursory information is available (G. M. Pradhan 1983; U. C. Pradhan 1974a,b, 1985c; Trudel 1983). More intensive field work is required without delay as the epiphytic and terrestrial orchid habitats are being decimated at an alarming rate, and very soon such studies may prove to be too late. The data provided are based primarily on personal observations and studies over two decades and represent an incidental rather than a detailed systematic survey. There is an acute need for such a survey, and presently the Botanical Survey of India has been undertaking this work.

5.9.2 Diversity

The Orchidoideae (especially subtribes Habenariinae and Orchidinae), and Epidendroideae subtribes Aeridinae, Coelogyninae, Eriinae, Dendrobiinae, Bulbophyllinae, and tribe Malaxideae dominate the orchid flora of this region in terms of number of species and also endemics (Table 5.9.1). The tribe Malaxideae and subtribes Habenariinae, Goodyerinae, Coelogyninae, Eriinae, Dendrobiinae, Bulbophyllinae, and Aeridinae are distributed throughout and exhibit great diversity. The north-eastern region, comprising Sikkim, Darjeeling, Gorkha Hill Council of West Bengal, Assam, Meghalaya, Tripura, Nagaland, Arunachal Pradesh, Manipur, Mizoram, and Bhutan, is certainly the richest with more than 70% of the species represented. Careful surveys may yet reveal many new species.

5.9.3 Threats

Nayar and Sastry (1987, 1988) list 58 species that are threatened. Threats to orchid species in the Indian region were first documented by U. C. Pradhan (1971, 1975a,b, 1978a) and G. M. Pradhan (1975). U. C. Pradhan (1978a) contributed the first Red Data Sheets on Indian orchids to the *IUCN Plant Red Data Book,* which served as a model for the production of the *Indian Plant Red Data Books* (Nayar and Sastry 1987, 1988). The major threats to orchid habitats in the Indian region can be broadly listed as follows:

1) Urbanisation and search for agricultural land,
2) Clear-felling of primary forests for commercial purposes,
3) Commercial collection,
4) Lack of public awareness and concern.

These threats should be addressed in conservation plans and action should be taken to reduce their impact on orchid populations. Extensive research on the pollination biology of orchids is also needed.

Presently some 35 species in the Indian region are considered extinct or on the verge of extinction, and over 100 species are threatened (Table 5.9.2). If we assume approximately 30% endemism, the number of threatened species could be doubled easily. For case histories see U. C. Pradhan (1978 a,b,c; 1982 a,b,c; 1985 a,b,d).

Udai C. Pradhan, Editor,
Himalayan Plant Journal, India

Table 5.9.1 Tribe/subtribe and number of genera, species, and endemics in the Indian region.

Taxon	Genera	Species	Endemics
Acianthinae	2	4	4
Acriopsidinae	1	2	1
Adrorhizinae	1	2	1
Aerangidinae	2	2	2
Aeridinae	39	145	35
Apostasiinae	1	3	-
Arundinae	1	2	1
Bletiinae	9	44	11
Bulbophyllinae	4	98	32
Caladeniinae	1	2	2
Calypsoeae	4	8	4
Chysiinae	1	1	-
Coelogyninae	9	64	8
Collabiinae	3	1	-
Corydinae	1	1	-
Cryptostylidinae	1	1	-
Cypripedioideae	2	13	8
Cyrtopodiinae	1	20	5
Dendrobiinae	3	95	30
Eriinae	5	55	19
Epipogiinae	1	3	1
Eulophiinae	2	27	12
Galeolinae	1	6	2
Gastrodiinae	2	5	1
Glomerinae	1	4	1
Goodyerinae	100	54	20
Habenariinae	6	109	45
Limodorinae	3	10	4
Listerinae	2	10	6
Malaxideae	4	103	35
Nervilieae	1	11	3
Orchidinae	9	26	9
Podochilinae	2	10	2
Polystachyinae	1	1	-
Satyriinae	1	1	-
Spiranthinae	1	2	-
Thelasiinae	2	7	3
Thuniinae	1	4	-
Tropidieae	2	5	1
Vanillinae	1	4	2
Total	234	965	310

Table 5.9.2 Most threatened Indian species and the nature of their threats. The *Red Data Book* status is indicated as follows: Ext=Extinct, End=Endangered, R=Rare, V=Vulnerable. Nature of threats are shown as follows: HD=Habitat destruction, LE=Localized/limited distribution Endemic, NS=Not seen for a long period, RD=Recently rediscovered, PR=Under propagation, CU=Unknown in cultivation, CK=Known in cultivation, CO=Depletion through commercial collections.

Species	RDB status	Nature of threat
Aerangis hologlottis (Schltr.) Schltr.	R	LE,CU
Angraecum zeylankum Lindl.	R	LE,CU
Anoectochilus nicobaricus Balak. & Chak.	End	LE,CU
A. rotundifolius (Blatt.) Balak.	Ext/End	NS
A. tetrapterus Hook.f.	R	LE,CU
Aphyllorchis gollani Duthie	Ext/End	NS
A. parviflora King & Pantl.	R	HD
Biermannia bimaculata (King & Pantl.) King & Pantl.	Ext/End	HD
Bulbophyllum acutiflorum A. Rich.	Ext/End	NS
B. albidum Hook.f.	Ext/End	NS
B. aureum (Hook.f.) J.J.Sm.	Ext/End	NS
B. ebulbum King & Pantl.	Ext/End	NS
B. elegantulum (Rolfe) J.J.Sm.	R	HD
B. elassonotum Summerh.	Ext/End	NS
B. kaitense (Wt.) Rchb.f.	R	HD,CU
B. nodosum (Rolfe) J.J.Sm.	R	HD,CU
B. parryae Summerh.	R	HD,CU
B. piluliferum King & Pantl.	R	HD,CU
B. rothschildianum (O'Brien) J.J.Sm.	R	LE,RD,PR
B. roxburghii (Lindl.) Rchb.f.	R	LE,CU
Bulleyia yunnanensis Schltr.	R	HD,CK
Calanthe alpina Hook.f. ex Lindl.	R	HD,CU
C. anthropophora Ridl.	End	LE,CU
C. mannii Hook.f.	R	LE,CU
C. uncata Lindl.	End	HD,NS
C. whiteana King & Pantl.	End	LE,RD,PR
C. pachystalix Rchb.f. ex Hook.f.	End	LE,HD,CU
Cephalanthera thomsonii Rchb.f.	Ext/End	NS
Coelogyne albo-lutea Rolfe	Ext/End	NS
C. mossiae Rolfe	R	HD
C. rossiam Rchb.f.	R	HD
C. treutkri Hook.f.	Ext/End	NS
Corybas himalaicus (King. & Pantl.) Pradhan	R	LE,CU
C.purpureus Joseph & Yogan.	R	LE,CU
Cymbidium tigrinum Parish	V	HD,CK,PR
C. whiteae King & Pantl.	R	HD,CK,PR
Cypripediutn elegans Rchb.f.	End	HD,CU
C. cordigerum D.Don	R	HD,CO
Dendrobium darjilingense Pradhan	End	NS
D. pauciflorum King & Pantl.	Ext/End	HD,CU
D.perula Rchb.f.	Ext/End	NS
D. rhodocentron Rchb.f.	Ext/End	NS
D. spatella Rchb.f.	Ext/End	NS
D. strongylanthum Rchb.f.	Ext/End	NS
D. tenuicaule Hook.f.	Ext/End	NS
D. wattii (Hookf.) Rchb.f.	End	NS
Didiciea cunninghamii King & Pantl.	End	LE,CU
Diplomeris hirsuta Lindl.	V	HD,CK,PR
D. pukhella D.Don	R	HD,CU
D, josephii Rao & Swamin.	R	LE,CU
Didymoplexis himalaicus Schltr.	R	HD,CU

Table 5.9.2 cont.

Diphylax urceolata (Clarke) Hook.f.	R	HD,CU
Eria acutiflora Lindl.	Ext/End	NS
E. albiflora Rolfe	R	LE,CU
E. crassicaulis Hook.f.	Ext/End	NS
E. occidentalis Seidenf.	R	NS
E. scabrilinguis Lindl.	Ext/End	NS
Eulophia mackinnoni Duthie	End	HD,CU
E. nicobarica Balak. & Nair	End	LE,HD,CU
Galeola falconeri Hook.f.	End	HD,CU
Gastrodia dyeriana King & Pantl.	End	HD,LE,CU
G. exilis Hook.f.	Ext/End	NS
G. zeylanica Schltr.	End	LE,CU
Goodyera alveolatus Pradhan	End	NS
G. *prainii* Hook.f.	End	NS
Habenaria barnesii Summerh.	R	LE,CU
H. caranjensis Dalz.	Ext/End	NS
H. cumminsiana King.& Pantl.	Ext/End	NS
H. pachycaulon Hook.f.	Ext/End	NS
H. pseudophrys King & Pantl.	R	LE,CU
Herminium kalimpongense Pradhan	End	NS
Hetaeria anomala Lindl.	Ext/End	NS
Liparis gamblei Hook.f.	End	NS
Loxoma maculata (Dalz.) Garay	R	HD,CU
L. straminea (Dalz.) Pradhan	R	HD,CU
L. viridiflora (Dalz.) Pradhan	R	HD,CU
Luisia abrahamii Vatsala	R	HD,CU
L. micrantha Hook.f.	Ext/End	NS
Malaxis aphylla (King & Pantl.) Tang & Wang	End	LE,CU
M. saprophyta (King & Pantl.) Tang & Wang	End	LE,CU
Malkola andamanica Balak. & Bharg.	V	LE,CU
Neottia inayatii (Duthie) Beauv.	End	HD,CU
Nervillia hookeriana (King & Pantl.) Schltr.	End	NS
Oberonia brachyphylla Blatt. & McCann	R	HD,CU
Oreorchis indica (Lindl.) Hook.f.	R	LE,CU
O. rolfei Duthie	End	LE,CU
Paphiopedilum druryi (Bedd.) Stein	End	CO,HD,CK
P. fairrieanum (Blume) Stein	V	CO,HD,CK
P. insigne (Wall. ex Lindl.) Pfitzer	V	CO,HD,CK
P. spicerianum (Rchb.f.) Pfitzer	R	CO,HD,CK
P. venustum (Wall. ex Sims) Pfitzer	V	CO,HD,CK
Phalaenopsis mysorense Saldanha	V	HD,CU
P. speciosa Rchb.f.	V	HD,CK
Physurus hirsutus (Griff.) Lindl.	End	NS
Platanthera dyeriana (King & Pantl.) Pradhan	R	LE,CU
Podochilus saxatilis Lindl.	R	LE,CU
Risleya atropurpurea King & Pantl.	R	LE,CU
Schoenorchis seidenfadenii Pradhan	R	LE,CU
Sirhookera latifolia (Wight) Kuntze	R	LE,CU
Stigmatodactylus paradox (Prain) Schltr.	R	LE,CU
Sunipia fusco-purpurea (Lindl.) Hunt	End	NS
Taeniophyllum gilimalense Jayaw.	R	LE,CU
Tainia khasiana Hook.f.	Ext/End	NS
Trichoglottis quadricornuta Kurz	End	NS
Trudelia alpina (Lindl.) Garay	R	LE,CK
Vanda wightii Rchb.f.	V	HD,CK
Vanilla andamanica Rolfe	V	HD,CU
V. moonii Thwaites	R	LE,HD,CU
V. walkerae Wight	R	LE,HD,CU
Yoania prainii King & Pantl.	R	LE,CU
Zeuxine pulchra King & Pantl.	End	HD,CU

5.10 Africa

5.10.1 North-east tropical Africa

This region comprises Ethiopia, Eritrea, Sudan, and Somalia, an area of approximately 4,358,865 km^2. Ethiopia and Eritrea are dominated by the Ethiopian highlands with many mountains rising to over 4000 m, the highest at 4620 m in the Simien (Simen) Mountains. Substantial tracts of lowland are found in the north and east, but the rainfall there is very low. Sudan is mostly lowland and hill country, the northern and western part arid or semi-arid, the southern part dominated by the flood plains of the Nile. The highest mountains are the Imatongs rising to 3167 m just north of the Ugandan border; other isolated mountains, notably Jebel Marra (3071 m) are found in the west near the Chad border. Somalia is mostly arid with a range of mountains, reaching 2416 m at Shimburo, in the north flanking the south coast of the Gulf of Aden.

Rainfall is seasonally high in the mountains but very low in the east and north of Ethiopia and Eritrea, and orchids are not a significant element of the flora. In Sudan orchids are found in the wetter south, especially in the Imatongs and other mountains. In Somalia they are virtually confined to the northern mountains.

5.10.1.1 Present state of knowledge

The orchid flora of Ethiopia and Eritrea has until recently been little studied and rather poorly collected by tropical African standards. Orchids were first collected there by the French botanists Quartin-Dillon and Petit (1838-1843). Later significant collections were made by George Schweinfurth, Schimper, and a number of Italian collectors, notably Ruspoli and Riva, Chiovenda, Negri, Senni, and Pichi-Sermoli. More recent collections include those of Ash, Burger, J.J. & W. de Wilde, Friis, Gilbert, Tewolde, Mesfin, Mooney, Rasmussen, and Thulin. The first published account of the Ethiopian orchids was that of Achille Richard (1850) who listed 34 species in 12 genera. The latest published account is that of Cufodontis (1972) in which 124 species in 24 genera are reported. An unpublished manuscript by Cribb and Thomas for the Flora of Ethiopia project should appear in 1996. They record 161 species in 34 genera for Ethiopia (including Eritrea). Of these, 126 species are terrestrial and 38 epiphytic or lithophytic. Many of these are known from less than five collections. The genus *Habenaria* accounts for nearly half of the orchid flora. Endemicity is moderate with about 30 species truly endemic (about 19%) and another ten near endemics. Both terrestrial and epiphytic species are included among the endemics.

The orchids of the Sudan are not well studied. The most recent account is that of Andrews (1956) in which 49 species in 18 genera are recorded. This is undoubtedly an underestimate, but no current work is underway on this flora.

Somalia has a very depauperate orchid flora, possibly fewer than 15 species, all found in the north of the country. The distribution of one terrestrial species, *Eulophia petersii*, extends into the more arid regions. An account of the orchid flora by Borge Pettersson is in preparation for a forthcoming volume of the *Flora of Somalia* (ed. M. Thulin).

The Arabian peninsula has a small but significant orchid flora with tropical African affinities (Cribb 1987b, 1979; Robbins 1992). None of the species are endemic.

5.10.1.2 Diversity

Orchids are relatively poorly represented in the flora of North-east Africa. The most significant orchid flora is to be found in the grasslands and forests of the mountains of Ethiopia. The affinities of the flora are tropical African with only one species, *Epipactis veratrifolia,* from the Middle East. This region is a centre of diversity for *Habenaria* sect. *Multipartitae* and a minor centre of endemism for the terrestrial genera *Holothrix* (2 spp.), *Habenaria* (13 spp.), *Roeperocharis* (2 spp.), *Satyrium* (1 sp.), *Disperis* (3 spp.), *Eulophia* (2 spp.), and *Eiparis* (1 sp.), and for the epiphytic genera *Cyrtorchis* (1 sp.), *Diaphananthe* (1 sp.), *Stolzia* (1 sp.), and *Polystachya* (3 spp.).

5.10.1.3 Threats

The major threats to orchids arise from three main sources: overpopulation in the highlands, famine caused by unpredictable rainy seasons, and war. The few remaining woodlands and forests of Ethiopia and Eritrea are greatly threatened by people collecting wood, particularly for charcoal-making, fuel, and construction. War and famine, often linked, have forced the population to over-exploit the natural resources on an unprecedented scale. Orchid tubers are a famine food in the more extreme cases.

The unpredictability of the rainy season that has become a recurrent feature of recent years throughout the region has led to increasing desertification in areas that previously had savanna woodland, grassland, or forest cover. Orchids, especially the epiphytic species, have undoubtedly suffered, although the scale of this is simply unknown.

5.10.1.4 Case histories

1) *Diaphanathe Candida* - This attractive Ethiopian epiphytic species with white flowers was described in 1979. It resembles one of the several *Aerangis* species found in Ethiopia. I have seen only four collections from three provinces, namely Kaffa, Sidamo, and Wollega. It is an obligate epiphyte, and the destruction of isolated trees and forest for fuel is undoubtedly threatening its survival.

2) Habenaria taeniodema - This is one of the largest terrestrial orchids in Ethiopia, up to a metre tall, with large green flowers. It was discovered by Hildebrandt early in the century and was described by Summerhayes in 1966. Only one other collection, made over 50 years ago, is known. The two collections came respectively from the highlands of Shoa and Wollega provinces. It grows in scrub, itself an endangered vegetation type in highland Ethiopia, and because it is so attractive it must be naturally very rare, possibly on the verge of extinction.

Phillip J. Cribb, Royal Botanic Gardens, Kew, UK

5.10.2 West Africa

Fourteen countries are included in this region which ranges from Senegal and the Gambia in the west to Nigeria and Cameroon in the east. It is bordered in the north by the Sahel and Sahara, areas which are of no significance in orchid terms. This region is 4,266,642 km^2 in extent and has a population of approaching 200 million people.

The climate is wet tropical especially near the coast where there were in historical times extensive areas of lowland rain forest. Mt. Cameroon, the highest mountain in West Africa at 4095 m and an active volcano, has the second highest recorded rainfall for anywhere in the world, exceeding 10,000 mm per annum. The wet forests of the region form part of the Guineo-Congolean regional centre of endemism (White 1983).

Further inland the rainfall decreases and forest gives way to savanna woodland and eventually to grassland and marshes, referred to by White as the Sudanian region. This riverine forest extends into the latter areas, particularly along the larger rivers. The rain forest and woodland cover in West Africa is much depleted in recent times because of the activities of man.

Two regions of rain forest can be distinguished in West Africa, and these are separated by a dry area called the Dahomy gap (White 1983).

5.10.2.1 Present state of knowledge

The orchid flora of West Africa has been, until recently, the best known of all tropical Africa because of the work of Schlechter in the early years of this century and, more recently, that of Summerhayes (1968). Summerhayes' account of the orchids for the *Flora of West Tropical Africa* (1964) remains the standard account of the orchids of the littoral countries from Senegal east to western Cameroon. Eastern Cameroon was not included because it was a French possession at the time this work was done. An as yet unpublished account of the family has been prepared for the *Flore de Cameroon* by Sanford.

Summerhayes includes 412 species in 58 genera in his account, easily workable keys being provided for the genera and species. All of the genera treated belong in the subfamilies Orchidoideae, Spiranthoideae, and Epidendroideae (*sensu* Dressier 1993); the Apostasioideae and Cypripedioideae are not found in Africa. Among the terrestrial orchids the Orchidoideae are very well represented by the genera *Habenaria* (52 spp.) and *Brachycorythis* (10 spp.) and the Epidendroideae by *Liparis* (10 spp.) and *Eulophia* (34 spp.); among the epiphytes *Polystachya* (54 spp.), *Bidbophyllum* (65 spp.), *Angraecum* (16 spp.), *Diaphananthe* (14 spp.), and *Tridactyle* (12 spp.), all in the Epidendroideae, are the most numerous.


Marc Dumont

Eulophia streptopetala

A number of recent revisons include West African species, notably those on *Aerangis* (Stewart 1979), *Bulbophyllum* (Vermeulen 1987), *Disa* (Linder 1981d), *Microcoelia* (Jonsson 1981), *Nervilia* (Pettersson 1990), various *Polystachya* sections (Cribb 1978b; Podzorski and Cribb 1979), and *Stolzia* (Cribb 1978a). These should be used in conjunction with Summerhayes' floristic account.

Undescribed species appear frequently in collections even nowadays. In a recent collection of about 100 specimens, representing about 60 species, from the Mt. Cameroon area collected by Cable, Cheek, etc. I found three species new to science (Cribb, pers. obs.).

Johansson (1974) studied the ecology of vascular epiphytes in theWest African rain forest of Mt. Nimba. His observations and those of Sanford (1974) are the most comprehensive studies available on the ecology of African orchids.

5.10.2.2 Affinities

The orchid flora has strong affinities to those of Central and tropical East Africa but is richer in epiphytes than the latter, a consequence of the greater extent of forest in West Africa. Endemism in the region (including E. Cameroon and the islands of Sao Tomé, Annobon, and Principe) is relatively high at about 139 species (29%), and endemics are found in a number of genera including *Habenaria, Brachycorythis, Polystachya, Bulbophyllum, Angraecum, Ancistrorhynchus,* and *Tridactyle.* Some species such as *Liparis kamerunensis, L. goodyeroides, Polystachya cooperi, P. geniculata, P. kingii, Genyorchis macrantha, G. apertiflora, Diaphananthe dorotheae, Rangaeris longicaudata,* and *Tridactyle muriculata* are narrow endemics, confined to a single mountain or locality. Three genera, *Chauliodon* (1 sp.), *Dinklaagella* (2 spp.), and *Ossiculum* (1 sp.) are endemic to the region. By far the majority of narrow endemics are to be found in the eastern part centred on Cameroon and western Nigeria.

5.10.2.3 Current protection

A few national parks or biosphere reserves have been created, particularly in forested areas to protect the wildlife, including the orchids. The most notable of these are in Cameroon: Mt. Cameroon, River Dja Region, Takamanda, and Korup. The last two are contiguous with two sections of the the Cross River National Park in Nigeria. Three national parks have been established in the western part of the region: Tai National Park in Cote d'lvoire; Sapo National Park in Liberia; and Mt. Nimba which straddles the Liberian and Cote d'lvoire borders. The latter two reserves are currently in war zones.

5.10.2.4 Threats

The current threats to orchids in the region are mainly twofold: 1) rapid population growth with concurrent destruction of forest and woodland for plantations of cash crops, subsistence agriculture and fuelwood, and 2) logging by multinational companies. The latter is particularly devastating in countries such as Cote d'lvoire, Sierra Leone, and Nigeria.

Orchid-collecting is not a significant problem, although some species are horticulturally desirable and occasionally appear in some quantity on the market. Species that fall into this category include *Ansellia africana, Ancistrochilus rothschildianus,* and *Plectrelminthus caudatus.*

5.10.2.5 Case histories

***1) Ossiculum aurantiacunt* -** This extraordinary epiphytic orchid is unique among African angraecoid orchids in having orange flowers. It was discovered by Henk Beentje in 1980 in the Mungo River Forest reserve in Cameroon, growing on the lower branches of a tree in primary rain forest. Plants of this collection flowered in cultivation at the Wageningen Botanical Garden in 1983. It was described by Cribb and van der Laan in 1986. It has not been seen since, and its status in the wild is unknown. However, its brightly coloured flowers suggest that it is likely to be rare in the wild and is probably endemic to a small area of Cameroon where it was first collected.

2) Ancistrochilus rothschildianus* and A. *thomsonianus - Only two species are known in the African genus *Ancistrochilus,* and both occur in West Africa. They are the only members of their tribe in the African flora and are distinctive and attractive orchids with flowers that are large and pretty for the size of the plants. Both species are found in lowland forest and when found (infrequently) are invariably collected as herbarium specimens or for the nursery trade. *Ancistrochilus rothschildianus,* with pink and purple rather than white flowers, is more common and has proved to be easy to grow and can be multiplied from seed without difficulty. Seedlings are occasionally offered for sale by European and American nurseries.

Phillip J. Cribb, Royal Botanic Gardens, Kew, UK

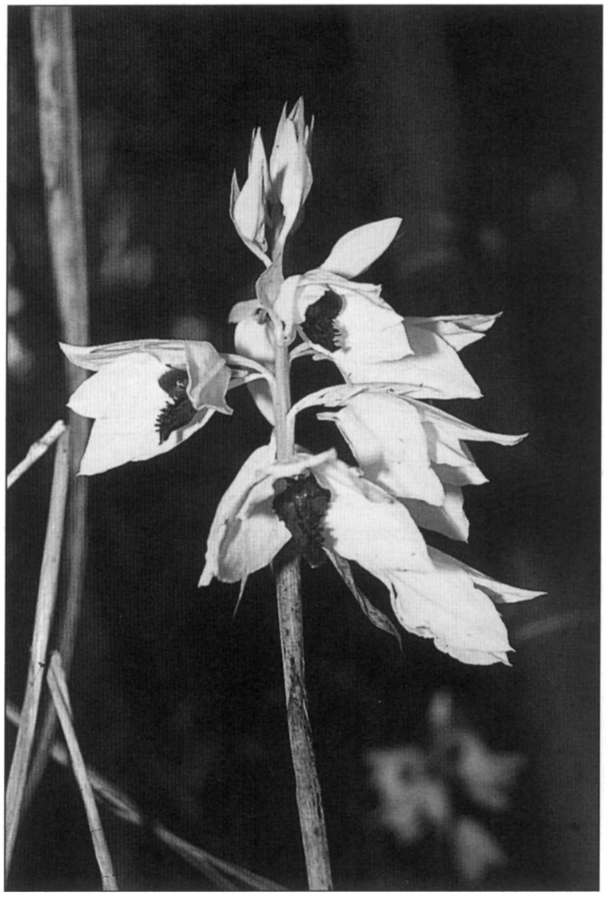
5.10.3 Central and south-central Africa

Parts of central Africa and south-central Africa remain the least well-known parts of Africa from a floristic viewpoint. I consider them here separately, central Africa having come more or less under the influence of francophone botanists, and south-central Africa under the influence of anglophone botanists until now.

Central Africa comprises the countries of the Central African Republic, Gabon, Congo, Zaire, Guinea, Rwanda, and Burundi, totalling an area of approximately 3,665,000 km^2 with a population in 1988 of over 50 million people. Much of the region forms the catchment area of the Zaire River, an area of lowland rain forest and riverine forest. These form the central African arm of the Guineo-Congolean region centre of endemism. On the marginal mountains in eastern and southern Zaire, Rwanda, and Burundi there are montane forests and grasslands, and in the Central African Republic savanna woodlands and grasslands.

South-central Africa comprises Angola, Zambia, Zimbabwe, Mozambique, Malawi, and Burundi, an area of 3,816,460 km^2 with a population of about 50 million people. Much of this region is covered by woodlands, savannas, and marshes. Rain forest occurs along rivers and on the wetter flanks of mountains such as Mlanje, Zomba, and the Nyika Plateau in Malawi; Gorongoza in Mozambique; and the Chimanimani and Vumba Highlands of Zimbabwe.

National parks protect several areas rich in orchids in the region. Notable examples are Kundelungu and Upemba National Parks in Zaire; Nyungwe in Rwanda; the Nyika Plateau straddling the Malawi and Zambia border; the Zomba Plateau in Malawi; and the Chimanimani Mountains in Zimbabwe. Others such as the Cristal Mountains in Gabon receive no protection at present.



Isobyl La Croix

Eulophia macrantha

5.10.3.1 Present status of knowledge

The orchids of Zaire, Rwanda, and Burundi have recently been revised by Geerinck (1984, 1992). He recognizes 515 species in 64 genera. Of these, 233 species are epiphytic, the remainder terrestrial. He has often adopted a broader species concept than authors working in adjacent areas, especially for larger genera such as *Habenaria* (79 spp.) and *Eulophia* (71 spp.). However, he has described a number of endemic species in genera such as *Polystachya, Eulophia, Disa,* and *Habenaria* that are undoubtedly distinct. A separate account of the orchids of Rwanda by Geerinck (1988) recognizes 160 species in 34 genera.

Gabon has a rich flora and a number of endemics, but it is very poorly understood and has yet to be written up for the *Flore de Gabon* project.

Marc Dumont

Polystachya cultriformis

A checklist of the orchids of the Central African Republic has been published recently by Cribb and Fay (1987), which adds several new records to the Flora. The Flora of this country is poor by West or East African standards, but new records are bound to be added as the country becomes better explored.

Angola falls within the remit of the now defunct *Conspectus Florae Angolensis* project for which the orchids have not been published. The other countries fall within the *Flora Zambesiaca* region. The orchid Flora of this latter region is being prepared and will be published in two volumes, the first in press (I. La Croix and Cribb). However, excellent accounts for parts of this region or particular elements of the orchid flora already exist: I., E., and T. La Croix's account of the *Orchids of Malawi* (1991); G. Williamson's *Orchids of South Central Africa* (1977) which concentrates on Zambia, northern Malawi, and Zimbabwe; Grosvenor's checklist of Zimbabwe orchids; and John Ball's account (1978) of the *Southern African Epiphytic Orchids.*

5.10.3.2 Affinities

The orchids of both regions belong to three of the subfamilies — Orchidoideae, Spiranthoideae, and Epidendroideae — recognised by Dressier (1993b). The former is very well represented in Rwanda and Burundi and in south-central Africa where grasslands and marshes predominate. The Spiranthoideae and Epidendroideae are better represented in Central Africa and the montane forests of both regions. Neither the subfamily Apostasioideae nor the Cypripedioideae is found here.

The affinities of the epiphytic orchids (233 spp.) and terrestrial forest species lie more with West and south-central Africa (Geerinck 1984, 1992). Conversely the terrestrial orchids, particularly the grassland and marshland species in southern Zaire and in Rwanda and Burundi, have much in common with the East African and south-central African floras.

Endemism is low in Rwanda, a mere six endemic species (less than 4%) being recorded by Geerinck (1988). For Zaire, Rwanda, and Burundi as a whole he records 61 endemics (nearly 12%). The genera with most endemics are *Polystachya* (14 spp.), *Eulophia* (10 spp.), *Habenaria* (9 spp.), and *Bulbophyllum* (7 spp.).

The orchids of south-central Africa have much in common with those of Tanzania, Rwanda, and Burundi and the copper belt of southern Zaire. A few South African elements such as *Schizochilus, Corycium, Monadenium,* and *Stenoglottis* are also present. A very small element of Madagascan flora is also present, notably *Jumellea* (2 spp.) and *Aeranthes* (1 or 2 spp.). Endemism is similar to that of East Africa. One endemic genus *Oligophyton* has recently been described.

5.10.3.3 Threats

As in West Africa the major threat to orchids in the region is habitat destruction caused by changes of land use, logging, and charcoal production. In Angola, Rwanda, Burundi, and Zaire war is a major factor in habitat destruction as people are forced to utilise forest and woodland for food, fuel, housing, and other products on an unsustainable scale. Famine often accompanies war, and the people have to resort to using plants for food that they would normally ignore. In this context, orchid tubers can be dug up and used as a famine food. Abnormal dry spells such as those experienced in recent years in Zimbabwe can also reduce orchid populations dramatically, interfering with normal growth patterns and reducing the chances of successful seed production and germination.

In Malawi, Zambia, and particularly Zimbabwe orchids are collected by local enthusiasts, tourists or, occasionally, commercial collectors. This can seriously affect the populations of locally endemic species. Showy orchids such as *Ansellia africana* and *Aerangis* species are most at risk.

5.10.3.4 Case histories

1) Polystachya songaniensis - This attractive terrestrial member of the genus *Polystachya* was described as recently as 1982 by Graham Williamson. It was discovered in a well-known Malawi beauty spot on the Zomba Plateau not far from the town of Zomba. It had been missed by earlier collectors in this much-visited spot because it flowers at a time of year, September and October, when little else does. Since its discovery it has been found in one or two other places on the plateau growing in cracks in the rock or around the edges of rocks in grassland and also on neighbouring Malosa and Mlanje Mts. The accessibility of its known localities on Zomba means that it is vulnerable to collecting and trampling.

2) Eulophia macrantha - This terrestrial orchid, with large pale yellow and maroon flowers, is one of the most spectacular of all Malawi orchids. It has a very restricted distribution in southern Malawi, its best known locality being on the track up to the Zomba Plateau from Zomba town where it grows under clumps of the introduced bamboo, *Bambusa vulgaris*. A single locality is also known in Mazoe District in Zimbabwe. It is vulnerable in Malawi because locals and tourists pick it or uproot it for its beauty and also because road-widening works and changes of land use remove the bamboo cover.

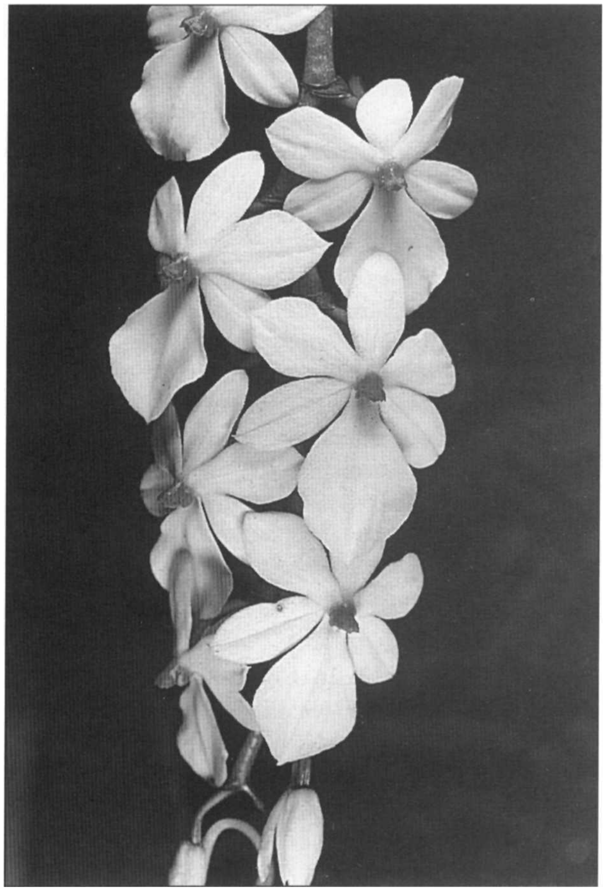
Phillip J. Cribb, Royal Botanic Gardens, Kew, UK

5.10.4 East Africa

The nations included in this region are Kenya, Uganda, and Tanzania. Dominant habitat types are savanna woodlands, bushlands, and grasslands with lowland forests at the coast and upland forests farther inland.

5.10.4.1 Present status of knowledge

Summerhayes (1968) published part one of the Orchidaceae for the *Flora of Tropical East Africa,* and Cribb (1984, 1989) published parts two and three. The first checklist for the epiphytic orchids of East Africa was prepared by Moreau and Moreau (1943). Copley *et al.* (1964) were the first to publish a list of the orchids of Kenya, later updated by Stewart (1973). Piers (1968) produced the most comprehensive guide on the orchids of East Africa to that time, while in the same year Leakey (1968) listed the orchids of Uganda. Most recently Khayota (1990) studied the genus *Ansellia* along the coast.



Phillip Cribb

Aerangis luteo-alba var. *rhodosticta*

Two field guides are now available: *Upland Kenya Wild Flowers* by Agnew and Agnew (1994), and the *Collins Guide to the Wild Flowers of East Africa* by Blundell (1987). An account of the orchid flora of Ethiopia (Cribb and Thomas) is in press at the time of writing.

Information on endangered and threatened orchids is available from the East African Herbarium, Nairobi; the University Herbarium, University of Dar-es-salaam, Tanzania; and the National Herbarium, Makerere University, Uganda. Other pertinent information is available in *Swara Magazine,* published by the East Africa Wildlife Society, and in the publications of the East African Natural History Society.

Apart from the ban in the trade of the leopard orchid (*Ansellia africana* Lindl.) in Kenya (Khayota 1993), the other orchid species are generally protected by CITES regulations. Though not specifically targeting orchids, a Presidential ban in Kenya on the felling of indigenous trees instituted in 1986/87 protects the orchid's habitat. Subsidiary legislation has been drawn up to establish rules on the use of certain gazetted forests. The East African countries have a network of protected areas representing different habitats, which affords *in situ* conservation for some orchid species.

5.10.4.2 Diversity

In the *Flora of Tropical East Africa,* three subfamilies and 22 subtribes of orchids are represented, with 686 species distributed among 75 genera. Of these species 143 are endemic to the region; there are 35 species of *Polystachya* alone which are endemic, most found in Tanzania. Areas rich in epiphytic species include the Eastern Arc Mountains in Kenya and Tanzania, the coastal lowland rain forests, and the East African highlands. The southern highlands of Tanzania and wetlands are rich in terrestrial species.

5.10.4.3 Threats

Most orchids in the region are threatened by loss and fragmentation of habitats. Moist forests, where most of the epiphytic orchid taxa occur, are especially at risk. Up to 80% of these habitats have been lost (World Resources Institute 1990), and this situation is further aggravated by the continual demand for agricultural land. In Kenya the coastal and highland forest are at considerable risk. In Uganda the forests remaining are widely separated from one another, forming ecological islands surrounded by other vegetation types (Sayer *et al.* 1992). Apart from being fragmented as well, the coastal and upland forests of Tanzania are under extreme pressure of encroachment and exploitation. Savanna woodlands and grasslands are at risk from unsustainable overstocking and eventual overgrazing. In the wake of a burgeoning population these fragile ecosystems are now being exploited unsustainably.

The number of extinct species in the region has not been determined. However, in Kenya and presumably elsewhere in the region, species most threatened are those that are showy and targeted for the horticultural trade. These include *Ansellia africana* Lindl., *Aerangis luteo-alba* (Kraenzl.) Schltr. var. *rhodosticta* (Kraenzl.) J. Stewart, *Polystachya bella* Summerh., *Angraecum eburneum* Bory var. *giryamae* (Rendle) Cribb & Senghas, and species of *Microcoelia* (Khayota 1990; Patel 1992). Throughout the region endemic species restricted to ecologically sensitive areas are threatened.

The major types of threats are: 1) selective logging and clear-felling of forested areas; 2) commercial development along the coastal belt for tourism; 3) designation of prime land for agriculture with consequent fragmentation of orchid populations; 4) overgrazing and uncontrolled use of fires affecting the life cycles of terrestrial species in particular; and 5) overcollecting from the wild for commercial purposes.

5.10.4.4 Current actions

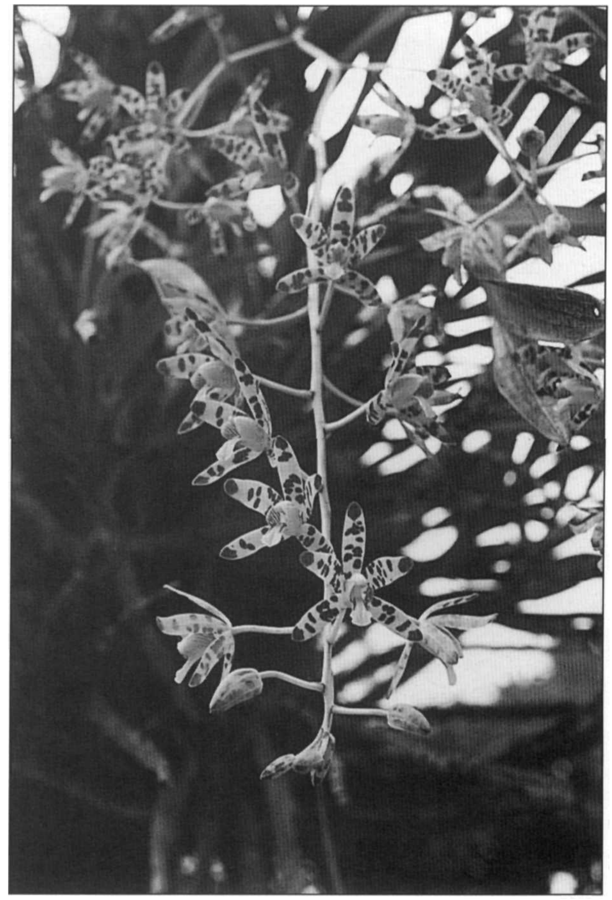
Noting the need to conserve the Kenyan plant biodiversity, especially the rare and endangered taxa, the Plant Conservation and Propagation Unit within the East African Herbarium (based at the National Museums of Kenya) is endeavouring to conserve target taxa by assessing their population status in the field, collecting germplasm for storage and propagation, developing appropriate propagation techniques, and facilitating *ex situ* conservation where possible. Reintroductions or translocations will be performed where appropriate. Links with the Kenyan Orchid Society have been established to promote conservation through sustainable utilisation. There is an ongoing Orchid Conservation Programme within the Unit, and efforts are being made to obtain germplasm for culture using micropropagation techniques. It is hoped that the plants generated will be available not only for conservation work but also to the horticultural market, thereby reducing pressure on the wild populations.

5.10.4.5 Case histories

1) Ansellia africana - *Ansellin africana* Lindl., the leopard orchid, belongs to a monotypic genus restricted in distribution to Africa south of the Sahara Desert. It is an epiphyte or lithophyte with flowers that have a characteristic yellow background with blotches of maroon. The degree of blotching varies from almost none to very dark patches that appear to obscure the yellow background completely. The flowers remain open for about one month.

This orchid has become popular with the local people as well as tourists, which has encouraged its indiscriminate commercial collection from the wild. With sponsorship from the East African Wildlife Society, Khayota (1990) surveyed the orchid trade at the Kenya coast and found that large quantities of *A. africana* were being collected from the south coast for sale to the local hotel industry and to local orchid hobbyists. Clumps were being sold for prices ranging from Ksh.40 to Ksh.600. In Nairobi plants were selling at an average price of Ksh.250. Areas near Kilifi and Ukunda had been almost cleared of the species. The situation was being made worse by the slow mode of transport and handling of the collected material, leading to over 90% mortality in captivity. To meet the demand more orchids were being scavenged from farther and farther inland. Following this survey and further communication with the relevant authorities, a ban on the collection of indigenous orchids from the wild, especially *A. africana*, was instituted.

As a follow-up, the Plant Conservation and Propagation Unit is propagating this species using tissue culture with the ultimate aim of producing sustainable quantities. These will also be made available to the local horticultural industry and other interested parties. The Kenya Orchid Society has also strongly urged its members and the public not to buy any orchids collected from the wild and plans to provide propagated material at its annual shows and auctions.


Mrs. D. Barrett

Ansellia africana

Christine Kabuye, East African Herbarium,
Nairobi, Kenya

5.10.5 Southern Africa

The southern African region includes South Africa, Lesotho, Swaziland, Botswana, and Namibia, an area of 2,662,850 km^2. The vegetation of this area is highly variable. The south-western tip and south coast is mountainous, with rugged quartzitic mountains. The climate is Mediterranean, with wet winters and dry summers, and the dominant vegetation is a heathland, locally known as 'fynbos' (Taylor 1978). The rest of the region has dry winters with the rain falling in summer. The eastern Cape Province and the arid areas of Natal are covered in a thorny scrub vegetation. The central portion of the region forms a high plateau, between 1000 and 2000 m above sea level, whereas the southern and western parts are dry, a semidesert, varying from shrubby in the south, to a grassland in the north. The northern margins grade into savanna woodlands, dominated by mimosoid and caesalpinoid trees and shrubs. The western coastline forms the arid Namib desert. Along the eastern escarpments the mountains reach to 3000 m, and the summits are vegetated by subalpine grasslands (Killick 1978), dominated by pooid and danthonoid grasses. Along the wet eastern foothills of the mountains are patches of Afromontane forests (White 1978). Tropical forests are found in favoured habitats along the eastern coastline (Moll and White 1978).

5.10.5.1 Present status of knowledge

The orchid flora of southern Africa has been relatively well studied. The first taxonomic studies date back to Linnaeus, and since then there has been a constant stream of taxonomic papers. Many of the larger groups have been monographed: the Disinae by Linder (1981a-f), *Eulophia* by Hall (1965), *Satyrium* by Hall (1982). Available information was compiled by Stewart *et al.* (1982) in *Wild Orchids of Southern Africa.* Since then a more comprehensive and detailed account of the flora has been prepared by numerous contributors (Linder *et al.*, in prep.), although it has not yet been published. This has been used as the source of information about the southern African orchid flora.

There have also been numerous detailed morphological (Kurzweil 1989; Kurzweil and Weber 1991; Kurzweil and Weber 1992; Kurzweil and Linder 1991; Kurzweil 1993), anatomical (Chesselet 1989), and palynological studies (Chesselet and Linder 1993) on the southern African orchids, largely directed at resolving the genetic limits in the flora. Linder and Kurzweil (1990) have addressed the vexing problem of the generic limits in the Disinae, and Kurzweil *et al.* (1991) addressed the redelimitation of the genera in the Coryciinae. Linder and Kurzweil (1994) have produced a phylogeny of the Diseae. Thus, in the Diseae, the two outstanding problems are still the generic limits in the Disinae and the phylogeny of *Satyrium.* The patterns of speciation in the flora have also been addressed by these authors. Steiner (1989), Johnson (1993), and Johnson and Bond (1992) have greatly expanded our knowledge of the pollination biology in the orchidoid genera. However, relatively little has been done on the other subfamilies.

An attempt has been made to locate all names known only from type specimens and to exclude them from the study. In view of the extensive field work during the last few decades, it is not likely that these names represent 'real' populations and may reflect monstrous specimens or just 'odd' plants.

The information presented here is based largely on incidental observations rather than of a detailed systematic survey of the status of the rarer species of southern African orchids and are largely preliminary. There is a real need for such a survey and a need to compile information from across the country.

5.10.5.2 Diversity

The Orchidoideae, in particular the Diseae (Disinae, Coryciinae, Huttoniinae, Brownleeinae, and Satyriinae), dominate the southern African orchid flora in terms of number of species and endemics (Table 5.10.1). Southern Africa is clearly the centre of diversity for the tribe. Most of the genera of the Orchideae are widespread in tropical Africa, often found in the montane grasslands, although there are a few endemic genera (e.g. *Bartholina*) and genera centred in southern Africa (e.g. *Schizochilus*). The other subfamilies are generally centered elsewhere, with a few species reaching into southern Africa. There are a few genera, such as *Mystacidium* and *Acmlophia,* which are largely restricted to southern Africa, while the large genus *Eulophia* is represented by many species in the region. However, it is evident that the southern African epiphytic orchid flora is relatively poorly developed.

The orchids are very unevenly distributed in southern Africa, with the vast majority occurring in the more mesic southern and eastern parts of the country. Particularly rich is the south-western Cape Province and the high Drakensberg on the border between Natal Province and Lesotho. The areas of endemism are strongly correlated with the areas of species richness. Outstanding would be the Cape Floristic Region (Goldblatt 1978). It is scarcely possible to delineate areas of endemism within this region, as virtually every mountainous area here has endemic orchid species. The second area of endemism is the Drakensberg, which forms the eastern border of Lesotho, although the eastern flanks of this range, in Natal, contain most species. The third area of endemism is the Drakensberg in Transvaal, around the towns of Dullstroom and Graskop, and northwards to Tzaneen. In addition, there are numerous small areas which contain one to several endemic species, scattered in this region. There has not yet been a rigorous analysis of the areas of endemism, although the data necessary for such a study are at hand.

5.10.5.3 Threats

The areas at risk are fortunately few, as the most species are found in mountainous areas, unsuitable for agriculture or development, and often included in reserves, as they are important water-catchment areas. However, there are two areas which are severely

Table 5.10.1 Subfamilies, tribes or subtribes, number of genera and species, and endemics in the southerr African orchid flora. Classification modified after Dressier 1981b.

Taxon	Genera	Species	Endemics
Orchidoideae			
Orchidinae	5	43	37
Habenariinae	5	54	20
Disinae	4	141	127
Huttonaeinae	1	5	5
Brownleeinae	1	6	4
Satyriinae	3	41	34
Coryciinae	5	68	61
Spiranthoideae			
Tropidiinae	1	1	0
Goodyerinae	3	3	0
Epidendroideae			
Nerviliinae	1	6	0
Gastrodiinae	2	2	1
Bletiinae	1	1	0
Malaxideae	2	4	2
Bulbophyllinae	1	4	0
Polystachyeae	1	11	3
Sarcanthinae	1	1	0
Angraednae	2	7	1
Aerangidinae	9	26	11
Cyrtopodiinae	4	57	27
Total	52	481	333

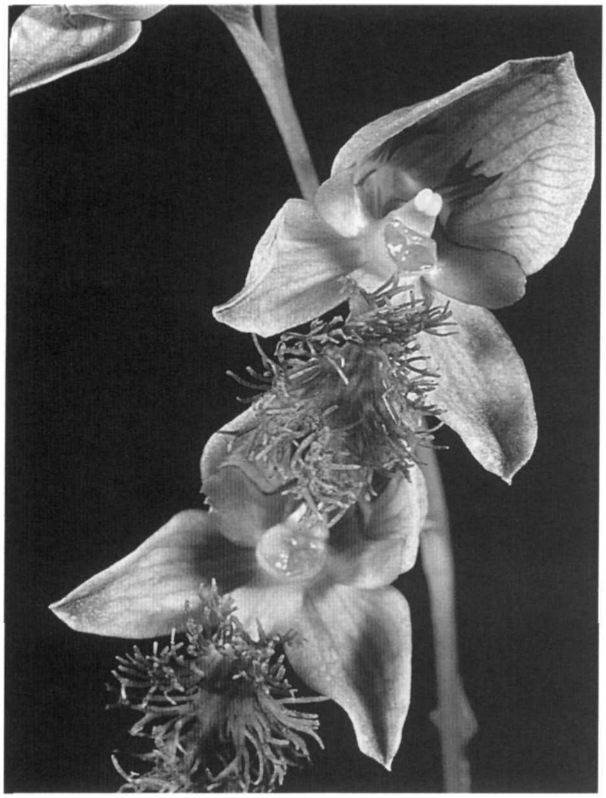
threatened. The first is the lowlands in the south-western Cape Province, which are being invaded by aggressive Australian acacias and rapidly developed for tourism and agriculture. There are few reserves in this area. The second area includes the montane grassland zone, reaching from southern Natal along the Drakensberg foothills to the Drakensberg in the Transvaal. This grassland area, the second centre of endemism, is rapidly being afforested. Large areas in the Transvaal and in southern Natal are already under pine plantations. There is no detailed survey available to indicate how much grassland will be lost, but it is possible that the only surviving habitat may be in fire-breaks. This poses the most severe long-term threat to the orchids, but another is the increasing population pressure on the grasslands. This will soon result in the degradation of large areas of grasslands, even the alpine grasslands on the high summits of the Drakensberg, and may result in the loss of the orchids endemic to these high-elevation grasslands. It is not clear how the new democratic government in South Africa will control this threat of grassland degradation.

Although at present it would appear as if only one species is extinct, *Monadeniajjhysodes* (Sw.) Rchb.f., some 20 species should be regarded as threatened. These taxa and their threats are summarized in Table 5.10.2.

At present there is no attempt at the *ex situ* conservation of threatened species, but it is likely that at least one species (*Herschelianthe barbata*) will soon be propagated from seed by flasking. It is to be hoped that this programme will be extended to the other threatened species, but because most are dry-land orchids with a pronounced dormant period they may prove to be difficult to establish and maintain in cultivation. At present all cultivation is carried out by amateurs, but it is possible that the National Botanic Gardens may take a more active interest in the future.

5.10.5.4 Case histories

1) Herschelianthe barbata -Judging from the frequency of herbarium collections, *Herschelianthe barbata* (L.f.) N.C.Anthony was once common along the margin between the hard soils at the base of Table Mountain and



Frieda Duckitt

Herschelianthe lugens

the sandy flats separating the Cape Peninsular from the 'mainland'. During the first half of this century this area was covered by suburban sprawl, and the only remaining piece of natural vegetation was along a horse race-course. This piece of habitat was destroyed some 15 years ago during the construction of dams for the race-course, and the species was thought to be extinct. Then it was discovered in a marsh some 80 km to the north, together with several of the associated species, also threatened by the transformation of the seasonally marshy, acid sandy flats along the eastern margins of the Cape Peninsular into suburbia. After a long struggle this new habitat, which was state-owned land leased to a local farmer, was declared a reserve. However, the area is threatened by invasive introduced species of *Acacia*, and the last remaining population of *H. barbata* now grows among these shrubs. Unless clearing action is taken within the next few years, this species will be extinct.

2) Schizochilusgerrardii - *Schizochilusgerrardii* (Rchb.f.) Bolus is restricted to a spur of mid-elevation grassland, penetrating into the surrounding, hot, lowland shrub of northern Natal (Linder 1980). As this spur of grassland is geographically isolated from other such ridges, this distinctive species has probably always been a narrowly endemic species. These montane or mid-elevation grasslands are extensively afforested, but *S. gerrardii* still survives in fire-breaks and in portions of the grassland not yet afforested. Further plantings could endanger the continued existence of this species, but no detailed field work has been carried out in the last 18 years to establish the present status of the species. There is a substantial number of other species which may be in a similar position, especially in the southern Natal and Transkei montane grasslands and the grasslands along the eastern Transvaal escarpment (see Table 5.10.2).

3) *Disa minor* - *Disa minor* (Sond.) Rchb.f. is a small, high-elevation terrestrial orchid that had not been collected for some decades. Consequently its status was unknown and was suspected to be endangered. However, it has recently been recollected on some high-elevation peaks and appears to flower only after fire. Although there is as yet no indication of how common it is, it is unlikely to be threatened, although it may be rare. Similar cases have been reported for a number of these high-elevation orchids, such as D. *neglecta* Sond. (Linder 1990). As these higher mountains are not presently under any threat, these orchids may be regarded as well conserved.

4) Disa scullyi - *Disa scullyi* Bolus is a terrestrial, marsh-inhabiting species, found in the mid-elevation zone of Natal along the foothills of the Drakensberg. It forms extensive populations in the boggy valley bottoms. However, it has become very rare and may even be extinct because this habitat has become extensively transformed. The main factors are a combination of damming the rivers, draining the marshy bottoms, and intensive grazing during the drought-years. There are serious needs to perform a detailed survey of the status of these bogs and to locate relatively 'healthy' bogs for conservation. The other bog-land orchids are more widespread and thus more likely to survive in a bog somewhere in a reserve.

H. Peter Linder, Bolus Herbarium,
University of Cape Town,
South Africa

Table 5.10.2 Species most threatened, and the nature of their threats. Status according to the old catagories in the *Red Data Book* is indicated in square brackets.

Disa alticola H.P.Linder (Disinae). Two large populations known. Risk medium. Afforestation.
D. amoena H.P.Linder (Disinae). Locally common, but restricted to one population in montane grassland. Risk medium. Afforestation.
D. galpinii Rolfe (Disinae). Poorly known. Risk medium. Afforestation.
D. intermedia H.P.Linder (Disinae). Single extensive population known. Risk high. Afforestation.
D. maculomarronina McMurtry (Disinae). Taxonomically uncertain. Risk medium. Forestry.
D. sanguinea Sond. (Disinae). Poorly known. Risk medium. Afforestation.
D. scullyi Bolus (Disinae). Habitat destruction, due to overgrazing. Risk high. Overgrazing and swamp-draining.
Herschelianthe barbata (L.f.) N.C.Anthony (Disinae). A single population remaining. Risk high. Alien plants in one reserve. [endangered]
H. excelsa nom. illeg. (Disinae). Single population of several plants known. Risk high. Aliens.
H. lugens (Bolus) Rauschert var. *lugens* (Disinae). Many populations extinct. Risk medium. Aliens. [vulnerable]
H. lugens (Bolus) Rauschert var. *nigrescens* (H.P.Linder) N.C.Anthony (Disinae). One population known. Risk medium. Aliens. [indeterminate]
H. spathulata (L.f.) Rauschert subsp. *tripartita* (Lindl.) N.C.Anthony (Disinae). Rare in a small area. Risk high. Agriculture. [critically rare]
H. venusta (Bolus) Rauschert (Disinae). Rare with few populations left, also with taxonomic problems. Risk high. Aliens. [uncertain]
Monadenia macrostachya Lindl. (Disinae). One small population of less than ten plants. Risk high. Grazing. [uncertain]
M. physodes (Sw.) Rchb.f. (Disinae). Probably extinct. Agriculture and urbanisation.
Pterygodium connivens Schelpe (Coryciinae). One population in the Cape Point Nature Reserve. May be a taxonomic artifact. Risk medium. Aliens. [indeterminate]
P. newdigateae Bolus var. *newdigitae* (Coryciinae). Poorly known, not seen for many years. Risk medium. Aliens. [indeterminate]
Schizochilus crenulatus H.P.Linder (Orchidinae). Restricted to one area in grasslands, risk medium. Forestry.
S. gerrardii (Rchb.f.) Bolus (Orchidinae). Restricted to and locally common in one area, risk high . Afforestation.
S. lilacinus H.P.Linder (Orchidinae). Restricted to a single area with few populations, risk medium. Forestry.
S. longipetalum Lindl. (Disinae). One good population known. Risk high. Aliens. [vulnerable]

5.11 Madagascar and surrounding islands

5.11.1 Madagascar

Madagascar is an island of 594,180 km^2 in the tropical zone of south-east Africa. The Tropic of Cancer passes south of Toliara (Tulear). The central part comprises high plateau averaging between 1000 and 1200 m in elevation. The highest mountains are Tsaratanana (2886 m), Ankaratra (2638 m), and Andringitra (2666 m). There are four climatic zones: in the north and east a tropical humid zone without a dry season; in the centre a higher altitude tropical humid zone, cooler with a distinct dry season; in the west a dry and hot tropical zone with a long dry season; and in the south a hot semi-desert with low and irregular rainfall. Humbert and Cours Darne (1965) also described a high-elevation climate with lower temperatures and abundant rainfall pertaining to a few mountains.

The primary vegetation is essentially evergreen forest in the eastern, central and north-western parts of the island, with deciduous forest in the west, and deciduous thicket in the south (Du Puy and Moat, in press). The remaining primary vegetation all over the island is the habitat of numerous orchids, with highest species numbers occurring especially in the mid-elevation eastern rain forests (700-1200 m). Much of the primary vegetation has been destroyed, with few vestiges remaining in the centre, and small percentages remaining in the west, the south and the eastern lowlands of the island. It has been replaced by impoverished grasslands subject to annual burning, where very few orchids survive. Only about 90,000 km^2 of primary vegetation remain, the largest areas surviving on the eastern escarpments (Du Puy and Moat, in press).

5.11.1.1 Present status of knowledge

The number of Malagasy orchid species can be estimated between 800-850, and most are restricted to Madagascar or to Madagascar and the adjacent islands of the Comoros and the Mascarenes. This number of species is not far short of the number of species which occur throughout the rest of continental Africa. Aubert Du Petit-Thouars (1822) described the first orchids from Madagascar. Since then numerous authors, among them H. G. Reichenbach (1885), Rolfe, Ridley (1885), Lindley, Kraenzlin, Schlechter (1925), Perrier de la Bâthie (1939, 1941), and Bosser (1970, 1971) have considerably expanded the number of species described. However, many parts of the island remain very poorly explored botanically and undoubtedly harbour additional species that await discovery.

Perrier de la Bathie (1939, 1941) published in two volumes an orchid flora of Madagascar in the *Flore de Madagascar* begun by Humbert. In the last 50 years revisions of certain genera have been published: *Vanilla* (Porteres 1954); *Graphorkis* (Senghas 1964); *Bulbophyllum* sections *Lichenophyllax, Humblotiochis, Lepiophyllax, Loxosepalum* subsection *Diphylli* (Bosser 1971); *Lemurella* (Bosser 1971); *Angraecum* (Garay 1973); *Oeceoclades* (Garay and Taylor 1976); *Microcoelia* (Jonsson 1981); *Aerangis* (Stewart 1986); *Nervilia* (Pettersson 1990). Another revision of *Oeceoclades* is being prepared by Bosser and Morat (1969). Many genera are in urgent need of critical revision, in particular the large and complex genus *Jumellea*. *A* checklist of the species combined with a full bibliography is being prepared (Du Puy *et al.*, in prep.). It will be bring together all of the species known and described from Madagascar, update the nomenclature, and provide a comprehensive bibliography. This checklist and bibliography will form the basis for further research by bringing all published names and literature references into a single book.

Apart from taxonomic studies, very few works on Malagasy orchids exist. However, some excellent pollination studies of several species have been published (Nilsson and Jonsson 1985; Nilsson *et al.* 1987).

5.11.1.2 Diversity

Madagascar has an exceptionally rich orchid flora, the vast majority of which consists of endemic species (Table 5.11.1). Several subfamilies are well represented in Madagascar. The most important is the Epidendroideae (*sensu* Dressier 1993b), especially subtribes Polystachyinae (*Polystachya*), Angraecinae (*Angraecum, Jumellea, Aeranthes*), Aerangidinae (*Aerangis*), Eulophiinae (*Eulophia, Oeceoclades*), and Cyrtopodiinae (*Eulophiella, Cymbidiella, Grammangis, Graphorkis*). The Orchidoideae are also represented by *Cynorkis, Habenaria,* and *Benthamia.* Among the Epidendroideae present are *Vanilla, Nervilia, Calanthe,* and *Phaius*. Several species of Spiranthoideae with a wide distribution also occur in Madagascar.

Madagascar is the centre of diversity for several genera, including the large genera *Angraecum, Jumellea, Aeranthes*, and *Cynorkis.* Ten genera are considered to be endemic: *Tylostigma (7* species); *Megalorchis* (1); *Imerinaea* (1); *Ambrella* (1); *Neobathiea* (4), *Sobennikoffia* (3), *Lemurorchis* (1), *Eulophiella* (4), *Cymbidiella* (3), and *Grammangis(2).*

Some genera are essentially Malagasy with one species in the neighbouring islands: *Oeonia* (4 species including one on Reunion), *Lemurella* (4 species including one on the Comoros), and *Physoceras* (6 species and one endemic to Reunion). Two large genera, *Jumellea* and *Aeranthes,* are represented mainly in Madagascar and the neighbouring islands with only a few species on the continent, and a third, *Angraecum,* has by far its greatest diversity in the region. A few widely distributed genera are also represented in Madagascar: *Bulbophyllum, Eulophia, Habenaria, Satyrium,* and *Liparis.* The affinities of the Malagasy orchid flora are essentially African except for a few Asian terrestrials *(Calanthe, Phaius)* and epiphytes *(Oberonia).*

Orchids occur in all climatic zones of Madagascar but are especially abundant in the mid-elevation rain forests of the east and the central plateaux. *Oeceoclades* has diversified in the dry formations of the west and south-west. Numerous species are currently known only from the type collections or a limited number of collections, and may be localised endemics or at least very rare plants.

5.11.1.3 Threats

The orchids of Madagascar are under considerable threat from continued habitat destruction or degradation. Within the past two or three decades vast areas of the natural forest and thicket throughout the island have been destroyed or seriously degraded by human activity. This trend continues with the desperate and ever increasing demand for land by the impoverished populace (Madagascar is one of the poorest countries in the world in terms of GNP), and the production of charcoal which is still used exclusively for cooking by almost the entire population. Madagascar has an extensive network of protected areas, in which the mid-elevation rain forest is generally well represented. However, actual protection is often minimal, and illicit exploitation is known to take place within many protected areas. It is also evident that the existing protected area network is inadequate to include anything but a limited fraction of the biodiversity of Madagascar.

Habitat fragmentation poses an additional threat. The biology of most species is too poorly known to determine whether existing populations of particular species isolated within the fragmented vegetation cover are viable in the medium to long term.

An extensive internal network trading in wild-collected plants exists within Madagascar, although little work has been done to evaluate the extent of this threat. The other major threat derives from the collecting and export of plants of the horticulturally attractive species of *Angraecum, Aerangis, Oeceoclades,* etc., leading to the disappearance of entire populations. Cases of international trade in wild-collected Malagasy orchid species come to light from time-to-time.

There can be little doubt that many individual species have become extinct in recent years, due to a combination of the factors mentioned above, and the survival of many others currently hangs in the balance. To date, a reliable list of threatened species has not been produced, nor is it feasible to do so given the current level of knowledge of the flora in most parts of the island. The orchid checklist being produced at Kew will provide an up-to-date list of known species, making the task of assigning threats to the species much more feasible.

5.11.1.4 Case histories

Among the taxa known to be threatened in the wild are *Angraecum sesquipedale* Thouars and *A. eburneum* Bory subsp. *superbum* (Thouars) H. Perrier, but these are widely cultivated by orchid hobbyists and are used in breeding. On the other hand, *Eulophiella roempleriana* Schltr. and *Cymbidiella flabellata* Rolfe are less easy to cultivate and certainly more endangered. Plants that grow in particular conditions or in limited areas are also in danger, such as *Cymbidiella pardalina* (Rchb.f.) Garay and *C. falcigera* (Rchb.f.) Garay; *Angraecum viguieri* Schltr. from Andasibe (Perinet), *A. magdalenae* Schltr. from Mt. Ibity, and *A. eburneum* subsp. *superbum* var. *longicalcar* Bosser, which has been totally eradicated from the type locality; *Grammangis ellisii* Rchb.f., sporadic in the eastern forests, and the rare *G. spectabilis* Bosser & Morat, sighted only in the dry forest of the Sakaraha region and now in rapid decline; *A. leonis* Veitch is known from few sites in the west and north and *Aeranthes henrici* Schltr. is now confined to relict populations in western forests.

5.11.1.5 Conservation efforts

Support and development of the existing protected areas are vital components of conservation activities in Madagascar, and recent efforts on the part of the Malagasy authorities and international bodies in this regard are welcomed. In particular, the improvement of the actual level of protection of Parks and Reserves, and the integration of conservation activities with rural development have been seen as priorities. Initiatives to

Phillip Cribb

Angraecum viguieri

increase the land area under protection have been in progress for a few years, and are being based on balanced biological and socio-economic criteria.

Little effort has been given to the establishment of rescue operations. Orchids on fallen trees in areas being cleared could be collected and transplanted in nearby protected habitats or else distributed and cultivated in botanical gardens. This activity should be coupled with development of local capacity to cultivate and propagate orchids, and other forms of *ex situ* conservation. Such an action would probably save certain orchid species and facilitate inventory for monographic and floristic studies.

An orchid cultivation project at the Parc de Tsimbazaza, Antananarivo, is using wild-collected seeds, germinated and grown initially in the laboratories at the Royal Botanic Gardens, Kew, to provide a legitimate source of cultivated specimens. The aim is to reduce collection pressure on the wild populations and encourage *ex situ* conservation through widespread cultivation.

Probably the greatest challenge for successful long-term sustainable conservation is to increase the awareness of the population at large of the value of Madagascar's exceptional biodiversity, in particular economically valuable plants such as orchids and medicinal species. However, this has to be coupled with appropriate economic development that will provide alternatives to the destructive practices prevalent in Madagascar.

5.11.1.6 Conclusions and recommendations

It is likely that many species still remain undescribed in Madagascar, and for many species which are known there is very little information about their rarity and distribution. This lack of precise information about current orchid distributions, and about their biology, coupled with the rapid degradation of the forests in Madagascar, makes it impossible to assess accurately which species are threatened or extinct. It is critical that renewed effort is made to address this problem and to use the available knowledge to provide as much protection as possible for the main orchid habitat types in Madagascar. Revisionary work and the assignation of threat categories should be assisted by the new orchid checklist and bibliography (Du Puy *et al*, in prep.).

1) A priority should be to assess the conservation status of as many species as possible. The remaining known populations of species already recognised as rare and endangered, and of the endemic or nearly endemic genera, should be assessed. Efforts should also be made to relocate and assess populations of selected species currently only recorded from one or a few restricted sites. Priority taxa include *Angmecum* (especially the large-flowered species such as *A. sesquipedale, A. eburneum* subsp. *superbum,* and var. *longicalcar, A. viguieri, A. magdalenae,* and *A. leonis), Aeranthes* (selected species e.g. *A. henrici), Aerangis* (selected species), *Jumellea* (selected species), *Eulophiella, Cymbidiella, Grammangis, Neobathiea, Sobennikoffia, Oeonia, Oeoniella, Oecoclades, Ambrella, Lemurella, Lemurorchis, Imerinaea, Beclardia, Megalorchis, Tylostigma, Physoceras,* and *Vanilla.*
2) The conservation of habitats of known importance for their species diversity, including orchids, which are restricted and are not adequately represented in the current system of protected areas, should be implemented. Such areas include the quartzite Itremo Massif in west-central Madagascar and its associated marble (cipolin) outcrops, the very few remaining coastal forests on the humid eastern seaboard, and areas around the main towns such as the Montagne des Français near Antsiranana (Diego Suarez) and the forests around Taolanaro (Fort Dauphin). These will all provide an important touristic resource for the future, the loss of which would not only damage the rare species which occur there but also the potential economy derived from tourism.
3) Further availability of seed-raised plants should be ensured to allow the dissemination of the species in botanical gardens and orchid collections for *ex situ* conservation. It must be assured that following any sale of plants derived from Malagasy species, a proportion of the sale profits will be returned to Madagascar. In this way the native forests of Madagascar, which hold the wild stocks, will gain value locally as a natural resource to be protected.
4) Renewed inventory work, focusing exclusively on orchids, should be undertaken in all vegetation types. The vegetation types, and the remaining areas of each vegetation type, should be identified using the electronic mapping (GIS) system and the derived maps developed for conservation planning in Madagascar by Du Puy and Moat (in press). Areas of importance for orchids, either as restricted vegetation types (e.g. eastern coastal forest on sand or on laterite), areas of high diversity, and areas of high local microendemicity, should be identified.
5) Taxonomic revisions of problematic genera should be commenced, particularly of the large and varied genus *Jumellea.* The genera *Angraecum* and *Aeranthes* contain species of horticultural importance which are subject to exploitation in the wild and would also be candidates for full revision.
6) Internal trade and exportation of wild-collected orchids, both overt and illicit, should be investigated

Table 5.11.1 Numbers of genera, species, and endemics of Madagascar. Classification follows Dressier 1993b.

Taxon	Genera	Species	Endemics
Aerangidinae	7	32	21
Aeridinae	1	1	0
Angraecinae	10	200	180
Bletiinae	2	13	12
Bulbophyllinae	1	150	140
Coryciinae	1	16	10
Cyrtopodiinae	6	50	40
Disinae	2	6	3
Gastrodiinae	2	2	2
Goodyerinae	5	16	11
Habenariinae	7	150	120
Malaxideae	3	44	40
Nervilieae	1	8	3
Podochilinae	1	1	0
Polystachyínae	2	21	17
Satyriinae	1	5	3
Tropidieae	1	1	0
Vanillinae	1	7	6
Total	54	723	608

and appraised, and measures introduced to reduce them. Any local nurseries which produce artificially propagated plants should be identified, monitored, and encouraged. Studies on breeding systems and pollination biology should be started to ensure that we understand the sizes of populations and the areas of forest which are needed to ensure the survival of species in the wild.

7) Continued efforts should be made to reduce the need for local people to cut the forests for agriculture and charcoal. Ecotourism should be a viable industry for the region, and with proper management a share of the profits should be ensured for the local community.

J. M. Bosser, Museum National d'Histoire Naturelle, France (translated by Jean-Jacques Beguin);
David Du Puy, Royal Botanic Garden, Kew, UK; and
Pete Phillipson, Botany Department, Rhodes University, South Africa

5.11.2 Comores Islands

Perrier de la Bathie (1939) described 60 species (27 endemics) among 36 genera in his *Flore de Madagascar*. Studies there since then have been few, so that the orchid flora is still poorly known. The floristic links with Madagascar are evident in the presence of species of *Angraecum*, *Cynorkis*, *Jumelka*, *Aerangis*, *Aeranthes*, and *Bulbophyllum*. As in Madagascar the forests are threatened. In Anjouan, an island with a dense population, deforestation is practically total. In the Karthala mountains of Grand Comore, one of the few areas with original forests, logging is in progress. The forest remnants on the islands of Mayotte and Moheli should be protected.

5.11.2.1 Recommendation

Urgent floristic and conservation assessments of the flora of the Comores, including its orchids, are needed, and a conservation management plan implemented.

5.11.3 Mascarene Islands

The Mascarene Islands, situated some 900 km east of Madagascar, include the islands of Mauritius, Reunion, and Rodrigues. Covering only some 4500 km^2, they are still very rich in orchids, although sadly many species are either Extinct or severely threatened with extinction. In fact on Mauritius, out of 89 recorded taxa, 24 of these are Extinct, with all the rest (apart from a handful of very versatile species) threatened (Strahm 1994). Rodrigues, although a smaller and drier island with a depauperate orchid flora, has lost about the same percentage of species: of the seven orchid species native to the island, two are Extinct and all the rest either Endangered or Vulnerable (Strahm 1989). As more native wet forest still exists on Reunion, the orchid flora is in a much better state, although out of 95 taxa, over 20 species are still threatened or even Extinct (Strahm 1994).

5.11.3.1 Diversity

The orchids of these islands were first described by Moore (1877) in *Flora of Mauritius and the Seychelles* and by Jacob de Cordemoy (1895) in *Flore de La Reunion*, and a revision of Orchidaceae is currently being undertaken by Bosser for the *Flore des Mascareignes* (Bosser, in prep). However preliminary revisions indicate that there are over 100 orchid taxa native to the Mascarene Islands, and although endemism for each island is relatively low, when the Mascarenes are taken together as a whole about half of the taxa are endemic (Strahm 1994; see Table 5.11.2).

Principal genera are *Angraecum*, *jumellea*, *Aeranthes*, *Cynorkis*, *Benthamia*, *Habenaria*, and *Liparis*, clearly Madagascan in their affinities. *Arnottia* is considered endemic, and *Hederorkis* has two species, one in Mauritius and one in the Seychelles. Of interest is that when the distribution of Mascarene Orchidaceae is examined, most species (94%) are endemic to the Madagascar-Mascarene region (much more than the 51% endemic to the Mascarenes), with very few species found farther away. In addition endemism of orchids on each island is much

Table 5.11,2 Approximate number and distribution of native Mascarene orchids (number of endemic taxa in brackets).

Total taxa (% Masc. endemism)	Mauritius	Reunion	Rodrigues	Mascarene	More wide-spread
107(51%)	89(9)	95(13)	7(1)	32	52

lower (between 10 and 14%) which indicates that there seems to be some movement between the Mascarene Island populations but very little movement outside of the Madagascar-Mascarene area (Strahm 1994).

5.11.3.2 Threats

Reasons for the decline include initial habitat loss for agriculture, followed by habitat degradation by the introduction of alien plant species which now form virtually monotypic stands, destroying forest habitat and microclimates. Introduced animals have also taken their toll, either affecting orchids indirectly (by altering the native vegetation) or directly (through predation). For example, in Mauritius, monkeys were introduced about the same time that people first inhabited the islands (in the 16th century), and have been observed pulling epiphytes off trees in a sort of 'joie de vivre'. Deer, introduced to all three islands (although fortunately now extinct on Rodrigues), have played a major role in depressing native regeneration. Since the islands had no herbivores prior to human colonisation (apart from the giant tortoises which disappeared soon after people arrived), the native species have few defences against mammalian predators. Deer and introduced pigs have been observed to eat and root up terrestrial orchids, respectively, and cause untold damage to native vegetation. Finally, in Mauritius, illegal collecting (all orchids on Crown Land are protected by Mauritian law) of the tiny remaining orchid populations is having an impact.

5.11.3.3 Case histories

Although too many threatened species exist in the Mascarenes to name each seperately in this work, a few notable cases should be mentioned. *Angraecum palmiforme* Thouars, like some other species, was once considered Extinct but was rediscovered recently on Reunion, which shows that some species may still exist, and further research is needed. *Graphorkis scripta* Lindl., on the other hand, is Endangered on Reunion, and collected for the last time in Mauritius in the 1950s, where it was cultivated in the Conservator of Forest's garden. However, both he and the plant have disappeared, and the orchid has not been seen on Mauritius since despite intensive searches. This species is also found on Madagascar (although is probably different), and on Reunion where it is Endangered. Finally, a very beautiful but rare orchid on Mauritius is *Bedardia macrostachya* (Thouars) A. Rich., and although it is also found on Mauritus and Madagascar, it requires special measures for protection on Mauritius where it is found only in the tiny patches of montane cloud forest which remain. These are only a few examples of very rare orchids in the Mascarenes, but give an idea of the many orchid species at the brink of extinction in the region.

5.11.3.4 Current conservation action

On Mauritius most of the little remaining forest has been protected as nature reserves, and some management is being undertaken to exclude introduced plants and animals. On Reunion the low-elevation forest has almost entirely disappeared, but in the higher elevations one can still find some of the original vegetation, and nature reserves are in the process of being proclaimed. Rodrigues, being drier, has a much smaller orchid flora, and no intact native vegetation remains on the island. However, two small nature reserves have been declared, and some management (fencing, weeding, and replanting of indigenous species) is being undertaken.

5.11.3.5 Recommended actions

The work already underway in the Mascarenes needs to be expanded and, where possible, introduced species eradicated or controlled. In particular high cloud forest, an extremely threatened vegetation type on Mauritius, found only at Mt. Cocotte and the summits of a few other high mountains, needs to be carefully managed, including removal of alien species (mainly guava and privet) and, in some cases, the judicious reintroduction of species. A strategy for the conservation of all the extant orchids on the Mascarenes needs to be written on a species-by-species basis (something which is possible as the flora is relatively well known), and gaps in the knowledge need to be filled by further field work. Finally, the process of declaring more nature reserves on Reunion (at the moment only one tiny nature reserve exists) needs to be accelerated and appropriate management measures undertaken.

5.11.4 Seychelles Islands

The Seychelles Islands include some 100 small islands. According to Francis Friedmann (pers. comm.), 21 species belonging to 17 genera exist. Apart from *Vanilla phalaenopsis* Rchb.f., all are threatened. The Seychelles government has created nature reserves on some of the islands which should help to conserve the native orchids, although an increased focus on the native orchids to ensure that viable populations of each species are found in a managed protected area is needed. As in the Mascarene Islands, introduced and invasive species are a threat to the native vegetation, and control measures are needed.

Wendy Strahm, IUCN/SSC, Switzerland; and
J. M. Bosser, Museum National d'Histoire Naturelle, France

5.12 Australia

The Australian continent including Tasmania covers an area of c. 8,000,000 km^2 and as a political unit encompasses a number of significant off-shore islands. This treatment is confined to the continental unit of Australia and its seven states comprising Western Australia, Northern Territory, Queensland, New South Wales, Victoria, Tasmania, South Australia, and the Australian Capital Territory.

The vegetation of the continent is highly variable and includes tropical, desert, mediterranean, temperate, and alpine units. Over two-thirds of the continent is desert to semi-desert dominated by sparse woodlands of mimosoid trees and shrubs, to open savanna communities of perennial grasses (*Plectmchne* and *Triodia* species). In the arid zone there can be a seasonal, often spectacular abundance of therophytes depending on rainfall patterns. The south, south-west, north, and eastern margins of the continent are generally wetter and support a diverse and highly endemic flora. Tropical rain forests are scattered on the eastern and north-eastern fringes with temperate rain forests in the south-east and much of the western and higher-elevation areas of Tasmania. The tropical rain forests of Queensland are noted for their diverse and highly endemic tree floras. Arid tropical savanna and monsoonal forests occur along the northern and extreme north-west of the continent with isolated rain forest/vine thicket communities in river valleys and on specialized soils. The south-west of Western Australia is the largest area of mediterranean type climate and remarkably speciose, containing in excess of 8000 of the 25,000-30,000 plant species for the continent.

5.12.1 Present status of knowledge

Floristic knowledge is variable across the continent. Comprehensive state Floras have been published for South Australia, Tasmania, New South Wales, Australian Capital Territory, and Victoria, whereas only regional Floras are available for parts of Queensland, Western Australia, and the Northern Territory. Checklists are available for the latter three. In addition, the comprehensive *Flora of Australia*, launched in 1981, aims to replace Bentham's (1863-1878) seven-volume *Flora Australiense* with some 50 volumes. Interestingly, the number of species in the Australian vascular flora treated by Bentham last century was 8125. It was estimated to be "over 20,000 species in 1981, but the recent surge of taxonomic work indicates that a minimum of 25,000 species is more likely. The number of known eucalypts, for example, has risen from 500 to 800+ in less than two decades.

In addition to comprehensive floristic publications, monographic treatments of selected taxa have been published for many Australian taxa in both the formal taxonomic literature and as popular field guides and handbooks. Because of their popularity, the orchids have received substantial attention. Again, Australian orchids have been the subject of a new age of discovery over the past few decades as botanists, often for the first time, have conducted comprehensive studies of living orchid populations across their geographic range and continued to unravel confusion surrounding the identity of orchids named last century by European and British botanists. Invaluable collaboration between many amateurs and professional orchidologists in this enterprise has revealed an extraordinary number of undescribed species (e.g. Jones 1991; Hoffman and Brown 1992).

The most recent comprehensive treatment of Australian orchids (Jones 1988) treats about 700 species in 110 genera. An additional 100 species have been described and/or discovered since then. Most states and some regions have popular handbooks covering their orchids, with especially noteworthy recent full-colour treatments for South Australian orchids by Bates and Weber (1990) and for south-west Australian orchids by Hoffman and Brown (1992).

Australian orchids are found mainly on the wetter continental margins flanking the central and western arid zone. The majority are South Temperate zone terrestrials, but epiphytes and lithophytes occur in the eastern and northern rain forests and vine thickets. About 90% of the terrestrial species are endemic to Australia, whereas the epiphytes show only 60% endemism, with many species occurring in rain forests on adjacent islands and beyond. This reflects the history of vegetation in Australia and adjacent regions. Rain forests dominated the region from the Cretaceous through much of the Tertiary over the past 100 million years; conditions that led to the drying of most of the continent began less than 10 million years ago as Australia drifted northward away from Antarctica into its present position. Rain forest plants became marginalised, and opportunities for plants adapted to temperate, semi-arid, and arid climates expanded. Consequently, explosive recent speciation occurred among tuberous terrestrials, especially those in south-western Australia. Some of the most speciose terrestrial genera, such as *Caladenia, Pterostylis,* and *Diuris,* each have more than 100 species. In contrast, most rain forest genera are much smaller.

In terms of relationships, the rain forest epiphytes include large pantropical genera such as *Bulbophyllum, Dendrobium,* and *Cymbidium.* There are some small Australian epiphytic genera that are endemic. In contrast, most of the large terrestrial genera are endemic or nearly so, representing a Gondwanan stock of diurid orchids whose affinities are with orchids found either in Africa (e.g. *Diuris)* or across the Pacific in New Zealand, New Caledonia, and South America (e.g. *Caladenia).* There are a few temperate terrestrial genera with tropical congeners to the north of the continent (e.g. *Cryptostylis, Corybas*) and many small endemic terrestrials with clear Australian origins.

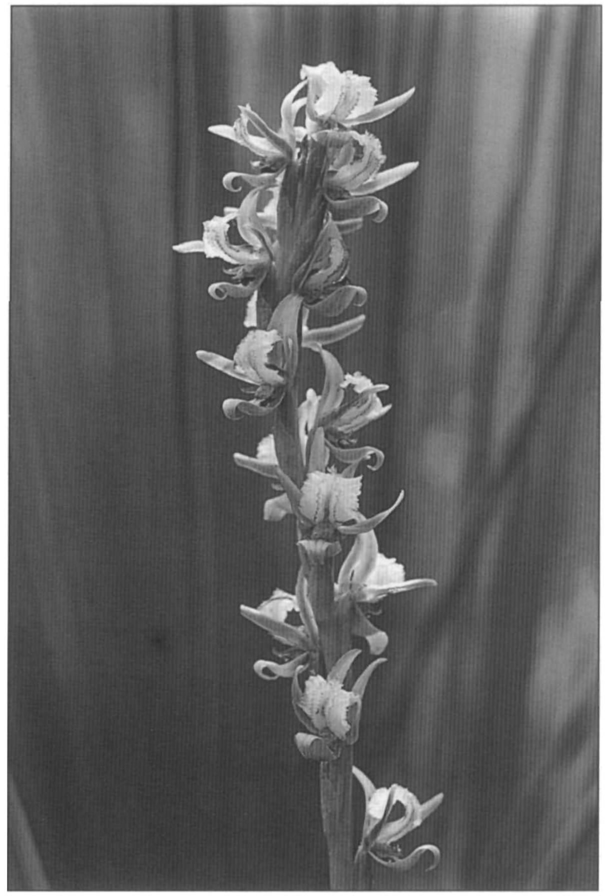
5.12.2 Legislative protection

Each state government has sovereignty over its respective flora and is the main authority exercising legislative control and protection over biological elements within the state. Similarly, the consistency of definition and scientific rigor applied to deriving the conservation status of plant species varies among the state agencies responsible for plant conservation. Federal control involves the administration of international treaties and conventions on biodiversity, etc. such as CITES and through federally funded endangered species programmes.

A degree of uniformity of approach has been achieved with the introduction of a national system of rare flora classification which includes orchid species. This system is administered by the National Endangered Flora Network of the Australian and New Zealand Environment and Conservation Council (ANZECC). The most recent list (Australian Nature Conservation Agency, June 1993) represents research and assessment efforts by botanists from state, territory, and federal agencies. This list is based on an earlier list prepared by Briggs and Leigh (1988). The national listing is interim and is proposed to be updated regularly. The conservation status of taxa indicated on the national listing is not necessarily the same as state listings and carries little legislative protection for the listed taxa.

5.12.3 Diversity

The geographical isolation of Australia may explain the high levels of endemism recorded for the region. Terrestrial taxa are the most noticeably endemic with 88% restricted to the continent, whereas 59% of epiphytic taxa are endemic (Jones 1988). *Caladenia, Diuris, Prasophyllum, Pterostylis,* and *Thelymitra* are the largest of the terrestrial genera for the continent and have a higher proportion of endemics, whereas the larger epiphytic genera — *Bulbophyllum, Dendrobium, Eria,* and *Liparis* — are widespread in other countries, particularly those in south-east Asia. Similarly, the terrestrial groups represent a larger proportion of endemic genera than found for the epiphytes. The south-west of Western Australia is the area with the highest recorded levels of generic and species endemism for terrestrial species, having 85% of species restricted to the state.



Alec Pridgeon

Prasophyllum fimbria

Epiphytic and lithophytic taxa are restricted to moister zones along the east coast from Queensland to Tasmania (two species) and along the northern coast of the Northern Territory, west to the Kimberley region of Western Australia. Only South Australia lacks epiphytic species. The epiphytic taxa are dominated by *Dendrobium* and *Cymbidium*, which are the most widespread genera and found in all states with epiphytic representatives. The richest zone for epiphytic taxa is in the moist tropical and monsoonal regions of north-eastern Queensland associated with dense rain forests. A remarkable taxon is the predominantly lithophytic *Dendrobium speciosum* Sm. which can tolerate extremes of climate and abject plant poverty well out of the range of most other epiphytic orchids.

The sclerophyll woodlands, forests, wetland, and heathland communities of the south are the centres of distribution for herbaceous terrestrial species. These geophytic plants enter seasonal dormancy in summer when soil conditions are too dry for growth. Most of the taxa are linked to the moist coastal margins and become less abundant and diverse with distance from the coast. The herbaceous terrestrials grow in a wide variety of soil types, from acidic to calcareous soils and depauperate to high-organic soils. Habitats range from coastal scrub, seasonally inundated wetlands to dry sclerophyll forests and, in recent times, exotic pine plantations. One species, *Spiculaea ciliata* Lindl., is remarkable for its ability to use the enlarged, nutrient-filled flower stem to sustain flowering and seed set into summer when surface temperatures of its favoured moss swards are in excess of 60°C. In contrast, a small and interesting group of terrestrial species occur in specialized habitats in the alpine zone in eastern Australia.

An interesting quality of Australian terrestrial species is their sheer abundance in many habitats to the point where the ground will be carpeted with colour. This phenomenon is well developed in south-west Western Australia where many of the most colourful species (e.g. *Caladenia flava*, *Diuris* spp.) are intensively clonal, so that plants can cover many square metres.

The tropical terrestrial species from northern Australia initiate growth in summer at the onset of the monsoon or wet season. The number of species is few compared to southern taxa; except for *Calochilus* and *Dipodium*, almost all taxa are restricted to the tropical zone. The terrestrial orchid flora of this region is dominated by the widespread genus *Habenaria*. These orchids can be locally abundant and occur across a wide range of habitats including woodlands, savanna, and wetlands.

5.12.4 Ecology

Orchid biology plays an important role in defining rare status. Cryptic species such as the totally subterranean species, *Rhizanthella gardneri* R.S.Rogers, or species which depend on fire for flowering, e.g. *Diuris purdiei* Diels, are listed as rare and threatened, but their growth characteristics make it difficult to assign an entirely accurate conservation status to them.

The complex and critical association orchids have with microbes, pollinators, and other non-orchid plants sets orchids apart from the habitat conditions governing growth of other plant groups. All orchid species are mycorrhizal at some stage of their growth and development cycle with high levels of fungal specificity recorded at the generic and specific (*Pterostylis*) levels (Ramsay *et al.* 1986, 1987). For most terrestrial species there is a special requirement for a particular endophyte in the germination and establishment phase in the wild. The importance of the seedling endophyte for subsequent growth and survival of the adult plant is not clearly understood for some genera such as *Thelymitra* and *Diuris*. These genera may be able to utilise common soil-borne fungi, whereas *Caladenia* and related genera have a specific requirement for specialized fungal types. There is an easily demonstrated and near absolute requirement for a mycorrhizal association in the so-called saprotrophs or 'green leafless' orchids such as *Dipodium*, *Rhizanthella*, and *Gastrodia*. In these species, a consistent association with a specialized fungus appears to be necessary for the survival of the adult plant and directly relates to the difficulty of growing most of these saprotrophic orchids. The complexity of the fungus interaction in orchids is typified by the underground orchid, *Rhizanthella gardneri*. This plant has a specialized fungal associate which links the root system of the broom honeymyrtle *(Melaleuca uncinata)* with the orchid, a process known as epiparasitism. *R. gardneri* therefore depends for its existence on maintaining two other non-orchid organisms in a healthy and symbiotically effective state.

5.12.5 Threats

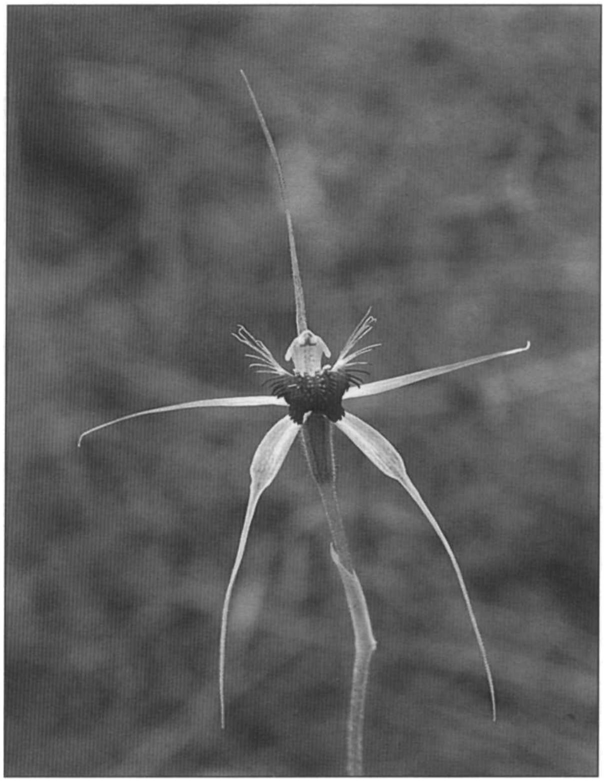
The greatest areas at risk are the epiphyte- and terrestrial-rich zones in north-east Queensland, New South Wales, and south-west Western Australia. In some states such as Victoria, the extensive clearing of almost 60% of the state has consigned once common taxa to rare status. Similarly, narrow endemics in the south-west of Western Australia comprise a proportion of the endangered taxa. However, in some of these cases the long periods of habitat alienation mean that it is difficult to ascribe endangerment simply to widescale clearing of a common habitat or the intrinsic rarity of a taxon. For epiphytic taxa in Queensland and New South Wales, clearing of rain forests for agriculture and urban development, overcollection by enthusiasts, and commercial exploitation have resulted in significant reduction in almost all epiphytic species. Overcollection of *Phaius tankervilleae* (Banks ex L'Hér.) Blume, a beautiful and distinctive terrestrial species from swamps in eastern Australia, has driven this once common and widespread species into isolated habitats.

Clearing and earth-moving, including road-building and maintenance activities in herbaceous terrestrial orchid habitats, can have a number of flow-on impacts. Particularly in south-west Western Australia, alienation of habitats has been caused by salination, eutrophication, altered fire regimes, encroachment by weed species, and spread of diseases. Disease is a recent phenomenon in southern regions from Victoria to south-west Western Australia. Key agents of disease are *Phytophthora* species and fungal stem-cankers. Although terrestrial orchid species are not directly affected by many of these diseases the permanent alteration in the abundance and composition of tree and shrub communities resulting from the often severe impacts of some of these diseases inevitably leads to decline in orchid numbers. Other than quarantining, there are no simple remedies for control or reinstatement of diseased habitats and their attendant orchid flora.

5.12.6 Management

In situ conservation of terrestrial orchids in most orchid groups is therefore dependent on maintaining a specific and potentially complex association with mycorrhizae and other synergistic associates. At present there are few systems available for managing mycorrhizae in wild situations, and most information relates to non-orchid fungi, e.g. vesicular-arbuscular mycorrhizae, ericoid mycorrhizae, and ecto-mycorrhizae of tree and shrubs. Until management prescriptions are able to determine the presence and vitality of fungi mycorrhizae in orchids and their habitats, it remains problematical if habitats can be effectively managed for target groups such as orchids. Studies are underway using molecular methods to determine the specificity of fungi with orchids and the relationship between fungal and orchid distribution. Outcomes of these studies will improve definition of orchid habitat criteria and lead to improving methods for orchid management.

Studies of orchid pollination syndromes have shown that there is a wide and diverse array of relationships in Australian orchids, particularly in terrestrial species where many of the associations are unique in the plant kingdom. Pollination interactions include:



Alec Pridgeon

Caladenia huegelii

- insect and floral mimicry (*Drakaea* and *Diuris*, respectively),
- nectar reward (*Prasophyllum*),
- pseudo-pollen (*Thelymitra, Caladenia*),
- scent (*Thelymitra*).

At present there are no examples where a management prescription for protecting an orchid has developed methods for sustaining orchid pollinators. Research of pollination syndromes in *Drakaea, Caladenia*, and *Diuris* has shown that the orchid provides little or no reward for the insect visitor (Stoutamire 1974a, 1975, 1981, 1983; Peakall 1990). For survival of a pollinator in a conservation reserve the correct balance of vegetation needs to be maintained to ensure sustenance and breeding opportunities for the insect associate. Little is known of the life cycle, mobility, and specificity of insect pollinators in nature, and only crude attempts can be made to design reserves and management prescriptions for managing orchid pollination agents.

5.12.7 Conservation status of Australian orchids

At present five taxa are presumed extinct, 44 endangered, and 73 vulnerable in Australia (Table 5.12.1). The present conservation listings of orchids are in a state of considerable flux as a result of ongoing inventory and monitoring work compounded with intense taxonomic revisionary studies occurring in many of the major orchid groups in Australia. In most states there are very active amateur native orchid groups with strong conservation ethics which affiliate with the national organizing body, the Australian Native Orchid Society. These groups, some with many hundreds of members, contribute volunteer assistance in searching and protecting orchid habitats across the country. Support for taxonomic and conservation studies on Australia species is also provided by the Australian Orchid Foundation; research support by this organization has been responsible for significant advances in conservation of native orchid species and their habitats.

Many other aspects of the unique qualities of Australian terrestrial orchids remain to be investigated. However, it is clear that the diversity of form and function requires broader concepts of conservation than are presently applied to conservation of other flowering plants. For example, since many terrestrial orchids share a symbiotic relationships with soil bacteria, managing wild orchids also requires an understanding of their fungal and bacterial partners (Wilkinson *et al.* 1994). Specific associations with pollinators or non-orchid plant species for nutrients or pollination provides further examples of the need for 'total system' conservation.

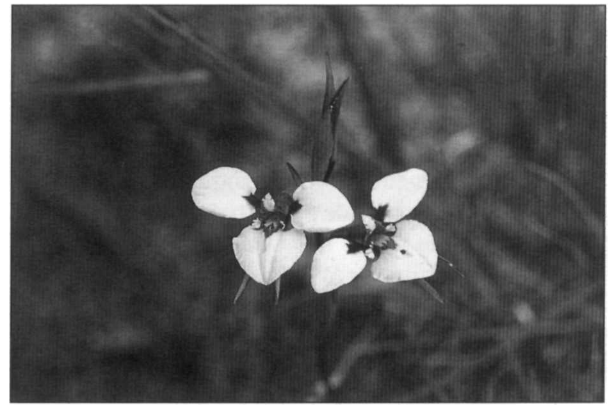
There have been a number of projects, mostly in the last 15 years, which have concentrated on the conservation and biology of Australian orchids. Conservation studies have involved investigation into the distributional status and *ex situ* conservation of terrestrial and epiphytic species and have used volunteer, federal- (through the Endangered Species Program of the Australian National Parks and Wildlife Service) and state-funded programmes. Non-government funding also plays a role in conservation, both *ex situ* and *in situ*. The Australian Orchid Foundation and the World Wide Fund for Nature have sponsored a number of investigations into the biology and status of key rare and endangered orchid species and habitats. Though the number of studies on orchids is not great, they are nonetheless significant in evolving benchmark data applicable to the broader issues facing orchid conservation.

5.12.8 Propagation methods

Seed propagation of epiphytic species is straightforward, and, depending on taxa, complete media such as Knudson's C or Fetherston's Orchid Formula (Jones 1988) are quite satisfactory. Additives to these media can include banana homogenates and coconut milk. For terrestrial species considerable progress has been made in the last 20 years in the development of *in vitro* and *in situ* seed propagation as well as tissue culture from flower stem sections. Following the pioneering work of Warcup (1973), Clements and Ellyard (1979), and other professional and amateur researchers, we now have fast and reliable methods for symbiotic (mycorrhiza-assisted) and asymbiotic (non-fungal) germination. Recent research by Collins and Dixon (1992) has established the first non-destructive method for *in vitro* cloning of terrestrial species. Using sections of the inflorescence stem of *Caladenia*, *Diuris*, and *Thelymitra*, parent genotypes can now be cloned with the added advantage that some taxa, e.g. cloned plants of *Diuris*, grow and flower more quickly than from seed.

5.12.9 Case histories

1) Diuris purdiei - *Diuris purdiei* Diels is a non-clonal species to 20 cm tall with a basal cluster of up to eight twisted leaves to ten cm long. Flowers are conspicuous, yellow with brown spots. The species is hemi-cryptic in its vegetative phase, flowering in the spring following a summer bushfire. Probably once common in the coastal plain south of Perth, Western Australia, the selective draining and clearing for agriculture and urban development of swampy habitats favoured by the species has reduced the known population of plants to less than 500 individuals.


Alec Pridgeon

Diuris purdiei

Conservation of this species is perilous as the majority of known plants occur in the Perth metropolitan region where rapid urbanization is leading to destruction of likely habitat with remnant areas subject to decline in habitat quality as a result of weed encroachment, changes to soil drainage, and general degradation resulting from human and feral animal activity.

Joint research undertaken by Kings Park and Botanic Garden and the Western Australian Department of Conservation and Land Management resulted in production of a species management plan which addresses the phenology, pollination ecology, genetics, propagation requirements, and mycorrhizal associates of the species. The plan is to guide the future management of the species in a way which will ensure its long-term existence in nature.

Seedlings have been produced by symbiotic germination procedures and plantlets produced via tissue culture of sections of inflorescences. Plants from seed were reintroduced into secure sites in 1991, and initial results indicate some success with establishment of plants into the reintroduction sites. However, the lack of dedicated funding limits any further research of this species and monitoring of reintroduction sites.

2) Rhizattthella gardneri - First discovered and described in 1928 from the wheatbelt region in the mid-south west of Western Australia, the underground orchid *Rhizanthella gardneri* R.S.Rogers is cryptic and produces no obvious above-ground signs. The other species in the genus, *R. slateri* (Rupp) M.A.Clem. & P.J.Cribb, is a hemi-cryptic species of eastern Australia found some 3000 km from the western species.

All discoveries of *R. gardneri* up to 1979 were purely accidental and resulted from clearing or farming activities. It is therefore not surprising that with the known range of the species confined to the sandy loam soils of the wheatbelt (near Corrigin) and south coast region (near Munglinup) of Western Australia that the major threat to the species is extensive clearing of habitat. Up to 95% of the probable range of the species has been cleared in the wheatbelt region, and bushland remnants containing the orchid are geographically and biologically isolated. Two of the three locations on the south coast occur on state-owned land within good-quality bushland, and the third is on private property.

The species grows in association with thickets of the broom honey myrtle (*Melaleuca uncinata*) with which the orchid is known to have an epiparasitic relationship (Warcup 1985). The orchid has an underground fleshy rhizomatous tuber and produces a subterranean, terminal capitulum of up to 150 small flowers protected within elongated, fleshy bracts. The species is clonal and persistent in a location and produces up to three daughter tubers subapically on a flowering plant. Termites (Dixon *et al.* 1990) and gnats (George 1980) are known pollinators. Seeds are produced in a fleshy fruit which takes five to six months to mature. In all specimens examined the fruits remain *in situ* and eventually decay to release the seeds. No seed dispersal agent has been observed in nature, although native marsupials are likely.

The species has been propagated by sowing seed of the orchid adjacent to inoculated root systems of potted one- to two-year-old plants of the broom honeymyrtle. Plants flower about 18 months after sowing.

During a 1981-1982 study sponsored by the World Wide Fund for Nature (Dixon and Pate 1984), methods were developed to locate the orchid and satellite imagery used to map likely habitats in the south-west of Western Australia. Visits to probable sites were facilitated by the knowledge that the species always associates with the broom honeymyrtle *(Melaleuca uncinata)* — a common and widespread species across southern Australia often occurring in dense thickets. As a result of the extensive field programme involving up to 35 volunteer assistants at a time, 150 plants were found in four locations, bringing to six the total number of known populations of the orchid.

Three of the six locations are nature reserves; two of these are focused on protecting the orchid. The remaining three sites are unvested reserves, and one locality is on private property. With prudent management, this orchid has a good chance of surviving. The lack of suitable seed dispersal agents (thought to be native marsupials) in some of the reserves is a concern, and genetic studies are needed to determine clonality and diversity in remnant populations, particularly in the wheatbelt populations.

3) Drakaea elastica - *Drakaea elastica* Lindl. is the rarest of nine species of a genus known as hammer orchids endemic to south-western Australia, among the most advanced in floral evolution toward insect mimicry. The labellum of the solitary flower is hinged and insectiform, resembling the flightless females of flower wasps (thynnids). The male wasps typically pick up females emitting sexual pheromones and mate in flight prior to feeding on nectar. *D. elastica* emits a pseudo-pheromone and deceives male thynnids into clasping the labellum, attempting to fly away, and being hurled upside down against the column by the hinge mechanism. With pollinia deposited on their back or previously placed pollinia from another plant rubbed against the stigma, the confused wasps release the labellum and fly away.

The female wasps burrow underground and parasitize beetle larvae for most of their adult lives. It has been found that colonies of females are constrained often to less than a hectare, as are the mating areas patrolled by flying males. Consequently, the hammer orchid is associated with a species-specific pollinator of extremely localized distribution.

Typically, *D. elastica* is confined to a series of disjunct small populations on the Swan Coastal Plain centred in suburban Perth. It favours bare sand beneath thickets of the myrtaceous shrub *Kunzea ericifolia.* The population genetics and ecology of *D. elastica* have been investigated in a programme given both federal and state funding.

Threats include destruction of habitat through urban development, harvesting of *Kunzea* stems for poles for market gardens, too-frequent fire (which kills the *Kunzea)*, and possibly competitive replacement of the thynnid wasp pollinator by introduced feral or hive honey bees. The latter needs careful investigation.

4) Diuris fragrantissima - *Diuris fragrantissima* D.L.Jones & M.A.Clem. is an attractive species from west of Melbourne, Victoria, with 18 cm long, grass-like leaves and flower stems to 20 cm tall with one to nine strongly fragrant flowers which are white with purple markings. The species is non-clonal, and adult plants are not persistent in habitat sites (Cropper 1993).

According to Cropper (1993), this once common orchid of grassland communities on basalt plains west of Melbourne is now restricted to a single remaining natural and highly vulnerable population of ten plants and one reintroduced stand of six plants.

The main threat to the species is extensive development of 99% of the native grassland habitat where the species may have occurred. Four populations have been lost as a result of other activities including mowing, herbicide application, and a mouse plague. Plants have also been lost as a result of overzealous photographers, illegal collection, and weed incursions.

The species has long been recognized as an endangered taxon. As early as 1950, members of the

Native Plant Preservation Society (Willis 1962) translocated plants to a sanctuary near St. Albans. Subsequently plants were propagated from seed in 1974 using symbiotic methods. Tubers from this programme were planted in 1982 into grassland sites within the former range of the species at Laverton; *ex situ* stocks of plants are maintained at a local university. Widespread publicity surrounded the flowering of plants at the introduction sites, resulting in significant damage to habitat and orchid alike. The introduced plants have steadily declined from the original 45 to just six individuals, and concerns are expressed for the sustainability of the population (Cropper 1993).

On present indications this taxon is at serious risk, and urgent measures are needed to ensure survival of the last remaining natural population. The improved flowering of the species following a summer fire also raises the issue of a fire management policy for the remaining sites of the species.

5) *Caladenia hastata* - An attractive member of the spider orchid group, *Caladenia hastata* (Nicholls) Rupp is restricted to coastal heath communities in the vicinity of Portland, west of Melbourne, Victoria. It is hard to locate except when stimulated to flower in the spring following a summer fire. In the vegetative phase the plant can be easily confused with other *Caladenia* species.

The major threats to the species are clearing for agriculture, industrial development, and encroachment by *Acacia sophorae* (coast wattle). The latter is a serious weed which, though natural to south-west Victoria, has greatly expanded its range in recent time and now threatens some of the last remaining populations of C. *hastata*. It is thought that the sudden range extension of the wattle is a result of changed management practices or is related to the spread of introduced starlings which use seed of the species as a staple.

Research sponsored by Portland Aluminium Pty. Ltd. was responsible for the development of *in vitro* symbiotic seed propagation of C. *hastata* and development of cryostorage of seed and the fungal symbiont. From this study over 100 seedlings were introduced in 1993 into secure heathland sites in the Portland area. Monitoring of introduced and natural plants is undertaken on an annual basis, and efforts are being made to control the spread of coast wattle. The long-term success of the reintroduction programme is yet to be determined.

This species is rarely observed except in the season following fire, and thus the exact status of extant populations is difficult to assess without precise tagging of individual plants. Regular burning to monitor orchid survival is not recommended because of the risk of weed incursions and unfavourable impacts on other heathland species. The conservation status of C. *hastata* is critical; continuing research, monitoring, and survey and propagation studies need to be undertaken to ensure its survival.

Kingsley Dixon and Stephen Hopper, Kings Park and Botanic Garden, Australia

Table 5.12.1 List of conservation taxa of Australian Orchidaceae (based on Australian Nature Conservation Agency 1993).

Conservation status*	Taxon	State**
Presumed Extinct		
	Acianthus ledwardii Rupp	Qld, NSW
	Caladenia atkinsonii Rodway	Tas
	C. pumila R.S.Rogers	Vic
	Oberonia attenuata Dockrill	Qld
	Prasophyllum subbisectum Nicholls	Vic
Endangered		
	Caladenia audasii R.S.Rogers	Vic
	C. busselliana Hopper & A.P.Brown	WA
	C. *cristata* R.S.Rogers	WA
	C. elegans Hopper & A.P.Brown	WA
	C. formosa G.W.Carr	Vic
	C. fragrantissima D.L.Jones & G.W.Carr ssp. *orientalis* D.L.Jones & G.W.Carr	Vic
	C. fulva G.W.Carr	Vic
	C. hastata (Nicholls) Rupp	Vic
	C. lowanensis G.W.Carr	Vic
	C. robinsonii G.W.Carr	Vic
	C. rosella G.W.Carr	NSW, Vic
	C. tensa G.W.Carr	Vic
	C. thysanochila G.W.Carr	Vic
	C. viridescens Hopper & A.P.Brown	WA
	Calochilus psednus D.L.Jones & Lavarack	Qld
	C. richiae Nicholls	Vic
	Dendrobium antennatum Lindl.	Qld
	D. mirbelianum Gaudich.	Qld
	D. nindii W.Hill	Qld
	Dipodium pictum (Lindl.) Rchb.f.	Qld
	Diuris fragrantissima D.L.Jones & M.A.Clem.	Vic
	D. micrantha D.L.Jones	WA
	D. pallens Benth.	NSW
	Drakonorchis drakeoides Hopper & A.P.Brown	WA
	Epiblema grandiflorum R.Br. ssp. *cyanea* K.W.Dixon	WA
	Genoplesium rhyoliticum D.L.Jones & M.A.Clem.	NSW
	G. tectum D.L.Jones	Qld
	Habenaria macraithii Lavarack	Qld
	Malaxis lawleri Lavarack & B.Gray	Qld
	Phaius bernaysii Rowland & Rchb.f.	Qld
	Phalaenopsis rosenstromii Bailey	Qld
	Prasophyllum chasmogamum R.J.Bates & D.L.Jones	Vic
	P. concinnum Nicholls	Tas
	P. diversiflorum Nicholls	Vic

Table 5.12.1 cont.

Conservation status*	Taxon	State**
	P. petilum D.L.Jones & R.J.Bates	NSW
	P. uroglossum Rupp	NSW
	Pterostylis arenicola M.A.Clem. & J.L.Stewart	SA
	P. despectans (Nicholls) M.A.Clem. & D.L.Jones	SA
	P. gibbosa R.Br.	NSW
	P. sp. *'Dimboola'*	NSW
	P. sp. *'Northampton'*	WA
	Thelymitra dedmaniae R.S.Rogers	WA
	T. epipactoides F.Muell.	SA
	Vrydagzynea paludosa J.J.Sm.	Qld
Vulnerable		
	Bulbophyllum boonjae B.Gray & D.L.Jones	Qld
	B. globuliforme Nicholls	Qld, NSW
	B. gracillimum (Rolfe) Rolfe	Qld
	B. longiflorum Thouars	Qld
	Caladenia bryceana R.S.Rogers	WA
	C. caesarea (Domin) M.A.Clem. & Hopper ssp. *mantima* Hopper & A.P.Brown	WA
	C. caudata Nicholls	Tas
	C. christineae Hopper & A.P.Brown	WA
	C. dilatata R.Br. ssp. *villosissima* G.W.Carr	Vic
	C. dorrienii Domin	WA
	C. excelsa Hopper & A.P.Brown	WA
	C. exstans Hopper & A.P.Brown	WA
	C. gladiolata R.S.Rogers	SA
	C. harringtoniae Hopper & A.P.Brown	WA
	C. hoffmanii Hopper & A.P.Brown	WA
	C. huegelii Rchb.f.	WA
	C. insularis G.W.Carr	Vic
	C. integra E.Coleman	WA
	C. longii R.S.Rogers	Tas
	C. ovata R.S.Rogers	SA
	C. rigida R.S.Rogers	SA
	C. tessellata Fitzg.	NSW, Vic
	C. versicolor G.W.Carr	Vic
	C. voigtii Hopper & A.P.Brown	WA
	C. wanosa A.S.George	WA
	Corybas limpidus D.L.Jones	WA
	Cryptostylis hunteriana Nicholls	NSW, Vic
	Dendrobium bigibbum Lindl. & Paxton	Qld
	D. callitrophilum B.Gray & D.L.Jones	Qld
	D. carronii Lavarack & P.J.Cribb	Qld
	D. fellowsii F.Muell.	Qld
	D.johannis Rchb.f.	Qld

Table 5.12.1 cont.

Conservation status*	Taxon	State**
	D. tozerensis Lavarack	Qld
	Diuris aequalis Fitzg.	NSW
	D. drummondii Lindl.	WA
	D. praecox D.L.Jones	NSW
	D. purdiei Diels	WA
	D. recurva D.L.Jones	WA
	D. sheaffiana Fitzg.	NSW
	D. venosa Rupp	NSW
	Drakaea concolor Hopper & A.P.Brown	WA
	D. confluens Hopper & A.P.Brown	WA
	D. elastica Lindl.	WA
	D. micranlha Hopper & A.P.Brown	WA
	Drakonorchis barbarella Hopper & A.P.Brown	WA
	Microtis globula R.Bates	WA
	Phaius australis F.Muell.	Qld, NSW
	P. pictus Hunt	Qld, NSW
	P. tatikervilleae (L'Hér.) Blume	SA, Vic
	Pomatocalpa marsupiale (Kraenzl.) J.J.Sm.	Qld
	Prasophyllum frenchii F.Muell.	SA, Vic
	P. morganii Nicholls	NSW, Vic
	P. pallidum Nicholls	SA
	P. truncatum Lindl.	SA, Vic, Tas
	P. validum R.Bates & D.L.Jones	SA
	P. wallum R.Bates & D.L.Jones	Qld
	Pterostylis bicornis D.L.Jones & M.A.Clem.	Qld
	P. cobarensis M.A.Clem.	NSW
	P. cucullata R.Br.	SA, Vic, Tas
	P. pulchella Messmer	NSW
	P. tenuissima Nicholls	SA, Vic
	Rhinerrhiza moorei (Rchb.f.) M.A.Clem., B.J.Wallace & D.L.Jones	Qld
	Sarcochilus fitzgeraldii F.Muell.	Qld, NSW
	S. hartmannii F.Muell.	Qld, NSW
	S. hirticalcar (Dockrill) M.A.Clem. & B.J.Wallace	Qld
	S. weinthalii Bailey	Qld, NSW
	Spathoglottis plicata Blume	Qld
	Thelymitra matthewsii Cheeseman	SA, Vic
	T. psammophila C.R.P.Andrews	WA
	T. stellata Lindl.	WA
	Trichoglottis australiensis Dockrill	Qld
	Vanda hindsii Lindl.	Qld
	Zeuxine polygonoides (F.Muell.) P.J.Cribb	Qld

* Conservation status following IUCN (1980), see Box 4.1.
** Australian states: WA: Western Australia; SA: South Australia; Vic: Victoria; NSW: New South Wales; Qld: Queensland; Tas: Tasmania.

5.13 South-east Asia and the south-west Pacific

This orchid-rich region spans the equator and encompasses the nations of Malaysia, Indonesia, Brunei, the Philippines, Papua New Guinea, Micronesia, the Solomon Islands, Vanuatu, New Caledonia, Fiji, and Samoa. Much of the area lies within the Pacific 'Ring of Fire', lying along the margins of several very active tectonic plates. This part of the world is characterised by volcanic activity and earthquakes, such as the devastating volcanic explosion on the island of Krakatoa between Java and Sumatra.

The main characteristic of the region is the fragmented nature of the land which comprises thousands of islands, ranging from New Guinea, the second largest island in the world, to the many tiny coral atolls that litter the tropical seas of the region. Other large islands include Sumatra, Java, Borneo, and Sulawesi in the west; Luzon, Mindoro, Mindanao in the north-east; and New Caledonia in the south-east. Only peninsular Malaysia is attached to a continental landmass. Despite the recent volcanic origins of many of the islands, some of the larger islands have substantial areas of rocks of more ancient origin. The ultrabasic rocks of New Caledonia are remnants of Gondwanaland, while in New Guinea, Borneo, and Sumatra older rocks are also found in limited areas. These areas often have distinctive floras with high rates of endemism.

The island arc running eastwards from Sumatra has a complex origin that can be traced to the fragmentation and northward drift of the ancient supercontinent Gondwanaland. Where the northern fringe of Gondwanaland met the southern margins of Laurasia, plate tectonic movements over the ages produced a changing pattern of land, at times joined in larger blocks, at other times fragmented into islands. In more recent times, the patterns of island formation have been changed still further by the changes in sea level associated with glaciation. The large western islands of Java, Sumatra, and Borneo were linked by land bridges to the Malay Peninsula during the glacial periods. Similarly, in the east, New Guinea, Australia, the Moluccas, and Lesser Sunda Islands were joined at times by land bridges allowing faunal and floral migrations. These land bridges disappeared in Quaternary times so that the animal life and, to a lesser extent, the plant life of the eastern and western regions are distinct.

The first naturalist to recognize this was Alfred Russell Wallace. Wallace's Line, named after him, runs between Borneo and Sulawesi and defines the boundaries of the Asiatic and Australasian faunal regions. The present-day faunal separations between, for example, tigers in Malaya, Sumatra, Java, and Bali, and the cockatoos in Australia, New Guinea, the Moluccas, and the Lesser Sunda Islands testify to the long geological separation of the two areas.

The distribution patterns of the plants of the region are similar to those of the animals, although the boundaries are less well defined. For example, eucalypts are found in Australia and New Guinea with a northerly extension into the Philippines, while the tall dipterocarps, which are important timber trees, are common and diverse in the western part of the region but are represented by far fewer species in Sulawesi and New Guinea. Overall, the orchids reflect this east-west divergence, but the dust-like nature of orchid seed and its easy dispersal has somewhat blurred the boundaries between the Asiatic and Australasian regions. Typical Australasian orchids such as the cane and *Latouria* dendrobiums, which are most diverse in New Guinea and north-east Australia, extend westward to Sulawesi and Java, respectively. Typical Asiatic orchids such as *Dendrochilum* and *Cymbidium* are represented by many species in Sumatra and Borneo but by only one or two species in New Guinea.

The predominant vegetation of the region is tropical rain forest, but according to elevation gradients and substrates there are also coastal mangrove forests, lowland and peat-swamp forest, and hill and montane forests. On the highest mountains of Borneo (Mt. Kinabalu, 4004 m) and New Guinea (Puncak Jaya, 4884 m), subalpine scrub merges into true alpine vegetation in their higher parts. Orchids are found in almost every habitat from the mangroves to the summits of the highest peaks. The favoured zones, however, are the lowland, hill, and montane forests up to about 2000 m. Above that the orchids can still be a prominent part of the vegetation, but the number of species drops rapidly with elevation.

5.13.1 Present status of knowledge

The study of the orchids of this extensive area has been sporadic and hampered, particularly in recent times, by several factors. The region is fragmented both physically and politically, and most accounts of the orchids have covered only a limited political or geographical area. Consequently, many widespread orchids have acquired two or more names over the years. Sorting out synonymy can be a difficult business, especially when collections in herbaria are few and fragmentary. Considerable parts of the region are still little-known botanically, leaving lacunae in our knowledge of orchid distributions. An even greater problem has been the destruction of the type material stored in the Berlin and Philippine herbaria during the Second World War. The most serious losses were of the type collections of Rudolf Schlechter, the eminent German orchidologist.

Study of the orchids of the region can be traced back to the 17th century when the German physician and naturalist Rumphius provided us with our first knowledge of Moluccan orchids in his seminal *Herbarium Amboinense* (1741-1750). He was the first to describe the beautiful moth orchid, *Phalaenopsis amabilis* (L.) Blume. The Dutch botanist Carl Ludwig Blume published the first post-Linnaean account of orchids from Java. The treatment of the orchids in Seeman's *Flora Vitiensis* (1864) gave us the first account of Pacific Islands' orchids. However, most of our knowledge of the orchids of the Malay Archipelago, the Philippines, New Guinea, and the Pacific Islands derives from the activities of orchid collectors working for the orchid nurseries that arose and flourished in Victorian England. Hugh Cuming collected in the Philippines, Hugh Low in Borneo, Thomas Lobb in Java and Borneo, Forstermann in Borneo, Micholitz in New Guinea, and Peter Veitch in New Guinea and the Solomon Islands. They sent orchids back in quantity to the nurseries of Veitch in Chelsea, Low in Clapton, and Sander of St. Albans. These plants, often new to science, were examined by John Lindley in London and H. G. Reichenbach in Hamburg and were described in the pages of journals such as the *Gardeners' Chronicle.*

Toward the end of the 19th century European and North American botanists attempted to catalogue the orchids of the region systematically, island by island. Significant contributions were published on the orchids of Borneo (Ridley 1895), north-east New Guinea (Schlechter 1911-1914), Java (Smith 1905), west New Guinea (Smith 1909-1934), New Caledonia (Kraenzlin 1929), and the Philippines (Ames 1925).

More recent influential floristic treatments have been those of Holttum (1953) of the orchids of Malay, and Seidenfaden's (1975-1988) extensive treatment of Thailand orchids, many of which extend to the Malay peninsula and archipelago. Holttum's treatment has recently been superseded by that of Seidenfaden and Wood (1992). Other important recent floristic treatments include those of Comber (1990) for Java; Wood, Beaman, and Beaman (1993) for Mt. Kinabalu in Sabah; Wood and Cribb (1994) for Borneo; Halle (1977) for New Caledonia; Lewis and Cribb (1989, 1991) for Vanuatu and the Solomon Islands and Bougainville; Kores (1991) for Fiji; and Valmayor (1987) for the Philippines. No recent definitive accounts exist for New Guinea, the Moluccas, Sulawesi, Micronesia, Sumatra or Samoa, although treaments for the last three are in preparation (Reinhard, pers. comm.; Comber, pers. comm.; Cribb and Whistler, in prep.).

A few monographs or revisions of individual genera well represented in the rgion have appeared in recent years. Notable among these are those of *Apostasia* and *Neuwiedia* by de Vogel (1969); *Phalaenopsis* by Sweet (1980); *Cymbidium* by Du Puy and Cribb (1987); *Paphiopedilum* by Cribb (1987a); *Dendrobium* sect. *Spatulata* and *Latouria* by Cribb (1983, 1986); *Chelonistele* and allies, *Pholidota*, six sections of new Guinea *Bulbophyllum, Acriopsis*, and *Tainia* and its relatives (in *Orchid Monographs*, edited by de Vogel 1986-1993). All future generic treatments of the orchids of the Flora Malesiana region (Malaysia, Indonesia, Brunei, the Philippines, Papua New Guinea, and the Solomon Islands) will appear in the *Orchid Monographs* series.

5.13.2 Diversity

Current estimates suggest that there may be 5000 or more species of orchids in the region, making it the most species-rich area in the Old World. All of the subfamilies of orchids are found there. It is the centre of diversity for the small subfamily Apostasioideae, considered by some to be the most primitive of living orchids. The two genera, *Apostasia* and *Neuwiedia*, are both found here, most species of each on the island of Borneo.

Subfamily Cypripedioideae is well represented in the region by over 40 species of *Paphiopedilum*, including some of the showiest and rarest species, such as *P. rothschildianum* (Rchb.f.) Stein and P. *sanderianum* (Rchb.f.) Stein.

The terrestrial subfamily Orchidoideae, most of which perennate by tubers, is poorly represented in terms of numbers of species with a few species of *Habenaria, Pecteilis, Peristylus,* and *Disperis* representing the western element in the flora and *Corybas, Microtis, Pterostylis, Thelymitra, Caladenia, Cryptostylis, Acianthus,* and *Stigmatodactylus* the Australasian. The strange genus *Megastylis* with about eight species is endemic to New Caledonia.

Subfamily Spiranthoideae is another predominantly terrestrial group and is well represented in the region. Most species live in the leaf litter on the forest floor and can often grow in deep shade. A few species are leafless saprophytes, such as *Cystorchis aphylla* Ridl. The primitive genera *Corymborkis* and *Tropidia,* which vegetatively resemble small bamboos, are well represented here. The best-known representatives are, however, the jewel orchids in genera such as *Anoectochilus, Dossinia, Macodes, Goodyera,* and *Ludisia.*

The majority of orchids in the region belong to the large polymorphous subfamily Epidendroideae. This assemblage includes most of the epiphytic genera and most of the showy orchids so popular in horticulture. Among the better-known genera found in the region are *Bulbophyllum, Cymbidium, Dendrobium,* Era, *Phalaenopsis, Renanthera,* and *Vanda. Bulbophyllum* is the largest genus in the region with over a thousand species, but

Dendrobium and *Eria* are almost as large. In Borneo alone there may be 250 species of *Bulbophyllum* (Vermeulen 1991), and there may be over 200 species of *Dendrobium* (Dauncey, pers. comm.) in New Guinea. Recent estimates based on monographic treatments of *Bulbophyllum, Dendrobium, Cymbidium, Dendrochilum,* and *Paphiopedilum* suggest that as many as 25% of the orchids of the region remain undescribed.

Bulbophyllum leratiae

5.13.3 Threats

Humans have had an immense impact on the landscape of the region, particularly during the present century. The population of the islands has increased dramatically in recent years, most noticeably on islands such as Java where fertile soils and better health care has led to annual population increases as high as 5%. Indonesia has attempted to solve this crisis of burgeoning population by its policy of transmigration, moving people from overpopulated islands such as Java, Bali, Sulawesi, and Menado to the less-populated islands of Sumatra, Borneo (Kalimantan), and Irian Jaya. Land clearance for agriculture, soil loss, climatic change, and increasing desertification have often resulted from this policy.

Traditional agricultural practices, such as the slash-and-burn systems adopted by the indigenous forest tribes in Sumatra and Borneo, led to the clearance of several hectares of forest at a time. However, it is unusual for such practices to have a lasting deleterious effect on orchid diversity. The rotation of plots which allows a patch of forest to return to forest after a few years ensures that the forest is not irreparably damaged.

The more systematic and large-scale utilisation of forest resources has had a more dramatic effect. Timber extraction on a massive scale has damaged the land, especially where clear felling has been practised, as in some regions of Kalimantan and Sumatra. The heavy machinery used in logging operations tends to compact a high percentage of topsoil, and the lack of trees allows the heavy monsoonal rains to wash away much of the remaining soil. Orchids rapidly disappear from regions subject to such treatment.

The need for cash crops such as oil palm, rubber, and cocoa has also led to the destruction of much forest throughout the region for plantations. Orchids will recolonize plantations but not with the diversity or to the levels found in primary or old secondary forest.

On a more local level, mining has been equally disastrous. The Bougainville copper mine is an open-cast operation that covers hundreds of hectares in the Panguna area. In Sabah the Mamut mine occupies an area that was formerly within the Kinabalu Park. Its activities have destroyed the forest along the Lohan River and poisoned the river as far as the sea. The Lohan River forest was the type locality of many of Kinabalu's showiest orchids, but none can be found there now.

Overcollecting for the nursery trade has often been cited as a major threat to orchids. In reality it is nowhere near as serious as the destruction of habitat that has occurred. This is not to say that collecting cannot endanger orchids. Many of the most horticulturally desirable species are naturally rather narrow endemics, i.e. found in a very limited area, sometimes a single locality. Overcollecting has certainly exterminated *Phalaenopsis javanica* Blume, known only from a single mountain in Java. It has also led many other species of *Phalaenopsis,* such as the Philippine *P. sanderiana* Rchb.f. and *P. schilleriana* Rchb.f., the Bornean *P. gigantea* J.J.Sm., the Malayan and Bornean forms of *P. violacea* Witte to the verge of extinction. *Phalaenopsis viridis* J.J.Sm. is believed to be on the verge of extinction in Sumatra where it is endemic. Others to suffer overcollection include several *Paphiopedilum* species, particularly in Indonesia and the Philippines, the Philippine *Renanthera imschootiana* Rolfe and the Sabahan *R. bella* J.J.Wood, all four *Paraphalaenopsis* species, the Malaysian *Papilionanthc hookeriana* (Rchb.f.) Schltr., some *Vanda* species, and the spectacular pink- and gold-flowered *Euanthe sanderiana* (Rchb.f.) Schltr. from the Philippines.

5.13.4 Case histories

1) Phalaenopsis javanica - *Phalaenopsis javanica* Blume is one of the moth orchids but by no means the showiest species in the genus. It was first described by Carl Blume from his own collection near Garut in West Java. Following a long period when it was thought to be extinct it was rediscovered in the 1960s on a mountain south of Cianjur growing between 700 and 1,000 m in montane forest and coffee plantations. Unfortunately, news of this rediscovery caught the attention of an Indonesian orchid nursery, and the plant was exterminated within two years (Comber 1990). Plants of *P. javanica* survive in a few collections, for example, in the Bogor Botanical Garden in West Java, but its future as a wild plant cannot be confirmed despite extensive efforts to refind it.

2) Cymbidium rectum - A close relative of the better-known *C. aloifolium* (L.) Sw. and *C. finlaysonianum* Lindl., this attractive orchid was first described by Henry Ridley in 1920 from a plant collected in Negri Sembilan in the Malay Peninsula. It has not been found there since.

The species was rediscovered in Sabah, north Borneo by Tony Lamb in the early 1980s, growing on *Baekea frutescens* and other small trees up to six m from the ground in peat swamp and kerangas forests on podsolic soils. Even there it proved to be naturally rare.


David Du Puy

Cymbidium rectum

Its habitat was logged extensively from 1983 onwards, and only tiny fragments remain today. Visits to these in recent years have failed to rediscover *C. rectum*. It may occur elsewhere in Borneo in similar habitats, but so far only a single additional locality has been located in East Kalimantan in severely degraded coastal podsol forest.

Seedlings raised from seed set on plants brought into cultivation have been widely distributed, and this seems to be the best chance for the survival of the species.

3) Paraphalaenopsis labukensis - This extraordinary 'rat-tailed phalaenopsis' was described as recently as 1981 by P. S. Shim, Tony Lamb, and Chan Chew Lun. It had been first found by estate managers clearing forest along the Kuala Labuk River in East Sabah. It grew on *Gymnostoma sumatrana* trees on steep ultrabasic slopes and cliffs above the river, its slender terete pendent leaves reaching two metres or more in length.


Jim Comber

Paraphalaenopsis laycocki

The only known localities have suffered a series of mishaps, ultimately leading to the destruction of much of the forest cover. In one, the spoil and the chemicals used to extract metals from the ore from the Mamut mine, part of the Kinabalu Park that had been degazetted by the Government, clogged up the river for several miles downstream and destroyed the adjacent forest. The locality of *P. labukensis* Shim, Lamb, & C.L.Chan remained within the Park until the mid 1980s when it was degazetted as a political gesture to the local people in Ranau. In 1992 on hearing that the Government was about to regazette this species-rich area, the locals burned the site, destroying the only locality of this and several other orchids, including the scarlet *Rcnanthera bella* and the strange dimorphic *Dimorphorchis rossii* Fowlie.

A few wild-collected plants of *Paraphalaenopsis labukensis* survive in collections around the world. Seedlings have been raised at the Singapore Botanic Gardens and at Kew and have been widely distributed. Its future as a wild plant, however, hangs in the balance.

Phillip J. Cribb, Royal Botanic Gardens, Kew, UK

Chapter 6

Action Plan Recommendations

6.1 General summary

6.1.1 *In situ* conservation

The most important way to conserve orchids is to conserve their habitat, and priorities should take into account species richness and endemicity, as well as political, technical, and financial feasibility. Therefore, *in situ* conservation must start with basic ecological research that includes an assessment of local orchid diversity, population biology, and site suitability. With this information a global checklist of orchid species (similar to Dodson's New World orchid checklist) including a realistic assessment of endemism, and the identification of areas of high priority for protection should be compiled. Due to the rapid pace of land degradation in many regions of the world, the establishment of protected areas should not necessarily wait for these detailed ecological assessments, but rather rely on recommendations of scientists familiar with the status of biodiversity in the region.

To accomplish the above, more work is needed. The lack of ecological research is acute in areas with highly diverse orchid floras (e.g. montane forests of New Guinea, Costa Rica, and the Andes of Ecuador and Colombia). Ideally, we need resident orchid specialists in every moist tropical country. Botanists, conservationists, and local growers must inform one another of the research and information needs each has and what they can contribute to conservation. Local administrations should work in close collaboration with field biologists and conservationists to identify important habitats for protection.

Once established, these protected areas should be monitored and actively managed. The collection and trade of wild plants should be prohibited unless the sustainability of extraction can be proven. Artificial propagation may be an appropriate and beneficial alternative to extraction. Because of the great number of orchid species and problems with taxonomic identification, reintroduction of orchids should only be undertaken according to very strictly controlled conditions and protocols.

Protected areas should include small as well as large sized habitats. Small patches of undisturbed habitat in ravines and similar places, commonly disregarded for conservation, can play a very important role in orchid conservation. However, many present agricultural practices and policies promote the disappearance of these small 'pockets of diversity.'

The conservation of orchids and certain other popular plants on private lands and other kinds of protected or semi-protected sites is increasingly important in the effort to conserve biodiversity, but management of these areas is rendered difficult by the family's extremely variable habitat requirements. Complex factors such as biotic associations with mycorrhizae, pollinators, or non-orchid plant species illustrate the need for 'total system' conservation. For example, not all orchids thrive in pristine conditions or old forest growth. For some species, periodic disturbance is required for regeneration, and management schemes should incorporate these disturbances to maintain the necessary successional habitat. All of these factors must be taken into account in any management plan, which should contain as little intrusive action as possible.

6.1.2 *Ex situ* conservation

Ex situ conservation involves reproductive and vegetative propagation which can include the following steps:

1) Removal of only a few plants or their propagules from the wild in such a way that the removal will not affect the future survival of that population, or
2) Removal where the habitat is destroyed and has no prospect of regeneration;
3) Propagation of plants where possible from seed, usually in aseptic conditions;
4) Growing the plants until they are large enough to divide;
5) Exchange of divisions with qualified growers to ensure against loss of the clone;
6) Sib-crossing one of each pair of divisions;
7) Dissemination of progeny among proficient and interested growers for continuance of the breeding programme.

An important goal of *ex situ* conservation is to make rare and new plants immediately available to the propagators (commercial growers and botanic gardens), so that they can produce large numbers of artificially propagated plants as soon as possible, thus making them widely available at reasonable prices. This should benefit *bona fide* propagators and traders in countries where the desirable species are native (range states) in accordance with the Convention on Biological Diversity.

Wild-collecting should be carried out following strict protocols to ensure that collecting will not have detrimental effects on wild populations. When enough plants exist in artificial propagation to satisfy market demand, there will be little reason other than salvage to go to the trouble of removing more plants of the same species from the wild. A system of licensing and management that is not open to corruption would make salvage a desirable option to acquire plants that would otherwise die, and could serve as parental stock in the country of origin. This would reduce pressure on those still endangered in the wild, although concurrent habitat protection measures for critically threatened species should make salvage operations less necessary. Nursery registration (CITES) for Appendix I species should be useful in this regard.

Hobbyists and scientists alike have roles to play in *ex situ* conservation. The amateur can contribute by maintaining a significant collection and using it to share seeds, pollen, and divisions with others. Botanic gardens should serve as repositories for living specialty orchid collections. To enhance their collections, they should increase interaction with both commercial and amateur growers, receiving and sharing plant material and new clones. Orchid societies and botanic gardens should promote a policy of selective purchase of artificially propagated plants as a complement to the main conservation strategy of habitat protection.

6.1.3 Communication, education, and regulation

The following institutions and organizations can play an important role in promoting communication, education, and effective regulation for orchid conservation:

1) Orchid societies can reinforce ethical practices and behaviour, develop programmes to conserve local orchid species, and provide cultural advice to their members through lectures in which commercial growers frequently attend.
2) Nature reserves and botanic gardens can provide environmental education through exhibits and programmes that illustrate the importance of biodiversity and how the position of orchids in the larger ecosystem is threatened in the face of increasing basic needs of a growing human population.
3) Authorities must maintain timely contact with individuals and organised societies within their jurisdiction so that all are aware of pending legislation that might affect orchids and orchid conservation.
4) Non-governmental organizations (NGOs) must work with other conservation groups and authorities to educate each other on the peculiarities of orchids and their habitat and growth requirements. It is important that they formulate consistent viewpoints, explain the reasoning behind them, and work for a mutual consensus.
5) The Orchid Specialist Group (OSG) should assist the CITES Plant Committee in its evaluation of the appendices by stimulating research on trade and conservation status, and by sharing information.

Both *in situ* and *ex situ* conservation of orchids can be greatly facilitated with communication and cooperation between local growers, botanists, and local and national authorities. Potential propagators and vendors should have access to modern information systems by which news about changes in trade regulations, phytosanitary certification, and potential markets at all levels of distribution is available. Teaching propagation techniques in countries of origin and making sources of supplies available is a useful way that nurseries in importing countries can help. A standardised list of propagated orchids should be distributed widely to prevent duplication, as well as to guide individuals wishing to obtain plants of a given species. The Artificially Propagated Orchids (APO) catalogue compiled by Jean-Jacques Beguin (see Box 4.3) was designed for this purpose and is updated every two years. All orchid lovers should use this important tool whenever purchasing orchids and should encourage nurseries to include their inventory in this catalogue.

Although CITES explicitly states that scientific institutions may be registered and permitted to exchange scientific material without having to obtain permits for every shipment, many countries have not set up such systems. Scientific institutions and the OSG should work together to solve this problem. Pressed and liquid-preserved material could be deregulated, as there is no real commerce in either type. However, collectors must honour a strict code of conduct in not overcollecting threatened species and abiding by the collecting rules of the country concerned.

CITES regulations are often criticised by orchid growers and traders. Incorrect or poor implementation by several countries, as well as uneven application of national regulations are sometimes counterproductive because they also hinder legitimate propagators and traders in an effort to combat illegal trafficking. In collaboration with other conservation groups, the OSG should help the national authorities to find the best ways to combine national and international regulations and implement them. All countries should relax restrictions on import and export of artificially propagated orchids, which is a valid sustainable use of biodiversity and promotes conservation.

Although it is not always easy to allocate financial reserves specifically for *in situ* or *ex situ* conservation, in cases where a choice can be made, it is often usually more beneficial to focus on habitat protection rather than on setting up sophisticated laboratories for *ex situ* propagation.

Much can and will be achieved in orchid conservation if specialists collaborate and work to persuade national authorities, NGOs, botanic gardens, and orchid societies to communicate more effectively and exchange knowledge and good will.

6.2 Implementation of recommended actions

In this section specific recommendations are presented that have been based on principles summarised in the previous section as well as those found in the rest of the Action Plan. Implementers of these actions include scientists, national governments, Orchid Specialist Group members, and orchid societies. Each subsection is headed by, although not limited to, the specific group that is qualified to implement these actions.

Scientists and national governments should:

1) Produce up-to-date, urgently needed orchid biodiversity assessments in the form of inventories or Floras for the following areas, using the revised IUCN Red List Categories and identifying major causes of threat/action required:
   a) Irian Jaya
   b) Papua New Guinea
   c) Sulawesi
   d) Moluccas
   e) Borneo (Sarawak, Sabah, Brunei, Kalimantan)
   f) China
   g) Myanmar (Burma)
   h) Central Africa (Congo, Equatorial Guinea, Cabinda)
   i) Gabon
   j) Cameroon
   k) Angola
   1) Colombia
   m) Peru
   n) Bolivia
   o) Brazil
   p) Greater Antilles
   q) Madagascar

2) Establish *a priori* a list of known sites of orchid diversity or endemism in collaboration with other species Specialist Groups.

3) Work together with national/local authorities, universities, and other NGOs to outline the possibility of conserving these sites for their biodiversity.

4) Provide political, technical, and financial support to:
   a) compile an on-line checklist of the world's orchids for conservationists and CITES orchid checklists for major genera in trade;
   b) gather detailed ecological, population biology, and pollination studies on all CITES Appendix I species, including a conservation assessment using the revised IUCN Red List Categories and CITES criteria.

5) With the Orchid Specialist Group, coordinate the preparation of information sheets on micropropagation, ecology, vegetative propagation, and cultivation of orchid species.

6) Undertake conservation status reviews of the following taxa which include species important to horticulture, problematic taxonomic groups, as well as those threatened by wild-collection:
   a) *Phalaenopsis*
   b) *Odontoglossum*
   c) *Vanda*
   d) *Cypripedium*
   e) *Oncidium*
   f) *Dendrobium* sect. *Dendrobium*
   g) *Dendrobium* sect. *Calyptrochilus*
   h) *Dendrobium*sect.*Formosae*
   i) *Calanthe*
   j) *Lycaste*
   k) *Ophrys*
   1) *Orchis* and allies
   m) *Dactylorhiza* and allies
   n) *Angraecum*
   o) *Jumellea*

7) With the SSC Reintroduction Specialist Group, initiate pilot studies on reintroduction of tropical epiphytic species.

8) Undertake (and fund) population studies, micropropagation, and *in situ* conservation of the following taxa known to be endangered but otherwise poorly known:
   a) *Selenipedium* species
   b) *Cattleya dowiana*
   c) *Phalaenopsis viridis*
   d) *Phalaenopsis javanica*
   e) *Phalaenopsis gigantea*
   f) *Cypripedium subtropicum*
   g) *Cypripedium segawii*
   h) *Phragmipedium* (=*Mexipedium*) *xerophyticum*
   i) *Laelia milleri*
   j) *Euanthe (Vanda) sanderiana*
   k) *Paphiopedilum* species
   1) *Phragmipedium* species

9) Support increased training for staff of national scientific and management authorities in the application and implementation of CITES to plants.

10) Facilitate movement of pressed and liquid-preserved materials among registered institutions and scientists (within the terms and spirit of CITES and the Convention on Biological Diversity).

11) With orchid societies, establish and support *ex situ* propagation units in countries with high orchid biodiversity.

12) Assess as appropriate orchid taxa which may be suitable for in-country sustainable use programmes.

13) Encourage the adoption of measures allowing supervised salvage of plants from logged and otherwise destroyed areas for conservation and horticultural purposes.

6.2.2 Orchid Specialist Group members should:

1) Recommend that each country select five flagship orchid species from their respective nations for educational purposes emphasising the important role of habitat protection in the conservation of biodiversity. Provide criteria for selection.

2) Review mechanisms by which resources of the horticultural trade and hobbyist can contribute both financially as well as transfer technology to range states to promote the conservation and sustainable use of orchid biodiversity.

3) Establish by December 1997 a clearly-targeted, five-year programme for the IUCN/SSC Orchid Specialist Group that will contribute to the long term conservation and sustainable use of orchid biodiversity; this includes the creation of a Secretariat for the OSG.

4) With orchid societies, ensure that the horticultural trade, scientific, and hobbyist communities are aware of the terms and spirit of CITES, the Convention on Biological Diversity, and the rights of nations over the use and access to their biological resources.

5) Update a conservation code to be adopted and complemented by orchid societies worldwide.

6.2.3 Orchid societies should:

1) Establish regional seed exchange programmes following the example of the Australian Orchid Foundation.

2) Extend present databases of endangered species in cultivation so that seed can be produced for horticulture and *ex situ* conservation programmes.

3) With the Orchid Specialist Group, produce educational materials such as a fund-raising videotape on endangered orchids and their conservation.

4) Encourage training programmes (if possible in country of origin) on propagation of threatened orchids.

Vinciane Dumont and Eric Hágsater,
Orchid Specialist Group; and
Phillip Cribb and Alec Pridgeon,
Royal Botanic Garden, Kew

Recommendations du Plan d'Action

6.1 Recapitulation

6.1.1 La préservation *in situ*

Les sites présentant une grandes richesse en orchidées endémiques devraient être préservés en priorité, et surtout si l'environnement politique, technique et financier le permet. Il faut commencer par la recherche de base écologique qui comprend une liste globale d'orchidées (comme celle de Dodson pour les orchidées du Nouveau Monde) en incluont, un répertoire réaliste de leur endémicité, et une identification des régions prioritaires à protéger. Etant donné la rapidité de dégradation de nombreuses régions du monde, il vaut mieux ne pas attendre les résultats des études détaillées d'écologie, mais suivre les conseils des scientifiques intéressés par la biodiversité de la région donnée.

De plus amples recherches écologiques sont nécessaires dans les régions à flore hautement diversifiée en orchidées (par exemple, les forêts montagneuses de la Nouvelle Guinée, le Costa Rica, les Andes d'Equateur et de Colombie). Idéalement, nous aurions besoin de la participation de spécialistes résidants dans chaque pays tropical-humide. Botanistes, naturalistes et producteurs locaux devraient s'entraider en partageant leurs informations et le résultat de leurs recherches. Les administrations locales devraient collaborer avec les biologistes de terrain et les naturalistes, pour identifier les espèces et habitats les plus concernés.

Une fois sélectionnées, ces régions protégées devraient être surveillées et gérées activement. La récolte et le commerce de plantes sauvages devraient être interdits sauf s'il est prouvé que ces pratiques ne sont pas préjudiciables à l'espèce. Une des alternatives possibles est la propagation artificielle. La réintroduction des orchidées dans la nature ne devrait être faite que sous contrôle très strict, vu le grand nombre d'espèces concernées et leurs problèmes d'identification.

Les zones à protéger devraient inclure des habitats de toutes tailles. De petits lopins restés à l'état naturel tels que des ravins, souvent délaissés, peuvent jouer un rôle très important dans la conservation des orchidées. Malheureusement, la politique et les pratiques agricoles poussent à la disparition ces petites 'poches de diversité'.

La gestion des orchidées et de certaines autres plantes populaires sur terrains privés et sur d'autres sites protégés ou semi-protégés deviendra toujours plus importante dans la quête d'une protection adéquate de la biodiversité, mais elle est difficile à mettre en oeuvre vu la multiplicité d'exigences des habitats de cette famille. Des éléments aussi complexes que les associations spécifiques de produits fongiques, de pollinisateurs ou des variétés de plantes autres qu'orchidées qui pourraient servir de fertilisants, illustrent les besoins d'une préservation de 'système global'. Par exemple, la survie des orchidées n'est pas nécessairement une question de maintien des conditions originelles ou le maintien de très vieilles forêts. Quelques espèces demandent certaines formes de dérangements pour se reproduire ou une succession d'habitat. Tous ces éléments doivent être inclus dans le plan de gestion. Celui-ci devra être adéquat et minimiser le mieux possible les intrusions externes.

6.1.2 La préservation *ex situ*

Le concept de conservation *ex situ* inclus la reproduction et la propagation végétative et comporte plusieurs étapes:

1) Récolte de seulement quelques plantes sauvages non préjudiciable à la survie de cette population, ou
2) Récolte de préférence dans des habitats détruits et sans espoir de régénération,
3) Semis de plantes, lorsque c'est possible et en général dans des conditions stériles,
4) Culture des plantes jusqu'à une maturation suffisante pour les multiplier,
5) Partage et échange de divisions entre cultivateurs qualifiés pour éviter les pertes,
6) Echange mutuel des divisions,
7) Dissémination des plantules entre cultivateurs intéressés par la continuité du programme de reproduction.

Un des buts principaux consiste à faire en sorte que les plantes rares et nouvelles soient immédiatement disponibles aux propagateurs (cultivateurs commerçants et jardins botaniques), de telle manière qu'elles puissent être reproduites artificiellement aussi vite que possible, les rendant ainsi accessibles à des prix raisonnables. Cela devrait satisfaire autant les cultivateurs et commerçants des pays dont ces espèces sont originaires que les pays importateurs, et être en accord avec la Convention sur la diversité biologique.

Le ramassage d'orchidées devrait être effectué suivant des lignes directrices strictes afin d'assurer que les récoltes s'effectueraient sans causer de préjudice à la biodiversité du lieu. Lorsqu'il y aura assez de plantes pour satisfaire la demande du marché, il restera peu de raisons valables d'aller récolter plus de pieds de la même espèce dans la nature. Un système de licence et de gestion non corrompu pourrait permettre la survie des plantes vouées à la disparition et faire ainsi de l'acquisition de ces plantes une action utile qui servirait de stock parental dans le pays d'origine. Cela réduirait la menace pour des plantes encore dans la nature, même si les mesures de protection des habitats des espèces les plus vulnérables tendent à diminuer l'opportunité de ces actions de sauvetages. L'enregistrement des pépinières reproduisant les plantes d'Annexe I (CITES) serait utile à ce sujet.

L'amateur et le scientifique ont un rôle à jouer. L'amateur peut contribuer, en maintenant une collection représentative et partageant ainsi graines, pollens et divisions avec d'autres. Les jardins botaniques devraient servir de dépositaires de collections d'orchidées particulières. Pour entretenir leurs collections, ils devraient communiquer beaucoup plus avec les cultivateurs tant commerciaux qu'amateurs, ainsi que recevoir et partager les tissus de plantes et de nouveaux clones. Les sociétés orchidophiles et les jardins botaniques devraient promouvoir des règles qui les engageraient à se fournir en plantes artificiellement reproduites comme complément de leur stratégie principale de conservation de l'habitat.

6.1.3 Communication, éducation et réglementation

Les institutions et organismes suivant peuvent jouer un rôle important en stimulant la communication, l'éducation et une réglementation appropriée pour la conservation des orchidées:

1) Les sociétés d'amateurs d'orchidées peuvent renforcer les pratiques éthiques et les comportements, offrir des programmes pour conserver les espèces d'orchidées locales, fournir des conseils de culture à leurs membres à travers des publications spécialisées ou des conférences auxquelles des cultivateurs commerciaux participaient fréquemment.
2) Les réserves naturelles et les jardins botaniques peuvent apporter à leurs visiteurs une éducation sur l'environnement par des expositions illustrant la biodiversité et son interaction avec le reste de l'écosystème face à l'augmentation des besoins de base d'une population humaine en expansion.
3) Les autorités devraient entretenir des contacts ponctuels avec les individus et les sociétés organisées à l'intérieur de leur juridiction, de façon à mettre chacun au courant de l'évolution de toute législation qui pourrait affecter les orchidées et leur conservation.
4) Les Organisations Non Gouvernementales (NGO) devraient travailler avec tous les autres groupes de conservation et les autorités pour éduquer chacun sur les particularités et les besoins des orchidées. Il est important qu'ils formulent leus points de vue de manière homogène, qu'ils puissent en expliquer les raisons et qu'ils travaillent en consensus mutuels.
5) Le Groupe Spécialiste des Orchidées (OSG) devrait assister le Comité des Plantes de la CITES dans son évaluation des annexes en stimulant la recherche sur l'état du commerce et de la conservation et en partageant les informations.

La préservation des orchidées *ex situ* et *in situ* sera bien facilitée dès le moment où la communication et la coopération entre cultivateurs, botanistes et les autorités locales et nationales existeront. Les propagateurs et vendeurs potentiels devraient avoir accès aux systèmes modernes d'information les renseignant sur les changements de législation commerciale et phytosanitaire ainsi que sur les marchés potentiels à tous les niveaux de distribution. L'enseignement des techniques de reproduction dans les pays d'origine et la fourniture du matériel nécessaire sont des aides qui peuvent être fournies par les pépinières des pays importateurs.

Une liste des espèces multipliées devrait être distribuée afin d'éviter les duplications et de guider les personnes désirant obtenir des plantes spécifiques. Le catalogue APO (Artificially Propagated Orchids), compilé par Jean-Jacques Beguin, (voir chapitre sur la préservation *ex situ)* a été rédigé à cet effet et est remis à jour tous les deux ans. Tous les amoureux des orchidées devraient encourager les cultivateurs professionnels à lui adresser leur liste de plantes et utiliser cet outil important lors de leurs achats.

Bien que la CITES précise de façon explicite que les institutions scientifiques peuvent être enregistrées et autorisées à échanger du matériel de recherche sans avoir besoin d'un permis pour chaque expédition, de nombreux pays à travers le monde ne mettent pas encore en pratique de tels avantages. Les jardins botaniques et l'OSG devraient coopérer pour résoudre ce problème. Les tissus séchés ou gardés dans des liquides de conservation pourraient être déréglementés, car il n'y pas de réel trafic pour ce type de produits. Toutefois, les collecteurs doivent suivre un code de conduite très strict pour ne pas ramasser trop de plantes vulnérables et obéir aux règles du pays concerné.

Les réglementations de la CITES sont souvent critiquées par les cultivateurs et commerçants d'orchidées. Leurs mises en oeuvre ou leurs implantations incorrectes dans plusieurs pays, de même que la non-application de règles nationales, sont contre-productives parce qu'elles poussent les propagateurs et commerçants légitimes vers le trafic illégal. Avec le concours d'autres groupes de conservation, l'OSG devrait aider les autorités nationales à trouver de meilleures solutions pour les insérer dans les réglementations nationales et internationales et ainsi les faire instaurer. Tous les pays devraient assouplir les restrictions sur les importations et exportations d'orchidées multipliées artificiellement, car ce trafic permet un usage valable et viable de la biodiversité et la promotion de la conservation.

Bien qu'il ne soit pas toujours facile d'allouer des fonds pour la conservation *in situ* ou *ex situ*, si le choix doit être fait, il vaut mieux se concentrer sur la protection des habitats que de monter des laboratoires sophistiqués pour la reproduction *ex situ.* La conservation des orchidées a tout à gagner si les spécialistes collaborent et persuadent les autorités nationales, les NGO, les jardins botaniques et les sociétés d'orchidophiles à communiquer plus efficacement et à partager leurs connaissances et leur bonne volonté.

6.2 Implémentation des actions recommandées

Dans cette section, des recommandations spécifiques, basée sur les principes énoncés dans les sections précédentes du Plan d'Action, sont présentées. Des scientifiques, des gouvernements nationaux, des groupes de spécialistes d'orchidées et des sociétés orchidophiles implémenteront ces actions. Au début de chaque sous-section, sera mentionné le groupe spécifique le plus qualifié pour la réalisation de ces actions.

6.2.1 Les scientifiques et les gouvernements nationaux devraient:

1) Produire, en priorite, des evaluations de la biodiversite en orchidee sous la forme d'inventaires ou de Flores dans les regions suivantes en utilisant la Liste Rouge des Categories revisee de l'IUCN et en identifiant les causes majeures de menaces et les actions appropriees a prendre:

   a) Irian Jaya
   b) Papouasie Nouvelle Guinée
   c) Sulawesi
   d) Moluques
   e) Borneo (Sarawak, Sabah, Brunei, Kalimantan)
   f) Chine
   g) Myanmar (Birmanie)
   h) Afrique centrale (Congo, Guinée equatoriale, Cabinda)
   i) Gabon
   j) Cameroun
   k) Angola
   l) Colombie
   m) Perou
   n) Bolivie
   o) Brésil
   p) Grandes Antilles
   q) Madagascar

2) Etablir une liste des sites connus à priori pour leur diversité et endémicité des orchidées en collaboration avec d'autres groupes spécialistes d'espèces.

3) Travailler avec les autorités nationales et locales, les universités et autres NGO pour étudier la possibilité de protéger ces sites pour leur biodiversité.

4) Etablir un support politique, technique et financier dans le but de:
   a) favoriser la compilation d'une liste de contrôle mondiale des orchidées pour les défenseurs de l'environnement ainsi que des listes de contrôle CITES pour les principaux genres commercialisés,
   b) rassembler des études détaillées sur l'écologie, la biologie des populations ainsi que sur la pollinisation des espèces de l'annexe I de la CITES incluant une évaluation de l'état de conservation en référence à la Liste Rouge des Catégories de l'UICN et les critères de la CITES.

5) Avec le Groupe specialiste des orchidees, coordonner l'elaboration de feuillets d'information sur la micropropagation, l'ecologie, la propagation vegetative et la culture des especes d'orchidees.

6) Fournir un rapport sur l'etat de conservation des taxons commercialement importants, incluant les groupes dont la taxonomie est problematique et ceux menaces par la collecte sauvage:

   a) *Phalaenopsts*
   b) *Odontoglossum*
   c) *Vanda*
   d) *Cypripedium*
   e) *Oncidium*
   f) *Dendrobium* sect. *Dendrobium*
   g) *Dendrobium* sect. *Calyptrochilus*
   h) *Dendrobium* sect. *Formosae*
   i) *Calanthe*
   j) *Lycaste*
   k) *Ophrys*
   l) *Orchis* et alliés
   m) *Dactylorhiza* et alliés
   n) *Angraecum*
   o) *Jumellea*

7) Initier, avec l'aide du SSC/groupe de réintroduction, des expériences pilotes sur la réintroduction d'espèces tropicales épiphytes.

8) Entreprendre (et financer) des études sur les populations, la micropropagation et la conservation *in situ* des taxons suivants, réputés en danger et mal connus:

a) *Selenipedium* (espèces)
b) *Cattleya dowiana*
c) *Phalaenopsis viridis*
d) *Phalaenopsis javanica*
e) *Phalaenopsis gigantea*
f) *Cypripedium subtropicum*
g) *Cypripedium segawii*
h) *Phragmipedium* (=*Mexipedium*) *xerophyticum*
i) *Laelia milleri*
j) *Euanthe* (*Vanda*) *sanderiana*
k) *Paphiopedilum* (espèces)
1) *Phragmipedium* (espèces)

9) Encourager l'information du personnel des autorités nationales scientifiques et de gestion sur l'application et l'implémentation de la CITES concernant les plantes.

10) Faciliter le mouvement des plantes sèchées ou conservées dans des liquides entre institutions et scientifiques (respectant les termes et l'esprit de la CITES et de la Convention sur la Diversité Biologique).

11) Avec le support de sociétés orchidophiles, établir et aider des unités de propagation *ex situ* dans les pays à grande biodiversité en orchidées.

12) Evaluer de façon appropriée les espèces sujettes à être protégées par un programme de conservation.

13) Encourager l'adoption de mesures permettant le sauvetage contrôlé de plantes de régions en déboisement ou en destruction, pour un usage horticole.

6.2.2 Les membres du groupe spécialiste des orchidées devraient:

1) Recommander que chaque pays sélectionne cinq espèces d'orchidées 'nationales' à des fins éducatives, en soulignant l'importance de la conservation de l'habitat pour le maintien de la biodiversité. Fournir des critères de sélection.

2) Passer en revue les mécanismes par lesquels les ressources du commerce horticole ou amateur, peuvent contribuer à la conservation et au renouvellement de la biodiversité des orchidées de leur pays, financièrement ou par transferts de technologie.

3) Etablir d'ici décembre 1997 un programme quinquennal, clairement ciblé, pour l'UICN/SSC/ groupe spécialiste des orchidées qui contribuera à la conservation à long terme et au renouvellement de la biodiversité des orchidées; ceci inclus la création d'un secrétariat de l'OSG.

4) Avec les sociétés orchidophiles, s'assurer que l'horticulture, la communauté scientifique et celle des amateurs, soient au courant des termes et de l'esprit de la CITES, de la convention sur la Diversité Biologique, ainsi que du droit des nations concernant l'usage et l'accès aux ressources biologiques.

5) Mettre à jour le code de conservation qui sera adopté et complété par les sociétés orchidophiles du monde entier.

6.2.3 Les Sociétés orchidophiles devraient:

1) Etablir des programmes d'échange de semences, prenant exemple sur l'Australian Orchid Foundation.

2) Etendre la base de données des espèces menacées et cultivées, pour pouvoir produire des semences pour l'horticulture et les programmes de conservation *ex situ.*

3) Avec le groupe spécialiste des orchidées, produire du matériel éducatif tel que des vidéocassettes sur les orchidées menacées d'extinction et leur conservation pour générer une aide financière.

4) Encourager des programmes de formation (si possible dans les pays d'origine) sur la propagation des espèces menacées.

Trad. Vinciane Dumont

Recomendaciones del Plan de Acción

6.1 Resúmen General

6.1.1 Conservación *in situ*

La estrategia más importante para conservar las orquídeas es conservar su hábitat y las prioridades deberán tomar en cuenta la riqueza de especies, la endemicidad, así como la factibilidad. Es por ello que la conservación *in situ* tiene que comenzar con investigación ecológica básica que incluya una evaluación de la diversidad local de orquídeas, la biología de poblaciones y la conveniencia del sitio. Con esta información, una lista global de especies de orquídeas (como la de Dodson de Orquídeas del Nuevo Mundo), con una evaluación realista sobre la endemicidad y la identificación de áreas de alta prioridad debe ser compilada.

Para lograr lo anterior, debe incrementarse la investigación. La falta de investigación ecológica es aguda en áreas de floras de rica diversidad en orquídeas (v.gr. bosques montanos de Nueva Guinea, Costa Rica y los Andes del Ecuador y Colombia). Idealmente necesitaríamos de especialistas residentes en todos los países tropicales húmedos. Botánicos, conservacionistas y cultivadores locales deben intercambiar información sobre las necesidades de investigación e información que cada uno tiene y de lo que pueden contribuir a la conservación. Los administradores locales deberían colaborar de cerca con biólogos de campo y conservacionistas para identificar las especies amenazadas así como los hábitats importantes.

Una vez establecidas, las áreas protegidas deben de ser monitoreadas y manejadas de manera activa. La colecta de plantas silvestres y su comercio deben ser prohibidos a menos que se pueda demostrar la sustentabilidad de su extracción. La propagación artificial puede ser una alternativa apropiada y benéfica en lugar de la extracción. Debido al gran número de especies y las dificultades en su identificación taxonómica, la reintroducción de orquídeas sólo debe de llevarse a cabo bajo condiciones y protocolos estrictamente controlados.

Las áreas protegidas deben incluir hábitats tanto de tamaño pequeño como grande. Los manchones pequeños de hábitat no perturbado en cañadas y lugares semejantes frecuentemente despreciados para la conservación, pueden ser muy importantes para conservación de orquídeas. Sin embargo, las prácticas agrícolas y políticas actuales promueven la desaparición de estas 'bolsas de diversidad'.

La conservación de orquídeas y ciertas otras plantas populares en terrenos privados y otros sitios protegidos o semi-protegidos es cada vez más importante en el esfuerzo por conservar la biodiversidad. Sin embargo, el manejo de estas áreas es difícil por los requerimientos del hábitat tan extremadamente variables para la familia de las orquídeas. Factores complejos como las asociaciones bióticas con micorriza, polinizadores o especies de plantas no orquidáceas ilustran la necesidad de un 'sistema total' de conservación. Por ejemplo, no todas las orquídeas prosperan en condiciones prístinas o bosques climax. Para algunas especies se requiere una perturbación periódica para la regeneración y los esquemas de manejo deben de incorporar estas perturbaciones para mantener la sucesión necesaria de hábitats. Todos estos factores deben ser considerados en cualquier plan de manejo. Sin embargo, como es tan poco lo que se sabe sobre la ecología de la mayoría de las orquídeas, es cuestionable si los hábitats pueden ser manejados efectivamente para grupos objetivos como las orquídeas sin conservar el resto del medio en que se desarrollan. En todos los casos, se propugna por un manejo prudente para minimizar acciones intrusivas.

6.1.2 Conservación *ex situ*

La conservación *ex situ* implica la propagación reproductiva y vegetativa, y puede incluir cualesquiera de los siguientes pasos:

1) Extracción de unas pocas plantas o sus propágulos del medio silvestre, de manera que su extracción no afecte la sobrevivencia futura de la población, o
2) Extracción de plantas de un hábitat destruido y que no tenga perspectivas de regeneración;
3) Propagación de plantas de semilla, donde sea posible, generalmente en condiciones asépticas;
4) Cultivo de plantas hasta que sean lo suficientemente grandes para ser divididas;
5) Intercambio de divisiones con cultivadores calificados para evitar la pérdida del clon;
6) Cruzamiento entre cada par de individuos de la misma progenie;
7) Distribución de la progenie entre cultivadores expertos e interesados para asegurar la continuidad del programa de propagación.

Una meta importante en la conservación *ex situ* es facilitar de inmediato plantas de especies nuevas o raras a los propagadores (viveristas o jardines botánicos), de manera que produzcan grandes cantidades de plantas artificialmente propagadas lo más pronto posible y que of rezcan ampliamente a precios razonables. Esto debe beneficiar a los propagadores y comerciantes de buena fe en los países en donde las especies son nativas, acorde con la Convención sobre Biodiversidad.

La colecta de orquídeas solamente debe llevarse a cabo siguiendo líneas directrices a fin de asegurar que la colecta no tenga efectos negativos sobre las poblaciones silvestres. Cuando hayan suficientes plantas artificialmente propagadas para satisfacer la demanda del mercado, habrán pocas razones para buscar plantas silvestres de dichas especies, fuera de operaciones de rescate. Un sistema de licenciamiento y manejo que no esté abierto a corrupción haría que las operaciones de rescate fuesen una alternativa deseable para obtener plantas que de otra manera se perderían y podrían servir como material de propagación en los países de origen. Esto debería de reducir la presión sobre las poblaciones silvestres amenazadas restantes, aunque una mejor protección del hábitat debería de disminuir la necesidad de llevar a cabo operaciones de rescate. El registro de viveros (CITES) para especies del Apéndice I debería de ser útil para ello.

Tanto aficionados como investigadores tienen un papel que jugar en la conservación *ex situ*. El aficionado puede contribuir manteniendo una colección significativa y utilizarla para compartir semillas, polen y divisiones con otros cultivadores. Los jardines botánicos deben de servir como guardianes de colecciones especializadas de orquídeas vivas. Para respaldar sus colecciones, deben interactuar más con viveristas y aficionados, recibiendo y compartiendo material vivo y clones nuevos. Las sociedades orquidófilas y jardines botánicos deben de promover una política de compra selectiva de plantas propagadas artificialmente como complemento a la principal estrategia de conservación del hábitat.

6.1.3 Comunicación, educación y reglamentos

Las siguientes instituciones y organizaciones pueden jugar un papel importante al promover la comunicación, educación y reglamentación efectiva para la conservación de orquídeas:

1) Las sociedades orquidófilas pueden reforzar prácticas y comportamientos éticos, ofrecer programas para conservar especies de orquídeas locales y dar consejos sobre cultivo a sus miembros a través de conferencias en las que los viveristas participen frecuentemente.
2) Las áreas naturales protegidas y jardines botánicos pueden ofrecer educación ambiental por medio de exposiciones y programas que ilustren la biodiversidad y su interacción con el resto del ecosistema frente a los requerimientos incrementales de una población humana creciente.
3) Las autoridades deben mantener contacto oportuno con individuos y sociedades organizadas dentro de su jurisdicción de manera que estén al tanto de legislación pendiente que pudiera afectar a las orquídeas y su conservación.
4) Las organizaciones no gubernamentales (NGO) deben trabajar con otros grupos conservacionistas y autoridades para educarse los unos a los otros respecto de las peculiaridades de las orquídeas y sus requerimientos. Es importante que formulen puntos de vista consistentes, explicando el razonamiento que les da apoyo y trabajando hacia un consenso mutuo.
5) El Grupo de Especialistas en Orquídeas (OSG) debe ayudar al Comité de Plantas del CITES en su evaluación de los apéndices, estimulando la investigación sobre comercio y el estado de conservación, y compartiendo información.

La conservación tanto *in situ* como *ex situ* puede facilitarse grandemente con la comunicación y cooperación entre cultivadores locales, naturalistas y botánicos. Propagadores y comerciantes potenciales deben de tener acceso a sistemas de información moderna con noticias sobre los cambios en los reglamentos comerciales, certificación fitosanitaria y mercados potenciales a todos niveles de distribución. Los viveristas de países importadores pueden enseñar técnicas de propagación en los países de origen y facilitar las fuentes de abastecimiento de materiales.

Una lista estandarizada de orquídeas comerciales, que incluya tanto especies propagadas como silvestres, debe de ser ampliamente distribuida para evitar la duplicación, y servir de guía para los individuos que deseen obtener plantas de una especie determinada. El catálogo APO (Artificially Propagated Orchids) compilado por Jean-Jacques Beguin (ver el recuadro en el capítulo sobre conservación *ex situ)* fue diseñado para este propósito y se pone al día cada dos años. Todos los orquidófilos deben usar esta importante herramienta cuando compren orquídeas y alentar a los viveristas para que incluyan sus inventarios en este catálogo.

Aunque el CITES explícitamente manifiesta que las instituciones científicas pueden ser registradas y facilitárseles el intercambio de material científico sin tener que obtener permisos para cada embarque, muchos países en todo el mundo aún no han implementado estos sistemas. Las instituciones científicas y el OSG deben de trabajar conjuntamente para resolver este problema. El material prensado y conservado en líquido podría ser excluido de permisos, ya que no hay ningún comercio significativo con este tipo de material. Sin embargo, los colectores deben de respetar un código de conducta estricto de no sobrecolectar especies amenazadas, respetando los reglamentos de colecta de cada país.

La reglamentación CITES ha sido frecuentemente criticada por cultivadores y comerciantes. Su implementación incorrecta por parte de varios países, así como la aplicación desigual de reglamentación nacional en un esfuerzo para combatir el tráfico ilegal, son en ocasiones contraproducentes porque dificultan las actividades lícitas de propagadores y comerciantes de buena fe. Con la ayuda de otros grupos conservacionistas, la OSG debería ayudar a las autoridades nacionales a encontrar mejores maneras de implementar y armonizar la reglamentación nacional e internacional. Todos los países deben relajar las restricciones sobre la importación y exportación de orquídeas propagadas artificialmente, ya que constituye un uso sustentable válido de la biodiversidad y promueve la conservación.

Aunque no siempre es fácil asignar recursos financieros específicamente para conservación *in situ* o *ex situ,* en los casos donde se pueda ejercer una opción, serían mejor utilizados en la conservación del hábitat que en el establecimiento de laboratorios sofisticados para propagación artificial *ex situ.*

Mucho se puede lograr mediante la educación si los especialistas en orquídeas colaboran para convencer a las autoridades nacionales, a las organizaciones no gubernamentales y a las sociedades orquidófilas para que se comuniquen más efectivamente entre sí e intercambien sus conocimientos y buena voluntad.

6.2 Implementación de las acciones recomendadas

En esta sección se presentan recomendaciones específicas que han sido basadas en los principios resumidos en la sección anterior, así como en las que se encuentran en el resto del Plan de Acción. Los implementadores de estas acciones incluyen a investigadores, gobiernos nacionales, miembros del Grupo de Especialistas en Orquídeas (GEO) a sociedades orquidófilas. Cada subsección la encabeza un grupo específico calificado para implementarlas, aunque no está limitado a dicho grupo.

6.2.1 Los investigadores y gobiernos nacionales deben:

1) Producir evaluaciones modernas, al día, urgentemente requeridas, sobre la biodiversidad de orquídeas tales como inventarios o floras para las siguientes regiones, utilizando las Categorías del Listado Rojo de la UICN, e identificando las principales causas de amenaza/acción requeridas:

   a) Irían Jaya
   b) Papua-Nueva Guinea
   c) Sulawesi
   d) Malacas
   e) Borneo (Sarawak, Sabah, Brunei, Kalimantán)
   f) China
   g) Myanmar (Burma)
   h) Africa central (Congo, Guinea Ecuatorial, Cabinda)
   i) Gabón
   j) Camerún
   k) Angola
   1) Colombia
   m) Perú
   n) Bolivia
   o) Brasil
   p) Antillas mayores
   q) Madagascar

2) Establecer *a priori*, una lista de sitios de diversidad o endemismo de orquídeas conocidos, en colaboración con otros Grupos Especialistas.
3) Trabajar junto con autoridades nacionales o locales, universidades y otras ONGs a fin de delinear las posibilidades de conservación de estos sitios en función de su diversidad biológica.
4) Estimular y apoyar:
   a) la obtención de información respecto de biología de poblaciones y estudios de polinización de todas las especies del Apéndice I del CITES, incluyendo evaluaciones del grado de amenaza utilizando las Categorías del Listado Rojo de la UICN y los criterios del CITES;
   b) la compilación de un listado de las orquídeas del mundo, así como un listado CITES de orquídeas de los géneros comercialmente más importantes. Estos listados deberan estar disponibles electrónicamente para cualquier usuario.
5) Conjuntamente con la GEO, coordinar la preparación de hojas de información sobre micropropagacíon, ecología, propagación vegetativa y cultivo de especies de orquídeas.
6) Llevar a cabo revisiones sobre el estado de conservación de los siguientes taxones de importancia comercial:
   a) *Phalaenopsis*
   b) *Odontoglossum*
   c) *Vanda*
   d) *Cypripedium*
   e) *Oncidium*

f) *Dendrobium* sect. *Dendrobium*
g) *Dendrobium* sect. *Calyptrochilus*
h) *Dendrobium* sect. *Formosae*
i) *Calanthe*
j) *Lycaste*
k) *Ophrys*
l) *Orchis* y sus aliados
m) *Dactylorhiza* y sus aliados
n) *Angraecum*
o) *Jumellea*

7) Con el Grupo de Especialista de Reintroducción de SSC, iniciar estudios piloto sobre la reintroducción de especies epífitas tropicales.

8) Llevar a cabo (y financiar) estudios de población, micropropagacíon y conservación *in situ* de los siguientes taxones que se saben amenazados pero en general poco estudiados:

a) Especies de *Selenipedium*
b) *Cattleya dowiana*
c) *Phalaenopsis viridis*
d) *Phalaenopsis javanica*
e) *Phalaenopsis gigantea*
f) *Cypripedium subtropicum*
g) *Cypripedium sagawii*
h) *Phragmipedium* (=*Mexipedium*) *xerophyticum*
i) *Laelia milleri*
j) *Euanthe* (Vanda) *sanderiana*
k) Especies de *Paphiopedilum*
l) Especies de *Phragmipedium*

9) Apoyar el mejor entrenamiento del personal de las autoridades científicas y administrativas en la aplicación e implementación del CITES en cuanto a plantas.

10) Facilitar el movimiento de material prensado y preservado en líquido entre instituciones registradas e investigadores (dentro de los términos y espíritu del CITES y la Convención Sobre Biodiversidad).

11) Junto con sociedades orquidófilas, establecer y apoyar a las unidades de propagación *ex situ* en países de alta biodiversidad de orquídeas.

12) Evaluar, según sea el caso, taxa de orquídeas suceptibles a ser objeto de programas de uso sustentable dentro del país.

13) Estimular la adopción de medidas que permitan el rescate de plantas de áreas de tala o de otra manera destruidas, para usos de conservación y horticultura.

6.2.2 Los miembros del Grupo de Especialistas en Orquídeas deben:

1) Recomendar que cada país seleccione 5 especies emblema nativas de su nación para usos educacionales. Proveer los criterios de selección.

2) Revisar los mecanismos por medio de los cuales los recursos del comercio hortícola y los aficionados pueden contribuir tanto financieramente como en términos de transferencia de tecnología a la conservación dentro de cada país y al uso sustentable de la biodiversidad de orquídeas.

3) Con sociedades orquidófilas, asegurar que el comercio hortícola, la comunidad científica y los aficionados, estén enterados de los términos y espíritu del CITES y de la Convención sobre Biodiversidad, y los derechos de las naciones sobre el uso y acceso a sus recursos biológicos.

4) Establecer para diciembre de 1997 un programa con metas claras, a 5 años, para la UICN/SSC, que contribuya a la conservación a largo plazo y uso sustentable de la biodiversidad de las orquídeas.

5) Poner al día un código de conservación para que sea adoptado y complementado por las sociedades orquidófilas de todo el mundo.

6.2.3 Las sociedades orquidófilas deberán:

1) Establecer programas regionales de intercambio de semillas utilizando el ejemplo de la Australian Orchid Foundation.

2) Extender las bases de datos de especies amenazadas en cultivo para que se produzcan semillas para fines hortícolas y programas de conservación *ex situ*.

3) Con el Grupo de Especialistas en Orquídeas, producir materiales educacionales tales como un video para recaudación de fondos para la conservación de especies de orquídeas amenazadas.

4) Fomentar programas de entrenamiento sobre propagación de especies amenazadas de orquídeas, especialmente dentro de los países de origen.

Traduc. Eric Hágsater

Appendix 1

Orchid Specialist Group members and contributing authors

Ackerman, Dr. James D.
Department of Biology
PO Box 23360
Rio Piedras, Puerto Rico 00931
USA

Andrews, Dr. Joan M.
Calle 1-D #254-A
Entre 36 y 38
Col. Campestre
Merida, Yucatan 97120
Mexico

Arditti, Professor Joseph
Department of Developmental and Cell Biology
University of California
Irvine, CA 92717
USA

Atwood, Dr. John T.
Marie Selby Botanical Gardens
811 S. Palm Avenue
Sarasota, FL 34236
USA

Balistieri, Carlo A.
P. O. Box 327
Ashiippun, WI 53003-0327
USA

Barretto, Mrs. Gloria D'Almada
Kadoorie Farm and Botanical Garden
Lam Tsuen Valley-Lam Kam Road
Hong Kong

Beguin, Jean-Jacques
9, Chemin des Vignettes
CH1231 Conches
Switzerland

Bennett, David
Francisco Tudela Varela No. 229
Miraflores, Lima 18
Peru

Borsos, Dr. Olga
Illes u. 25
Budapest 1083
Hungary

Bosser, M. Jean-Michel
Laboratoire de Phanerogamie
Museum National d'Histoire Naturelle
16, rue Buff on
75005 Paris
France

Brasch, Dr. James D.
2100 Highview Drive
Burlington, Ontario L7R 3X4
Canada

Bruyninckx-De Langhe, Kenneth
Laarsebeekdree 4
B-2900 Schoten
Belgium

Carnevali, Dr. Germán
Missouri Botanical Garden
P. O. Box 299
St. Louis, MO 63166-0299
USA

Catling, Dr. Paul M.
Biosystematics Research Institute
Saunders Bldg., C.E.F.
Ottawa, Ontario KlA 0C6
Canada

Chase, Dr. Mark W.
Laboratory of Molecular Systematics
Royal Botanic Gardens, Kew
Richmond, Surrey TW9 3AB
United Kingdom

Chavarria Samayoa, Jose Abel
12 Avenida 44-25, Zona 12
Prados de Monte Maria 01012
Guatemala

Chen, Professor Sing-chi
Laboratory of Systematic and Evolutionary Botany Institute of Botany, Academia Sinica Xiangshan,
Beijing 100093
P. R. China

Christenson, Dr. Eric A.
1646 Oak Street
Sarasota, FL 34236
USA

Clements, Dr. Mark A.
Australian National Botanic Gardens
P. O. Box 1600
Canberra, ACT 2601
Australia

Cribb, Dr. Phillip
Herbarium
Royal Botanic Gardens, Kew
Richmond, Surrey TW9 3AB
United Kingdom

Delforge, Pierre
Section Orchidees d'Europe des Naturalistes
Beiges avenue du Pic Vert 3
B-1640 Rhode-Saint-Genese
Belgium

Diaz, Dra. Marta Aleida
Jardin Botanico Nacional
Carretera de Rocio, km 35
Calabazar, Boyeros
C.P. 19320, Habana
Cuba

Dix, Dra. Margaret
Universidad de Valle de Guatemala
Departmento de Biologia
Apartado Postal 82
Guatemala City 01901
Guatemala

Dixon, Dr. Kingsley
Kings Park and Botanic Garden
West Perth 6005, Western Australia
Australia

Dodson, Dr. Calaway
H. Casillal7-12-499
Suc. 12 de Octubre
Quito
Ecuador

Dressier, Dr. Robert L.
Rt. 2, Box 565C
Micanopy, FL 32667
USA

Driller, Jonathan
OrchidNet
626 Homboldt Street
Richmond, CA 94805-1970
USA

Dumont, Vinciane
37, Chemin Jean-Achard
1231 Conches-Geneve
Switzerland

Du Puy, Dr. David
Herbarium
Royal Botanic Gardens, Kew
Richmond, Surrey TW9 3AB
United Kingdom

Easton, Andy W.
Geyserland Orchids
P. O. Box 162
Rotorua
New Zealand

Englert, Sergio Ignacio
Ricsel Orquideas
Av. Arlindo Pasqualini, 575
91769 - 140 Porto Alegre, RS
Brasil

Escobar, Rodrigo
Jardin Botanico Joaquin Antonio Uribe
Apartado Aereo 4725
Medellin
Colombia

Fernandez, Ricardo
Museo de Historia Natural
Casilla 140434
Lima 14
Peru

Gibson, Alex R.
No. 6, Sinclair Hill
Diego Martin
Trinidad
West Indies

Hágsater, Ing. Eric
Asociacion Mexicana de Orquideologia
Apartado Postal 53-123
11320 Mexico, D. F.
Mexico

Head, Cordelia
J & L Orchids
20 Sherwood Road
Easton, CT 06612
USA

Held, Mrs. Meta
Foundation for the Protection of Wild Orchids
Murwiesenstrasse 49
Zurich 8057
Switzerland

Hill, Cynthia
728 Solana Circle East
Solana Beach, CA 92075
USA

Hirtz, Alejandro
Asociacion de Orquideas de Quito
Casilla Postal 9084-7
Quito
Ecuador

Hopper, Dr. Stephen
Kings Park and Botanic Garden
West Perth 6005,
Western Australia
Australia

Jesup, Ann Lauer
183 Fox Den Road
Bristol, CT 06010
USA

Kabuye, Dr. Christine
East African Herbarium
P. O. Box 40658
Nairobi
Kenya

Koopowitz, Dr. Harold
UCI Arboretum
University of California
Irvine, CA 92717
USA

Kreutz, Mr. C. A. J.
Oude Landdgraaf 35 A
Landgraaf 6373 B.E.
Netherlands

Kukulczanka, Dr. Krystina
Ogorod Botaniczny
Ul. Sienkiewicza 23
50-335 Wroclaw
Poland

Lamb, Anthony
Agricultural Research Station
P. O. Box 197
Tenom, Sabah 89908
Malaysia

Lavarack, Dr. Peter S.
National Parks and Wildlife Service
Pallarenda
P. O. Box 5391
Townsville, Qld. 4810
Australia

Lecoufle, Marcel
5, rue de Paris
94470 Boissy St. Leger
France

Linder, Dr. Peter
University of Cape Town
Bolus Herbarium
Privage Bag
Rondebosch 7700
South Africa

Lojtnant, Dr. B
Gortlervej 87
DK-8900 Randers
Denmark

Lückel, Emil
Bornemannstrasse 2
D-6000 Frankfurt 70
Germany

McCraith, Gerald
Australian Orchid Foundation
107 Roberts Road
Essendon, Vic. 3040
Australia

Miller, David
Rio Atlantic Forest Project
7 Gray Lane
Barnard Castle, County Durham
DL12 8PD
United Kingdom

Morrison, Hon. Alasdair A. O.
Maisemore Lodge
Maisemore, Nr. Gloucester GL2
8HX
United Kingdom

Nair, Dr. Helen
Department of Botany
University of Malaya
59100 Kuala Lumpur
Malaysia

Nash, Mr. Ned
American Orchid Society
6000 S. Olive Ave.
West Palm Beach, FL 33405
USA

Neirynck, Mr. Hendrik
European Orchid Committee
K. Astridlaan 159
Bottelare B-9820
Belgium

Ooi, Michael H. C.
Persiaran Bukit Jambul
11900 Penang
Malaysia

Ortiz Valdivieso,
Fr. Pedro Universidad Javierana
Carrera 10 No. 65-48
Bogotá, D.C. 1
Colombia

Ospina H, Prof. Mariano
Fundación Mariano Ospina Pérez
Avenida 22 No. 39-32
Bogotá, D.C. 1
Colombia

Phillipson, Dr. Peter
Botany Department
Rhodes University
Grahamstown 6140
South Africa

Pradhan, Udai
Abhijit Villa
B.P.O. Ecchey
Kalimpong734 301
Darjeeling, W. Bengal
India

Pridgeon, Dr. Alec M.
Royal Botanic Gardens, Kew
Richmond, Surrey TW9 3AB
UK

Pupulin, Franco
Via Correggio 57
20149 Milano
Italy

Rasmussen, Dr. Finn N.
Institute of Systematic Botany
Gothersgade 140
DK-1123 Copenhagen K
Denmark

Rawat, Dr. Gopal. S.
Wildlife Institute of India
Dehra Dun
P. O. New Forest, Dehra Dun
248006
India

Renz, Dr. Jany
Kirschblütenweg 12
4051 Basel
Switzerland

Retana, Dora E. Mora
Jardin Lankester
Escuela de Biologia
Universidad de Costa Rica
San Jose 1000
Costa Rica

Romero, Dr. Gustavo
Oakes Ames Orchid Herbarium
Harvard University Herbaria
22 Divinity Street
Cambridge, MA 02138
USA

Rossi, Dr. Walter
Dipartimento de Scienze
Ambientali
Universita dell' Aquila
167010 Coppito
L'Aquila
Italy

Sagarik, Professor Rapee
6 Paholyothin Road, Soi 41
Bangken, Bangkok 10900
Thailand

Salazar, Gerardo A.
Herbario AMO
Apartado Postal 53-123
11320 Mexico, D.F.
Mexico

Schneckenburger, Dr. Stephan
Botanischer Garten der Technischen
Hochschule Schnittspahnstrasse 5
D-64827 Darmstadt
Germany

Sebeseri, Otto
Therwilerstrasse 23
CH 4107 Ettingen
Switzerland

Seidenfaden, Dr. Gunnar
Borsholmgard
3100 Hornbaek
Denmark

Soto Arenas, Miguel Angel
Herbario AMO
Apartado Postal 53-123
11320 Mexico, D.F.
Mexico

Stewart, Joyce
The Royal Horticultural Society's
Garden, Wisley, Woking
Surrey GV23 6QB
UK

Strahm, Dr. Wendy
Plant Officer
IUCN - The World Conservation
Union
Rue Mauverney 28
CH-1196 Gland
Switzerland

Stojanova, Dr. Petrova Antoaneta
Institute of Botany
Bulgarian Academy of Science
P. O. Box 664
1000 Sofia
Bulgaria

Tan, Dr. Kiat W.
Singapore Botanic Gardens
Cluny Road
Singapore 1025
Singapore

Tang, Dr. Zhen-Zi
P. O. Box 1041
Macau
(via Hong Kong)

Tinschert, Otto
Apartado Postal 2565
Guatemala Cd. 01901
Guatemala

Titus, Jonathan
OrchidNet of Richmond
7730 SE Washington St #1
Portland, OR 97215
USA

Tremblay, Raymond L.
Department of Biology
P. O. Box 23360
University of Puerto Rico
San Juan, Puerto Rico 00931-3360
USA

Upton, Walter T.
P. O. Box 215
West Gosford, NSW 2250
Australia

Valmayor, Dr. Helen L.
College of Agriculture
University of Philippines
Los Banos College, 2204 Laguna
Philippines

Vasquez, Roberto
Casilla 4039
Santa Cruz
Bolivia

Vogel, Dr. E. de
Rijksherbarium
P. O. Box 9514N
2300 RA Leiden
The Netherlands

von Arx, Dr. Bertrand
2064 Trinity Valley Road
Lumby BC 2G0 V0E
Canada

Walter, Dr. Kerry S.
Royal Botanic Garden, Edinburgh
Inverleith Road
Edinburgh EH3 5LR
United Kingdom

Warren, Dr. Richard C.
Rio Atlantic Forest Project
7 Gray Lane
Barnard Castle, County Durham
DL12 8PD
United Kingdom

Weatherhead, Dr. Maureen A.
Department of Botany
Hui Oi Chow Science Building
University of Hong Kong
Hong Kong

References

Ackerman, J. D. 1989. Limitations to sexual reproduction in *Encyclia krugii* (Orchidaceae). *Syst. Bot.* 14: 101-109.

Ackerman, J. D. 1995. An orchid flora of Puerto Rico and the Virgin Islands. *Mem. New York Bot. Gard.* 73: 1-203.

Ackerman, J. D.and Del Castillo, M. 1992. *The orchids of Puerto Rico and the Virgin Islands: Las orquídeas de Puerto Rico y las Islas Virgenes*. University of Puerto Rico Press, San Juan.

Ackerman, J. D. and Galarza-Pérez, M. 1991. Patterns and maintenance of extraordinary variation in the Caribbean orchid, *Tolumnia (Oncidium) variegata. Syst. Bot.* 16:182-194.

Ackerman, J. D. and Montalvo, A. M. 1990. Short- and long-term limitations to fruit production in a tropical orchid. *Ecology* 71: 263-272.

Ackerman, J. D. and Montalvo, A. M., and Vera, A. 1989. Epiphyte host specificity of *Encyclia krugii,* a Puerto Rican endemic orchid. *Lindleyana* 4: 74-77.

Ackerman, J. D. and Montero Oliver, J. C. 1985. Reproductive biology of *Oncidium variegatum*: moon phases, pollination and fruit set. *Amer. Orchid Soc. Bull.* 54: 326-329.

Ackerman, J. D., Rodríguez-Robles, J. A., and Melendez, E. J. 1994. A meager nectar offering by an epiphytic orchid is better than nothing. *Biotropica* 26: 44-49.

Acuña Galé, J. 1939. Catálogo descriptivo de las orquídeas cubanas. *Est. Exper. Agron. Santiago de las Vegas, Bol. Tec.* 60.

Adams, CD. 1972. *Flowering plants of Jamaica.* University of the West Indies, Mona, Jamaica.

Agnew, A. D. Q., and Agnew, S. 1994. *Upland Kenya wild flowers.*. 2nd ed. East Africa Natural History Society, Nairobi, Kenya.

Albert, V. A. 1994. Cladistic relationships of the slipper orchids (Cypripedioideae: Orchidaceae) from congruent morphological and molecular data. *Lindleyana* 9: 115-132.

Albert, V. A. and Pettersson, B. 1994. Expansion of genus *Paphiopedilum* to include all conduplicate-leaved slipper orchids (Cypripedioideae: Orchidaceae). *Lindleyana* 9: 133-139.

Ames, O. 1925. *Enumeration of Philippine Aposstasiaceae and Orchidaceae.* Bureau of Printing, Manila

Ames, O. and Schweinfurth, C. 1931. Orchidaceae. Pages 345-353 *in* H. A. Gleason (ed.), Botanical results of the Tyler-Duida Expedition. *Bull. Torrey Bot. Club* 58: 277-514.

Andrews, F. W. 1956. The flowering plants of Anglo-Egyptian Sudan 3: 309-325.

Anonymous. 1976. *Iconographia cormophytorum sinicorum, V.* Science Press, Beijing.

Anonymous. 1981. Proceedings of Symposium on North American Terrestrial Orchids, Southfield, Michigan.

Anonymous. 1985. *The Nature Conservancy News* 35(3).

Anonymous. 1990. Proceedings of Conference: *North American Native Terrestrial Orchid Propagation and Production.* March 10-11, 1989 the Brandywine Conservancy, Chadds Ford, Pennsylvania. The Conservancy, 1990-viii, 139p.

Anonymous. 1992a. *American Orchid Society Bulletin* 61:1250.

Anonymous. 1992b. East Hampton orchids: will they survive? *Long Island Bot. Soc. Newsletter,* Nov.-Dec: 4-5.

Anonymous. 1993a. Protecting species of special concern. *World Wildlife Fund Focus* 15: 4-5.

Anonymous. 1993b. Singapore orchids: a blossoming trade. *Singapore Trade News,* July/August 1993: 8-13.

Arditti, J. 1992. *Fundamentals of orchid biology.* Wiley-Interscience, New York.

Arditti, J., Clements, M. A., Fast, G., Hadley, G., Nishimura, G., and Ernst, R. 1982. Orchid seed germination and seedling culture — a manual. Pages 243-370 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, II.* Cornell University Press, Ithaca, New York.

Arditti, J. and Ernst, R. 1988. Physiology of germinating orchid seeds. Pages 177-222 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, III.* Cornell University Press. Ithaca, New York.

Arditti, J. and Ernst, R. 1993. *Micropropagation of orchids.* Wiley-Interscience, New York.

Arnold, H. J. and Arnold, N. 1985. L'utilisation du sahlep en Syrie aujourd'hui. *Coll. Soc. Franç. Orchidophilie* 8: 143-154.

Atwood, J. T., Jr. 1986. The size of the Orchidaceae and the systematic distribution of epiphytic orchids. *Selbyana* 9: 171-186.

Aubert du Petit-Thouars, A. 1822. *Histoire particuliere des plantes Orchidees recueillies sur les trois îles australes d'Afrique, de France,de Bourbon, et de Madagascar.* Paris.

Aublet, J. B. C. F. 1775. *Histoire des plantes de la Guiane Francaise I-IV.* Pierre-Francpis Didot Jeune, London and Paris.

Australian Nature Conservation Agency. 1993. *Threatened Australian flora.* Australian Nature Conservation Agency, Canberra.

Averyanov, L. V. 1988. A review of the genus *Dactylorhiza.* Pages 159-206 *in* J. Arditti (ed.), *Orchid Biology: Reviews and Perspectives, V.* Timber Press, Portland, Oregon.

Ayensu, E. S. 1975. Endangered and threatened orchids in the United States. *Amer. Orchid Soc. Bull.* 44: 384-394.

B.G.C.I. 1994. *A CITES manual for botanic gardens.* Botanic Gardens Conservation International, London.

Ball, J. S. 1978. *Southern African epiphytic orchids.* Conservation Press, Johannesburg.

Banerji, M. L. and Pradhan, P. 1984. *The orchids of Nepal Himalaya.* Cramer, Vaduz.

Banerji, M. L. and Thapa, B. B. 1969-1973. Orchids of Nepal. *J. Bom. Nat. Hist. Soc.* 66: 286-296, 577-583; 67: 139-152; 68: 29-36, 660-665; 69: 283-289; 70: 25-35, 330-338.

Barradas, V. L. and Fanjul, L. 1986. Microclimatic characterization of shaded and open grown coffee (*Coffea arabica* L.) plantations in Mexico. *Agricultural and Forest Meteorology* 38: 101-112.

Barrett, S. C. and Kohn, J. R. 1991. Genetic and evolutionary consequences of small population size in plants: implications for conservation. Pages 3-30 *in* D. A. Falk and K. E. Holsinger (eds.), *Genetics and conservation of rare plants.* Oxford University Press, New York.

Bates, R. and Weber, J. Z. 1990. *Orchids of South Australia.* Government Printer, Adelaide.

Baumann, H. and Künkele, S. 1980. Das OPTIMA-Projekt zur Kartierung der mediterranen Orchideen. *Jahresber. Naturwiss. Ver. Wuppertal* 33: 146-163.

Baumann, H. and Künkele, S. 1982. *Die wildwachsenden Orchideen Europas.* Kosmos Naturführer, Franckh'sche Verlagshandlung, Stuttgart.

Baumann, H. and Künkele, S. 1986. Die Gattung *Ophrys* L: eine taxonomische Übersicht. *Mitt. Bl. Arbeitskr. Heim. Orch. Baden-Württ.* 18: 306-688.

Baumann, H. and Künkele, S. 1988a. *Die Orchideen Europas.* Kosmos Naturfuhrer, Franckh'sche Verlagshandlung, Stuttgart.

Baumann, H. and Künkele, S. 1988b. Neue Beiträge zur Taxonomie europäischer und mediterraner Orchideen. *Mitt. Bl. Arbeitskr. Heim. Orch. Baden-Wurtt.* 20: 610-651.

Baumann, H. and Kiinkele, S. 1989. Die Gattung *Serapias* L.: eine taxonomische Ubersicht. *Mitt. Bl. Arbeitskr. Heim. Orch. Baden-Wurtt.* 21: 701-946.

Baumann, H. and Kiinkele, S., and Lorenz, R. 1989. Die nomenklatorischen Typen der von Linnaeus verröffentlichen Namen europäischer Orchideen. *Mitt. Bl. Arbeitskr. Heim. Orch. Baden-Wurtt.* 21: 355-700.

Bechtel, H., Cribb, P., and Launert, E. 1992. *The manual of cultivated orchid species.* Ed. 3. MIT Press, Cambridge, Massachusetts.

Béguin, J. J. 1993. *The world artificially propagated orchid species sourcebook.* Jaysquare, Geneva, Switzerland.

Bell, M. 1985. *The face of Connecticut.* State Geological and Natural History Survey of Connecticut, Hartford, Connecticut.

Bennett, D. E. and Christenson, E. A. 1994 New species and new combinations in Peruvian Orchidaceae. *Brittonia* 46: 24-53.

Benzing, D.H. 1986. The genesis of orchid diversity: emphasis on floral biology leads to misconceptions. *Lindleyana* 1:73-89.

Benzing, D.H. 1987. Vascular epiphytism: taxonomic participation and adaptive diversity. *Ann. Missouri Bot. Gard.* 74: 183-204.

Benzing, D.H. 1990. *Vascular epiphytes: general biology and related biota.* Cambridge University Press, New York.

Benzing, D.H. and Atwood, J. T., Jr. 1984. Orchidaceae: ancestral habitats and current status in forest canopies. *Syst. Bot.* 9: 155-165.

Bernhardt, P. 1977. San Salvador's urban orchids. *Natural History* 86: 64-71.

Berry, P., Hoist, B., and Yatskievych, K. In press. Introduction. *In* J. Steyermark and P. Berry (eds.), *Flora of the Venezuelan Guayana.* Timber Press, Portland, Oregon.

Blundell, M. 1987. *Collins guide to the wild flowers of East Africa.* William Collins & Sons, London.

Bosser, J. 1970. Contribution a 1'etude des Orchidaceae de Madagascar et des Mascareignes. XIV. Le genre *Lemurella* Schltr., *Adansonia* sér. 2, 10: 367-373.

Bosser, J. 1971. Contribution a 1'etude des Orchidaceae de Madagascar et des Mascareignes. XVII. Revision du genre *Phajus* Lour. *Adansonia* sér. 2, 11: 519-541.

Bosser, J. and Morat, P. 1969. Contribution a 1'etude des Orchidaceae de Madagascar et des Mascareignes. IX. Les genres *Grammangis* Rchb.f. et *Eulophiella* Rolfe. *Adansonia* ser. 2, 9: 529-547.

Braem, G. J. 1986. *Tolumnia* — Der neue, aber doch alte, Name fur die 'Variegaten Oncidien'. *Die Orchidee* 37: 55-59.

Bratton, S.P. and White, P.S. 1980. Rare plant management - after preservation what? *Rhodora* 82: 49-75.

Briggs, J. D. and Leigh, J. H. 1988. *Rare and threatened Australian plants.* Australian National Parks and Wildlife Service, Special Publication 14: 1-278.

Britton, N. L. 1901. *Manual of the flora of the northern states and Canada.* Henry Holt & Co., New York.

Burns-Balogh, P. 1988. A monograph of the genus *Deiregyne* Schlechter (Orchidaceae). *Orquídea (Méx.)* 11: 202-232, figs. 160-201.

Burns-Balogh, P. and Bernhardt, P. 1988. Floral evolution and phylogeny in the tribe Thelymitreae (Orchidaceae: Neottioideae). *Pl. Syst. Evol.* 159: 19-47.

Buttler, K. P. 1986. *Orchideen: Die wildwachsenden Arten und Unterarten Europas, Vorderasiens und Nordafrikas.* Steinbachs Naturführer, Mosaik Verlag, München.

Buttler, K. P. 1991. *Field guide to orchids of Britain and Europe.* The Crowood Press, Swindon.

Calvo, R. N. 1993. Evolutionary demography of orchids: intensity and frequency of pollination and the cost of fruiting. *Ecology* 74: 1033-1042.

Cameron, K. M., Jarrell, D., and Chase, M. W. 1994. Evidence from rbcL sequences and phylogenetic relationships of major lineages within Orchidaceae. *Amer. J. Bot.* 81 (abstracts): 145.

Camus, E. G. and Camus, A. 1921-1929. *Iconographie des Orchidees d'Europe et du bassin mediterraneen.* Lechevalier, Paris.

Carnevali, G., Ramirez, I. M., Romero, G. A. 1994. Orchidaceae Dunstervilleorum VIII: new *Encyclia* species and combinations from Venezuelan Guayana. *Lindleyana* 9: 59-70.

Case, F. W. Jr. 1983. Notes concerning changes in Great Lakes orchid populations. Pages 133-141 *in* E. H. Plaxton (ed.), *Proc. Symposium II and lecture: North American terrestrial orchids.* Michigan Orchid Society, Southfield, Michigan.

Case, F. W. Jr. 1987. *Orchids of the western Great Lakes region.* Revised ed. Cranbrook Institute of Science Bulletin 48. Bloomfield Hills, Michigan.

Case, F. W. Jr. 1990. Native orchid habitats: the horticulturalist's viewpoint. Pages 1-14 *in* C. E. Sawyers (ed.), *Proc. Conf. North American native terrestrial orchid propagation and production.* Brandywine Conservancy, Mt. Cuba Center, Chadds Ford, Pennsylvania.

Catling, P. M. 1990. Auto-pollination in the Orchidaceae. Pages 121-158 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, V.* Timber Press, Portland, Oregon.

Catling, P. M. 1989. Biology of North American representatives of the subfamily Spiranthoideae. Pages 49-67 *in* C. E. Sawyers (ed.), *Proc. Conf. North American native terrestrial orchid propagation and production.* Brandywine Conservancy, Mt. Cuba Center, Chadds Ford, Pennsylvania.

Catling, P. M. and Catling, V. R. 1991. A synopsis of breeding systems and pollination in North American orchids. *Lindleyana* 6: 187-210.

Catling, P. M. and Catling, V. R. 1987. Orchids in a tropical orchard. *Amer. Orchid Soc. Bull.* 56: 904-908.

Catling, P. M. and Catling, V. R., and Lefkovitch, L. P. 1986. Epiphytic orchids in a Belizean grapefruit orchard: distribution, colonization, and association. *Lindleyana* 1: 194-202.

Catling, P.M. and Knerer, G. 1980. Pollination of the small white lady's-slipper *(Cypripedium candidum)* in Lambton County, southern Ontario. *Canad. Field-Naturalist* 94: 435-438.

Champlin, R. L. 1976. Scotch pine as an associate of the tesselated rattlesnake plantain. *Rhodora* 78: 788-789.

Chase, M. W. 1987. Obligate twig epiphytism in the Oncidiinae and other Neotropical orchids. *Selbyana* 10: 24-30.

Chase, M. W. and Palmer, J. D. 1992. Floral morphology and chromosome number in subtribe Oncidiinae (Orchidaceae): evolutionary insights from a phylogenetic analysis of chloroplast DNA restriction site variation. Pages 324-337 *in* P. S. Soltis, D. E. Soltis, and J. J. Doyle (eds.), *Molecular systematics of plants.* Chapman and Hall, New York.

Chen, S. C. 1989. Status of the conservation of rare and endangered plants in China. *Cathaya* 1: 161-190.

Chen, S. C. 1983. A comparison of orchid floras of temperate North America and eastern Asia. *Ann. Missouri Bot. Gard.* 70: 713-723.

Chen, S. C. and Tang, T. 1982. A general review of the orchid flora of China. Pages 39-81 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, II.* Cornell University Press, Ithaca, New York.

Chesselet, P. 1989. Systematic implications of leaf anatomy and palynology in the Disinae and Coryciinae (Orchidaceae). M.Sc, thesis (unpubl.). University of Cape Town, Cape Town.

Chesselet, P. and Linder, H. P. 1993. Pollen morphology of the Diseae (Orchidoideae; Orchidaceae). *Grana* 32: 101-110.

Chin, H. E, Krishnapillay, B., and Stanwood, P. C. 1989. Seed moisture: recalcitrant vs orthodox seeds. Pages 15-22 *in* P. C. Stanwood and M. B. McDonald (eds.), *Seed moisture.* CSSA Spec. Publs., No. 14, Madison, Wisconsin.

Christenson, E. A. and Boggan, K. K. 1992. Orchidaceae. Pages 312-331 *in* J. Boggan *et al.* (eds.), *Checklist of the plants of the Guianas.* Biological Diversity of the Guianas Program, Smithsonian Institution, Washington.

Clements, M. A. 1982. Developments in the symbiotic germination of Australian terrestrial orchids. Pages 269-273 *in* J. Stewart (ed.), *Proc. 10th World Orchid Conf.*, Durban, South Africa.

Clements, M. A. and Ellyard, R. K. 1979. The symbiotic germination of Australian terrestrial orchids. *Amer. Orchid Soc. Bull.* 48: 810-816.

Clements, M. A. , Muir, H. J., and Cribb, P. 1986. A preliminary report on the symbiotic germination of European terrestrial orchid species. *Kew Bull.* 41: 437-445.

Cogniaux, A. 1893-1906. Orchidaceae. *In* Martius, *Flora Brasiliensis* 3, parts 4-6.

Cogniaux, A. and Urban, I. 1909-1910. Orchidaceae. Pages 293-696 *in* I. Urban (ed.), *Symbolae Antillanae,* vol. 6, *Florae Indiae Occidentalis.* Fratres Borntraeger, Lipsiae.

Colchester, M. 1994. The new sultans. *Ecologist* 24: 45-52.

Collins, M. T. and Dixon, K. W. 1992. Micropropagation of an Australian terrestrial orchid, *Diuris longifolia* R.Br. *Austral. J. Exp. Ag.* 32: 131-135.

Comber, J. 1990. *Orchids of Java.* Royal Botanic Gardens, Kew.

Copley, G. C, Tweedie, E. M., and Carroll, E. W 1964. A key and checklist to Kenya orchids. *J. East Africa Nat. Hist. Soc.* 24: 1-59.

Correll, D. S. 1950. *Native orchids of North America north of Mexico.* Chronica Botanica Co., Waltham, Massachusetts.

Correll, D. S. and Correll, H. B. 1982. *Flora of the Bahama Archipelago.* J. Kramer, Vaduz.

Coulon, F. 1992. Section Orchidees d'Europe. Bilan des activites 1990-1991. *Natural. beiges* 73: 145-154.

Couret, P. 1977. Study on the morphology and pigmentation of *Catasetum pileatum* Reichb.f. and its natural hybrids. *Amer. Orchid Soc. Bull.* 47: 200-208.

Couret, P. 1982. The rediscovery of the red varieties of *Catasetum pileatum* I-II. *Orchid Rev.* 90: 277-281, 317-321.

Couret, P. 1973. Research on the 'red' *Catasetum pileatum* Reichb.f. in Venezuela — a preliminary report. *Amer. Orchid Soc. Bull.* 43: 992-998.

Cremers, G., and Hoff, M. 1992. *Inventaire taxonomique des plantes de la Guyane Francaise. II-* Les Orchidacees. Museum National D' Histoire Naturelle, Paris.

Cribb, P. 1978a. A revision of *Stolzia* (Orchidaceae). *Kew Bull.* 33: 79-89.

Cribb, P. 1978b. Studies in the genus *Polystachya*. *Kew Bull.* 32: 743-766.

Cribb, P. 1979. Orchids of Arabia. *Kew Bull.* 33: 651-678.

Cribb, P. . 1983. A revision of *Dendrobium* sect. *Latouria*. *Kew Bull.* 38: 229-306.

Cribb, P. 1984. Orchidaceae, Part 2. *In* R. Polhill (ed.), *Flora of tropical East Africa.* Balkema, Rotterdam.

Cribb, P. 1986. A revision of *Dendrobium* sect. *Spatulata*. *Kew Bull.* 41: 615-692.

Cribb, P. 1987a. *The genus* Paphiopedilum. Royal Botanic Gardens, Kew, and Collingridge Books, London.

Cribb, P. 1987b. New records of Orchidaceae for Arabia. *Kew Bull.* 42: 461-463.

Cribb, P. 1989. Orchidaceae, Part 3. *In* R. Polhill (ed.), *Flora of tropical East Africa.* Balkema, Rotterdam.

Cribb, P. , and Fay, J. M. 1987. Orchids of the Central African republic — a provisional checklist. *Kew Bull.* 42: 711-737.

Cropper, S. C. 1993. *Management of endangered plants*. CSIRO, East Melbourne, Victoria.

Cufodontis, G. 1972. Enumeratio Plantarum Aethiopiae Orchidaceae. *Bull. Jard. Bot. Nat. Beige* 40 Suppl.: 1597-1622.

Curtis, J. T. 1946. Use of mowing in management of white ladyslipper. *J. Wildlife Managem.* 10: 303-308.

Curtis, J. T. and Greene, H. C. 1953. Population changes in some native orchids of southern Wisconsin, especially in the University of Wisconsin Arboretum. *Orchid J.* 2: 152-155.

Danesch, O. and Danesch, E. 1972. *Orchideen Europas: Ophrys-Hybriden*. Hallwag, Bern and Stuttgart.

Darwin, C. 1862. *On the various contrivances by which British and foreign orchids are fertilized by insects.* John Murray, London.

Davies, P., Davies, J., and Huxley, A. 1988. *Wild orchids of Britain and Europe.* The Hogarth Press, London.

de Cordemoy, J. 1895. Orchidées *in Flore de La Réunion*. Klinksieck Ed., Paris.

Delforge, P. 1990. Le groupe *d'Ophrys bertolonii* Moretti. *Mem. Soc. Roy. Bot. Belg.* 11: 7-29.

Delforge, P. 1994. *Guide des Orchidees d'Europe, d'Afrique du Nord et du Proche-Orient.* Delachaux et Niestle, Lausanne-Paris.

Delforge, P. and Tyteca, D. 1984. *Guide des orchidees d'Europe dans leur milieu naturel.* Duculot, Gembloux-Paris.

Devillers, P. 1986. Evaluation of the European importance of sites for dragonflies and orchids. Pages 283-292 *in* B.K. Wyatt (ed.), *CORINE. Register of sites of importance for nature conservation in Europe. Specifications for data content and format of the standard site record.* Commission des Communautés Européennes XI/5/87, Bruxelles.

Devillers, P. , Beudels, R. C, Devillers-Terschuren, J., Lebrun, P., Ledant, J. P., and Sérusiaux, E. 1990. Un projet de surveillance de l'etat de l'environnement par bio-indicateurs. *Natural, beiges* 71: 74-98.

Devillers, P. and Devillers-Terschuren, J. 1994. *A classification of Palearctic habitats.* Conseil de l'Europe, Strasbourg.

Devillers-Terschuren, J. and Devillers, P. 1988. Les *Ophrys* 'arachnitif ormes' du bassin méditerranéen occidental. *Natural. beiges* 69: 98-112.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. *Biol. Conservation* 7: 129-146.

Dixon, K. W, Buirchell, B., and Collins, M. T. (eds.). 1989. *Orchids of Western Australia: cultivation and natural history*. Second edition. Western Australia Native Orchid Study and Conservation Group Inc., Perth.

Dixon, K.W. and Pate, J.S. 1984. Biology and distributional status of *Rhizanthella gardneri* Rogers (Orchidaceae), the Western Australian underground orchid. *Kings Park Research Notes* No. 9. Kings Park Board, West Perth, Western Australia.

Dixon, K. W and Pate, J.S., and Kuo, J. 1990. The Western Australian subterranean orchid, *Rhizanthella gardneri* Rogers. Pages 37-62 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, V.* Timber Press, Portland, Oregon.

Dodson, C. H. and R. Escobar R. 1994. *Native Ecuadorian orchids I.* Hola Colina, Medellín.

Dodson, C.H. and Gentry, A. H.. 1978. Flora of Rio Palenque. *Selbyana* 4:1-628.

Dodson, C.H. and Gentry, A. H. 1991. Biological extinction in western Ecuador. *Ann. Missouri. Bot. Gard.* 78: 273-295.

Dodson, C. H. and Gentry, A. H., and Valverde, F. M. 1985. Flora of Jauneche. *Selbyana* 8: 1-512.

Dodson, C. H and Neudecker, T. 1990. Die Gattung *Paphinia. Die Orchidee* 41: 230-234; 42: 45-50, 79-85.

Dressier, R. L. 1969. Una *Encyclia* nueva de Panamá. *Orquideología* 4: 91-94.

Dressier, R. L. 1979. Una *Sievekingia* Ilamativa de Panamá. *Orquideologia* 13: 221-226.

Dressier, R. L. 1981a. *Maxillaria insolita,* especie nueva panamena. *Orquideologia* 14: 203-208.

Dressier, R. L. 1981b. *The orchids: natural history and classification.* Harvard University Press, Cambridge, Massachusetts.

Dressier, R. L. 1982a. Biology of the orchid bees (Euglossini). *Ann. Rev. Ecol. Syst.* 3: 373-394.

Dressier, R. L. 1982b. Dos *Brachionidium* nuevas de Panama. *Orquideología* 15: 152-164.

Dressier, R. L. 1983. *Palmorchis* in Panama mit einer neuen Art, *Palmorchis nitida,* an einer unerwarteten Standort. *Die Orchidee* 34: 25-31.

Dressier, R. L. 1989a. The improbable *Selenipedium chica. Amer. Orchid Soc. Bull.* 58: 549-552.

Dressier, R. L. 1989b. *Stanhopea avicula,* a new twin-flowered species from eastern Panama. *Amer. Orchid Soc. Bull.* 58: 885-886.

Dressier, R. L. 1993a. Four new species of *Erythrodes* from Costa Rica and Panama. *Orquíea (Méx.)* 13: 255-260.

Dressier, R. L. 1993b. *Phylogeny and classification of the orchid family.* Cambridge University Press, Cambridge.

Dunn, H. A. 1948. Orchid collecting in Panama. *Amer. Orchid Soc. Bull.* 17: 537-544.

Dunsterville, G. C. K. and Garay, L. A. 1958-1976. *Venezuelan orchids illustrated* 1-6. Andre Deutsch, London.

Dunsterville, G. C. K. and Garay, L. A. 1979. *Orchids of Venezuela: an illustrated field guide.* Harvard Univ. Press, Cambridge, Massachusetts.

DuPuy, D. and Cribb, P. J. 1987. *The genus* Cymbidium. Christopher Helm, London.

Du Puy, D.J. and Moat, J. (In press). A refined classification of the primary vegetation of Madagascar based on the underlying geology: using GIS to map its distribution and to assess its conservation status. Proceedings of the International Symposium on the Biogeography of Madagascar, Paris, September 1995, including 3 detailed computer-generated (GIS) maps.

Duthie J.F. 1906. The orchids of North-Western Himalaya. *Ann. Roy. Bot. Gard. Calcutta 9.*

Duvigneaud, J. 1983. Quelques reflexions sur la protection et la gestion des pelouses calcaires. *Natural. beiges* 64: 33-53.

Fahrig, L. and Merriam, G. 1985. Habitat patch connectivity and population survival. *Ecology* 66: 1762-1768.

Fahselt, D. 1988. The dangers of transplantation as a conservation technique. *Nat. Areas J.* 8: 238-244.

Flora and Fauna Preservation Society. 1994. FFPS in action (salep project). *Fauna and Flora News* 1: 5.

Ferrusquía-Villafranca, I. 1993. Geology of Mexico: a synopsis. Pages 3-107 *in* T. P. Ramamoorthy, R. Bye, A. Lot, and J. Fa (eds.), *Biological diversity of Mexico: origins and distribution.* Oxford University Press, Oxford.

Fiedler, P. L. 1986. Concepts of rarity in vascular plant species, with special reference to the genus *Calochortus* Pursh (Liliaceae). *Taxon* 35: 502-518

Foldats, E. 1969-1970. Orchidaceae. Vol. 15 in T. Lasser (ed.), *Flora de Venezuela.* Univ. de Venezuela, Caracas.

Foster, B. 1984. Guidelines on management and research in ecological areas. *Canadian Council on Ecological Areas, Occasional Papers* 1: 1-11.

Fournet, J. 1978. *Flore illustrée des phanérogames de Guadeloupe et de Martinique.* Institut National de la Recherche Agronomique, Paris.

Fowlie, J. A. 1964. *Epidendrum pfavii* and its over-specialization. *Amer. Orchid Soc. Bull.* 33: 562-563.

Fowlie, J. A. 1971. Obscure species. Three distinctive species of *Chysis* from Central America. *Orchid Dig.* 35: 85-87.

Frankel, O. H. 1983. The place of management in conservation. Pages 1-14 *in* C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde, L. Thomas. (eds.), *Genetics and conservation: a reference for managing wild animal and plant populations.* Benjamin/Cummings.

Freudenstein, J. V and Doyle, J. J. 1994. Plastid DNA, morphological variation, and the phylogenetic species concept: the *Corallorhiza maculata* (Orchidaceae) complex. Syst. *Bot.* 19: 273-290.

Freudenstein, J. V. and Rasmussen, F. N. 1994. Systematic implications of pollinium development in the Orchidaceae. *Amer. J. Bot.* 81 (abstracts): 155.

Frey, G. 1977. Beitrag zur Orchideenflora Madeiras (I.Teil). *Jahresber. Naturwiss. Ver. Wuppertal* 29: 59-61.

Frey, G. and Pickering, C. H. C. 1975. Contribution to the knowledge of the orchids of Madeira and the Azores. *Bocagiana* 38: 1-6.

Fu, L. K. 1992. *China plant red data book: rare and endangered plants, I.* Science Press, Beijing.

Furuse, M. and Chen, S. C. 1988. The discovery of *Archineottia* (Orchidaceae) in Japan. *Acta Phytotax. Sin.* 26: 139-143.

Gade, S. 1987. State-by-state summary of protection afforded to native orchid species. *Amer. Orchid Soc. Bull.* 56: 147-163.

Garay, L. A. 1973. Systematics of the genus *Angraecum* (Orchidaceae). *Kew Bull.* 28: 495-516.

Garay, L. A. 1979. Orchidaceae. Pt. 1 in G. Harling and B. Sparre (eds.), *Flora of Ecuador.* University of Goteborg, Gothenburg.

Garay, L. A. and Sweet, H. R. 1974. Orchidaceae *in* R. A. Howard (ed.), *Flora of the Lesser Antilles.* Arnold Arboretum, Harvard University, Jamaica Plains, Massachusetts.

Garay, L. A. and Taylor, P. 1976. The genus *Oeceoclades* Lindl. *Bot. Mus. Leaflets Harvard Univ.* 24: 248-274.

García Peña, M. del R. and Peña, M. 1981. Uses of orchids in Mexico from Precolumbian times to the present. *Orquídea (Méx.)* 8: 59-86.

Geerinck, D. 1984. *Flore d'Afrique Centrale Orchidaceae* 1. Jardin Botanique nationale de Beige.

Geerinck, D. 1988. Orchidaceae, *in* G. Troupin (ed.), *Flore du Ruanda* 4: 505-629.

Geerinck, D. 1992. *Flore d'Afrique Centrale Orchidaceae 2*. Jardin Botanique rationale de Beige.

Gentry, A. H. 1977. Endangered plant species and habitats of Ecuador and Amazonian Peru. Pages 136-149 *in* G. T. Prance (ed.), *Extinction is forever*. New York Botanical Garden, New York.

Gentry, A. H. 1982a. Neotropical floristic diversity: phytogeographical connections between Central and South America, Pleistocene climatic fluctuations, or an accident of the Andean orogeny? *Ann. Missouri Bot. Gard.* 69: 557-593.

Gentry, A. H. 1982b. Patterns of Neotropical plant diversity. *Evol. Biol.* 15: 1-15.

Gentry, A. H. 1988. Changes in plant community diversity and floristic composition on environmental and geographical gradients. *Ann. Missouri Bot. Gard.* 75: 1-34. 1988.

Gentry, A. H. and Dodson, C. H. 1987. Diversity and biogeography of Neotropical vascular epiphytes. *Ann. Missouri Bot. Gard.* 74: 205-233.

Gentry, A. H. and Dodson, C H. 1991. Biological extinction in western Ecuador. *Ann. Missouri Bot. Gard.* 78: 273-295.

George, A. S. 1980. *Rhizanthella gardneri* R. Rogers - the underground orchid of Western Australia. *Amer. Orchid Soc. Bull.* 49: 631-646.

Gerlach, G. and Schill, R. 1993. Die Gattung *Coryanthes* Hook. (Orchidaceae). *Tropische und subtropische Pflanzenwelt* 83: 1-205.

Gibson, W. H. 1905. *Our native orchids*. Doubleday, Page & Co., New York.

Gill, A.M. 1981. Coping with fire. Pages 65-87 *in* J. S. Pate and A. J. McComb (eds.), *The biology of Australian plants*. University of Western Australia Press, Nedlands, Western Australia.

Gilpin, M. E. and Soulé, M. E. 1986. Minimum viable populations: processes of species extinctions. Pages 19-34 *in* M. Soulé (ed.), *Conservation biology: the science of scarcity and rarity*. Sinauer, Sunderland, Massachusetts.

Goldblatt, P. 1978. An analysis of the flora of southern Africa: its characteristics, relationships, and origins. *Ann. Missouri Bot. Gard.* 65: 369-436.

González-Díaz, N. and Ackerman, J. D. 1988. Pollination, fruit set and seed production in the orchid *Oeceoclades maculata*. *Lindleyana* 3: 150-155.

Graham, E. H. 1934. Flora of the Kartabo region, British Guiana. *Ann. Carnegie Mus.* 22: 17-292.

Grant, B. 1895. *The orchids of Burma*. Hanthawaddy Press, Rangoon.

Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *Amer. Naturalist* 111: 1169-1194.

Grime, J. P. 1979. *Plant strategies and vegetation processes*. John Wiley & Sons, Toronto, Ontario.

Grisebach, A. H. R. 1864. *Flora of the British West Indian Islands*. Lovell Reeve & Co., London.

Hadley, G. and Pegg, G. F. 1989. Host-fungus relationships in orchid mycorrhizal systems. Pages 57-71 *in* H. Pritchard (ed.), *Modern methods in orchid conservation*. Cambridge University Press, Cambridge.

Hagan, P. 1991. Gardening: save the wildflowers. *Wall Street Journal*, November 9.

Hágsater, E. 1993a. *Epidendrum floridense* Hágsater. Plate 133 *in* E. Hágsater and G. A. Salazar (eds.), *Icones Orchidacearum 2. A century of new species in* Epidendrum. Asociación Mexicana de Orquideologia, Mexico City.

Hágsater, E. 1993b. New combinations in *Encyclia* and *Epidendrum*. *Orquídea (Méx.)* 13: 215-218.

Hágsater, E. 1993c. *The genus* Epidendrum *1: A century of new species in* Epidendrum. *Icones Orchidacearum 2*. Asociacion Mexicana de Orquideología, Mexico City.

Hágsater, E. and Salazar, G. A. 1990. *Icones Orchidacearum I. Orchids of Mexico. Part 1*. Asociación Mexicana de Orquideología, Mexico, D.F., Mexico.

Hágsater, E. and Stewart, J. 1986. Strategies for orchid conservation. *Orquídea (Méx.)* 10: 213-227.

Hall, A. V. 1965. Studies of South African species of *Eulophia*. *J. S. Afr. Bot.*, suppl. 5: 1-248.

Hall, A. V. 1982. A revision of the southern African species of *Satyrium*. *Contrib. Bol. Herb.* 10: 1-142.

Halle, N. 1977. Orchidacées. Volume 8 *in* A. Aubréville and J. F. Leroy (eds.), *Flore de la Nouvelle-Caledonie et Dépendances*. Muséum National d'Histoire Naturelle, Paris.

Handa, S. S. 1986. Orchids for drugs and chemicals. Pages 89-100 *in* S. P. Vij (ed.), *Biology, conservation and culture of orchids*. East-West Press, New Delhi.

Handley, P. 1992. In the pink: Thailand's orchid exports blossom. *Far Eastern Economic Review*, 27 February 1992: 58-59.

Harrington, J. F. 1972. Seed storage and longevity. Pages 145-245 *in* T. T. Kozlowski (ed.), *Seed biology*. Academic Press, New York.

Hashimoto, T. 1987. Our recent knowledge of the Japanese orchid flora. Pages 118-126 *in* K. Saito and R. Tanaka (eds.), *Proc. 12th World Orchid Conf*, Tokyo.

Hegde, S. N. 1984. *Orchids of Arunachal Pradesh*. Itanagar.

Heidorn, R. 1991. Vegetation management guidelines: exotic buckthorns - common buckthorn (*Rhamnus cathartica* L.), glossy buckthorn (*Rhamnus frangula* L.), dahurian buckthorn (*Rhamnus davurica* Pall.). *Nat. Areas J.* 11: 216-217.

Hernandez Apolinar, M. 1992. Dinamica poblacional de *Laelia speciosa* (H.B.K.) Schltr. Thesis, Fac. Ciencias UNAM, Mexico City.

Higgs, A. J. and Usher, M. B. 1980. Should nature reserves be large or small? *Nature* 285: 568-569.

Hirtz, A. 1993. El mundo desconocido de las flores del Ecuador. Pages 102-111 in *Vida Silvestre*. Conservation Department of Spain (Icona), Madrid, Spain.

Hoehne, F. C. 1940-1953. Orchidaceas. *Flora Brasílica* 12, parts 1-2, 6-7.

Hoffman, N. and Brown, A. 1992. *Orchids of South-West Australia.* Second edition. University of Western Australia Press, Nedlands.

Holttum, R. E. 1953. *A revised flora of Malaya.* Vol. 1. Orchids. Government Printer, Singapore.

Homoya, M. A. 1993. *Orchids of Indiana.* Indiana Academy of Science, Bloomington, Indiana.

Hooker, J. D. 1890. Orchideae, *in Flora of British India* 5-6. L. Reeve & Co., London.

Hooker, J. D. 1895. A century of Indian orchids. *Ann. Roy. Bot. Gard. Calcutta* 5. Calcutta.

Horich, C. K. 1966. Rediscovered: *Sievekingia fimbriata. Amer. Orchid Soc. Bull.* 34: 8-9.

Horich, C. K. 1974. The Costa Rican *Stanhopea* species. *Orchid Dig.* 38: 108-113.

Horich, C. K. 1992a. Schone und seltene *Acineta-Arten. Die Orchidee* 43: 197-202.

Horich, C. K. 1992b. Zur Entdeckung der *Schlimia jasminodora* in Costa Rica. *Die Orchidee* 43: 273-277.

Huber, O. 1987. Considerations sobre el concepto de Pantepui. *Pantepui* 1: 2-10.

Huber, O. 1988a. Vegetation y flora de Pantepui, Region Guayana. *Acta Bot. Bras.* 1: 41-52 (suppl.).

Huber, O. 1988b. Guayana Highlands versus Guayana Lowlands: a reappraisal. *Taxon* 37: 595-614.

Huber, O. 1994. Recent advances in the phytogeography of the Guayana region, South America. *Mem. Soc. Biogeogr.* (3 serie) 4: 53-63.

Huber, O. In press. Geographical features. *In* J. Steyermark and P. Berry (eds.), *Flora of the Venezuelan Guayana.* Timber Press, Portland, Oregon.

Humbert, H. and Cours Dame, G. 1965. *Carte Internationale du Tapis Vegetal et des Conditions Ecologiques: 'Madagascar.' Trav. Sect. Sci. Techn.* Inst. Franc,. Pondichery, Hors Ser. 6.

Humboldt, A., Bonpland, A., and Kunth, K. 1816. Orchideae. *Nova Genera et Species Plantarum* 1: 330-369, t. 71-94 (quarto edition), 265-295, t. 71-94 (folio edition). Librairie Grecque-Latine-AUemande, Paris.

Humboldt, A., Bonpland, A., and Kunth, K. 1825. *Flora Orinoci et Fluminis Nigri. Nova Genera et Species Plantarum 7:* 248-260 (Folio edition); 315-332 (Quarto edition). Librairie Grecque-Latine-AUemande, Paris.

Hutchings, M. A. 1987. The population biology of the early spider orchid, *Ophrys sphegodes* Mill. I. A demographic study from 1975 to 1984. *J. Ecol.* 75: 711-727.

IUCN. 1980. *How to use the IUCN Red Data Book categories.* Threatened Plants Unit, IUCN, Kew. 9 pp.

IUCN Conservation Monitoring Center. 1983. List of rare, threatened and endemic plants in Europe. (1982 edition). Nature and Environment Series No. 27, European Committee for the Conservation of Nature and Natural Resources, Strasbourg.

Jain, S. K. and Mehrotra, A. 1984. *A preliminary inventory of orchids in India.* Botanical Survey of India, Calcutta.

Järvinen, O. 1982. Conservation of endangered plant populations: single large or several small reserves? *Oikos* 38: 301-307.

Jayaweera, D. M. A. 1981. Orchidaceae, *in* M. D. Dassanayake (ed.), *Flora of Ceylon. 2.* Balkema, Rotterdam.

Johansson, D. 1974. Ecology of West African epiphytes. *Acta Phytogeographica Suecica* 59: 1-129.

Johnson, S. D. 1993. Carpenter bee pollination of *Herschelianthe graminifolia* (Orchidaceae) on the Cape Peninsula. *Flora, Morphol. Geobot. Oekophysiol.* 188: 383-386.

Johnson, S. D. and Bond, W. J. 1992. Habitat-dependent pollination success in a Cape orchid. *Oecologia* 91: 455-456.

Jones, D. L. 1988. *Native orchids of Australia.* Reed Books, Frenchs Forest, New South Wales.

Jones, D. L. 1991. New taxa of Australian Orchidaceae. *Austral. Orchid Res.* 2: 1-207.

Jonsson, L. 1981. *A monograph of the genus* Microcoelia (*Orchidaceae*). *Ada Univ. Upps. Symb. Bot. Upps.* 23 (4).

Joseph, J. 1987. *Orchids of Nilgiris.* Botanical Survey of India, Calcutta.

Judd, W. S., Stern, W. L., and Cheadle, V. I. 1993. Phylogenetic position of *Apostasia* and *Neuwiedia* (Orchidaceae). *Bot. J. Linn. Soc.* 113: 87-94.

Kagan. 1990.

Kaiser, R. 1993. *The scent of orchids.* Elsevier, Amsterdam.

Kajan, E., Kreutz, K., and Jansen, H. 1992. Mit dem Reisemobil durch die Türkei. Tagebuchaufzeichnungen einer Orchideen-Exkursion im Mai 1988. *Ber. Arbeitskr. Heim. Orch.* 9: 153-156.

Kataki, S. K. 1986. *Orchids of Meghalaya.* Government of Meghalaya, Shillong.

Katz, L. S., Orrick, S., and Honig, R. 1993. *Environmental profiles.* Garland Publishing, Inc., New York.

Keenan, P. E. 1986. New stations for *Platanthera flava* and *Triphora trianthophora* and other observations. *Rhodora* 88: 409-410.

Keller, G., Schlechter, R., and Soó, R. von. 1930-1940. *Monographie und Iconographie der Orchideen Europas und des Mittelmeergebietes.* Bd. 2-5. *Fedde Repert.,* Sonderbeih. Nachdruk 1972, Konigstein.

Khayota, B. N. 1990. A survey of the leopard orchid at the coast. *Swam Magazine* 13: 22.

Khayota, B. N. 1993. The genus *Ansellia* Lindley. *Kew Magazine* 10: 27-35.

Killick, D. J. B. 1978. The Afro-alpine region. Pages 515-560 *in* M. J. A. Werger (ed.), *Biogeography and ecology of southern Africa.* W. Junk, The Hague.

King, G. and Pantling, R. 1898. The orchids of the Sikkim-Himalaya. *Ann. Roy. Bot. Gard. Calcutta* 8, 3 vols.

Koopowitz, H. and Hasegawa, N. 1988. *Paphiopedilum sanderianum:* some observations. *Amer. Orchid Soc. Bull.* 57: 36-40.

Koopowitz, H. and Kaye, H. 1983. *Plant extinction: a global crisis*. Stone Wall Press, Washington, D.C.

Koopowitz, H. and Thornhill, A. 1994. Gene banking and orchid seeds. *Amer. Orchid Soc. Bull.* 63: 1383-1386.

Kores, P. 1991. Flora Vitiensis Nova 5. Orchidaceae. National Tropical Botanical Garden, Kauai, Hawaii.

Kraenzlin, F. 1929. Neu-Caledonische Orchidaceen. *Viertelj. Naturf. Ges. Zurich* 74: 62-98.

Krause, F. 1985. From the field: an interview with Mark Sheehan. *Nature Conservancy News* 35: 12-17.

Kullenberg, B. 1961. Studies in *Ophrys* pollination. *Zool. Bidr. Uppsala* 34: 1-340.

Kumar, Raj (ed.). 1993. *Frank School Atlas*. Frank Bros. & Co., New Delhi.

Kurzweil, H. 1989. An investigation of the floral morphogenesis of *Bonatea speciosa* (Orchidaceae). S. *African J. Bot.* 55: 433-437.

Kurzweil, H. 1993. The remarkable anther structure of *Pachites bodkinii* (Orchidaceae). *Bot. Jahrb. Syst.* 114: 561-569.

Kurzweil, H. and Linder, H. P. 1991. A comparative study of the floral morphology in the genus *Disperis* (Orchidaceae). *Beitr. Biol. Pflanzen* 66: 433-477.

Kurzweil, H. and Linder, H. P., and Chesselet, P. 1991. The phylogeny and evolution of the *Pterygodium corycium* complex (Coryciinae, Orchidaceae). *Pl. Syst. Evol.* 175: 161-223.

Kurzweil, H. and Weber, A. 1991. Floral morphology of southern African Orchideae. I. Orchidinae. *Nordic J. Bot.* 11: 155-178.

Kurzweil, H. and Weber, A. 1992. Floral morphology of southern African Orchideae II. Habenariinae. *Nordic J. Bot.* 12: 39-61.

Kyte, L. 1987. *Plants from test tubes*. Timber Press, Portland, Oregon.

La Croix, I. F., La Croix, E. A. S., and La Croix, T. M. 1991. *Orchids of Malawi*. Balkema, Rotterdam.

Lande, R. 1988. Genetics and demography in biological conservation. *Science* 241: 1455-1460.

Landwehr, J. 1977. *Wilde orchideeën van Europa. 2* vols. Vereniging tot Behoud Natuurmonumenten in Nederland's, Graveland.

Lawler, L.J. 1984. Ethnobotany of the Orchidaceae. Pages 27-149 *in* J. Arditti (ed.), *Orchid biology: reviews and perspectives, III.* Cornell University Press, Ithaca, New York.

Leakey, C. L. A. 1968. Orchids of Uganda. *Amer. Orchid Soc. Bull.* 37: 883-886, 978-983, 1052-1055; 38: 49-52.

Lemée, A. 1955. Orchidacees. *Flora de la Guyane Francaise I:* 368-470. Paul Lechevalier, Paris.

Lewis, B. and Cribb, P. J. 1989. *Orchids of Vanuatu.* Royal Botanic Gardens, Kew.

Lewis, B. and Cribb, P. J. 1991. *Orchids of the Solomon Islands and Bougainville.* Royal Botanic Gardens, Kew.

Linder, H. P. 1980. An annotated revision of the genus *Schizochilus* Sond. (Orchidaceae). *J. S. African Bot.* 46: 379-434.

Linder, H. P. 1981a. Taxonomic studies in the Disinae (Orchidaceae) IV. A revision of *Disa* Berg. sect. *Micranthae* Lindl. *Bull. Jard. Bot. Nat. Belg.* 51: 255-346.

Linder, H. P. 1981b. Taxonomic studies on the Disinae: 1. A revision of the genus *Brownleea* Lindl. *J. S. African Bot.* 47: 13-48.

Linder, H. P. 1981c. Taxonomic studies on the Disinae: 2. A revision of the genus *Schizodium* Lindl. *J. S. African Bot.* 47: 339-371.

Linder, H. P. 1981d. Taxonomic studies on the Disinae. III. A revision of the genus *Disa* Berg. excluding sect. *Micranthae. Contr. Bolus Herb.* 9: 1-370.

Linder, H. P. 1981e. Taxonomic studies in the Disinae. V. A revision of the genus *Monadenia. Bothalia* 13: 339-363.

Linder, H. P. 1981f. Taxonomic studies in the Disinae. VI. A revision of the genus *Herschelia* Lindl. *Bothalia* 13: 365-388.

Linder, H. P. 1990. Notes on a rare Cape *Disa*. *Bothalia* 20: 216-217.

Linder, H. P. and Kurzweil, H. 1990. Floral morphology and phylogeny of the Disinae (Orchidaceae). *Bot. J. Linn. Soc.* 102: 287-302.

Linder, H. P. and Kurzweil, H. 1994. The phylogeny and classification of the Diseae (Orchidoideae: Orchidaceae). *Ann. Missouri Bot. Gard.* 81: 687-713.

Lindley. J. 1843. Orchidaceae. *In* G. Bentham (ed.), Contribution towards a flora of South America. Enumeration of plants collected by Mr. Schomburgk in British Guiana. *J. Bot. (Hooker)* 2: 670-674.

Ling, R., Mowen, P., and Reilly, B. 1989. Propagation of *Cypripedium acaule*: tissue culture, greenhouse, and garden trials. Pages 93-94 *in Proc. Conf. North American Native Terrestrial Orchid Propagation and Production.* Brandywine Conservancy, Chadds Ford, Pennsylvania.

Liverani, P. 1991. *Orchidee specie spontanee.* Editrice Sardegna, Cagliari.

Lovejoy, T. E., Bierregard, R. O., Jr., Rylands, A. B., Malcom, J. R., Quintella, C. E., Harper, L. H., Brown, K. S., Jr., Powell, A. H, Powell, G. V. N., Schubart, H. O. R., and Hays, M. B. 1986. Edge and other effects of isolation on Amazon forest fragments. Pages 257-285 *in* E. Soulé (ed.), *Conservation biology: the science of scarcity and diversity.* Sinauer, Sunderland, Massachusetts.

Luer, C. A. 1972. *Native orchids of Florida.* New York Botanical Garden, New York.

Luer, C. A. 1975. *Native orchids of the United States and Canada (excluding Florida).* New York Botanical Garden, New York.

Luer, C. A. 1986-1993. *Icones Pleurothallidinarum* 1-10. Missouri Botanical Garden, St. Louis, Missouri.

Lyster, S. 1985. *International wildlife law.* Grotius Publications, Cambridge.

Mabberley, D. J. 1990. *The plant-book.* Cambridge University Press, Cambridge.

MacArthur, R. H. and Wilson, E. D. 1967. *The theory of island biogeography*. Princeton University Press, Princeton, New Jersey.

Madison, M. 1977. Vascular epiphytes: their systematic occurrence and salient features. *Selbyana* 2: 1-13.

Madison, M. 1979. Distribution of epiphytes in a rubber plantation in Sarawak. *Selbyana* 5: 207-213.

Madson, J. 1992. Seas of grass. *Hartford Courant* (Connecticut), July 26.

Maekawa, E 1971. *The wild orchids of Japan in colour*. Seibundo-Shinkosha, Tokyo.

Marshall, D. R. and Brown, A. D. H. 1975. Optimum sampling strategies in genetic conservation. Pages 53-80 *in* O. H. Frankel and J. G. Hawkes (eds.), *Crop genetic resources for today and tomorrow*. Cambridge University Press, Cambridge.

Martinelli, G., Calvacanti, M. J., and Schuback, P. 1990. *Conservacao da biodiversidade*. Jardim Botanico do Rio de Janeiro, Rio de Janiero.

McVaugh, R. 1985. Orchidaceae *in* W. R. Anderson (ed.), *Flora Novo-Galiciana*, vol. 16. University of Michigan Press, Ann Arbor, Michigan.

Mehrhoff, L. A. 1989. The dynamics of declining populations of an endangered orchid, *Isotria medeoloides*. *Ecology 70:* 783-786.

Melendez, E. J. and Ackerman, J. D. 1993. The effects of a rust infection on fitness components in a natural population of *Tolumnia variegata* (Orchidaceae). *Oecologia* 94: 361-367.

Melendez, E. J. and Ackerman, J. D. 1994. Factors associated with rust infection (*Sphenosphora saphaena*) in an epiphytic orchid *(Tolumnia variegata). Amer. J. Bot.* 81:287-293.

Meney, K., Nielssen, G., and Dixon, K. W. 1994. Seed bank patterns in Restionaceae and Epacridaceae after wildfire in heath (kwongan) in south-western Australia. *J. Veg. Sci.* 5: 5-12.

Meyer, G. E W. 1819. *Primitiae Florae Essequeboensis*. Henrich Dieterich, Gottingen.

Migenis, L. E. and Ackerman, J. D. 1993. Orchid-phorophyte relationships in a forest watershed in Puerto Rico. *J. Trop. Ecol.* 9: 231-240.

Miller, D. F. and Warren, R. C. 1994. *Orchids of the Atlantic high mountain rain forest in south-eastern Brazil*. Salamandra, Rio de Janeiro.

Miranda, F. E. 1990. Brazilian laelias - Part III: section *Parviflorae*. *Amer. Orchid Soc. Bull.* 59: 462-472.

Miranda, F. E. and Hernández X, E. 1963. Los tipos de vegetaciòn de Mexico y su clasificación. *Bol. Soc. Bot. Méx.* 28: 29-179.

Moll, E. J. and White, F. 1978. The Indian Ocean Coastal belt. Pages 561-598 *in* M. J. A. Werger (ed.), *Biogeography and ecology of southern Africa*. W. Junk, The Hague.

Montalvo, A. M. and Ackerman, J. D. 1987. Limitations to natural fruit production in *Ionopsis utricularioides* (Orchidaceae). *Biotropica* 19: 24-31.

Moore, S. 1877. Orchideae *in* J. G. Baker (ed.), *Flora of Mauritius and the Seychelles*. L. Reeve & Co., London.

Moreau, W. M. and Moreau, R. E. 1943. An introduction to the epiphytic orchids of East Africa. *J. East Africa Nat. Hist. Soc.* 17: 75-76.

Morgan, R. and Glicenstein, L. 1993. Additional California taxa in *Piperia* (Orchidaceae). *Lindleyana* 8: 89-96.

Morris, F. and Eames, E. A. 1929. *Our wild orchids*. Charles Scribner's Sons, New York.

Mosquin, T. 1986. *A management plan for the showy lady's-slipper,* Cypripedium reginae, *in the Purdon Conservation Area, Lanark County, Ontario.* Mosquin Bio-information Ltd., Lanark, Ontario.

Mossberg, B. and Nilsson, S. 1987. *Orkideer: Europas vildväxande arter*. Walhstrom and Widstrand, Stockholm.

Moya, S. and Ackerman, J. D. 1993. Variation in floral fragrance composition in *Epidendrum ciliare* (Orchidaceae). *Nordic J. Bot.* 13: 41-47.

Nayar, M. P. and Sastry, A. R. K. 1987. *Red data book of Indian plants*. Vol. 1. Botanical Survey of India, Calcutta.

Nayar, M. P. and Sastry, A. R. K. 1988. *Red Data Book of Indian Plants*. Vol. 2. Botanical Survey of India, Calcutta.

Nelson, E. 1962. *Gestaltwandel und Artbildung erörtert am Beispiel der Orchidaceen Europas und der Mittelmeerländer, insbesondere der Gattung* Ophrys *mit einer Monographic und Ikonographie der Gattung* Ophrys. Chernex, Montreux.

Nelson, E. 1968. *Monographic und Ikonographie der Orchidaceen-Gattungen* Serapias, Aceras, Loroglossum, Barlia. Chernex, Montreux.

Nelson, E. 1976. *Monographie und Ikonographie der Orchidaceengattung* Dactylorhiza. Speich, Zurich.

Nevski, S. A. 1935. Orchidaceae. Pages 448-554 *in* V. L. Komarov (ed.), *Flora of the U.S.S.R., IV*. (English translation 1968), Jerusalem.

Merenberg, L. 1972. The mechanisms for maintenance of species integrity in sympatrically occurring equitant oncidiums in the Caribbean. *Amer. Orchid Soc. Bull.* 41:873-882.

Nigam, V. N. 1984. *A complete course in certificate geography*. Rep. 1990. New Delhi.

Niles, G. G. 1904. *Bog-trotting for orchids*. Knickerbocker Press, New York.

Nilsson, L. A. and Jonsson, L. 1985. The pollination specialization of *Habenaria decaryana* H. Perr. (Orchidaceae) in Madagascar. *Bull. Mus. natl. Hist. nat. Paris*, ser. 4, 7, sect. B, *Adansonia* 2: 161-166.

Nilsson, L. A. and Jonsson, L., Ralison, L., and Randrianjohany, E. 1987. Angraecoid orchids and hawkmoths in central Madagascar: specialized pollination systems and generalist foragers. *Biotropica* 19: 310-318.

Nir, M. A. 1988. The survivors: orchids on a Puerto Rican Coffee finca. *Amer. Orchid Soc. Bull.* 57: 989-995.

Ohwi, J. 1978. *Flora of Japan.* Rev. ed. Shibundo, Tokyo.

Oldfield, S. 1991. *Review of significant trade in species of plants listed on Appendix II of CITES 1983-89.* 2 vols. Wildlife Trade Monitoring Unit, Cambridge, England.

Pabst, G. and Dungs, F. 1977. *Orchidaceae Brasilienses.* Band 1 and 2. Kurt Schmersow, Hildesheim, Germany.

Parrilla, A. T. and Ackerman, J. D. 1990. Epiphyte roots: anatomical correlates to environmental parameters in Puerto Rican orchids. *Orquídea (Méx.)* 12: 105-116.

Pate, J. S. and Hopper, S. D. 1993. Rare and common plants in ecosystems, with special reference to the south-west Australian flora. Pages 293-325 *in* B. D. Schultze and H. A. Mooney (eds.), *Biodiversity and ecosystem function.* Springer Verlag, Berlin.

Patel, D. 1992. The endangered species of orchids in Kenya. *Swara Magazine* 15: 28-30.

Paulus, H. F. 1988. Beobachtungen und Experimente zur Pseudokopulation auf *Ophrys*-Arten (Orchidaceae) Kretas (II) mit einer Beschreibung von *Ophrys sitiaca* H.F. Paulus & C.+ A. Alibertis nov. spec. aus dem *Ophrys fusca-omegaifera*-Formenkreis. *Mitt. Bl. Arbeitskr. Heim. Orch. Baden-Wurtt.* 20: 817-882.

Paulus, H. F. and Gack, C. 1990a. Pollinators as prepollinating isolation factors: evolution and speciation in *Ophrys* (Orchidaceae). *Israel J. Bot.* 39: 43-79.

Paulus, H. F. and Gack, C. 1990b. Pollination of *Ophrys* (Orchidaceae) in Cyprus. *Pl. Syst. Evol.* 169: 177-207.

Paulus, H. F. and Gack, C. 1992a. Untersuchungen zur Pseudokopulation und Bestäuberspezifität in der Gattung *Ophrys* im östlichen Mittelmeergebiet *(Orchidacea, Hymenoptera, Apoidea). Jahresber. Naturwiss. Ver. Wuppertal* 43: 80-118.

Paulus, H.F. and Gack, C.. 1992b. Zur Pseudokopulation und Bestäuberspezifität der Gattung *Ophrys* in Sizilien und Süditalien. *Jahresber. Naturwiss. Ver. Wuppertal* 43: 119-141.

Peakall, R. 1990. Responses of male *Zaspilothynnus trilobatus* Turner wasps to females and the sexually deceptive orchid it pollinates. *Functional Ecol.* 4:159-167.

Perrier De La Bathie, H. 1939. Orchidees, t. 1 *in* H. Humbert, *Flore de Madagascar.* L'Imprimerie Officielle, Tananarive.

Perrier De La Bathie, H. 1941. Orchidees, t. 2 *in* H. Humbert, *Flore de Madagascar.* L'Imprimerie Officielle, Tananarive.

Perry, D. R. 1978. Factors influencing arboreal epiphytic phytosociology in Central America. *Biotropica* 10: 235-237.

Pettersson, B. 1990. *Nervilia* (Orchidaceae) in Africa. Ph.D. thesis, Uppsala Univ.

Pianka, E.R. 1970. On r- and K-selection. *Amer. Naturalist* 104: 592-597.

Pickett, S.T.A. and Thompson, J.N. 1978. Patch dynamics and the design of nature reserves. *Biol. Conservation* 13: 27-37.

Piers, F. 1968. *Orchids of East Africa.* J. Cramer, Lehre.

Pijl, L. van der and Dodson, C. H. 1966. *Orchid flowers: their pollination and evolution.* Univ. of Miami Press, Coral Gables, Florida.

Pimental, D., Stachow, U., Takacs, D. A., Brubaker, H. W., Dumas, A. R., Meaney, J. J., O'Neil, J. AS., Onsi, D. E., and Corzilius, D. B. 1992. Conserving biological diversity in agricultural/forestry systems. *BioScience* 42: 354-362.

Pimental, D., Wen, D., Eigenbrode, S., Lang, H., Emerson, D., and Karasik, M. 1986. Deforestation: interdependency of fuelwood and agriculture. *Oikos* 46: 404-412.

Plaxton, E.H. (ed.) 1983. Proceedings from a conference: North American terrestrial orchids. October 1981. American Orchid Society and Mid-America Congress Meetings. Michigan Orchid Society, Livonia, Michigan 143p.

Plowright, R. C, Thomson, J. D., and Thaler, G. R. 1980. Pollen removal in *Cypripedium acaule* (Orchidaceae) in relation to aerial fenitrothion spraying in New Brunswick. *Canad. Entomol.* 112: 765-769.

Podzorski A., and Cribb, P. J. (1979). A revision of *Polystachya* sect. *Cultriformes* (Orchidaceae). *Kew Bull.* 34: 147-186.

Plucknett, D. L., Smith, N. J. H., Williams, J. T., and Anishetty, N. M. 1987. *Gene banks and the world's food.* Princeton University Press, Princeton, New Jersey.

Porteres, R. 1954. Le genre *Vanilla* et ses especes. Pages 94-290 *in* G. Bouriquet (ed.), *Le Vanillier et la vanille dans le monde.* Paul Lechevalier, Paris.

Post, J. 1990. Orchid growing in Holland. Pages 72-73 *in* J. Kernohan (ed.), *Proc. 13th World Orchid Conf.* 1990 World Orchid Conference Trust, Auckland.

Pradhan, G. M. 1975. Habitat destruction of Himalayan orchid jungles. Pages 193-198 *in* K. Senghas (ed.), *Proc. 8th World Orchid Conf.* Deutsche Orchideen Gesellschaft, Frankfurt.

Pradhan, U. C. 1971. Orchid conservation attempts in Sikkim and E. India. *Amer. Orchid Soc. Bull.* 40: 4.

Pradhan, U. C. 1974a. *Paphiopedilum insigne* (Wall.) Pfitz.: a survey. *Orchid Dig.* 36: 6.

Pradhan, U. C. 1974b. *Diplomeris hirsuta:* a survey. *Ame.r Orchid Soc. Bull.* 43: 525-528.

Pradhan, U. C. 1975a. Conservation of Eastern Himalayan orchids : problems and prospects. Pages 335-340 *in* K. Senghas (ed.), *Proc. 8th World Orchid Conf.* Deutsche Orchideen Gesellschaft, Frankfurt.

Pradhan, U. C. 1975b. The Himalayan cypripediums. Pages 199-204 *in* K. Senghas (ed.) *Proc. 8th World Orchid Conf.* Deutsche Orchideen Gesellschaft, Frankfurt.

Pradhan, U. C. 1976. *Indian orchids: guide to identification and cultivation.* Vol. 1. Bharat Lithographing Co., Calcutta.

Pradhan, U.C. 1978a. *Dendrobium pauciflorum. IUCN Plant Red Data Book.* 363.

Pradhan, U.C. 1978b. *Diplomeris hirsuta. IUCN Plant Red Data Book.* 365.

Pradhan, U. C. 1978c. *Paphiopedilum druryi. IUCN Plant Red Data Book.* 377.

Pradhan, U. C. 1979. *Indian orchids: guide to identification and cultivation.* Vol. 2. Bharat Lithographing Co., Calcutta.

Pradhan, U. C. 1982a. Himalayan Plant Red Data Sheets - 1. *Cymbidium whiteae. Himal. Pl. J.* 1: 15.

Pradhan, U. C. 1982b. Himalayan Plant Red Data Sheets - 3. *Calanthe alpina. Himal. Pl. J.* 1: 49.

Pradhan, U.C. 1982c. Himalayan Plant Red Data Sheets- 4. *Zeuxine pulchm. Himal. Pl. J.* 2: 17.

Pradhan, G. M. 1983. *Vanda cristata. Amer. Orchid. Soc. Bull.* 54: 464-468.

Pradhan, U.C. 1985a. Himalayan Plant Red Data Sheets - 6. *Anoectochilus tetrapterus. Himal. Pl. J.* 3: 19.

Pradhan, U. C. 1985b. Himalayan Plant Red Data Sheets - 7. *Coelogyne treutleri. Himal. Pl. J.* 3: 49.

Pradhan, U. C. 1985c. The ecology and cultivation of *Pleione humilis. Himal. Pl. J.* 3: 58.

Pradhan, U. C. 1985d. Himalayan Plant Red Data Sheets - 8. *Calanthe whiteana. Himal. Pl. J.* 3: 80.

Pridgeon, A. M. (ed.). 1992. *The illustrated encyclopedia of orchids.* Weldon Publishing, Sydney.

Pritchard, H. W. and Prendergast, F. G. 1989. Factors influencing the germination and storage characteristics of orchid pollen. Pages 1-16 *in* H. Pritchard (ed.), *Modern methods in orchid conservation.* Cambridge University Press, Cambridge.

Proctor, G. R. 1984. *Flora of the Cayman Islands.* Kew Bull. Acad. Ser. XI.

Pulle, A. 1906. *An enumeration of the vascular plants known from Suriname.* E. I. Brill, Leiden.

Rabinowitz, D., Cairns, S., and Dillon, T. 1986. Seven forms of rarity and their frequency in the flora of the British Isles. Pages 182-204 *in* E. Soulé (ed.), *Conservation biology: the science of scarcity and diversity.* Sinauer, Sunderland, Massachusetts.

Raizada, M. B., Naithani, H. B., and Saxena, H. O. 1981. *Orchids of Mussoorie.* Bishen Singh Mahendra Pal Singh, Dehra Dun.

Ralegh [Raleigh], W. 1596. *The Discoverie of the Large, Rich and Bewtiful Empyre of Gviana.* Robert Robinson, London.

Ramsay, R. R., Dixon, K. W., and Sivasithamparam, K. 1986. Patterns of infection and endophytes associated with Western Australian orchids. *Lindleyana* 1: 203-214.

Ramsay, R. R., Sivasithamparam, K., and Dixon, K. W. 1987. Anastomosis groups among *Rhizoctonia*-like endophytic fungi in south western Australian *Pterostylis* species (Orchidaceae). *Lindleyana 2:* 161-167.

Raven, P. H., Berg, L. R., and Johnson, G. B. 1993. *Environment.* Saunders College Publishing, Fort Worth, Texas.

Rawes, M. and Welch, D. 1972. Trials to recreate floristically-rich vegetation by plant introduction in the northern Pennines, England. *Biol. Conservation* 4: 135-140.

Reed, C. F. 1981. *Cypripedium kentuckiense* Reed, a new species of orchid in Kentucky. *Phytologia* 48: 426-428.

Reichenbach, H. G. 1849. Orchidaceae. *In* F. Klotzsch (ed.), Beiträge zu einer Aequinoctiaflor Amerika's. *Linnaea* 22: 809-858.

Reichenbach, H. G. 1851. *Icones Florae Germanicae et Helveticae simul Pedemontanae, Lombardoveneticae, Istriacae, Dalmaticae, Hungaricae, Transsylvanicae, Borussicae, Danicae, Belgicae, Hollandicae, Alsaticae ergo Mediae Europae.* Vol. XIII-XIV. Lipsiae.

Reichenbach, H. G. 1859. Orchideae Splitgerberianae Surinamenses. *Ned. Kruidk. Arch.* 4: 319-335.

Reichenbach, H. G. 1877. Orchideae Surinamenses Kegelianae recesitae. *Linnaea* 41: 119-134.

Reichenbach, H. G. 1885. Comoren Orchideen Herrn L. Humblot. *Flora* 68: 377-382, 535-544.

Renz, J. 1992. The genus *Habenaria* in the Guianas. *Candollea* 47: 483-512.

Renz, J. and Taubenheim, G. 1984. Orchidaceae. Pages 450-552 *in* P. H. Davis (ed.), *Flora of Turkey.* Vol. 8. University Press, Edinburgh.

Reznicek, A. A. 1987. Are small reserves worthwhile for plants? *University of Michigan, School of Natural Resources, Endang. Spec. Update* 5: 1-3.

Richard, A. 1850. Tentamen Florae Abyssiniae 2: 281-303.

Richard, L.C. 1792. Catalogue Plantarum. *Actes Soc. Hist. Nat. Paris* 1: 1792.

Ridley, H. N. 1885. The orchids of Madagascar. *J. Linn. Soc. (Bot.)* 21: 456-523.

Ridley, H.N. 1887. Orchideae. *In* F. Im Thum (ed.), Botany of the Roraima expedition of 1884. *Trans. Linn. Soc. 2.* ser. Bot. 2(13): Orchidaceae 58-65.

Ridley, H. N. 1895. An enumeration of all Orchidaceae hitherto recorded from Borneo. *J. Linn. Soc. (Bot.)* 31: 261-305.

Robbins, S. 1992. Additional records of Orchidaceae for the Flora of Arabia. *Kew Bull.* 47: 721-724.

Rodriguez-Robles, J. A., Melendez, E. J., and Ackerman, J. D. 1992. The effects of display size, flowering phenology, and nectar availability on effective visitation frequency in *Comparettia falcata* (Orchidaceae). *Amer. J. Bot.* 79: 1009- 1017.

Rodriguez-Robles, J. A., Ackerman, J. D. and Melendez-Torres, E. J. 1990. Host distribution and hurricane damage to an orchid population at Toro Negro Forest, Puerto Rico. *Carib. J. Sci.* 26: 163-164.

Romero, G. A. 1993a. Unique orchid habitats in southern Venezuela I: inselbergs, lajas, or granite outcrops. *Amer. Orch. Soc. Bull.* 62: 699-707.

Romero, G. A. 1993b. Unique orchid habitats in southern Venezuela II: arbustales or white-sand shrublands. *Amer. Orch. Soc. Bull.* 62: 810-818.

Romero, G. A. 1994. The genus *Epidendrum*, Part 1. A century of new species in *Epidendrum*. *Icones Orchidacearum II* (review). *Amer. Orchid Soc. Bull.* 63: 1168-1170.

Royal Horticultural Society. 1991. *Sander's list of orchid hybrids. Addendum 1986-1990.* Unwin Brothers Ltd., Old Woking, Surrey, England.

Rozsa, L. 1994. Plant poachers stealing wild orchids. *Miami Herald* (Florida), March 6.

Rückbrodt, U. and Rückbrodt, D. 1990. Beitrag zur Kenntnis und verbreitung der Orchideen von Madeira. *Ber. Arbeitskr. Heim. Orch.* 7: 44-54.

Rückbrodt, U. and Rückbrodt, D., Hansen, K, and Hansen, R. B. 1992. Bemerkungen zu den in der Türkei vorkommenden Orchideenarten und iher Verbreitung. *Ber. Arbeitskr. Heim. Orch.* 9: 104-152.

Rumphius, G. E. 1741-1750. *Herbarium Amboinense.* Amsterdam.

Rzedowski, J. 1965. Relaciones geográficas y posibles orígenes de la flora de Mexico. *Bol. Soc. Bot. Méx.* 29: 121-177.

Rzedowski, J. 1978. *Vegetacion de Mexico.* Ed. Limusa, Mexico, D. E, Mexico.

Rzedowski, J. 1993. Diversity and origins of the phanerogamic flora of Mexico. Pages 129-144 *in* T. P. Ramamoorthy, R. Bye, A. Lot, and J. Fa. (eds.), *Biological diversity of Mexico: origins and distribution.* Oxford University Press, Oxford.

Salazar, G., and Romero, G. 1994. Novelties in the genus *Mormodes* from the Venezuelan Guayana. *Lindleyana* 9: 255-263.

Salazar, G. and Soto Arenas, M. A. 1994. Una revision del genero *Lepanthes* Sw. (Orchidaceae; Pleurothallidinae) en Mexico. Thesis. Facultad de Ciencias, Universidad Nacional Autonoma de Mexico, Mexico City.

Salkowski, H. E. 1988. Bemerkungen zu *Goodyera macrophylla* Lowe auf Madeira. *Ber. Arbeitskr. Heim. Orch.* 5: 55-58.

Sanford, W. W. 1974. The ecology of orchids. Pages 1-100 *in* C. L. Withner (ed.), *The orchids: scientific studies.* John Wiley & Sons, Toronto, Ontario.

Santapau, H. and Kapadia, Z. 1966. *The orchids of Bombay.* Publications, Civil Lines, Delhi.

Sather, N. 1991. *Western prairie fringed orchid—threatened prairie plant.* Minnesota Heritage Program.

Sauleda, R. 1988. A revision of the genus *Psychilis* Rafinesque (Orchidaceae). *Phytologia* 65: 1-33.

Sauleda, R. and Adams, R. M. 1984. A reappraisal of the orchid genera *Broughtonia* R. Br., *Cattleyopsis* Lem. and *Laeliopsis* Lindl. *Rhodora* 86: 445-467.

Sauleda, R. and Adams, R. M. 1982. Orchidaceae. Pages 366-401 *in* D. S. Correll and H. B. Correll (eds.), *Flora of the Bahama Archipelago.* J. Kramer, Vaduz.

Sauget, J. and Barbier, J. S. 1946. Gimnospermas-Monocotiledoneas. *In* Hermano Leon, *Flora de Cuba*, vol. 1. Contrib. Ocas. Mus. Hist. Nat. Col. Cultura, S.A., Habana.

Sayer, J. A., Harcourt, C. S., and Collins, N. M. (eds.). 1992. *The conservation atlas of tropical forests.* IUCN, Macmillan, London.

Schelpe, E. 1970. Fire induced flowering among indigenous South African orchids. *S. African Orchid J.* 1:21-22.

Schlechter, R. 1911-1914. *Die Orchidaceen von Deutsch-Neu-Guinea. In* Fedde, *Repert. Beih.* 1 & 21 (English transl., Australian Orchid Foundation 1982).

Schlechter, R. 1917. Die Gattung *Acineta* Ldl. *Orchis* 11: 21-48.

Schlechter, R. 1921. Die Orchideenfloren der Sudamerikanischen Kordillerenstaaten. 3. Ecuador. *Repert. Spec. Nov. Reg. Veg. Beih.* 8.

Schlechter, R. 1924. Beitrage zur Orchideenkunde von Colombia. *Repert. Spec. Nov. Veg. Beih.* 27. Schlechter, R. 1925. Orchidaceae Perrierianeae. *Repert. Spec. Nov. Reg. Veg. Beih.* 33.

Schomburgk, M. R. 1848. *Versuch einer Fauna und Flora von Britisch-Guiana.* J. J. Weber, Leipzig.

Schomburgk, R. H. 1836. Report of an expedition into the interior of British Guayana in 1983-36. *J. Roy. Geogr. Soc.* 6: 224-284.

Schomburgk, R. H. 1837a. Diary of an ascent of the river Corentyn, in British Guayana in 1836. *J. Roy. Geogr. Soc.* 7: 285-301.

Schomburgk, R. H. 1837b. Diary of an ascent on the river Berbice, in British Guayana in 1836-7. *J. Roy. Geogr. Soc.* 7: 302-350.

Schomburgk, R. H. 1840. *A description of British Guiana.* Simpkin, Marshall, and Co., London.

Schweinfurth, C. 1948. Orchidaceae. Pages 212-230 *in* B. Maguire *et al.* (eds.), Plant explorations in the Guayana in 1944, chiefly to the Tafelberg and the Kaieteur Plateau. *Bull. Torr. Bot. Club* 75: 56-115, 189-230, 286-323, 374-438, 523-580, 633-671.

Schweinfurth, C. 1958-1961. Orchids of Peru. *Fieldiana: Bot.* 30: 1-1026.

Schweinfurth, C. 1967. Orchidaceae of the Guayana Highlands. *Mem. New York Bot. Gard. 14:* 69-214.

Seal, U. S. 1985. The realities of preserving species in captivity. Pages 71-95 *in* R. J. Hoage (ed.), *Animal extinctions.* Smithsonian Institution Press, Washington, D.C.

SEDESOL. 1994. Norma Oficial Mexicana NOM-059-ECOL-1994. Diario Oficial de la Federacion. CDLXXXVIII. No. 10 (16 May 1994).

Seeman, B. 1864. *Flora Vitiensis. Orchideae.* L. Reeve, London.

Seidenfaden, G. 1975-1988. Orchid genera in Thailand I-XIV. *Dansk Bot. Arkiv* 29-34, and *Opera Bot.* 62-95.

Seidenfaden, G. and Arora, C. M. 1982. An enumeration of the orchids of North-western Himalaya. *Nord. J. Bot.* 2: 7-27.

Seidenfaden, G. and Smitinand, T. 1959-65. *The orchids of Thailand: a preliminary list.* The Siam Society, Bangkok.

Seidenfaden, G. and Wood, J. J. 1992. *The orchids of peninsular Malaysia and Singapore.* Olsen and Olsen, Fredensborg.

Senghas, K. 1964. Die Gattung *Graphorkis. Die Orchidee* 15: 61-66.

Senghas, K. 1980. The native orchids of Europe and their conservation. Pages 291-295 *in* M. R. Sukshom Kashemsanta (ed.), *Proc. 9th World Orchid Conf.* Bangkok, Thailand.

Senghas, K. 1993. *Orchids: plants of extremes, contrasts, and superlatives.* Paul Parey, Berlin.

Sezik, E. 1984. Orkidlerimiz. Sandoz Kültür Yayinlari 6.

Sezik, E. 1990. Turkish orchids and salep. *Coll. Soc. Franq. Orchidophilie* 11: 181-189.

Sheviak, C. J. 1974. *An introduction to the ecology of the Illinois Orchidaceae.* Illinois State Museum (Springfield) Scientific Papers 14.

Sheviak, C. J. 1983. United States terrestrial orchids - - patterns and problems. Pages 49-60 *in* E. H. Plaxton (ed.), *Proc. Symposium II and Lectures, North American terrestrial orchids.* Michigan Orchid Society, Southfield, Michigan.

Sinoda, K. 1994. Orchids in horticulture in Japan. Pages 161-165 *in* K. Konishi, S. Iwahori, H. Kitagawa, and T. Yakuwa (ed.), Proc. *XXIVth International Hort. Congress.*

Smith, J. J. 1909-1934. Die Orchidaceen von Néederlandisch-Neu-Guinea. *In* Resultats de l'Expedition Scientifique Neerlandaises a la Nouvelle Guinee. E. J. Brill, Leiden.

Smith. J. J. 1905. *Die Orchideen von Ambon.* Departement fur Lanwirtschaft, Batavia

Smith, W. R. 1993. *Orchids of Minnesota.* University of Minnesota Press, Minneapolis.

Smreciu, E. A. and Currah, R. S. 1989. Symbiotic germination of seeds of terrestrial orchids in North America and Europe. *Lindleyana* 4: 6-15.

Snuverink, J. H. 1980. The genus *Habenaria* in Suriname. Doctoraal Verslag Instituut voor Systematische Plantkunde. Rijksuniversiteit Utrecht.

Soto Arenas, M. A. 1988. Listado actualizado de las orquideas de Mexico. *Orquídea (Méx.)* 11: 233-277.

Soto Arenas, M. A. 1994. Population studies in Mexican orchids. Pages 153-160 *in* A. Pridgeon (ed.), *Proc. 14th World Orchid Conf.* HMSO, Edinburgh.

Soto Arenas, M. A. and Hágsater, E. 1990. Algunas ideas acerca de la Conservacion de las orquideas mexicanas y un listado preliminar de los taxa amanazados. Pages 155-172 *in* J. L. Camarillo and F. Rivera (eds.), *Areas naturales protegidas y especies en extinción.* National University of Mexico, Mexico, D. F., Mexico.

Soto Arenas, M. A., Salazar, G. A., and Hágsater, E. 1990. *Phragmipedium xerophyticum,* una nueva especie del sureste de Mexico. *Orquídea (Méx.)* 12: 1-10.

Soulé, M. E.. 1983. What do we really know about extinction? Pages 101-117, 210-213 *in* L. R. Brown *et al.*, (eds.), *State of the world.* Norton, New York.

Soulé, M. E. 1987. Introduction. Pages 1-10 *in* M.E. Soulé (ed.), *Viable populations for conservation.* Cambridge University Press, Cambridge.

Steiner, K. M. 1989. The pollination of *Disperis* (Orchidaceae) by oil-collecting bees in southern Africa. *Lindleyana* 4: 164-183.

Stern, W. L., Cheadle, V. I., and Thorsch, J. 1993a. Apostasiads, systematic anatomy, and the origin of Orchidaceae. *Bot. f. Linn. Soc.* 111: 411-455.

Stern, W. L., Morris, M. W., Judd, W. S., Pridgeon, A. M., and Dressier, R. L. 1993b. Comparative vegetative

Stewart, J. 1973. A second checklist of the orchids in Kenya. *Amer. Orchid Soc. Bull.* 42: 525-531.

Stewart, J. 1979. A revision of the African species of *Aerangis* (Orchidaceae). *Kew Bull.* 34: 239-318.

Stewart, J. 1986. Stars of the islands: a new look at the genus *Aerangis* in Madagascar and the Comoro Islands. *Amer. Orchid Soc. Bull.* 55: 792-802, 902-909, 1008-1015, 1117-1125.

Stewart, J. 1987. Orchid conservation: the survival and maintenance of genetic diversity of all orchids throughout the world. Pages 106-109 *in* K. Saito and R. Tanaka (eds.), *Proc. 12th World Orchid Conf.*, Tokyo.

Stewart, J. 1993a. Conservation, horticulture and trade in orchids. Pages 11-16 *in* M. Groves, M. Read, and B. A. Thomas (ed.), *Species endangered by trade — a role for horticulture?* Fauna and Flora Preservation Society, London.

Stewart, J. 1993b. The Sainsbury Orchid Conservation Project: the first ten years. *Kew Mag.* 10: 38-43. anatomy and systematics of Spiranthoideae (Orchidaceae). *Bot. J. Linn. Soc.* 113: 161-197.

Stewart, J., Linder, H. P., Schelpe, E. A., and Hall, A. V. 1982. *Wild orchids of southern Africa.* MacMillan, Johannesburg.

Steyermark, J. A. 1982. Relationships of some Venezuelan forest refuges with lowland tropical floras. Pages 183-220 *in* G. T. Prance (ed.), *Biological diversification in the tropics.* Columbia University Press, New York.

Stoutamire, W. P. *1974a.* Australian terrestrial orchids, thynnid wasps, and pseudocopulation. *Amer. Orchid Soc. Bull.* 43: 13-18.

Stoutamire, W. P. 1974b. Terrestrial orchid seedlings. Pages 101-128 *in* C. L. Withner (ed.), *The orchids: scientific studies.* John Wiley & Sons, Toronto, Ontario.

Stoutamire, W. P. 1975. Pseudocopulation in Australian terrestrial orchids. *Amer. Orchid Soc. Bull.* 44: 226-233.

Stoutamire, W. P. 1981. Pollination studies in Australian terrestrial orchids. *Nat. Geog. Soc. Res. Reports* 13: 591-598.

Stoutamire, W. P. 1983. Wasp-pollinated species of *Caladenia* (Orchidaceae) in south-western Australia. *Austral. J.Bot.* 31: 383-394.

Strahm, W.A. (1989). *Plant Red Data Book for Rodrigues.* Koeltz, Germany. 241 pp.

Strahm, W.A. (1994). *The conservation and restoration fo the flora of Mauritius and Rodrigues.* PhD Thesis, Dept of Botany, University of Reading, England.

Stuckey, I. H. 1967. Environmental factors and the growth of native orchids. *Amer. J. Bot.* 54: 232-241.

Summerhayes, V. S. 1968. Orchidaceae, part 1. *In* F. Milne-Redhead & R. M. Polhill (eds.), *Flora of tropical East Africa.* Crown Agents, London.

Svenson, H. K. 1946. Vegetation of the coast of Ecuador and Peru and its relation to the Galapagos Islands. *Amer. J. Bot.* 33: 394-398.

Sweet, H. 1980. *The genus* Phalaenopsis. Orchid Digest Corporation, Los Angeles, California.

Takhtajan, A. 1978. *Floristic regions of the world.* University of California Press, Berkeley, California.

Tamm, C. O. 1972. Survival and flowering of some perennial herbs. II. The behaviour of some orchids on permanent plots. *Oikos* 23: 23-28.

Taubenheim, G. 1980. Die Verbreitung der Orchideen in der Türkey IV/2. *Die Orchidee* 31: 5-10.

Taylor, H. C. 1978. Capensis. Pages 171-239 *in* M. J. A. Werger (ed.), *Biogeography and ecology of southern Africa.* W. Junk, The Hague.

Tazan, G. de and Valverde, E M. 1979. Cubierta vegetal de la Peninsula de Santa Elena. Fac. Cienc. Natural. Publ. 2: 1-236.

The Diagram Group. 1993. *Running Press Cyclopedia.* Running Press, Philadelphia, Pennsylvania.

Thompson, P. A. 1977. *Orchids from seed.* Royal Botanic Gardens, Kew and Wakehurst Place.

Thornhill, A. and Koopowitz, H. 1992. Viability of *Disa uniflora* Berg (Orchidaceae) seeds under variable storage conditions: is orchid gene-banking possible? *Biol. Conservation* 62: 21-27.

Toledo, V. M. and Ordonez, M. J. 1993. The biodiversity scenario of Mexico: a review of terrestrial habitats. Pages *757-777 in* T. P. Ramamoorthy, R. Bye, A. Lot, and J. Fa (eds.), *Biological diversity of Mexico: origins and distribution.* Oxford University Press, Oxford.

Tremblay R. and Ackerman, J. D. 1993. A new species of *Lepanthes* from Puerto Rico. *Brittonia* 45: 339-342.

Trudel, N. 1983. *Papilionanthe uniflora*—a self-pollinator. *Himal. Pl. J.* 2: 47.

Tuyama, T.. 1966. Orchidaceae. Pages 424-452 *in* H. Hara (ed.), *The flora of Eastern Himalaya.* University of Tokyo Press, Tokyo.

Tuyama, T. 1971. Orchidaceae. Pages 176-196 *in* H. Hara (ed.), *The flora of Eastern Himalaya: second report.* University of Tokyo Press, Tokyo.

Tuyama, T. 1975. Orchidaceae. Pages 137-164 *in* H. Ohashi (ed.), *The flora of Eastern Himalaya: third report.* University of Tokyo Press, Tokyo.

Tyteca, D. and Tyteca, B. 1994. Orchidees de Madere. *L'Orchidophile* 25: 62-63.

U. S. Fish and Wildlife Service. 1994. *Platanthera praeclara* (western prairie fringed orchid) recovery plan. Technical/agency draft. U. S. Fish and Wildlife Service, Fort Snelling, Minnesota.

Valmayor, H. L. 1984. *Orchidiana Philippiniana.* Eugenio Lopez Foundation Inc., Manila.

Valverde, F. M. 1991. Estaso actual de la vegetation natural de la Cordillera de Chongon-Colonche. Universidad de Guayaquil, Guayaquil, Ecuador.

van Vliet, G. and Grimm, U. 1994. European orchids, possibilities and probabilities of their protection. *In* P. Brederoo and D. W. Kapteyn den Boumeester (eds.), *Eurorchis 92.* Stichting Uitgeverij Koninklijke Nederlandse Natuurhistorische Vereniging, Utrecht, the Netherlands.

Vermeulen, J. J. 1987. A taxonomic revision of the continental African Bulbophyllinae. *Orchid Monographs 2.* Brill, Leiden.

Vermeulen, J. J. 1991. *Orchids of Borneo. 2. Bulbophyllum.* Royal Botanic Gardens, Kew, and Sabah Society.

Veyret, Y. 1982. Apomixie et variation chez *Epidendrum nocturnum* Jacq. (Orchidaceae). *Bull. Mus. Natl. Hist. Nat., B, Adansonia* 4: 183-192.

Vogel, E. de. (ed.) 1969. Monograph of the tribe Apostasieae (Orchidaceae). *Blumea* 17: 313-350.

Vogel, E. de. (ed.) 1986-1993. *Orchid Monographs,* vols.l-7. E. J. Brill and Rijksherbarium, Leiden.

Warcup, J. H. 1973. The symbiotic germination of some Australian terrestrial orchids. *New Phytologist 72:* 387-392.

Warcup, J. H. 1985. *Rhizanthella gardneri* (Orchidaceae), its *Rhizoctonia* endophyte and close association with *Melaleuca uncinata* (Myrtaceae) in Western Australia. *New Phytologist* 29: 273-280.

Warren, R. C. and Miller, D. 1992. Taking root. *Amer. Orchid Soc. Bull.* 61: 146-149.

Wells, T. C. E. 1969. Botanical aspects of conservation management of chalk grasslands. *Biol. Conservation* 2: 36-44.

Wells, T. C. E. 1981. Population ecology of terrestrial orchids. Pages 281-295 *in* H. Synge (ed.), *Biological aspects of rare plant conservation.* John Wiley & Sons, London, England.

Wendt, T. 1993. Composition, floristic affinities, and origins of the canopy tree flora of the Mexican Atlantic slope rain forests. Pages 595-680 *in* T. P. Ramamoorthy, R. Bye, A. Lot, and J. Fa (eds.), *Biological diversity of Mexico: origins and distribution.* Oxford University Press, Oxford.

Werkhoven, M. C. M. 1986. *Orchids of Suriname.* Uitg. Vaco N.V., Paramaribo.

Werkhoven, M. C. M. 1992. Altitudinal distribution of orchid species in Suriname. *Compt. Rend. Seances Soc. Biogeogr.* 68: 55-76.

White, F. . 1978. The Afromontane region. Pages 463-513 *in* M. J. A. Werger (ed.), *Biogeography and ecology of southern Africa.* W. Junk, The Hague.

White, F. 1983. *The vegetation of Africa.* Unesco, Paris.

White, P. S. 1979. Pattern, process, and natural disturbance in vegetation. *Bot. Rev.* 45: 229-299.

Wijnstekers, W. 1992. *The evolution of CITES.* Revised ed. CITES Secretariat, Geneva, Switzerland.

Wilcove, D. S., McLellan, C. H., and Dobson, A. P. 1986. Habitat fragmentation in the temperate zone. Pages 237-256 *in* E. Soulé (ed.), *Conservation biology: the science of scarcity and diversity.* Sinauer, Sunderland, Massachusetts.

Wilkes, B. 1977. The myth of the non-consumptive user. *Canad. Field-Naturalist* 91: 343-349.

Wilkinson, K. G., Sivasithamparam, K., Dixon, K. W., Fahy, P. C, and Bradley, J. K. 1994. Identification and characterisation of bacteria associated with Western Australian orchids. *Soil Biol. Biochem.* 26: 137-142.

Williams, J. G., Williams, A. E., and Arlott, N. 1978. *A field guide to the orchids of Britain and Europe with North Africa and the Middle East.* Collins, London.

Williams, L. O. 1951. *The Orchidaceae of Mexico. Ceiba* 2: parts 1-4.

Williams, L.O. and Allen, P. H. 1946,1949. Orchidaceae, *in* Flora of Panama. *Ann. Missouri Bot. Gard.* 33: 1-140, 315-404; 36: 1-245.

Williamson, G. 1977. *The orchids of south-central Africa.* Dent, London.

Williamson, G. 1982. *Polystachya songaniensis. Orchid Rev.* 90: 128.

Willing, B. and Willing, E. 1977. Bibliographie über die Orchideen Europas und der Mittelmeerländer 1744-1976. *Willdenowia* Beiheft 11, Berlin.

Willing, B. and Willing, E. 1985. Bibliographie uber die Orchideen Europas und der Mittelmeerlander. 1st supplement. *Englera* 5, Berlin.

Willis, J. H. 1962. *A handbook to plants in Victoria.* Volume 1. Melbourne University Press, Melbourne.

Withner, C. L. 1976. Observations on equitant oncidiums as examples of introgressive hybridization. Pages 34-45 *in* H. H. Szmant and J. Wemple (eds.), *Symposium on scientific aspects of orchids.* University of Detroit, Detroit, Michigan.

Withner, C. L. and Stevenson, J. C. 1968. The *Oncidium tetrapetalum-pulchellum* syngameon. *Amer. Orchid Soc. Bull.* 37: 21-32.

Wood, J. J. and Cribb, P. J.. 1994. *A checklist of the orchids of Borneo.* Royal Botanic Gardens, Kew.

Wood, J. J., Beaman, R., and Beaman, J. 1993. *The plants of Mount Kinabalu. 2. Orchids.* Royal Botanic Gardens, Kew

World Conservation Monitoring Centre. 1992. *Global biodiversity: status of the Earth's living resources.* Chapman and Hall, London.

World Resources Institute. 1990. *World resources: 1990-1991.* Oxford University Press, Oxford.

Zettler, L. W. 1994. Extinction in your own backyard. *Amer. Orchid Soc. Bull.* 63: 686-688.

Zettler, L. W. and McInnis, T. M., Jr. 1992. Propagation of *Platanthera integrilabia* (Correll) Luer, an endangered terrestrial orchid, through symbiotic seed germination. *Lindleyana* 7: 154-161.

Zettler, L. W. and Mclnnis, T. M., Jr. 1993. Symbiotic seed germination and development of *Spiranthes cernua* and *Goodyera pubescens* (Orchidaceae). *Lindleyana* 8: 155-162.

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IUCN Communications Division
Rue Mauverney 28, CH-1196 Gland, Switzerland
Tel: ++41 22 999 00 01, Fax: ++41 22 999 00 10, E-mail: mail@hq.iucn.org

IUCN Publications Services Unit
219c Huntingdon Road, Cambridge, CB3 ODL, United Kingdom
Tel: ++44 1223-277894, Fax: ++44 1223-277175, E-mail: iucn-psu@wcmc.org.uk

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