

Orchids: a review of their use, trade and conservation

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Abstract: The Orchidaceae is one of the largest families of flowering plants, and one that is widely traded--both legally and illegally, sustainably and unsustainably--for a variety of purposes, including as ornamental plants, medicinal products, and as food. However, there are considerable gaps in our understanding of both orchid ecology and trade dynamics, and there is growing concern as the trade appears to be intensifying, threatening the survival of hundreds of orchid species. This review covers the state of knowledge on the international and domestic trade of orchids globally, across different types of products and uses, and both legal and illegal trade. It further highlights trade issues that represent particular conservation concerns, current gaps in knowledge, and emerging priorities.

Introduction

Orchids are globally distributed and are one of the largest families of flowering plants: 29,199 species are currently accepted (IPNI, 2012), several hundred new species names are published each year (e.g. 370 new names were published in 2013: Schuiteman, 2017), and it is estimated that 31,000 species exist in total (Joppa et al.

2010). Owing to their taxonomic and geographic diversity, and orchids are also widely used for a variety of reasons, both legally and illegally, sustainably and unsustainably. However, orchids are perhaps best known for their use in the horticultural trade, as they are among the most popular plants in the global potted plant and flower trades (FloraHolland 2015; De et al. 2015). They are also harvested, grown, and traded as plants and flowers for cultural purposes, as flavourings and other edible food products, and as constituents within cosmetics and traditional medicines in many parts of the world.

The vast majority of global orchid trade is as artificially propagated cut flowers and plants grown under controlled conditions. However, orchids are also widely subject to harvest from the wild for local, regional and international trade. There are growing concerns that this trade is threatening wild orchid populations and species in many places (e.g., Davenport & Ndangalasi 2003; Flores-Palacios 2007; Subedi et al. 2013; Phelps and Webb 2015). Orchids may be particularly vulnerable to harvest and trade because many species are naturally rare, due to a range of interacting factors such as recent speciation, specialised pollination mechanisms, habitat specificity and the restricted distribution of mycorrhizal symbionts; as a result many orchids have a limited range and/or occur at low densities (e.g., Dodson and Gentry 1991; Swarts & Dixon 2009; McCormick and Jacquemyn 2014). Consequently, commercial harvest has the potential to eliminate geographically restricted populations, or profoundly disrupt the ecology of species with low natural abundance. The very limited ecological studies on the conservation impacts of wild-collection of epiphytic orchids suggests a very low tolerance to harvest (Mondragón 2009; Hu et al. 2017).

Legal-regulatory Context

Due to concerns over the potential impacts of unsustainable harvest, orchids are subject to unique levels of legal protection. Wild orchids are subject to blanket protections from the pressures of international trade, and the legislation of many countries further restricts their harvest from the wild. On paper, orchids are among the best protected plant taxa globally.

CITES Regulations

The Convention on the International Trade of Endangered Species of Wild Fauna and Flora (CITES) is a multilateral environmental agreement that regulates the international trade of species that are or may become threatened as a result of international trade. Species of concern are included in one of its three Appendices, with over 35,000 species currently listed. Notably, orchids represent more than 70% of CITES-listed species (Fig. 1). This broad inclusion of orchids under CITES, which dates back to the 1970s, is the result of a precautionary approach, as many members of the family resemble other species (look-alike principle) (Clemente-Munoz 2009) and are therefore likely candidates for misidentification by the non-experts often responsible for inspecting trader shipments. This means that international trade in most orchids, whether for personal, commercial or scientific purposes, must be approved by the relevant CITES agencies.

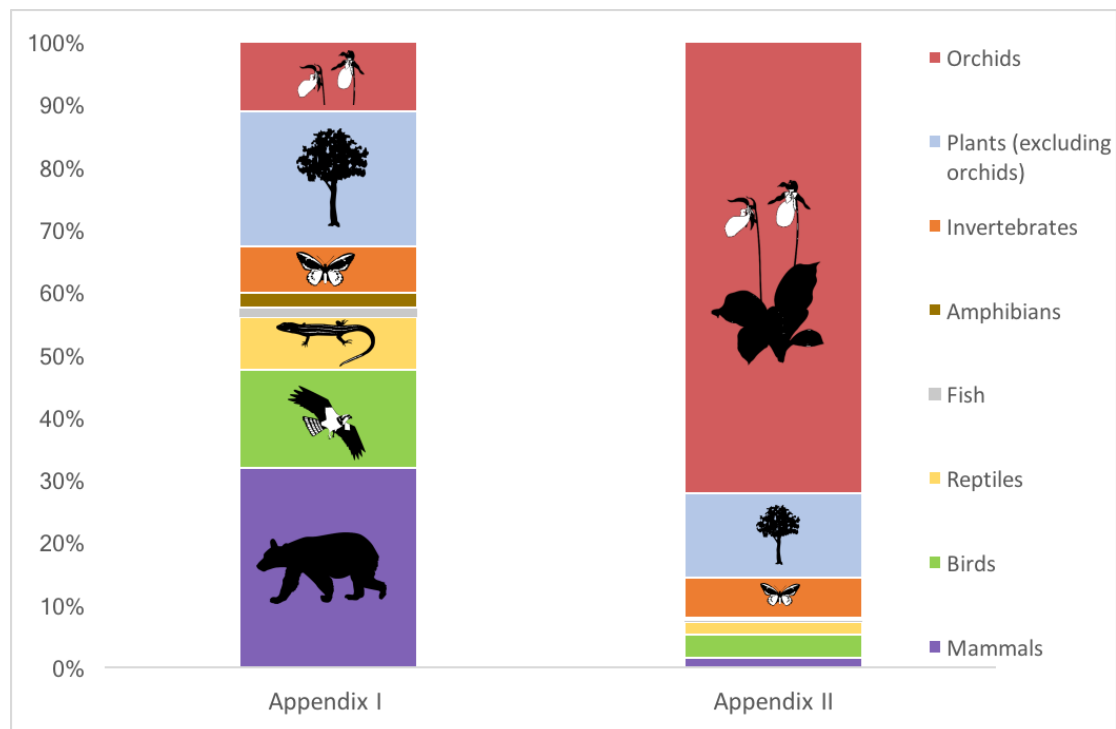


Figure 1. Taxonomic breakdown of CITES Appendices I and II, showing the large proportion of orchids in the total number of species listed by the Convention. Adapted from original in Hinsley (2016) using updated data from UNEP-WCMC (2015). Vector images courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/).

A subset of species, notably two slipper orchid genera (*Paphiopedilum* spp. and *Phragmipedium* spp.) are listed on CITES Appendix I, which bans international commercial trade, unless material is artificially propagated from legally-harvested founder stock (Table 1). In contrast, all remaining orchid species are listed under CITES Appendix II, which allows for the legal commercial trade of orchids, even if the plants are wild-collected. These cases require import and export permits, as well as a demonstration that the export is not detrimental to the survival of the species (via a CITES Non-Detriment Finding).

Table 1. Restrictions on international trade of orchid species listed in CITES Appendix I and Appendix II

Category	Species	CITES regulations ^a
CITES Appendix I ^b	<i>Aerangis ellisii</i> <i>Dendrobium cruentum</i> <i>Laelia jongheana</i> <i>Laelia lobata</i> <i>Peristeria elata</i> <i>Renanthera imschootiana</i> <i>Paphiopedilum</i> spp. <i>Phragmipedium</i> spp.	<ul style="list-style-type: none"> · An import permit issued by the MA of the State of import is required. This may be issued only if the specimen will not be used for primarily commercial purposes and if the import is for purposes that are not detrimental to the survival of the species. In the case of a live animal or plant, the SA must be satisfied that the proposed recipient is suitably equipped to house and care for it. · An export permit or re-export certificate issued by the MA of the State of export or

re-export is also required.

- An export permit may be issued only if the specimen was legally obtained, the trade will not be detrimental to the survival of the species, and an import permit has already been issued.
- A re-export certificate may be issued only if the specimen was imported in accordance with the provisions of the Convention and, in the case of a live animal or plant, if an import permit has been issued.
- In the case of a live animal or plant, it must be prepared and shipped to minimise any risk of injury, damage to health or cruel treatment.

CITES App. II	All other species in the family Orchidaceae	<ul style="list-style-type: none"> · An export permit or re-export certificate issued by the MA of the State of export or re-export is required. · Export permit may be issued only if the specimen was legally obtained and if the export is not detrimental to the survival of the species. · A re-export certificate may be issued only if the specimen was imported in accordance with the Convention. · In the case of a live animal or plant, it must be prepared and shipped to minimise any risk of injury, damage to health or cruel treatment. · No import permit is needed unless required by national law.
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^a Summary of CITES regulations as presented in Clemente-Munoz (2009)

Between 1996 and 2015, the majority of commercial orchid trade reported to CITES by importing Parties was from artificially propagated sources, including 99.9% of the over 1.1 billion live orchid plants in trade and more than 31 million kilogrammes of stems (Table 2).

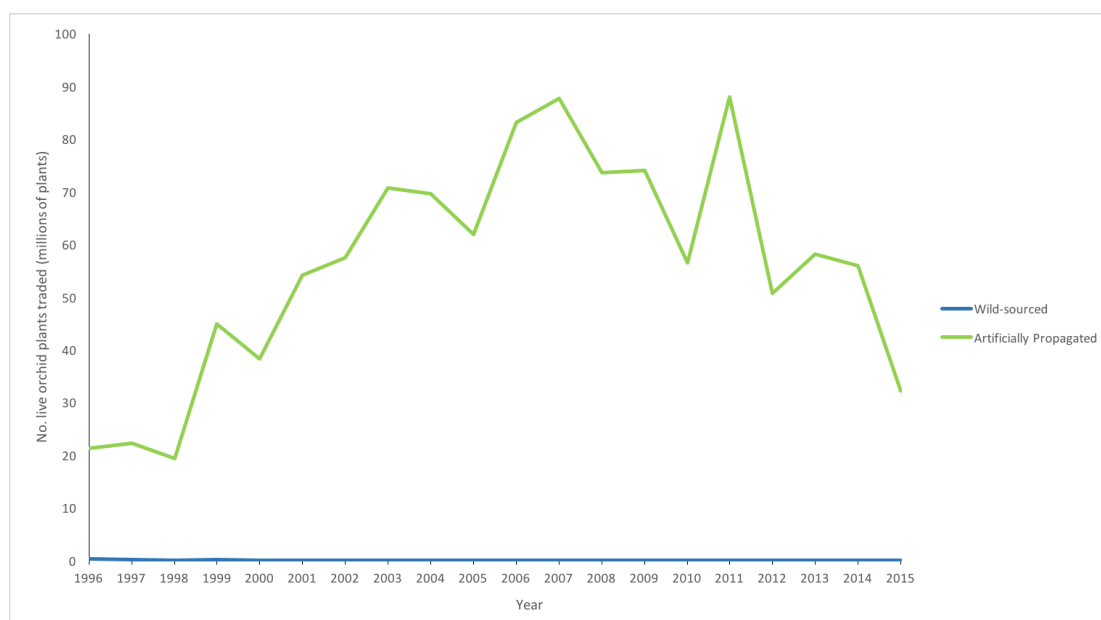
Table 2. Summary of commercial orchid trade reported to CITES between 1996-2005, including all importer-reported trade in weight and number of items. Very small amounts of trade reported in unquantifiable units (e.g. boxes, cartons) and potentially misreported terms (e.g. logs, leather products) were omitted. ‘Wild-sourced’ is defined as trade reported as source W,U, and no source; ‘Artificially propagated’ is defined as trade reported under the the source codes for plants (A, D) and captive-bred animals (C, F), the latter to capture small amounts of misreported data. Data: UNEP-WCMC CITES Trade Database, <https://trade.cites.org>, downloaded March 2017.

Product	Artificially propagated trade	Wild trade
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	Trade reported as individual items (no. of items)	Trade reported by weight (kg)	Trade reported as individual items (no. of items)	Trade reported by weight (kg)
Live plants	1,119,675,302	16,776,179	1,057,251	576,839
Roots	4,127,740	762,359	304	677,842
Cultures	1,735,829	-	1,200	-
Seeds	912,542	-	-	-
Dried Plants	730,015	7,440,721	13,700	157,500
Derivatives ¹	230,138	1,131,050	418	8,056
Flowers	47,842	305	351	-
Stems	2,731	31,415,634	-	-
Specimens	105	-	664	-
Leaves	66	1,180	-	-

¹ Combined figures for trade reported as derivatives, extract, medicine, and powder.

Live artificially propagated plants were the most traded orchid product over this period, with trade peaking at just under 90 million plants per year in 2007 and 2011



(Fig 2).

Figure 2 Reported commercial trade in live artificially propagated and wild sourced orchid plants over the twenty year period 1996-2005, as reported by importers. ‘Wild-sourced’ is defined as trade reported as source W,U, and no source; ‘Artificially propagated’ is defined as trade reported under the the source codes for plants (A, D) and captive-bred

animals (C, F), the latter to capture small amounts of misreported data. Data: UNEP-WCMC CITES Trade Database, <https://trade.cites.org>, downloaded March 2017.

The vast majority of trade in all products was in Appendix II species with the small amounts of trade in Appendix I taxa dominated by artificially propagated live plants (approximately 1.2 million plants). Some commercial trade in wild-sourced Appendix I *Paphiopedilum* species (31,204 live and 300 dried plants) was reported.

Taiwan and Thailand were the biggest exporters of artificially propagated live plants, with over half of all reported trade in these plants exported from Taiwan. The biggest importers of these plants were South Korea (40%), the United States (27%) and Japan (20%).

National Legislation

The wild harvest and trade of orchids is also regulated through national regulations, notably protected species lists, restrictions on harvest in protected areas and/or on native flora, and agricultural and trade legislation, including regulations that serve to operationalise country commitments to CITES. In addition, orchids can also be governed by rules associated with phytosanitary requirements, as well as legislation on food, medicinal or cosmetic product standards. We highlight examples of India and the United States to illustrate the diversity of rules that apply to orchid harvest and trade.

In India, orchid harvest and trade is shaped by a number of pieces of national legislation. Eleven of its ~1,450 orchid species (principally *Paphiopedilum* spp.) are listed within the Wildlife Protection Act 1972, and legally protected irrespective of where they grow (i.e. whether inside or outside a designated protected area), although harvest permission can be granted for research and education purposes. The collection of all wild flora is prohibited within protected areas (WPA 1972; Indian Forest Act 1927), although Scheduled Tribes and other Traditional Forest Dwellers can apply for a waiver (Recognition of Forest Rights Act 2006; State Territory Minor Forest Produce Act 2005). There is no rule, however, that prohibits the harvest of non-protected orchids outside protected areas. Some states have additional local restrictions on the felling of trees (e.g., West Bengal Tree Protection and Conservation in Non-Forest Areas Act 2006) that provides indirect protection to many epiphytic orchids. India maintains a list of species for which international trade is banned, including the 11 protected orchid species and a select group of species perceived to be under threat of trade (e.g., *Cypripedium* spp.; Foreign Trade Policy of India 2015-2020). Trade is further regulated by domestic legislation informed by the Customs Act (1962), which also provides CITES certificates, and the Biological Diversity Act of India (2002), which protects all domestic biological resources as informed by the National Biodiversity Board, including prohibition on the collection, import and export of orchid seeds and DNA samples, with exceptions for some non-commercial uses. As such, orchids can only be commercially traded from India if proof can be provided that they were obtained prior to 1972, or from outside India in accordance with CITES and phytosanitary regulations.

In the United States of America, wild harvest of orchids is similarly restricted by both generic legislation (e.g., that protects habitat), as well as protections for particular species. The harvest of all flora is banned within all federal lands, including national parks (36 CFR §2.1., 2016). Additional protections ban harvest of endangered and

threatened species nationally, including 15 orchid species (e.g., *Piperia yadonii*, *Spiranthes delitescens*, and *Spiranthes parksii* spp., *Bulbophyllum* spp., *Platanthera* spp., *Nervilia* spp. except for conservation and restoration purposes with permits; Federal Endangered Species Act, 1973; Title 50 of Code of Federal Regulations [50 CFR §17.61,1985). In addition, State-level endangered and threatened species lists can provide additional protections based on local-level assessments. For example, in the State of Florida, *Dendrophylax lindenii* is recognised as an endangered species, whose wild harvest is banned (The Florida Statutes (Section 581.185), 2016).

Additional state legislation restricts all wild harvest of native flora without specific permits (e.g., Preservation of Native Flora of Florida). International trade is regulated by the Lacey Act, Federal Endangered Species Act, CITES, and State laws. The Lacey Act prohibits the illegal import of wild plants into the United States. The law is strict enough to cover illegally harvested wild orchids. These pieces of legislation reinforce the regulation of wild orchid trade, unless the trader provides an import permit issued by the United States Department of Agriculture (USDA) and other documents, including CITES and phytosanitary certificates, thereby proving that the plants are not wild collected.

Types of commercial trade

Orchids are traded for a wide range of purposes and at many different scales. This includes a number of large-scale commercial trades, as well as non-commercial, often subsistence use of wild plants (e.g., as medicines, materials for weaving, ornaments, food and dyes, Lawler, 1984 REF). There are also other, emerging commercial uses of orchids, such as in perfumes and cosmetic products, that have been the subject to little research. Here we provide an overview of the key types of established commercial trades in wild orchids globally.

Horticulture

Orchids have long been commercialised as ornamental plants within the horticultural and floricultural trade, involving several distinct types of markets and consumers. This trade is, unsurprisingly, dominated by species with attractive flowers, but also includes species admired for their unusual growth habits (e.g., leafless orchids, *Dendrophylax* spp. *Chiloschista* spp.), miniature size (e.g. *Platystele* spp., *Bulbophyllum moniliforme*), scent (e.g. *Cattleya* spp., *Dendrochilum glumaceum*), and patterned leaves (e.g., jewel orchids in the genera *Anoectochilus*, *Goodyera*, *Ludisia* and *Macodes*).

The vast majority of contemporary orchid trade involves artificially propagated plants and cut flowers cultivated in commercial greenhouses, often of hybrids in a small number of genera (e.g., *Cymbidium*, *Dendrobium*, *Phalaenopsis*; Table 3). Orchids are consistently ranked amongst the best sellers in the global potted plant trade (FloraHolland 2015; USDA 2015) and also comprise approximately 10% of all fresh cut flowers traded internationally (De et al. 2015). This represents an economically significant global trade, with exports of potted orchids from the Netherlands alone valued at almost €500 million in 2015 (FloraHolland 2015). The largest areas of production are in Thailand, Taiwan, the Netherlands and Japan, with demand for both potted and cut flowers growing in economic value annually (Griesbach 2002; Hanks 2015). There is also considerable domestic and regional trade in cultivated orchids; Thailand, for example, sells roughly half of the orchids it produces within the domestic market (Thammasiri 2014).

Table 3: Top 10 reported orchid taxa commercially traded as artificially propagated live plants in the 10 year periods 1996-2005 and 2006-2015 (as reported by importers), including trade reported at genus and family level. Source codes for both artificially propagated plants (A, D) and captive-bred animals (C, F) were used, the latter to capture small amounts of misreported data. Data: UNEP-WCMC CITES Trade Database, <https://trade.cites.org>, downloaded March 2017.

Rank	1996-2005 (Total no. live plants: 459,857,389)		2006-2015 (Total no. live plants: 627,636,2329)	
	Reported Taxa	No. live plants	Reported Taxa	No. live plants
1	Orchidaceae spp.	165,962,470	<i>Cymbidium</i> spp.	177,536,162
2	Orchidaceae hybrid	123,939,767	Orchidaceae hybrid	168,516,359
3	<i>Dendrobium</i> spp.	92,482,163	Orchidaceae spp.	114,499,142
4	<i>Phalaenopsis</i> spp.	31,572,618	<i>Phalaenopsis</i> hybrid	66,315,556
5	<i>Cymbidium</i> spp.	24,672,878	<i>Phalaenopsis</i> spp.	28,941,053
6	<i>Oncidium</i> spp.	7,077,873	<i>Dendrobium</i> spp.	22,691,473
7	<i>Phalaenopsis amabilis</i>	4,769,951	<i>Cymbidium</i> hybrid	21,802,311
8	<i>Cattleya</i> spp.	2,375,391	<i>Dendrobium</i> hybrid	15,075,529
9	<i>Cymbidium kanran</i>	1,478,658	<i>Cattleya</i> spp.	2,266,214
10	<i>Vanda</i> spp.	1,130,662	<i>Oncidium</i> spp.	1,479,275

Ornamental horticultural trade also includes wild, often illegally harvested plants. This can involve small-scale harvest for household use (Hinsley, 2011), but is also frequently conducted on a commercial scale. Historically, tropical orchids were collected in the hundreds of thousands for international export to Europe-dating back to the Victorian “orchid craze” (see Sanders 2017). International trade of wild horticultural orchids to Europe, the United States and Japan was widespread up to the establishment of CITES in the 1970s (Cribb et al. 2003; Koopowitz et al. 2003). However, commercial trade in wild plants continues, in response to both domestic (e.g., Flores-Palacios and Valencia-Diaz 2007) and regional horticultural demand from hobbyist growers (e.g., Phelps and Webb 2015), as well as specialist international demand from enthusiasts who target rare species for their collections (Hinsley et al. 2015; Phelps 2015). Contemporary, commercial wild trade has been formally documented in Mexico (Flores-Palacios and Valencia-Diaz 2007), continental Southeast Asia (Phelps and Webb 2015), and Nepal (Subedi et al. 2013). Trade in wild orchids is also known anecdotally from a number of other countries, including China, Costa Rica, Cambodia, Madagascar, Viet Nam, Indonesia, Lao PDR, Peru, Malaysia, Philippines and Venezuela (authors’ observations).

Cultural ornamental uses

Historically, orchid flowers have been, and continue to be traded for their ornamental value in a wide range of cultural and religious ceremonies. For example, *Dendrobium maccarthiae* flowers are used as special temple offerings in Sri Lanka, and *Laelia* spp. flowers and pseudobulbs in Mexican Day of the Dead ceremonies (Dougal 1971). Orchid flowers are also used as national symbols, including Myanmar's national flower, *Bulbophyllum auricomum* (and similar species, such as *B. sukhakulii*), that has long been used to adorn women's hair (Goh 2013) and whose trade has increased as people have sought to emulate pro-Democracy leader Aung San Suu Kyi (J.Phelps, pers. obs.).



Figure X. Myanmar leader, Aung San Suu Kyi, with flowers of *Bulbophyllum* sp. in her hair (Photo from Le Monde. Credit: AFP/FREDERIC DE LA MURE).

Edible orchids

Orchids used for human consumption include globally important products such as *Vanilla* flavourings, as well as edible products used on national and regional scales.

Vanilla

Vanilla is a globally traded orchid, commercially produced as a food flavouring since Spanish explorers introduced it as a product to Europe in 1500s (Cameron, 2012). Although wild *Vanilla* species and cultivated varieties are used medicinally in different cultures (e.g. Madagascar, Randriamiharisoa et al. 2015), *Vanilla* is primarily traded as a flavouring. Of the numerous edible *Vanilla* taxa cultivated, *Vanilla planifolia* is the main species used for trade as a food, with the hybrid *Vanilla x tahitensis* being the second most cultivated variety of *Vanilla* (Bory et al. 2008, De la Cruz et al. 2009, Lubinsky et al. 2008a, Lubinsky et al. 2008b, Schipilliti et al. 2016). *Vanilla* seed pods are harvested unripened and processed in order for the characteristic vanilla flavour to develop (Correll 1953), the main chemical component of which is vanillin (3-methoxy-4-hydroxybenzaldehyde) (Gallage et al. 2014). Madagascar is the biggest producer of *Vanilla* with its production of 3,719 tonnes in 2014 (comprising 48% of global production), followed by Indonesia with 2,000 tonnes (FAOstat 2014).

Salep

Another food product, *salep*, is made from the nutritional, polysaccharide-rich tubers of wild orchids that are dug up in spring and traded predominantly in Turkey, with collection and trade also reported in Greece, Iran and Albania (Ghorbani et al. 2014;

Kreziou et al. 2015; Quave & Pieroni 2015). This trade was reported as far back as 1850, when seasonal harvest of salep tubers was recorded from what is now Greece (Landerer 1850). After collection the orchid tubers are boiled in water, milk or *ayran* (a yogurt based drink) to render the enzymes within them inactive and prevent tubers from regrowing (Tamer et al. 2006). They are then dried and ground into a powder called *salep*, which is used to make the drink called *salep* and ice cream called *maraş dondurma* (Kasperek & Grimm 1999). Ethnobotanical surveys of plant use in Turkey report that *salep*, served in the form of a drink, is also ascribed medicinal properties (Çömlekçioğlu & Karaman 2008, Korkmaz et al. 2011, Gürdal & Kültür 2013).

At least 35 species of orchids are used to make *salep* (Ghorbani et al. 2015, Kasperek & Grimm 1999, Kreziou et al. 2015) and tuber collection in Turkey has been estimated to annually use tubers from 30-120 million orchid plants, producing over 15 tonnes of *salep* (Kreutz 2002, Sezik 2002). Earlier estimates for Turkey by Read and Groves (1994) put this figure at 10-20 million, and Kasperek and Grimm (1999) at 9.8-19.6 million. More recent estimates suggest that 80 tonnes of orchid tubers are collected annually in Turkey (Mediterranean Conservation Society, 2013). Kreziou et al. (2015) also report diverse *salep* trade in Greece, and informants reported a renewed interest in *salep* as a natural product.

Chikanda

The tubers of terrestrial orchids are also used in several African countries to make *chikanda*, a large cake with a meat-like structure, made of ground orchids and peanuts baked together with ashes or baking soda (Kaputo, 1995; Bingham, 2009). *Chikanda* is a dish that was traditionally eaten by the Bemba tribe in Northern Zambia (Richards, 1939), and by tribes in the Katanga province of the Democratic Republic of Congo (Malaisse & Parent, 1985), the Sumbawanga region in Tanzania (Leedal, 1975; Cribb & Leedal, 1982; Davenport and Ndangalasi, 2003; Nyomora, 2005), Malawi (Kasulo et al., 2009) and the Bayam people in Cameroon, where the dish is prepared in a similar way with two species of *Habenaria* tubers and called *napssié* (Menzepoh, 2011). At first the dish was only used on a household-scale and in times of famine, but its popularity has increased and it is now a national dish in Zambia (Davenport & Ndangalasi, 2003; Bingham, 2009; Veldman et al., 2014). *Chikanda* is sold as a snack on local markets, can be found in the supermarket and is advertised on the menus of upscale bars and restaurants (Davenport & Ndangalasi, 2003; Bingham, 2009). To accommodate the increased taste for *chikanda*, tuber are now also imported from surrounding countries. In 2003, between 2.2-4.1 million tubers were reportedly exported annually from Tanzania to Zambia (Davenport & Ndangalasi, 2003), a trade volume estimate that was verified in 2014 (Veldman et al. 2014).

Orchids used for *chikanda* belong to three different genera: *Disa*, *Habenaria*, *Satyrium* (Bingham et al. 2002; Davenport & Ndangalasi, 2003; Bingham, 2003; Nyomora, 2005; Hamisy, 2007; Challe & Struik, 2008; Challe & Price, 2009). Recent surveys have shown that species from the genera *Brachycorythis* (Bingham et al., 2003; Hamisy 2008), *Eulophia* (Hamisy 2008) and *Roeperocharis* (Hamisy 2008; Challe and Price 2009) are now also harvested because of local scarcity of the other taxa (Veldman et al. 2017).

Table xx. Orchid species recorded as ingredients in *chikanda*

Species	Country	Reference
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<i>Habenaria xanthochlora</i>		Hamisy, 2007; Challe & Price, 2009
<i>Disa</i> aff. <i>similis</i>		Veldman et al. 2017
<i>Disa erubescens</i>		Veldman et al. 2017; Nyomora, 2005; Hamisy, 2007; Mapunda, 2007; Challe & Price, 2009
<i>Disa miniata</i>		Veldman et al. 2017
<i>Disa ochrostachya</i>		Veldman et al. 2017; Hamisy, 2007; Mapunda, 2007
<i>Disa robusta</i>		Veldman et al. 2017; Davenport & Ndangalasi, 2001; Hamisy, 2007; Mapunda, 2007; Challe, 2009
<i>Disa satyriopsis</i>		Veldman et al. 2017
<i>Habenaria clavata</i>		Veldman et al. 2017
<i>Habenaria macrostele</i>		Veldman et al. 2017
<i>Habenaria praestans</i>		Veldman et al. 2017; Nyomora, 2005
<i>Satyrium</i> aff. <i>elongatum</i>		Veldman et al. 2017
<i>Satyrium</i> aff. <i>trinerve</i>		Veldman et al. 2017
<i>Satyrium anomalum</i>		Veldman et al. 2017
<i>Satyrium breve</i>		Veldman et al. 2017; Nyomora, 2005
<i>Satyrium carsonii</i>		Veldman et al. 2017
<i>Satyrium comptum</i>		Veldman et al. 2017
<i>Satyrium coriophoroides</i>		Veldman et al. 2017
<i>Satyrium elongatum</i>		Veldman et al. 2017
<i>Satyrium riparium</i>		Veldman et al. 2017; Bingham et al., 2003
<i>Satyrium shireense</i>		Veldman et al. 2017
<i>Satyrium trinerve</i>		Veldman et al. 2017; Bingham et al., 2003; Hamisy, 2007 (mentioned under the synonym <i>S. atherstonei</i>); Mapunda, 2007 (mentioned under the synonym <i>S. atherstonei</i>).
<i>Satyrium volkensisii</i>		Veldman et al. 2017
<i>Brachycorythis pleistophylla</i>		Hamisy, 2007; Mapunda, 2007
<i>Brachycorythis</i> sp.		Bingham et al., 2003
<i>Disa aequiloba</i>		Nyomora, 2005
<i>Disa baurii</i>		Hamisy, 2007 (mentioned under the synonym <i>D. hamatopetala</i>)
<i>Disa leucostachys</i>		Davenport & Ndangalasi, 2001; Nyomora, 2005
<i>Disa welwitschii</i> subsp. <i>occultans</i>		Nyomora, 2005 (mentioned under the synonym <i>D. tangayikensis</i>)
<i>Disa zombica</i>		Hamisy, 2007
<i>Eulophia schweinfurthii</i>		Hamisy, 2007; Mapunda, 2007
<i>Habenaria adolphii</i>		Nyomora, 2005
<i>Habenaria cornuta</i>		Nyomora, 2005
<i>Habenaria humilis</i>		Nyomora, 2005

<i>Roeperocharis wentzeliana</i>		Hamisy, 2007; Challe, 2009
<i>Satyrium sceptrum</i>		Hamisy, 2007 (mentioned under the synonym <i>S. acutirostrum</i>)
<i>Satyrium buchananii</i>		Davenport & Ndangalasi, 2001; Hamisy, 2007; Mapunda, 2007; Challe, 2009
<i>Satyrium chlorocorys</i>		Nyomora, 2005
<i>Satyrium crassicaule</i>		Nyomora, 2005; Hamisy, 2007
<i>Satyrium monadenum</i>		Davenport & Ndangalasi, 2001
<i>Satyrium robustum</i>		Hamisy, 2007
<i>Satyrium sacculatum</i>		Nyomora, 2005

Faham

On the Indian Ocean islands of Réunion and Mauritius, the aromatic leaves of *Jumellea fragrans* (Thouars) Schltr., and *J. rossii* Senghas. are traded as *faham* and used to flavour rum, as well as to make ‘Bourbon tea’ (Thé de Bourbon) or ‘Madagascan tea’ (Thé de Madagascar) (Decary 1955). Coumarin is the main compound responsible for the flavour of faham (Sing & Smadja 1992) and the leaves are also used in Creole medicine (Longuefosse 2010).

Medicinal uses

Orchids are also used in a number of traditional medicine systems around the world, from subsistence to commercial levels of exploitation. Some of the most widespread, commercial uses of orchids include the Chinese and South Asian Ayurvedic medicinal traditions (Teoh 2016), although they are also known to be used in some African medicinal traditions (e.g., *Angraecum* spp. in Madagascar, REF), North American Native American traditions (e.g., *Cypripedium* spp., REF) and Unani Perso-Arabic medicinal tradition (e.g., *Dactylorhiza hatagirea*, *Vanda tessellata*, *Cymbidium bicolor*, *Ipsea speciosa*, Jayaweera 1981; Thakur and Dixit 2007; Khajuria et al. 2017).

Chinese traditional medicine

Orchids appear in Chinese pharmacopoeia in the 17th century, but their medicinal value was reportedly first recognised by Shennong, China’s founding emperor and patron deity of agriculture, in the 28th century BC (Hong 2004; Bulpitt 2005). With the recent development of a consumer economy in China, demand for Traditional Chinese Medicine (TCM) has surged (Nijman 2010; Hong et al. 2014; Zhang & Yin 2014), further amplifying the value of traditionally used species (Zhang et al. 2008; Liu et al. 2015).

Scientific interest in the herbal constituents of TCMs commenced in the 20th century (Smith & Stuart 1911; Kimura & Migo 1936; Hu 1970), with the most prominently cited orchids being various *Dendrobium* spp. used to make the drug *Shih-hu* (particularly *D. catenatum*, *D. loddigesii*, *D. moniliforme*, *D. nobile* and *D. officinale*); . in addition, *Gastrodia elata* tubers (from which prepared), *Bletilla striata* rhizomes, the rhizomes and stems of *Anoectochilus* spp., and the corms of *Cremastra appendiculata* are all widely used in medicines (Teoh . The purported therapeutic benefits of preparations containing these species include the treatment of

thirst, fever, impotence, menstrual pain and hyperglycaemia for *Shih-hu*; headaches, dizziness, epilepsy, muscular pain and tinnitus for *Tian-ma*; and bleeding, tuberculosis and ulcers for *Bai-ji* (Bulpitt 2007). Only relatively recently have these effects been subjected to scientific scrutiny, with some studies reporting the presence of bioactive compounds of potential clinical significance in certain species (e.g. Ojemann et al. 2006; Wang et al. 2014).

Ayurvedic medicinal tradition

Ayurvedic medicine originated in the Indian Subcontinent and has become globally practised as part of the spread of complementary and alternative medicines. It includes a wide range of medicinal preparations, including Asthavarga preparations that involve various combinations of eight different plants used to treat a wide range of ailments (e.g., Chyawanprash tonic, Dhyani et al. 2010). Several orchid species are commonly used across Asthravaga, notably *Crepidium acuminatum*, *Habenaria intermedia*, *Herminium edgeworthii*, and *Malaxis muscifera* (Hossain 2009; Dhyani et al. 2010; Khajuria et al. 2017). None of these species, however, are known to be in commercial cultivation.

Orchids in the genus *Eulophia* are also widely used medicinally across large parts of India (*E. dabia*, *E. spectabilis*; Jalal et al. 2014), as is *Dactylorhiza hatagirea* to treat a range of ailments (Pant & Rinchen 2012). Estimates suggest that between 6,200-31,000 kg of *Dactylorhiza* are harvested annually within northeast Himalayan region of Sikkim (Rai et al. 2000; Uniyal et al. 2002), with each kilo comprised of approximately 100 individuals (Pant & Rinchen 2012). *Paphiopedilum druryi*, an IUCN-listed Critically Endangered species endemic to South India, also continues to be collected for medicinal use and horticulture (Maridassa et al. 2008; Rankou and Kumar 2015).

Conservation Challenges

These diverse types of trade present five main categories of conservation challenges. Notably, (1) trade is often associated with unsustainable, sometimes illegal forms of harvest and trade. Orchid trade also presents conservation challenges associated with (2) shifting patterns in the behaviour of consumers and intermediaries, including a trend towards adulterating medicinal orchid products with other species, the emergence of online trade platforms, and consumer preferences for orchids that are wild-harvested instead of cultivated. Conservation efforts are also hindered by (3) taxonomic complexity of the family, resulting in management challenges associated with (mis-)identification, and the challenges of identifying practicable genetic tools to improve species-level identification. There are also (4) basic ecological data gaps that limit sustainable management of orchid resources, including the lack of conservation assessments for orchids and the limited body of ecological research. Finally, (5) institutional context presents challenges, as plants continue to be perceived as a low priority within broader efforts to address the unsustainable wildlife trade, and so current structures limit, rather than promote, legal international orchid trade in ways that constrains scientific exchange and potentially beneficial commerce.

Unsustainable, often illegal harvest

There are considerable gaps in our understanding of how wild harvest affects orchid populations and species, due both to the lack of baseline ecological information and

monitoring of populations and trade (discussed below). However, there is widespread, largely anecdotal evidence, that the commercial harvest and trade for a number of uses is negatively affecting wild populations.

For example, trade in ornamental Southeast Asian orchids is suspected to be negatively impacting wild populations at local and regional scales--notably based on reports from harvesters themselves, who report dramatically declining populations (Schuiteman et al. 2008; Phelps et al. 2015). In addition, out of 347 species identified in ornamental trade, 58 of the species were either endemic or had been identified as domestically threatened within Thailand (Phelps 2015). There are also numerous, although largely anecdotal, cases of species extirpations and extinctions as a result of intensive harvest, primarily of lady slipper orchids in the genera *Paphiopedilum* and *Phragmipedium*. For example, *Paphiopedilum glaucophyllum* is now absent from most of its range in Java, Indonesia, (Whitten et al. 1997). More recently, the newly discovered Vietnamese species, *Paphiopedilum canhii*, suffered commercial harvest of 99.5% of its population (Averyanov et al., 2014), following the fate of many other charismatic species in the region (e.g., Malaysia *Paphiopedilum* species, such as *P. barbatum*, *P. bullenianum* var. *bullenianum*, *P. callosum*, *P. lowii* var. *lowii*, *P. niveum*; Leong 2014). Similarly, the Neotropical lady slippers have been intensively harvested; *Phragmipedium kovachii* was extirpated from its limited range following its discovery in Peru in 2001 (Pillon & Chase 2007). However, other groups are also vulnerable to intensive harvest. *Phalaenopsis javanica* was thought collected to extinction from its only known site in Java, Indonesia (Whitten et al. 1997), although a commercial trader has reportedly rediscovered it at a new locality (pers. obs.), and in the early 1990's almost all individuals of *Grammangis spectabilis* were collected its habitat in Madagascar, with only nine individuals found in the wild during recent surveys (Rajaovelona & Gardiner 2017).

Trade in edible orchids is also suspected to lead to over-harvesting of populations of many species in many range countries. Trade in orchids for *chikanda* is suspected to threaten up to 85 species in Tanzania (Davenport & Ndangalasi, 2003) and Zambia (Bingham & Kokwe, 2001; Golding, 2002). The intensive overexploitation threat led to the establishment of Kitulo National Park in Tanzania specifically to protect orchids (Davenport & Bingham, 2004). Orchids for *chikanda* have reportedly become so depleted in Zambia that traders are now having to import tubers from several neighbouring countries (Davenport & Ndangalasi, 2003; Veldman, 2014). Market surveys and interviews with collectors show that demand outstrips supply and that intermediaries and collectors now report sourcing tubers from as far afield as Mozambique, Malawi, DR Congo, and Angola (Veldman et al., 2014)

Threats from the edible orchid trade are not restricted to *chikanda*; the trade in multiple orchid species for *salep* is reportedly impacting populations in several countries. The depletion of resources in Turkey has reportedly caused traders to look abroad, and have fuelled an orchid harvesting boom in neighboring Iran, where 5.5 – 11 million orchids are harvested annually, mainly for export to Turkey (Ghorbani et al. 2014). Similarly, in Reunion *J. fragrans* is considered to be a conservation priority due to the impact of wild harvesting for *faham* from its already fragmented populations (Blambert et al., 2015).

Increased demand and the resulting harvest of many medicinal orchids is also proving unsustainable in many cases. For example, Ayurvedic medicinal orchids such as *Habenaria intermedia* and *H. pubescens* have been extirpated from parts of their native ranges (Chauhan et al. 2007); populations of *Eulophia dabia* and *Dactylorhiza hatagirea* are declining in the Indian Himalayan Region due to over-harvest (Kala 2000; Jalal et al. 2014), and the related literature is widely concerned with the conservation impacts of medicinal harvest across India, Nepal and Bangladesh (e.g., Hossain 2009; Subedi et al. 2013; Khajuria et al. 2017). Increased demand for orchid-containing TCM is reportedly unsustainable within China, and has driven sourcing for some orchids (e.g., *Dendrobium* spp.) to neighbouring countries, including Laos, Myanmar and Vietnam (Zhang et al. 2008; Lamxay 2009; Subedi et al. 2013; Hong et al. 2014; Phelps 2015).

Unsustainable harvest is often fuelled by illegal collection that violates domestic and international legislation. Notably, much of the unsustainable harvest and international trade that has been documented by researchers is not reflected in official CITES trade statistics (including for *salep*, Ghorbani et al, 2014a, 2014b; *chikanda*, Veldman et al. 2014; ornamental species, Phelps and Webb 2015; and medicinal orchids, Lamxay 2009). This means that, even in cases of CITES Appendix II listed species for which international trade *might* be legal, trade is frequently occurring without the requisite permits and CITES Non-Detriment Findings. In many cases, this appears to be an issue of non-enforcement of environmental and CITES legislation, as at the open cross-border trade and public plant markets in many parts of Southeast Asia (Phelps and Webb 2015). In other cases, it involves smuggling, as at the Iran-Iraq and Iran-Turkey borders where *salep* passes in bags as almonds (Ghorbani and de Boer, pers. obs.). At the Tanzania-Zambia border, border guards report that no *chikanda* passes the border, while traders report that they transport *chikanda* tubers marked as potatoes in 100-150 kg bags (Veldman and de Boer, pers. obs.). In other cases, illegal trade involves the laundering of wild specimens as artificially propagated species to circumvent protections on wild plants (Phelps 2015; D.Roberts, J.Phelps, A.Hinsley pers. obs.).

Shifting trade and consumer patterns

Substitutions and adulteration of orchid products

Within traditional pharmacopoeias, substitutions in which one species is replaced for another are common (e.g., Khajuria et al. 2017). However, as an effect of growing demand and reduced wild supply of some orchid species, there is evidence that some products are being both substituted and adulterated with other, non-target species, including those not traditionally considered within pharmacopoeias. Medicinal orchids in TCM have been adulterated with both substitute taxa and farmed products that are purportedly from the wild (Lau et al 2001; Zhang et al. 2005; Heubl 2010; Williamson et al. 2013). For example, a wide range of *Dendrobium* species are often used as adulterants within the traditional medicine *shi hu* (Lau et al. 2001; Wu et al. 2009). Similarly, edible *salep* is being adulterated with tubers and bulbs of plants, including substitute orchid and non-orchid species (e.g., *Ranunculus ficaria*, *Colchicum cilicium*; Sezik 2002). Substitutions are also occurring among *Eulophia* spp. with Ayurvedic medicine, as some species become scarce (Jalal et al. 2014). Increased use of substitutes and adulterants presents an issue not only for consumers, but is potentially shifting the impact of unsustainable wild harvest onto a broader

range of orchid species and on to other taxonomic groups, with potential cascading conservation effects.

Emerging online orchid sales

Wildlife trade has become established on the Internet, with legal and illegal trade in animal and plant products occurring on a variety of online platforms (Shirey et al. 2013; Lavorgna 2014; Yu and Jia 2015). There is initial evidence that online platforms are becoming increasingly important for the sale of wild orchids (Phelps et al. 2015; Hinsley, 2016). A survey of a large international social media website found that trade was occurring in all geographic regions, and that up to 46% of trade was in wild-collected plants (Hinsley et al. 2016b). The availability of wild orchids for sale online may be of conservation concern, as buyers of ornamental orchids who shop online are more likely to prefer to buy rare plants (Hinsley 2015), and online trade is used by sellers to bypass CITES regulations (Hinsley et al. 2016c). Indeed, at the 16th CITES Conference of the Parties in 2013, countries recognised the threat from unregulated online trade with Decision 15.57, which urged Parties to assess the extent and trends in wildlife e-commerce (CITES 2010).

Consumer preferences for wild plants

Efforts to reduce unsustainable and/or illegal wild-harvest of orchids have often prompted efforts to cultivate (artificial propagate) target species to meet demand and reduce pressures on wild populations. Such efforts, however, are hampered in some cases by consumer preferences for wild, often rare plants over cultivated alternatives.

Preference for wild plants has been shown in ornamental markets due to perceived differences in attributes such as robustness, fragrance and ‘authenticity’ (Phelps et al. 2013). Similar preferences and price premiums have been found for rare species (Hinsley et al. 2015), supported by surveys of plant markets in Southeast Asia and Mexico that have found many species with small, often obscure flowers (Flores-Palacios and Valencia-Diaz 2007; Phelps and Webb 2015). This can be linked to the desire to collect and be the first to own new or unusual species and varieties (A.Hinsley, D.Roberts pers. obs.; cf Hall et al. 2008) as well as to produce new hybrids from these species that can be named and publically shown for horticultural awards. This is likely the driver for a phenomenon where orchid species enter commercial trade even prior to scientific description (e.g., Vermeulen et al. 2014).

The preference of wild harvested orchids is also present in some parts of traditional medicine trade, where wild-harvested treatments are viewed as more effective (Hong et al. 2014). This may even extend to a preference for a specific provenance of the plants collected from mountains and even villages within a species range, which are purported for producing plants of superior quality (Bao et al. 2001). The greater value placed on these plants (Liu et al. 2015) has led to populations at many of these ‘famed’ locations becoming economically or biologically extinct (Bao et al. 2001; Ding et al. 2008; He et al. 2009).

Challenges of species identification

Taxonomic (mis)identification

The Orchidaceae is an exceptionally large family, for which accurate species identification generally requires training, and whose taxonomy is based heavily on floral characteristics, which limits the identification of sterile material. This is further

limited by the lack of complete and up-to-date taxonomic references for many countries and genera, and is further aggravated by the tendency by some for over-description within the orchid family motivated by the charisma, enthusiasm and vested financial interests of traders that often accompany orchid work (Pillon & Chase 2007). Taxonomic challenges are compounded in the case of products that contain orchids, where constituent parts are generally processed by drying and curing, making species identification based on morphology practically impossible.

These taxonomic barriers present particular challenges to customs officials expected to implement trade regulations at border crossings. Non-experts, in most cases, struggle with even genus-level identification (cf. McGough et al. 2004), and most experts are unable to confidently identify many orchids to the species or subgenus level when presented with sterile specimens (see Phelps & Webb 2015). Strengthening the capacity of customs officers to correctly enforce CITES is a priority for the Convention (Decision 17.34 (REF)). However, the diversity of orchid species in trade and the variety of forms in which they are traded presents customs agents with a significant challenge, and may make it difficult to determine whether or not the item is even an orchid, whether a CITES permit is needed, what CITES Appendix applies, and whether the plant is wild-collected or artificially propagated (McGough et al. 2006).

Genetic tools for orchid identification

Molecular genetic tools aid species-level orchid identification, and such tools are increasingly part of wildlife trade monitoring for traded animals of conservation concern (e.g., tigers, pangolins and lizards; Wilson et al, 2016). This includes Sanger sequencing-based DNA ‘barcoding’ techniques, which for plants typically compare two DNA regions (or ‘markers’) from each specimen with a library of verified reference samples (i.e., the identity of each reference sample being known and related to a voucher specimen deposited in a herbarium for future re-verification; Hollingsworth et al. 2009). They also include Next Generation Sequencing techniques that use the whole genome or a much larger number of markers from across the entire genome to compare with a reference library.

Barcoding approaches have been trialled for the monitoring of ornamental orchid trade (Phelps 2015), to identify constituent species within processed medicinal products (e.g., Lau et al 2001; Yao et al. 2009; Wu et al. 2009), and most recently to identify species within edible orchid products (Ghorbani et al. 2016; Veldman et al. 2017). However, the application of these techniques to orchids has presented several challenges. Notably, there is still a lack of reference samples for most orchid groups and high diversity areas, and a high quality, vouchered, and comprehensive library of reference sequences is essential for such tools to enable species level identification. Public DNA databases such as GenBank (<https://www.ncbi.nlm.nih.gov/genbank/>) and BOLD (<http://www.boldsystems.org/>) are important repositories of DNA sequence data. Both include large numbers of Orchidaceae DNA sequences, but especially GenBank include many that are not vouchered and the identifications cannot be reliably verified, and thus fall far short of the minimum criteria to be used as barcode reference sequences (Nilsson et al. 2006). In many parts of the world, there are no comprehensive live collections of orchid taxa within national botanical institutions (e.g., BGCI PlantSearch 2017; SE Asia, Phelps 2015), let alone

specimens that represent the range of genetic diversity across widely distributed species.

Other challenges include the lack of consistent DNA markers for barcoding that can confidently achieve species-level identification in areas with high levels of orchid diversity; while some studies have proposed options (Lau et al 2009; Gigot et al 2007; Ghorbani et al 2016), others have questioned their accuracy due to large inter- and intra-specific variation (Phelps 2015; Guo et al. 2016). In addition, hybridisation, cross-pollination, and wide-ranging species can reduce the accuracy of identifications based on limited reference samples (REF). It is likely that many orchid species may be virtually identical when standard DNA barcoding regions are compared, even though they may be morphologically very different (as the result of rapid evolution of different floral traits, often as a result of pollinator-driven adaptation), making such species extremely difficult to distinguish using such regions (DeSalle et al. 2005). Finding suitable markers for species distinction is facilitated by innovations in high-throughput sequencing approaches that provide vastly more data for selection of variable markers, such as gene-capture and target-enrichment sequencing, genome skimming and Hyb-Seq (Mamanova et al. 2010). Standard DNA barcoding is likely to remain important for identification of plants, but genomic barcoding will play an important role in identification and selection of suitable high resolution markers (Coissac et al. 2016).

Data gaps in conservation assessments, ecological data, and harvest studies

There are major gaps in our understanding of basic orchid ecology and conservation (Cribb et al. 2003; Corlett 2016). In spite of recent efforts to increase the number of orchids assessed (IUCN 2014; Fay 2016), the number of global IUCN Red List assessments published remains extremely low. Just 880 orchid species have been formally evaluated using IUCN Red List Criteria, 3% of the entire family, and many of these assessments are over a decade old (Nic Lughadha et al. 2017; IUCN 2017). These are dominated by recent focused Red Listing of taxa in target countries (e.g. China and Madagascar: Fig. xx) and a small number of charismatic tropical and subtropical genera (e.g. the Cypripedioideae subfamily of slipper orchids), and the efforts of the Sampled Red List Index of Plants project (Brummitt and Bachman, 2010; Brummitt et al, 2014; Brummitt et al. 2015) . This presents considerable challenges to efforts to determine the environmental impacts of harvest, including efforts to conduct CITES Non-Detriment Findings to decide whether or not international trade in Appendix II listed species should be legally permitted.

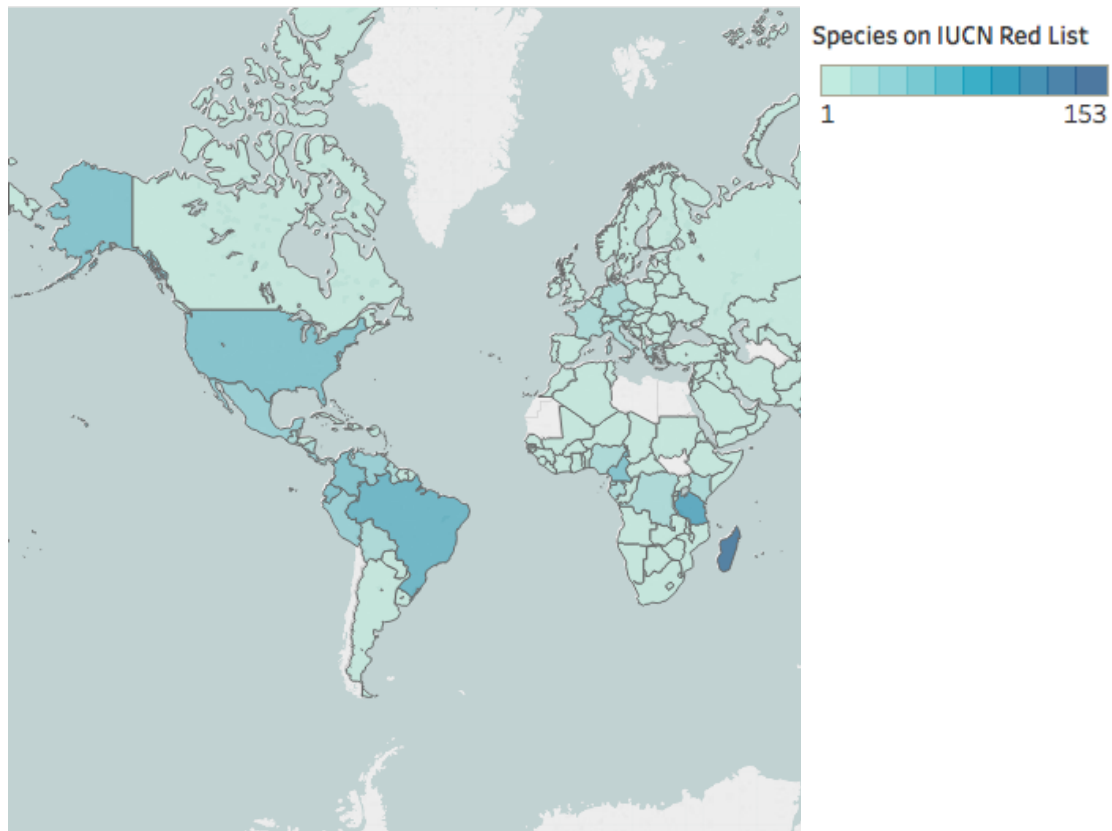


Figure xx. Number of native orchid taxa assessed for the IUCN Red List (IUCN 2017)

The lack of global conservation assessments for orchids reflects profound gaps in the ecological knowledge about orchids and challenges of studying the family as well . This includes taxonomic challenges, which limit the viability of research into population dynamics (and related population viability analyses), especially in species-rich ecosystems where it is challenging to reach species-level identifications of non-reproductive individuals (Mondragón 2011; although see Tremblay and Hutchings 2003; Mondragón 2009). Moreover, many orchid species have restricted distributions, brief visible growth phases (e.g., many terrestrial species, leafless species), ephemeral flowers (e.g. *Sobralia* spp.) and/or short blooming seasons, and epiphytic growth habits that make them physically hard to access, and the need to consider both horizontal and vertical distributions for epiphytic species (Mondraón 2011).

Institutional barriers

Plants as a low conservation priority

Amidst growing interests and concern over wildlife trade, focus has been disproportionately on charismatic megafauna, and taxa such as plants have been largely overlooked by conservation organisations, government agencies and the public (Phelps and Webb 2015; cf. Nijman et al. 2012; Small 2012). Where there has been willingness to tackle some challenging and contentious trade issues, including non-compliance of countries that have allowed illegal wildlife trade (e.g., elephants, van Aarde and Ferrera 2009; rosewood, Barrett et al. 2010), there is not similar public support to address illegal trade in plants (see Phelps & Webb 2015). Similarly, orchids are unlikely to be a priority for customs officers, park rangers or other enforcement officials, when compared to wildlife products such as ivory and rhino horn. This bias

is manifest in a number of ways; for example, the ASEAN Wildlife Enforcement Network focuses only on fauna; the UK's Department for International Development fund to address illegal wildlife trade (IWT Challenge Grant) excludes funding for botanical trade and conservation (DFID 2017); enforcement and education efforts to reduce illegal wildlife trade at Bangkok's Chatuchak Market have focused on fauna while the illegal trade of wild ornamental orchid remains rampant (Phelps 2015). This relatively low profile represents an ongoing challenge to recruiting funding and action for botanical conservation and promoting sustainable use of wild plant resources.

Barriers to legal trade

In an effort to protect species from the pressures of intense international trade, (as well as invasive species, bioprospecting, etc.) legislators have placed significant legislative controls on the legal international trade of plants, for both commercial and scientific purposes. This can include particular restrictions on transport of CITES-listed orchids, which in many countries, require extensive permitting, are slow, and involve high economic costs.

There have been complaints that these represent undue burdens on commercial and hobbyist traders who seek to comply with the law, and also limits the exchange and movement of scientific samples needed for taxonomic and conservation research (e.g., plants, seeds, dried/pickled specimens, DNA, REF; A.Hinsley, J.Phelps pers. obs). Through CITES, exemptions have been made for the international, non-commercial loan, donation or exchange of museum and herbarium specimens (Resolution Conf. 11.15, Rev. CoP12), which allows movement of orchid specimens between Registered Scientific Institutions (RSI list https://cites.org/common/reg/e_si.html). However, implementation relies on individual Parties and, existence of an RSI does not mean scientific material can be effectively transported. Authorities in many countries are unfamiliar with the processes, which means that despite exemptions, CITES permits are sometimes still necessary. Elsewhere, bureaucratic demands mean that the process regularly takes 2-3 months, often endangering plant material (including of live plants of new species).

These burdens limit science and legal trade, and *potentially* create incentives for illegal action, by hobbyists, commercial traders and scientists eager to move specimens between countries. There are particular motivations for rule-breaking when compliance represents such a burden, relative to the ease with which much illegal activity seems to occur in many contexts (Hinsley et al. 2016c).

Conservation priorities to address orchid trade

Future priorities for the conservation of orchids in trade must take into account the diversity of orchid products, markets, and specific conservation challenges facing practitioners and policy makers attempting to tackle illegal and unsustainable trade. Whilst other areas of research and conservation action undoubtedly exist, we consider the following four areas to be the most pressing and feasible, given existing budgetary and institutional limitations.

Conduct basic research on trade dynamics and impacts of harvest

There are huge gaps in our understanding of orchid trade. In many regions, there is little certainty over exactly which species are being actively harvested, traded and used. There is little published information about key products that contain orchids,

including cosmetics and many medicinal products, and where these plants originate. As a result, there is little information on related harvest dynamics, including sites of harvest, scales of trade, number of people involved, and value chains. These data, however, are particularly important given the size of the family, and the need to prioritise enforcement, research, and conservation efforts. The blanket protection of the family from trade via CITES and some national legislation potentially creates an illusion of conservation outcomes, but there is nevertheless a need to understand what species are actually being targeted.

Moreover, there is a need to understand how different commercial trades impact wild populations and species survival. A great deal of orchid science has focused on taxonomy, with comparatively little study on orchid population ecology, distribution and conservation. Even less attention has been paid to impact assessments and population viability analyses, particularly in tropical and subtropical regions of greatest orchid diversity. These data, however, are instrumental to understanding how commercial harvest affects populations, and to determining whether sustainable harvest is viable (e.g. during CITES Non-Detriment Findings). Given the size of the family and the logistical challenges of studying it, species that are known to be facing intense harvest pressures may be priorities for such research.

Address illegal trade and CITES non-compliance

Large-scale commercial unsustainable, illegal orchid trade should be addressed via CITES enforcement mechanisms. Although orchids represent the majority of CITES-listed species (Fig. 1), in many cases this designation exists only on paper, and existing rules have been poorly operationalised, with cases of non-compliance largely overlooked. Moreover, orchids are under-represented on the contemporary CITES agendas (e.g., CITES CoP). While there is considerable attention on trade in many species of megafauna, there is apparently comparatively little awareness or concern within CITES about the scope and scale of orchid trade that does not comply with the provisions of the Convention.

There is a clear need to raise the profile of orchids within the CITES process, including to ensure Parties are aware of and prioritise application of existing regulations to protected plant taxa from unsustainable trade. For orchids, this may mean efforts to transition existing undocumented and illegal orchid trade into a legal, regulated trade in Appendix II species (see Table 1). A priority is thus to understand the scope and potential for shifting some of this into legal trade.

Moreover, there is a need for action by CITES Parties to address documented cases of illegal trade, and other forms of non-compliance with the Convention. The prevalence of illegal orchid trade means that most orchid trade is 'invisible' in official records and thus generally overlooked. This contributes to a lack of awareness of the scale of orchid trade, and also prevents real trends from being identified during the Review of Significant Trade process, which is designed to alert CITES to emerging unsustainable trade. Currently, there is no process within CITES to identify trends in the illegal trade of orchids, although this does exist for other taxa. For example, in response to illegal trade of CITES-listed elephants, CITES Parties have approved two programmes to monitor and help reduce illegal elephant poaching and trade, Monitoring the Illegal Killing of Elephants (MIKE), and The Elephant Trade Information System (ETIS), which now help to inform policy responses.

Explore viability of artificial propagation and improved traceability

While it may be possible to facilitate a legal sustainable trade in some wild Appendix II orchid species, their propagation has been widely proposed as a potential conservation strategy (Subedi et al. 2013; Liu et al. 2014; REFS). Propagation for domestic trade can involve growing plants in greenhouses or shadehouses, or semi-wild cultivation in natural habitats (e.g. Liu et al. 2014), although for international trade, compliance with the CITES definition of artificially propagated requires plants to be grown in ‘non-natural’ and ‘controlled conditions’ (CITES Res. Conf. 11.11 (Rev. CoP17)). Propagation may provide a sustainable source of species that are already traded in large commercial quantities, as well as newly discovered species whose propagation may help to offset demand for wild specimens. However, the provision of artificially propagated plants does not automatically prevent wild harvesting, and there is a need to consider the conditions under which it is most likely to yield conservation benefits (Phelps et al. 2013).

One major drawback of artificially propagated trade is the opportunity it presents for wild-collected material to be laundered into the legal trade chain (REFS Phelps 2015), and so conservation relies on traceability methods to confirm the provenance of propagated plants. For customs agents checking shipments, identifying the origin of traded orchids using visual identification can be difficult for live orchid plants and impossible for processed derivatives. This has led to the development of more sophisticated traceability techniques for determining wild origin. The need for a more coordinated traceability approach for orchids and other horticultural plants was recognised at the 17th CITES Conference of the Parties in 2016, with suggestions to create international frameworks for standardising traceability of these products (UNCTAD 2016). Traceability can draw on molecular techniques discussed above, or on stable isotope analysis that examines ratio of stable isotopes present in a tissue sample to establish its geographical origin and potentially the conditions under which the plant was grown (Hinsley et al. 2016a). This method has been applied to traceability in the *Vanilla* trade to determine natural vanillin from mislabelled artificial substitutes (Hansen et al. 2014), and to establish provenance in the frog leg trade (Dittrich et al. 2017), but has yet to be widely applied.

Raise the profile of orchid conservation

Orchids are unique for their charisma, prominent place in popular culture, and wide following among horticulturalists (Hansen 2001). Efforts to address unsustainable and illegal trade would benefit from efforts to raise the profile of orchid conservation, as central to guiding buying behaviour, policy responses and conservation investments. Communities of horticultural orchid hobbyists represent a large, often influential community of enthusiasts with clear potential to help raise the profile of orchid conservation.

Orchid societies exist globally, including in tropical developing countries that face significant domestic and regional orchid trades. Some societies have engaged to buy habitat for orchid conservation and raise funds for conservation research that can yield direct conservation benefits. For example, the Angraecoid Alliance (<http://www.angraecoids.org>) was established by hobbyist growers of Angraecoid orchids to support *in situ* and *ex situ* conservation, as well as educating the wider orchid growing community about orchid conservation issues. Many societies also

work to promote conservation education via public orchid shows, but the related opportunities remain under-realised in many societies, especially in range countries. Experience with other taxa (e.g., pangolins) has demonstrated the benefits of generating public support to motivate policy makers, donors and civil society groups to engage with previously unrecognised conservation issues. Orchid societies globally could serve to raise issues of orchid legislation, overlooked issues of trade in edible and medicinal trade, as well as illegal orchid trade of ornamental plants.

Indeed, the horticultural community is often aware of, and even implicated in creating commercial demand for rare and protected species. Efforts to engage this community more deeply in conservation efforts have the potential to establish new codes of practice that condemn, rather than reward collecting practices that threaten species conservation. This community can also help to identify emerging conservation issues, including species that are being targeted for trade from the wild, which is particularly significant in the context of newly discovered, narrow endemic species.

However, some horticultural orchid growers and traders distrust CITES and efforts to limit trade (Hansen 2001), with many feeling that trade regulations are hampering, rather than helping species conservation (Hinsley et al. 2016c). There has historically been little engagement between traders, growers and policy makers, and efforts to improve dialogue between these groups is a priority for tackling non-compliance and ensuring legal trade (Hinsley et al. 2016c). This has been successful in the past; exemptions to the CITES orchid listings to allow unregulated trade in certain artificially propagated hybrids was of great benefit to commercial growers, highlighting the potential value of increased representation at CITES meetings.

Conclusion?

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Section	Sub-section	Contributors
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Introduction	Size of the family, global relevance/importance	Destario Metusala
	Economic importance of the family	Samantha Gunasekara
	Orchid as a group particularly vulnerable to trade (endemism, low density)	Samantha Gunasekara
Legal regulatory context	Overview of CITES rules and exemptions	Amy Hinsley
	Agricultural regulations (brief)	Dinesh Agrawal
	Overview of the types of domestic legislation that shape orchid harvest and trade (couple of small case studies, where information is available).	Dinesh Agrawal, Pankaj Kumar, Jacob Phelps, Shan Wong
Legal trade trends	Analysis of CITES trade data for orchids	Amy Hinsley
Types of trade	Edible: Salep	Susanne Masters, Hugo de Boer
	Edible: Chikanda	Sarina Veldman, Hugo de Boer
	Edible: Vanilla	Susanne Masters
	Medicinal: Chinese medicine	Stephan Gale, Jiang-Yun Gao
	Medicinal: Ayurvedic medicine	Pankaj Kumar
	Ornamental	Jacob Phelps, Destario Metusala
	Cosmetic	Susanne Masters
Challenges	Lack of scientific institutions who can handle material/reluctance to move material	Lauren Gardiner
	Customs agents and taxonomic challenges	Dave Roberts
	Over-collection of species before formal description	Destario Metusala
	Distinguishing cultivated from wild specimen	Jacob Phelps
Research and	Traceability - molecular techniques	Lauren Gardiner and Sarina Veldman (Sanger), Hugo de Boer (metabarcoding)

conservation for traded orchids - current activities, and gaps/future priorities	Traceability - other techniques (stable isotopes etc)	Amy Hinsley, Dave Roberts
	Traceability - approaches for chain of custody (UNCTAD)	Jacob Phelps
	In vitro conservation strategies	
	Engaging key groups/stakeholders – hobbyists, orchid societies, conservation organizations	Dave Roberts
	Online trade	Shan Wong
	Other examples of activities to tackle unsustainable/illegal orchid trade (one or two examples)	