A review of the trade in orchids, and its implications for conservation

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Orchids comprise one of the largest plant families and are commercially traded for a variety of purposes, including as ornamental plants, medicinal products and food. These markets involve thousands of species, which may be traded legally or illegally, sustainably or unsustainably, and at local, national or international scales. In this review we provide the first overview of commercial orchid trade globally, and highlight the main types of trade that involve wild-collected plants. Much of this trade is the result of illegal harvest and trade, meaning that it is little documented, and absent from official statistics, whilst also being of growing conservation concern. We discuss the associated legal-regulatory context, identify key conservation challenges, and highlight four key priorities to address these challenges. These are: (1) research trade dynamics and the impacts of harvest; (2) strengthen the legal trade of orchids; (3) adopt measures to reduce illegal trade; and (4) raise the profile of orchid trade among policy makers, conservationists and the public.

Additional keywords: CITES – horticulture – overharvesting – Orchidaceae – plant trade – wildlife trade

INTRODUCTION

Orchids comprise one of the largest families of flowering plants (e.g. Chase *et al.*, 2015) and are globally distributed. To date, 29,199 species have been accepted (Govaerts *et al.*, 2017), with several hundred new species names published each year (e.g. 370 in 2013: Schuiteman, 2017) and 31,000 species estimated to exist in total (Joppa *et al.*, 2010). In addition to their geographical and taxonomic diversity, orchids are also widely used and traded for a variety of reasons, both legally and illegally, sustainably and unsustainably (Fay, 2015, and references therein). One of the best-known plant groups in the global horticultural and cut flower trades (FloraHolland, 2015; De, 2015), orchids are also harvested, grown and traded for a variety of purposes, including as ornamental plants, medicinal products and food.

Most formal, global orchid trade is in artificially propagated cut flowers and plants grown under controlled conditions: between 1996 and 2015, most legal, reported commercial orchid trade reported was from artificially propagated sources, including 99.9% of the >1.1 billion live orchid plants in trade and >31 million kilogrammes of stems (UNEP-WCMC, 2017; Table 1). During this period, Taiwan and Thailand were the largest exporters, with most plants sent to South Korea (40%), the United States (27%) and Japan (20%) (UNEP-WCMC, 2017). The reported legal trade in wild-sourced plants was much lower, peaking at just under 375,000 plants in 1996 (UNEP-WCMC, 2017). However, despite this well-developed legal trade, orchids are also widely, and illegally harvested from the wild for local, regional and international trade. There are growing concerns that trade, although largely unreported, is threatening wild orchid populations and species in many places (e.g. Davenport & Ndangalasi, 2003; Flores-Palacios, 2007; Subedi *et al.*, 2013; Phelps & Webb, 2015; Pant *et al.*, 2016). Orchids may be particularly vulnerable to over-harvest because many species have a limited range and/or occur at low densities, due to a variety of interacting factors such as recent speciation, specialized pollination mechanisms, habitat specificity and the restricted distribution of mycorrhizal symbionts (e.g.

Dodson & Gentry, 1991; Swarts & Dixon, 2009; McCormick & Jacquemyn, 2014). The limited ecological studies on the conservation impacts of wild-collection of epiphytic orchids suggest a low tolerance to harvest (Mondragón, 2009; Hu *et al.*, 2017).

This review provides a first-of-its-kind overview of the global commercial trade of orchids, focused on wild plants. Based on literature review and expert consultation across the IUCN Species Survival Commission Orchid Specialist Group, the review identifies the main types of contemporary commercial trade in orchids globally; provides an overview of the legal-regulatory context that shapes orchid harvest and trade, and discusses the related conservation challenges.

TYPES OF COMMERCIAL TRADE

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

HORTICULTURE

Orchids have long been commercialized as ornamental plants in the horticultural and floricultural trade, involving several distinct types of markets and consumers. This trade is, unsurprisingly, dominated by species with attractive flowers, but it also includes species admired for their unusual growth habits (e.g. leafless orchids, such

as species of *Dendrophylax* Rchb.f. and *Chiloschista* Lindl.), miniature size (e.g. species of *Platystele* Schltr. and *Bulbophyllum moniliforme* F.Muell.), scent (e.g. species of *Cattleya* Lindl. and *Dendrochilum glumaceum* Lindl.) and patterned leaves (e.g. jewel orchids in the genera *Anoectochilus* Blume, *Goodyera* R.Br., *Ludisia* A.Rich. and *Macodes* Lindl.).

The vast majority of contemporary orchid trade involves artificially propagated plants and cut flowers cultivated in commercial greenhouses. Reported CITES trade in live artificially propagated plants is dominated by a small number of genera, with a large proportion of trade in hybrids (e.g. *Cymbidium* Sw., *Dendrobium* Sw. and *Phalaenopsis* Blume; Table 3). Orchids are consistently ranked among the best sellers in the global potted plant trade (FloraHolland, 2015; USDA, 2015), and also comprise *c.* 10% of all fresh cut flowers traded internationally (De, 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 in the domestic market (Thammasiri, 2014).

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 fever (Sanders, 2017). For example, Joseph Hooker oversaw the collection of "seven men's loads" of *Vanda coerulea* Griff. ex Lindl. for Kew, although few survived (Allan, 1967, p. 183). 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 & Valencia-Diaz, 2007) and regional horticultural demand from hobbyist growers (e.g. Phelps & Webb, 2015) and specialist international demand from enthusiasts who target rare species for their collections (Hinsley *et al.*, 2015; Phelps, 2015). Contemporary, commercial horticultural trade in wild plants has been formally documented from Cambodia (Hinsley, 2011), China (Shepherd et al., 2007; Gale et al. 2014), Indonesia (TRAFFIC, 2008; Hinsley *et al.*, 2016b), Thailand, Myanmar and Lao PDR (Lamxay, 2009; Schuiteman, 2013; Phelps & Webb, 2015), Vietnam (Grieser-Johns & Thomson, 2005; Hinsley *et al.*, 2016b), Nepal (Subedi *et al.*, 2013), Mexico (Flores-Palacios & Valencia-Diaz, 2007) and Peru (Cribb, 2005). Formal research is limited but collection of wild orchids for the horticultural trade is also known to be occurring in many more countries, including Costa Rica, Madagascar, Malaysia, the Philippines, and Venezuela (authors' observations).

CULTURAL ORNAMENTAL USES

Orchid flowers have historically been and continue to be traded for their ornamental value in a wide range of cultural and religious ceremonies. For example, flowers of *Dendrobium maccarthiae* Thwaites are used as special temple offerings in Sri Lanka, and flowers and pseudobulbs of species of *Laelia* Lindl. are used in Mexican Day of the Dead ceremonies (Duggal, 1971). Orchid flowers are also used as national

symbols, including the national flower of Myanmar, *Bulbophyllum auricomum* Lindl., and similar species, such as *B. sukhakulii* Seidenf., which are often used to adorn women's hair (Goh, 2013).

EDIBLE ORCHIDS

Orchids used for human consumption include globally important products, such as vanilla flavourings (extracts of *Vanilla* Plum. ex Mill.), and other edible products used on national and regional scales.

Vanilla

Vanilla spp. are globally-important edible orchids, with records of use, cultivation and trade in Mesoamerica dating back to 1350-1500 (Lubinsky *et al.*, 2008a). Although wild *Vanilla* spp. and cultivated varieties are used medicinally in different cultures (e.g. Madagascar; Randriamiharisoa *et al.*, 2015), *Vanilla* is traded primarily as a flavouring, and trade in artificially propagated material is exempt from CITES regulation (CITES 2017a). Of the numerous edible cultivated taxa of *Vanilla*, *Vanilla planifolia* Andrews is the main species used for the food trade, with the hybrid *Vanilla* ×*tahitensis* J.W.Moore being the second most cultivated (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 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 3,719 tonnes being produced in 2014 (comprising 48% of global production), followed by Indonesia with 2,000 tonnes (FAOSTAT, 2014; http://www.fao.org/faostat/en/#home).

Salep

Salep is made from the polysaccharide-rich tubers of wild orchids that are traded predominantly in Turkey as part of a seasonal trade recorded from as far back as 1850 (Landerer, 1850). Contemporary collection is also reported in Greece, Iran, Iraq and Albania (Ghorbani *et al.*, 2014; Kreziou *et al.*, 2016; Quave & Pieroni, 2015; A. Ghorbani & H. de Boer, pers. obs.). After collection, the orchid tubers are boiled in water, milk or ayran (a yogurt-based drink) to render the enzymes in 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 (Kasparek & 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, including species from the genera *Anacamptis* Rich., *Dactylorhiza* Neck. ex Nevski, *Himantoglossum* Spreng., *Ophrys* L., *Orchis* L., *Serapias* L. and *Steveniella* Schltr. (Ghorbani *et al.*, 2016; Kasparek & Grimm, 1999; Kreziou *et al*., 2016). Not everything sold as salep is, however, salep; tubers or bulbs of plants other than orchids, including *Ranunculus ficaria* ssp. *ficariiformis* Rouy & Foucaud and *Colchicum cilicicum* (Boiss.) Dammer are sold as salep (Kasparek & Grimm, 1999; Sezik, 2002; Kreziou *et al*., 2016), although this is noted as possibly being rare by Ghorbani *et al*. (2014).

Chikanda

The tubers of terrestrial orchids are used in several African countries in the production of chikanda, a large cake with a meat-like structure, made of ground orchids and peanuts baked with ashes or baking soda (Kaputo, 1996; 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 & 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 tubers of two species of *Habenaria* Willd. and called *napssié* (Menzepoh, 2011).

More than 85 orchid species are used for chikanda, generally belong to three genera (*Disa* P.J.Bergius, *Habenaria* and *Satyrium* L.: Bingham *et al.,* 2002; Davenport & Ndangalasi, 2003; Bingham, 2003; Nyomora, 2005; Hamisy, 2007; Challe & Struik, 2008; Challe & Price, 2009), but surveys have shown that species of *Brachycorythis* Lindl. (Bingham *et al.*, 2003; Hamisy, 2008), *Eulophia* R.Br. (Hamisy, 2008) and *Roeperocharis* Rchb.f. (Hamisy, 2008; Challe & Price, 2009) are now also harvested because of local scarcity of the other taxa (Veldman *et al.*, 2017).

Faham

On the Indian Ocean islands of Réunion and Mauritius, the aromatic leaves of *Jumellea fragrans* (Thouars) Schltr. and *J. rossii* Senghas have long been traded as faham used to flavour rum and in the production of '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). Very little is known on the scales or nature of contemporary commercial trade.

MEDICINAL USES

Orchids are also used in traditional medicine systems around the world, from subsistence to commercial levels of exploitation. Some of the most widespread, commercial medicinal uses of orchids include Chinese and South Asian Ayurvedic traditional medicine (Leon & Lin, 2017; Teoh, 2016). They are also known to be used in some African traditional medicine (e.g. *Vanilla madagascariensis* Rolfe in Madagascar: Randriamiharisoa *et al.*, 2015), North American folk medicine (e.g. *Cypripedium acaule* Aiton and *C. parviflorum* Salisb.: Henkel, 1906) and the Unani medicine system [e.g. *Dactylorhiza hatagirea* (D.Don) Soó *Vanda tessellata* (Roxb.) Hook. ex G.Don, *Cymbidium bicolor* Lindl. and *Ipsea speciosa* Lindl.: Jayaweera, 1981; Thakur & Dixit, 2007; Khajuria *et al.*, 2017]. Medicinal orchids are also traded much more widely around the world, including to Europe as various traditional medicines and health supplements (Brinkmann 2014).

Chinese traditional medicine

Orchids appeared in the official Chinese pharmacopoeia in the 17th Century, but their medicinal value was reportedly first recognized in the 28th Century BC by Shennong, China’s founding emperor and patron deity of agriculture (Hong, 2004; Bulpitt, 2007). With the recent development of a consumer economy in China, demand for Traditional Chinese Medicine (TCM) has surged (Nijman, 2010; Liu *et al.*, 2014;

Zhang & Yin 2014), further amplifying the value of traditionally used species (Zhang *et al.*, 2008; Liu *et al.*, 2015).

The most prominently cited orchids in TCM are various *Dendrobium* spp. used to make the drug *shi-hu* [particularly *D. catenatum* Lindl. (including *D. officinale* Kimura & Migo), *D. loddigesii* Rolfe, *D. moniliforme* (L.) Sw. and *D. nobile* Lindl.) (Leon & Lin, 2017; Teoh, 2016). In addition, tubers of *Gastrodia elata* Blume (from which *tian-ma* is prepared), rhizomes of *Bletilla striata* (Thunb.) Rchb.f. (from which *bai-ji* is derived), the rhizomes and stems of *Anoectochilus* spp. (*jin-xian-lian)* and the corms of *Cremastra appendiculata* (D.Don) Makino, *Pleione bulbocodioides* (Franch.) Rolfe and *P. yunnanensis* (Rolfe) Rolfe (from which *shan ci gu* is prepared) are all used (Leon & Lin, 2017; Teoh, 2016). Only relatively recently have the effects of some of these drugs 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; Paudel *et al.*, 2015).

Ayurvedic medicine

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 medicines, including Asthavarga preparations (e.g. chyawanprash tonic: Dhyani *et al.*, 2010) used to treats a variety of ailments.

Nepal's Ayurvedic trade has been reported to involve approximately 94 orchid species (Acharya and Rokaya 2010; Subedi et al. 2013, including *Crepidium acuminatum* (D.Don) Szlach., *Habenaria intermedia* D.Don, *Herminium edgeworthii*

(Hook.f. ex Collett) X.H.Jin, Schuit., Raskoti & Lu Q.Huang and *Malaxis muscifera* (Lindl.) Kuntze (Hossain, 2009; Dhyani *et al.*, 2010; Khajuria *et al.*, 2017). *Eulophia* spp. are also widely used medicinally across large parts of India [*E. dabia* (D.Don) Hochr., *E. spectabilis* Suresh in D.H.Nicolson, C.R.Suresh & K.S.Manilal (= *E. nuda* Lindl.): Jalal *et al.*, 2014] and *Dactylorhiza hatagirea* is used to treat a range of ailments (Pant & Rinchen, 2012). Estimates suggest that 6,200-31,000 kg of *D. hatagirea* are harvested annually in the north-eastern Himalayan region of Sikkim (Rai *et al.*, 2000; Uniyal *et al.*, 2002), with each kilo comprised of *c*. 100 individuals (Pant & Rinchen, 2012). *Paphiopedilum druryi* (Bedd.) Stein, an IUCN-listed Critically Endangered species endemic to southern India, also continues to be collected for medicinal use and horticulture (Maridassa *et al.*, 2008; Rankou & Kumar, 2015).

LEGAL-REGULATORY CONTEXT

This prevalence and diversity of orchid trade is remarkable because orchids are among the best protected plant taxa globally. Orchids are subject to unique levels of legal protection, including wide protections from the pressures of international trade, and national legislation in many countries further restricts their harvest from the wild.

CITES REGULATIONS

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a multilateral environmental agreement that regulates the international movement of species that are, or may become threatened as a result of international trade. Species of concern are included in one of three appendices, with >35,000 species currently listed. Notably, orchids constitute >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 (the so-called 'look-alike' principle) (Clemente-Munoz, 2009) and are therefore likely candidates for misidentification by the non-experts often responsible for inspecting trade shipments. Whilst some exemptions have been made for certain types of orchid material (e.g. seeds, seedlings in sterile flasks) or taxa (e.g. *Vanilla*, some ornamental hybrids), the international movement in most orchids, whether for personal, commercial or scientific purposes, must be monitored and sanctioned by the relevant CITES agencies (CITES, 2017a).

The vast majority of legally traded orchids species are listed under CITES Appendix II, which allows for the legal commercial trade of orchids, even if the plants are wild-collected. However, these cases require import and export permits, and a demonstration that any export will not be detrimental to the survival of the species (via a CITES Non-Detriment Finding). A small number of orchid species, notably members of two slipper orchid genera (*Paphiopedilum* Pfitzer and *Phragmipedium* Rolfe) are listed on CITES Appendix I, which does not allow international commercial trade unless the material is artificially propagated from legally-obtained founder stock (Table 1). Between 1996 and 2015, CITES-reported trade in Appendix I taxa was dominated by artificially propagated live plants (*c*. 1.2 million plants). Between 1996 and 2015, most legal, reported commercial orchid trade reported was from artificially propagated sources, including 99.9% of the >1.1 billion live orchid plants in trade and >31 million kilogrammes of stems (UNEP-WCMC, 2017). During this period, Taiwan and Thailand were the largest exporters, with most plants sent to South Korea (40%), the United States (27%) and Japan (20%). The reported legal

trade in wild-sourced plants was much lower, peaking at just under 375,000 plants in 1996.

NATIONAL LEGISLATION

The wild harvest and trade in orchids is also regulated through national regulations in many countries, 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 operationalize country commitments to CITES. In addition, orchids can also be governed by rules associated with phytosanitary requirements and legislation on food, medicinal or cosmetic product standards. We highlight examples of India and the United States of America to illustrate the diversity of rules that apply to orchid harvest and trade.

In India, orchid harvest and trade is shaped by several pieces of national legislation. Eleven of the *c.* 1,450 orchid species that occur in India (principally *Paphiopedilum* spp.) are listed in the Wildlife Protection Act 1972 and are 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 in protected areas (WPA, 1972; Indian Forest Act 1927: Ministry of Environment, Forest and Climate Change, 1927), although Scheduled Tribes and other Traditional Forest Dwellers can apply for a waiver (Ministry of Law and Justice, 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 cutting down of trees (e.g. West Bengal Tree Protection and Conservation in Non-

Forest Areas Act 2006) that provide 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. species of *Cypripedium* L.; Department of Commerce, 2015). Trade is further regulated by domestic legislation informed by the Customs Act (1962), which also makes provisions for CITES, and the Biological Diversity Act of India (National Biodiversity Authority, 2002), which protects all domestic biological resources as, 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 they were originally obtained from outside India in accordance with CITES and phytosanitary regulations (Department of Commerce, 2015).

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 (GPO, 2016). Some exemptions exist for plant harvest in national parks by Native American tribes but this is predominantly for subsistence use and handicrafts (NPS, 2016). Additional protections ban harvest of endangered and threatened species nationally, including 15 orchid species, including *Piperia yadonii* Rand.Morgan & Ackerman [=*Platanthera yadonii* (Rand.Morgan & Ackerman) R.M.Bateman], *Spiranthes delitescens* Sheviak and *Spiranthes parksii* Correll, except for conservation and restoration purposes with permits (Federal Endangered Species Act, 1973; Title 50 CFR part 17.61, 1985). In addition, State-level endangered and threatened species lists can provide additional protections based on local-level

assessments. For example, in Florida, *Dendrophylax lindenii* (Lindl.) Benth. ex Rolfe is recognized as an endangered species, the wild harvest of which is banned [The Florida Statutes (Section 581.185): The Florida Senate, 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 (USDA, 2008), 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.

CONSERVATION CHALLENGES

We identify five main conservation challenges associated with global orchid trade. Notably, (1) trade is often associated with unsustainable, sometimes illegal, forms of harvest and trade. In addition, (2) there are shifting patterns in the behaviour of the people involved in orchid trade, notably consumers and intermediaries. Another hindrance is (3) the taxonomic complexity of the family, which presents management challenges for species identification. Furthermore, (4) there are basic gaps in ecological data and conservation status assessments, which limit sustainable management of orchid resources. Finally, (5) institutional barriers arise from the low priority placed on plants within broader efforts to address the unsustainable wildlife trade, and limit the legal international orchid trade in ways that constrain scientific exchange and potentially beneficial commerce.

UNSUSTAINABLE AND ILLEGAL HARVEST

There is widespread, if largely anecdotal evidence, that the commercial harvest and trade for several 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 in continental Southeast Asia, 58 of the species were either endemic or had been identified as domestically threatened in 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's slipper orchids in the genera *Paphiopedilum* and *Phragmipedium*. For example, *Paphiopedilum glaucophyllum* J.J.Sm. is now absent from most of its range on Java, Indonesia (Whitten *et al.*, 1997). More recently, the newly discovered Vietnamese species, *Paphiopedilum canhii* Aver. & O.Gruss, suffered commercial harvest of 99.5% of its population (Averyanov *et al.*, 2014), following the similar fate of many other charismatic species in the region [e.g. Malaysian *Paphiopedilum* spp., such as *P. barbatum* (Lindl.) Pfitzer, *P. bullenianum* (Rchb.f.) Pfitzer var. *bullenianum*, *P. callosum* (Rchb.f.) Stein, *P. lowii* (Lindl.) Stein var. *lowii*, *P. niveum* (Rchb.f.) Stein; Leong, 2014]. Similarly, some Neotropical lady's slippers have been intensively harvested; *Phragmipedium kovachii* J.T.Atwood, Dalström & Ric.Fernández was virtually extirpated from its limited range following is discovery in Peru in 2001 (Cribb, 2005). However, other groups are also vulnerable to intensive harvest. *Phalaenopsis javanica* J.J.Sm. was thought to have collected to extinction from its only known site

on Java, Indonesia (Whitten *et al.*, 1997), although a commercial trader has reportedly rediscovered it in a new locality (D. Metusala, pers. obs.). Similarly, in the early 1990s almost all individuals of *Grammangis spectabilis* Bosser & Morat were collected from 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. Although chikanda was traditionally used at a household-scale and in times of famine, 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 and in supermarkets and is advertised on the menus of upscale bars and restaurants (Davenport & Ndangalasi, 2003; Bingham, 2009). To accommodate the increased demand for chikanda, tubers are now also imported from surrounding countries. In 2003, 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). Trade in orchids for chikanda is thought to threaten up to 85 species in Tanzania (Davenport & Ndangalasi, 2003) and Zambia (Bingham & Kokwe, 2001; Golding, 2002). The intensive over-exploitation threat contributed 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 importing 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; trade in several of the orchid species used for salep is reportedly having an impact on populations in different countries. Collection in Turkey has been estimated to involve tubers from 30-120 million orchid plants annually, producing > 15 tonnes of salep (Kreutz, 2002; Sezik, 2002). Earlier estimates for Turkey by Read & Groves (1994 cited in Kasparek & Grimm, 1999) and Kasparek & Grimm (1999) put the figure at 10-20 million and 9.8-19.6 million, respectively. More recent estimates suggest that 80 tonnes of orchid tubers are collected annually in Turkey (Kızılkaya pers. comm. to Hattam, 2013). The depletion of resources in Turkey has reportedly caused traders to look abroad and has fuelled an orchid harvesting boom in neighbouring Iran, where 5.5-11.0 million orchids are harvested annually, mainly for export to Turkey (Ghorbani *et al.*, 2014). Kreziou *et al*. (2016) also reported a renewed interest from Greece in salep as a natural product.

Similarly, *Jumellea fragrans* is now extremely rare in Mauritius, potentially due to collection for faham (D. Roberts pers. obs.).

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* Lindl. 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 there is widespread concern in the related literature about the conservation impacts of medicinal harvest across India, Nepal and Bangladesh (e.g. Hossain, 2009; Subedi *et al.*, 2013; Pant & Raskoti, 2016; Khajuria *et al.*, 2017). Increased demand for orchid-containing TCM is reportedly unsustainable in China and this has driven sourcing for some orchids (e.g. *Dendrobium* spp.) to neighbouring countries, including Lao PDR, Myanmar, Nepal, and Vietnam (Zhang *et al.*, 2008; Lamxay, 2009; Subedi *et al.*, 2013; Liu *et al.*, 2014; Phelps, 2015; Pant *et al.*, 2016).

Unsustainable harvest pressure on wild orchid populations can be the result of 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.*, 2014), chikanda (Veldman *et al.*, 2014), ornamental species (Phelps & 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 (Hinsley *et al.*, 2016c). In many cases, this appears to be an issue of non-enforcement of environmental and CITES legislation, such as at the open cross-border trade and public plant markets in many parts of Southeast Asia (Phelps & Webb, 2015). In other cases, it involves smuggling, as at the Iran-Iraq and Iran-Turkey borders where salep passes in bags labelled as almonds (A. Ghorbani & H. de Boer, pers. obs.). At the Tanzania-Zambia border, border guards report that no chikanda passes the border, whereas traders report that they transport chikanda tubers marked as potatoes in 100-150 kg bags (S. Veldman & H. 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; S. Gale, L. Gardiner, A. Hinsley, J. Phelps & D. Roberts pers. obs.).

SHIFTING TRADE AND CONSUMER PATTERNS

Substitutions and adulteration of orchid products

In 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 in 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, many *Dendrobium* spp. are often used as adulterants in 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 cilicicum*; 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 onto 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 & 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 geographical 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 et al., 2015) and online trade is used by some sellers to bypass CITES regulations (Hinsley *et al.*, 2016c). To recognise this threat, CITES has multiple Decisions urging Parties to assess the extent and trends in wildlife e-commerce (CITES, 2017b).

Consumer preferences for wild plants

Efforts to reduce unsustainable and/or illegal wild-harvest of orchids have often prompted efforts to cultivate (artificially 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 & Valencia-Diaz, 2007; Phelps & Webb, 2015). This can be linked to the

desire to collect and be the first to own new or unusual species and varieties (cf. Hall *et al.*, 2008; Hinsley et al., 2015;) and 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 by which 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, in which wild-harvested treatments are viewed as more effective (Liu *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 to produce 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).

TAXONOMIC COMPLEXITY

Species identification

Orchidaceae are one of the largest family of angiosperms (Chase *et al*., 2015), with a taxonomy based heavily on floral characteristics (and reflected in genetic relationships), meaning that accurate species identification requires training and is challenging for sterile material. This is further limited by the lack of complete and up-to-date taxonomic reference material and literature in many countries and genera and is further aggravated by the tendency by some authors towards over-description of species in the family - with motivating factors including the charisma, enthusiasm and vested financial interests that often accompany orchid work (Pillon & Chase,

2007). Taxonomic challenges are compounded in the case of products that contain orchids, in which constituent parts may be processed by drying and curing, making species identification based on plant morphology practically impossible.

These identification 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 identify many orchids confidently to species or subgenus level when presented with sterile specimens (e.g. Phelps & Webb, 2015). Strengthening the capacity of customs officers to enforce CITES correctly is a priority for the Convention, highlighted in Decision 17.34 (CITES, 2017c). 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 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). Techniques include Sanger sequencing-based DNA 'barcoding' techniques, which for plants typically compare two or more 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 an herbarium for future re-verification; Hollingsworth *et al.*, 2009). They also include so-called 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 in processed medicinal products (e.g. Lau *et al.*, 2001; Yao *et al.*, 2009; Wu *et al.*, 2009) and, most recently, to identify species in 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 and both include large numbers of DNA sequences of Orchidaceae; however such databases often include many taxa that are not vouchered. Since these identifications cannot be reliably verified, the sequences 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 in 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. Although 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 intraspecific variation (Phelps, 2015; Guo *et al.*, 2016); however, extended reference databases may address this (Veldman *et al.*, 2017). In addition, it is likely that hybridization, cross-pollination, and wide-ranging and therefore genetically diverse species can reduce the accuracy of identifications based on limited reference samples. Further, many orchid species may be virtually identical when standard DNA barcoding regions are compared, even though they may be morphologically different (as the result of rapid evolution of different floral traits, often due to 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). Despite recent efforts to increase the number of orchids assessed (IUCN, 2014; Fay, 2014), 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 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 in certain countries (e.g. China

and Madagascar: Fig. 3) and in a small number of charismatic genera (e.g. the slipper orchids, subfamily Cypripedioideae) and by the efforts of the Sampled Red List Index of Plants project (Brummitt & 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 by CITES scientific authorities to conduct the necessary non-detriment findings (NDFs) to ensure that international trade in Appendix II listed species is not having a negative impact on wild populations, and should be legally permitted.

The lack of global conservation assessments for orchids reflects profound gaps in the ecological knowledge about orchids and challenges of studying the family. 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 & 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. species of *Sobralia* Ruiz & Pav.), short blooming seasons and/or epiphytic growth habits that make them physically hard to access; in addition, there is a need to consider horizontal and vertical distributions for epiphytic species (Mondragón, 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 as a result taxa such as plants have been largely overlooked by conservation organisations, government agencies and the public (Phelps & 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. elephant ivory, van Aarde & Ferrera, 2009; rosewood, Barrett *et al.*, 2010), there is not the similar public support to address illegal trade in non-timber 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 high-profile wildlife products such as ivory and rhino horn. This bias is manifest in several ways; for example, the ASEAN Wildlife Enforcement Network focuses only on fauna, the UK Department for International Development fund to address illegal wildlife trade (IWT Challenge Fund) excludes funding for botanical trade and conservation (DEFRA, 2017) and enforcement and education efforts to reduce illegal wildlife trade at the Chatuchak Market in Bangkok 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 commercial and scientific purposes. This can include restrictions on transport of CITES-listed orchids,

which in many countries, require extensive permitting, are slow and involve high economic costs.

These may represent undue burdens on commercial and hobbyist traders who seek to comply with the law (Hinsley *et al.*, 2016c) and may also limit the exchange and movement of scientific samples needed for taxonomic and conservation research, such as plants, seeds, dried/pickled specimens and DNA (Roberts & Solow, 2008). CITES allows the international, non-commercial loan, donation or exchange of museum and herbarium specimens (Article VII Exemptions and Other Special Provisions Relating to Trade, paragraph 6 and CITES Res. Conf. 11.15, Rev. CoP12), between Registered Scientific Institutions (RSIs, see https://cites.org/common/reg/e_si.html for a list of RSIs by country), and some in-country CITES authorities grant fee waivers for movement of orchid specimens and plants for scientific and conservation reasons (e.g. https://www.gov.uk/government/publications/endangered-species-application-for-a-waiver-from-paying-permit-fees). However, many countries that are Parties to CITES do not have any RSIs and, even where they exist, authorities are often unfamiliar with the processes or unaware of the exemptions, meaning that costly and time-intensive CITES permits are sometimes still required. Bureaucratic processes in many countries mean that the process regularly takes 2-3 months, and often substantially longer, delaying conservation research, and potentially endangering plant material, including of live plants of new species (Roberts & Solow, 2008).

These burdens limit science and legal trade and potentially create incentives for illegal action, by hobbyists, commercial traders and even scientists eager to move specimens between countries. Further, 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 IN THE GLOBAL ORCHID TRADE

Future priorities for the conservation of orchids in trade must consider the diversity of orchid products, markets and specific conservation challenges facing practitioners and policy makers attempting to tackle illegal and unsustainable trade. Although 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. Although some work has been done to document the use of orchid derivatives in key cosmetic and medicinal products (Brinkmann 2014), little published information exists, particularly on the species involved, where the plants originate and whether they are wild-collected or nursery-grown. For the trade in orchids for fragrances, flower extracts and cosmetic products this is, in part, due to industry confidentiality issues (Groves & Rutherford, 2017). 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 prioritize 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 which species are actually being targeted.

Moreover, there is a need to understand how different commercial trades impact wild populations and species survival. Little attention has been paid to assessments of the impact of harvesting and population viability analyses, particularly in tropical and subtropical regions of greatest orchid diversity. These data are, however, instrumental to assessing the impact of trade on the conservation status of species (e.g. during Red Listing), understanding how commercial harvest affects populations and 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 orchids, species that are known to be facing intense harvest pressures should be priorities for such research.

REDUCE ILLEGAL TRADE AND CITES NON-COMPLIANCE

International 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 operationalized, with cases of non-compliance being largely overlooked. Moreover, orchids are under-represented on the contemporary CITES agendas (e.g. CITES 17th Conference of Parties https://cites.org/eng/cop/index.php). Although there is considerable attention on trade in many species of megafauna, there is apparently comparatively little awareness or concern among the CITES community

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 ensuring Parties are aware of and prioritize 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 in wild plants 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, as shown by the official reported trade statistics in Figure 2. This contributes to a lack of awareness of the scale of orchid trade and 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.

STRENGTHEN AND SUPPORT LEGAL TRADE

Although it may be possible to facilitate legal sustainable trade in some wild Appendix II orchid species, propagation has been widely proposed as a better conservation strategy (Subedi *et al.*, 2013; Liu *et al.*, 2014). 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 and newly discovered species for which 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 trade in artificially propagated plants is the opportunity it presents for wild-collected material to be laundered into the legal trade chain (Phelps, 2015), meaning that strong traceability methods are required to confirm the provenance of propagated plants. Customs agents checking shipments are unlikely to have specialist knowledge on plants and identifying the origin of traded orchids using visual inspection may be difficult for live orchid plants and impossible for processed derivatives (McGough *et al.*, 2006). This process may be improved by using more sophisticated traceability techniques for determining wild origin. The need for a more coordinated traceability approach for orchids and other horticultural plants was recognized at the 17th CITES Conference of the Parties in 2016, with suggestions to create international frameworks for standardizing traceability of these products

(UNCTAD, 2016). Traceability can involve physically marking plants, for example with microdots (as trialled in South African cycads: Nordling, 2014), or it can draw on molecular techniques discussed above. Another option is 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 (Nordling, 2014; 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. Implementing robust traceability systems could also underpin other conservation action, such as the development of certification schemes for sustainably produced orchids, a model that is already applied to certain plant products in the medicinal and aromatic trade via the FairWild standard (http://www.fairwild.org).

RAISE THE PROFILE OF ORCHID CONSERVATION

Orchids are unique for their charisma, prominent place in popular culture and wide following among horticulturalists (Hansen, 2001). However, efforts to address unsustainable and illegal trade are hampered by a lack of awareness of the importance of this work, and the low profile of orchid conservation relative to that of other taxonomic groups. This is recognized in CITES itself, which specifically mentions the importance of working with trade organisations, NGOs and botanic gardens to educate people on the importance of legal trade and the implementation of the Convention for plants [Res. Conf. 11.11 (Rev. CoP17)]. However, whilst local-scale awareness raising of orchid conservation has taken place in some areas where they are wild-collected (e.g. Nepal: Pant *et al.*, 2016), two groups that have been

difficult to engage have been the international traders and end-users of orchids, particularly in the horticultural trade (Hinsley *et al.*, 2016c). Members of the horticultural community are often aware of commercial demand for rare and protected species, with some actively seeking to buy rare species (Hinsley *et al.*, 2015). This puts them in a unique position to help to identify emerging conservation issues, including species that are being targeted for trade from the wild. Engaging this community more deeply in conservation efforts has the potential to establish new codes of practice that condemn, rather than reward, collecting practices that threaten species conservation. We therefore suggest that communities of horticultural orchid hobbyists represent a large, influential community with clear potential to help raise the profile of orchid conservation. Orchid societies globally could serve to raise issues of orchid legislation, overlooked issues of trade in edible and medicinal trade and illegal orchid trade of ornamental plants.

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 (e.g. Angraecoid Alliance: www.angraecoids.org). Many societies also work to promote conservation education via public orchid shows, but the related opportunities remain under-realised in many societies, especially in the range countries of some of the popular species in trade. Experience with other taxa has demonstrated the benefits of generating public support to motivate policy makers, donors and civil society groups to engage with previously unrecognized conservation issues (e.g. pangolins: Challender *et al.*, 2017). One barrier to this may be the fact that 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). We suggest that addressing the lack of engagement between traders, growers and policy makers to improve dialogue between these groups is a priority for tackling non-compliance and strengthening legal trade.

CONCLUSIONS

Despite appearing to be, at least on paper, one of the most legally protected groups of organisms, many orchid species around the world are under threat from illegal and unsustainable trade for many purposes, primarily for horticulture, food and medicine. In addition to habitat preservation, a conservation priority for orchids should be to better understand trade, and to address its threats. This should take the form of conducting basic research on trade dynamics and impacts of harvest, addressing illegal trade and CITES non-compliance, strengthening and supporting legal trade, and raising the profile of orchid trade as an important conservation issue - worthy of wider attention and conservation efforts.

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Figure Legends

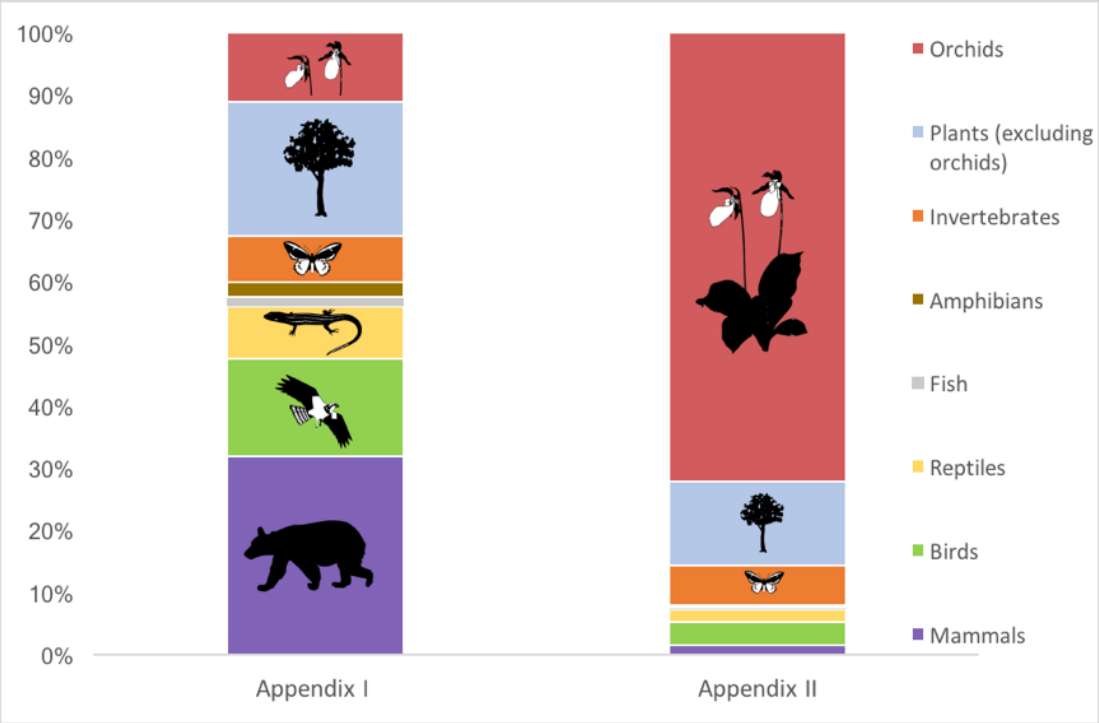

Figure 1. Taxonomic breakdown of CITES Appendices I and II, showing the large proportion of orchids in the total number of species listed by the Convention. Adapted from original in Hinsley (2016) using updated data from UNEP-WCMC (2015). Vector images courtesy of the Integration and Application Network,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

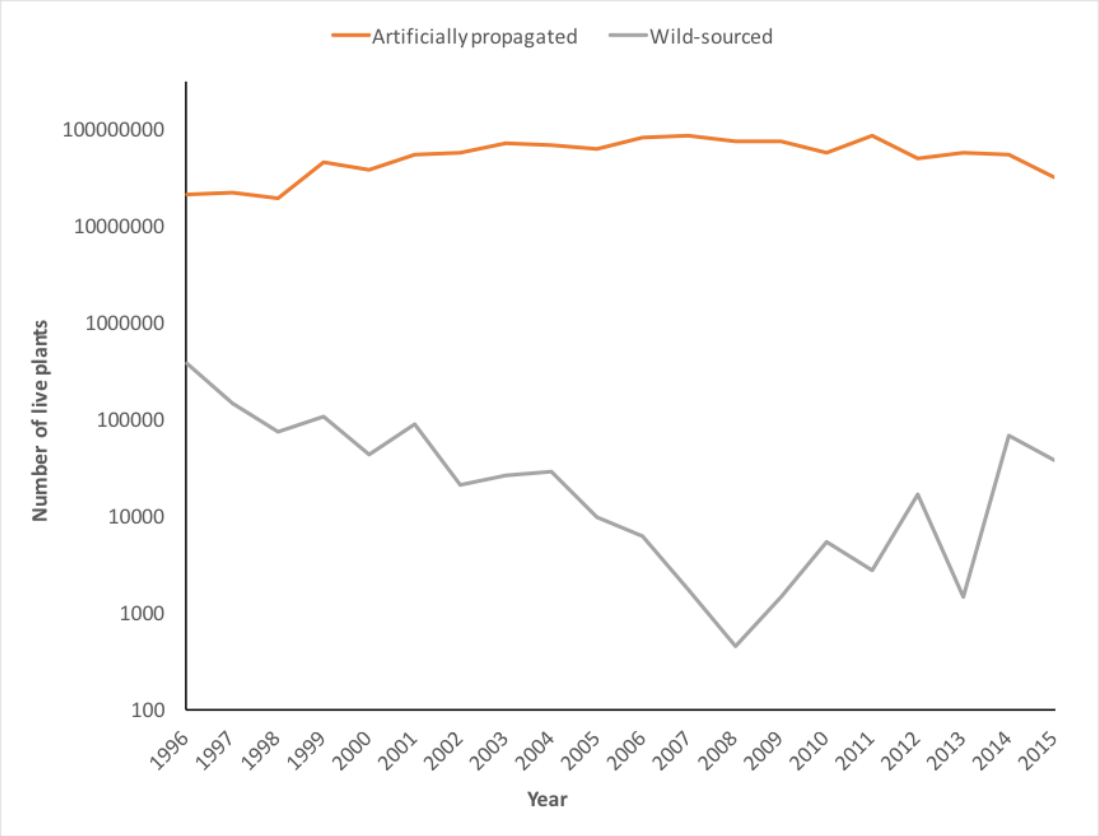

Figure 2. Reported commercial trade in live artificially propagated and wild-sourced orchid plants between 1996 and 2015, as reported by importers. 'Wild-sourced' is defined as trade reported as source W, U and no source; 'Artificially propagated' is defined as trade reported under the source codes for plants (A, D) and captive-bred animals (C, F), the latter to capture low levels of misreported data. Data: CITES trade statistics derived from the CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK https://trade.cites.org, downloaded May 2017.

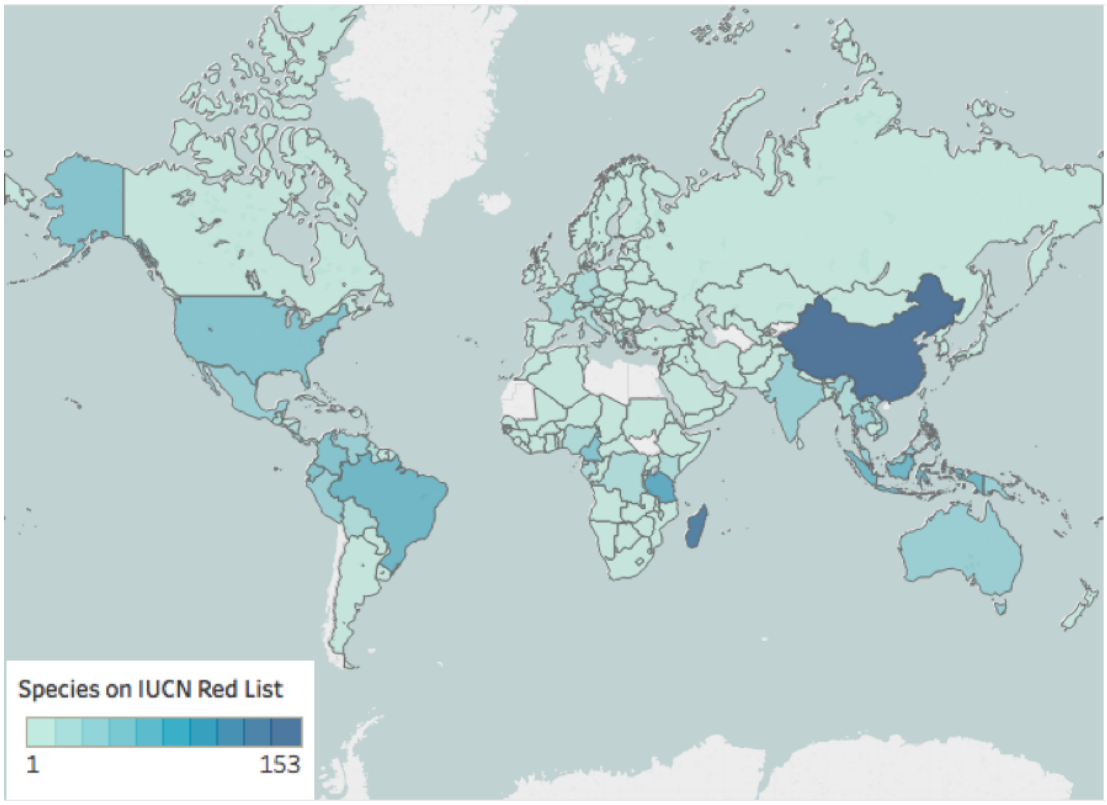

Figure 3. Number of native orchid taxa in each country currently assessed for the IUCN Red List (Data: IUCN, 2017; downloaded March 2017)

Tables

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	*Aerangis ellisii* (B.S.Williams) Schltr. *Dendrobium cruentum* Rchb.f. *Laelia jongheana* Rchb.f. [=*Cattleya jongheana* (Rchb.f.) Van de Berg] *Laelia lobata* (Lindl.) A.H.Kent (=*Cattleya lobata* Lindl.) *Peristeria elata* Hook. *Renanthera imschootiana* Rolfe *Paphiopedilum* spp. *Phragmipedium* spp.	● An import permit issued by the Management Authority (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 Scientific Authority (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 Appendix II	All other species in the family Orchidaceae	● 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.

[a] Summary of CITES regulations as presented in Clemente-Munoz (2009)

Table 2. Summary of commercial orchid trade reported to CITES in 1996-2015, including all trade reported by weight and number of items as reported by importers (exporter-reported trade included in parentheses where this was higher). 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 source codes for plants (A, D) and captive-bred animals (C, F), the latter to capture low levels of misreported data. Data: CITES trade statistics derived from the CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK https://trade.cites.org, downloaded March 2017.

Product	**Artificially propagated trade**		**Wild trade**	
	Reported in number of items	Reported by weight (kg)	Reported in number of items	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 (E: 1178)	677,842
Cultures[1]	1,842,969 (E: 4,937,676)	-	1,200 (E: 92)	
Seeds	912,542	(E: 1)	-	-
Dried Plants	730,015	7,440,721	13,700	157500 (E: 177,436)
Derivatives[2]	230,138 (E: 7,060,030)	1,130,050	418	8,056
Flowers	47,842 (E: 70,963)	306 (E: 3000)	351 (E:1095)	-
Stems	-	31,415,634	-	- (E: 1665)
Specimens	105 (E:419)	-	664	-
Leaves	66 (E: 71,650)	1,180	- (E: 5)	-

[1] Combined figures for all trade in cultures and trade reported as live plants with the unit 'flasks', as a 'culture' is likely to refer to a sterile flask containing multiple seedlings; [2]Combined figures for trade reported as derivatives, extract, medicine and powder.

Table 3. Top ten 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 artificially propagated plants (A, D) and captive-bred animals (C, F) were used, the latter to capture low levels of misreported data. Data: CITES trade statistics derived from the CITES Trade Database, UNEP World Conservation Monitoring Centre, Cambridge, UK https://trade.cites.org, downloaded May 2017.

Rank	**1996-2005** (Total number live plants: 459,857,389)		**2006-2015** (Total number live plants: 659,817,913)	
	Reported Taxa	**Number live plants** (% total)	**Reported Taxa**	**Number live plants** (% total)
1	Orchidaceae species	165,962,470 (36.1%)	Orchidaceae hybrids	189,447,122 (28.7%)
2	Orchidaceae hybrids	123,939,767 (27.0%)	*Cymbidium* spp.	177,536,225 (26.9%)
3	*Dendrobium* spp.	92,482,163 (20.1%)	Orchidaceae species	124,907,316 (18.9%)
4	*Phalaenopsis* spp.	31,572,618 (6.9%)	*Phalaenopsis* hybrids	66,683,709 (10.1%)
5	Species of *Cymbidium* Sw.	24,672,878 (5.4%)	*Phalaenopsis* spp.	28,954,444 (4.4%)
6	Species of *Oncidium* Sw.	7,077,873 (1.5%)	*Dendrobium* spp.	22,692,242 (3.4%)
7	*Phalaenopsis amabilis* (L.) Blume	4,769,951 (1.0%)	*Cymbidium* hybrids	21,813,621 (3.3%)
8	*Cattleya* spp.	2,375,391 (0.5%)	*Dendrobium* hybrids	15,134,974 (2.3%)
9	*Cymbidium kanran* Makino	1,478,658 (0.3%)	*Cattleya* spp.	2,276,462 (0.4%)
10	Species of *Vanda* R.Br.	1,130,662 (0.3%)	*Oncidium* spp.	1,489,956 (0.2%)