Quantifying the trade in wild-collected ornamental orchids in South China: diversity, volume and value gradients underscore the primacy of supply

Abstract

Despite the grave threat illegal wildlife trade poses to species survival, few studies have attempted to link supply and demand data for the same wildlife product. All ca. 29,000 orchid species are listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and many are protected under domestic legislation too, but a growing body of evidence suggests that orchids continue to be subject to unsustainable harvesting and undocumented trade. South China is a known black spot for trade in wild-collected ornamental orchids but understanding of the drivers determining the flow of species diversity, volume and value remains wanting. We conducted systematic monthly surveys at five markets along a West-East transect from Yunnan to Hong Kong for one year, recording variables including species, numbers of individuals, weight and price. Although wild orchid diversity is highest in Yunnan, the diversity of orchids in trade increased eastwards and mean price per stem rose more than four-fold, albeit always significantly cheaper than that for artificially produced hybrids. Part of this trade appears to be in breach of CITES. Few orchids in trade conformed to six criteria highlighted in prior demand-side studies as being of higher utility value, but most conformed to a combination of four or more, suggesting that vendors can readily offer products that meet a majority of consumer preferences. Effective supply-side regulation, through government intervention and social media campaigns, is needed to facilitate behavioural change and allow artificially propagated plants to compete in the market-place.

Keywords CITES, Consumer preferences, Factor Analysis of Mixed Data (FAMD), Illegal wildlife trade, Market surveys, Supply-side regulation.

1 Introduction

Illegal wildlife trade poses a grave threat to species survival (Challender et al., 2015) for which regulation is implemented through both national legislation and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). However, monitoring of domestic markets is often absent and the bans (for Appendix I species) and controls (for Appendix II and III species) imposed by CITES on cross-border trade are frequently bypassed through laundering, counterfeiting and corruption (Lyons & Natusch, 2011; Underwood et al., 2013; UNODC, 2016). This has led to the development of non-enforcement measures, including farming/cultivation of exploited species (Bulte & Damania, 2005), market reduction methods (Schneider, 2008) and strategies for changing consumer behaviour (Truong et al., 2015). In reality, however, little is known about what drives most wildlife markets or how effective such interventions are in reducing unsustainable harvesting. Few studies have attempted to link supply and demand data for the same wildlife product, meaning that interventions are often implemented with limited understanding of supply-demand dynamics.

Gauging which species are being traded where and in what numbers relative to the size, occurrence and regenerative capacity of remaining wild populations is vital in order to infer the impact of exploitation and establish the urgency of protective measures. The CITES non-detriment finding process acknowledges this by facilitating the export of a wild-sourced Appendix II species only where the transaction is deemed to fall within sustainable harvest levels (Challender et al., 2015). However, data of this sort are almost invariably lacking (Phelps et al., 2010). The consequences of this knowledge gap are likely to be acute where trade is a factor determining a species' threatened status. For example, of the 979 orchid species that have so far been assessed against Red List Criteria (IUCN, 2018), 554 (57%) are threatened with extinction (i.e. VU, EN or CR) and for 263 (47%) of these harvest for trade is a major cause.

Orchids are traded as ornamental plants, medicinal products, cosmeceuticals and food (Hinsley et al., 2018). Because of the difficulty in distinguishing high-value species that are vulnerable to exploitation from other less threatened ones, all ca. 29,000 species are listed by CITES, mostly under Appendix II but with a subset of six species and all members of the genera *Paphiopedilum* and *Phragmipedium* placed in Appendix I (CITES, 2018). Official statistics suggest that the bulk of international orchid trade involves artificially propagated plants, with declared trade in wild-sourced plants amounting to less than 0.1% of the >1.1 billion live plants traded during 1996–2015 (Hinsley et al., 2018). However, a growing number of studies reveal that the volume of illegal, undeclared trade in wild-sourced plants in fact far outstrips this legal component (Davenport & Ngangalasi, 2003; Phelps & Webb, 2015). For example, tubers from an estimated 7–11 million wild-collected terrestrial orchids were illegally exported from Iran to Turkey in 2013 alone to meet demand for *salep*, a polysaccharide-rich ingredient used to make drinks and ice cream (Ghorbani et al., 2014).

Despite horticulture constituting the family's most universal use, data on the scale of wild-collected ornamental orchid trade remain scarce (Phelps, 2015; Hinsley et al., 2018). Whilst there is evidence to suggest that trade increasingly takes place via the internet (Hinsley et al., 2016), roadside sales of wild-collected plants remain commonplace in biodiversity-rich developing countries where traders lack access to online markets or the means to maintain plants in cultivation (Koopowitz et al., 2003). Local harvesting and small-scale trade has been documented in Mexico (Flores-Palacios & Valencia-Diaz, 2007; Cruz-Garcia et al., 2015) and Cambodia (Hinsley, 2011), revealing individual motivations for involvement in the supply chain. In contrast, Subedi et al. (2013) quantified large-scale illicit export of orchids from Nepal to China and India, and Phelps & Webb (2015) uncovered nationwide trafficking of plants across Thailand's borders with Cambodia, Laos and Myanmar. These studies provide evidence of extensive violations of both domestic law and CITES, and for the commodification of at least 592 species for horticultural trade. However, understanding of the drivers that determine the flow of species diversity, volume and value from source to sink remains wanting (IUCN SSC Orchid Specialist Group Global Trade Programme, 2017).

Orchids are prized for their showy flowers, elegant habit and attractive leaves (IUCN/SSC Orchid Specialist Group, 1996; Nash et al., 2003). Among hobby growers, individual plants can fetch several thousand US dollars (Yokoi & Milliken, 1991), driving a black market in rare or newly discovered species (Thomas, 2006; Hinsley et al., 2015; Phelps, 2015). Charismatic species in sought-after genera have been collected to extinction within a few years of description as a result (e.g. Cribb, 2005; Averyanov et al., 2014). Ornamental orchid consumers surveyed in Asia expressed a preference for plants with multiple, fragrant, white flowers, and for those that were rare in the wild and in trade (Hinsley et al., 2015; Williams et al., 2018). Although consumers appear to lack awareness of the legal protections that restrict orchid trade, there was no evidence of demand for wild-collected plants over artificially propagated ones (Williams et al., 2018). Rather, consumers preferred cheaper plants regardless of source (Hinsley et al., 2015; Williams et al., 2018).

China is Asia's largest consumer of illegally sourced wildlife (World Bank, 2005) and the country's southern border with Myanmar, Laos and Vietnam is a known black spot for wild orchid trade (Shepherd et al., 2007; Lamxay, 2009; Kurzweil & Lwin, 2014). The wider Indo-Burma region is a biodiversity hotspot with a greater concentration of CITES Appendix I-listed orchids (namely, *Dendrobium cruentum*, *Renanthera imschootiana* plus 35 *Paphiopedilum* species) than any other, highlighting it as a priority for both trans-border and domestic trade regulation (Liu et al., 2015; Li et al., 2018). However, legal protection of wild plants in Mainland China remains weak compared to that for animals (McBeath & McBeath, 2006) and no orchids are protected by law (State Council of China, 1999). For CITES purposes, the China-Hong Kong boundary functions as an international border, and the possession and sale of native orchids is restricted under Hong Kong law (Department of Justice, 2018).

Despite its inferred role as major source and sink for illegally traded plants, China's wild ornamental orchid trade has never been investigated. In part this may be attributed to the prominence of the wild animal trade (e.g. Zhang et al., 2008), as well as to the difficulty in identifying orchids and estimating plant numbers (Phelps & Webb, 2015). Despite these challenges, clarifying basic trade parameters is vital to bolster species conservation via improved monitoring, regulation and enforcement (UNODC, 2016), as well as to help shape market-based instruments for mitigation (Phelps et al., 2010; Liu et al., 2019). Here we examine how diversity, volume and value gradients drive trade across South China, allowing us to assess the degree to which supply at points-of-sale reflects stated consumer preferences and therefore the extent to which supply- as opposed to demand-side measures are likely to be effective in reducing wild orchid trade in the region.

2 Materials and Methods

2.1 Ethics statement

The methods used were approved by KFBG's Nature Conservation Forum and Bangor University Ethics Committee prior to commencing the research.

2.2 Study sites

Our study focused on the tropical south of Yunnan, Guangxi and Guangdong Provinces, plus the Special Administrative Region of Hong Kong, which account for the bulk of the Chinese portion of the Indo-Burma Biodiversity Hotspot (Fig. 1). Consultation with local botanists and preliminary field visits revealed nine markets in the region that trade wild-collected plants, of which five were selected for investigation, taking into account their geographic and commercial characteristics (Table 1). Orchid diversity in South China exhibits a West–East gradient, with species richness declining eastwards from Yunnan Province towards the coast (Zhang et al., 2015). To place the wild orchid trade in a biogeographic context, we compiled lists of orchid species known to occur naturally in the vicinity of each market site at the province- (in the case of Yunnan, Guangxi and Guangdong) and territory- (in the case of Hong Kong) level using the treatments of Chen et al. (2009), Barretto et al. (2011), Gale et al. (2014) and Zhou et al. (2016).

2.3 Market surveys and data management

The markets were surveyed on single days either once (in June) in the case of Jingxi (hereafter JX), or monthly in the case of Banna (BN), Lingnan (LN), Foshan (FS) and Mong Kok (MK) during the 12-month period June 2015 to May 2016. The surveys were conducted by four of the authors (SG, PK, JG and ZLL), who collectively have >60 years' experience researching the taxonomy of tropical Asian orchids, together with local assistants. As far as possible, each market was visited on the same day of the week and at the same time of day on each occasion. During the first visit to all markets except JX, a sketch map was prepared to record the location of each stall/outlet to facilitate cross-referencing from month to month, with additional stalls/outlets added as they appeared. On each visit, we counted the total number of stalls/outlets selling whole ornamental plants (excluding cut flowers) as well as the number selling orchids (whether artificially propagated or wild-sourced). For each stall/outlet selling evidently wild-sourced orchids (see below), we estimated the proportion of floor/shelf space dedicated to wild orchids (bracketed as 1–5%, 6–25%, 26–50%, 51–75% or 76–100%). To gauge the relative value of wild orchids, we also recorded the price of three or more randomly selected potted, single-stem *Phalaenopsis* hybrids on sale at (or close to) each market on each visit; this was not possible at JX, at which only wild-collected plants were available.

Plants were determined as being of wild origin based on one or a combination of the following (CITES Secretariat, 2002; Phelps & Webb, 2015): random mixtures of species, sizes, conditions and age classes; species not known in cultivation; plants growing on severed branches of forest trees; plants presented loose or in sacks and sold by weight; roots bare, bearing mosses and lichens or with pieces of bark attached; roots with evidence of damage caused by removal from original substrate; roots wrapped in wild moss; leaves with signs of herbivory or water stress, or bearing mosses and lichens. Stalls/outlets selling wild-collected orchids were inspected in turn, and for each product we recorded species name, whether flowering or not, presentation (attached to original branch from forest, bare-rooted and loose, bare-rooted and tied in bundles, mounted on wooden boards, or potted), whether sold by unit weight or unit number, an estimate of the total weight (in Kg, for products sold bare-rooted) or number of items (for products mounted on boards, attached to branches, tied in bundles or potted), the number of individuals per unit and the price.

Species were identified by checking for diagnostic characters and named following standard nomenclature (Govaerts et al., 2018). We were able to determine to genus level in all cases, and for plants belonging to the species-rich genera *Bulbophyllum* and *Dendrobium* we were sometimes able to determine to sectional level. For unfamiliar species, we asked the vendor to tell us the local name in Chinese, show us a photo they had taken of the plant in flower, or to point to the species in a guidebook which they sometimes kept to hand; we then verified the name by confirming details of the plant. Failing that, we photographed the plant for later consultation of the regional floras cited above and other reference works as necessary (e.g. Wood, 2006; Xu et al., 2010). Where we were altogether unable to assign a species name, we recorded the plant as "sp.", followed by a number to distinguish it from other unidentified species of the same genus; as far as possible, this number was applied to the same unidentified 'operational taxonomic unit' (OTU) if we encountered it elsewhere. *Eria* was interpreted in the broad sense for placement of unknown species because of the difficulty in differentiating segregate genera when not in flower (Ng et al., 2018).

If a vendor presented the same species for sale in more than one way (e.g. mounted on wood and tied in bundles), we recorded data pertaining to each product separately. The same applied for species presented in the same way but priced differently because, for example, they varied in size or physical condition. Thus, for the purposes of this study, a ‘product’ was defined as all units (weight or number of items) of a single species presented for sale in the same way for the same price by a single vendor. The total weight of a product was estimated by directly weighing a defined subset (e.g. one bundle or one plant) and multiplying by the total number of units (e.g. all bundles or all plants) of approximately the same size as determined by visual assessment; this method was therefore referred to as a ‘visual estimate’. The number of individuals was counted as all pseudobulbs/shoots/stems (hereafter, PSS) per unit item, bracketed as 1, 2–5, 6–10 or >10 to expedite counting. To scale up from number of individuals per item to total number per product, these number classes were later transformed into median values if <10 (i.e. 1=1, 2–5=3.5, 6–10=8) or into a mean value derived from counts of the actual number of PSS in a minimum of three replicates per species if >10; for unidentified species, we used the mean value for all named species in that genus (Table S1).

To facilitate conversion between weights and numbers of individual PSS, we derived a mean weight (in Kg) per PSS (±SE) for virtually all species encountered by weighing a minimum of three bare-rooted plants and counting the number of PSS present in each; for unidentified species, we used the mean value for all named species in that genus (Table S2). To verify the robustness of these conversion factors, we compared our visual estimate of total product weight against a calculated estimate derived by multiplying the calculated number of PSS per product by mean individual PSS weight, for a random selection of 50 products representing 36 species at FS and

LN. Regression analysis revealed the two sets of values to be strongly correlated and scale almost to 1 (Fig. S1).

Because prices were generally not displayed except occasionally at MK, we had to ask vendors for prices one by one. This irritated some vendors and so we were unable to obtain prices in all cases. Prices were recorded in the local currency (RMB or HKD) and later converted into USD for comparison; an exchange rate for either currency was calculated by taking the mean USD rate on the 15th day of each month for the 12 months of our study, using the website www.xe.com/currency tables/.

To identify potential CITES violations, we downloaded official trade statistics for China and Hong Kong for the years 2015 and 2016 using the search terms 'Orchidaceae' for family, 'China' or 'Hong Kong' for importer, 'live' or 'stems' for term, plus all possible sources and purposes as well as both exporter- and importer-reported quantities, from the CITES Trade Database (CITES, UNEP-WCMC, 2018). Species encountered in trade in our surveys but not native to China or Hong Kong, or claimed by the vendor to have been sourced from other countries, were checked against these official import data to identify discrepancies in taxon, quantity or source.

2.4 Statistical analyses

We used first-order jackknife richness estimation to assess completeness of sampling at each market individually and for all five markets in combination. Each stall/outlet was scored each month for presence/absence of all species identified over the entire survey period, with randomised resampling without replacement conducted 1000 times in EstimateS 9.1.0 (Colwell, 2013) to estimate total expected diversity. Percentage similarity in species diversity among market and wild sites was calculated using the species lists compiled from the surveys and the regional floras cited above. Prevalence in trade was expressed as total cumulative sightings per species over 12 months. Cumulative totals of mean number of PSS and mean weight per species were regarded as approximations as it was not possible to determine what proportion of stock, if any, had been carried over from the previous visit. Mean price per PSS was calculated for each species separately and for all species together at each market in turn, as well as across all markets in combination, in SPSS ver. 25 (IBM Corp.). Significance in price variation among markets was tested using single-factor ANOVA and a Tukey-Kramer post-hoc range test.

The significance of the relationship between price and a set of three product attributes observed during the surveys (flowering/non-flowering, whether sold by weight or number and presentation) was tested by calculating mean price per PSS for all species at all markets together and at each market separately using ANOVA and a Tukey-Kramer post-hoc test. For presentation, we also grouped the crudest, 'unmodified' methods (attached to original branch from forest, bare-rooted and loose or bare-rooted and tied in bundles) and the more resource-demanding, 'modified' methods (mounted on wooden boards or potted) into two categories to assess whether mounting or potting plants results in significant added value.

To examine the effect of other potentially desirable traits on market value, we compiled the following data for 130 named species encountered in trade for which complete data were available (Table S3): inflorescence size (single- or multi-flowered), flower colour (purple/red, pink, yellow/orange, green or white) and floral scent (unscented/unpleasantly scented or fragrant), inferred from plants encountered in the field and from descriptions given in the floras cited above; conservation status (LC, NT, VU, EN or CR), derived from the most recent China Red List (Ministry of Ecology and Environment of the People's Republic of China and the Chinese Academy of Sciences, 2018) and the global Red List (IUCN, 2018), with the higher level of threat of the two being used for species that appear in both; and prevalence in trade, in terms of total cumulative sightings (log10-transformed to obtain normality) per species across all markets over the full survey period. These traits were chosen because they were used in two previous studies (Hinsley et al., 2015; Williams et al., 2018) to explicitly test preferences among ornamental orchid consumers in East Asia, including at two of the market sites visited in the present study (BN and MK). The relationship between these variables and mean individual price (log10-transformed to obtain normality) for each species across all markets together was tested through multiple regression, using the lm() function in R (R Core Team, 2018).

Finally, in order to address the null hypothesis that total diversity of species in trade (a proxy for supply) does not reflect stated consumer preferences (a proxy for demand), we conducted Factor Analysis of Mixed Data (FAMD) using the package FactoMiner (Pagès, 2004) in R to analyse similarity among the 130 named species for which complete data were available, using the same five variables used in the multiple regression analysis plus mean price (Table S3). Among total point dispersion in the first two dimensions, we defined 95% confidence ellipses (Fox & Weisberg, 2011) for species that met successive combinations of the following six criteria, which received the highest utility values among consumers in Hinsley et al. (2015) and Williams et al. (2018): multi-flowered inflorescence, white-flowered, fragrant, rare in wild (i.e. with a Red List assessment of VU, EN or CR), rare in trade (i.e. cumulative sightings <26.94, the mean for all 130 species over the survey period) and cheap (i.e. mean price per PSS <US$2.28, the mean for all 130 species over the entire survey period). More data points meeting more criteria was taken as evidence of an optimised market providing more species with preferred traits.

3 Results

3.1 Scale and diversity of wild orchid trade

JX was the largest market, with 104 out of its 622 stalls/outlets (16.7%) selling wild-sourced orchids. The number of stalls/outlets varied from one visit to the next at the four daily markets, but at BN a mean (±SD) of 8.8 (±3.4) out of 20.0 (±5.7) stalls/outlets (44.0%) sold wild-collected orchids; at LN, 13.8 (±3.6) out of 344.7 (±143.0) stalls/outlets (4.0%) sold wild-collected orchids; at FS, 8.8 (±3.7) out of 61.2 (±8.6) stalls/outlets (14.4%) sold wild-collected orchids; and at MK, 5.3 (±2.1) out of 70.9 (±13.3) stalls/outlets (7.5%) sold wild-collected orchids. At stalls/outlets engaged in wild orchid trade, the proportion of floor/bench space dedicated to wild orchids was, on average, 76–100% at JX and BN, 50–75% at LN and FS, and 6–25% at MK.

We recorded a total of 5073 products, all of which were identified at least to genus level; 4812 products (94.9%) were identified as 266 named species belonging to 61 genera, with the remaining 261 products (5.1%) being assigned to 174 unnamed OTUs belonging to 25 genera, including four genera (*Chiloschista*, *Otochilus*, *Porpax*, *Tainia*) not represented by a named species. Because of their morphological similarity when not in flower, we were unable to reliably differentiate between *Dendrobium acinaciforme* and *D. spatella*, *D. densiflorum* and *D. thyrsiflorum*, and *D. jenkinsii* and *D. lindleyi*, and so data for each of these species pairs were combined. *Bulbophyllum* was the most problematic genus to identify to species level when sterile, with 62 unnamed OTUs. It is unlikely that all unnamed OTUs were distinct, but it was often not possible to match unidentified plants to the same OTU when encountered at different stalls/outlets, at different markets or on different dates. Cumulative 12-month sightings frequency for all named and unnamed taxa is shown in Fig. 2.

Species diversity was highest at FS with 180 named species plus 76 unnamed OTUs, followed by LN (158 named species plus 75 unnamed OTUs), MK (84 named species plus 20 unnamed OTUs), BN (95 species plus 8 unnamed OTUs) and JX (29 named species). Species accumulation curves indicated incomplete sampling at all markets (Fig. 3). The number of species observed was 69.6%, 70.0%, 70.9%, 72.4% and 80.6% of the total expected diversity at FS, LN, JX, MK and BN, respectively; for all markets together, the observed species total was

70.0% of that expected. Both observed and expected species diversity in trade therefore declined in the order FS > LN > MK > BN > JX.

In contrast, species lists compiled from the literature (Table S4) confirmed a decline in wild species diversity from West to East (Table 2), with Yunnan being the richest, followed by Guangxi, Guangdong and Hong Kong. In terms of composition, species in trade at all markets had greatest similarity to the wild orchid flora of Yunnan Province, with between 79.8–95.8% overlap. Percentage similarity between markets and the wild declined eastwards, with only 15.5–27.6% of traded species being native to Hong Kong.

Estimates of the total PSS and weight of wild orchids available on each survey at each market, and for all markets together, are given in Table 3. JX was the largest market in terms of both mean PSS and mean weight of wild orchids in trade per monthly survey, with the mean for the four other markets declining in the order FS > LN > BN > MK. On any one day, a mean (±SD) of 102,979.1 (±60,775.0) PSS and 1982.8 (±1224.7) Kg of wild orchids were estimated to be in trade across all markets. However, the number of plants in trade varied considerably through the year, with peaks in April/May and October (Fig. 4). The peak in April/May coincided with a period of greater availability of flowering stems.

The 25 most traded species in terms of mean daily PSS and weight are shown in Fig. 5. Thirteen species of *Dendrobium* (*D. aphyllum*, *D. chryseum*, *D. chrysotoxum*, *D. crepidatum*, *D. crystallinum*, *D. densiflorum/thyrsiflorum*, *D. devonianum*, *D. findlayanum*, *D. hancockii*, *D. jenkinsii/lindleyi*, *D. loddigesii*, *D. nobile* and *D. parcum*) and *Paphiopedilum hirsutissimum* were common to both.

3.2 Determinants of price

Prices were recorded for 3168 products (62.4% of all products). Based on these data, we estimate a mean (±SD) daily stock value of US$3246.4 (±2723.8) at BN, US$7263.7 (±3722.9) at LN, US$10,762.5 (±7547.7) at FS and US$2914.7 (±1890.7) at MK; the single survey at JX indicated a stock value of US$3871.0. For all markets combined, the mean daily stock value was US$25,071.8 (±7711.2). Scaling for missing data (37.6% of products across all markets), the following values are estimated: US$5202.6 at BN, US$6203.5 at JX, US$11,640.5 at LN, US$17,247.6 at FS, US$4671.0 at MK and US$40,179.2 for all markets combined.

Variation in mean (±SE) price per individual wild-collected PSS and artificially propagated *Phalaenopsis* hybrid at each market is shown in Fig. 6. ANOVA reported a significant difference in mean price per stem among both wild orchids and *Phalaenopsis* hybrids across all markets (P<0.01). However, the Tukey-Kramer test indicated significance in pairwise comparisons only between BN/LN, BN/MK, FS/LN, FS/MK and LN/MK, and between BN, FS and MK and all markets combined for wild orchids (P<0.05), and in pairwise comparisons between BN/LN, BN/MK, FS/MK and LN/MK, and between FS, LN and MK and all markets combined for *Phalaenopsis* hybrids (P<0.05). The mean cost of a single hybrid *Phalaenopsis* was significantly higher than the mean cost of a single wild-collected orchid PSS at all markets where hybrids were available (ANOVA P<0.01; Tukey-Kramer P<0.05).

Mean price per PSS was found to be significantly higher for flowering versus non-flowering individuals across all markets together (ANOVA P<0.01; Tukey-Kramer P<0.05; Fig. 7A). However, when each market was assessed individually, ANOVA detected significant variation only at BN (P<0.05), FS (P<0.05) and MK (P<0.01), and the Tukey-Kramer test detected significant variation only at MK (P<0.05). Mean price per PSS was also found to be significantly higher when plants were sold by number rather than by weight at all markets together (ANOVA P<0.01; Tukey-Kramer P<0.05; Fig. 7B). This difference was confirmed at BN, LN and FS with

ANOVA (*P*<0.01) and at JX, LN and FS with the Tukey-Kramer test (*P*<0.05). Throughout the survey period, the proportion of PSS sold by number (rather than weight) at BN, JX, LN, FS and MK was 82.0%, 3.2%, 51.2%, 17.8% and 100%, respectively; for all markets combined, the proportion was 31.7%.

For all markets combined, mean price per PSS varied significantly across all presentations (ANOVA *P*<0.01) and among all pairwise comparisons of presentations except 'attached to original branch/mounted on boards' and 'bare-rooted, loose/bare-rooted, bundled' (Tukey-Kramer *P*<0.05) (Fig. 8A). Significance in price variation among presentations was also confirmed at each of BN, LN, FS and MK individually (ANOVA *P*<0.01). Significant variation in pairwise price comparisons was detected for 'attached to original branch/potted', 'bare-rooted, loose/mounted on boards', 'bare-rooted, loose/potted', 'bare-rooted, bundled/mounted on boards', 'bare-rooted, bundled/potted' and 'mounted on boards/potted' at BN (Tukey-Kramer *P*<0.05); for all comparisons except 'attached to original branch/potted' and 'bare-rooted, loose/bare-rooted, bundled' at LN (*P*<0.05); for 'attached to original branch/potted', 'bare-rooted, loose/potted' and 'mounted on boards/potted' at FS (*P*<0.05); and for 'attached to original branch/potted' at MK (*P*<0.05). No pairwise comparisons at JX differed significantly.

The effect of presentation on mean price per PSS was clearer when unmodified presentations were compared with modified presentations (Fig. 8B): at all markets apart from JX, modified plants were significantly more expensive than unmodified plants (ANOVA *P*<0.01; Tukey-Kramer *P*<0.05). The proportion of PSS being sold in each of the different presentations at each market is shown in Fig. 8C.

Multiple regression revealed the five variables (inflorescence size, flower colour, scent, conservation status and prevalence in trade) to explain 20.4% of total variance in price

(R^2=0.204, F (11, 118)=2.755, *P*<0.01). A significant positive correlation was reported between price per PSS and a conservation status of either NT or EN at the *P*<0.01 level, and between price per PSS and a conservation status of either VU or CR at the *P*<0.05 level. Meanwhile, a significant negative correlation was reported between price per PSS and green flower colour and between price per PSS and cumulative sightings at the *P*<0.05 level.

3.3 Association between orchid supply and stated consumer preferences

The first two dimensions in the FAMD analysis explained 28.3% of total variance among the six variables (inflorescence size, flower colour, scent, conservation status, prevalence in trade and price); individual points and centroid values were scattered with no obvious clustering (Fig. 9A). Eigenvalues revealed centroids for a conservation status of CR, single-flowered inflorescences and unscented/unpleasantly scented flowers to contribute most to the first component, whereas those for pink flowers, a conservation status of NT, EN or CR, and mean price to contribute most to the second component (Table S5). Mean price was negatively associated with cumulative sightings, suggesting that species that are less prevalent in trade are associated with a higher market value.

Nine species included in this analysis conformed to two stated consumer preferences, 29 conformed to three, 53 conformed to four, 31 conformed to five and eight species conformed to all six (Table S3). These ‘most preferred’ eight species were narrowly clustered with 95% confidence ellipses for successive combinations of six, five and four preferred traits arranged concentrically around them (Fig. 9B). Fifteen heavily traded species (Fig. 5) conformed to four or more criteria, suggesting considerable overlap between preferred traits and trade volume.

3.4 Evidence of CITES breaches

Thirty species encountered in trade at BN, JX, LN or FS are not reported from Mainland China (i.e. excluding Hong Kong) and were therefore regarded as non-native; products pertaining to a further eight native Chinese species were claimed by vendors to have been sourced in neighbouring countries (India, Laos, Myanmar, Thailand or Vietnam; Table 4). Together, these amount to 82,936.7 PSS and 562.8 Kg of wild orchid imports, equivalent to an estimated 7.0% of total PSS and 2.4% of total Kg observed on sale at the four Mainland markets throughout the study period. There were no declared imports in the trade database for all but one of these species during 2015–16, the one exception being *Dendrobium chrysotoxum*, for which an import of 15,000 artificially propagated stems (i.e. source: A) was reported from Laos. A further 20,025 live plants were imported from Japan during this period as artificially propagated 'Orchidaceae', but neither of these declared imports are likely to account for the wild-sourced imported species seen in trade.

Sixty-nine species encountered at MK are not reported from Hong Kong and were therefore regarded as non-native, amounting to 21,441.7 PSS and 324.9 Kg of wild orchid imports, equivalent to an estimated 50.5% of total PSS and 83.3% of total Kg observed on sale at MK throughout the study period (Table S6). The CITES trade database lists imports into Hong Kong for only ten of these species (*Dendrobium chrysotoxum*, *D. delacourii*, *D. thyrsiflorum*, *D. moniliforme*, *D. nobile*, *D. pendulum*, *D. unicum*, *Paphiopedilum bellatulum*, *P. concolor* and *Phalaenopsis pulcherrima*) during 2015–16 (Table 5). However, none of these declared imports were claimed to have been sourced from the wild and the stated quantities do not match for at least two species (*D. chrysostoxum* and *D. densiflorum/thyrsiflorum*). For a further four species or species groups (i.e. *Aerides rosea*, *Paphiopedilum* spp., *Phalaenopsis hygrochila* and *Schoenorchis fragrans*; Table 5), declared imports at the genus level appear in the database, but the stated source (A) does not match and the quantity does not equate for two (*Paphiopedilum* and *Phalaenopsis*).

4 Discussion

Despite severe conservation impacts (Hinsley et al., 2018; Liu et al., 2019), very few studies have sought to quantify overexploitation of wild-collected orchids for ornamental trade (Flores-Palacios & Valencia-Dias, 2007; Subedi et al., 2013; Phelps & Webb, 2015). For the first time, our study applies a systematic approach to species identification, individual stem and plant weight estimates and associated value to provide direct evidence of large-scale extraction of orchids from the wild for sale in established plant markets. We confirm trade in up to 440 species of orchids, involving more than 1.2 million individuals and almost 24 tonnes of plants, potentially valued at over US$14.6 million, over a one-year period in South China. At least part of this trade appears to be in breach of CITES. In the context of declining populations of many native orchid species in the region (Li et al., 2018), this trade is unlikely to be sustainable.

Although wild orchid diversity is highest in Yunnan Province, the western-most of the three provinces in our study, and that it declines towards Hong Kong, orchid diversity in trade was found to increase eastwards, peaking in Guangzhou, with up to 256 species recorded at FS alone. This is despite the fact that market size tends to decline along the same transect, with JX having the largest number of stalls/outlets and MK the fewest (Fig. 10). The proportion of floor/bench space dedicated to wild orchid sales at individual outlets in these markets similarly declined from BN to MK, suggesting that revenue from wild orchids, relative to that from artificially propagated orchids or other plants, drops in significance, even though mean daily stock value of wild orchids in trade was found to increase from BN to FS and that mean price per stem increased more than four-fold from BN to MK. In terms of species composition, most orchids traded domestically are probably sourced from towards the west of the transect, with species diversity at all markets consistently exhibiting greater similarity to the orchid flora of Yunnan than to that of the province/territory in which the market is situated. Wild orchid trade in South

China therefore appears to drive the concentration of species diversity, quantity and value in markets in large eastern cities, far removed from the species' native origin.

Our study also revealed that, although relatively few species occur frequently in trade, several species account for disproportionately great trade volume. Overwhelmingly, these heavily traded species are members of *Dendrobium*, as well as *Bulbophyllum* and *Paphiopedilum* to a lesser degree, and frequently they satisfy the majority of stated consumer preferences. It is inferred that wild populations of members of these genera face a heightened risk of decline and extirpation as a result, confirming anecdotal evidence reported elsewhere (Liu et al., 2014; Li et al., 2018). The appearance in trade of highly endangered, narrow endemics such as *Bulbophyllum tigridum*, *Dendrobium wangliangii* and *Paphiopedilum wenshanense* is particularly worrying in this regard. This information is likely to be of value in undertaking Red List assessments of highlighted species and should help draw attention to those most in need of conservation, including enhanced protection at remaining wild sites and development of restoration programmes. Our approach underscores the value of long-term, systematic market surveys to draw evidence-based conclusions on wildlife trade that can inform the design of meaningful interventions.

Our data also validate prior studies of stated consumer preferences for ornamental orchids in Asia (Hinsley et al., 2015; Williams et al., 2018) by revealing that species of all IUCN threatened categories (VU, EN and CR) plus NT are likely to be associated with a higher price, and that green-flowered species and those that appear more frequently in trade are likely to be associated with a lower price. Rarely have demand-side metrics been independently corroborated by supply-side data in this way (McNamara et al., 2016; Nuno et al., 2018). Although few orchids in trade conform to all six traits claimed to be preferred by consumers in those prior studies, most conform to a combination of four or more. In many cases this is likely to be sufficient, since not all consumers seek a combination of all stated preferences (Hinsley et al., 2015). As long as vendors can bring a broad selection of plants to market, either as target species or as 'by-catch' (i.e. opportunistic, accidental or incidental exploitation; Branch et al., 2013), they will therefore be able to offer products that appeal to most consumers. Given that many orchid species naturally occur in similar habitats in Indo-Burma, it would appear to be in the traders' interest to gather as many as possible at the same time to reduce unit costs and maximise potential for sale, especially since the value of any individual plant is likely to be low.

Williams et al. (2018) found price to be the most important attribute among ornamental orchid consumers in China, with relatively inexpensive plants receiving the highest mean utility value. In this regard, our finding that wild-sourced orchids are consistently priced significantly cheaper than artificially produced hybrids is problematic from the perspective of encouraging consumers to boycott the wildlife trade because it means that sales will inherently be biased towards the former. This is despite the fact that only a minority of vendors present their customers with a choice, and it would in any case require that consumers were able to distinguish the two—an unrealistic expectation given that wild-sourced and artificially propagated plants are often sold side-by-side and that telling them apart requires familiarity with minor details (CITES Secretariat, 2002). Again, this suggests that, as long as traders can source plants from the wild and bring them to market at low unit cost, they will be able to exploit a natural tendency among their customers to purchase them. Unless the market is regulated to restrict such nefarious activity, heavily traded, desirable species are likely to be collected to economic extinction as a result (Courchamp et al., 2006; Nijman, 2010).

Even within the under-valued wild orchid market, our data suggest vendors have several means of maximising revenue. These include selling a greater proportion of stems in flower, by number rather than by weight and in modified form (mounted on boards or potted): all of these attributes command significantly higher prices. In this regard, it is noteworthy that market size (in terms of number of stems in trade) was greatest across South China during peak flowering season (April and May), that the three primarily retail markets (BN, LN and MK) sell an above-average proportion of their plants by unit number, and that these same three markets sell a greater proportion of stock in modified form. Indeed, MK stands out for selling all wild-sourced orchids by unit number and for having more of them available in value-added form. Taken together, these features of the wild orchid trade in South China suggest that vendors knowingly shape trade in their favour, providing compelling evidence for the primacy of supply.

Clearly both domestic and international trade in wild-sourced orchids in South China has the potential to adversely affect wild populations, even those situated far from points of sale. As demonstrated for other wildlife products, this often masks declines in local populations and can bring about shifts to substitute taxa once wild sources have been significantly reduced (Nijman et al., 2017). Given the supply-side nature of this damaging and sometimes illegal trade, national and provincial/regional government is called upon to ensure tighter enforcement of existing international law and to establish effective domestic policy that could reduce overexploitation. Presently there are clearly too few incentives for traders to operate legally or within environmentally desirable norms: within China, no wild orchids are protected by law and our data make it clear that CITES rules are not being adequately followed, with breaches detected from all countries directly bordering South China and, more significantly, from Mainland China into Hong Kong. Moreover, it is likely that the scale of these infringements is greater than that documented here, since only in a limited number of cases did traders freely reveal the source of their stock. Indeed, observations of natural areas across South China reveal populations of many orchids to have been extirpated (Liu et al., 2014; Li et al., 2018), suggesting that many of the native Chinese species seen in trade are in fact being sourced from neighbouring countries.

Action deemed necessary to confront this underappreciated threat includes increasing the cost of sourcing wild orchids via prosecutions for violations of CITES and domestic law (Keane et al., 2008), and reducing the cost of artificially propagated hybrids through subsidies and other market instruments, which have proven to be effective in certain conservation contexts (Rundlöf et al., 2008; Liu et al., 2019). Nevertheless, artificial propagation will only be able to compete in the market-place if wild trade is better regulated (Williams et al., 2014, 2018; Tensen, 2016; Liu et al., 2019). Certification has been used as a tool to shift markets for wild plants and other wildlife products towards more ethical consumption patterns (Timoshyna, 2018), and could have a similar role to play in the horticultural plant trade. However, given the proven impact of government interventions and social media campaigns to conserve particular species or reduce trade volumes of certain wildlife products in China (Eriksson & Clarke, 2015; Wu et al., 2018), we urge concerted action to develop policy, tighten enforcement, raise concern and facilitate behavioural change for improved orchid conservation in the country.

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Table 1. Markets in South China that trade wild-collected orchids. Those surveyed in this study are shown in bold and abbreviations used elsewhere in this paper are given in parentheses.

Province/ territory	City/town	Setting	Frequency	Consumer base	Size (approx. no. of stalls/outlets)
Yunnan	**Banna (BN)**	**Rural, border**	**Daily**	**Retail**	**20**
	Pu'er	Rural	Weekly	Retail	60
	Kunming	Urban	Daily	Retail	40
	Wenshan	Urban, border	Weekly	Retail	30
Guangxi	**Jingxi (JX)**	**Rural, border**	**Annual**	**Wholesale**	**620**
	Nanning	Urban	Daily	Retail	100
Guangdong	**Lingnan (LN)**	**Urban**	**Daily**	**Wholesale & retail**	**400**
	Foshan (FS)	**Urban**	**Daily**	**Wholesale**	**80**
Hong Kong	**Mong Kok (MK)**	**Urban, border**	**Daily**	**Retail**	**80**

Table 2. Percent similarity species composition between market sites and the wild at the province- and territory-level.

Market (No. of named species in trade)	Province/territory (No. of species occurring naturally)			
	Yunnan (1050)	Guangxi (284)	Guangdong (180)	Hong Kong (134)
BN (95)	95.8	36.8	21.1	18.9
JX (29)	93.1	68.9	41.4	27.6
LN (158)	80.4	38.6	18.4	15.8
FS (180)	77.8	36.1	72.8	16.1
MK (84)	79.8	38.1	25.0	15.5

Table 3. Calculated standing stock of wild-collected orchids in terms of individual numbers of pseudobulbs/shoots/stems (PSS) and weight (Kg) on single-day monthly surveys at each market and at all markets together, June 2015 to May 2016.

	BN		JX		LN		FS		MK		**Total**	
	PSS	Kg	PSS	Kg	PSS	Kg	PSS	Kg	PSS	Kg	**PSS**	**Kg**
Jun	10,473.0	717.1	110,499.9	1,553.8	11,283.3	188.3	13,036.8	156.1	12,653.6	62.4	**157,946.7**	**2,677.7**
Jul	3,960.8	257.4	-	-	31,951.1	605.0	4,629.9	122.1	9,517.4	37.6	**50,059.3**	**1,022.0**
Aug	1,523.4	61.3	-	-	19,675.0	309.0	8,517.5	256.1	7,435.8	32.5	**37,151.6**	**658.8**
Sep	3,502.7	147.8	-	-	14,975.8	229.4	59,191.2	676.4	3,174.5	13.4	**80,844.2**	**1,066.9**
Oct	2,204.2	146.3	-	-	31,383.3	335.3	112,852.9	963.5	1,655.6	16.6	**148,096.0**	**1,461.7**
Nov	3,923.7	171.1	-	-	19,572.8	471.9	64,442.1	970.5	1,046.3	18.9	**88,984.9**	**1,632.5**
Dec	7,927.1	520.8	-	-	17,277.7	486.2	65,432.0	718.5	652.4	25.2	**91,289.2**	**1,750.5**
Jan	4,771.6	171.2	-	-	7,082.8	161.1	16,599.1	523.4	469.6	12.5	**28,923.2**	**868.1**
Feb	6,745.5	406.2	-	-	26,514.7	590.5	14,924.1	417.7	473.0	6.7	**48,657.3**	**1,421.1**
Mar	9,645.8	513.2	-	-	36,795.0	1,009.9	56,182.6	1,819.7	1,005.1	51.7	**103,628.5**	**3,394.4**
Apr	9,964.4	755.5	-	-	45,938.4	1,424.0	129,827.3	2,396.8	1,666.6	50.1	**187,396.6**	**4,626.4**
May	8,304.6	452.3	-	-	53,854.3	847.6	147,784.0	1,850.1	2,829.3	62.7	**212,772.3**	**3,212.7**
Total	**72,946.9**	**4,320.2**	**110,499.9**	**1,553.8**	**316,304.2**	**6,658.0**	**693,419.6**	**10,871.0**	**42,579.2**	**390.1**	**1,235,749.8**	**23,793.1**
Mean	6,078.9	360.0	110,499.9	1,553.8	26,358.7	554.8	57,785.0	905.9	3,548.3	32.5	**102,979.1**	**1,982.8**
SD	3,150.5	234.7	-	-	14,162.8	377.5	49,743.2	740.3	4,061.8	20.1	**60,775.0**	**1,224.7**

Table 4. CITES Trade Database corroboration of observed wild orchid imports into China, 2015–2016.

Species in trade	Native to China?	Market(s)	Stated source	Quantity observed	Reported in CITES trade database 2015/16?	Reported exporter, quantity and source
Aerides houlletiana	No	LN, FS	Myanmar	8.0 PSS/0.6 Kg	No	
Bulbophyllum longissimum	No	FS	-	162.3 PSS/2.0 Kg	No	
Bulbophyllum moniliforme	No	LN	-	N/A	No	
Bulbophyllum wendlandianum	No	FS	-	888.9 PSS/10.0 Kg	No	
Cymbidium bicolor	No	FS	-	8.0 PSS/0.3 Kg	No	
Dendrobium albosanguineum	No	LN, FS	Laos, Myanmar	83.5 PSS/1.6 Kg	No	
Dendrobium amabile	No	FS	-	643.4 PSS/31.0 Kg	No	
Dendrobium anceps	No	LN	-	5234.6 PSS/23.5 Kg	No	
Dendrobium bensoniae	No	LN, FS	India	319 PSS/3.5 Kg	No	
Dendrobium cumulatum	No	FS	-	10.5 PSS/0.2 Kg	No	
Dendrobium delacourii	No	LN, FS	Myanmar	2203.5 PSS/5.9 Kg	No	
Dendrobium draconis	No	LN, FS	-	856.9 PSS/24.6 Kg	No	
Dendrobium formosum	No	LN	-	3.5 PSS/0.1 Kg	No	
Dendrobium griffithianum	No	LN, FS	-	96.0 PSS/2.7 Kg	No	
Dendrobium henryi	No	BN	-	29.0 PSS/N/A	No	
Dendrobium lamellatum	No	FS	-	10.5 PSS/N/A	No	
Dendrobium linguella	No	FS	-	23.5 PSS/0.8 Kg	No	
Dendrobium ochreatum	No	LN, FS	Laos	1336.2 PSS/21.0 Kg	No	
Dendrobium parcum	No	LN, FS	-	58,566.3 PSS/222.9 Kg	No	
Dendrobium pulchellum	No	LN, FS	-	923.1 PSS/59.2 Kg	No	
Dendrobium scabrilingue	No	FS	Myanmar	29.0 PSS/0.1 Kg	No	
Dendrobium secundum	No	LN, FS	Myanmar	176.5 PSS/7.4 Kg	No	
Dendrobium senile	No	LN, FS	-	1370.1 PSS/8.8 Kg	No	
Dendrobium signatum	No	LN, FS	-	503.5 PSS/11.1 Kg	No	
Dendrobium tortile	No	FS	-	235.1 PSS/5.0 Kg	No	
Dendrobium trantuanii	No	FS	Vietnam	154.0 PSS/0.6 Kg	No	
Dendrobium unicum	No	LN, FS	-	740.0 PSS/1.4 Kg	No	
Pelatantheria insectifera	No	LN, FS	-	669.5 PSS/6.9 Kg	No	
Schoenorchis scolopendra	No	FS	-	N/A	No	
Thecostele alata	No	LN	-	1.0 PSS/0.01 Kg	No	
Dendrobium aphyllum	Yes	LN	Vietnam	406.2 PSS/5.7 Kg	No	
Dendrobium chrysotoxum	Yes	FS	Myanmar	266.0 PSS/32.6 Kg	Yes	Laos: 15,000 stems, A
Dendrobium densiflorum/thyrsiflorum	Yes	FS	Vietnam	104.9 PSS/12.9 Kg	No	
Dendrobium exile	Yes	LN	Myanmar	3.5 PSS/0.01 Kg	No	
Dendrobium findlayanum	Yes	FS	Thailand	287.3 PSS/2.9 Kg	No	
Dendrobium jenkinsii/lindleyi	Yes	LN, FS	Thailand, Vietnam	5964.7 PSS/41.0Kg	No	
Dendrobium lituiflorum	Yes	FS	Myanmar	96.0 PSS/187.2 Kg	No	
Dendrobium polyanthum	Yes	FS	Laos	522.8 PSS/12.4 Kg	No	

Table 5. CITES Trade Database corroboration of observed wild orchid imports into Hong Kong, 2015–2016.

Species in trade	Native to Hong Kong?	Market	Quantity observed	Reported in CITES trade database 2015/16?	Reported exporter, quantity and source
Dendrobium chrysotoxum	No	MK	894.5 PSS/109.5 Kg	Yes	Thailand: 50 live plants, A
Dendrobium delacourii	No	MK	3.5 PSS/0.01 Kg	Yes	Thailand: 347 live plants, A
Dendrobium densiflorum/thyrsiflorum	No	MK	187.9 PSS/23.2 Kg	Yes (*Dendrobium thyrsiflorum*)	Thailand: 4 live plants, A
Dendrobium moniliforme	No	MK	240.0 PSS/0.5 Kg	Yes	Japan: 213 live plants, A
Dendrobium nobile	No	MK	442.8 PSS/14.6 Kg	Yes	Netherlands: 1054 live plants, A
Dendrobium pendulum	No	MK	59.2 PSS/1.3 Kg	Yes	Thailand: 50 live plants, A
Dendrobium unicum	No	MK	17.5 PSS/0.03 Kg	Yes	Thailand: 450 live plants, A
Paphiopedilum bellatulum	No	MK	7 PSS/0.1 Kg	Yes	Thailand: 6 live plants, D
Paphiopedilum concolor	No	MK	32.5 PSS/1.0 Kg	Yes	Thailand: 17 live plants, D
Phalaenopsis pulcherrima	No	MK	2.0 PSS/0.1 Kg	Yes	Thailand: 2 live plants, A
Aerides rosea	No	MK	29.0 PSS/7.5 Kg	'*Aerides* spp.'	Thailand: 50 live plants, A
Paphiopedilum armeniacum, *P. bellatulum*, *P. concolor*, *P. emersonii*, *P. henryanum*, *P. hirsutissimum*, *P. micranthum*	No	MK	1413.9 PSS/25.1 Kg	'*Paphiopedilum* spp.'	Netherlands, Thailand: 157 live plants, A & D
Phalaenopsis hygrochila,	No	MK	50.0 PSS/6.7 Kg	'*Phalaenopsis* spp.'	Thailand: 3 live plants, A
Schoenorchis fragrans	No	MK	21.0 PSS/N/A	'*Schoenorchis* spp.'	Thailand: 30 live plants, A

Figure captions

Fig. 1. Location of the five markets surveyed in the present study (Banna, Jingxi, Foshan, Lingnan and Mong Kok; closed circles) plus four additional plant markets identified in preliminary consultations (open circles) in South China. The Indo-Burma Biodiversity Hotspot (shaded) in relation to the extent of the main map is shown inset.

Fig. 2. Cumulative 12-month sightings of all 440 named and unnamed orchid taxa encountered at five markets in South China, June 2015 to May 2016.

Fig. 3. Observed (light tones) and expected (dark tones) species accumulation curves, derived from jackknife richness estimation with 1000 random resampling events, for each of the five markets (BN blue, JX grey, LN ochre, FS green, MK purple) and for all markets together (red).

Fig. 4. Estimated number of flowering (grey) and non-flowering (black) pseudobulbs/shoots/stems of wild-collected orchids on sale across all five markets on single-day monthly surveys.

Fig. 5. The 25 most traded wild-collected orchid species across five markets in South China in terms of daily mean (±SE) number of pseudobulbs/shoots/stems (A) and daily mean (±SE) weight (B).

Fig. 6. Mean (±SE) price per individual wild-collected orchid pseudobulb/shoot/stem (black dot) and mean (±SE) price per individual *Phalaenopsis* hybrid (grey dot) at each market and for all markets together. *Phalaenopsis* hybrids were not available at JX.

Fig. 7. A. Mean price (±SE) per individual flowering (Fl) and non-flowering (NFl) wild-collected orchid pseudobulb/shoot/stem at each market individually and across all markets together. B. Mean price (±SE) per individual wild-collected orchid pseudobulb/shoot/stem sold by weight (Wt) and number (No) at each market individually and all markets together.

Fig. 8. A. Mean (±SE) price per individual wild-collected orchid pseudobulb/shoot/stem presented for sale still attached to the original branch from the forest (OB), bare-rooted and loose (BL), bare-rooted in bundles (BB), mounted on boards (MB) or potted (PT) at each market individually and across all markets together. B. Mean (±SE) price per individual wild-collected orchid pseudobulb/shoot/stem presented for sale in an unmodified (UN) or modified (MD) state at each market individually and across all markets together. C. Proportion of wild-collected orchid pseudobulbs/shoots/stems presented for sale still attached to the original branch from the forest (dark green), bare-rooted and loose (green), bare-rooted in bundles (light green), mounted on boards (ochre) or potted (brown) at each market individually and at all markets combined.

Fig. 9. A. Factor Analysis of Mixed Data for 130 orchid species (dots) encountered in trade. Trend lines are shown for two quantitative variables (cumulative sightings and mean price per PSS) and centroid values (triangles) are shown for the following four qualitative variables: single- and multiple-flowered inflorescences (IS_si, IS_mu); purple/red, pink, yellow/orange, green and white flowers (FC_pr, FC_pk, FC_yo, FC_gr, FC_wh); unscented and

scented flowers (FS_us, FS_sc); and a conservation status of least concern, near threatened, vulnerable, endangered and critically endangered (CS_lc, CS_nt, CS_vu, CS_en, CS_cr). B. 95% confidence ellipses plotted on the same data shown in A indicating dispersion among data points meeting successive combinations of any the following six preferred criteria: IS_mu; FC_wh; FS_sc; CS_vu, CS_en or CS_cr; cumulative sightings <26.94; mean price per PSS <US$2.28.

Fig. 10. Schematic summary of gradients in species diversity, quantity and value along the West-East transect from BN in Yunnan Province to MK in Hong Kong. Circles are scaled to a percentage of the largest value for each variable.

Supplementary files

Fig. S1. Relationship between visual estimates and calculated estimates of the total stock weight of 50 products representing 36 species on sale at Lingnan and Foshan markets, $y = 0.9972x + 1.0211$, $r = 0.843$, $r^2 = 0.711$.

Table S1. Mean number of individual pseudobulbs/shoots/stems per unit item for each species encountered in trade, for products in which number of pseudobulbs/shoots/stems >10. Values for unnamed species are based on the mean for all named species in that genus.

Table S2. Mean (±SE) weight per pseudobulb/shoot/stem for each species encountered in trade. Values for unnamed species are based on the mean for all named species in that genus.

Table S3. Data matrix used in multiple regression analysis and FAMD showing character states for four qualitative characters (inflorescence size: single- or multi-flowered; flower colour: purple/red, pink, yellow/orange, green or white; floral scent: unscented/unpleasantly scented or fragrant; and conservation status: LC, NT, VU, EN or CR) and two quantitative characters (prevalence in trade and mean price per individual pseudobulb/shoot/stem) for 130 named species in trade. Species meeting each of the following six 'ideal' conditions preferred by consumers are indicated: multi-flowered inflorescence, white-flowered, fragrant, rare in wild, rare in trade and cheap.

Table S4. Native Chinese orchid species reported from Yunnan, Guangxi and Guangdong Provinces and Hong Kong Special Administrative Region, based on Chen et al. (2009), Barretto et al. (2011), Gale et al. (2014) and Zhou et al. (2016).

Table S5. Eigenvalues computed for each of 130 species, centroids for 14 qualitative character states and two quantitative characters in FAMD.

Table S6. Data pertaining to 350 products comprising 69 species not native to Hong Kong observed on sale at MK.