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ORIGINAL RESEARCH

A hedonic analysis of the market for Southeast Asian slipper orchids (*Paphiopedilum*)

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Abstract

Since the Victorian era, orchids have been in continuous demand within the horticultural trade. As a result, the entire family of over 29,000 species are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), making up over 73% of the species listed on CITES. With the continued threat from (often illegal) over-exploitation of orchids and discovery of new species of potential horticultural value, this raises the question as to whether we can develop statistical models to identify species likely to be threatened through over-exploitation by identifying those plant attributes that attract the highest price premium. Using species of Southeast Asian slipper orchids (*Paphiopedilum*) as a model system, we analyse market level data from a systematic survey of online trade using hedonic regression analysis to assess the relationship between price and plant attributes. Our analysis reveals that a range of plant attributes (taxonomic sections, plant size, plant colour and rarity on the market) influence price and that these vary by species. Importantly, our study reveals that coding observable attributes such as colour (primary and other) for use in statistical analysis is complicated. Future research on how colour and other attributes affect choice would benefit from employing more advanced consumer research techniques such as eye-tracking that can help inform what is specifically driving consumer choice.

Keywords CITES · Hedonic regression · Orchidaceae · *Paphiopedilum* · Wildlife trade

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Introduction

The trade in wildlife, including animals, plants, and their derivatives, is estimated to have been worth between c.$2.49 and 4.4 billion from 1997 to 2016 (Andersson et al. 2021), involving markets as diverse as fisheries, timber, medicines, foods, horticulture, and exotic pets. While legal activities make up most of the trade in wildlife, the estimates on the value of the illegal trade in wildlife have been put somewhere between c.$5 to $24 billion per year excluding fisheries and timber ('t Sas-Rolfes et al., 2019).

With the renewed interest in the illegal wildlife trade over the last 20 years, initiatives have focused on regulation and enforcement, supply-side interventions (e.g. anti-poaching and livelihood initiatives), and demand-side interventions (e.g. behavioural change and demand-reduction) (World Bank 2016). While much progress has been made to understand the diverse drivers of demand (Thomas-Walters et al. 2020), most studies have focused on single charismatic species and commodities, such as rhino horn, bear bile or pangolin scales, rather than trades involving living organisms and more species-rich groups (although see Burivalova et al., 2017; Williams et al. 2018; and studies into the Anthropogenic Allee Effect).

Trades that involve newly described species are of particular concern, as these species are more likely poorly known, naturally rare, and likely to be threatened (Joppa et al. 2011; Roberts et al. 2016). Due to the threat over-exploitation poses to newly described species, it has been suggested that locality data should be withheld from publications to make it more difficult for those searching for, and illegally exploiting, these species for the wildlife trade (Lindenmayer and Scheele, 2017). This, however, is not only an issue for newly discovered species, as it could impact species that are known but are yet to enter the trade, such as those from more remote areas or where consumer preferences change. It is therefore critical that we understand the drivers of demand, particularly within those markets that have the potential to include trade in newly described species [e.g. reptiles for the exotic pet trade (Marshall et al. 2020) and orchids for the horticultural trade (Hinsley and Roberts 2018)]. Such an understanding will provide knowledge to law enforcement officers to aid in the identification of potentially illegal trade in those species, as well as the development of strategies to allow for legal, sustainable trade. It should, however, be noted these are just some of a number of potential strategies needed to tackle the illegal wildlife trade.

The family Orchidaceae is one of the largest families of flowering plants with over 29,000 known species described to date (Hinsley et al. 2018). Humans have used orchids throughout history for a range of purposes including flavourings (e.g. vanilla and *Jumellea fragrans*), as a source of starch (e.g. salep and chikanda) and medicinal products (e.g. *Dendrobium* spp. for shi-hu) (Hinsley et al. 2018). However, since the Victorian era, orchids have been in continuous and significant demand within the horticultural trade (Hinsley et al. 2018). As a result, and because of the difficulty in distinguishing between similar species, the entire family is listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), making up over 73% of the species listed on CITES (Hinsley et al. 2018). Of these, c.140 species of orchids are listed at the very highest level of CITES (Appendix I), the majority being from the genus *Paphiopedilum* (> 100 species). Since 1999, there has been a steady flow of new *Paphiopedilum* species being described, many of which rapidly enter the horticultural trade illegally (Averyanov et al. 2023; Hinsley and Roberts 2018). One example is the slipper orchid, *Paphiopedilum vietnamense*, which was described new to science in 1999 only to be declared extinct in the wild through illegal over-collection for the international horticultural market within 5 years (Averyanov et al. 2003); currently it is listed as Critically Endangered on the IUCN Red List, with fewer than 50 plants remaining in the wild, although it is acknowledged that it may already be extinct in the wild (Rankou and Averyanov 2015). Based on the most recent IUCN Red List assessments of slipper orchids, 99% of the 85 assessed species of *Paphiopedilum* are considered threatened, with over-exploitation for the horticultural trade being a major driver (IUCN 2024). Even so, why *P. vietnamense* was in such great demand and collected to possible extinction, while other species of slipper orchids, described around the same time, were not, is unclear. Attributes such as colour, shape, size, and rarity in trade and/or the wild, may be factors that drive demand.

To date, the economic analysis of the demand for plants traded has frequently employed hypothetical stated preference research methods such as choice experiments (Rihn et al. 2014; Rombach et al. 2018), conjoint (Rihn et al. 2015, 2016) or experimental auctions (Yue et al. 2015). In contrast, few studies have examined actual supply and/or demand of horticultural plants using market data. One exception is Hovhannisyan and Khachatryan (2017) who examine the demand for ornamental plants reporting that they are price-elastic, where demand for a product is highly sensitive to changes in its price. Regarding orchids, two studies have investigated consumer preference, using hypothetical stated preference methods. Hinsley et al. (2015) used choice experiments to provide an understanding of consumer preference for attributes such as flower colour, species v hybrid, single v multi-flowered and rarity at a UK orchid show. They found that c.50% of the sampled population preferred white, multi-flowered orchids; these correspond to the mass-produced moth orchids, *Phalaenopsis* hybrids. Also, c.25% of the sample preferred rare species bought over the internet and likely represented specialist collectors. Williams et al. (2018) used conjoint analysis to study consumer preference for orchids in China and Hong Kong. They found that price was the most important attribute, followed by flower colour. In contrast, Wong and Liu (2019) studied the online marketplace taobao.com and found 97 species of wild-sourced orchid for sale in China presenting geographical, temporal and price data. While Gale et al. (2019) collected market level data for orchids across a West-East transect from Yunnan to Hong Kong for a year. Within the results they report a multiple regression model that identified five variables influencing price: inflorescence size, flower colour, scent, conservation status and prevalence in trade.

Due to the large number of potential attributes that influence price in the horticultural trade, hedonic analysis, frequently employed in economics (Gibbons et al. 2014; Núñez et al. 2024), allows us to examine how variation in product attributes such as colour, size and market rarity influence price. Hedonic analysis stems from an alternative theory of consumer demand developed by Lancaster (1966). The theory assumes utility is derived from consuming goods that combine attributes desired by the consumer. This means that demand for goods such as plants is a function of the attributes specific plants provide. Thus, any plants such as orchids can be differentiated given the specific set of attributes they provide. This means that demand for any trait can be determined by consumer choice for a specific plant, which in this case will be the many types of orchid available on the market. Or to put it another way, hedonic analysis enables researchers to disaggregate any good or service into the underlying set of attributes and to estimate models relating price to the set of attributes describing a good or service (Costanigro et al. 2011).

In this study, we aimed to identify attributes that influence demand using market level data for species of Southeast Asian slipper orchids (*Paphiopedilum*). We examine how multiple flower colours relate to price, an important feature of orchids but one that has been overlooked in earlier research. Specifically we ask the questions, what are the set of plant attributes that might determine price? Which plant attributes have a statistically significant impact on price, particularly in relation to complex flower colour? And how does this relate to geographical location and taxonomy? By developing a hedonic statistical model, we anticipate that future research will be able to predict the demand for species new to the trade.

Methods

Prior to the start of the study, ethical approval was received from the Research and Ethics Committee of the School of Anthropology and Conservation, University of Kent.

Study species

The genus *Paphiopedilum*, is the largest of the five slipper orchid genera within the subfamily Cypripedioideae of the family Orchidaceae. Its common vernacular name derives from the modified petal or labellum, that forms a slipper-like structure. The genus comprises over 100 species, predominately found in Southeast Asia, although it extends west into the Indian Subcontinent, north into southern China and southeast as far as the Solomon Islands (Cribb 1998; Govaerts et al. 2019; WCSP 2019). Based on the most recent IUCN Red List assessments of the genus, all but one (*P. philippinense*) of the 85 species assessed is threatened with extinction, with 53% listed as Critically Endangered. This level of threat is largely driven by demand from the horticultural trade, followed by habitat destruction (IUCN 2024). Such is the popularity within the horticultural community, that the Royal Horticultural Society (RHS) lists over 30,000 hybrids within its International Orchid Register (RHS 2025). As a result of the demand from the horticultural trade, the entire genus has been listed in CITES Appendix I since 1990 (Govaerts et al. 2019; UNEP-WCMC 2024).

Trade data

Market level data was collected using a systematic survey of online trade (Roberts, Mun and Milner-Gulland 2022) from English language platforms. A Google search was conducted on 26 June 2019 to identify a list of potential sites where orchids of the genus *Paphiopedilum* were being sold. The following search terms were used: “Paphiopedilum AND sale OR price”. Based on this search, we recorded 111 unique URLs (after removal of duplicates). The screening process was then conducted between 28 June and 22 July 2019. Each URL linking to online sellers was screened for *Paphiopedilum* sale posts, by exploring the menus or shop section if relevant, or by searching *Paphiopedilum* within the in-site search box. No vernaculars were used as they are very rarely used within the orchid collector community and other similar specialist collector communities (e.g. see Lynn and Roberts 2023). Any links to sites that had search functionality (e.g. aliexpress, Amazon, eBay), were searched using the search term “Paphiopedilum” although this varied slightly depending on the search function. On social media platforms, where a post gave a link to an external website, these were also searched. Only posts in English were included. A summary of the search activities and strategy are given in the Supplementary Information (Table SI1).

Data were only collected for living plants of *Paphiopedilum* species offered for sale. Hybrids and plants of uncertain taxonomic identity were excluded. In cases where there was uncertainty over the taxon's identity, data were collected and checked later. At this point a decision as to whether to include or exclude the data point was made following a review. Data were collected on the following attributes: name of seller and trading platform; species; subgenus; section; country of sale; price converted to US dollars using www.xe.com (as of 19 July 2019); quantity; size category. The study period is sufficiently short so as not to cause any issues regarding significant currency variation and impacts on our econometric analysis. Taxonomic data were updated to match the current accepted taxonomy of the genus. This was done by creating a list of accepted *Paphiopedilum* species names and synonyms extracted from the World Checklist of Selected Plant Families website (WCSP 2019). This was then cross-checked with the CITES Checklist for Appendix I Orchids (Govaerts et al. 2019) and any inconsistencies were clarified with anonymous species experts.

Morphological attribute data

A matrix of attributes deemed potentially relevant to price was constructed with one row for each species. Morphological attributes were selected in consultation with an anonymous orchid expert and an anonymous qualified judge at orchid shows. The morphological attributes were recorded for each species (Table 1). We also collected data on plant size where 'Near-flowering size' generally refers to plants that have not flowered previously but have a reasonable expectation to flower within approximately the next 12 months. In contrast, flowering size plants generally refers to plants that have flowered in the past, or of a size

Table 1 Morphological attributes recorded for each species of *Paphiopedilum*

Attributes	Description
Leaf patterning	Tessellated/patterned or lacking tessellation/green
Leaf length	Maximum length (cm)
Leaf width	Maximum width (cm)
Leaf ratio	Maximum length divided by maximum width
Number of flowers	Maximum number of flowers held on a single inflorescence
Peduncle length	Maximum length (cm)
Petal length	Maximum length (cm)
Petal width	Maximum width (cm)
Petal ratio	Maximum length divided by maximum width
Lip length	Maximum length (cm)
Lip width	Maximum width (cm)
Lip ratio	Maximum length divided by maximum width
Colour	Primary – base colour of the flower
Colour pigment 1	Secondary – second most prominent flower colour
Colour pigment 2	Tertiary – third most prominent flower colour
Flower patterning (spots)	Spots either mild or heavy
Flower patterning (stripes)	Stripes either mild or heavy

that one would expect to flower. Morphological attribute information was collated from the following sources to ensure consistency in attribute assignment: "The Genus *Paphiopedilum*" (Cribb 1998) and "Slipper orchids of Vietnam" (Averyanov et al. 2003). For species described after the monographs were published, information was extracted from the original published descriptions, and where this was not accessible, we used photographs verified by an anonymous taxonomic expert. In addition, for each species the following attributes were also recorded: date of first description, conservation status (IUCN Red List), and frequency in the market (frequency within our sample).

Data cleaning

Cleaning of the data resulted in 1,065 data points, with each data point representing trade in one species per vendor, unless the vendor had, for example, two different sizes of plants for sale. The final set of variables used in the statistical models are shown in Table 2.

The set of plant attributes presented in Table 2 show a unique feature of this data set: there are potentially 33 three-colour combinations. Descriptive statistics and frequency of each colour by category are shown in Tables SI2-5. All possible three-colour combinations in the data set are shown in Table SI6. In the statistical analysis we present, we combine the three-colour combinations for plants that have 25 or less data points resulting in 20 variables. For those, combinations with less than 25 we combined them into a variable called "Other". We took this decision as 33 three-colour combinations was too many but wished to examine if colour combinations did have an impact on price; this represented a trade-off between trying to be as general as possible whilst maintaining a meaningful model specification. We follow standard practice within the hedonic literature by employing the natural log of price (Lnprice) as the dependent variable. The data transformation is made because this type of data will frequently have extreme values that mean that the distribution of the raw data is significantly skewed and in cross-sectional data this is likely to result in heteroscedasticity.

Data analysis

We examined the relationship between the natural log of price and the plant attributes listed in Table 2 by employing various hedonic regression models estimated using Ordinary Least Squares, Random Effects and Median Regression specifications. Our Random Effects specification is for the colour combinations we examine which is a categorical variable that is assumed to be drawn from a normal distribution. We employed a Median Regression specification to check for the influence of outliers. All models were estimated using code written in Python (https://www.python.org/about/). We also employed White's robust standard errors to take account of possible heteroskedasticity in the model specifications. All model specifications were tested for functional form misspecification by employing the Ramsey RESET test (Wooldridge 2020) as well as examining model error structure. Finally, we note that our decision regarding how we have aggregated certain explanatory variables (i.e., three-colour combinations, country of seller, species) is an important modelling choice. However, in making these choices, we have done so to control for the very heterogeneous nature of the data (i.e., 96 species listed) as well as arrive at a parsimonious model specifica-

Table 2 Variable names and definitions

Variable Type	Variable Label (Name)	Units
Price per unit	Price	US Dollars (2019)
Taxonomic Sections	Barb (Barbata) Brach (Brachypetalum) Coch (Cochlopetalum) Corya (Coryopedilum) Paph (Paphiopedilum) Pardal (Pardalopetalum) Parvi (Parvisepalum)	Dummy Variable
Regions	Amer (America) Asia (Asia) Eur (Europe) Nocou (No country)	Dummy Variable
Flower Colour Pigmentation Base (primary)	Green (gr) Pale Yellow (pa) Purple (pr) White (wh) Yellow (ye)	Dummy Variable
Flower Colour Pigmentation (secondary and/or tertiary)	Black Purple (bp) Brown (br) Green (gr) Maroon (ma) None (no) Orange (or) Pink (pi) Purple (pu) Red (re) White (wh) Yellow (ye)	Dummy Variable
Log of the count of the colour combinations	Lncfreq	Value
Plant Size	Flowering Size (FS) Near-Flowering Size (NFS) Seedlings (Seed)	Dummy Variable
Lip Ratio (lip max length/lip max width)	Lipratio	cm^2
Spots on Flower (mild, heavy)	Spots	Count
Stripes on Flower (mild, heavy)	Stripes	Dummy Variable
Frequency on the Market	Lnrarity	Log of Count

Associated descriptive statistics are provided in Tables SI2-5

tion. If we did not make these choices, then for example, including dummy variables for all species would yield a hugely over parameterised specification with little explanatory power for many of the parameters being estimated. As such any modelling strategy has to trade-off data availability and model feasibility.

Results

We examined various model specification and estimators arriving at our preferred model. A summary of the models examined, and the main parameter estimates (excluding colour) are shown in Table SI7. The key model parameter estimates are relatively robust to model specification. As a result, our preferred specification is OLS with the set of three-colour combinations. These results are shown in Table 3.

The results for our preferred model specification reveal various interesting aspects of how the global market for slipper orchids offered for sale is working (Table 3). First, we can see that less than half of the three-colour combinations are statistically significant. All the estimates are negative relative to the excluded level of gr_br_pu (Green, Brown, and Purple). We also included a variable, the natural log of the count of three-colour combinations (Lncfreq) to see if price is related to frequency on the market of specific colour combinations. In this case there is no statistical relationship between price and availability.

Second, in terms of taxonomic Sections (with Barbata (Barb) as the excluded category) these are all positive and statistically significant except for Cochlopetalum (Coch) which is not statistically significant ($P=0.700$). The Sections attracting the highest price estimates are Coryopedilum (Corya) and Pardalopetalum (Pardal).

Third, we note that the region dummies are negative if significant or statistically nonsignificant relative to the excluded category which is Amer. This result is not surprising, given that several of the most highly priced slipper orchids in the data set are being offered for sale without an indication of the source country. Thus, although orchids for sale in Europe appear to attract a lower price, the signal based on location is not that strong.

Regarding plant size, we see that both Near-Flowering Size (NFS) and Flowering Size (FS) are positive and statistically significant, and as we might expect, plants at Flowering Size have a higher parameter estimate.

Next, we consider flower Stripes, Spots, and the Lip Ratio of the flower. In two cases the coefficients are statistically nonsignificant, but for Lip Ratio the estimate is positive and statistically significant. The implication of this result is that orchid price is higher for plants with a larger lip ratio.

The final parameter we included in our model specification is the frequency of orchid by Section type (Lnrarity) on the market. This parameter is negative and statistically significant. It measures the number of times a particular species occurs in the data set. What we are therefore observing is that infrequently offered plants attract a higher price, or alternatively, plants being offered frequently on the market do not attract a price premium; price premium refer to the extra a customer is willing to pay for a product compared to a similar, less expensive, alternative, thus allowing the identification those attributes that statistically elicit this price premium. Thus, it is rarity of plant species in the marketplace and not rarity of plant colour combinations that positively relates to price (Table 3).

Finally, we did joint F tests of significance of the categorical non-binary variables (i.e., Taxa, Regions and Colour). The test results are shown in Table SI8, and they indicate that all the categorical non-binary variables are jointly statistically significant ($P<0.001$). This means that each of these variables statistically contribute to the overall fit of the model specification.

Table 3 Full data set ($n = 1{,}065$) employing OLS, **three-colour** combinations with dependent variable Ln price

Variables	Coeff	SE	$P>\|z\|$	[0.025	0.975]
Intercept	**2.720*** **	**0.472**	**<0.001**	1.795	3.645
Colour Combinations					
Green, Maroon, Purple	−0.136	0.144	0.346	−0.418	0.147
Green, Maroon, White	**−0.468*** **	**0.136**	**0.001**	−0.734	−0.202
Green, Maroon, Yellow	−0.152	0.178	0.395	−0.501	0.198
Green, Misc	−0.166	0.232	0.475	−0.62	0.288
Green, Purple, Maroon	−0.225	0.179	0.209	−0.576	0.126
Green, Purple, White	**−0.417*** **	**0.140**	**0.003**	−0.691	−0.143
Other	−0.037	0.277	0.895	−0.579	0.506
White, Green, Purple	−0.146	0.202	0.471	−0.542	0.250
White, Maroon, Green	−0.112	0.144	0.439	−0.395	0.171
White, Maroon, Yellow	**−0.530** **	**0.227**	**0.019**	−0.974	−0.086
White, Misc	−0.367	0.238	0.123	−0.833	0.100
White, Pink, Yellow	**−0.447** **	**0.183**	**0.014**	−0.805	−0.089
White, Purple, Green	−0.184	0.243	0.448	−0.659	0.291
White, Purple, None	**−0.477* **	**0.244**	**0.051**	−0.956	0.002
White, Purple, Yellow	**−0.491*** **	**0.156**	**0.002**	−0.796	−0.185
White, Yellow, Maroon	**−0.584*** **	**0.177**	**0.001**	−0.932	−0.236
Yellow, Green, None	−0.253	0.202	0.210	−0.649	0.142
Yellow, Maroon, Green	**−0.537*** **	**0.135**	**<0.001**	−0.802	−0.273
Yellow, Misc	**−0.611*** **	**0.215**	**0.004**	−1.032	−0.190
Yellow, Purple, None	**−0.686*** **	**0.210**	**0.001**	−1.098	−0.274
Lncfreq	−0.011	0.093	0.907	−0.192	0.171
Taxonomic Sections					
Brachypetalum	**0.363*** **	**0.131**	**0.006**	0.106	0.620
Cochlopetalum	−0.049	0.126	0.700	−0.296	0.198
Coryopedilum	**0.982*** **	**0.098**	**<0.001**	0.789	1.174
Paphiopedilum	**0.298*** **	**0.085**	**<0.001**	0.131	0.465
Pardalopetalum	**0.675*** **	**0.141**	**<0.001**	0.398	0.952
Parvisepalum	**0.544*** **	**0.124**	**<0.001**	0.301	0.787
Regions					
Asia	0.095	0.085	0.266	−0.072	0.262
Europe	**−0.263*** **	**0.042**	**<0.001**	−0.346	−0.180
No Country	0.304	0.221	0.170	−0.130	0.737
Plant Attributes					
Flowering Size	**0.682*** **	**0.059**	**<0.001**	0.567	0.797
Near Flowering Size	**0.329*** **	**0.065**	**<0.001**	0.200	0.457
Stripes	−0.040	0.052	0.438	−0.142	0.062
Lip Ratio	**0.200** **	**0.091**	**0.028**	0.021	0.379
Spots	0.055	0.038	0.141	−0.018	0.129
Lnrarity	**−0.116*** **	**0.027**	**<0.001**	−0.169	−0.063
Model Diagnostics					
R-squared	0.305				
Adj. R-squared	0.281				
F-Statistic (Model)	13.74***		<0.001		

Notes ***, **, * statistical significance at 1%, 5%, 10% level respectively. All models estimated employing White heteroscedasticity robust covariance matrix. Excluded levels for the dummy variables are: Green, Brown, Purple; Barbata; America; and Seed

Discussion

In our study of Southeast Asian slipper orchids (*Paphiopedilum*), the model results we present are the product of an extensive examination of different model specifications and how we treat colour. Unlike standard hedonic models that include a colour attribute, in this data set there are a larger number of possible colour combinations. In examining the colour combinations, we have carefully considered how robust the model results are to the exclusion of colour and the inclusion of primary only, primary, and secondary and all colour combinations (see Table SI7). What we can conclude from these modelling efforts is that colour can matter at the individual plant level as there are several significant parameter estimates, although in all cases it appears to have a negative relationship with price (a function of how we have dummy coded the data and the excluded category). However, the actual size of the effect in aggregate is small in terms of explaining overall model fit and variation in price although it is statistically significant (see Table SI8). When we move from a model that excludes all colours, to one only including only primary plant colour to three-colour combinations there is minimal improvement in model fit (Adjusted R^2 moves from 0.240 to 0.263 to 0.281). Thus, the inclusion of colour only explains at most 5% of the variation in price. Our findings on colour reinforce those reported by Gale et al. (2019) for orchids on sale in physical markets across South China. They report that price is negatively related to a green flower colour. However, our results go further in that we also observe that frequency of colour combination available on the market is not related to price.

Our research shows that not all species of *Paphiopedilum* are equally valued due to differences in the value of their attributes, especially availability of species in the market. In our analysis, we also considered for all species the extent to which threat status influenced price. However, as the entire slipper orchid genus *Paphiopedilum* is listed in Appendix I of CITES (Hinsley and Roberts 2018) and the majority are threatened according to the IUCN Red List (IUCN 2024), it was not statistically possible to determine the extent to which threat status in the wild influences price or time since first being described. In the future it may be interesting to look at measures of rarity in the wild such as Extent of Occurrence (EOO) or Area of Occupancy (AOO). With regard to taxonomic sections, we find that Coryopedilum (Corya) and Pardalopetalum (Pardal) attract the highest price premiums. These two sections are characterised by large growing multifloral species that can take a significant amount of time to reach a flowering size and space (e.g. *P. gigantifolium*; Hinsley and Roberts 2018).

While it may be possible to identify attributes and their levels that increase the value of *Paphiopedilum* species and from this identify those species that are likely to be impacted through illegal trade, the fact is that newly described species are likely to be highly rare and localised (Roberts et al. 2016) and thus, any unmanaged extraction is likely to threaten a species irrespective of whether the demand is significantly high compared to other species. However, as we have found, it is the rarity of specific species on the market (Table SI4) as opposed to other plant attributes that appears to be key to determining price (Table 3).

Slipper orchids, particularly those of the genus *Paphiopedilum*, are highly threatened through over-collection of plants from the wild, often illegally (IUCN 2024). As the entire genus of *Paphiopedilum* are listed at the highest level of CITES, Appendix I, commercial trade in wild collected plants is not permitted (Hinsley and Roberts 2018). Further, for plants to be considered artificially propagated under the definition of CITES, it requires two or more generations. This, however, presents a challenge in terms of bringing newly described species to the market legally due to the time required to grow them to F2 generation to meet the CITES definition of Artificial Propagation (Hinsley and Roberts 2018).

Further, while the knowledge that a plant is of wild origin does not seem to be a driver of demand for collection from the wild (Gale et al. 2019 but also see Blackhall-Miles et al. 2023), collection from the wild appears to be driven by the fact it is the only source of material for newly described species, and that they are cheaper than artificially propagated material (Gale et al. 2019). Further, many species, such as *Paphiopedilum gigantifolium* from Sulawesi, occur in remote locations where local communities are poor and that plants are likely collected during their normal activities in the hope of selling them to supplement their income. However, in some cases, species may be targeted for collection if there is a known demand or that they are collected to order (Bullough et al. 2021).

Micropropagation facilities within range states could provide a legal, sustainable, source for the horticultural trade, as well as revenue to the local economy. This is particularly relevant for highly sought-after and recently described species. One example is *P. rungsuriyanum* from Laos that caused a sensation on its discovery because of its flower colour, but particularly for its diminutive size that was seen as having significant potential for breeding miniature (also known as tea cup) window-sill *Paphiopedilum* hybrids (Gruss 2024). However, given the technological requirements to established facilities, it is unlikely to provide benefits to local communities where the species grow (Roberts pers. obs.), who would still collect plants in the hope of selling them as they are still likely to be a cheaper source compared to micropropagated plants (see Gale et al. 2019). In addition, as Hinsley et al. (2015) showed in their choice experiment, half of the demand for orchids is driven by the trade in common hybrids such as *Phalaenopsis*, compared to the 25% of consumers that desire rare species. Therefore, from a business perspective it is likely that micropropagation facilities would grow the high demand hybrids before moving into the rather niche market of species orchids (T. Huynh pers. comm.).

In summary, this study using market level data and hedonic regression analysis aimed to examine the relationship between a range of plant attributes, particularly flower colour, and price for species of Southeast Asian slipper orchids (*Paphiopedilum*). Our analysis reveals that taxonomic sections, plant size, plant colour and rarity on the market, influence price. However, it is important to note that that coding colour (primary and other) for statistical analysis is challenging. This resulted in a model capable of explaining approximately 30% of the variation in price. Thus, although we can begin to understand the extent to which observable plant attributes influence price there is clearly scope to improve model performance. Given the heterogenous nature of how orchids are advertised and sold, future modelling exercises need to collect more data so that the potential variation in price can be more precisely captured. With improvements in this type of model specification it may then become possible to investigate new species coming to market that are of greatest conservation concern.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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