Short Communication

Running Header: The wild origin dilemma

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Abstract

The sustainable production of trade plants, animals and their products, including through artificial propagation and captive breeding, is an important strategy to supply the global wildlife market, particularly when the trade in wild specimens is restricted by CITES or other wildlife trade legislation. However, these production methods can become a potential mechanism for the laundering of material illegally collected from the wild, leading to recent calls for the development of traceability methods to determine the origin of traded products. Currently, identifying wild origin can be complex and may require expert knowledge and/or resource intensive molecular techniques. Here we show, using CITES Appendix I slipper orchids as a model system, that production times can be used as a threshold to identify plants in trade that have a high likelihood of being of wild origin. We suggest that this framework could be used by enforcement officers, online vendors, and others to flag material of potential concern for orchids and other high value plants in trade. Specifically, this knowledge combined with nomenclature and the CITES trade database could be used to construct a species watch list and automate online search. The results suggest that had this been applied, questions would have been raised regarding online sales of three recently described species.

Keyword: CITES, enforcement, horticulture, illegal wildlife trade, Orchidaceae, traceability

Highlights

- Laundering of wild origin material has resulted in calls for improve traceability
- Frequently used methods can be expensive and impractical for species-rich taxa
- Production times can provide thresholds to identify material of questionable origin

1. Introduction

Whilst artificial propagation and captive breeding may provide a sustainable source of wildlife for trade, both plants and animals, it also provides an opportunity for laundering of wild specimens into legal trade. Physical examination of specimens is often used to identify wild-origin, using factors including the general size and condition of the individual, and specific signs such as insect damage on the leaves and roots in plants, or damage such as scars in animals. Due to the subjective nature of this approach, and the difficulty that non-experts may face in making this judgement, there has been a move towards the use of molecular techniques such as DNA fingerprinting (Dawnay et al., 2009) and isotope analysis (Kelly et al., 2008) to determine wild-origin. Whilst these techniques have great utility, they require time, funding and technical capacity that makes them difficult to apply universally (Hinsley et al., 2016a).

The threat that laundering poses to legal, sustainable wildlife trade has led to an increased awareness of the need for traceability within the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES). Traceability was the focus of multiple decisions at the 2016 CITES Conference of Parties (e.g. Decision 17.152) and there have been several reports on traceability in major CITES species groups in recent years (e.g. reptiles: UNCTAD, 2013; sharks: Mundy and Sant, 2015; ornamental plants: UNCTAD, 2016). One such report commissioned by the United Nations Conference on Trade and Development's (UNCTAD) BioTrade Initiative in consultation with the CITES Secretariat highlighted the need for improved traceability in ornamental plants, the product group containing the largest number of species listed by the Convention (CITES, 2011). The high number of ornamental plant species on CITES is mainly due the listing of all orchids, which account for over 70% of all CITES taxa, with over 26,000 species known to science and a further 5,000 likely awaiting discovery (Joppa et al., 2010). Currently several hundred new orchid species names are published annually (e.g. 370 in 2013: Schuiteman, 2017) and the family level listing means that these are automatically included on the CITES Appendices. New species of certain genera are listed automatically on Appendix I, including the entire Southeast Asian slipper orchid genus *Paphiopedilum*. This group is highly sought-after by the trade, leading to extreme depletion and extinction of wild populations of newly described species in some cases (e.g. *Paphiopedilum canhii*: Rankou and Averyanov, 2015). The process of species discovery, description and entry into the trade can vary. Following discovery, species can then be described relatively soon after, or in some cases they can languish unnoticed in museum collections before description. However, some species enter the trade under the name of an existing species, or as a trade name, only to be recognised as a distinct species at a later date.

Here we describe a potential method to address the need for improved traceability to prevent laundering of ornamental plants, using the trade in CITES Appendix I *Paphiopedilum* orchids as a model system. Laundering to bypass CITES rules is known to occur in the orchid trade (Hinsley et al., 2016b) and laundering via plant nurseries may give plants the appearance of being artificially propagated, making the identification of wild plants using physical features particularly difficult for a non-specialist. One strategy that may help address both points is to identify those species that have the greatest likelihood of being of wild origin, to focus attention and resources on the most 'at risk' species. Here we outline a method to do this, using the minimum timings for key growth stages as a potential metric to identify those species that are unlikely to have been artificially propagated. This method could equally be applied to animals to determine whether, given their growth rates, they could have been captive bred.

2. Materials and Methods

Our study was approved by the University of Kent, School of Anthropology and Conservation's Research and Ethics Committee. We sent an online survey (hosted on SurveyGizmo.com) to professional commercial and hobbyist growers, and botanical gardens with Paphiopedilum collections (See Supplementary material A1 for survey). A call for survey participants was also shared through the British Paphiopedilum Society newsletter. Snowball sampling was also used to reach more experts; participants were asked to suggest anybody they knew with experience growing Paphiopedilums from seed until all new suggestions had already been contacted.

We asked participants to state the geographical location where they grew their orchids, and to rate the extent of their growing experience at the genus level, and specifically in relation to each subgenus and section of Paphiopedilum. For each section or subgenus where they had the relevant experience, we asked for the shortest, longest and average time (in months) from (a) seed to flowering and (b) pollination to seed. On the last page of the survey we provided an open text box for feedback, including a request for any specific information not gathered that may influence the timings from seed to flowering size.

We used the shortest and longest times reported by respondents to produce descriptive statistics for all sections and subgenera, including mean, median, maximum and minimum length of time from seed to flowering, and pollination to seed. We used these statistics to produce box and whisker graphs to show the distribution of the times stated, and a summary of estimated timings to produce key traded orchid products.

3. Results

We sent questions about seed to flowering, and pollination to seed timings for Paphiopedilum orchids to international experts. A total of 37 people accessed the survey page, with 18 completing at least one of the questions about pollination to seed, or seed to flowering times. The majority of people (n = 14) who abandoned the survey did so on the first question about specific experience of growing different subgenera and sections. As not all growers have expertise on all species, questions on timings from pollination to seed for specific subgenera or sections received between five and eight responses, and for seed to flowering between four and six. Some people responded by email to say that very few in the industry had specific knowledge of the growing times requested. Respondents also noted that timings may be affected by the growing conditions, including climatic conditions in different locations.

Respondents who gave their country of origin were from the United States (n = 9), United Kingdom (n = 4), Malaysia, the Netherlands, Spain, Switzerland and Viet Nam (n = 1 each), and were hobbyists specialising in Paphiopedilums (n = 7), professional growers (specialising in Paphiopedilum: n = 5 or other genera: n = 3), and researchers (n = 4). The median timings from pollination to seed ranged from 6 months (subgenus Brachypetalum and section Pardalopetalum) to 9 months (section Paphiopedilum), and from seed to flowering from 24 months (section Barbata) to 60 months (section Coryopedilum). The minimum timings from pollination to seed ranged from 3 months (sections Pardalopetalum and Coryopedilum) to 10 months (subgenus Parvisepalum and section Coryopedilum) and from seed to flowering from 8 months (section Barbata) to 96 months (section Coryopedilum). The distribution of timings from seed to flowering are shown in Figure 1, and from pollination to seed in Figure 2 (See Supplementary material A2 for all data).

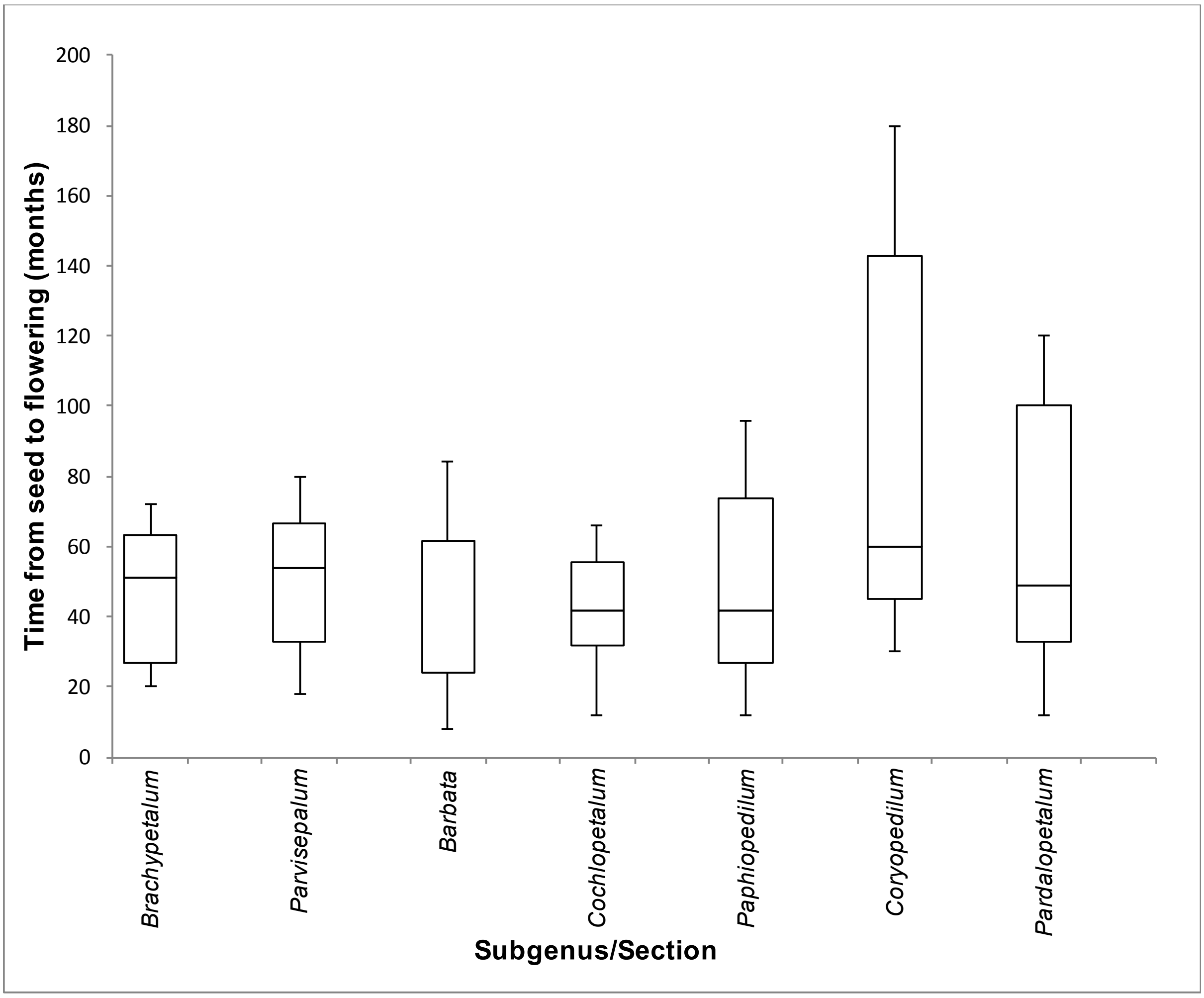

Figure 1: Box and whisker plot showing distribution of responses for the shortest and longest time from seed to flowering of different Paphiopedilum subgenera and sections

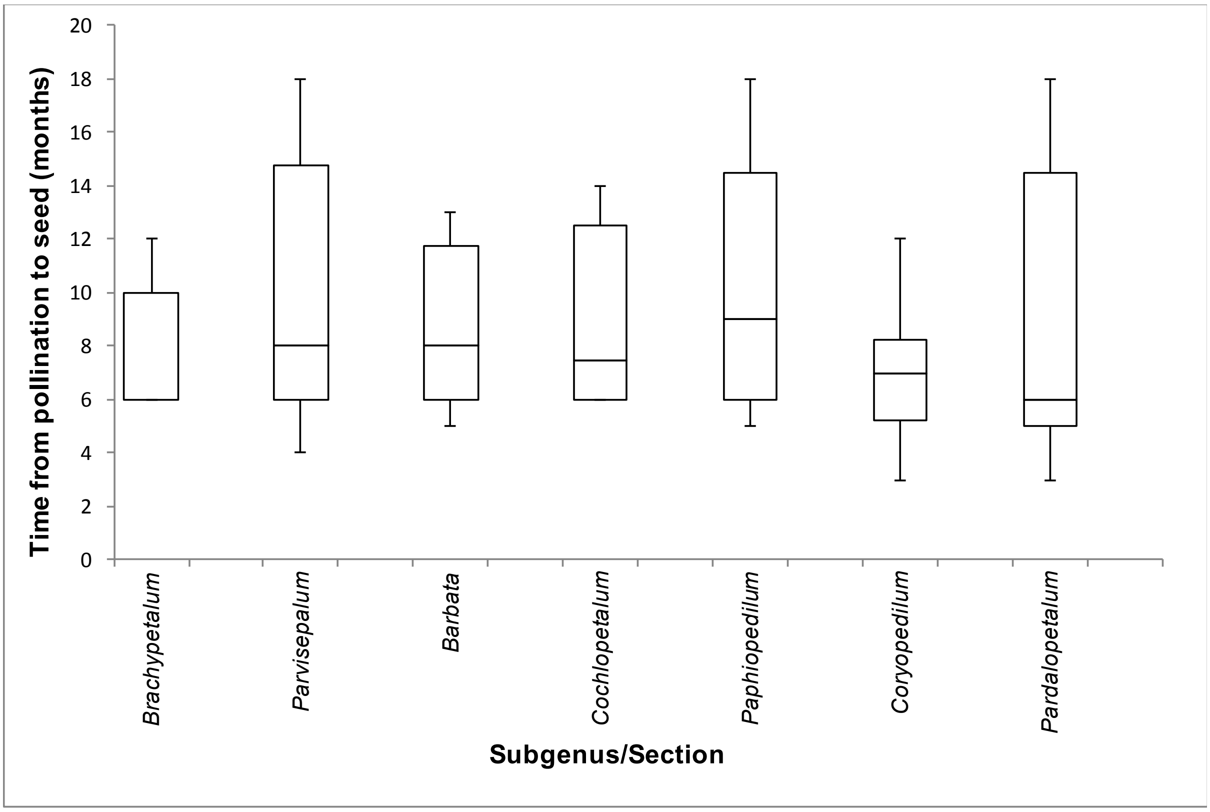

Figure 2: Box and whisker plot showing distribution of responses for the shortest and longest time from pollination to seed of different Paphiopedilum subgenera and sections

We can use the minimum timings to estimate the shortest amount of time needed to produce artificially propagated plants of a newly discovered species according to the following steps. While rumours may exist of new species, it is the point at which the species is described that it may become known within the wider community. Generally when orchids are collected from the wild for horticultural purposes it is as plants that can be flowering or non-flowering; it is unlikely to be as seeds. As a result for wild plants to flower it can take 0 (assuming it was collected in flower) to 1 year (assuming it flowers within the next season); although given the impact of collection it may take longer to recover and acclimatize. The plant is pollinated and seeds are produced, these are then sown and eventually, after a period of time, a flowering plant is produced. This would be the absolute minimum time required to produce artificially propagated plants. However, for international trade, the CITES definition of artificially propagated states that the parent plant itself must be cultivated (except where the species is too long lived for this to be feasible) (CITES Res. Conf. 11.11 (Rev. CoP17)). This means that two generations are needed before a plant meets this definition of artificially propagated. Considering this requirement, plus the time that would be required to gain permission to collect material and commercialise the species, and obtain permits for export, as a precaution the time from pollination to flowering should be doubled to allow plants from artificially propagated parent stock to be potentially produced legally particularly in the case of an Appendix I species. This resulted in minimum timings of between approximately 2.0 to 6.5 years, depending on the subgenus or section, (Table 1).

Table 1: Minimum number of months required following the description of a new Paphiopedilum species to produce artificially propagated material, assuming pollination on collection.

Subgenus/ Section	**Estimated minimum time to produce artificially propagated material (accumulated time) in months**		
	Pollination to first seed	Seed to flowering plant using micropropagation	Pollination to flowering x 2
Brachypetalum	6	20 (26)	26 (52)
Parvisepalum	4	18 (22)	22 (44)
Barbata	5	8 (13)	13 (26)
Cochlopetalum	6	12 (18)	18 (36)
Paphiopedilum	5	12 (17)	17 (34)
Coryopedilum	3	30 (33)	33 (66)
Pardalopetalum	3	12 (15)	15 (30)

4. Discussion

The global and diverse nature of the wildlife trade means that monitoring and controlling such trade requires a variety of approaches. As a result there are increasing moves towards the use of ever more sophisticated techniques for providing traceability of wildlife, such as molecular techniques and stable isotope analysis (Kelly et al., 2008; UNCTAD, 2013). Whilst these methods have application in some cases, simple techniques are also needed to allow effective trade regulation in cases where funding and capacity are limited. Here we demonstrate a simple method for judging whether a traded plant is likely to be compliant with CITES, using an example of an Appendix I orchid genus, *Paphiopedilum* (Southeast Asian slipper orchids).

We estimated the time from pollination to seed and from seed to flowering of species from the slipper orchid genus *Paphiopedilum*, a group that is in high demand within the horticultural industry, and for which a number of species have been recently discovered (e.g. *P. nataschae*: Braem, 2015). This knowledge can help focus attention on those species in trade that are most likely to be of wild origin, as it is highly unlikely, if not impossible, for plants to have been artificially propagated in less time. Further, CITES states that for a species to be traded as artificially propagated the parent stock has to be legally acquired, or the permit is invalidated (CITES Res. Conf. 11.11 (Rev. CoP17)). This includes material traded *in vitro*, for which permits are usually not required (annotation #4: CITES, 2011). Applying this to a real example, one of the most recently described *Paphiopedilum* species was *P. nataschae*, a species in section *Barbata* that was described in May 2015 (Braem, 2015). Using our estimated timings, if plants were legally collected for propagation in the month of description then seed from pollinated plants of *P. nataschae* would have been place *in vitro* as early as October 2015, with flowering sized plants being available in June 2016. Further, plants meeting the CITES definition of artificially propagated would be available in July 2017, suggesting that any material offered for sale internationally until then should have been questioned. It is interesting to note that a flowering size plant of this species was sold on eBay from a non-range state in November 2016 (pers. obs.). A further example, again from the section *Barbata*, is *P. canhii*, described in May 2010 (Averyanov et al., 2010), and offered for sale on eBay from a non-range state in June 2011 (pers. obs.). The earliest we estimate artificially propagated plants would have been produced is June 2011, assuming legal collection of flowering material for the production of seed at the time of description. For the production of *P. canhii* plants meeting the CITES definition of artificially propagated, the earliest we estimate they would be available is July 2012 (using the 2 x from pollination to flowering). It is important to note that in the case of orchids, they are, with a few exceptions, grown for their flowers. It is the period, from discovery to the first legally artificially propagated plants of flowering size, during which wild populations are particularly vulnerable to over-exploitation as they are the only source of flowering plants for collectors and those wishing to produce the first hybrids. In the case of *P. vietnamense* (section *Parvisepalum*) it was described in 1999 new to science only to be declared extinct in the wild in 2003 due to over-collection for the horticultural trade (Averyanov et al., 2003); ironically this is approximately the precautionary threshold for legal production. In some cases, wild plants are being collected before formal description, such as the species *P. lunatum* and *P. bungebelangi* (section *Barbata*) described in March 2017 (Metusala, 2017). In these cases, the threshold for legal plants would be May 2019, but *P. bungebelangi* was being traded on Instagram under its new name in April 2017, only one month after its description (pers. obs.). Although in cases such as these nursery-grown plants may enter trade earlier than described here, the legality of plants produced from material collected before description would depend on national legislation regulating collection of wild plants.

Newly described species from taxa that are sought after are at risk from over-exploitation (Lindenmayer and Scheele, 2017). The framework described here could be applied beyond orchids to other traded plant taxa that are species-rich, of horticultural value, and for which new species are still being discovered. This includes aloes, euphorbias, carnivorous plants, and cacti, with all newly discovered species of the latter reported to be under pressure from illegal trade (Goettsch et al., 2015). Further, by the very fact that some species are only now being discovered means they are likely restricted in range and therefore threatened (Joppa et al., 2010; Roberts et al., 2016), including from over-exploitation. In some cases it is this rarity that appeals to collectors (Courchamp et al., 2006; Hinsley et al., 2015). As a result there have been calls for locality data to be withheld from descriptions from new species (Lindenmayer and Scheele, 2017). The method could also be extended to species-rich animal taxa that are collected for trade, and for which discoveries continue to be made, such as poison arrow frogs and chameleons. The latter is an interesting case as until recently many Malagasy chameleon species, particularly from the genera Calumma and Furcifer, were largely unavailable in trade as they had a zero quota, in effect making them analogous to newly discovered species.

Returning to plant related examples, this knowledge of production time could be used in conjunction with the International Plant Names Index (www.ipni.org) or similar resources (e.g. World Checklist of Selected Plant Families - http://apps.kew.org/wcsp or The Plant List - www.theplantlist.org) that provide a continuously update list of species as they are described, to construct a 'Species To Watch' list; a list of species that are unlikely to be available for legal trade at the current time. Such a system could be automated and, with moves towards electronic permitting (CITES, 2013), potentially linked into the CITES permitting process, as well as online sites through which plants are be being sold. Certainly if such a system had been in place, merely using the Latin name (most plants and animals in the horticultural and the exotic pet trades are traded under their Latin name) of these newly described slipper orchids, then their sale on eBay would undoubtedly have been identified immediately by eBay and/or law enforcement.

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