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"INVISIBLE" WILDLIFE TRADES: SOUTHEAST ASIA'S UNDOCUMENTED ILLEGAL TRADE IN WILD ORNAMENTAL PLANTS

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"Invisible" wildlife trades: Southeast Asia's undocumented illegal trade in wild ornamental plants

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ABSTRACT

Conservation and environmental management often rely heavily on official statistics, but there are often concerns over accuracy and reliability, particularly true when dealing with sensitive issues such as illegal harvest and trade. A growing number of cases highlight commercial trades in wild flora and fauna that have been undocumented in official data. Here we present the first in-depth study of the trade of wild-collected ornamental plants in continental Southeast Asia, focusing on the four largest wildlife markets in Thailand. Botanical surveys revealed a massive, previously undocumented commercial trade in wild, protected ornamental plants involving Thailand, Lao PDR and Myanmar, focusing primarily on the Orchidaceae. The results indicate that illegal trade threatens not only charismatic Southeast Asian mammals, reptiles and amphibians, but also hundreds of tropical plant species. Trade surveys identified 347 orchid species in 93 genera, including many listed as threatened. The observed cross-border trade moves plants at a rate orders of magnitude larger than government-reported statistics, and directly conflicts with official policy statement. Harvester interviews strongly indicated that wild collection was negatively affecting the majority of species they traded. Despite three decades of broad restrictions on the international trade of all wild orchids, these results highlight a major conservation challenge that has been almost completely overlooked. There is urgent need to improve botanical trade monitoring, to operationalize existing conservation commitments, and as part of a broader, multifaceted response to illegal trade. We call for increased attention to botanical trade and conservation in Southeast Asia, and argue that efforts to tackle illegal wildlife trade must ensure they include flora.

1. Introduction

1.1. Challenging official statistics on illegal wildlife trade

Conservation and environmental management often rely heavily on official statistics, generated or compiled by government agencies. However, there is concern that these baseline datasets are unreliable, potentially supporting "bad policy" (cf. Friess and Webb, 2011). Such data limitations are particularly notable in the context of the illegal harvest and trade of wild plants and animals. A growing number of studies highlight that low detection rates, under-reporting and non-reporting in government statistics has resulted in a number of "invisible" phenomena that threaten biodiversity (e.g., Flores-Palacios and Valencia-Diaz, 2007; Challender and Hywood, 2012; Caillabet, 2013). Opportunities to verify and improve official wildlife trade data are thus intensely important to designing improved interventions.

Commercial wildlife trade is a leading threat to biodiversity. Improved data on these illegal trades is critically important in the context of charismatic, rare and/or high-value species, such as rhinoceros, rosewood, tigers and elephants, as well as wide range of smaller, less well-known species (e.g., seahorses, plants, reptiles, amphibians; see Nijman et al., 2012). International trade of nearly 34,000 species is restricted under the Convention on the International Trade in Endangered Species of Flora and Fauna (CITES), a multilateral agreement established in with 180 national signatories that restricts (and in some cases bans) the international trade of species threatened by commerce.

Government agencies, notably national CITES Scientific and Management Authorities, are responsible for collecting data on the international trade of CITES-listed species. They also set domestic harvest quotas for some species, and conduct Non-Detriment Finding studies to identify cases in which international trade can be allowed without harming wild populations (see

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Rosser and Haywood, 2002). Official trade data further help to guide enforcement intervention, inform threat assessments (e.g., IUCN Red List, CITES listings) and guide conservation interventions (e.g., protected area designations). There are mounting efforts to support governments to improve trade monitoring, including multilateral efforts such as the Lusaka Agreement Task Force (http://lusakaagreement.org/?page_id=24), ASEAN Wildlife Enforcement Network (http://www.asean-wen.org), the Last Great Ape Association (http://www.laga-enforcement.org) and the Wildlife Enforcement Monitoring Systems (WEMS) Initiative (Chandran et al., 2013).

However, a growing number of third-party monitoring and research efforts are challenging official statistics on wildlife trade. Despite the methodological difficulties of studying illegal trade (see Keane et al., 2008; Wyatt, 2009), recent investigations have uncovered illegal wild trade that are otherwise "invisible" based on official statistics. These include documentation of existing trades, such as the South Korean market-based trade of mink whale meat (Baker et al., 2007), bushmeat trade from Africa into Europe via air (Chaber et al., 2010), and commercial seahorse harvest in Viet Nam (Giles et al., 2006). Recent cases have documented novel trades in species that were previously not widely traded, such as a recent emergence of trade in tokgay geckos for the medicinal trade (Caillabet, 2013). Independent investigations have documented shifts in the geographies and intensities of harvest and demand, including a broadening regional demand for edible Tanzanian orchid tubers (Davenport and Ndangalasi, 2003), and a growing Asian demand for African pangolins (Challender and Hywood, 2012). Studies have uncovered manipulations of international trade regimes, such as trade via 3rd countries (Nijman and Shepherd, 2010). Notably, the non-governmental wildlife trade monitoring network, TRAFFIC, has documented a wide range of cases of previously unreported illegal trade (see http://www.traffic.org/bulletin/). A number of alternative strategies are also emerging to improve trade monitoring efforts, even in contexts where trade is hidden. These include harvest and trade modeling techniques (Clarke et al., 2006; Keane et al., 2008), analysis of trade seizure data (Underwood et al., 2013), mark-recapture techniques (Baker et al., 2007), and integration of data from across diverse sources and platforms (Scotson and Stoner, 2014). There are also mounting efforts to engage civil society and crowd-sourcing to monitor and illegal harvest and trade (Brack and Leger 2013; TCSA, 2014).

1.2. Trade in orchids and other ornamental plants

Ornamental plants are widely traded for their horticultural values. The family Orchidaceae is of particular interest because all orchid species are CITES-listed, and the family represents more than 70% of CITES-listed species (CITES, 2014). This broad regulation is the result of a precautionary approach because Orchidaceae includes many "look alike" species (Clemente-Munoz, 2009). These "look alike" species include those for which "a non-expert, with reasonable effort, is unlikely to be able to distinguish among the species, or that a species is of a taxon of which most of the species are included in Appendix II or Appendix I closely resemble CITES-listed species" (CITES, 2002). As a result, the vast majority of orchids are CITES Appendix II-listed, which allows international trade with permits and Non-Detriment Findings. A sub-set of species, notably in the pan-Asian genus *Paphiopedilum*, are listed on CITES Appendix I, which fully bans international commercial trade.

Southeast Asia is the center of global orchid diversity (Table 1). The region has a long history of commercial trade in wild ornamental plants resulting in extirpated local populations and threats to species conservation, such as to *Paphiopedilum* species (Cribb, 1987; Cribb et al., 2003; Averyanov et al., 2003, 2010). Indeed, commercial trade is a well-recognised stressor on Southeast Asian biodiversity (e.g., Sodhi et al., 2004, 2010; McNeely et al., 2009; CBD, 2010; Nijman, 2010).

Table 1
Approximate number of orchid genera and species in Thailand, Myanmar, Lao PDR.

Country	Genera	Species	Reference
Thailand	~162	~1200	(Schuiteman and de Vogel, 2000; Govaerts, 2012)
Myanmar	<150	~800	(Kurtzweil, pers. comm. 2009)
Lao PDR	108	485	(Schuiteman et al., 2008)

Botanical trade in Southeast Asia has been subject to little research, limited to several short and local surveys (Foppes et al., 1996; Ashwell and Walston, 2008; WWF, 2009; Hinsley, 2011), and anecdotal reports (e.g., Rusea et al., 2009; Schuiteman et al., 2008; Lamxay, 2008; Averyanov et al., 2003, 2010). The commercial trade dynamics have thus remained largely undocumented.

We sought to highlight this under-recognised conservation challenge by conducting the first in-depth study of the trade of wild-collected ornamental plants in continental Southeast Asia, illustrating the need and potential for improved monitoring in the field. Here we present species lists from botanical surveys conducted at four plant markets in Thailand, complemented with an overview of regional trade dynamics that includes evidence of cross-border trade derived from market surveys and interviews with plant traders, intermediaries and harvesters. Finally, we contrast market survey results against government-reported CITES data to reveal an extensive ornamental plant trade that is almost completely undetected by official statistics. We consider the implications of our results specifically for wildlife trade monitoring and trade restrictions, as central parts of broader, multifaceted botanical conservation efforts.

2. Methods

2.1. Study sites and market survey design

We identified plant markets across Thailand, with the assistance of traders, collectors and local experts. We visited markets across the country and used a chain referral approach to identify additional sites, the largest of which were selected for in-depth study. Over the course of one year (2011–2012), we conduced botanical surveys and interviews with traders at all stalls selling live, wild-collected plants at the four largest plant markets in Thailand (Fig. 1): Jatujak (Bangkok, Thailand), the Mukdahan Indochine (Thailand-Lao PDR border), Chedi Sam Ong and Dan Singkorn (Thailand-Myanmar border). Long-term surveys were conducted in order to account for phenology and ensure maximum species detection.

Botanical surveys were conducted to construct species lists, establish relative abundances, and document countries of origin. These included quarterly surveys at the three target border markets. Jatujak Market, due to its relative size and accessibility, was subject to monthly surveys, and additional 'rapid surveys' every 2 weeks to ensure maximum detection, including of species that might only be traded during relatively short periods (e.g., only while in bloom). Heavy flooding in the last quarter of 2011 eliminated one of the quarterly surveys at the border markets and both November surveys at Jatujak.

Surveys were conducted on the main market day of each site, and started as traders arrived at the market to set up. Each survey began at a random stall in the marketplace and included all stalls selling wild plants in the market. Wild plants were easily

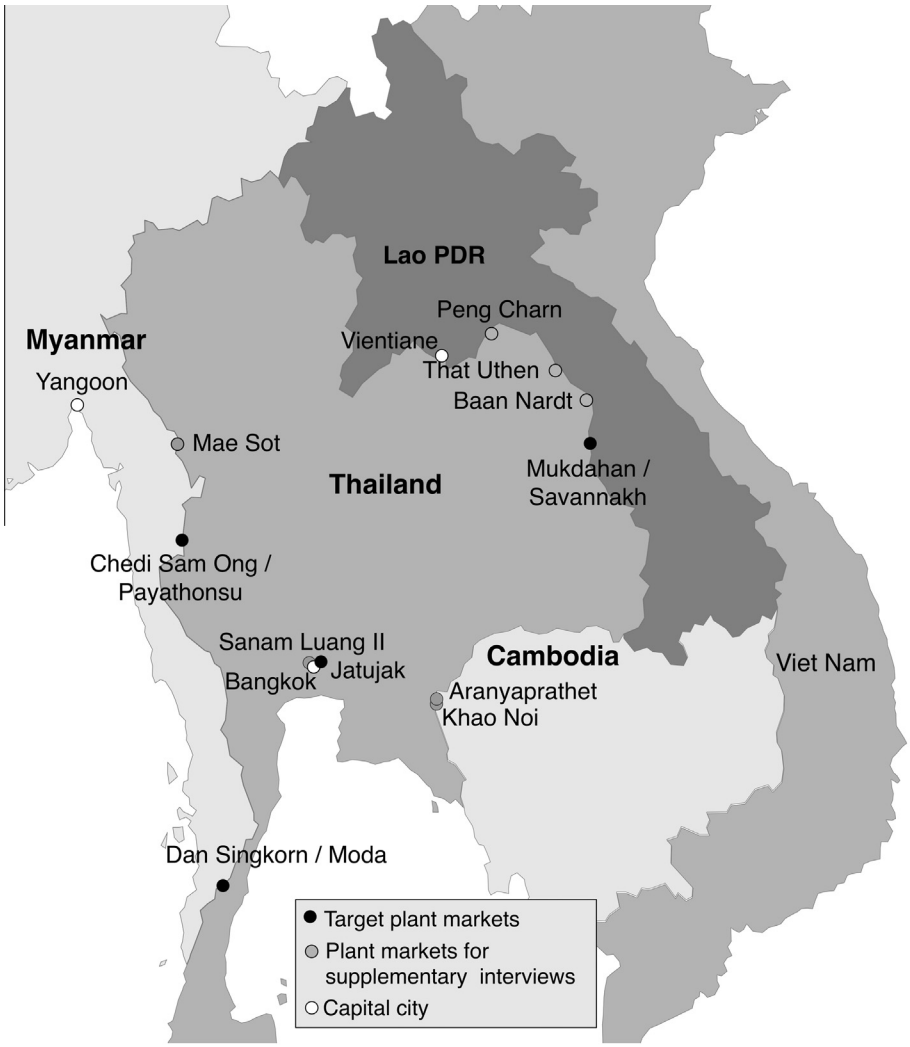

Fig. 1. Location of study sites, including target plant markets for surveys and trader interviews, and sites of supplementary interviews. Map indicates both Thai place names and names of corresponding cross-border towns in Myanmar and Lao PDR.

distinguished from farmed based on their physical condition, using guidelines from Kew Botanic Gardens and the CITES Secretariat for customs agents (McGough and Groves, 2004; GreenCustoms ND). Surveys were conducted quickly, in order to be completed before the plants were sold and before market end. With the exception of Dan Singkorn, which is particularly large, all surveys were conducted within one day. During surveys, all specimens at each wild plant stall were identified, counted, and information was collected on plant origin.

2.2. Taxonomy

There remains considerable taxonomic debate within Orchidaceae. We generally relied on existing nomenclature, following the observations of Schuiteman et al. (2008) that recent nomenclatural or phylogenetic studies have, in a number of cases, resulted in unnecessary changes. The ensuing shifts are often burdensome, including because the required combinations for naming are not yet available and because the limited existing taxonomic references for the region become obsolete. Moreover, the classification of several large taxa (e.g. *Coelogyne, Liparis, Eria*) remains unstable. Additional notes on taxonomic approach are available in Table A1.

Most plants encountered were sterile (84.1%), which presented a taxonomic challenge because most orchids are identified based on floral characteristics. As such, surveys were conducted over a one-year period to account for phenology. Identification was also restricted from collecting live vouchers due to the illegality of purchasing plants, as well as the high costs and logistics of purchasing plants to grow them plants until they bloom.

While previous studies in the region have claimed near 100% species-level identification during market surveys (Foppes et al., 1996; WWF, 2009), even experts struggle to identify many orchids from sterile plants (see Flores-Palacios and Valencia-Diaz, 2007). As such, reliable identification in most cases was only possible to the genus level. Sterile specimens of the genera *Dendrobium* and *Paphiopedilum* were reliably identified to section and subgenus, and blooming specimen were identified to species. Using this hierarchy, the first author (JP) was 'certain' in his identification of the vast majority of records (4810/5841, 82%). When possible, samples of flowering specimens were collected, preserved in 70% ethanol and 30% water, and deposited at the Bangkok Royal Forest Herbarium. In addition, photographic vouchers (2341) were taken of all flowering specimens, for genera that were encountered for the first time during surveys, and specimens for which field identification was uncertain.

A sample of 596 records was selected for external verification by the Bangkok Royal Forest Herbarium. This represented 11.5% of total observations, including 7% of identifications about which the researcher was 'certain', and 46% of 'uncertain' identifications. The number of external verifications was limited by the time availability of domestic taxonomic expertise. There was high congruence between identifications made during market surveys and the external verifications: 94.6% agreement with 'certain' genus-level identifications and 83.3% agreement with 'certain' species-level identifications. There was also high congruence between section-level identifications for the genera *Dendrobium* (89.9%) and *Paphiopedilum* (90.0%). Agreement for the 'uncertain' identifications was predictably lower: 63.2% agreement at the genus-level and 46.6% at the species-level. However, those records represented only 7.9% of total orchid records. Moreover, review of the external verifications identified that 19% of disagreements were at the species-complex level and/or likely represented mistakes.

Despite proposals that DNA barcoding techniques can be used to confidently identify illegally traded orchids (Sosa et al., 2013; Subedi et al., 2013), this proved impractical in this study due to cost, remaining uncertainty over species-level resolution within genera with many closely related species, and the demands of creating a genetic library for the ~1500 species in the region.

2.3. Plant quantities, origins and trends

For each species encounter at a market stall, the number of plants was recorded. Unlike for other taxa, such as animals and trees where individuals are clearly distinct, this is less clear for plant ramets, where reproduction can be sexual or by rhizomes, corms or tubers. Units in observed counts were thus based on the number of plant bundles (potentially including multiple individuals or cuttings of different individuals) plus the number of individuals (potentially divisions of larger plants), both recorded as single units. This follows the CITES approach and that used elsewhere (see Flores-Palacios and Valencia-Diaz, 2007; Phelps et al., 2010), but is not necessarily representative of the number of genetically distinct individuals.

Each time a blooming specimen was encountered during the market surveys, the trader was asked to report on its region or country of origin, if known. Traders tended to use the same procurement lines over time and so usually knew the country of origin of their plants, if not the specific collection details. In addition, we identified a group of 20 species (from 11 genera) that were regularly encountered during surveys at all four markets (see Fig. A4). Each time one of these species was encountered, we collected reported country of origin.

We also conducted informal interviews with wild plant harvesters, traders and intermediaries in Thailand, Lao PDR and Myanmar (Fig. 1). We interviewed the primary owner of every stall in the marketplace at Jatujak ($N = 16$), Mukdahan ($N = 34$), Chedi Sam Ong ($N = 22$) and Dan Singkorn ($N = 63$). This represented near saturation sampling of the markets, and we encountered very few refusals, except at Jatujak where seven traders refused to participate in interviews (although they permitted botanical surveys). Supplementary interviews were conducted traders at That Uthen, Sanam Luang II and Mae Sot Markets ($N = 13$). Opportunistic interviews, obtained via referrals from market traders, were conducted with middlemen and harvesters from central Lao PDR around Savannakhet Province ($N = 12$), and with harvesters in Southern Myanmar around the vicinity of Dan Singkorn, Chedi Sam Ong and Mae Sot Markets ($N = 20$). These interviews were fewer and more restricted than market trader interviews due to limited access to respondents due to their scattered geography and, in some cases, non-response due to the sensitivity of illegal trade. Further informal discussions were held with traders at several other markets (Fig. 1).

Interviews were semi-structured, private, and conducted in respondents' preferred language (Thai, Lao, Burmese, Karen), facilitated by skilled research assistants. Interviews explored a range of socio-economic and demographic information (not presented here), as well as information on plant origins and trends, which is the principle focus of this analysis. Interviews included ranking exercises, in which respondents were presented with cards with the names, flags and outlines of countries in Southeast Asia, and asked to order them, from the country from which they received the most of their plants down to those from which they received the fewest or none. This served to cross-check origin data obtained during market surveys. Interviews with harvesters further included open-ended questions about changes in plant populations in the time since when they started collecting.

2.4. Survey limitations

The survey method only captured a fraction of trade volume for several reasons. First, plants sales occurred throughout the day so not all plants were detected during the survey. Some traders operated outside of the marketplace, making additional bulk sales by the kilo. Further, while we targeted surveys on the largest market days, many stalls were open on multiple days of the week. While new plant stock usually arrived in preparation for the largest market day, some traders were also seen to receive new stock on other days. In addition, despite long-term surveys to account for phenology, species accumulation curves (Fig. A1) show that additional species continued to be encountered at Jatujak Market and so the species list remains incomplete.

In addition, the technical limitations on identifying genetically distinct individuals in trade means that the study cannot yield precise trade volumes or detail species-specific conservation implications. Relative abundances may be skewed by this phenomenon and must be interpreted with caution. These limitations to detection were similar to those facing government data-collection, the CITES database, and enforcement.

2.5. Government-reported trade on the CITES database

We collected international orchid trade volumes from the CITES online database (2014). The database, managed by UNEP-WCMC, includes all records of international import, export and re-export of CITES-listed species reported by signatory countries. We considered records starting in 2004, when Lao PDR and Myanmar became CITES signatories, until 2012. These records were compared with market observations.

2.6. Conservation threat analysis

We conducted a coarse threat analysis for the species encountered (Table A2), integrating available published information. Preliminary conservation assessments for Thailand were available for approximately one-third of the encountered species from Thailand, taken from "The Preliminary Check-list of Threatened Plants in Thailand" (Pooma, 2005), and the "Thailand Red Data: Plants" checklist of threatened plant species (Santisuk et al., 2006) to identify species of particular concern. Neither checklist used updated IUCN criteria, and justifications for individual species listing were not provided. Nevertheless, Brito et al. (2010) demonstrated significant concurrence between national-level threatened species lists and IUCN Red Lists, suggesting that lists prepared for Thailand are likely to overlap with more rigorous evaluations.

No detailed species-specific life history or distributional data has been published for most of the species encountered, and

existing evaluations drew from taxonomic references rather than conservation assessments (UNEP-WCMC, 2010). No species in the target region had been evaluated using the IUCN Red List guidelines (IUCN-OSG, 2009; IUCN, 2012), and rigorous application of the IUCN Red List criteria based on published material would likely list most species as Data Deficient (IUCN, 2012). In the absence of existing evaluations, we determined Extent of Occurrence (EOO), and gathered assorted information on conservation status or abundance from the World Conservation Monitoring Center Threatened Species Database (UNEP-WCMC, 2010), Kew World Checklist of Orchidaceae (Govaerts, 2012), lists of threatened plants for Thailand (Pooma, 2005; Santisuk et al., 2006), and diverse taxonomic references (e.g., Seidenfaden, 1975–2003). Conservation status and EOO were integrated with market survey data (Table A2). Where species encountered in trade (>10 units encountered) overlapped with records that indicated the species had been designated as threatened (according to any of the available literature and their respective threat categories) or as a country endemic, we considered these as potentially threatened by regional trade (Table A2). Considering the lack of ecological and trade data, the analysis was supplemented by reports from interviews with harvesters (see Section 2.3).

3. Results

3.1. Trade species composition

Markey surveys revealed a large commercial trade in live, wild-collected ornamental plants. Orchidaceae was overwhelmingly the principle family traded at all four target markets (87.2%). Owing to methodological limitations, this is a highly conservative volume and mostly relevant in terms of understanding relative abundances. Trade also included an eclectic mix of other ornamental taxa (>25 families and >32 genera) in comparatively smaller volumes, including the genera *Tacca, Huperzia, Platycerium, Cycas, Hoya, Amorphophallus, Impatiens, Curcuma, Nepenthes, and Hynophytum/Myrmecodia*. The Appendix includes a species checklist for the four markets, observed trade volumes and relative abundances (Tables A1 and A2).

Botanical surveys revealed 347 orchid species in 93 genera in trade (Table 2). Based on trader-reported country origins (discussed below), this represented approximately 13% of Thailand's known orchid flora (Govaerts, 2012), 22% of Lao PDR's known orchid flora (see Schuiteman et al. 2008), and 15% of Myanmar's known orchid flora (see Govaerts, 2013). Market surveys also uncovered the new species *Bulbophyllum anodon* J.J.Verm., Thavipoke & Phelps, a still undescribed *Thrixsperumum* sp., and several new species country records for both Myanmar and Lao PDR (see Vermeulen et al., 2014). Despite the intensive sampling, new species were regularly added to the Jatujak Market species list; even following 12 months of surveys species accumulation remained at a constant, linear rate (Fig. A1). Predictably, accumulation curves at the genus level began to asymptote much more quickly at all markets, with the most common genera identified on the first survey (Fig. A1).

Table 2
Number of orchid genera and species identified at four target plant markets.

	Jatujak	Mukdahan	Chedi Sam Ong	Dan Singkorn	Total
Number of genera	90	49	46	71	93
Number of species	290	53	51	117	347

Despite high observed richness, a comparatively small number of orchid genera accounted for the bulk of trade (Table 3), with 21 genera traded in volumes exceeding 500 units over the survey period: *Schoenorchis, Calanthe, Seidenfadencia, Chiloschista, Eulophia, Papilonanthe, Geodorum, Habenaria, Coelogyne, Cymbidium, Phalaenopsis, Cleisostoma, Vanda, Ascocentrum, Pholidota, Eria*, the Subtribe Bulbophyllinae (notably the genus *Bulbophyllum*), *Paphiopedilum, Rhynchostylis, Aerides*, and *Dendrobium*. While patterns varied somewhat across markets, trade was dominated by plants with charismatic, large flowers in the genera *Dendrobium, Rhynchostylis, Aerides* and, to a lesser extent, *Paphiopedilum* (Table 3, Table A2). In contrast, *Pholidota, Cleisostoma, Eria* and the Subtribe Bulbophyllinae (including *Bulbophyllum* and allied genera) were highly ranked but are not characterized by particularly charismatic or large flowers. Several non-orchid genera were highly ranked in trade, in particular *Tacca* and *Platycerium*.

Trade in the large genus *Dendrobium* was dominated by species from Section Dendrobium (35.9% *Dendrobium* encounters) and Section Callista (24.4%), including *D. chrysotoxum, D. lindleyi, D. jenkinsii, D. farmeri, D. thyrsiflorum*, as evidenced by both trader reports and market surveys. These species are generally characterized by species with large, brightly colored flowers (Table A3).

The genus *Paphiopedilum* also ranked among the most abundant in trade (Table 3), although all species in the genus are considered locally and globally endangered and are listed on CITES Appendix I. The most commonly traded species were from the Subgenus Brachypetalum, specifically the widely-distributed *P. concolor* (Fig. A2), although most of the species native to Thailand, Lao PDR and Myanmar were encountered, even if only in relatively small volumes.

3.2. Widespread international trade

Interviews revealed that most traders at border markets sourced the majority of their plants (both orchids and non-orchids) from the adjacent country, despite domestic protections and CITES restrictions on international orchid trade (Table 4). All traders at Chedi Sam Ong reported sourcing plants exclusively from Myanmar, as did 91.1% of traders at Dan Singkorn. Similarly, 91.7% of traders at Mukdahan sourced principally from Lao PDR. Thailand was not ranked the leading source country at any of the four markets, but was a secondary source of orchids for a subset of traders at Dan Singkorn and Mukdahan.

In contrast, Bangkok-based traders at Jatujak Market sourced their plants (orchids and non-orchids) from the three principle countries, but also sourced a small proportion of their inventories from Indonesia and Philippines. These trends were corroborated by the origin data collected for all blooming orchids during the market survey (Table 5). However the interview data and market survey data indicate some disagreement in the relative importance of the three sourcing countries. Whereas during interviews the majority of traders reported that plants originated from Lao PDR (50%), market survey data indicates that the role of harvest within Thailand was more pronounced (Table 5). The majority of blooming orchids encountered at Jatujak were reportedly harvested within Thailand (~60%), while only approximately 25% were from Lao PDR (Table 5; Fig. A3). Similar patterns were observed at Jatujak Market for the subset of 20 target species (Fig. A4).

3.3. Comparison of observed vs. official CITES trade statistics

The observed trade volumes and richness of plants illegally imported into Thailand (as reported by traders) during one year of surveys greatly exceeded CITES-reported trade volumes from 2004 to 2012 (Table 6). CITES statistics over this period reported

Table 3
Ten most abundant genera traded at four target plant markets.

Jatujak	RA[a]	Mukdahan	RA	Chedi Sam Ong	RA	Dan Singkorn	RA
Dendrobium	29.9	*Dendrobium*	35.5	*Dendrobium*	19.3	*Dendrobium*	29.9
Rhynchostylis	6.4	*Aerides*	13.6	*Tacca*	15.9	*Aerides*	9.9
Paphiopedilum	6.4	*Paphiopedilum*	6.0	*Platycerium*	8.4	*Philodota*	8.6
Aerides	5.5	*Rhynchostylis*	5.5	*Rhynchostylis*	6.2	*Eria*	8.0
Bulbophyllinae [b]	5.4	*Vanda*	4.0	*Calanthe*	5.3	*Rhynchostylis*	7.9
Bulbophyllum	4.9	*Geodorum*	3.0	*Papilionanthe*	4.1	Bulbophyllinae [b]	6.3
Ascocentrum	3.0	Bulbophyllinae [b]	2.3	*Bulbophyllum*	4.1	*Platycerium*	4.9
Vanda	2.9	*Pleione*	2.1	*Cheirostylis*	3.6	*Paphiopedilum*	3.1
Phalaenopsis	2.3	*Habenaria*	2.1	*Eria*	3.6	*Eulophia*	2.2
Cleisostoma	2.1	*Cleisostoma*	2.1	*Philodota*	3.2	*Bulbophyllum*	1.7

[a] Relative abundance in trade as percent of trade volume at each market.
[b] Subtribe Bulbophyllinae includes >100 genera, including *Bulbophyllum*, which also independently ranks in several lists.

Table 4
Trader rankings[a] of top source countries for ornamental plants.

Rank	Thailand	Myanmar	Lao PDR	Malaysia [b]	Vietnam [b]	Other (Country)
Traders at Jatujak Market (N = 14)						
First	21.4	21.4	50.0	–	–	7.1 (Cambodia)
Second	35.7	14.3	14.3	7.1	–	14.3 (Uncertain)
Third	14.3	28.6	7.1	7.1	14.3	–
Fourth	7.1	14.3	7.1	7.1	–	7.1 (Uncertain)
Fifth	–	7.1	–	7.1	14.3	–
Sixth	–	–	–	7.1	–	–
None	21.4	14.3	21.4	64.3	71.4	71.4
Traders at Dan Singkorn Market (N = 56)						
First	5.4	91.1	3.6	–	–	–
Second	14.3	3.6	3.6	–	–	1.8 (Uncertain)
Third	5.4	1.8	3.6	–	–	–
Fourth	–	1.8	–	–	1.8	–
Fifth	–	1.8	–	1.8	–	–
Sixth	–	–	–	–	–	–
None	75.0	–	89.3	98.2	98.2	98.2
Traders at Chedi Sam Ong Market (N = 12)						
First	–	100	–	–	–	–
None	–	–	100	100	100	100
Traders at Mukdahan Market (N = 24)						
First	4.2	–	91.7	–	4.2	–
Second	20.8	8.3	8.3	–	16.7	4.2 (Uncertain)
Third	20.8	–	–	–	8.3	–
Fourth	–	12.5	–	–	4.2	–
Fifth	–	–	–	–	–	8.3 (Uncertain)
Sixth	–	–	–	4.2	–	–
None	54.2	79.2	–	95.8	66.7	87.5

[a] Values represent the percent of respondents ranking each country first to sixth in importance, based on the relative volume of plants sourced from each country. Blanks indicate that no plants were sourced from that country.
[b] Vietnam and Malaysia were selected principally to enable cross-check regarding respondents awareness of their sourcing, as we knew *a priori* that comparatively few orchids were coming from these countries.

no wild orchid trade into Thailand from Myanmar, Cambodia, Indonesia, Malaysia, or Philippines, although wild plants were found in open trade during surveys. The CITES-reported trade of wild orchids from Lao PDR between 2004 to 2012 represented only 0.22% of the trade volume observed during surveys, which were themselves highly conservative. Observed trade was also strongly skewed towards Myanmar and Lao PDR given the geography of the market sites, such that broader surveys would likely indicate larger-scale illegal trades from other countries in the region.

Table 5
Source country for blooming orchid specimens encountered during market surveys at four target markets in Thailand. Data are restricted to blooming specimens identified to the species-level.

Country	Number of genera (species)				
	Total	Jatujak	Chedi Sam Ong	Dan Singkorn	Mukdahan
Thailand	56 (175)	52 (168)	0	9 (20)	12(16)
Myanmar	54 (130) [a]	15 (38)	35 (64)	46 (94)	2 (2)
Lao PDR	41 (109)	33 (84)	0	10 (23)	20 (42)
Cambodia	7 (11)	5 (8)	0	3 (3)	1 (1)
Malaysia	5 (7)	5 (7)	0	0	0
Vietnam	4 (9)	3 (7)	0	0	3(3)
Indonesia	1 (1)	1 (1)	0	0	0
Philippines	3 (3)	3 (3)	0	0	0

[a] Includes records that traders specifically reported as from Myanmar and specimens sold by traders in Chedi Sam Ong and Dan Singkorn, as interviews showed that plants were almost exclusively from Myanmar.

3.4. Evidence of conservation impacts

Of the orchid species reportedly collected within Thailand, 57 species were listed in the published literature as threatened according to some metric (e.g., endangered, rare, threatened, vulnerable, Table A3). In addition, data was only available to map the estimated EOO for 91 of the encountered species, most of which (50 species) had widespread distributions that extended beyond continental Southeast Asia. There were 13 species with distributions restricted to 2 countries, and an addition 13 species endemic to a single country.

In the absence of reliable data, harvesters in Myanmar ($N = 20$) were asked to describe any changes in abundance of ornamental plants since they started collecting (median of 6 years trading). All respondents reported declines, with most (14) stated that all orchid species had declined; the rest specifically mentioned declines in the species *Dendrobium lindleyi, Aerides rosea, Rhynchostylis retusa, Huperzia* spp., *Dendrobium chrysotoxum,* and *Eria* spp. Several traders (6) specifically described orchid extirpations around village areas that had been subject to heavy harvest, including forests within walking distance of Chedi Sam Ong and Dan Singkorn. This echoes findings of Schuiteman et al. (2008) during surveys of Lao PDR, during which "on more than one occasion villagers have told us, when we came looking for orchids near their village, that we should have come a few years earlier, before all the orchids were collected!" Although largely anecdotal and regional, these harvester reports suggest that harvest is likely affecting wild populations.

Table 6
Comparison of government-reported CITES orchid trade and observed trade of orchids that traders reported had been imported into Thailand. CITES records[a] of live orchid imports into Thailand from countries in SE Asia 2004–2012[b] compared with trade observed during 1-year of market surveys[c].

	Import volume	Genus count	Species count
Lao PDR → Thailand			
CITES Database			
Artificially propagated [d]	0	0	0
Wild-collected	20	3	4
Observed in this study	9251	41	109
Myanmar → Thailand			
CITES Database			
Artificially propagated	0	0	0
Wild-collected [e]	0	0	0
Observed in this study	18850	54	130
Vietnam → Thailand			
CITES Database			
Artificially propagated	0	0	0
Wild-collected [e]	1650	4	4
Observed in this study	159	4	9
Cambodia → Thailand			
CITES Database			
Artificially propagated	0	0	0
Wild-collected [e]	0	0	0
Observed in this study	1194	7	11
Philippines → Thailand			
CITES Database			
Artificially propagated	3673	20	81
Wild-collected [e]	0	0	0
Observed in this study	5	3	3
Indonesia [e] → Thailand			
CITES Database			
Artificially propagated	126487	7	7
Wild-collected [e]	0	0	0
Observed in this study	48	1	1
Malaysia → Thailand			
CITES Database			
Artificially propagated	8224	54	165
Wild-collected [e]	0	0	0
Observed in this study	163	5	7

[a] The CITES count is based on records on the UNEP-WCMC managed CITES database (CITES 2014). For methods used in observed count see Section 2.3. Not that comparison includes only plants that traders reported had originated from outside Thailand (i.e. local trade is excluded as it does not relevant to CITES restrictions).

[b] Signatory nations are intended to submit trade statistics of CITES-listed species annually, but submissions are often less frequent. Since 2006, when National Annual Reports to the CITES Secretariat were made available online, Thailand and Malaysia have submitted annually, Lao PDR submitted in only 2010; Myanmar in 2009, 2010 and 2012; Cambodia in 2009 and 2013, and Philippines in 2007, 2008, 2011.

[c] Represent significant under-estimates, as origin data was only collected for a sub-set of specimens at only four markets (see Section 2.3).

[d] Artificially propagated plants include hybrids.

[e] Very small volumes of wild plants were also imported for exhibition.

4. Discussion

4.1. Uncovering the "invisible" orchid trade

The results of this study strongly indicate that illegal trade threatens not only charismatic Southeast Asian mammals, reptiles and amphibians, but also tropical plant species. This study reveals a previously undocumented, large-scale commercial trade in hundreds of wild-collected ornamental orchid species. The observed cross-border trade moves plants at a rate orders of magnitude larger than government-reported statistics, and directly conflicts with the Thailand CITES Management Authority's statement that illegal trade in ornamental orchids is limited, "...found in small case [*sic*] in some parties" (CITES, 2004). The huge discrepancy between observed and reported trade is alarming, and demonstrates the need for strengthened botanical conservation efforts that include improved trade monitoring. It also highlights the importance of 3rd party cross-checking of official statistics, particularly on sensitive topics such as illegal trade.

Conservation impacts of trade remain difficult to determine, but the evidence presented here suggests unsustainable levels of collection across many orchid genera. Southeast Asia lacks botanical conservation assessments (Giam et al., 2011), a shortcoming clearly echoed by this study. Little is known about the impacts of harvest on most epiphytic plants (Elliott and Ticktin, 2013), although existing information suggests that many Neotropical orchids occur in low densities (Pupulin, 1998; Flores-Palacios and Valencia-Diaz, 2007), and may be vulnerable even at low levels of harvest (Mondragón-Chaparro, 2009). Even in the absence of more robust conservation assessments, the restricted EOO of some traded species, data from exiting national-level threat evaluations for Thailand, and trader reports cumulatively suggest that commercial harvest is impacting dozens, if not hundreds of species.

Importantly, while the majority of trade (>50% encountered volume) comprised five genera with large charismatic, colorful and/or fragrant flowers, such as *Dendrobium, Rhynchostylis, Aeries* and *Paphiopedilum,* trade also heavily targeted genera that might not be commonly expected in the horticultural trade. For example, most species in the genera *Pholidota, Cleisostoma, Eria* and the Subtribe Bulbophyllinae (including *Bulbophyllum* and allied genera) have relatively small, uncharismatic and/or non-fragrant flowers, but were still common in trade. Our findings thus reveal trade in ornamental orchids that affects a far greater number of species than previously thought, as has been noted in the Neotropics (Flores-Palacios and Valencia-Diaz, 2007). Conservation strategies for ornamental plants must include species that might not traditionally be considered of widespread horticultural value. Moreover, significantly more documentation of trade pressures is needed in order to contribute to future species assessments, in particular IUCN Red List evaluations.

Previous characterizations of illegal trade have often focused on consumption outside the region, e.g. in Europe, Japan, China and North America (e.g., Cribb et al., 2003; Sodhi et al., 2004; Engler and Parry-Jones, 2007). However, our results suggests significant demand for ornamental plants arising from within Thailand itself. It is therefore important to recognize Southeast Asian demand as a contributing driver of illegal domestic, regional and international harvest and trade (cf. Nijman and Shepherd, 2007, 2011; Nijman, 2010), and for corresponding policy and monitoring responses.

4.2. Simple, effective improvements to botanical trade monitoring

There is broadening recognition that efforts to reduce illegal wildlife trade must involve broad, multifaceted interventions (Bowen-Jones et al., 2010; Brashares et al., 2014; Challender et al., 2015). Nevertheless, monitoring and enforcement remain important components to any functional natural resource management system (cf. Gibson et al., 2005; Phelps et al., 2014), and were a principle focus of the market surveys and this analysis. This study highlights the opportunity and feasibility of simple, effective efforts to introduce basic visual monitoring of botanical trade, as well as the potential for 3rd parties to cross-check, supplement and challenge official data. Comprehensive plant market surveys can be achieved with limited human and financial resources (see also Flores-Palacios and Valencia-Diaz, 2007), and represents a 'low hanging fruit' for biodiversity conservation. In this study, a survey effort of two people for 1–2 days per survey over 12 months identified the majority of genera in trade, and was especially effective at the regional markets with comparatively low species richness. Basic monitoring can be readily extended beyond airports, to also include public markets, land-borders and greenhouses (Phelps et al., 2010). This is particularly true in this context, as our study found a relatively limited number of border crossings,

and much of the illegal trade occurred openly, with all of our survey data collected at public markets. Monitoring efforts can be further leveraged to gather basic information about specimen origin, price, and destinations, to help inform future conservation interventions, which can contribute to more centralized monitoring efforts (Toledo et al., 2012). Such basic monitoring is achievable for many CITES signatory countries, and is well within reach for countries such as Thailand.

Improved monitoring requires strengthened capacities to deal with "look alike" species. As this study shows, there are practical challenges of species-level identification for groups with many "look-alike" species, such as orchids, sea cucumbers (Bruckner et al., 2003) and frogs (Warkentin et al., 2009). This also applies to taxa that are often substituted with fake goods (e.g., ivory, Sims et al., 2011) and taxa that are transformed in ways that makes identification challenging, such dried herbs, processed fish and shark fins, and sawn timber (e.g., Gasson et al., 2010). There is considerable optimism that DNA-based identification tools will eventually allow non-specialist identification of challenging taxa and products (Gaston and O'Niell, 2004; Alacs et al., 2009), and enable the identification of harvest locations to inform future interventions (e.g., geographically targeted conservation actions; reintroduction, Swarts and Dixon, 2009). Such forensic tools are increasingly viable for plants, including orchids (e.g., Subedi et al., 2013; Sosa et al., 2013), but continue to face technical and practical barriers (see Methods). Efforts to improve botanical monitoring must prioritize the development of rapid, accurate, affordable DNA testing, while recognizing that these approaches are unlikely to replace traditional visual monitoring.

More fundamentally, there is considerable scope to strengthen basic visual monitoring and enforcement of botanical trade through improved identification skills. Only basic training would be required to help agents differentiate among wild and cultivated plants (see GreenCustoms ND), and to identify the major ornamental plant families and genera observed during this study. This is particularly viable for smaller orchid genera (e.g., *Rhynchostylis, Dendrobium* Section Callista, *Paphiopedilum*), which coincidentally include some of the genera encountered in greatest volumes during surveys. Genus-level identification is especially relevant to the CITES Appendix I genus *Paphiopedilum,* as the whole group is threatened by trade, and can be readily distinguished from other groups with basic training (McGough and Groves, 2004). Given that trade was dominated by a small group of taxa, targeted references can be created for both the most common and the most threatened species (e.g., Cooper et al., 2011). Several small orchid identification booklets have been prepared in Thailand, but neither focus on the most commonly traded nor most threatened species, nor do they detail vegetative characteristics. Thailand also hosts several botanical and academic institutions with taxonomic expertise that can be leveraged to provide training and support occasional surveys (cf. Phelps et al., 2010).

4.3. Taking botanical conservation seriously

Following three decades of broad restrictions on the international trade of all wild orchids, there is a clear need for significant reform in how botanical conservation is addressed in Southeast Asia, to include greater awareness of illegal trade pressures.

Botanical conservation requires concerted efforts to operationalize existing government commitments to protect biodiversity and tackle illegal trade. Evidence highlights meager monitoring and enforcement efforts and an apparent lack of focus on botanical conservation. The widespread underestimation of the problem calls into question any likelihood of achieving The Convention on Biological Diversity's Global Strategy for Conservation of Plants, which by 2020 aims to ensure that "no species of wild flora (is) endangered by international trade" (CBD, 2010).

For example, while evidence suggests increased monitoring and enforcement at Jatujak Market for many faunal groups (see Round, 1990; Fraser, 2012), illegal plant trade remains rampant. There is a need for improved commitment to botanical conservation that necessitates increased effort, capacity and resources. Moreover, it requires an expanded view of illegal wildlife trade that considers not only the trade of charismatic megafauna and hardwood timber species, but also the broad range of flora also subject to trade. For example, the ASEAN Wildlife Enforcement Network (http://www.asean-wen.org) has restricted its focus to faunal trade, but is equally relevant and appropriate for monitoring and enforcing illegal botanical trade. Similarly, numerous wildlife trade awareness campaigns (including at Jatujak Market) have focused on charismatic animals. Domestic botanical institutions, the Secretariats and national representatives to CITES, the Convention on Biological Diversity and the IUCN Specialist Groups are well-positioned to remind government bodies of the need to include plants in their conservation monitoring and planning. Similarly, external monitoring and cross-checking by non-governmental and academic institutions can play an important role in driving this type of reform (see Coston, 1998).

Taking botanical conservation seriously requires diverse interventions, at a number of different points along value chains, which also extend beyond monitoring and enforcement (Challender and MacMillan, 2014; Phelps et al., 2014). This is particularly true given our growing understanding of the complexities of trade dynamics, and recognition that enforcement-focused strategies can generate large social and financial costs and result in unintended consequences (e.g. Rivlan et al., 2007). Efforts to strengthen ornamental plant conservation should thus consider a broader mixed interventions, such as consumer sanctions, alternative livelihoods, captive breeding, enforcement at points of transportation and trade monitoring. Enforcement-oriented conservation strategies should also consider diverse enforcement options that may help curb illegal trade (e.g., confiscations, fines, warnings, monitoring and surveillance), but be judicious in exercising criminal sanctions on trade participants that are poor, such as at some of the market sites.

There are many contexts in which monitoring illegal wildlife trade represents significant challenges. This, however, is not currently the case for much of the region's trade in protected ornamental plants. The open and prevalent nature of trade in protected plant species means that monitoring is viable, given increased commitment and reasonable levels of investment into capacity building and human resources. Such modest reforms are critical to ensuring that wildlife trade statistics are credible and able to support evidence-based policy.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2015.03.030.

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