Contributed Paper

Estimating the extent and structure of trade in horticultural orchids via social media

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Abstract: *The wildlife trade is a lucrative industry involving thousands of animal and plant species. The increasing use of the internet for both legal and illegal wildlife trade is well documented, but there is evidence that trade may be emerging on new online technologies such as social media. Using the orchid trade as a case study, we conducted the first systematic survey of wildlife trade on an international social-media website. We focused on themed forums (groups), where people with similar interests can interact by uploading images or text (posts) that are visible to other group members. We used social-network analysis to examine the ties between 150 of these orchid-themed groups to determine the structure of the network. We found 4 communities of closely linked groups based around shared language. Most trade occurred in a community that consisted of English-speaking and Southeast Asian groups. In addition to the network analysis, we randomly sampled 30 groups from the whole network to assess the prevalence of trade in cultivated and wild plants. Of 55,805 posts recorded over 12 weeks, 8.9% contained plants for sale, and 22–46% of these posts pertained to wild-collected orchids. Although total numbers of posts about trade were relatively small, the large proportion of posts advertising wild orchids for sale supports calls for better monitoring of social media for trade in wild-collected plants.*

Keywords: e-commerce, online trade, ornamental plant trade, social commerce, social network analysis, wildlife trade

Estimación del Tamaño y la Estructura del Mercado de Orquídeas Cultivadas por medio de las Redes Sociales

Resumen: *El mercado de vida silvestre es una industria lucrativa que involucra a miles de especies de plantas y animales. El uso creciente del internet para el mercado de vida silvestre, tanto legal como ilegal, está bien documentado, aunque existen evidencias de que el mercado puede estar surgiendo en nuevas tecnologías en línea, como las redes sociales. Con el mercado de orquídeas como estudio de caso, realizamos el primer censo sistemático del mercado de vida silvestre en una red social internacional. Nos enfocamos en foros temáticos (grupos), en los que las personas con intereses similares pueden interactuar subiendo imágenes o textos (publicaciones) que son visibles para otros miembros del grupo. Utilizamos el análisis de redes sociales para examinar las conexiones entre 150 de estos grupos sobre orquídeas y así determinar la estructura de la red. Encontramos cuatro comunidades de grupos cercanamente conectados con base en un idioma compartido. La mayor parte del mercado ocurrió en una comunidad que consistió de grupos angloparlantes del sureste asiático. Además del análisis de redes, muestreamos al azar a 30 grupos de toda la red social para valorar la prevalencia del mercado en las plantas cultivadas y silvestres. De 55, 805 publicaciones registradas a lo largo de doce semanas, 8.9 % contenía plantas en venta, y 22 – 46 % de estas publicaciones eran en respecto a orquídeas colectadas en vida silvestre. Aunque el número total de publicaciones acerca del mercado era relativamente pequeño, la gran proporción de publicaciones anunciando orquídeas silvestres en venta*

1

apoya al llamado de un mejor monitoreo de las redes sociales en torno al mercado de plantas colectadas en vida silvestre.

Palabras Clave: análisis de redes sociales, comercio cibernético, comercio social, mercado en línea, mercado de plantas ornamentales, mercado de vida silvestre

Introduction

The wildlife trade is a lucrative industry involving the sale of thousands of species for purposes ranging from plant derivatives for medicinal use to live animals for the pet trade (Broad et al. 2003). Although an important source of income for many people, the overexploitation of wildlife for trade can be a serious threat if collection is not sustainable. Ensuring sustainability requires monitoring of trade and the status of wild populations. This monitoring may take place through both national legislation that prohibits or sets quotas for the wild-collection of certain species (e.g., Republic of Indonesia 1999) and international agreements, for example, the Convention on the International Trade in Endangered Species (CITES).

The value of certain wildlife products can motivate traders to sell illegally. The threat of prosecution may drive illegal traders to rapidly adopt new methods to evade detection (Broad et al. 2003), which can lead to constantly evolving trade routes, networks, and methods (Bennett 2011). Little is known about the scale or value of the illegal wildlife trade, but it is estimated to be worth $10 billion/year (Haken 2011). Because of the illicit nature of wildlife trade, the volume of traded species, and the interactions between legal and illegal trade, controlling wildlife trade is a complex undertaking. Law enforcers and conservationists need to discover, monitor, and respond to new developments quickly.

The increasing use of the internet by wildlife traders, especially those involved in illegal trade, is a substantial challenge to conservation of traded species (Bennett 2011), especially those in niche markets (Lavorgna 2014). Both legal and illegal traders use the internet in similar ways: to facilitate and enhance communication with suppliers and customers (Grabosky 2013). This allows illegal wildlife traders to procure animals and plants more efficiently and expand their networks and consumer base (Lavorgna 2014). E-commerce allows new traders and small businesses to establish themselves on the global market at relatively little cost (Brenner 2002), and there is the added benefit of increased anonymity for illegal traders (Grabosky 2013). A wide range of wildlife products are traded online, including plants (Sajeva et al. 2013; Shirey et al. 2013; Krigas et al. 2014), reptiles and amphibians (De Magalhães & São-Pedro 2012), and ivory (IFAW 2005, 2007). To date, studies of the online wildlife trade have focused mainly on auction websites, which resulted in eBay banning the sale of ivory in 2009 (Coghlan 2008). However, recent evidence from China suggests that increased regulation of e-commerce websites may be driving wildlife traders to sell via social media (Yu & Jia 2015).

The benefits of social media for businesses are numerous. Social-media sites have grown and proliferated rapidly since the launch of MySpace in 2003 and the expansion of Facebook in 2005 (Boyd & Ellison 2007). In mid-2015 social-media websites were the second (Facebook), third (YouTube), eighth (QQ), and ninth (Twitter) most visited global websites (Alexa Internet 2015). Users are numerous and diverse. In March 2015, Twitter had 302 million monthly users tweeting in 33 languages (Twitter 2015), and Facebook reported 1.44 billion monthly users, 83% of which were outside North America (Facebook 2015). Their size and reach means the potential of social commerce is being increasingly recognized, and social-media websites are facilitating this trend by introducing easier ways to advertise and take payments (Chaumond 2010). This has been especially important for small businesses (Lee et al. 2008); in April 2015, there were over 40 million small businesses operating on Facebook alone (Facebook for Business 2015). Monitoring illegal businesses through social media is more challenging, so it has received less attention. Yet monitoring of social-media wildlife trade is considered a conservation-research priority (Yu & Jia 2015). Moreover, the anonymity available online may mean that illegal businesses are growing at an even faster rate than legal businesses.

We built on previous work to uncover trade via local and national social-media networks (De Magalhães & São-Pedro 2012; Yu & Jia 2015) to carry out the first large-scale survey of wildlife trade on an international social-media site. We focused on orchids, a group that makes up over 70% of all CITES species (CITES 2013). Orchid hybrids are among the most high-value horticultural plants in mass-market trade (USDA 2015), and there is a separate hobbyist trade focused on species rather than hybrids (Hinsley et al. 2015). Whereas much of the orchid trade is in nursery-grown stock, the hobbyist trade has been linked to overcollection of wild plants (Vermeulen et al. 2014) due, in part, to demand for rare species (Hinsley et al. 2015). This has led to several new species being described from plants already in trade (Vermeulen et al. 2014). Trade in orchids via eBay (Vermeulen et al. 2014) and nursery websites (Krigas et al. 2014) has been recorded but no studies of their sale on social media have been carried out. Here, we examined whether trade is occurring on a

social-media website within orchid-themed interest groups; the proportion of trade in wild-collected plants; and whether analysis of the network within which trade is occurring can reveal information useful for conservation.

Methods

Background and ethics

Our study design was approved by the University of Kent, School of Anthropology and Conservation's Research and Ethics Committee. Because of the global nature of the orchid trade, we focused on a large international social-media website. The conditions of our ethical approval meant we could not name the website, which is standard practice for studies of this type. We focused on specialist forums (or groups) within the website that allow members with shared interests to communicate and connect. These groups may be accessible to anybody with a website membership or visible by invitation only. According to the website terms and conditions, we did not visit personal pages, did not use automated web scrapers, collected only anonymized member names, and did not collect any other personal information about members. The research account we set up on the website prominently displayed a statement that research on social-media orchid trade was being conducted. We did not interact with individual members, attempt to buy plants or post to any groups. Where group or member names were collected, these were immediately anonymized and stored on an encrypted USB drive.

Sampling

We searched the website for the word *orchid* in English, French, Spanish, Portuguese, German, Japanese, Indonesian, Malay, Chinese (traditional), Thai, and Vietnamese. We did not include simplified Chinese because most international social-media websites are restricted in Mainland China, and Chinese language social-media sites (e.g. QQ, Weibo) are much more widely used in the country (Alexa Internet 2015). Each group page provides an automatically generated list of groups with related content, and we used this to perform a form of snowball sampling, a method in which new individuals are added to the sample after being referred by previous respondents (Biernacki & Waldorf 1981). We added all relevant suggested groups to our sample until no new groups were found, even after the page was refreshed twice. This resulted in 156 groups, of which 6 were removed because they were duplicates or unrelated to orchids. Based on the title, description, or visible activity of the group, we manually categorized them as taxonomic (focused on one particular genus of orchid); geographic (specifically for orchid growers from a particular town, region, or country); general hobbyist (no specialization other than orchids); natural history (focused on discussion or photography of in situ wild orchids); or trade (sole purpose is selling or exchanging plants). Some groups had a combined geographic and taxonomic focus. For each group, we recorded the language and the presence of trade, defined as either an explicit statement that trade was permitted or a visible presence of trade in the last 50 posts on the day of sampling.

Network analyses

We represented our data as an undirected, weighted network and used the methods of Opsahl et al. (2010) to conduct a network analysis in R version 3.1.2 (R Core Team 2014) with package tnet version 3.0.11 (Opsahl 2012). We anonymized member lists manually for each group and constructed an adjacency matrix that showed shared members between all pairs of groups. We represented the network as an undirected, weighted graph; each node represented one group. When 2 groups shared at least one member, they were connected by an edge and the weight of this edge was defined by the number of shared members. The network had 150 nodes, connected by 7,801 edges, and a total weight of 312,323. The simplest network measure is the degree (number of edges from a single node), which means that the node with the highest degree is considered the most central. The sum of the weights of all edges from a node gives the node strength. In some situations, one may consider the node with the highest strength, not degree, the most central. Opsahl et al. (2010) combine these 2 measures to give the centrality measure:

$$C_D^{w\alpha}(i) = k_i \times \left(\frac{S_i}{K_i} \right)^{\alpha} = K_i^{(1-\alpha)} \times S_i^{\alpha} \qquad (1)$$

where k_i is the degree of node i, s_i is the strength of node i, and $\alpha \geq 0$. For a central node, $C_D^{w\alpha}$ is large. When $\alpha \geq 1$, Eq. (1) gives the node degree, and when $\alpha = 1$, it gives the node strength. When $\alpha < 1$, nodes with a high degree are more central. When $\alpha > 1$, nodes with a large mean weight are more central. For example, a node with an edge with weight 1 and an edge with weight 7 has a mean weight of 4. For alpha >1, this node then has a higher $C_D^{w\alpha}$ than a node with 3 edges, each with weight 1. However, for $\alpha < 1$, the latter node with more but weaker connections is more central. Opsahl et al. (2010) were interested in social networks where the transfer and sharing of knowledge requires strong ties (Hansen 1999). Therefore, we chose $\alpha = 1.5$, which provides a centrality measure that favors strong ties rather than the number of ties (the degree).

The centrality measure (Eq. 1) does not reveal much about network structure because it does not account for
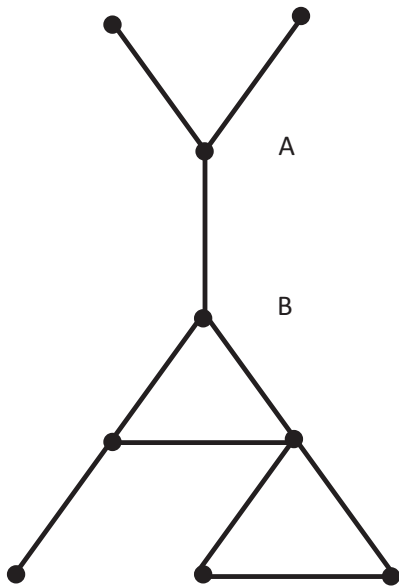
Figure 1. Diagram illustrating the network-analysis measure of betweenness. Node B has greater betweenness (paths passing through it) than A, even though they have the same degree (number of edges connecting to other nodes).

paths that pass through a particular node. For example, nodes A and B in Fig. 1 have the same degree, but B is the preferred node to transmit information because more paths pass through it.

We used betweenness to relay information on network structure. Betweenness is used to assess the total amount of flow a node carries when a unit of flow between each pair of nodes is divided evenly over the shortest paths (Easley & Kleinberg 2010). Nodes of high betweenness are critical to the network structure. We used closeness to find the smallest number of connections taken to reach all nodes in the network. We found consistently small closeness scores for all nodes so do not discuss this further (Supporting Information). Betweenness is defined as

$$C_B(i) = \frac{g_{jk}(i)}{g_{jk}} \qquad (2)$$

where g_{jk} is the number of binary shortest paths between 2 nodes, $g_{jk}(i)$ is the number of these paths that pass through node i, and $j = 1, 2, \ldots, 150$. For example, in Fig. 1 $C_B A = 13$ and $C_B B = 19$. This quantifies what can be seen in Fig. 1; that is, node B is more critical to the network structure.

The maximum modularity, $0 \leq Q \leq 1$, of a network describes the best partition of a network into its communities; large Q values represent distinct communities. There are a number of ways to produce the optimum partition and thus the modularity (e.g., Fortunato 2010; Newman 2010). We used a standard method that successively iden-

tifies a bisection of subsets within the present partition that produces the maximal increase to the overall modularity. It halts when no further bisections of any subset improves the modularity. This method is implemented in Mathematica FindGraphCommunities, with the option Method → Modularity (Wolfram Research 2014).

Trade survey and kappa analyses

A sample of 30 groups was chosen by randomly selecting unique members and sampling all groups they belonged to until 30 groups was reached. Email alerts of all text, images, and other media posted to these groups by their members (hereafter referred to as posts) were received for 12 weeks between November 2014 and January 2015. All sampled groups (26 open groups, 4 closed) accepted our requests to join. Because of the large number of alerts received ($n = 55,805$), a random sample of approximately 1% ($n = 560$) were selected for the final survey. We assessed sampled posts with a 2-person kappa analysis, which involves 2 independent raters with relevant expertise assigning each post to discrete categories (Cohen 1960). Two analyses were carried out for presence of trade and presence of wild-collected plants. Categories were yes, no, and maybe for each post. Both raters had extensive experience studying the orchid trade, but they had different specific skills in taxonomy, knowledge of online trade, and relevant languages. We used the R irr package version 0.84 (Gamer et al. 2012) to calculate percent agreement, Cohen's weighted kappa coefficient (Cohen 1968), Stuart-Maxwell marginal homogeneity (Stuart 1955; Maxwell 1970), and rater bias. Categorization of all posts not agreed upon in the first analysis were reanalysed by both raters and discussed until an agreement was reached.

Results

Summary group statistics

A total of 150 groups containing 43,509 unique members was found, and there was a range of group types, sizes, and language (Table 1). We found that 17.3% ($n = 26$) of groups prohibited trade and 28.6% ($n = 43$) explicitly permitted trade or allowed it to occur. The presence of trade could not be ascertained in the remaining 54% ($n = 81$) of groups. Over 25% ($n = 11$) of groups with visible trade operated in Indonesian; trade occurred in 50% of all Indonesian groups sampled. Other notable languages of groups with trade included English, Portuguese, Vietnamese, and Malay (each: 11.6% of total trade, $n = 5$). The majority of Portuguese and Spanish groups appeared to be predominantly made up of members in Latin America rather than Europe, and 10 of 14 Chinese groups stated they were based in Taiwan or Hong Kong. English-speaking groups appeared to be predominantly

Table 1. Summary statistics for all orchid groups on the social-media website studied classified by theme of group.

Group type	No. groups	No. members (mean)	No. members (median)	No. languages	No. with visible trade
Natural history	6	385.2	457.0	5	2
Geographic	28	636.5	269.5	8	7
Hobbyist	80	891.6	636.5	16	17
Taxonomic	16	851.7	707.0	8	5
Taxonomic/geographic	5	535.8	231.0	3	1
Trade	15	601.5	736.0	8	15
All groups	150	778.6	360.5	17	47

composed of members from the United Kingdom, United States, and Australia, although the membership of many groups was international.

Network analyses

The centrality results showed that, generally, groups shared members with many others, making the network highly connected. Centrality scores, with $\alpha = 1.5$, ranged from 0 to 246,011 (mean of 35,167). One group with a joint focus on orchids and bonsai was completely isolated from the network. It had a score of 0 for all measures, which suggests orchids were not the focus of this group. Betweenness ranged from 0 to 3897 (mean of 204), which implies there were few heavily weighted paths in the network. Three groups were key to the network. These groups had the highest centrality (Eq. 1) and betweenness (Eq. 2) scores. All had centrality measures of over 235,617 (approximately 200,000 above the mean) and betweeness of >3,500. Two of these groups were English with visible trade (one taxonomic, one geographic) and one was an English-Spanish (English was the main language) hobbyist group with no trade. The network modularity was 0.0139, meaning many edges connected the communities within the network.

We identified 5 communities (Fig. 2). Community 5 was the single isolated group mentioned above, and the remaining 4 communities were based on language groups and had distinct characteristics (Table 2). Community one had the most members and contained the 3 key groups. However, the centrality scores in this community varied greatly (median of 13,156 and minimum of 1). In contrast, community 3 had consistently high centrality scores (median of 104,346 and minimum of 9805) (Supporting Information). Although the centrality scores for community 2 and 4 were relatively low, community 2 had some betweenness scores that were almost as high as the top-scoring groups in the network (Table 2).

Trade survey and kappa

One sampled group was deleted by its owner shortly after data collection began, leaving 29 sampled groups. Over the study period there were 55,805 posts from 12,089 unique members. Groups had from 0 to 14,923 posts. The kappa analyses showed high levels of agreement but different uses of categories. Rater one was more likely to use the wild category (Table 3). Both the kappa and sensitivity analyses showed no significant differences in results when all maybe responses were counted as yes for either trade or wild analyses. A difference in use of the wild category between raters was due to rater 2's taxonomic skills (e.g., identifying artificial hybrids that could not be wild) and rater 1's language skills (e.g., familiarity with different phrases used to describe wild-collected plants in Indonesian and Malay).

After reanalysis, 8.9% ($n = 50$) of posts were identified as likely to be offering plants for sale (yes = 46; maybe = 4) and 7.0% ($n = 39$) as likely to contain pictures or descriptions of wild plants (yes = 39; maybe = 13). Some posts were about wild plants that were not for sale. With these posts removed, 4.1% ($n = 23$) of posts definitely (yes = 11) or possibly (maybe = 12) were about the sale of wild plants. Accounting for uncertainty, 22% ($n = 11$) to 46% ($n = 23$) of trade posts were about wild-collected plants, although our sample was small. It was not possible to extrapolate this to the volume of plants being traded because, although one plant was often pictured, these may have been advertisements for available stock. For example, one picture showing a few plants of a *Dendrobium* sp. was accompanied by pricing for up to 50 kg (Supporting Information).

Identification of wild-collected species for sale was not always possible, but wild-collected species for sale included *Bulbophyllum macrochilum, Coelogyne pandurata, Dendrobium amabile, Dendrobium findlayanum, Paphiopedilum kolopakingii, Paraphalaenopsis serpentilingua,* and unidentified species of *Dendrobium, Coelogyne, Flickingeria,* and *Paphiopedilum* (Supporting information). Trade in horticultural plants such as *Hoya* spp. (wax flowers) and *Nepenthes* spp. (pitcher plants) was observed within study groups. No animals were traded in the 150 groups in our sample.

Discussion

Ours is the first survey of wildlife trade via a global social-media site and the first systematic analysis of
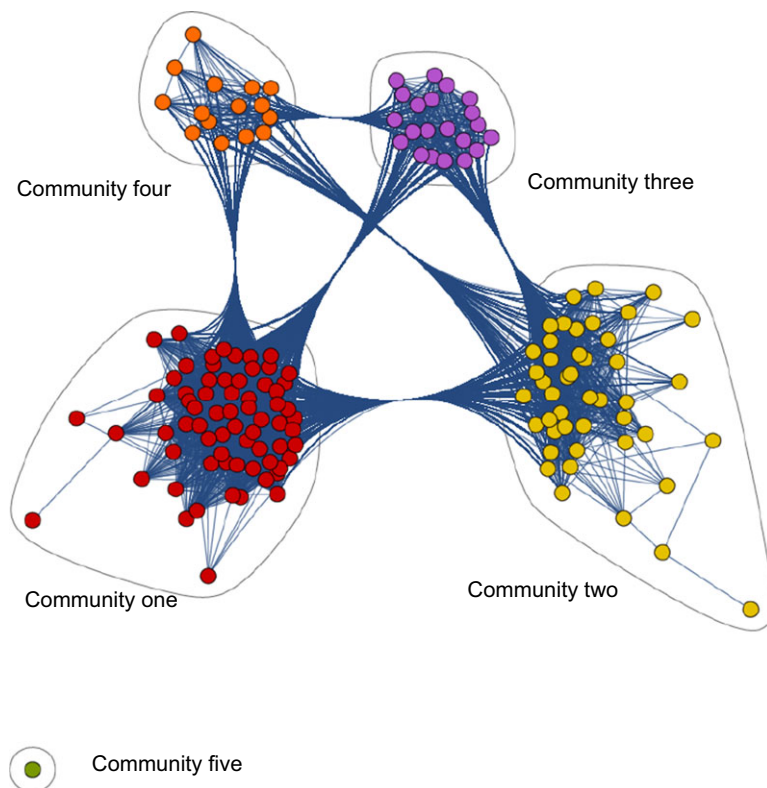
Figure 2. Structure of the network based on the results of social-network analysis, showing the 4 main, distinct communities of orchid-themed groups on the social-media website studied and the isolated group of community 5.

Table 2. Characteristics of the 4 main communities identified during the social-network analysis of orchid groups on the social-media website studied.

Community	No. groups	Mean group size (median)	Type of group (% of community)*	Languages (% of community)	Mean centrality (maximum)	Mean betweenness (maximum)
1	68	2928.5 (1048)	H (35.9); G (28.1); Ta (17.2); Tr (15.6); NH (3.1)	English (41.2); Indonesian (32.8); Malay (8.8); Thai (7.4); Chinese (4.4); French (2.9); Portuguese (1.5); German (1.5)	42623.8 (246011.2)	279.4 (3896.8)
2	45	282.7 (169)	H (75.6); G (11.1); NH (8.9); Ta (2.2); Tr (2.2)	German (33.3); Italian (24.4); French (17.8); Turkish (8.9); Indonesian (4.4); Greek, Danish, Filipino, Finnish, Norwegian (2.2 each)	3758.7 (48035.3)	188.6 (3261.0)
3	21	1535.0 (1264)	H (71.4); Tr (14.3); Ta (9.5); G (4.8)	Portuguese (76.2); Spanish (23.8)	92272.2 (155174.5)	86.4 (1100.0)
4	15	1459.2 (696)	H (53.8); G (30.8); Ta (7.7); Tr (7.7)	Chinese (66.7); Vietnamese (33.3)	17983.2 (59918.9)	87.7 (579.0)

Abbreviations: H, hobbyist; G, geographic; Ta, taxonomic; Tr, trade; NH, natural history.

networks containing trade in wild-collected species on social media. Our network-analysis results showed that trade in orchids occurred within each of the 4 main communities represented on the website we examined. Although based on a small sample of posts, 22% of posts were likely about trade in wild-collected specimens.

Implications for orchid conservation

In addition to real-world markets (Flores-Palacios & Valencia-Díaz 2007; Phelps et al. 2014) and traditional commerce or auction websites (Krigas et al. 2014; Vermeulen et al. 2014; Hinsley et al. 2015), we found wild

Table 3. Results of two-rater kappa analysis used to determine the occurrence of trade and wild plants in each sampled post from groups on the social-media website studied a.

Focus of analysis	Agreement between raters (%)	Marginal homogeneity (Stuart-Maxwell)		Cohen's kappa		Rater bias[a]	
		$\chi 2$	P	unweighted[b]	P	$\chi 2$	P
Trade	93.6	0.6	0.8	0.6	<0.001	0.4	0.5
Wild	86.3	60.4	<0.001	0.3	<0.001	32.9	<0.001

[a]*Measure of whether either rater showed bias toward a particular category (yes, no, maybe).*
[b]*Unweighted because the 3 categories (yes, no, maybe) were not ordinal.*

orchids being traded openly via social media. Trade can pose a serious threat to groups such as this, and trade is the number one threat to cacti, the largest plant group assessed for the International Union for Conservation of Nature (IUCN) Red List (Goettsch et al. 2015). Although the conservation status of relatively few orchids has been assessed, those that have show similar trends: 84% of tropical Asian slipper orchids (*Paphiopedilum* spp.) are threatened with extinction, and trade is one of the primary threats (IUCN 2015).

Orchids are naturally vulnerable to overcollection because of their sensitivity to other threats and small population sizes (Koopowitz 2001), and it is likely that some of the trade we found may be the result of collection that could be of conservation concern. One species we found being traded, *P. kolopakingii*, was assessed by the IUCN as critically endangered (Rankou 2015), and at least 2 others (*C. pandurata* and *P. serpentilingua*) are listed as protected in the country from which they were being sold. Because orchid hobbyists who buy on the internet have a preference for rare species (Hinsley et al. 2015), the sale of wild orchids on social media, if left unchecked, is likely to contribute to pressure on vulnerable wild populations. However, relatively little attention is paid to the trade in horticultural plants (Phelps & Webb 2015), and, although all orchids are CITES listed and many are protected from collection under national legislation, protected orchids are still collected for trade. Action is needed to address this.

Our results suggest where this action might best be aimed to monitor and address social-media trade. The largest community in our study comprised all English speaking groups, some European groups, and the majority of those from Indonesia, Malaysia, and Thailand, major centers of orchid diversity and export (Thomas 2006; WCSP 2015). The relatively strong ties between these groups matches the known trade connections between Southeast Asia and the important orchid-importing areas of the United States, European Union, and Australia, and it is possible that these connections on social media may facilitate trade between individuals in these areas. Some groups in this community had the strongest con-

nections to the rest of the network and scored high on betweenness, suggesting that they are key to the network as a whole. This, along with the fact that this community had the most trade-focused groups, suggests social-media communities in these countries should be a priority for monitoring trade. In particular, one-quarter of trade groups were based in Indonesia, a country with >2,000 orchid species and a well-documented role in the legal and illegal wildlife trade (Lee et al. 2005), including online (Nijman et al. 2012). In Indonesia, 28 orchid species are legally protected from collection for trade (Republic of Indonesia 1999), but wild plants of the protected species *C. pandurata* and *P. serpentilingua* were found for sale from Indonesian vendors in our study.

Other communities in the network also contained trade, particularly a highly connected community of Latin American groups. There is evidence of wild-orchid trade in the region (Flores-Palacios & Valencia-Díaz 2007), and our results suggest this may also be occurring on social media. Finally, a community of groups from Vietnam, Taiwan, and Hong Kong suggests a second community in Asia with little interaction with the first. Vietnam has been an important center of discovery for new *Paphiopedilum* species (*P. vietnamense* in 1999 and *P. canhii* in 2010) that have become overcollected for trade (Averyanov et al. 2014). One of the first destinations for trade in both species was Taiwan (Averyanov et al. 2014). Similarly, Hong Kong is a recognized trade hub for Southeast Asian wildlife (Lau 2014). Although originally omitted from our sample, no groups from Mainland China were found during snowball sampling, even though wildlife trade has been recorded on social media in the country (Yu & Jia 2015). This may be due to restrictions on international social media in the country, but it is important to acknowledge this omission in a global study such as ours because Mainland China is the biggest consumer of wildlife in Asia (Grieser-Johns & Thomson 2005).

The largest community contained 3 of the most connected groups in our network, 2 of which had visible trade. Offline networks of plant enthusiasts focus on key individuals who disseminate important information and

knowledge (Morris 2010). Assuming that social-media members follow this pattern and share interesting information from key groups with their contacts, targeting one of these highly connected groups with well-designed conservation marketing messages about overcollection of orchids for trade would be the most efficient way to spread messages through the network. We acknowledge that conservation marketing is a new discipline, however, there are rigorous studies from the field of health that show social marketing can change behavior if carefully designed (e.g., Stead et al. 2007). However, any conservation intervention in these groups may lead to greater secrecy by illegal traders, which may hamper monitoring efforts. In addition, education about the rules regulating trade may not be effective for all orchid growers because a subset of traders and buyers dismiss these rules and distrust conservationists (personal observation). An understanding of how and why people break the rules is key to designing effective interventions, and the study of the networks and behavior of illegal traders in an open forum such as social media is a good opportunity to do this.

Identifying the structure of online trade networks

The conservation community needs to strengthen its current approach to tackling wildlife trade (Toledo et al. 2012; Challender & MacMillan 2014) and apply more quantitative analytical methods to the study of the structure and function of trade networks (Schneider 2008). Network analysis has been used to identify major players in the international trade in tigers, ivory, and rhinoceros horn (Patel et al. 2015), and our results add further support to the use of this method for the study of wildlife trade. Our application of network analysis has demonstrated a clear need for further work to understand online wildlife trade networks, particularly on social media. The growth of social commerce is beneficial to small businesses (Chaumond 2010), but the potential for illicit trade is great. Large international social-media websites reportedly host trade in illegal guns (Frier 2014) and drugs (Babb 2014), but scientific research into trade via these networks is scarce and limited to studies of counterfeit drugs (e.g., Mackey & Liang 2013). For wildlife, systematic research has been restricted to studies of national networks (De Magalhães & São-Pedro 2012; Yu & Jia 2015), although emerging trades on global networks have been noted (e.g., Instagram [Hernandez-Castro & Roberts 2015]). Our findings demonstrate that these trades exist, take place in structured networks, and are relatively easy to observe. Although our focus was orchids, we found links to groups trading in other wild-collected taxa. Several nonorchid suggested groups visited during the sampling phase openly advertised a wide range of reptiles, mammals, and birds for sale, including live hornbills, leopard cats, macaques, lorises, and turtles. Both captive and wild specimens were advertised in the same groups (Supporting Information). Further analysis should focus on links between traders selling different wildlife products to identify key groups or people in these extended networks.

In addition to research, our findings highlight the potential benefit that monitoring these websites could have for law enforcement and conservation. Even if the Ebay ban on the sale of ivory has not been completely successful (Fleming 2013), it demonstrates that monitoring can provide information to underpin action. In addition to bans, this information could be used to provide intelligence to law-enforcement agencies on the key people involved in trade, or to conservationists and policy makers on the species being traded that may need further protection. Currently, large-scale monitoring by law-enforcement agencies would be difficult to achieve, primarily due to limitations of time to dedicate to this work and problems that nonexperts face in the identification of the species and origin of products for sale. One solution to this could be the development of automated tools to detect potentially illegal trade on different platforms. Currently, tools to detect illegal online trade via auction websites are being developed (Hernandez-Castro & Roberts 2015). Although structured commerce websites facilitate this kind of detection, social-media websites with free-form text present more of a challenge. However, developing similar tools in collaboration with social-media companies may overcome these problems, improve understanding of the nature and extent of the trade, and inform efforts to tackle it.

Supporting Information

The equation for the network-analysis closeness measure (Appendix S1), results of the network analysis for all communities (Appendix S2), orchid taxa found for sale (Appendix S3), all nonorchid taxa found for sale (Appendix S4), and the presence and absence of trade within the network structure of each community (Appendix S5) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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