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Mediating ethical considerations in the conservation and sustainable biocommerce of the jewels of the rainforest

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ABSTRACT

Threats to biodiversity have necessitated the implementation of timely conservation strategies. Negative anthropogenic impacts on species classically include habitat modification, fragmentation or loss. However in addition to these some species face additional risks such as those associated with (illegal) unsustainable harvests related to private collection, trade and commerce. Although commerce in plants and animals has a long history, recent findings suggest that online networking enhances connectivity between wildlife vendors and collectors, and can catalyze demand. In recent years conservation organizations have turned to biocommerce to offer legal and sustainable alternatives to smuggled or wild collected species. Here we provide a compendium of considerations related to the ethics and application of biocommerce in wildlife using case studies of two highly collected groups of tropical organisms; neotropical orchids and poison frogs. While we are in favor of biocommerce due to benefits such as the potential to mitigate unsustainable wildlife trade and provide funding for conservation programs, we also feel it is timely to provide an important overview detailing historical shortcomings in sustainability, and attempt to provide an ethical compass facilitating the future fusion of conservation and exotic hobbies.

1. Introduction

Longstanding threats to biodiversity in the tropics are driven primarily by anthropogenic activities, centered around habitat modification, fragmentation or overall loss of habitat (Tilman et al., 2017), where in geographical regions such as neotropics their impacts are well advanced (Achard et al., 2002). These threats can be compounded further by human-mediated activities such as over-collection. Ever-growing international trade has increased overall numbers of demanding customers where novel offerings are highly coveted, and because of this, species new to science are often placed at risk upon the first image shared online (Brown et al., 2011; Pepper, Brown, & Twomey, 2007). Social media platforms generate fervent demand for exotic species where illegal wild-collected individuals can be found for sale in local markets (Phelps & Webb, 2015) or globally via online vendors (Hinsley, Lee, Harrison, & Roberts, 2016). Poaching and illegal harvests have reached mainstream news media in large charismatic species; although similarly threatened by illegal trade, small ornamental species may fly under the radar of most conservationists. Biocommerce (alternatively entitled 'BioTrade', UNCTAD, 2007) has been offered as an alternative means to generate funding for conservation by harnessing interest otherwise directed towards obtaining illegal specimens. This potential is currently remarkably underutilized yet could offer a sustainable alternative (Hinsley & Roberts, 2018), which competes directly with smuggled species and their descendants in the marketplace. Contemporary implementation, however, has revealed concerns.

To better understand the interplay between international commerce and conservation we investigated two neotropical groups, miniature orchids and poison frogs. Both include highly charismatic species with substantial international demand (Hinsley et al., 2018; Nijman & Shepherd, 2010), which can represent a threat to wild populations. To the best of our knowledge, formal definitions of the term biocommerce first arose in 1996 during talks related to the Convention on Biological Diversity and broadly relate to the collection and commercial use of wild-derived goods (Mendoza, 2014). We offer a small refinement for purposes of our discussion, defining sustainable biocommerce as the captive (or manipulated *in situ*) cultivation of a species for the explicit purpose of sales to private individuals as part of a hobby/trade, or sales to private/public institutions.

To further explore how conservation and biocommerce interests can meld in these groups we contribute what we feel are essential discussions, which are currently absent in the literature. These include potential benefits and problems, or where current applications of

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biocommerce are misguided. It is our aim to open a dialogue by first extolling the benefits and potential contributions of biocommerce towards sustainability in international trade. Our discussions then turns to common ethical pitfalls, and elaborates on hobbyist cultures related to acquisition of illegal and grey market plants and animals. We define grey market as individuals descended from illegal collections, offered by agencies with permits but not demonstrably sustainable, or sold under false pretenses (e.g. claimed to be farmed, when wild). We detail the relatively short history of sustainable biocommerce done by conservation agencies in these species by investigating the successes and failures of several start-ups, and place their contributions within the context of overall international commercial trade for the species they deal in. It is our hope that this discussion will help to develop a viable and sustainable means to generate perpetual revenue to fund research and conservation where it has historically proven difficult.

1.1. Biocommerce in miniature orchids

For centuries orchids have been coveted for their beauty, resulting in unsustainable and/or illegal harvest of orchids species have resulted in declines and even extirpations (Orejuela-Gartner, 2012) and their listing in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices 1 and 2. These behaviors are encouraged by the use of online platforms such as taxon-specific pages or classifieds which encourage demand from consumers and facilitate trade in illegal plants through networking via e-commerce and social media (Hinsley et al., 2018). Epiphytic orchids have evolved to occupy specific niches which have limited dispersal abilities (Murren & Ellison, 1998) and can be restricted to small regions of suitable habitat. Therefore the impacts of habitat loss or illegal harvest can be amplified. While no precise data exists to permit quantification of the true extent of smuggling, the negative impact on wild populations from illegal collections for hobbyists is becoming increasingly clear (Vermeulen, Phelps, & Thavipoke, 2014 and references therein).

Parental stock for orchid biocommerce may come from purpose-collected individuals subsequently reproduced *ex situ*. However individuals may alternatively collect “salvage” or “rescues” which are sold directly, including undescribed species that are flowered in captivity and later described (Luer & Thoerle, 2012). In these instances plants are ostensibly collected from sources such as felled trees, the byproducts of tree trimming, or construction of roads. While collections can be sustainable, unscrupulous individuals could take advantage of loose rescue definitions to collecting large numbers of plants for immediate resale. The term “orchid rescuing” has been used so broadly that delimiting legal and ethical interpretations has proven difficult. We propose the rescue/salvage of orchids should only occur in instances when there is no chance that plants will survive or thrive under present or immediate future conditions, and only when in conjunction with proper permits from environmental authorities.

Overall there is little attention paid to how new orchid species arrive into captivity, where hobbyists’ collections often include large quantities of undescribed species exported (either erroneously or fraudulently) under alternative or incorrect names. Even when species are blatantly smuggled, memories regarding these incidents are short. A prime example includes *Phragmipedium kovachii*, a species Michael Kovach purchased from local Peruvians and smuggled plants to the US, depositing several directly in the hands of staff from the Selby Botanical Gardens– who subsequently raced to describe the new species in their in-house journal (Atwood, Dalström, & Fernandez, 2002). The allure and prestige of describing a large and attractive species seemingly outweighed any concern over the legality of the specimens, as they were aware it came from an illegally smuggled specimen (Edwards, 2004). In time Kovach was convicted of illegal possession of an endangered species resulting in convictions and fines both for Kovach and Selby Botanical Gardens (Borrell, 2007) illustrating the first instance of a botanical gardens charged with violations of the endangered species act (Edwards, 2004).

1.2. Biocommerce in poison frogs

Poison frogs (family: Dendrobatidae) are highly charismatic where many species displaying conspicuous aposematic (warning) coloration (Santos, Coloma, & Cannatella, 2003). High demand for animals coupled with regular exports (both legal and illicit) has resulted in significant pressures faced by many species. Many distinct populations and/or species are characterized by highly restricted geographic ranges and limited dispersal capabilities (Ringler, Ursprung, & Hödl, 2009; Twomey, Vestergaard, & Summers, 2014), placing them at risk for overcollection (Posso-Terranova & Andrés, 2018). Since 1987 all brightly colored Dendrobatid frogs common in trade are protected from listing in Appendix II of CITES. In practice this should regulate all commercial trade of these species, however in application protection afforded by this listing has seen significant challenges. The movement of large numbers of animals show mismatches and gaps in reporting (Nijman & Shepherd, 2010) and several species common in the pet trade have never been legally exported from the country of origin. One such case includes *Adelphobates galactonotus*, an endemic species to Brazil where all wildlife is protected and export for commercial purposes is prohibited. In an internal CITES factsheet it’s reported that it is widely known all specimens have illegal origins, yet trade in the species continues openly; even known smuggling events were investigated by Brazilian authorities for a short time which ended without arrests or repercussions (CITES, 2015).

Faced by repeated smuggling of Colombian endemic species, Tesoros de Colombia (Bogotá, Colombia) was formed with a fundamental goal of curbing smuggling by offering sustainable, captive bred options to replace illegal origin animals. They have worked with several species of poison frogs including *Oophaga histrionica* and *O. lehmanni* which are both highly threatened/endangered, and regularly smuggled. A goal central to their operations is to make threatened species commercially available while encouraging hobbyists to refer to ‘Tesoros’ lineage animals (with legal origins), clearly distinguishing them from smuggled or grey market lineages (I. Lozano *pers. comm*). In 2010 WIKIRI Selva Viva (Quito, Ecuador) has recognized that by using novel trade names for their offerings functionally serves as a means to identify their offerings from illegal origin lineages. WIKIRI identifies a trait unique to each frog species and picks a word in the indigenous Quechua language as a trade name. This is additionally meant to discourage laundering illicit lineage animals with their legal offerings (L. Guarderas, *pers. comm*). This type of marketing is similarly used Understory Enterprises (Chatham, Canada) where new sustainably produced frog morphs are labeled by arbitrary names which commonly reference a vague geographic region, or unique attribute of the population, rather than any specific locality name.

1.3. Examples of biocommerce and other alternative revenue sources to fund conservation

A persistent concern in conservation, particularly acute in Latin America, is how to maintain sufficient funding over long periods of time. Grants in aid of conservation (e.g. small grants for amphibian conservation provided by the Amphibian Ark, the National Geographic, or the Mohamed bin Zayed species conservation fund) are difficult to obtain and each successful funding sustains programs only a few years at a time. More recently emerged alternative funding such as crowdfunding platforms have shown considerable promise, facilitating in transferring money from regions of high incomes to projects in lower income areas (Gallo-Cajiao et al., 2018). However the duration for which funds from crowdfunding last is similarly short unless projects have very low financial requirements, the projects funding generates a surplus, or donors are seduced into funding multiple campaigns. Some organizations have identified alternative means by which to raise funds

for conservation by commercializing species to exploit interests, and offer an ethical alternative to illegal or unsustainable imports.

Local habitats may be limited in resources that dictate population densities. In amphibian species the number of tadpole deposition sites is a prime example of a population limiting resource; it is possible to increase some frog populations simply by enriching territories with additional sites for offspring rearing (Summers, 2002). For a short time the non-governmental organization Instituto de Investigación Biológica de las Cordilleras Orientales (INIBICO, Tarapoto, Peru) used this methodology to incentivize local farmers to protect their forests by ranching poison frogs. Landowners were encouraged to place halved plastic bottles filled with water around their forests, and were paid for collecting 'surplus' tadpoles that were deposited in their bottles. Income from sales was meant to offset the opportunity costs of cutting their forests, and provide a predictable, long-term income. At the time this concept was novel, and in 2003 gained the support of a development grant from the World Bank entitled "Poison Dart Frog Ranching to Protect Rainforest and Alleviate Poverty" for a starting budget of $64,000 and total project budget of over $1.8 million (it is unclear what amount was ultimately paid). To remain viable over time, their management proposal scheduled for annual introductions of new species, as well as rotation of species in market cycles (World Bank., 2003). Backing from the World Bank indicated an early acceptance from financial institutions, and support of biocommerce as a viable option for generating revenue in support of conservation. The project successfully exported frogs twice before falling silent.

Fundamentally one could argue that biocommerce (even when sustainable) would work against the goals of conservation by associating a species with a monetary value. One could even question the ethics of hobbies centered around exotic wildlife, particularly questioning the desires of consumers for species which are rare or threatened in their natural habitats. However biocommerce has been shown to successfully leverage commercial interests (Figs. 1–3, Sinovas & Price, 2015) where funds contribute to protection and conservation of species. Organizations such as Tesoros de Colombia and Understory Enterprises promote conservation by introducing legal and sustainable animals to hobbyist markets and use biocommerce funding to purchase private reserves (I. Lozano, M. Pepper). WIKIRI Selva Viva is the biocommerce arm of a research and conservation facility called Centro Jambatu which boasts state of the art laboratories, veterinary clinic and museum (Guarderas, 2017). Both WIKIRI and Centro Jambatu fall under a broader organization called Fundacion Otonga, which additionally manages several private reserves (Guarderas, 2017.). The biocommerce of Tesoros de Colombia works in conjunction with the foundation Bioparque La Reserva in operating a privately funded educational and outreach zoo. They utilize confiscated animals in educational displays emphasizing conservation, sustainable use and animal welfare. Additionally, according to Colombian law Tesoros is required to pay back 100 % of the commercial value of parental stock (used to generate offspring for biocommerce), and 5% of the value of all exports. This can be paid in non-currency forms such as habitat restoration or animals for reintroductions, or financially compensated to environmental authorities (I. Lozano *pers. comm*).

2. Examples of the efficacy of biocommerce in international trade

In addition to securing funding for research and conservation a central goal of biocommerce is to assist in supplanting illegal activities by offering legal and sustainable alternatives. Because of the relatively few years of sustainable biocommerce in species like poison frogs evidence of suppressing illegal activities is primarily anecdotal, however we present what data can be gleaned from recent years. For biocommerce to remain a viable funding option, products must be competitive within local markets and interest maintained long term. Although biocommerce is new, and records difficult to obtain (detailed below), we were able to glean a preliminary look at the relative success. We analyzed CITES import records of frogs, comparing overall numbers imported to those reported from biocommerce agencies. This provides us a comparative framework to infer the strength of biocommerce in relation to overall imports (including grey market animals). Our comparisons are limited to the United States as it is the country where the majority of biocommerce animals are shipped, and imports are well documented in the database. We are able to observe many instances where sustainable biocommerce imports represent either a significant margin, or in some cases constitute all imports of a given species (Figs. 1–3).

In brief, to obtain CITES records we searched the CITES trade statistics which were derived from the CITES Trade Database (UNEP World Conservation Monitoring Center, Cambridge, UK) for "gross imports" to the "United States" with the following import search parameters: trade term: "live"; purposes: "breeding in captivity or artificially propagated", "educational", "reintroduction or introduction into the wild", "circus or traveling exhibits", "botanical gardens"," personal", "commercial" and "zoo". This encompasses all parameters by which animals could be imported and reach hobbyists, while excluding importations of species uniquely permitted for research (scientific and/or medical) or law enforcement. It is worth reinforcing that reports are voluntary and may be prone to errors. As we chose to be conservative and include gross imports, re-exports are possible. However we are primarily interested in comparing proportions of biocommerce to other imports, both likely have the same probability of re-export, and unlikely to alter comparisons. Export records from biocommerce companies were reported directly by respective agencies. We show the numbers exported by each biocommerce agency (across active years, 2018 CITES data not yet available) relative to all US imports to illustrate the contribution (proportion) of biocommerce in the market.

In most cases imports from biocommerce represent a substantial portion of imports, or in many instances entire import quotas (Figs. 1–3). Biocommerce offerings have a remarkable hold (75–100 % of imports) in species with low reproductive output and high market prices (e.g. *Oophaga* species, Figs. 1 and 2). In contrast, other species show high fluctuations in markets, such as exports of *Phyllobates* species

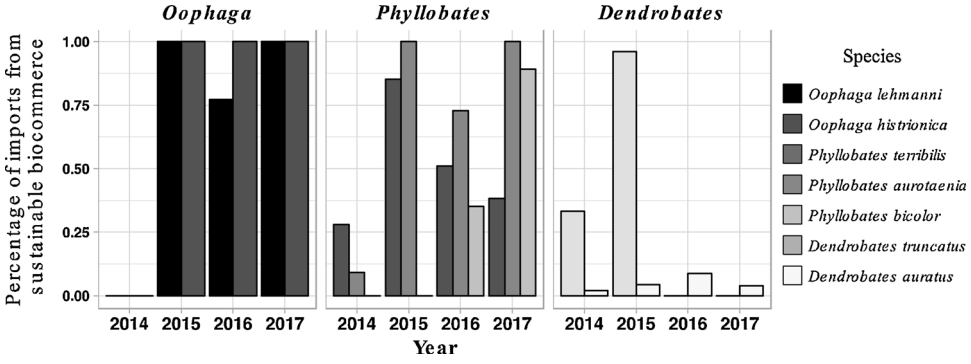

Fig. 1. The relative percentage of poison frogs imported from Tesoros de Colombia relative to all imports to the United States. Tesoros sustainable exports of species such as *Oophaga lehmanni* and *O. histrionica* tend to dominate import numbers whereas *Phyllobates* spp. vary between years, yet retain a notable portion of the markets. Tesoros exports of *Dendrobates truncatus* grew from 2014 to 2015 but then ended abruptly. Sustainable *Dendrobates auratus* were unable to make any appreciable dent in overall import numbers due to the vast number exported from Panama (see text for further details).

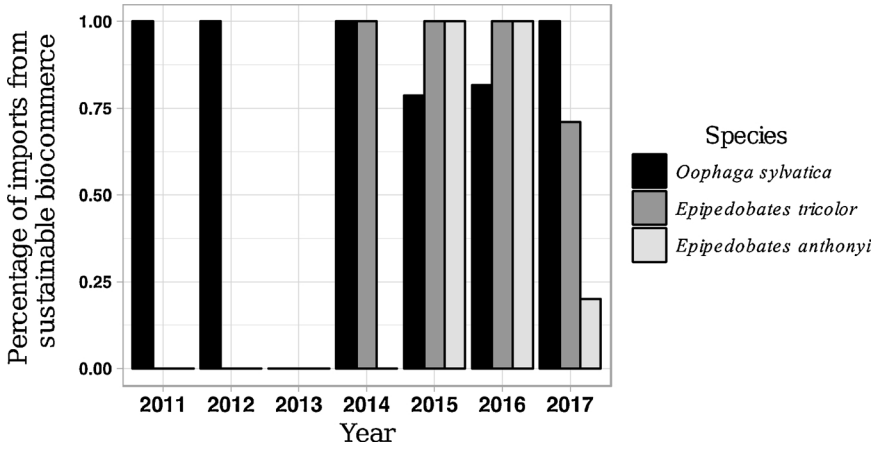

Fig. 2. The relative percentage of poison frogs imported from WIKIRI Selva Viva relative to all imports to the United States. In nearly all years frogs originating from sustainable biocommerce represent an overwhelming majority of imports reported to CITES authorities.

and *Dendrobates truncatus* (Fig. 1), or exports of *Epipedobates* species (Fig. 2). Only one species, *Dendrobates auratus* (Fig. 1), failed to capture any significant portion of the market, however this is due to the overwhelmingly high numbers of *D. auratus* exported from Panama every year (Fig. 4). When biocommerce organizations like Understory Enterprises introduce novel species or morphs, interest in new offerings dominates imports even for species that have been previously established in captive populations for many years (Fig. 3).

We caution that these figures do not include data related to animals involved in illegal smuggling, as detailed records do not exist (see Brown et al., 2011 for a summary of what is known) and reports are only published in local newspapers where numbers may be inflated. Nonetheless, subsequent movements of illegal animals descendants (grey market) into the United States are reflected in CITES records. It is also important to note that the overwhelming majority of trade in Dendrobatid frogs within the United States takes place in the form of direct hobbyist-to-hobbyist sales, and therefore would not be reflected in any of these data we are able to present. However, these CITES records represent the origins of novel or supplemental breeding stock, which will serve as the basis for future in-country sales. Therefore recognizing their sustainability will directly dictate the extent to which downstream between-hobbyist trade is ethical.

3. Problems associated with the sales of wildlife

Obtaining legal permits: An obstacle to biocommerce is the ability to acquire permits. In some countries legal collection permits for wild orchids is nearly impossible due to restrictions imposed by the ministry of the environment, and in the case of poison frogs can be both difficult and costly (I. Lozano *pers. comm*). Concerns held by governmental agencies range from the loss of proprietary genetic or biological resources, rarity of a species (or lack of relevant data), or general lack of interest in encouraging biocommerce. Taking into account the legacy of illegal traffic in natural resources from developing countries, including orchids and poison frogs, some governmental authorities have taken narrow viewpoints on the uses of such resources.

How novel offerings can arrive in commercial trade: In past decades, dozens of new species of orchids have reached the hands of orchid growers, many prior to their formal description. An “honest mistake” guise is employed whereby undescribed species are exported under the name of similar species, or perhaps more commonly simply exported lacking specific names (Fig. 5). Collectors therefore obtain new species immediately upon discovery, before any population assessments or protection can be obtained for them. Ironically, many species descriptions of orchids include permutations of such phrases as: “bought from nursery as known species, flowered in cultivation and resulted as an undescribed species.” In some instances the initial (potentially illegal) collector is rewarded with a patronym when the species is described (L. Baquero *pers. obvs*). With negligible risks and high rewards, these practices have increased in recent years.

Another example of a well-known plant with illegal origin is *Lepanthes matamorosii*, an orchid species endemic to Costa Rica. Specimens were collected and exported to Ecuador, where they were cultured *in vitro* and made commercially available to international

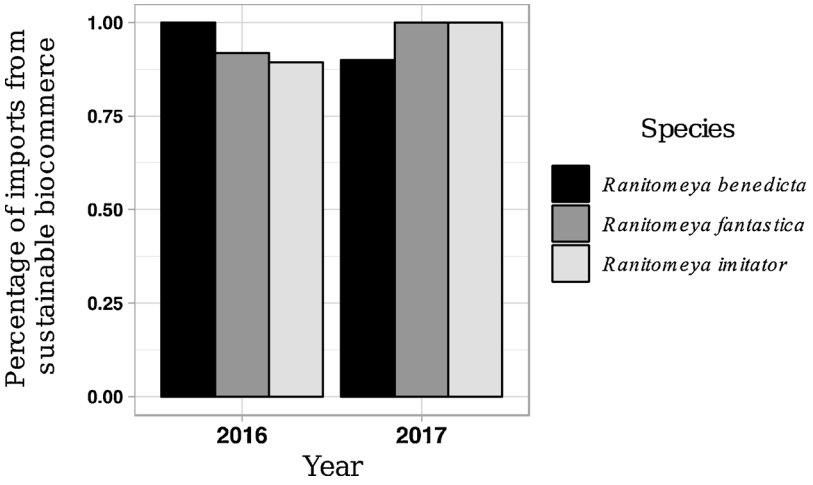

Fig. 3. The relative percentage of imports from Understory Enterprises for three species that represent their highest numbers of *Ranitomeya* species exports, and novel offerings to the market. Although Understory Enterprises exports a wide number of species, they are best known for introducing novel species and morphs of a genus of small poison frogs, *Ranitomeya* which overwhelmingly dominate US imports for these species.

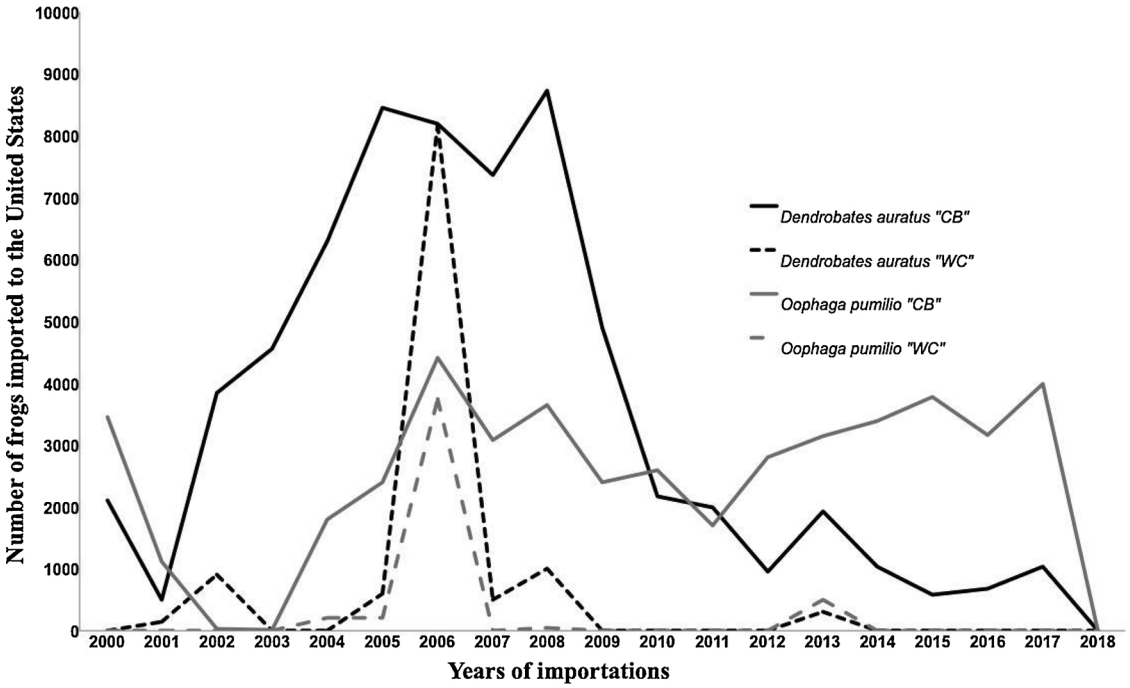

Fig. 4. Exportations of two species poison frogs (*Dendrobates auratus* and *Oophaga pumilio*) originating from Panama represent an overwhelming majority of frog importations to the United States. Since 2000 the majority of exported animals were classified as "captive bred" ("CB") origins, however in 2006 equal number animals were exported from wild/farmed ("WC") and captive bred origins. Husbandry demands to produce the quantities of captive bred frogs reported, coupled with this rapid increase in frogs classified as wild caught/farmed in 2006 make it difficult to ascertain the ethical status of frogs exported from Panama.

markets. Although individuals for sale were cultured *in vitro*, the fact remains that founding stock does not appear to have been legally exported from the country of origin. Furthermore, CITES records indicate only one plant moving from Ecuador to Germany, yet photos of newly acquired specimens are readily available online (L. Baquero *pers. obvs*).

Species of poison frogs new to science are immediate targets for smugglers. Local villagers are shown photographs of the species sought after and are paid meager fees (e.g. $1-2 per frog in Peru, Pepper et al., 2007) to collect large numbers. In at least three instances species descriptions or published photos resulted in frogs' immediate smuggling and arrival to international markets (Brown et al., 2011). Smuggled frogs are hidden in false bottoms of boxes containing fish shipments, and exported internationally, or hidden in film canisters contained within hand luggage (Associated Press, 2017). Many new lineages have entered into the commercial trade through these sorts of activities (Pepper et al., 2007), and although subsequent international movements can appear legal, the true origin of many lineages is difficult to decipher.

3.1. Troubling reports in international trade

The United States poison frog hobby receives a large number of Panamanian exports, which makes up roughly half (76,869 live frogs) of their 144,343 imported animals from the years of 2000–2017 (UNEP-WCMC, 2019). With this many animals, it is unsurprising there are problematic importations. It is immediately clear that hundreds of animals are the descendants of illegally smuggled animals, particularly the genus *Adelphobates* originating from Brazil (CITES, 2015), for which 877 individuals were imported. Similarly, *Excidobates mysteriosus* is a Peruvian endemic species listed as endangered both in Peru and internationally (IUCN SSC Amphibian Specialist group, 2018). Despite this, it has been imported twice (30 individuals in 2003 and 100 individuals in 2011, UNEP-WCMC, 2019) despite never having been legally exported from Peru.

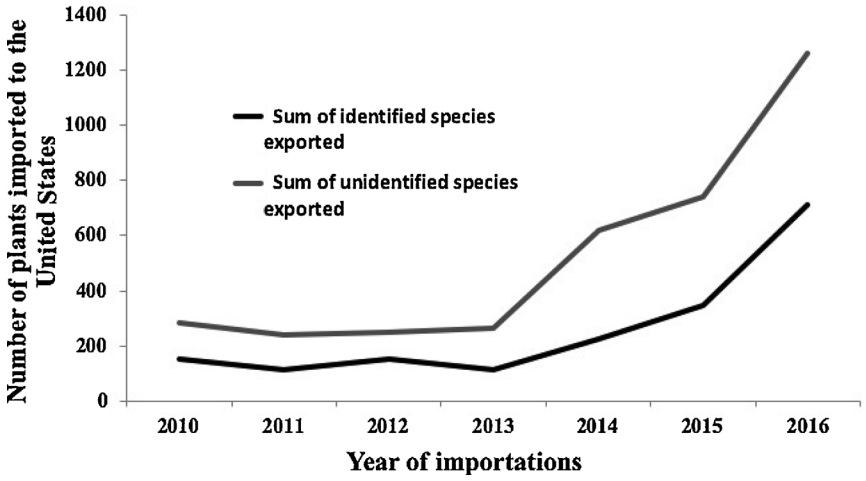

Fig. 5. Species new to science, or which may have illegal origins can be regularly traded as plants imported without specific epithets. The practice of importing non-specific plants has increased proportionally with overall plant imports and always exceeds the overall quantity of identified species exported, as is illustrated by orchids of the genus *Lepanthes* exported from Ecuador to the United States.

Beyond blatantly illegal imports of species never legally exported from their country of origin, there are additionally troubling findings. According to exporter records from the CITES database (UNEP-WCMC, 2019) between 2001 and 2016 Panama exported roughly 127,238 live poison frogs for the pet trade, the majority of which were represented by two species (Fig. 4), *Dendrobates auratus* (78,524 individuals) and *Oophaga pumilio* 46,903 individuals. Although these numbers are shocking, that the majority are reported to be of captive bred origin is what is most surprising. The notable exception to this was in 2006 where 8175 *D. auratus* and 3750 *O. pumilio* were exported as wild caught/farm raised where in all other years similar numbers are reported as coming from non-wild origins (UNEP-WCMC, 2019). To put this into perspective, in captivity a highly productive pair of *O. pumilio* (whose fecundity is much lower than *D. auratus* due to obligate parental care) could be expected to produce a maximum of approximately 12 offspring per year (R. Zahradnik *pers. comm.*. In 2014 there were 6300 'captive bred' *O. pumilio* exported (UNEP-WCMC, 2019). To attain this level of production 525 captive breeding pairs would need to be maintained, which would require an unprecedented husbandry investment, particularly to ensure optimal reproduction across all pairs and no mortality. Because previous years exports of *O. pumilio* summed 5,220 and 6180 individuals 2013 and 2012 respectively, UNEP-WCMC, 2019) it is unlikely that the *O. pumilio* exported in 2014 included any carry-over offspring produced from previous years.

Other irregularities from Panama in CITES records include the 2001 export of 'captive bred' *O. sylvatica* (79 individuals) and *O. histrionica* (79 individuals) whose Northern distributions extend only as far as Southern Colombia (*O. sylvatica*; Coloma, Ron, Grant, & Lötters, 2004, IUCN red list) to North-Central Colombia (*O. histrionica*; Bolívar, Lötters, & Grant, 2004, IUCN red list). From 1975–2001 only 10 'bodies' of each species were ever imported from Ecuador to Panama (1992, UNEP-WCMC, 2019, and neither species described to range has extended into Panama. Finally a total of 1550 *Dendrobates ssp*. frogs (imported into the United States between 2007 and 2015) could represent a significant introduction of grey origin animals into the United States, which would be impossible to track, and contribute to the difficulty in tracking the sustainability of biocommerce for using databases such as CITES.

Tracking orchid species movements is complicated significantly due to incomplete or inaccurate CITES records. The genus *Lepanthes* are miniature orchids highly collected for their diversity in flower and leaf ornamentation (JY, LB *pers. obvs*). Due to their small sizes, large numbers of miniature orchids can be easily cultivated in small indoor terraria, and collectors prize undescribed species. However tracking the movements of specific species *Lepanthes* is particularly difficult as the overwhelming majority of *Lepanthes* species imported into the United States from Ecuador are done without specific epithets (Fig. 5). The number of *Lepanthes* spp. has always surpassed the combined sum of all identified species imported, and increases proportionally with overall orchid imports in recent years. While we are confident these vendors are propagating and selling *in vitro* cultured plants, by failing to provide accurate reporting to CITES databases the movements of illegal or grey origin species could be facilitated and difficult, and all but impossible to monitor.

3.2. Market competition and consumers preferences

Promoting biocommerce in species where there are already conservation concerns can seem paradoxical. After all, it is plausible that offering legal and sustainable specimens can increase overall demand for a species, which could result in raising market prices and incentivizing smugglers. This would particularly be the case should demand exceed the ability to produce sustainable offspring. Even were this not the case, it is beneficial to differentiate biocommerce offerings from grey market or illegal options. In frogs, online sellers are encouraged to list specific data in advertisements including the sexes, age and 'lineage' of their offering. Lineages refer to the origin in trade, and can refer to 'brand' (e.g. Tesoros, WIKIRI or Understory Enterprises), importer name (often year of import), or "old line." Old line is a hobbyist-specific synonym applied to illegal, unknown or grey market offerings. Although no formal market studies exist, conversations with hobbyists say it is clear that animals from sustainable origins will generally fetch significantly higher prices than "old line" animals, lending support to the efficacy of biocommerce projects (R. Zahradnik *pers. obvs*).

Fundamentally biocommerce will not succeed without gaining traction in consumer preferences. Because plants can be propagated, and animals bred in captivity, wildlife products are unique in terms of economics. In short time biocommerce products will be in direct competition with their own offspring. Prices for individuals produced within a country are understandably more affordable than imports, due to importation costs. This is worsened by the fact that biocommerce products are not only in direct competition with their descendants, but also grey market and illegal offerings. Although this could seem insurmountable, we are optimistic that this is far true. On one hand, affordable exotic hobbies are likely to experience growth, increasing the potential consumer base. New hobbyists can be taught by experienced members to prefer sustainable biocommerce options, education could occur on social media platforms where new members could learn cultural preferences. However passively disseminated education may not be enough and hobbyists should also organize formal discussions and demonstrate their membership preferences via seminars at trade expositions, or society meetings. The success of biocommerce hinges on organizing and solidifying support from consumers and organically growing a clientele base.

3.3. Proposed best practices for sustainable biocommerce

It is our goal to initiate discussion, and provide a guideline for authorities and hobbyists. For their part, governments could facilitate biocommerce by providing clear requirements which enumerate what is required for individuals for to apply for biocommerce permits, where regulations are straightforward facilitating both compliance by companies and assessment by the governmental agencies. Ideally these requirements would promote sustainability and include wild population impact studies. With diligent marketing, biocommerce species should command higher market prices and permit a proportion of generated revenue to conserve original habitats. Ideally, this would include money that could be devoted to fund research and education, where new findings could increase the 'value' of protected lands, and incentivize conservation done by local communities.

While unique names associated with biocommerce can attenuate laundering with illegal or grey market individuals by promoting the isolation of sustainable lineages, truly only market demands and attentive buyers can prevent it. Hobbyists must act cooperatively to educate one-another and develop a culture which financially support biocommerce, while simultaneously demonstrating intolerance for novel illegal lineages. Preferably records would be maintained with details as buyer's names (or represented by codes to facilitate anonymity) and sales details including numbers and date of purchase. Subsequent 'aftermarket' trades or sales could be updated, as could the reporting of resulting offspring accompanied by supporting photographic evidence. However, it requires considerable effort on the part of consumers, and could be unpopular. Therefore creative solutions or incentives may be necessary to promote compliance. Ultimately ensuring persistent demands for sustainable-origin species from consumers is key to the success of sustainable biocommerce initiatives.

Even sustainable biocommerce imports bear a potential risk of novel pathogen introduction, which can increase resistance from scientists and/or politicians. For example the movement of pet trade amphibians is proposed to be responsible for the introduction of the infectious chytrid fungus *Batrachochytrium salamandrivorans* into Europe from

Asia (Nguyen, Van Nguyen, Ziegler, Pasmans, & Martel, 2017). Justifiable concerns this may occur in the United States has prompted calls for a moratorium on the trade of amphibians entering the country (Angulo et al., 2017). In a recent study, some feel this temporary salamander import ban is the safeguard which prevented *B. salamandrivorans* from being detected in a large survey of captive salamanders (Klocke et al., 2017). Prudent implementation of animals testing and treatment prior to import is key to mitigate concerns for known pathogens, which although they have been implemented long ago by some organizations, to date it is not a standard practice. Such safeguards should add accrued benefits to biocommerce offerings, further increasing their value to hobbyists over wild alternatives. In plant exports phytosanitary permits are granted after completion of predefined treatment protocols, which are required prior to importation. Biocommerce specimens should meet or exceed all required health or sanitary protocol to promote acceptance with legal and scientific entities, and ensure they are hobbyist preferences.

3.4. Concluding remarks

Although ample problems are identified related to biocommerce, and shortcomings present in application to date, we are confident that biocommerce offers a viable alternative means to generate funding and can in fact aid conservation. While we present specific issues for biocommerce of these two groups and the potential benefits, we have not forgotten broader preoccupations over ownership and sovereignty of biodiversity, including potential treats due to biopiracy (Hayden, 2006).

Future research will need to clarify if sustainable offerings can replace wild-collected offerings (Phelps, Carrasco, & Webb, 2013), and identify mechanisms which ensure biocommerce offerings replace wild-collections. Conservation groups must treat biocommerce opportunities as a legitimate business subject to the laws governing economics. Relying on the goodwill of hobbyists for sales is not financially viable. However we believe sustainable biocommerce affords a timely opportunity which can blend with, and greatly benefit conservation, and can be used to as a mechanism to improve existing problems of exotic hobbies.

Impact statement

Biocommerce is a divisive, yet ultimately powerful tool that can be harnessed to generate revenue to aid conservation.

Declaration of Competing Interest

JY was a former student of L. Coloma of WIKIRI Selva Viva and personally is familiar with operators of biocommerce institutions. No institution encouraged nor supported this work in any way.

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