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PERSPECTIVE

Can sustainable biocommerce continue to support conservation, or will the captive breeding of offspring be its Achilles heel?

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Abstract

1. The trade in high-value natural resources, particularly exotic plants and animals (henceforth biocommerce), can lead to both positive and negative impacts on wild populations. The exotic plant and animal hobbies are highly organized with internal cultures that are often poorly understood by non-members; however, understanding them is of central importance for biocommerce with both direct and indirect consequences for the conservation of wild populations.
2. Growing international demands for exotic species leaves simple questions related to the economics of biocommerce unexplored. The long-term success of biocommerce businesses requires constant income, meaning they obtain and retain significant market proportions. Some biocommerce products can be reproduced by hobbyists and undercut business efforts based on sustainably produced exports.
3. We analyse a test case in Neotropical poison frogs where sustainable biocommerce is burgeoning, yet (export-based) businesses face direct market competition from the offspring produced within the countries, which receive their exports, and therefore are forced to rely on fervent customer support.
4. *Solution*: We survey customers' behaviours where we find different classes of consumers, which differ in where they place higher values within the hobby. By taking into account these different classes, we gain insights and potential solutions to promote the stability of this unique type of biocommerce.

KEYWORDS
behavioural economics, biocommerce, conservation, fundraising, hobby, smuggling

1 | INTRODUCTION

The global trade in plants and animals exceeds 100 million individual specimens each year (Harfoot et al., 2018), with international pet trades generating approximately 93 billion euros a year in the EU markets alone (Engler & Parry-Jones, 2007). While the prevalence of captive-produced plants and animals has steadily increased over the last 40 years, overcollection from wild populations remains an issue (Harfoot et al., 2018; Hughes et al., 2023; Liu et al., 2019). Overcollection to satisfy the demands of global trade networks can lead to substantial negative impacts on wild populations. A sustainable biocommerce model, (sensu Yeager

et al., 2020) that emphasizes captive, or semi-natural rearing conditions for the production of plants and animals specifically for trade, could reduce impacts on wild populations and reduce risks often associated with the trade of wildlife. Additional sustainability benefits from biocommerce include where the sales from sustainable biocommerce products can potentially generate revenue to fund initiatives such as both in situ and ex situ conservation, education or research. Entire businesses have been built exclusively on biocommerce, however there are also less specialized agencies such as conservation groups which use biocommerce to help raise additional funds through the captive in-country production for export.

There is a rich history of international ornamental plant markets (Griesbach & Berberich, 1995), among them orchids (Hinsley et al., 2018), succulents (Margulies, 2020) and aroids (Chapman, 2019). Exotic animal hobbies have a similarly long history (Mitchell, 2009), yet many of the most basic details related to biocommerce are unresolved in even commonly traded species (Green et al., 2020). Perhaps the poorest understood form of wildlife (biocommerce) products are those which enter the pet trade *and* are capable of being reproduced in captivity. While some examples exist, such as the marine aquarium hobby, marine species vary in their ability to be reproduced (Pouil et al., 2020), and markets represent a mix of wild caught and captive bred species. These products offer logistic challenges when customers reproduce offspring, serving as direct market competitors and potentially undercutting sales for the primary business. In addition to generating revenue, sustainable biocommerce can defray demand from unsustainable or illegal practices (BBC, 2020; Robinson et al., 2015; Thomas-Walters et al., 2021). Yet there are also ethical considerations related to sustainable biocommerce, which should be considered and mitigated (Yeager et al., 2020) in parallel the development of biocommerce in novel species. However it is presumptive and occasionally incorrect (Phelps et al., 2013) to assume that sustainable biocommerce is a universal solution to illegal smuggling. Products which need to be exported internationally face logistic considerations, costs associated with exports, the potential for disease transmission (Kolby, 2014; Yeager et al., 2020), which are all concerns that can influence consumer decisions. A more profound understanding of consumer preferences and priorities is essential to stem the consistent pressures of smuggling on small wild populations (Alund, 2024) and for income derived from sales of sustainable biocommerce products to be a reliable revenue stream, which can fund research and conservation.

Despite economic potential, many aspects of biocommerce are poorly studied, and issues associated with the implementation are infrequently discussed (Hinsley et al., 2018; Yeager et al., 2020). Social media trends can drive geographic and temporal variance in international consumer preferences and demand (Hinsley et al., 2016; Wallen & Daut, 2018). Market surveys are useful to assess consumer preferences and can be used to infer market stability (Hinsley et al., 2015). The availability of sustainable products does not guarantee they will overtake markets of grey market or illegal products. Even when sustainable specimens represent superior quality and are offered at equivalent prices, they still may not dominate marketplaces (Phelps et al., 2013). As biocommerce in species that can be captive bred increases, it becomes essential to understand consumer dynamics. To understand the stability of sustainable biocommerce as a mechanism to generate funds for conservation, we need to more thoroughly understand how hobby-related values are generated, and to what extent customers' importance in environmental values translates into purchase decisions. This information is essential as biocommerce operating budgets are often based on expectations of futures income derived from multiple-year sales.

For the long-term success of agencies relying on income from biocommerce, their offerings need to obtain and retain a significant portion of markets to remain a viable source of revenue. Unlike traditional natural resources, some biocommerce products are produced in the country of origin, as well as are readily capable of being reproduced in captivity by customers. Primary consumers can sell their offspring to secondary consumers in-country, without any potential logistical complications or costs derived from importing while offspring from imported animals serve as principal market competition. Neotropical poison frogs, of the family Dendrobatidae, are highly coveted and high-dollar species are commonly traded. While sustainable biocommerce is burgeoning, businesses face direct market competition from both their own offspring and illegal (or grey market) animals, and therefore rely on fervent customer support. To gain insights into the stability of this unique side of biocommerce, and how biocommerce businesses can remain viable despite intense competition, we survey customers' behaviours to better understand consumer tendencies, lending essential information towards the long-term potential of sustainable biocommerce in species which generate their own market competition, such as is the case for poison frogs.

We present a pilot study focused on a group of conspicuously coloured poison frogs from the family Dendrobatidae, where hundreds of variants have been kept as pets worldwide for decades (Edmonds, 2021). Market surveys are informative for poison frog trade because peer-to-peer domestic trade is nearly impossible to track without participant-reported data. However, care must be taken in interpreting consumer behaviours—consumer preferences have proven more complex than expected in commerce where both wild and cultivated offerings are simultaneously available (Hinsley & 't Sas-Rolfes, 2020). We aim to demystify basic concepts around the economics of biocommerce of species that reproduce in captivity by primary or secondary consumers to understand consumer preferences and values, so that sustainable biocommerce businesses can remain economically viable, thereby permitting them to also continue their missions of conservation and research. Although our test case deals specifically with poison frogs, the concepts and results afford broader insights which should be relevant to other traded species.

2 | METHODS

2.1 | Survey design

We created an online survey on the SurveyMonkey.com© platform to assess consumer preferences and purchasing behaviours (human ethics approval granted from UDLA CEISH committee project code: JY-210423-001). Our questions aimed to identify specific customer preferences related to their hobby-related interests, purchasing decisions and price stability, and specifics related to the direct competition dynamics between biocommerce animals and their offspring in shared markets. We assess whether broader ethics such as supporting conservation, legality or sustainability could influence consumer decisions. Three types of questions were used in the survey to be able to quantify consumer preferences (Hinsley & 't Sas-Rolfes, 2020). Multiple-choice questions contextualized the individual's participation within the hobby with regards to the diversity of species kept, time in the hobby and annual spending. Additionally, questions with ranked importance (from 1 to 5) were used to assess the importance of provenance and legality of purchases, the importance of price in dictating purchasing decisions, the importance of status (gained from owning rare species) and their interest in sustainability. Finally, short answer and multiple-choice questions sought to clarify details related to offspring selling expectations, including understanding the competition between biocommerce offerings and in-country produced offspring.

Surveys were distributed broadly through social networks, with personalized invitations sent to active hobbyists. For 2 months, repeated social media posts were made in specialized groups, and we created an Instagram profile for the survey, which advertised the questionnaire using daily posts that featured in situ images of rare species of poison frogs to draw in participants. We acknowledge potential downsides of our sampling: first, our questionnaire excludes hobbyists (albeit likely a minority) who are not active on platforms; second, responses were voluntary and required participant motivation, and may underrepresent casual hobbyists; and third, although surveys were anonymous, participants' replies may be biased when providing responses that would be looked down upon by the hobby (Barnett, 1998)—relevant to questions related to their opinions related to the legality of animals, or the importance of the 'status' in the hobby.

2.2 | Data analysis

We built a Logit model of latent classes (LCM) using Stata statistical software® (version 15.1). We aimed to define types of hobbyists and define their interests within the hobby. This type of model has been shown to successfully identify heterogeneity of preferences (Hinsley et al., 2015). Due to homogeneity in ranked importance responses, a Logit model was developed with the variables: price (importance of price purchasing decisions), status (importance of rare animals/social status), tendency to purchase in-country offspring and importance of (re)sales (ability to generate revenue from offspring). This model identifies the variables that best explain the preferences of each latent group or class, but does not determine the number of these, so statistical information criteria must be used to define discrete groups (Birol et al., 2009), where we used the Akaike information criterion (AIC) and the Bayesian information criterion (BIC), for modelling latent class models (MacDonald, 2018).

A latent classes model was built encompassing questions related to animal prices, hobby-status (owning rare/expensive animals), likelihood of directly purchasing/supporting biocommerce businesses and resale potential using binary variables. In the last category data were averaged scores of importance, from different questions that were asked in the survey, these values were considered as 0 if they belonged to the range between 1–3 and 1 if they belonged to the range between >3 and 5, apart from the variable resale which was considered false = 0 and true = 1.

3 | RESULTS

3.1 | Biocommerce hobbyist profiles

Detailed replies were obtained from 64 hobbyists (67% of those who initiated the survey) from nine countries: USA (68.75%), Canada (7.81%), Belgium (4.68%), UK (4.68%), Holland (3.12%), Japan (1.56%), Germany (1.56%), Denmark (1.56%) and France (1.56%). Most participants had been involved in the hobby for more than 5 years (79.68%), with spending exceeding $1000 (42.18%) or between $500 and $1000 (28.12%). This indicates that participants show considerable time and financial investment in the hobby. Most keepers (67.18%) maintain collections comprised of multiple genera, and 68.75% of participants report maintaining more than five different species within their collection, indicating they prefer diversity over being specialized in only one or few species.

3.2 | How classes of consumer groups differ

Latent classes analysis revealed collectors segregate into two classes (Table 1), the first group are less concerned over the price of the frogs in their purchase decisions and are less concerned with their status within the hobby due to the rarity of species they keep than group 2. The second group are more likely to buy the offspring produced nationally than from those imported from biocommerce agencies, though are more concerned with resale potentials (Figure 1). Therefore, group 1 could be categorized by 'hobbyist collectors' and group 2 'commercial collectors' (Table 1).

Our specific aim was to understand how behaviours influence the market dynamics between biocommerce products and national production upon the initiation of direct competition. Roughly half of participants actively sell offspring for the same value that they paid for stock from biocommerce businesses (54.68%), a slightly lower

TABLE 1 Summary of measures of model fit for the latent class models with model fit values Akaike information criterion (AIC), Bayesian information criterion (BIC), corrected AIC with a penalty factor of 3 (AIC3) model described in the Methods. The model suggests that hobbyists can be split into two distinct classes, which differ in key components of where they value elements of the hobby, such as their concern with prices, resale potential and rarity of species kept (Figure 1).

Model type (num. of clusters)	Number of parameters	Log likelihood	BIC (LL)	AIC (LL)	AIC3 (LL)
2	9	−137.738	312.907	293.477	302.477
3	14	−135.927	330.079	299.855	313.855

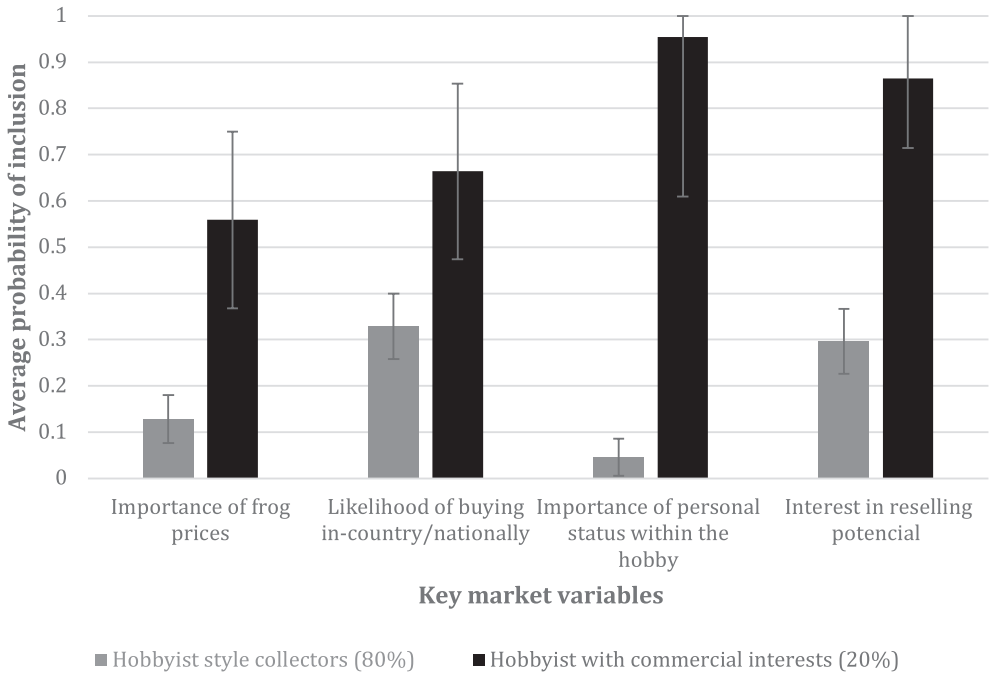

FIGURE 1 Visual representation of the latent two-class model explaining hobbyist behaviours. The average probability of inclusion (*y*-axis) in key market variables that inform purchase decisions (*x*-axis) are shown between the two classes of buyers: Commercial style (black) and hobbyist style collector (light grey).

proportion reduce prices (39.06%), and in rare instances (6.25%), hobbyists are able to command a higher price. Most participants (68.75%) affirm their direct customers also buy from biocommerce businesses, demonstrating that domestic production does not cause a complete divestment of interest nor entirely replace the demand for imports from biocommerce agencies. However, in-country prices are important; 36% of sellers confirm that their customers prefer their offspring because they are cheaper, owing in part to savings on permitting, shipping and import fees. While biocommerce offerings are not cost-prohibitive, the majority of respondents (75%) indicate that there are reasons other than prices why their clients prefer buying locally.

4 | DISCUSSION

This study provides important preliminary insights into the market competition around sustainable biocommerce products and their production using poison frog markets as a test case. Understanding the long-term stability of income from biocommerce is of vital importance for businesses who rely on sales of these products. Neotropical poison frog species are brightly coloured exotics which command high prices and are sold internationally by several specialized sustainable biocommerce businesses (Edmonds, 2021; Yeager et al., 2020). Without a monopoly over offerings, and while often asking higher prices, biocommerce businesses need to somehow incentivize customer loyalty to reduce income loss to domestic competitors. Appealing to consumers interest to support conservation or research are likely insufficient reasons to convert consumers.

We find some commonalities are shared widely among biocommerce consumers. For example, those buying from biocommerce businesses have typically collected animals for several years, spend considerable amounts (>$500) on new acquisitions and have broad interests in the breadth of species they keep. Keepers who participate in hobby-related groups for several years have exposure to hobby-specific cultural norms and are aware that biocommerce businesses are the only potential source for new, legal offerings. However, during this time, consumers likely also developed in-country connections to source the same species and understand the differences in pricing. Survey results indicate that prices are an important consideration, which unsurprisingly strongly influences consumer decisions.

Therefore, market prices could play a significant role in purchasing decisions, especially if buyers do not place added importance on directly supporting sustainable biocommerce businesses.

Market prices commanded may differ between private hobbyist breeders and biocommerce agencies due to the cost of production. For agencies these fixed costs can include infrastructure such as a physical facility, legal costs and permitting fees, acquisition of parental founding stock, animal husbandry, export permitting and international shipping. Private entities within domestic markets are often small enough to mitigate many of these costs, and while they may retain initial offering prices in the short run when supply is limited, they can offer more competitive prices when markets move toward saturation.

When biocommerce businesses first offer a new product, there is often ample demand which exceeds production capabilities. Over time early customers offer domestically bred offspring to satisfying existing demand. As demand is met by both biocommerce and national production, prices can lower. Although the advent of sustainable biocommerce in Neotropical poison frogs is relatively new compared to the longevity of wildlife trade, our results indicate competition has already begun. Given many species reach sexual maturity rapidly (as little as months), it is reasonable to expect that competition will increase. Models from microeconomics, such as a classic Bertrand-Edgeworth duopoly, can clarify some potential dynamics of the biocommerce system. Roughly half of survey participants indicated that they currently sell offspring at equal prices to those charged by biocommerce companies, with rare exceptions where hobbyists charge more. Therefore, markets may be leaving an equilibrium where both biocommerce and hobbyists experience maximum revenue. One of the classes we identified place a high value on possessing rare species, desire for lower prices and the ability to generate revenue from offspring. It stands to reason that these attributes are not likely to favour price cooperation but rather competition. Therefore, while they represent a potentially significant source of income for both biocommerce and private hobbyists, in practice market prices may additionally depend on production potentials (Toomes et al., 2022).

While new offerings can be logistically and financially costly to produce, they can be important drivers of consumer interest. However, new species could incentivize illegal collectors; once new frog species are found they are often immediately smuggled (Pepper et al., 2007). Because breeding for biocommerce often requires controlled (e.g. field or laboratory) conditions, there is often a considerable delay before their market introduction, compared to the direct introduction of smuggled animals. However, survey participants indicated that they value the legality of animals in their collection, a point in favour of biocommerce. Yet again, customers clarify that they largely do not feel it is necessary to acquire new (legal) stock directly from biocommerce businesses and would acquire animals in-country. Therefore, private collectors who offer in-country offspring from biocommerce parents are at a significant advantage, given they can offer the lineage animals with reduced production costs.

All of these points suggest the importance of biocommerce businesses disentangling customer tendencies to focus strategic marketing. The first class of collectors place little concern on aspects related to price and their status within the hobby, and generally keep what interests them. These customers can be encouraged by interactions with social media or educational campaigns to deepen the interest hobbyists have in biocommerce companies. This could encourage hobbyists to continue supporting businesses either with purchases or by maintaining biocommerce market prices. Previous work has shown that hobbyists are willing to pay significant amounts for rare species or novel populations (Hinsley et al., 2015; Lyons & Natusch, 2013). The second class of consumers are more concerned with financial concerns, both in terms of what they buy (and from where) and the resale potential, including offspring they produce. Biocommerce companies can encourage customer loyalty and engage this second class by developing incentives (such as limiting new offerings) for returning customers, which could also reengage previously lost customers. However, this group is the most likely to destabilize the equilibrium of markets by lowering prices, reducing income potential of biocommerce businesses.

Sustainable biocommerce in exotic animals is often lauded as a solution to reduce overcollection and aid in combating illegal smuggling, among many other benefits. However much remains unknown about its long-term economic stability markets. Our results suggest market shares for biocommerce frogs may be at an inflection point, indicating they will likely experience increased competition. Therefore, understanding consumer motivations is necessary to translate interests into actions, and we suggest how they can improve their market shares. Ultimately, it is likely the plasticity of sustainable biocommerce business' responses to adjusting markets which will dictate the economic longevity of biocommerce products which breed, or if they are an Achilles heel prohibiting long-term commercial success for these businesses.

AUTHOR CONTRIBUTIONS

Justin Yeager conceived the study, created the questionnaire and wrote the initial manuscript. Juan Manuel Scarpetta Gonzalez contributed to the original study concept, analysed the data and reviewed the final version. Alexander Shepack contributed intellectually to the study, helped revise the original manuscript and subsequent revisions.

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CONFLICT OF INTEREST STATEMENT

All authors are familiar with owners of sustainable biocommerce agencies, but none were aware of the study or had any influence over the study; therefore no conflicts are declared.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12381.

DATA AVAILABILITY STATEMENT

Data related to questionnaire anonymous replies are available at https://doi.org/10.5061/dryad.zgmsbccmw (Yeager et al., 2024).

STATEMENT OF INCLUSION

Justin Yeager and Juan Manuel Scarpetta Gonzalez are both researchers in countries where sustainable biocommerce agencies are based (Ecuador and Colombia, respectively).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supporting Information S1. Informed consent for research participants.

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