

Exploring business stakeholder engagement in sustainable business practices: Evidence from the US pet amphibian industry

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Abstract

The recent decline in wild populations of amphibians worldwide coincides with the period of rapid growth in the global trade of wildlife. The potential for pathogen transmission within and beyond the pet amphibian trade network makes it important to explore the attitudes and behavior of businesses involved in the industry. We surveyed US businesses involved in the pet amphibian trade industry to characterize their attitudes and behaviors and identify business characteristics that could influence perceived risk of pathogen transmission in trade. We found that amphibian businesses acquire their animals from a variety of sources (e.g., importers, wholesalers, retailers, breeders, hobbyists, wild), are aware of the threat of emerging pathogens, and are concerned about the potential spillover of pathogens from captive to wild populations. Attitudes and behaviors of businesses toward pathogens varied among business types (e.g., size of business, the share of amphibian sales, mode of business operation). Moreover, businesses expressed a strong interest in acquiring amphibians that are free of pathogens and indicated a willingness to pay a price premium to acquire certified disease-free animals. Our results indicate that the US pet amphibian trade industry is willing to participate in healthy (clean) trade practices and increasing product prices may be one option to compensate for expenses. A government program to support pathogen-free certification would likely facilitate implementation.

KEYWORDS

amphibians, biosecurity, clean trade, disease, pathogens, spillover

1 | INTRODUCTION

Sustainable business management requires understanding how businesses of various scope and characteristics experience the risk and respond to contemporary environmental issues. Emergence of risk anywhere along a given business supply chain can have impact on sustainability of individual business entity as well as the entire industry

(Hofmann et al., 2014; Pereira et al., 2023). Literature on business strategy in environmental context has argued that natural environment can be impacted adversely by misconduct of corporate entities (Comyns et al., 2023), whereas incentives can encourage pro-environmental corporate behavior (Poudyal et al., 2012). Social science research can be useful in assessing the knowledge, perceived risk, attitudes, and behavior of businesses and offer new insights to

explain business's relative preference for and acceptability of regulatory and market-based mechanisms to promote sustainable business practices.

One of the recent issues facing business community involved in pet trade is potential threat of pathogen transfer through trade and its impact on natural biodiversity. As worldwide trade of wildlife has increased over the past several decades, scientists have documented growing evidence indicating that populations of amphibian species around the globe are declining at an alarming rate. In some regions, amphibians have declined by as much as 75% since the 1970s (Whitfield et al., 2007). Worldwide, at least 2468 amphibian species (43.2%) are undergoing some form of population decline (Stuart et al., 2004), and the IUCN Red List indicates 1895 of the planet's 6285 amphibian species are in danger of extinction, making them the most threatened group of vertebrate wildlife (IUCN, 2021). Emerging infectious diseases, such as chytridiomycosis, caused by the zoosporic fungus, *Batrachochytrium dendrobatidis* (*Bd*) and more recently described *B. salamandrivorans* (*Bsal*), and ranaviral disease (*Rv*) have been linked to population declines and extinction events globally (Berger et al., 1998; Brunner et al., 2015; Lips et al., 2006; Martel et al., 2020; Mendelson et al., 2006; Scheele et al., 2019; Schloegel et al., 2009; Stegen et al., 2017; Yap et al., 2018). The regional or international trade of live animals is thought to have played at least a partial role in the emergence of these pathogens (Daszak et al., 2003; Jancovich et al., 2005; Martel et al., 2014; Picco & Collins, 2008; Schloegel et al., 2009).

The international trade of amphibians involves hundreds of species and exists on every continent where amphibians occur (Gorzula, 1996; Nace et al., 1971; Schlaepfer et al., 2005). Amphibians ranked third on the list of the most imported animals in the United States between 2000 and 2009 (Smith et al., 2009) and are generally among the most commonly traded animals in many regions (e.g., Nijman, 2010), with imports of live animals potentially running into the millions annually (Schlaepfer et al., 2005). A large component of the trade remains unregulated and may be a pathway for the spread of emerging infectious diseases (Rosen & Smith, 2010). The global distribution of *Bd* has been linked to amphibian trade-in, and the introduction, of amphibians (e.g., Weldon et al., 2004). For example, *Bd* has been detected in pet stores, zoo animals, introduced species, and the laboratory animal trade (Daszak et al., 2003). Similarly, *Bsal* was likely introduced into wild and captive salamander populations in Europe via the pet trade from Southeast Asia (Martel et al., 2014), and while not yet found in North America, the threat of *Bsal*'s introduction into North American amphibians is a grave concern (EFSA, 2018; Gray et al., 2015).

The ongoing decline of natural amphibian populations combined with the potential for transmission of *Bd*, *Bsal*, and *Rv* (hereafter referred to as "amphibian pathogens") within and beyond the pet trade network has led researchers and stakeholders to become increasingly interested in the husbandry and biosecurity practices of pet amphibian businesses and their attitudes and perceptions toward pathogen threats. To date, the literature on the commercial amphibian trade has almost exclusively focused on the prevalence of pathogens in trade (e.g., Daszak et al., 2003; Fisher & Garner, 2007; Hanselmann

et al., 2004; Weldon et al., 2004) and understanding the attitudes of the general public (Pienaar et al., 2022). However, little is known about the awareness, attitudes, or perceptions of individuals and players engaged at various stages of the industry supply chain concerning biosecurity, or the extent to which these characteristics may affect whether or how pathogens move through the system. Research has demonstrated, for example, that individuals' support for biosecurity actions to mitigate risks depends on their perceptions of risk (e.g., Hanisch-Kirkbride et al., 2013; Trietzenberg et al., 2014). By identifying the motivations, perceived barriers, and opportunities that pet amphibian dealers face in adopting clean trade practices, the current research can be of tremendous help in formulating new policies (e.g., regulations, incentives) and outreach strategies to engage industry stakeholders.

The complexity of, and data gaps in, the various stages of wildlife trade networks adds significant challenges in designing and implementing programs to monitor and manage health outcomes in trade (Sinclair et al., 2021). By establishing a unique partnership with the pet amphibian trade industry, this study characterized attitudes and behaviors of US businesses, ranging from awareness and knowledge of the amphibian pathogens, current husbandry and disposal practices, use of biosecurity practices, and attitudes and values toward acquiring pathogen-free amphibians. Considering the recent growth of disease in amphibians worldwide, the findings of this study will be instrumental in assessing the first one to investigate these issues in amphibian pet trade industry in particular and provide new perspective on behavior and attitudes of business entities relative to adoption of healthy trade business practices.

2 | OBJECTIVES

The specific objectives of this study were to (1) understand the characteristics of US businesses engaged in the pet amphibian trade; (2) assess the awareness and attitudes of these businesses concerning the amphibian pathogens; (3) understand the value businesses place on pathogen-free amphibians; and (4) understand whether awareness, attitudes, and intentions to adopt biosecurity practices differ with business characteristics (e.g., annual sales, years in business, amphibian sales as a share of total business sales, and whether the business maintains an in-store operation). The findings from this study can be used to identify potential opportunities and barriers to developing an industry-led healthy trade program that ensures animal well-being, reduces disease-related financial losses for businesses, and increases customer satisfaction.

3 | METHODS

Similar to Morrissey et al. (2011), we initiated a collaborative partnership with members of the amphibian pet care community, including the Pet Advocacy Network (PAN), a national pet care community advocacy organization that promotes animal well-being and

responsible pet ownership. PAN facilitated communications with the US pet amphibian industry and the recruitment of two prominent US amphibian dealers to contribute to the study design and ensure the relevance of survey questions.

A semi-structured questionnaire survey was developed after a series of consultations with the industry partners and a review of relevant literature on clean trade and corporate social responsibility. The survey questionnaire contained questions addressing numerous aspects of the amphibian trade, including awareness and knowledge of the amphibian pathogens, current husbandry and disposal practices, agreement with statements regarding biosecurity practices, and motivations and values regarding acquiring pathogen-free amphibians (Data S1). The anonymous and voluntary survey instrument and protocols were reviewed and approved by the University of Tennessee Knoxville (UTK) Institutional Review Board for human subjects research (Approval#: UTK IRB-21-06494-XM). Using the Qualtrics online survey platform, the survey was initially launched in the late summer of 2021 with an email message sent from our industry partners, who helped us extend the invitation throughout the US amphibian trade business network. The survey was also placed on the project website located in the public web domain of the investigators' institution. In addition, we promoted the survey at several industry trade shows by posting a flyer containing a QR Code and a direct link to the survey.

To understand whether values, attitudes, perceptions, or practices of responding businesses were associated with key business characteristics, respondents were divided into subgroups along four separate criteria: (1) Size (total annual sales \leq \$200,000 or $>$ \$200,000; small vs. large), (2) Duration (businesses dealing with amphibians \leq 10 years or $>$ 10 years; short vs. long), (3) Share (businesses whose amphibian sales account \leq 50% or $>$ 50% of total sales volume; low vs. high), and (4) Operation (businesses who sell amphibians in-store vs. those that sell online or at tradeshow). The criteria used to characterize the four subgroups were chosen based on the literature on corporate social responsibility that suggests these characteristics can influence the environmental attitudes and behaviors of businesses (e.g., Lavorgna, 2014; Purwandani & Michaud, 2021). We hypothesized that the knowledge, attitudes, and behavior of businesses concerning pathogen transmission and clean husbandry practices would differ significantly within each of the four subgroups. Additionally, we expected the long, large, high, and in-store businesses to be more knowledgeable and concerned about pathogens and report a greater willingness to adopt biosecurity practices relative to their subgroup counterparts. Chi-squared tests of independence were performed to determine if differences in responses within subgroups were statistically significant (Upton & Cook, 2001).

4 | RESULTS

4.1 | Respondent characteristics

A total of 120 businesses completed the survey, the majority of which identified themselves as amphibian breeders (59%) or retailers (57%).

Seventy-five percent of businesses indicated they traded both reptiles and amphibians, while 16% traded only amphibians. A large majority of businesses obtained their animals from breeders (81%), hobbyists (66%), and wholesalers (60%) and sell to hobbyists (84%) and households (67%). Nearly half of the respondents (48%) reported being in the amphibian business for over 20 years. In terms of annual sales, 30% of businesses reported less than \$5000, while 20% reported annual sales exceeding \$1,000,000. Approximately half (51%) of the respondents indicated amphibians accounted for $<$ 10% of their total sales, while 12% reported amphibians accounted for 76%–100% of their total sales.

The most frequently reported type of business ownership was sole proprietorship (44%) followed by limited liability company (31%). Eighty-two percent of respondents indicated they only conducted business with buyers and sellers of amphibians in the United States. The Midwest region of the country accounted for the most respondents to the survey (33%), followed by the Southeast (20%), with respondents being relatively evenly distributed across the other regions of the country. The majority of respondents (60%) reported selling amphibians through an in-store operation.

4.2 | Factors important in business decisions

When asked to rate the importance of various factors in making business decisions, a high level of importance was placed on issues of ethics, social concerns, and legal compliance. Ninety-two percent of respondents indicated following ethical business practices was very important, while 88% indicated legal compliance was very important. Improving public image, increasing profit, and responding to issues of social concern were also rated very important by 68%, 64%, and 63%, of businesses, respectively.

4.3 | Awareness of pathogens and current biosecurity practices

When asked about their awareness of harmful pathogens, 81% of the respondents indicated they were aware, before reading the survey, that amphibian pathogens can be transmitted through the pet trade. Moreover, 17% of the respondents indicated a pathogen had been detected in amphibians at their facility. Of those, 18% percent indicated *Bd* had been detected, 6% indicated *Rv* had been detected, and 12% indicated *Bsal* had been detected at their facilities. Sixty-five percent of businesses reported the detection of amphibians infected with a pathogen other than the amphibian pathogens. Sixty-three percent of businesses indicated having an amphibian(s) at their facility die from illness or disease, with an average total monetary loss of \$145 per animal reported by respondents. More than half (55%) of respondents indicated they were very concerned that transmission of pathogens through the trade network may impact the amphibians in their facility.

Most (92%) businesses reported using disinfectants to clean surfaces and tanks, wearing gloves when handling animals (60%), and

quarantining new animals in a separate room (66%). Relatively fewer businesses reported testing new acquisitions for pathogens (18%), testing routinely to monitor for disease (22%), or treating recirculating water (23%) or wastewater (24%) before disposal.

4.4 | Preference for and willingness to pay for pathogen-free amphibians

Eighty-six percent of respondents indicated it was extremely or very important that animals be healthy and free of the amphibian pathogens when introduced to their facility. Nearly all (97%) indicated they would be interested in acquiring an animal that is certified free of amphibian pathogens, and 59% indicated they would be willing to pay more for an animal that is certified pathogen-free. Those willing to pay more were asked if they had the opportunity to acquire an amphibian that is certified free of the amphibian pathogens, how much more they would consider paying compared to the price for not certified or not confirmed to be free of the amphibian pathogens. About 22% indicated they would be willing to pay 1%–5% more, 36% indicated 6%–10% more, and 28% indicated they would be willing to pay 11%–20% more for a certified amphibian compared to one not certified.

When asked about their perceived ability to improve the biosecurity at their facility without increasing the sales price, only 25% indicated they can do so, 29% indicated they cannot, and 46% indicated they were unsure. When businesses were asked how much they would expect the average amphibian sales price to increase if they were to ensure the animal was free of the amphibian pathogens, 27% indicated “Not sure,” 27% indicated an 11%–20% increase, and 24% indicated a 6%–10% increase in price. When asked about the maximum increase in operating cost their business may be willing to accept and still improve biosecurity practices to keep their amphibians free of the amphibian pathogens assuming increasing the sales price is not an option, 30% indicated “Not sure,” 24% indicated 6%–10%, and 21% indicated a 1%–5% increase in operating cost.

4.5 | Attitudes and intentions regarding adoption of preventative biosecurity practices

Overall, the majority (85%) of the respondents somewhat or strongly agreed that the threat of the spread of amphibian pathogens is serious, and 87% somewhat or strongly agreed to protect natural populations of amphibians from amphibian pathogens is important to their business. Also, 84% of businesses somewhat or strongly agreed they can help prevent spillover of the amphibian pathogens to natural areas, and 90% somewhat or strongly agreed that businesses should take part in reducing pathogen transmission in the trade network. In addition, the majority (59%) somewhat or strongly disagreed that it takes too much time and money for their business to adopt biosecurity practices to prevent the transmission of these pathogens, and a similar proportion (61%) agreed that it is not difficult to adopt

biosecurity practices to prevent transmission to the natural environment. Over half (52%) of businesses somewhat or strongly agreed that people at their facility know what it takes to keep amphibians free of amphibian pathogens. Only 14% of the respondents indicated that they have been unable to implement biosecurity practices.

Fifty-three percent of the respondents somewhat or strongly agreed that containing the amphibian pathogens will impact their business, 82% of respondents somewhat or strongly agreed that keeping amphibians at their facility free of the amphibian pathogens will enhance their public image, and only 6% somewhat or strongly disagreed that keeping amphibians at their facility free of the amphibian pathogens will be profitable. Almost half (46%) of the respondents somewhat or strongly agreed that implementing biosecurity practices to contain amphibian pathogens will improve their amphibian sales or help them grow into new markets. When asked about their intention, 58% of the respondents somewhat or strongly agreed that they intend to implement biosecurity practices at their facility to contain the amphibian pathogens, regardless of the actions of others in the industry.

4.6 | Comparison among business subgroups

4.6.1 | Small businesses versus large businesses

Large businesses placed greater importance on reducing operating costs, increasing profit, improving public image, and being a leader in the industry than did their smaller subgroup counterparts (Table 1). The levels of importance placed on issues of legal compliance, responding to issues of social concern, and following ethical business practices were not different between these two groups. A significantly greater proportion (68%) of small businesses indicated they would be willing to pay more for an animal certified as free of amphibian pathogens, compared to large businesses (50%; $p = 0.05$). A significantly greater percentage (38%) of small businesses also indicated that it was possible to improve biosecurity practices at their facility without increasing prices to consumers compared to large businesses (10%; $p = 0.01$). A significantly greater percentage (69%) of large businesses compared to small businesses (29%) indicated that they would need to increase sales prices of amphibians between 6% and 20% to ensure the amphibians in the facility were free of the amphibian pathogens ($p = 0.02$), while a significantly greater percentage of small businesses (42%) than large businesses (15%) indicated they were unsure if they would need to increase sales prices of amphibians to ensure the amphibians in their facility were free of the amphibian pathogens ($p = 0.02$).

Small businesses were significantly more concerned about pathogens impacting amphibians in their facility and interested in using “probiotics” (Table 2). Attitudes and perceptions toward amphibian pathogens or the adoption of biosecurity practices to mitigate their transmission were not significantly different between small and large businesses (Table 3). The only exception was that large businesses expressed greater agreement with the statement that it takes too

TABLE 1 Importance of factors in making business decisions, by respondent segments.

Factors ^a	Annual sales		Business duration		% amphibian sales		In-store sales	
	Small (up to 200 k)	Large (over 200 k)	Short (up to 10 years)	Long (over 10 years)	Low (up to 50)	High (over 50)	In-store sales (in-store)	No in-store sales (no in-store)
Reducing operating costs	2.27	2.58	2.38	2.4	2.51	1.88	2.52	2.21
Improving public image	2.29	2.74	2.54	2.4	2.63	1.69	2.69	2.17
Increasing profit	2.07	2.84	2.24	2.54	2.59	1.44	2.72	1.93
Being a leader in the industry	1.71	2.51	1.9	2.2	2.23	1.13	2.38	1.60
Legal compliance	2.75	2.93	2.76	2.9	2.88	2.56	2.93	2.69
Responding to issues of social concerns	2.45	2.47	2.4	2.5	2.51	2.13	2.59	2.26
Following ethical business practices	2.84	2.93	2.82	2.94	2.90	2.75	2.93	2.81

Note: Bold and italics indicate the difference in mean value between the corresponding segments is significant ($p < 0.10$).

^aLevel of importance was measured in 3-point scale (1 = not at all important, 3 = very important).

much money and time for their business to implement biosecurity practices necessary to prevent amphibian pathogens compared to small businesses. Compared to large businesses, small businesses expressed greater agreement that implementing biosecurity practices to contain the amphibian pathogens at their facility would reduce the risk of regulatory burden in the future and that they intend to implement biosecurity practices to contain the amphibian pathogens regardless of the actions of others in the industry (Table 4). No difference was detected between small and large businesses in terms of their agreement regarding the perceived impact of implementing biosecurity measures on the public image of their firm, sales, profit, or ability to enter into new markets.

4.6.2 | Businesses with in-store operation versus businesses with no in-store operation

Businesses with in-store operations placed a greater level of importance on reducing operating costs, improving public image, increasing profit, being a leader in the industry, and responding to issues of social concerns compared to businesses with no in-store operation (Table 1). Compared to businesses with in-store operation, those operating online or through other means indicated significantly higher awareness of and interest to use "probiotics" (Table 2) and agreement with the statement that the personnel at their facility know what it takes to keep their amphibians free of the amphibian pathogens and that their business partners expect them to adopt biosecurity practices to prevent transmission of the amphibian pathogens. Similarly, they also indicated significantly higher agreement that protecting natural populations of amphibians from pathogens is important to their business and that businesses should take an active part in preventing transmission (Table 3). Businesses of in-store operation also indicated

significantly higher agreement with the statement that it takes too much time and money for their business to implement biosecurity practices. On the other hand, businesses with no in-store sales also indicated significantly greater agreement with the statement that implementing biosecurity practices will reduce the risk of regulatory burden in the future and expressed significantly greater intention to implement such practices at their facility (Table 4). A significantly larger percentage of businesses with no in-store operation ($p = 0.03$) were also willing to pay a greater price premium for a certified pathogen-free amphibian compared to in-store businesses.

4.6.3 | Businesses with low share of amphibian sales versus businesses with high share of amphibian sales

Businesses with a lower share of amphibian sales placed a greater level of importance on reducing operating costs, increasing profit, improving their public image, being a leader in the industry, and legal compliance than their high-share subgroup counterparts (Table 1).

Compared to lower share businesses, those with a greater share of amphibian sales agreed more strongly that the threat of transmission of the amphibian pathogens from pets to natural areas is serious, people that work at their facility know what it takes to keep amphibians free of the amphibian pathogens and that their business partners expect them to adopt biosecurity practices to prevent transmission of the amphibian pathogens (Table 3).

Compared to low-share businesses, high-share businesses indicated a greater level of agreement that whether or not they follow biosecurity practices, containing the amphibian pathogens at their facility would have no impact on their business (Table 4). However, high-share businesses indicated greater agreement than low-share

TABLE 2 Awareness of pathogens and adoption of biosecurity practices, by respondent segments.

Statements	Annual sales		Business duration		% amphibian sales		In-store or not	
	Small (up to 200 k)	Large (over 200 k)	Short (up to 10 years)	Long (over 10 years)	Low (up to 50)	High (over 50)	In-store (in-store sales)	No in-store (no in-store sales)
^a Before reading this survey, were you aware of beneficial microbes, such as <i>Bacillus mycooides</i> , that can kill harmful microbes and increase disease resistance in amphibians?	0.46	0.47	0.44	0.50	0.46	0.56	0.38	0.60
^b Would you consider administering treatment to your pet amphibian using “probiotics” such as <i>B. mycooides</i> ?	2.55	2.34	2.440	2.50	2.43	2.60	2.37	2.46
^a Before reading this survey, were you aware that the pathogens (Bd, Bsal, Rv) can be transmitted through the pet trade?	0.83	0.77	0.77	0.84	0.78	0.93	0.74	0.90
^c How concerned or not concerned are you that transmission of pathogens through the trade network of pets or pet products may impact the amphibian(s) in your facility?	2.50	2.33	2.43	2.42	2.40	2.53	2.42	2.43
^a Have you ever had an amphibian die from illness or disease in your business facilities?	0.55	0.73	0.51	0.74	0.58	0.77	0.59	0.68

Note: Bold and italics indicates the difference in mean value between the corresponding segments is significant ($p < 0.10$).

^aMean survey response reported (1 = yes, 0 = no).

^bMean survey response reported recoded (1 = definitely no, 3 = definitely not, 2 = maybe, but need more information).

^cMean survey response reported (1 = not concerned, 2 = slightly concerned, 3 = very concerned).

businesses that keeping amphibians at their facility free of the amphibian pathogens will reduce the risk of regulatory burden in the future. Accordingly, high-share businesses reported a greater intention than their subgroup counterparts to implement biosecurity practices at their facility to contain the amphibian pathogens regardless of the actions of others in the industry. Perceptions of the impacts of keeping amphibians at their facility free of the amphibian pathogens on their business' public image, sales, or ability to grow into new markets did not differ between businesses with high and low amphibian sales.

4.6.4 | Short-duration businesses versus long-duration businesses

Longer-duration businesses placed a greater level of importance on reducing operating costs than their short duration counterparts (Table 1). A significantly greater percentage of short-duration

businesses (36%) indicated that it was possible to improve biosecurity practices without increasing the selling price to their consumers compared to longer-duration businesses (15%; $p = 0.03$). Short-duration businesses also indicated a greater level of agreement with the statement that their business partners (e.g., suppliers, buyers) expect them to adopt biosecurity practices to prevent transmission of the amphibian pathogens compared to large businesses (Table 3). Compared to long-duration businesses, short-duration businesses indicated a greater level of agreement that they could help prevent transmission of the amphibian pathogens from pets to natural areas. There was no difference between short- and long-duration businesses in terms of their attitudes toward the threat of the amphibian pathogens to natural populations of amphibians, their ability to implement biosecurity practices to protect captive amphibians from the amphibian pathogens, the importance to their business of protecting natural amphibian populations from the amphibian pathogens, or their belief that they should actively take part in preventing transmission of the amphibian pathogens in the pet trade network.

TABLE 3 Attitudes toward pathogen and adoption of biosecurity practices, by respondent segments.

Statements ^a	Annual sales		Business duration		% amphibian sales		In-store sales	
	Small (up to 200 k)	Large (over 200 k)	Short (up to 10 years)	Long (over 10 years)	Low (up to 50)	High (over 50)	In-store sales (in-store)	No in-store sales (no in-store)
The threat of transmission of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> pathogens from pets to natural areas is serious	4.55	4.31	4.54	4.38	4.33	5.00	4.28	4.71
Preventing transmission of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> from the pet trade network to natural areas is beyond an individual firm's control	2.57	2.89	2.43	3.00	2.80	2.08	2.89	2.45
Our business has not been able to implement biosecurity practices necessary in protecting amphibians from <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i>	2.23	2.63	2.40	2.43	2.51	1.69	2.64	2.09
People that work at our facility know what it takes to keep amphibians free of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i>	3.64	3.23	3.83	3.10	3.42	3.77	3.21	3.82
It takes too much money and time for my business to implement biosecurity practices necessary in preventing <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i>	2.00	2.37	2.05	2.30	2.20	2.00	2.34	1.94
Our business partners (e.g., suppliers, buyers) expect us to adopt biosecurity practices to prevent transmission of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i>	3.24	2.80	3.40	2.70	3.00	3.23	2.72	3.52
Business managers like me can help prevent transmission of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> from pets to natural areas	4.34	4.25	4.45	4.15	4.31	4.38	4.30	4.30
Protecting natural populations of amphibians from <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> is important to my business	4.47	4.40	4.63	4.26	4.42	4.54	4.43	4.45
Businesses should actively take part in preventing transmission of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> in the pet trade network	4.62	4.38	4.62	4.43	4.45	4.85	4.35	4.76
It is not difficult for my business to adopt biosecurity practices to prevent <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> transmission to natural environment	3.89	3.63	3.90	3.65	3.83	3.69	3.72	3.85

Note: Bold and italics indicates the difference in mean value between the corresponding segments is significant ($p < 0.10$).

^aAgreement with each statement was measured using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*).

Short-duration businesses expressed a significantly greater level of agreement than long-duration businesses that implementing biosecurity practices to contain pathogens at their facility will help them grow in new markets and reduce the risk of regulatory burden in the future. However, no difference between these businesses was

detected in terms of their intention to implement biosecurity practices at their facility to contain the amphibian pathogens, regardless of the actions of others in the industry.

No difference was detected within the four subgroups in terms of the level of importance placed on following ethical practices (Table 1)

TABLE 4 Attitudes toward adopting biosecurity practices to prevent pathogen transmission, by respondent segments.

Statements ^a	Annual sales		Business duration		% amphibian sales		In-store sales	
	Small (up to 200 k)	Large (over 200 k)	Short (up to 10 years)	Long (over 10 years)	Low (up to 50)	High (over 50)	In-store (in-store sales)	No in-store (no in-store sales)
Whether or not we follow biosecurity practices, containing <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> at our facility would have no impact on our business	2.51	2.38	2.50	2.41	2.40	2.62	2.64	2.18
Keeping amphibians at my facility free of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> will enhance the public image of my business	4.29	4.12	4.36	4.08	4.17	4.31	4.17	4.27
Keeping amphibians at my facility free of <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> will be profitable	3.83	3.59	3.75	3.72	3.68	3.92	3.67	3.82
Implementing biosecurity practices to contain <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> will improve our amphibian sales	3.67	3.27	3.75	3.26	3.43	3.77	3.38	3.64
Implementing biosecurity practices to contain <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> at our facility will help us grow the business in new markets	3.64	3.15	3.78	3.11	3.32	3.85	3.32	3.58
Implementing biosecurity practices to contain <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> at our facility will reduce the risk of regulatory burden in the future	4.31	3.85	4.28	3.95	3.97	4.69	4.02	4.21
I intend to implement biosecurity practices at my facility to contain <i>Bd</i> , <i>Bsal</i> , and <i>Rv</i> regardless of what others in the industry do	4.19	3.67	4.14	3.79	3.83	4.62	3.67	4.33

Note: Bold and italics indicates the difference in mean value between the corresponding segments is significant ($p < 0.10$).

^aAgreement with each statement was measured using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*).

or having a newly purchased animal free of the amphibian pathogens. Similarly, there was no significant difference within the four subgroups in terms of interest in acquiring an animal that is certified as free of the amphibian pathogens when introducing a new animal to their business. In terms of the maximum increase in operating costs, their business may be willing to accept and still adopt improved biosecurity practices to keep the amphibians in their facility free of the amphibian pathogens, there was no difference within any of the four business subgroups, nor concerning perceived barriers in adopting biosecurity practices to prevent or contain the amphibian pathogens in their facilities.

5 | DISCUSSION

Amphibian businesses in the United States acquire animals from a variety of predominantly domestic sources and sell through a variety

of primarily domestic channels, with in-store sales being the most common. Approximately 10% of amphibian sales were international, suggesting that imports are likely very important for introducing pathogens to the network, while biosecurity and treatment activities in domestic trade are important for amplifying or dampening pathogen occurrence. Six to eighteen percent of businesses reported previous detection of chytrid fungi or ranavirus in their facility, which corresponds with previous reports for *Bd* and *Rv* prevalence in US trade (Eskew et al., 2020; Picco & Collins, 2008; Schloegel et al., 2009). Interestingly, two US businesses indicated positive detection of *Bsal*. This report is surprising, because (1) only a limited number of US laboratories are known to be testing for *Bsal* infection (using quantitative PCR) and have the capacity to confirm the disease *Bsal* chytridiomycosis (via histopathology), (2) it is best practice for laboratories that record positive results for a novel pathogen to have a second laboratory confirm a positive *Bsal* result to minimize uncertainty, and (3) known *Bsal* testing laboratories have been instructed to report

results to the North American *Bsal* Task Force, which has not occurred to date. Thus, we assume the businesses that entered this response made an error. Businesses that reported mortality indicated average loss of \$145 (median \$65, range \$5–\$700) per animal. Approximately 4 M amphibians are imported into the United States every year (Eskew et al., 2020), about half of which are American bullfrogs (*Lithobates catesbeianus*) not destined to the pet amphibian network; thus, about 2 M amphibians are imported annually into the United States for the pet trade, which represents about 10% of the market according to our study, or a total of approximately 20 M pet amphibians in the US market. While estimates of chytrid and ranavirus prevalence in amphibian trade range from 10% to 60% (Kolby et al., 2014; Picco & Collins, 2008; Schloegel et al., 2009), even if we assume 5% of these animals are lost (likely an underestimate), about \$140 M per year could be lost in total. It should be noted that some animals are rare breeding species, and therefore, loss of it would also impact future revenues for businesses significantly. Collectively, these results illustrate the need for healthy trade practices to help support market stability.

Our survey revealed that US businesses generally had a high level of awareness about the transmission of pathogens in the trade as well as concern about the potential impact on their animals or spillover to natural areas. This finding is different from a similar study conducted in Australia that found limited awareness and understanding of pest risk among businesses in the marine wildlife trade (Morrisey et al., 2011), which might reflect greater US industry losses due to amphibian pathogens or that US businesses are more informed about the threats. The global amphibian crisis has been ongoing for decades (Collins & Crump, 2009), and we now know that disease has played a major role in those declines (Scheele et al., 2019). It should also be noted that our consultation with businesses involved in the industry during the study design phase indicated that securing cooperation of businesses in this survey would require providing some background information to explain the context, purpose, and value of the study (Data S1 and S2). While the information presented was very minimum and that the respondents were specifically requested to respond according to their level of awareness prior to receiving our survey, possible effect of this alone or any additional research they did on the subject while responding to our survey may not be ruled out. However, since the information provided in the paragraph is science-based facts (i.e., synthesized by the scientists in the research team and agreed by the collaborating businesses), we believe that its impact on their response may be very minimum, if any.

Most businesses believe using biosecurity practices to control amphibian pathogens in trade is their responsibility, within their control, and will benefit their operations. Most businesses (>60%) use disinfectants, and disposable gloves when handling animals, and quarantine new shipments; however, few businesses (<25%) test arriving or resident animals for pathogen infection. Additionally, 75% of businesses do not decontaminate wastewater, which can be a pathway for pathogen spillover to wild populations. Routine testing (especially animal arrivals) and decontaminating wastewater and other aquaria contents destined for disposal are important components of

captive amphibian biosecurity practices (Pessier & Mendelson, 2017), and according to our study, represents an opportunity for industry education and possible government-facilitated support (Cassells & Lewis, 2011). Businesses strongly supported (86%) the concept of healthy trade; however, some expressed concern over time and the financial commitments required to implement biosecurity practices. Even though a high proportion of respondent businesses expressed intention to adopt biosecurity practices, a rather low rate of current adoption of certain practices such as testing and decontaminating posits a question as to why they are not already adopting these critical practices. Social science theories of human behavior indicate that intentions are proximal determinants of actual behavior (Vaske 2009), but some barriers (e.g., lack of skills, resources, tools) can prevent intentions translating into actions. Hence, promoting wider adoption of these important biosecurity practices may be achieved by removing these barriers through provision of efficient testing tools, incentives to compensate for time/effort involved in implementation of biosecurity practices, etc.

Businesses reported a general willingness to pay a higher price for certified pathogen-free amphibians, and only fewer than a third believed improving biosecurity would lead to increased sales prices for their customers. Since businesses reported a preference for acquiring certified animals and most indicated the ability to improve biosecurity practices at their facility without increasing the price burden to consumers, they could become enthusiastic participants of a market-based healthy trade program, where each player along the supply chain contributes to keeping the industry free of pathogens. We also found that decision-making by US amphibian businesses is influenced to varying degrees by reducing operating costs, improving public image, increasing profit, and legal compliance. This result suggests heterogeneity in the market, and the individualized norms shaped by these values could have an impact on support for healthy trade in the industry (Bamberg & Moser, 2007). Most differences detected were associated with gross annual sales, the percentage of sales attributed to amphibians, and whether businesses maintained an in-store operation. These differences (discussed below) indicate that the values and underlying motivations of these businesses may be different, and a one-size-fits-all approach to have them work toward clean trade goals could be unsuccessful.

The size of business influenced several responses, with small businesses showing greater appreciation toward adopting biosecurity practices to benefit their business. Relative to smaller businesses, larger businesses, on the other hand, seemed to consider the time and money required to implement biosecurity practices a potential barrier, agreed less strongly that implementing such practices would reduce the risk of future regulatory burden, and were less likely to implement biosecurity practices. This highlights the gap between small and large businesses in terms of perceived benefits and the likelihood of adopting biosecurity practices. While it is reasonable to expect that larger businesses may have more resources, implementation of such practices may be logistically cumbersome and more costly for them, especially if an economy of scale cannot be achieved. Although drivers of the adoption of environmentally friendly practices among businesses

are mixed, these results are consistent with the findings of Revell et al. (2010) who reported that small and medium-sized enterprises see it as their responsibility to help solve environmental problems. Rao et al. (2009) also found that small businesses were more likely to voluntarily adopt environmental initiatives as long as they were not too expensive or daunting, whereas environmental improvements in larger businesses were motivated by compliance with environmental regulations and the potential to increase profits by reducing costs (e.g., Baylis et al., 1998). Smaller businesses have also been found to place more value on environmental products that generate co-benefits for society (Poudyal et al., 2015).

Businesses with no in-store operations reported greater awareness that amphibian pathogens can be transmitted through the pet trade and were more likely to report their business partners expected them to adopt biosecurity practices to contain the amphibian pathogens than businesses with in-store operations. Businesses with no in-store operations were also more likely to indicate that people at their facilities know what it takes to keep their amphibians free of the amphibian pathogens and report a greater intention to adopt biosecurity practices at their facility to contain the amphibian pathogens, compared to their subgroup counterparts. This is not surprising because the businesses that primarily deal with amphibians may be more up-to-date on amphibian-specific threats and health issues than those that only occasionally or rarely trade amphibians. Those primarily dealing with amphibians are likely to have more exposure to the information about issues specific to amphibians and may also be concerned more about it because of the magnitude of potential risk to their business.

Businesses with a greater share of amphibian sales are also more likely than their subgroup counterparts to consider the threat of a spillover of the amphibian pathogens from pets to natural areas to be serious, believe their employees possess sufficient knowledge of practices to keep amphibians free of these pathogens, and show greater intention to adopt biosecurity measures; While they do not see consequences of not following biosecurity practices in their business, they do recognize that keeping the facility free of these pathogens will be profitable to the business. This may indicate the perceived behavioral control and self-confidence among the high-share businesses. Since amphibians make up the majority of these businesses, this may be attributable to their level of specialization in properly handling and treating amphibians for a safe and clean operation. The sustainability and financial health of their business depend on the health of the amphibians, and it is possible that they have invested in securing resources necessary to prepare for any health issues including these pathogens.

Similarly, those with in-store operations may be more motivated to stay current on emerging threats than their subgroup counterparts, because, unlike businesses that have their facilities away from their clientele, in-store businesses may be more sensitive to perceived ethical and logistical shortcomings in their facility because of direct interaction with consumers. This observation is in contrast with some previous studies, where online businesses have been linked with poor biosecurity practices (Derraik & Phillips, 2010; Lavorgna, 2014).

Years in the business were another factor that affected business attitudes and behaviors. Compared to businesses that have been in the market for a longer period, short-duration businesses agreed more strongly that they could help prevent transmission of the amphibian pathogens from pets to natural areas, their business partners expect them to adopt biosecurity practices to reduce the likelihood of spillover, and incorporating biosecurity practices at their facility will help them grow into new markets. This observation sheds light on the contrasting behavior between businesses that have recently entered the industry and those already established. It is possible that newly emerging and growing businesses realize the importance of environmental health and see an opportunity in being competitive or penetrating into new markets by establishing a responsible corporate image (Revell et al., 2010). Thus, healthy trade buy-in from longer-established businesses may be more difficult and highlight the need for educational outreach in biosecurity benefits.

Observed differences in attitudes and intentions of businesses of different characteristics corroborate the conclusions regarding business behavior in the growing literature on corporate social responsibility. It is important to note that both the internal factors (e.g., size, mode of operation) and external factors (e.g., incentives, regulatory benefit, public image) could be driving forces in a business' adoption of pro-environmental and sustainable business practices (Handrito et al., 2021). Despite these findings, a caveat should be noted. Due to the lack of a complete list of businesses that are involved in the amphibian trade, establishing a truly random sample of businesses was not possible. Nonetheless, as the amphibian market is a relatively small share of the wildlife trade industry (Can et al., 2019), we believe our sample captured a reasonable proportion of those businesses. Future studies should compare and contrast the results from this study with other stakeholders (e.g., consumers) in the wildlife trade network.

6 | CONCLUSION AND IMPLICATIONS

Businesses can play an instrumental role in affecting the risk of pathogens in the wildlife trade. There were several novel findings in our study. First, pet amphibian businesses place high importance on ethics, public image, and individual responsibility to engage in healthy trade activities. These findings are encouraging and suggest that industry-led activities to promote healthy trade are feasible. Second, US pet amphibian businesses are aware of emerging pathogens and recognize the potential threat of spillover from captive to wild populations; thus, educational campaigns describing this threat may not need to be robust. Third, US pet amphibian businesses recognized the potential benefits (e.g., public image, profit, market penetration, mitigating regulatory burden) of adopting biosecurity practices to prevent transmission of amphibian pathogens. They also expressed a responsibility to take action and indicated a strong desire to participate in healthy trade. As intentions are considered direct correlates of behavior, converting intention (i.e., plan to take action) to behavior (i.e., taking action) should be the next step. It should be noted that

businesses expressed concern regarding the time and money required to participate in clean trade activities. Cost barriers could be reduced with the introduction of market-based instruments (e.g., pathogen-free certification) and government subsidies to support biosecurity practices. Businesses expressed strong interest in acquiring amphibians certified as pathogen-free. It is reasonable to expect that consumers (i.e., amphibian pet owners) who are ultimately served by these businesses may also be willing to pay a significant price premium for pathogen-free animals. A similar study of willingness to pay among pet amphibian owners will offer more insight into whether, and to what extent, the cost of certification can be transferred to consumers.

Fourth, evidence suggests that attitudes and behavior of amphibian businesses regarding pathogen transmission are related to various characteristics of the business. Specifically, the perception of risk, attitudes, and intention to adopt biosecurity practices differ according to the size of the business, the share of amphibian sales, and the mode of business operation. This new knowledge will help identify distinct segments within the market (e.g., concerned vs. not concerned, likely vs. unlikely adopter) so that appropriate outreach and education resources can be targeted to those segments. Contrasting attitudes and intentions among business categories indicate that the industry is heterogeneous and there exists a typology (i.e., segments) of businesses. Our findings will be useful in identifying the characteristics of business segments that perceive the risk and barriers differently and may respond to the risk differently. Also, business characteristics (e.g., in-store or not, size, etc.) that are found to be significantly related to attitudes and behavior can be used in models to predict the behavioral intentions of businesses.

Finally, taking the key findings of this study together, it is reasonable to suggest that efforts to promote conservation of wildlife and biodiversity should be broadened to bring in active participation of business community involved in trade of wildlife. Considering the global connection of wildlife communities and the extent of trade involved, protection of biodiversity and wildlife should go beyond habitat protection at protected areas or population management within a given geography and think more comprehensively to engage external stakeholders. Evidence from this study confirms that community of businesses seems interested in cooperating and become a part of the solution either by adopting property preventive actions or participating in certification programs. Government and nongovernment agencies interested in promoting business engagement in healthy trade may see benefit in prioritizing their effort and resources to understand the heterogeneity in business market and allocate resources to educate them on risk, build capacity to take preventive actions, and remove other factors this study identified as likely barriers. It should be noted that even though this study was specific to pet amphibian trade, the conclusions drawn from empirical evidences add valuable new knowledge to explaining how businesses, particularly facing different circumstances in business characteristics and operation, perceive and respond to contemporary environmental issues and sheds new perspective on the viability of establishing

market-based policy mechanism to promote environmental sustainability in the business sector.

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CONFLICT OF INTEREST STATEMENT

Authors declare no conflict of interest.

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SUPPORTING INFORMATION

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