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Understanding the demand for and value of pathogen-free amphibians to US pet owners

Kevin Cavasos[1] | **Ram K. Adhikari**[1,2] | **Neelam C. Poudyal**[1] | **Jesse L. Brunner**[3] | **Alexa R. Warwick**[4] | **Matthew J. Gray**[1]

[1]School of Natural Resources, University of Tennessee, Knoxville, Tennessee, USA

[2]Department of Forestry, New Mexico Highlands University, Las Vegas, NM, USA

[3]School of Biological Sciences, Washington State University, Pullman, Washington, USA

[4]Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan, USA

Correspondence
Neelam C. Poudyal, School of Natural Resources, University of Tennessee, Knoxville, TN, USA.
Email: npoudyal@utk.edu

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Abstract

Pathogen transmission through wildlife trade has become a significant One Health issue, but businesses involved in trade can take actions to minimize pathogen spread within and beyond trade networks. Such actions could include an industry-led clean-trade certification program whereby retailer costs for enhanced biosecurity and disease-free product certification are offset by increased prices to consumers. However, we currently know little about the demand for, and value of such a program to consumers. With the case of pet amphibian owners in the United States, we assessed what characteristics make people more likely to demand certified wild animals and how much more in price premium they are willing to pay for such animals. Findings suggested that the demand for pathogen-free amphibians was driven by the perceived risk of pathogen spillover to wild populations, behavioral control in preventing transmission, and other characteristics related to pet ownership and demographics. On average, respondents were willing to pay $38.65 per animal more for certified pathogen-free amphibians than non-certified amphibians. Findings lend support for the viability of an industry-led clean-trade program aimed at enhancing animal well-being, increasing customer satisfaction, and reducing the risk of pathogen transmission within and beyond the pet trade network.

KEYWORDS

amphibian, certification, clean trade, consumer, wildlife trade, willingness to pay

1 | INTRODUCTION

The trade of live animals for food, research, and pets provides a conduit for the spread and spillover of novel emerging infectious diseases (Cunningham et al., 2003; Daszak et al., 2000; Fèvre et al., 2006). Of particular concern for global amphibian populations are the chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), which has been implicated in the declines of hundreds of species around the world, the recently emerging *B. salamandrivorans* (*Bsal*) and a suite of lethal viruses in the genus *Ranavirus* (*Rv*) (Daszak et al., 2003; Fisher & Garner, 2007; Fitzpatrick et al., 2018; Kolby & Daszak, 2016; Scheele et al., 2019; Searle et al., 2011). All three threaten amphibian biodiversity and are known to have spread in the trade of live amphibians (Daszak et al., 2003; EFSA, 2018;

Fisher & Garner, 2007; Kolby et al., 2014; Lips et al., 2016; Martel et al., 2014; Picco & Collins, 2008; Schloegel et al., 2009; Stuart et al., 2004). Mitigating or even detecting these pathogens in trade is an enormous challenge.

An estimated five million live amphibians enter the United States every year without having undergone required screening or quarantining procedures (Kolby & Daszak, 2016). Once infected animals have entered the commercial trade it is extremely difficult, if not impossible, for responsible government agencies to contain the infection or prevent further transmission within the trade network or spillover to nature using traditional top-down interventions. As a consequence, government, research, and industry stakeholders are increasingly considering alternative strategies to reduce the anthropogenic spread of pathogens, such as *Bd*, *Bsal*, and *Rv*, and the resulting impacts on native amphibians and businesses in the commercial trade (e.g., Garner et al., 2009; Gray et al., 2015; Grear, 2021; Meredith et al., 2018; Sinclair et al., 2021).

One alternative put forward is an industry-led, government-facilitated, clean-trade program whereby amphibian dealers participate in an amphibian biosecurity certification process enabling them to market their amphibians as "certified pathogen-free" (CPF) (e.g., Pienaar et al., 2022; Watts et al., 2019). While the details of such a program are not yet developed (e.g., training, testing requirements, biosecurity practices, and facility requirements), it would inevitably involve increased operating costs for participating businesses, which would need to be passed on to consumers through increased prices for CPF animals. The feasibility of such a program thus depends on the attitudes of pet amphibian owners and their preference for, and the likelihood of paying more for, CPF animals and the amount of premium they are willing to pay. Moreover, understanding the value amphibian pet owners place on acquiring pathogen-free amphibians, along with the factors influencing their demand, is critical in designing an economically viable clean-trade program, as well as for targeted messaging to encourage buy-in on the part of industry stakeholders. However, little is currently known regarding consumer[1] demand for CPF amphibians, particularly the characteristics that predict consumer preferences.

Pet owners have demonstrated their interest in paying for preventative care for their pets and companion animals (e.g., Chiu et al., 2021; Paul III & Skiba, 2012). The public has also been shown to support interventions related to invasive species (Gramza et al., 2016; Episcopio-Sturgeon & Pienaar, 2020) and generally places importance on protecting the health of native wildlife and nature from pathogens transmitted through the reptile and amphibian trades (Pienaar et al., 2022). These findings suggest pet amphibian owners may value, and be willing to pay a premium for, CPF animals to mitigate pathogen threats.

The specific objectives of this study were to: (1) understand US pet amphibian owners' concerns regarding pathogen transmission and spillover; (2) understand the influence of these characteristics on pet amphibian owners' demand for (i.e., the likelihood of paying more to acquire) CPF animals; and (3) estimate the amount of premium (i.e., WTP) pet owners are willing to pay for a certified pathogen-free amphibian compared to the price of an amphibian not certified as pathogen-free.

2 | METHODS

2.1 | Survey design and administration

For assistance with study design, the relevance of questionnaire items, and survey participation, we collaborated with two prominent US amphibian dealers (Josh's Frogs and Reptiles by Mack) and the Pet Advocacy Network (previously the Pet Industry Joint Advisory Council), a national pet care community advocacy organization that promotes animal well-being and responsible pet ownership. The anonymous and voluntary survey instrument and protocols were approved by the University of Tennessee Institutional Review Board for human subjects' research (Approval#: U IRB-21-06494-XM). The survey, launched in July 2021, was administered through the Qualtrics online platform (www.qualtrics.com). It was promoted with an email message from our industry partners to individuals in their membership lists, a link on the project website located on the public web domain of the investigators' institution, and at several pet trade shows using flyers containing a QR code and a web link to the survey. The survey instrument contained questions addressing pet husbandry and care that could have been perceived as sensitive in nature to some respondents. Directly asking sensitive questions could induce a social desirability bias, a tendency to underreport undesirable behaviors, or a nonresponse bias resulting from an unwillingness to participate in the survey (Nuno & St. John, 2015). In such cases, alternative methods including participatory research tools and ethnobiological methods are commonly used (Newing, 2011). However, those methods are qualitative and the conclusions derived from a selected and rather small number of respondents have less generalizability, compared to those from structured, quantitative surveys involving hundreds of respondents. To minimize non-response and social desirability bias, the survey in this study was administered online without the direct presence of the investigator at the time of the survey and was anonymous, meaning that no personally

TABLE 1 Description of variables used in predicting the demand for certified amphibians.

		n	Median
VETERINARY	Frequency of veterinary care or diagnostic tests (Ordinal variable: 1 = never, 2 = as needed, 3 = occasionally, 4 = regularly)	394	2
AESTHETIC	Aesthetic value as motivation for acquiring pet amphibian (Ordinal variable: 1 = not at all important, 2 = slightly important, 3 = moderately important, 4 = very important, 5 = extremely important)	382	3
SCIENTIFIC	Scientific or educational value as motivation for acquiring pet amphibian (Ordinal variable: 1 = not at all important, 2 = slightly important, 3 = moderately important, 4 = very important, 5 = extremely important)	383	3
CONCERN	Concern about pathogens when acquiring recent amphibian (Ordinal variable: 1 = not at all concerned, 2 = slightly concerned, 3 = very concerned)	380	1
SPILLOVER RISK	Perception that "the threat of transmission of Rv, Bd and Bsal pathogens from pets to natural areas is serious" (Ordinal variable: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither disagree nor agree, 4 = somewhat agree, 5 = strongly agree)	358	5
SPILLOVER PREVENTION	Perception that "Protecting natural populations of amphibians from Rv, Bd, and Bsal is important to me" Ordinal variable: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither disagree nor agree, 4 = somewhat agree, 5 = strongly agree)	355	5
BEHAVIORAL CONTROL	Perception that "preventing transmission of Rv, Bd, and Bsal from the pet trade network... is beyond an individual household's control" (Ordinal variable: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither disagree nor agree, 4 = somewhat agree, 5 = strongly agree)	359	2
EDUCATION	Education level (Binary variable: 1 = bachelor's degree or higher, 0 less than bachelor's degree [reference category])	356	0
HOUSEHOLD	Size of household (Continuous variable: number of individuals in household)	352	3
YEARS	Length of amphibian ownership in years (Ordinal variable: 1 = 1–4, 2 = 5–7, 3 = 8–10, 4 = >10)	394	2
AMPHIBIAN	Total number of amphibians owned (Ordinal variable: 1 = 1, 2 = 2–4, 3 = 5–7, 4 = 8–10, 5 = >10)	394	3
AGE	Owner's age in years (Ordinal variable: 1 = 18–24, 2 = 25–34, 3 = 35–44, 4 = 45–54,5 = 55–64, 6 = >65)	357	3
GENDER	Male (Binary variable: 1 = male, 0 = otherwise [reference category])	353	0

identifiable information was collected. Respondents were able to decline to answer individual questions and exit the survey before completion. During the approximately 7 weeks applicants were recruited, 394 respondents, who self-identified themselves as pet amphibian owner, participated in the survey. Based on the response, our respondents represented all regions across the United States. The majority of respondents (31%) came from the Midwest, followed by the West (25%), Southeast (20%), Northeast (19%), and 5% from the Southwest. A description of survey questions and model variables is contained in Table 1. A copy of the survey questionnaire has been included in Appendix S1.

2.2 | Description of variables

The survey questionnaire contained questions regarding amphibian ownership motivations and history, concerns and beliefs regarding pathogen transmission and spillover, demand (i.e., the likelihood of paying more to acquire) for CPF amphibians, and socio-demographic characteristics including AGE, EDUCATION, GENDER, HOUSEHOLD SIZE (Table 2). Ownership questions addressed the number of years the respondent had owned amphibians (YEARS), the total number of amphibians owned during that time (AMPHIBIAN), frequency of veterinary visits (VETERINARY), and whether science and

TABLE 2 Estimates from regression model predicting the demand for certified disease-free amphibian.

Variables	Coefficient	Standard error	*P*	Odds ratio
VETERINARY				
Never (reference)				
As needed or occasionally	0.645	0.312	0.039	1.906
Regularly	0.247	0.598	0.679	1.280
AESTHETIC	0.089	0.114	0.437	1.093
SCIENTIFIC	−0.236	0.116	0.042	0.789
CONCERN				
Not at all (reference)				
Slightly concerned	0.346	0.326	0.288	1.41
Very concerned	1.083	0.838	0.196	2.95
SPILLOVER RISK	0.300	0.132	0.023	1.351
SPILLOVER PREVENTION	0.369	0.226	0.103	1.446
BEHAVIORAL CONTROL	−0.250	0.117	0.032	0.778
EDUCATION	0.004	0.165	0.980	1.004
HOUSEHOLD SIZE	−0.225	0.098	0.022	0.798
YEARS				
1–4 years (reference)				
5–10 years	−0.157	0.396	0.692	0.854
>10 years	−0.457	0.406	0.261	0.633
AMPHIBIAN	−0.076	0.124	0.537	0.925
AGE	−0.067	0.107	0.530	0.934
GENDER				
Female (reference)	0.039	0.294	0.893	1.040
Male	0.174	1.452	0.904	1.190
CONSTANT				
Model summary				
Observations	337			
Log likelihood	−160.700			
LR chi2 (16)	40.83			
Prob>chi2	0.000			
Pseudo r2	0.11			
Hosmer-Lemeshow test				
Pearson chi2(320)	335.47			
Prob>chi2	0.265			

educational values (SCIENTIFIC) or aesthetic values (AESTHETIC), were important in the ownership of amphibians. Questions about concerns and beliefs regarding transmission and spillover included whether respondents had been concerned that their most recently acquired amphibian had been infected with *Rv*, *Bd*, or *Bsal* before the acquisition (CONCERN), whether respondents believed the threat of transmission of pathogens from pet amphibians to natural areas was serious (SPILLOVER RISK), protecting natural populations of amphibians from pathogens is important to them (SPILLOVER PREVENTION) and whether they believed preventing spillover of amphibian pathogens from the pet trade network to natural areas was beyond an individual household's control (BEHAVIORAL CONTROL).

Demand for CPF amphibians was measured in terms of a person's likelihood of paying more for a certified amphibian by using their response (1 if Yes, 0 otherwise) to the question "When acquiring a pet amphibian, would you be willing to pay more for an animal that is certified

free of the *Bd*, *Bsal*, and *Rv* pathogens?". Before asking this question, respondents were requested to read the following script to make them aware of the benefits of pathogen-free amphibians:

> Evidence suggests amphibian populations are experiencing declines around the world, in part, from the spread of harmful pathogens including *Ranavirus* (*Rv*), *Batrachochytrium dendrobatidis* (*Bd*) and *Batrachochytrium Salamandrivorans* (*Bsal*). If these pathogens (*Rv*, *Bd*, and *Bsal*) are not contained, many species of amphibians in natural areas could be infected and disappear within the next few decades. The long-term survival of amphibian populations and their environmental services will require reducing the likelihood of the spread of pathogens from the captive amphibian trade (e.g., pets, food) into nature.

Subsequently, the amount of premium (i.e., WTP) pet owners are willing to pay for a CPF animal was measured using a single-bound dichotomous choice question: "If you had the opportunity to acquire an amphibian that is certified free of the *Bd*, *Bsal*, and *Rv*, would you consider paying $*C* extra for this certified animal compared to the price for not certified or not confirmed to be free of these pathogens?" where *C* was a randomly selected value from the following levels: US$1, $2, $3, $5, $7, $10, $20, $30, $50. The bid range was designed in consultation with industry partners that currently sell amphibians and with consideration of the general price range of amphibian animals and the expected cost of testing for the above-mentioned pathogens. We chose the single-bound dichotomous choice method over alternative methods (e.g., double bounded) because it requires less information and is easier to implement at the data collection and estimation stages. It also avoids systematic bias in responses resulting from the introduction of the follow-up (i.e., "anchoring effect") (Johnston et al., 2017). Socio-demographic questions included the age of the respondent, gender, education level attained, and household size. Survey questions regarding amphibian ownership history and motivations, and concerns and beliefs regarding pathogen transmission and spillover were rated on five-point Likert scales of importance and agreement, respectively (Not at all important—Extremely important; Strongly disagree—Strongly agree). All ordinal variables (AESTHETIC, SCIENTIFIC, SPILLOVER RISK, SPILLOVER PREVENTION, BEHAVIORAL CONTROL, EDUCATION, HOUSEHOLD SIZE, AMPHIBIANS) that were measured with at least a five-point Likert scale were treated as continuous variables in the model. Textbooks in survey research methods suggest that ordinal variables can be treated as continuous if they include responses in order and contain five or more categories (Vaske, 2019, p. 83), and this has been common practice (Carlson et al., 2022; Cleary et al., 2021; Donelley & Vaske, 1995; Lubeck et al., 2019; Vayer et al., 2021). All other variables with fewer than five response categories (VETERINARY, CONCERN, YEARS, GENDER) were treated as categorical (Appendix S2).

2.3 | Modeling the factors influencing the demand for certified pathogen-free amphibians

We assumed that respondents select the choice (i.e., pay more for certified amphibian or not) that they believe will maximize their utility, or individual satisfaction. Past studies have similarly used consumer utility theory to assess the demand for wildlife conservation (e.g., Morse-Jones et al., 2012), endangered species protection (e.g., Choi & Fielding, 2013; Kotchen & Reiling, 2000), invasive species control (e.g., Meldrum, 2015; Roberts et al., 2018), and disease-free pets and livestock (Bir et al., 2021; Chiu et al., 2021; Ochieng & Hobbs, 2016). We analyzed participants' demand for an animal certified free of *Bd*, *Bsal*, and *Rv* with a logistic regression using the "logit" command in Stata 16.1 and estimated the magnitude of the effects of the individual explanatory variables on pet owners' demand using odds ratios (e^{β}). When the dependent variable is a dichotomous response (e.g., Yes, No), a binary logistic regression is the appropriate estimation method (Vaske, 2019).

2.4 | Estimating the amount of premium or willingness to pay for certified pathogen-free amphibians

We used maximum likelihood estimation (MLE), a nonparametric approach developed by Turnbull (1976) to estimate the mean premium (i.e., WTP) respondents are willing to pay for CPF amphibians because it makes minimal assumptions about the distribution of premiums that respondents consider paying. The TURNBULL package available in Stata 16.1 (Azevedo, 2010) was used for this computation. It estimates the mean and median values of the amount of willingness to pay as lower-bound estimates using the proportion of respondents that responded "yes" to each presented dollar amount (Egan et al., 2015). The Turnbull method is a robust estimator and has been used in valuation studies of public goods (Dimal & Jetten, 2021; Petrolia & Kim, 2009; Richardson & Lewis, 2022; Subade & Francisco, 2014). Finally, since the estimates of premiums

calculated at the individual level are often aggregated to the consumer population and used in benefit–cost analysis, the lower bound estimates provided by the Turnbull estimator can be taken as conservative estimates of benefit in ex-ante policy analysis (Whitehead, 2018).

Respondents in our survey were asked "If you had the opportunity to acquire an amphibian that is certified free of the *Bd*, *Bsal*, and *Rv* pathogens, would you consider paying c_j extra for this certified animal compared to the price for not certified or not confirmed to be free of these pathogens?" Following Haab and McConnell (1997), the c_j are indexed $j = 0, 1, ..., M$ and $c_0 = 0$. Furthermore, c_j represents the ordered values $(c_0 < c_1 < c_2 < ... < c_M < c_{M+1})$ of the M observed finite intervals. If p_j is the probability the premium amount the respondent is willing to pay lies in the interval c_{j-1} to c_j, this can be denoted

$$p_j = P\left(c_{j-1} < \text{WTP} \le c_j\right) \text{ for } j = 1, ..., M+1.$$

The cumulative distribution function is denoted

$$F_j = P\left(\text{WTP} \le c_j\right) \text{ for } j = 1, ..., M+1,$$

where $F_{M+1} = 1$.then

$$p_j = F_j - F_{j-1}$$

and $F_0 \equiv 0$. Using either the $F_j, j = 1 \to M$ or $p_j, j = 1 \to M$ as parameters, the likelihood function can be written

$$L(p;N,Y) = \sum_{j=1}^{M} \left[N_j ln\left(\sum_{i=1}^{j} p_i \right) + Y_j ln\left(1 - \sum_{i=1}^{j} p_i \right) \right] \quad (3)$$

where N_j and Y_j are the number of "no" and "yes" responses, respectively, to c_j and $(1 - F_M) = p_{M+1}$ is the probability that WTP is greater than the highest finite bid (Haab & McConnell, 1997). The following equations were used to compute mean and variance for the WTP estimates:

$$E_{LB}(\text{WTP}) = \sum_{j=0}^{M^*} c_j \cdot p^*_{j+1} \quad (4)$$

$$V(E_{LB}(\text{WTP})) = \sum_{j=1}^{M^*} \frac{F^*_j\left(1 - F^*_j\right)}{T^*_j} \left(c_j - c_{j-1}\right)^2 \quad (5)$$

where M^* is the indexing number, p^* represents the probability density function, F^* represents the cumulative density function, and T^* is the total number of responses after pooling back of response frequencies, respectively.

3 | RESULTS

3.1 | Respondent characteristics

Of 394 respondents that self-identified as pet amphibian owners, 17% also had amphibian-related businesses including retailer, importer, wholesaler, breeder, etc. Of the 353 respondents that responded to the question, 40% were male (Table 1). The average age of the respondents was 38 years, 48% of which had completed a bachelor's degree or higher level of education. On average, pet-owner households had three members. The majority of pet owners owned an amphibian pet for the duration of 1–7 years.

Thirty-six percent of respondents each indicated they were concerned about pathogens when acquiring their most recent pet amphibian and that they knew what it takes to keep amphibians free of *Rv, Bd*, and *Bsal*. Most respondents (84%) agreed the threat of pathogen transmission from pets to natural areas is serious, however, 26% believed that preventing pathogen transmission from the pet trade network to natural areas is beyond an individual household's control. More than three-quarters (76%) of respondents indicated they were willing to pay a premium for an amphibian that is certified free of the *Rv*, *Bd*, and *Bsal* pathogens and 90% subsequently responded that they were willing to pay the price premium presented to them in the survey questionnaire to acquire a certified animal compared to an animal not certified to be pathogen-free.

3.2 | Factors influencing pet amphibian owners' demand for certified pathogen-free amphibians

Regression estimates along with the odds ratio associated with each of the explanatory variables are presented in Table 2. Computed values of VIFs were well below the critical threshold of five (Vaske, 2019), and suggested multicollinearity is not an issue in the model. The odds of demanding certified pathogen-free animals were lowest for those who indicated scientific or educational motivations for owning amphibians. The importance of aesthetic value as a motivation for owning amphibians was not significantly related to the odds of demanding certified animals. However, respondents who occasionally or on an as-needed basis take their amphibians to the veterinarian, were likely to have significantly higher odds than those who never take their amphibians to the veterinary (Table 2).

TABLE 3 Turnbull lower bound welfare estimates for pathogen free pet amphibian.

Bid (c_j)	Number of "No" responses (N_j)	Number of "yes" responses (Y_j)	Total number of responses (T_j)	Unrestricted F_j ($F_j = N_j/T_j$)	Turnbull F_j*	Turnbull p_j*
$1	0	40	40	0	0	0
$2	2	36	38	0.05	0.01	0.01
$3	0	37	37	0	Pooled back	–
$5	0	37	37	0	Pooled back	–
$7	0	40	40	0	Pooled back	–
$10	1	33	34	0.03	0.03	0.01
$15	2	27	29	0.07	0.07	0.04
$20	6	29	35	0.17	0.17	0.10
$30	11	25	36	0.31	0.31	0.13
$50	13	25	38	0.34	0.34	0.04
$50+	–	–	–	1	1	0.66
Total	35	329	364	–	–	–
Welfare estimates						
Mean		$38.65				
Standard error		$1.78				
95% confidence intervals		$35.16–$42.14				

The odds of demanding certified pathogen-free animals increased for those who thought pathogens from pets threatened natural areas (i.e., risk of spillover) but declined significantly if the respondent perceived transmission prevention as beyond individual households' control (Table 2). The concern about pathogens in recent purchases of amphibians was not statistically significant.

Except for the number of people living in the respondent's home, which was significantly negatively associated with demand for certified pathogen-free animals, none of the other socio-demographic variables including age, gender, and education level were significant predictors in the model. As indicated by the odds ratio, a one-person increase in household size resulted in a 21% decrease in the odds pet owners would demand a certified disease-free amphibian.

The mean premium respondents were willing to pay for a certified pathogen-free animal compared to the price of a non-certified amphibian was US$38.65 (2021 US$) with a 95% confidence interval of US$35.16–42.14 (Table 3).

4 | DISCUSSION

This study used an online survey of US pet amphibian owners to understand their concerns and beliefs regarding pathogen transmission and spillover, and the influence of these characteristics on their demand for CPF animals. Additionally, survey responses were used to estimate the amount of premium pet owners are willing to pay for a certified pathogen-free amphibian compared to the price of an amphibian not certified as pathogen-free. The lack of reliable data on pet amphibian ownership in the United States makes it challenging to determine how the size of our sample relates to the population of US amphibian owners. Survey respondents were, on average, more educated and contained a higher proportion of females than the US population; however, they were relatively evenly distributed in terms of years of amphibian ownership and total number of pet amphibians owned. We found strong economic support from consumers for amphibians certified pathogen-free, both in terms of the proportion of respondents indicating their willingness to pay a premium—some three-quarters—and in the amount they are willing to pay. The estimated premium—US$38.65—is sizeable compared to the price the majority of amphibian owners reported paying for their most recently acquired amphibian (69% of respondents reported paying over US$25 and 20% reported paying more than US$75) and their monthly cost of care (51% of respondents reported spending more than US$25). Collectively, this suggests amphibian owners place a substantial value on the certainty that their newly acquired amphibian is pathogen-free. Our findings are consistent with prior work showing that pet

owners are willing to pay significantly more for pet insurance policies that cover preventative care (Chiu et al., 2021), but extend this willingness to pay for prevention to these less common, "niche" pets.

We identified several characteristics and beliefs that can help us determine who is willing to pay more for CPF animals and perhaps better target future programs or marketing. First, we found that owners whose amphibians receive veterinary care or diagnostic tests were 1.9 times more likely to be willing to pay a premium for CPF amphibians compared with those who never sought out such care, suggesting concern about individual animal health is an important driver of demand. The insignificance of those who regularly receive such care may be explained by the notion that these pet owners are already proactive in investing time and money in veterinary care for their existing pets and feel confident about their ability to maintain a clean and healthy animal once they acquire one. However, messaging and outreach targeting those pet amphibian owners who never receive veterinary care or tests regarding the value and importance of mitigating pathogen threats may be warranted.

Indeed, the length of time pet owners reported owning amphibians was not associated with demand for CPF amphibians. Even though we did not have a priori assumption regarding the effect of this variable, we interpret this observation as an indication that more seasoned owners, perhaps based on their perceived ability to identify diseased animals or experience with a particular retailer, have confidence that their next amphibian acquisition is likely to be healthy in the absence of pathogen-free certification. Additionally, this may suggest that owners develop confidence in their biosecurity practices or ability to appropriately treat illness or disease in their amphibians over time; However, only 36% of overall participants indicated they knew what it takes to keep their amphibian(s) free of *Rv*, *Bd*, and *Bsal*.

Counterintuitively, whether owners expressed concern that their most recently acquired amphibian may have been infected with *Rv*, *Bd*, or *Bsal* before the acquisition was not a significant predictor of the likelihood of paying a premium for a CPF animal. This surprising result may be due to the disparity between reported concern and actual demand for pathogen-free animals. The majority (64%) of owners reported being unconcerned that their most recently acquired amphibian had been infected, while an even larger proportion (76%) responded favorably to paying more for CPF animals. This result is encouraging in that it suggests consumers see value in pathogen-free certification despite their lack of concern for recently purchasing an infected animal themselves.

The likelihood of paying more for CPF animals also appears to stem from concern about wild amphibians. Pet amphibian owners who indicated they believed the threat of transmission of *Rv*, *Bd*, and *Bsal* from pets to natural areas was serious were more likely to pay a premium than their counterparts. This result is logical and consistent with similar studies that have found the public places importance on protecting the health of native wildlife and the natural environment from pathogens associated with the amphibian pet trade (Pienaar et al., 2022). That said, respondents who believed that preventing transmission of *Rv*, *Bd*, and *Bsal* from the pet trade network to natural areas is beyond an individual household's control, were less likely than their counterparts to consider paying a premium. This is logical in that the more strongly owners believed that spillover was beyond their control, the less likely they were willing to pay a premium for CPF amphibians. Collectively, this suggests efforts to promote and increase buy-in for a clean-trade certification program may benefit from outreach emphasizing the status of global amphibian populations and their susceptibility to pathogen spillover, and the importance of preventative biosecurity by businesses and pet owners.

Compared to their counterparts, owners reporting higher importance of scientific or educational values when acquiring their most recent pet amphibian were less likely to pay a premium for a CPF animal than owners reporting scientific or educational values to be unimportant. Conversely, owners reporting higher importance of aesthetic value when acquiring their most recent amphibian were not different from their counterparts in indicating demand for CFP. While there is no preceding literature on this topic to compare our results, one possible explanation of negative affect is that people who acquire an amphibian for scientific or educational reasons would be more willing to accept what they may consider a natural outcome (i.e., illness, disease). It may also relate to greater confidence in understanding and mitigating the risks of infection in one's collection. The mixed and perhaps counterintuitive result found in this study suggests that the likelihood of paying more for a pathogen-free amphibian is not driven by the motivation of ownership alone. However, more research is necessary to understand how diverse ownership motivations impact willingness to pay a premium for clean animals.

Among the demographics, larger households were less likely to pay a premium for certified pathogen-free amphibians, which is partly due to budget constraints that larger households face in taking care of their own needs. Other demographic characteristics were not significant predictors of the likelihood of paying a premium. This is in line with similar studies that have found attitudes, beliefs, and perceptions of risk to be stronger

predictors than demographic characteristics of individuals' support for managing risks associated with the live animal trade (Episcopio-Sturgeon & Pienaar, 2020; Steele & Pienaar 2021).

Promoting clean trade in the pet industry involves cooperation from all stakeholders, including pet owners themselves. Understanding whether and how much pet amphibian owners care about the risk of pathogens and the value they place on acquiring CPF amphibians will be instrumental in evaluating the economic viability of a clean-trade program in the pet amphibian industry. In this regard, evidence from this study confirms that pet amphibian owners believe the threat of transmission of *Rv*, *Bd*, and *Bsal* from pets to natural areas is serious, and preventing transmission of these pathogens from the pet trade network to natural areas is important and within their control. Moreover, despite confidence that their most recently acquired amphibian had not been infected before acquisition, pet amphibian owners showed demand for CPF amphibians and are willing to pay a fee for such an assurance. As potential mechanisms to promote clean trade are examined by stakeholders and government agencies, these findings suggest the feasibility of a clean-trade certification program whereby business costs for certification and enhanced biosecurity are offset, at least in part, by higher prices paid by consumers. Ultimately, government assistance with public outreach, establishing certification standards, and supporting diagnostic testing may be needed to ensure a viable pathogen-free certification program for amphibians. Our findings may also imply that pet owners of other wildlife species may be willing to support clean trade programs.

A few caveats of this study should be noted. First, the design of the survey questionnaire involved all structured questions for quantitative analysis whereas more qualitative methods could have been more effective in collecting information on sensitive matters. Second, due to the lack of a reliable estimate of the population of amphibian pet owners and their mail or email information to contact them directly, the survey administration relied on a network of prominent industry players to help promote the survey and increase participation. As a result, a completely random sample was not possible to generate for this study. Nonetheless, the findings generated from this new study still offer valuable insights to help us understand the characteristics, and motivation of amphibian pet owners in the United States and the value they place on clean, pathogen-free amphibian animals.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Raw data used in this paper were collected by assuring the participants that only aggregated data and summary statistics will be presented. Such de-identified data will be available from authors upon reasonable request.

ETHICS STATEMENT

The final survey instrument and survey protocols were approved by the University of Tennessee Institutional Review Board for human subjects' research (Approval#: UTK IRB-21-06494-XM).

ORCID

Neelam C. Poudyal https://orcid.org/0000-0003-1230-0679
Jesse L. Brunner https://orcid.org/0000-0003-4894-8274

ENDNOTE

[1] For the purpose of this study, consumers refer to the amphibian pet owners.

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SUPPORTING INFORMATION

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

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