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Exotic pet owners' preferences for different ectothermic taxa are based on species traits and purchase prices in the United States

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Abstract

The exotic pet trade has resulted in substantial invasion and disease risks, owing to the release of pets into new environments. Scientists have conjectured that pet owners acquire and release species with undesirable traits because they are imperfectly informed about the traits of these animals. However, few studies have used social science methods to elicit pet owners' preferences for exotic pets. In 2019 we administered a best-worst choice survey to 1,055 exotic pet owners in the United States (who own pet reptiles, amphibians, fish, or invertebrates) to examine how human preferences and incomplete information may contribute to the risks of the exotic pet trade. Respondents preferred colorful and patterned species. On average, respondents preferred medium-sized amphibians and reptiles, small fish, and large invertebrates, although they demonstrated heterogeneity in preferences with respect to the adult size of pets. Respondents also preferred amphibians and reptiles with medium life expectancies and fish and invertebrates with long life expectancies, although they again demonstrated heterogeneity in preferences with respect to pets' life span. Respondents preferred docile animals, and were more likely to purchase lower-cost pets. We found some evidence that respondents' decision to purchase exotic pets depended on whether these animals were native, rare, had unusual morphological features, and breed easily. Respondents' decision to purchase specific taxa as exotic pets also depended on their age, education, and housing. Most respondents stated that they searched for information on pets' diet, behavior, adult size, life span, costs of care such as equipment or veterinary costs, and whether the animal was captive bred before purchasing these animals. Excepting pets' diets, fewer than half of respondents had been offered information on pets' traits by sellers. On average, respondents rated the information they had been offered as average. Respondents typically obtained additional information about pets from online searches. Our results suggest that certification systems that provide critical information on exotic pets' behaviors, adult size, longevity, fecundity, and husbandry needs should be implemented to prevent pet owners acquiring animals that they may subsequently abandon.

Keywords
Amphibians, animal behavior, best-worst choice experiments, coloration, consumer preferences, fish, invertebrates, reptiles, size

Introduction

Although it is financially lucrative, the global exotic pet trade has resulted in the overexploitation of species, the introduction and spread of invasive species and pathogens, risks to public health and safety, and animal welfare concerns (Bush et al. 2014; Warwick et al. 2018; Gippet and Bertelsmeier 2021; Harrington et al. 2022; Toomes et al. 2022). Exotic pets are animals that are non-native and/or do not have a history of domestication, and which people purchase for companionship, ornament, or entertainment (Warwick et al. 2018). Responding to the various risks posed by the exotic pet trade is challenging because we have incomplete knowledge of the demand for exotic pets, largely derived from trade data (Lockwood et al. 2019; Sinclair et al. 2021). Better understanding of pet owners' preferences for different species and exotic pet traits (e.g., life history, aesthetic appeal, captive care requirements, monetary costs) is necessary to design interventions that appropriately target pet owners' choice of pets (Burivalova et al. 2017; Sung and Fong 2018; Lockwood et al. 2019; Hausmann et al. 2023; Street et al. 2023), in order to prevent potential risks associated with owners acquiring and subsequently releasing undesirable pets (Harrington et al. 2022; Toomes et al. 2022).

In this paper, we focus on the trade in reptiles, amphibians, fish, insects, and arachnids as exotic pets. Over 550 reptile, 170 amphibian, and 860 invertebrate species are sold as pets in the United States and United Kingdom (Warwick et al. 2018). Further estimates suggest that ~160 million ornamental fishes are kept in aquaria in the United States, encompassing ~20 million marine fish (Biondo and Burki 2020). To help elucidate how human preferences and incomplete information may contribute to the risks of the exotic pet trade, we administered a survey to exotic pet owners in the United States. We focused on 1) people's decision to acquire exotic pets, specifically which traits increase their likelihood of purchasing a pet; 2) which traits reduce the desirability of a pet; 3) how exotic pet owners acquire information about exotic pets (e.g., husbandry requirements); and 4) their assessment of the quality of the information they received when purchasing their pets.

Based on existing studies of species in the exotic pet trade, we hypothesized that pet owners would prefer species that are colorful or patterned (van Wilgen et al. 2010; Vall-llosera and Cassey 2017), and animals with distinctive or rare aesthetic or morphological features (Burghardt 2017; Sung and Fong 2018; Harrington et al. 2022; Hausmann et al. 2023). We further hypothesized that pet owners would have heterogeneous preferences with respect to the adult size and lifespan of exotic pets. People may prefer larger invertebrate species (Barua et al. 2012), but their preferences for size in pet fishes (Harrington et al. 2022) is not clear. Exotic pet owners have cited the higher longevity of certain exotic pet species relative to common domesticated animals as part of their decision to acquire exotic pets (Goins and Hanlon 2021). However, vertebrates with larger body sizes and long reproductive lifespans tend to escape captivity or be released by exotic pet owners (Toomes et al. 2022; Street et al. 2023), which suggests that these may not be preferred traits. We further posited that most pet owners would prefer species that do not require live food, and that are docile and easy to handle and maintain (van Wilgen et al. 2010; Vall-llosera and Cassey 2017). Dangerous species or species that require specialized care or housing are typically only desired by experienced pet owners and hobbyists, who are capable of caring for such species (van Wilgen et al. 2010; Vall-llosera and Cassey 2017; Hausmann et al. 2023).

We had no prior predictions on whether species rarity or captive breeding are preferred traits in exotic pets. Species that are novel, threatened or protected are traded at higher prices (Bush et al. 2014; Sung and Fong 2018; Siriwat et al. 2019). However, species that are rare in the wild may be common in the pet trade, which has been demonstrated to diminish pet owners' preferences for these species (Krishna et al. 2019). Studies are inconsistent in their findings as to whether exotic pet owners prefer wild-caught or captive-bred animals, or whether they prefer species that are common in the wild and abundant in the market (Burivalova et al. 2017; Sung and Fong 2018; Hausmann et al. 2023). What is clear from trade data is that species that are abundant in the pet trade are sold at lower prices (van Wilgen et al. 2010; Vall-llosera and Cassey 2017), which would make these pets affordable for a larger number of people. Species that are easier to breed in captivity also tend to be traded at higher volumes (van Wilgen et al. 2010). For example, amphibians and reptiles traded as exotic pets tend to have relatively high reproductive rates and long reproductive lifespans, but these species also tend to be accidentally or deliberately released by pet owners which suggests that fast life history traits are not preferred (Toomes et al. 2022; Street et al. 2023).

Although pet owners may acquire species based on a set of preferred traits (e.g., appearance, rarity), pet owners who are unable to care for pets with undesirable traits (e.g., behavior, adult size) or who are unable or unwilling to pay the veterinary expenses associated with exotic pets may abandon or release their pets into the wild (Pasmans et al. 2017). Abandonment and release of exotic pets occurs because owners are misinformed about animal behaviors (e.g., defensive behaviors such as biting and scratching) and pets' husbandry requirements and costs of care, with exotic pets often being mislabeled 'easy to keep' or 'beginner' animals (Warwick et al. 2018; Siriwat et al. 2019). However, animals' level of specialization in the wild is correlated with their temperaments and needs, which means that highly specialized species are difficult to handle and care for (Bush et al. 2014). Pet owners may lack information about pets' requirements for specific diets, habitat structure, lighting, heating, humidity, physical activity, play, stimulation, and large spaces (Bush et al. 2014; Burghardt 2017; Warwick et al. 2018). Pet owners may also be unaware that certain species exhibit aggressive or stressed behaviors when exposed to humans and multispecies assemblages (Bush et al. 2014). Poor animal husbandry is compounded by inaccurate, incomplete, and poor-quality information about exotic pet care provided by sellers or online searches (Pasmans et al. 2017; Warwick et al. 2018). Based on the literature, we hypothesized that pet owners receive incomplete information about the traits and husbandry requirements of exotic pets, and that they rely on online searches to obtain additional information about the exotic pets they have purchased.

Methods

Survey design

We administered an online survey to exotic pet owners. We initially asked respondents to check all types of pets that they owned from an extended list that included birds and mammals. Respondents who selected reptiles, amphibians, insects, arachnids, and/or fish were directed to the questionnaire. We elicited information on both the number of exotic pets respondents owned as a child and the number of exotic pets they currently owned. We further elicited information on how respondents acquired their current pets. We asked respondents to indicate where they had purchased pets (e.g., from a breeder, commercial store, or trade show) and whether they had purchased any of their pets online.

We then asked respondents "If you were going to purchase another pet, which of these animals are you most likely to purchase?" (response options of 'snake', 'lizard/chameleon', 'turtle', 'tortoise', 'frog/toad', 'salamander/newt', 'fish (saltwater or freshwater)', and 'insect/arachnid'). We allocated respondents questions specific to one of the taxa they had selected. We programmed the survey to ensure that (to the extent possible) an equal number of respondents were assigned questions for each taxon. We informed respondents that we were interested in their preferences for four pet traits (coloration, size, life span, and behavior) as well as the purchase price of the pet.

We presented respondents with images of different pets that varied in coloration and asked them what color and/or pattern they would prefer for their next pet ('neither colorful nor patterned', 'colorful but not patterned', 'patterned but not colorful', or 'both colorful and patterned'; Fig. 1). We also provided respondents with different examples of adult sizes for that pet type and asked them what size they would prefer the adult pet to reach ('small', 'medium', or 'large'; Table 1). We provided respondents with images of potential exotic pets when we described pet coloration and size to ensure that respondents were answering subsequent questions about whether they would purchase pets with different attributes based on identical understanding of what we meant by coloration and size. To the extent possible, we attempted to ensure that the species we presented in these images were similar in morphology (excepting coloration or size) so that respondents focused on the indicated pet trait (coloration, size). It is possible that respondents who are familiar with the species we presented took other characteristics of the species into account when answering these initial questions, but we controlled for this later in the survey (see below).

To elicit respondents' preferences for pet longevity we informed them that "The life span of potential pets can differ greatly, impacting the length of time a pet owner is responsible for their pet," and we asked them what length of time they would prefer to own their next pet. The time ranges we presented to respondents were based on the life expectancies of different species within that group of exotic pets. We defined three different levels of behavior for pets, namely: 'docile' pets that can be easily handled and/or are not aggressive towards other pets; pets with an 'intermediate' temperament that are active, can be handled, and may occasionally be aggressive; and 'aggressive' pets which are highly active, pose threats to other pets, and are difficult to handle. We modified the wording for fish to remove any reference to handling the animal. Respondents indicated which temperament they would prefer in their next pet. We also asked respondents to indicate the approximate cost of the last pet of that taxa they had acquired.

After asking respondents to consider their preferences for pet traits and what price they paid for their last pet, we presented them with six best-worst choice (BWC) questions to rigorously measure their preferences for pet traits (see below for a more detailed description of this methodology). We presented respondents with written descriptions of six different potential pets that had specific traits (coloration, adult size, longevity, and behavior) and the price at which the pet could be purchased (Fig. 2). It is important to note that we did not provide images of species in the BWC questions to ensure that respondents focused on the traits we identified, rather than other morphological or behavioral traits. We asked respondents to complete three tasks for each question: 1) to select which aspect (traits, price) of the pet they liked most; 2) to select which aspect of the pet they liked least; and 3) to indicate whether they would buy the pet exactly as described. If respondents stated that they would purchase the pet, we asked them to indicate on a 10-point scale how certain they were that they would purchase that pet (very uncertain = 1; very certain = 10). If respondents stated that they would not purchase the pet, we asked them to indicate why. The possible response options to this question were: 'I do not like the coloration of the animal'; 'I do not like the size of the animal'; 'I do not like the life span of the animal'; 'I do not like the behavior of the animal'; 'I do not like the price of the animal'; 'I do not want another pet'; or respondents could provide another reason for not purchasing the pet. We presented respondents with an example of how to complete the BWC questions before asking them to answer these questions. The different traits and prices we presented for each of the exotic pets included in the survey are presented in Table 1.

We used data provided by Stringham and Lockwood (2019) and in-person and online searches of pet retailers to identify prices at which different pets were being sold at the time of survey design to determine the prices presented in the BWC questions. We visited 4 pet retailers (2 general pet retailers that sold an array of pets and pet products; 1 retailer that specialized in pet herpetofauna, 1 retailer that specialized in aquarium fish) in person once to record prices. We searched the inventory of pets sold by 13 online pet retailers (2 general pet retailers, 2 retailers that specialized in pet turtles and tortoises, 2 retailers that specialized in pet herpetofauna, 2 retailers that specialized in pet invertebrates, 1 retailer that specialized in pet herpetofauna and invertebrates, 4 retailers that specialized in aquarium fish). Finally, we searched 3 websites that provided information about husbandry requirements and typical purchase prices for an array of exotic and traditional pets. We only visited each website once during survey development. We assumed that the prices for the regular stock of species traded by pet retailers would not vary greatly over time.

Table 1. Attributes and level scale values for different exotic pets.

	Snake	Lizard/Chameleon	Turtle	Tortoise	Frog/Toad	Salamander	Insect/Arachnid	Fish
Color (example species that closely matched different levels of coloration and patterning):								
Neither colorful nor patterned	Black rat snake (*Pantherophis obsoletus*)	Bearded dragon (*Pogona vitticeps*)	Mud turtle (*Kinosternon subrubrum*)	Burmese brown mountain tortoise (*Manouria emys emys*)	American bullfrog (*Lithobates catesbeianus*)	Jefferson salamander (*Ambystoma jeffersonianum*)	Dead leaf mantis (*Deroplatys desiccata*)	Black molly (Genus: *Poecilia*)
Colorful, not patterned	Green tree python (*Morelia viridis*)	Electric blue gecko (*Lygodactylus williamsi*)	Cumberland slider (*Trachemys scripta troostii*)	Cherry head red foot tortoise (*Geochelone carbonaria*)	Golden mantilla (*Mantella aurantiaca*)	Yellow-eye ensatina (*Ensatina eschscholtzii xanthoptica*)	Jewel beetle (Genus: Buprestidae)	Yellow tang (*Zebrasoma flavescens*)
Patterned, not colorful	Fire ball python (*Python regius*)	Leopard gecko (*Eublepharis macularius*)	Black-knobbed map turtle (*Graptemys nigrinoda*)	Radiated tortoise (*Astrochelys radiata*)	Great plains toad (*Anaxyrus cognatus*)	Two-lined salamander (*Eurycea bislineata*)	Ten-lined june bug (*Polyphylla decemlineata*)	Convict cichlid (*Amatitlania nigrofasciata*)
Both colorful and patterned	Corn snake (*Pantherophis guttatus*)	Panther chameleon (*Furcifer pardalis*)	Ornate wood turtle (*Rhinoclemmys pucherrima*)	High yellow pancake tortoise (*Malacochersus tornieri*)	Poison dart frog (Dendrobatidae spp)	Fire salamander (*Salamandra salamandra*)	Gooty tarantula (*Poecilotheria metallica*)	Mandarinfish (*Synchiropus splendidus*)
Adult size:								
Small	~1–3 feet long	~3–6 inches (not including tail)	~4–5 inches long, ~0.5 lbs	~8–10 inches long, 1–3 lbs	~1–2.5 inches long	~3–5 inches long	<0.5 inches long	~1–3 inches long
Medium	~4–6 feet long	~8–12 inches (not including tail)	~6–9 inches long, ~2–3 lbs	~12–18 inches long, ~15–25 lbs	~3–5 inches long	~6–14 inches long	~0.5–2 inches long	~5–9 inches long
Large	~8 feet or longer	~16–24 inches (not including tail)	~12–24 inches long, ~6–14 lbs	~22–36 inches long, ~70–100 lbs	~7 inches or longer	~16–45 inches long	~4 inches or longer	~12 inches or longer
Life expectancy:								
Short	<10 years	<5 years	<16 years	<25 years	<5 years	<10 years	<6 months	<5 years
Average	10–25 years	5–15 years	16–40 years	25–60 years	5–12 years	10–25 years	6–12 months	5–10 years
Long	>25 years	>15 years	>40 years	>60 years	>12 years	>25 years	>12 months	>10 years
Behavior:								
Docile	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	An animal that is easy to handle, and not aggressive	A fish that is peaceful and does not pose a threat toward other fish
Intermediate	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	An animal that can be handled, and may be aggressive, but only occasionally	A fish that is active, and may be occasionally aggressive toward other fish
Aggressive	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	An animal that, due to its aggressive nature, is typically difficult to handle	A fish that is highly active, and typically poses a threat to other non-dominant fish

	Snake	Lizard/Chameleon	Turtle	Tortoise	Frog/Toad	Salamander	Insect/Arachnid	Fish
Price:								
Lowest	$90	$50	$25	$100	$20	$20	$12	$8
Price 2	$140	$90	$50	$150	$50	$50	$25	$25
Price 3	$250	$200	$100	$200	$70	$70	$45	$50
Highest	$450	$450	$250	$400	$110	$100	$80	$90

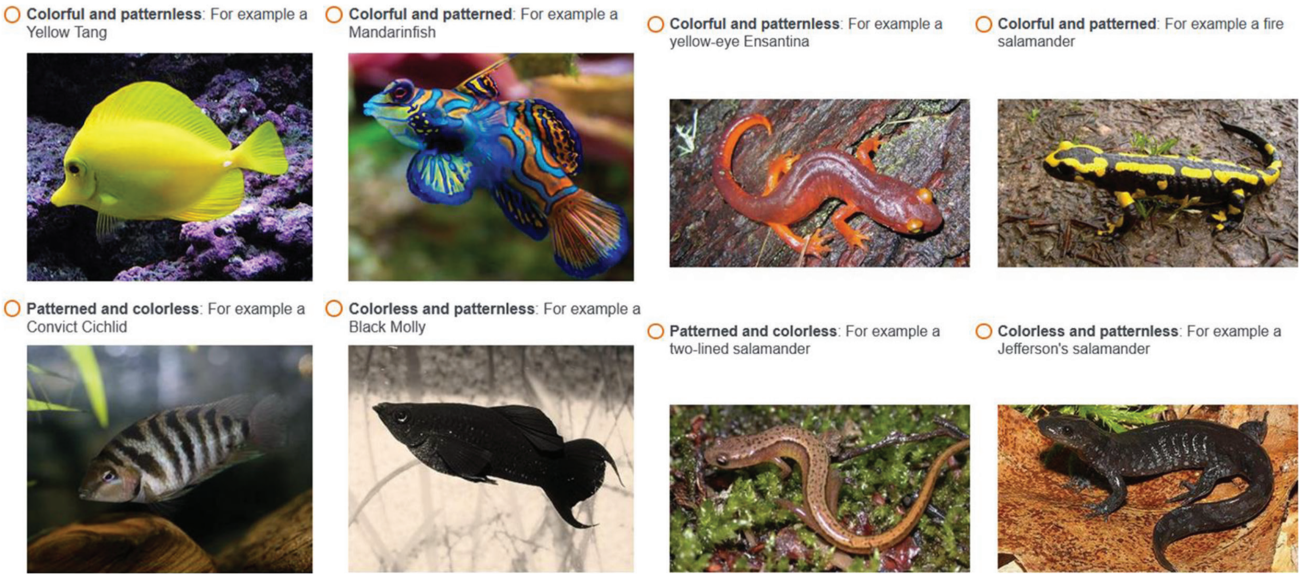

Figure 1. Example images used to capture different coloration for exotic pets, specifically fish and salamanders. Image attribution: • Yellow tang: Arpingstone, Public domain, via Wikimedia Commons • Madarinfish: Luc Viatour (https://lucnix.be/), CC BY-SA 2.5 <https://creativecommons.org/licenses/by-sa/2.5>, via Wikimedia Commons • Convict cichlid: shutterbusterbob CC BY-NC-SA 2.0 <https://creativecommons.org/licenses/by-nc-sa/2.0/>, via flickr • Black molly: Pmalkowski, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons • Yellow-eye ensatina: Greg Schechter, CC BY 2.0 <https://creativecommons.org/licenses/by/2.0>, via Wikimedia Commons • Fire salamander: StefanHoffmann, Free Use, via pixabay • Two-lined salamander: John D. Wilson, Public domain, via Wikimedia Commons • Jefferson's salamander: Todd Pierson, CC BY-NC-SA 2.0 <https://creativecommons.org/licenses/by-nc-sa/2.0/>, via flickr.

We are interested in your preferences for pet snakes. In the following questions we will ask you whether you would consider buying 6 different snakes. These snakes vary in their coloration, size, life span, behavior, and cost. The snakes do not represent specific species.

In each of the following questions you will be asked to perform the same tasks. We are interested in:

1. Which trait of the snake you like **MOST**.
2. Which trait of the snake you like **LEAST**.
3. Whether you would buy a snake with **ALL** these 5 traits.

Snake A (select one trait you **like most** and one trait you **like least**).

Like MOST		Like LEAST
○	Colorful and patterned	○
○	Small size	○
○	Lives less than 10 years	○
○	Aggressive behavior	○
○	Price: $90	○

Would you purchase a snake with the five traits above?

- ○ Yes
- ○ No

Figure 2. Best-worst choice question for a pet snake.

Once respondents had completed the BWC questions, we elicited their preferences for additional pet traits by asking them to indicate on a 5-point scale (very negative=-2, somewhat negative=-1, neither positive nor negative=0, somewhat positive=1, very positive=2) how additional traits would influence their decision to purchase an exotic pet, namely that the pet was captive-bred, wild caught, native to the area in which the respondent lives, or rare. We also asked how the pet's diet (expensive diet, diet of animal products), appearance (an unusual shape, a pre-historic appearance, an appearance that changes as the pet ages) and fecundity would influence respondents' decision to purchase a pet. We derived the term 'pre-historic' from interviews with pet trade participants, who equated 'pre-historic' with species that resembled dinosaurs, with scales, long/curved claws, wide heads, and long necks and/or tails (Episcopio-Sturgeon and Pienaar 2019). Pre-tests confirmed that survey recipients interpreted 'pre-historic appearance' as we intended.

To assess whether respondents researched the needs of pets before acquiring them, we asked respondents which information they looked up about a pet before purchasing it. We also asked which information they were offered about their current pets at the time of acquisition, how they would rate the quality of the information they received, and which information they wish they had received prior to acquiring any of their current pets. We further asked which additional information they had looked up on their pets after acquiring them and the source of that information. Finally, we collected respondents' demographic information (gender, age, education level, income level, job status, type of residence, number of household members ≤ 18 years old).

Before finalizing the survey, we pre-tested the questionnaire with nine experts in the design and implementation of social sciences surveys, six invasion ecologists who study the pet trade, and 14 exotic pet owners. The final survey was approved by the University of Florida's Institutional Review Board (protocol number: IRB201802439).

Best-worst choice methodology

We used the BWC methodology (Lusk and Parker 2009), which combines best-worst scaling (BWS) with dichotomous choice experiments (DCE), to elicit pet owners' preferences for different traits of exotic pets, and whether they would purchase pets with different combinations of traits. BWS was first implemented in the field of marketing in the 1990s (Finn and Louviere 1992) to assess consumer preferences for goods and services. For the purposes of our study, respondents completed two tasks: 1) they chose which characteristics (traits and purchase price) of an exotic pet they liked most and least (the BWS task); and 2) they indicated whether they would buy the pet with the described traits at that purchase price (the DCE task).

We used optimal designs generated by SAS statistical software (JMP Version 14.1) to maximize information derived from the BWC questions while minimizing the length of the survey. The optimal design (D-efficiency = 95.02) generated 18 choice tasks (i.e., pet descriptions). We used SAS to split these 18 choice tasks into three blocks of six choice tasks to reduce respondents' cognitive burden. Accordingly, we generated three different survey versions for each exotic pet, which presented respondents with six examples of the pet that varied in traits and purchase price (see Suppl. material 1: table S1).

Analysis of the best-worst scaling data

The main advantage of BWC is that the BWS task allows researchers to directly measure the (dis)utility that pet owners derive from pet traits and the purchase price for pets (Lusk and Parker 2009). BWS allows researchers to measure both attribute 'impacts' (mean utility of an attribute across all its levels on a latent, or unobserved, utility scale) and 'level-scale values' (LSVs; utility of an attribute level, i.e., deviations from mean utility; Flynn et al. 2007; Louviere et al. 2013). The attributes (coloration, adult size, longevity, behavior, purchase price) and LSVs (e.g., docile, intermediate, or aggressive behavior) for different pets are presented in Table 1.

We used paired estimation ("maxdiff") at the respondent level to analyze the BWS data (Lusk and Briggeman 2009; Louviere et al. 2013). In completing this BWS task, respondents identified every possible pair of items available in the choice set (i.e., profile of attributes), calculated the difference in utility between each pair of items (i.e., attribute levels), and chose the pair of items that maximized their utility difference (Flynn et al. 2007). The number of possible pairs per choice set equaled $J(J-1)$, where J was the number of items in each choice set (J=5 for our study: type of coloration; adult size; longevity; behavior; purchase price). For a pair of items (j,k), if a respondent liked j most and liked k least then the location of j (λ_j) on the respondent's underlying utility scale was higher than λ_k (Lusk and Briggeman 2009). The utility that individual i derived from j is given by $I_{ij} = \lambda_{ij} + \varepsilon_{ij}$ where ε_{ij} is a random error term. The probability that individual i liked j most and k least from a choice set of J items was thus equal to the probability that the difference between I_{ij} and I_{ik} exceeded the difference between all other $J(J$-1)-1 possible pair combinations in the choice set:

$$\Pr[(I_{ij} - I_{ik}) > (I_{il} - I_{im})]$$

where l and m were all other possible pair combinations. Assuming independently and identically distributed type I extreme value errors, the multinomial logistic estimation procedure may be used to analyze BWS data, i.e.

$$\Pr(\text{like } j \text{ most, like } k \text{ least}) = \frac{e^{\lambda_j - \lambda_k}}{\sum_l \sum_m e^{\lambda_l - \lambda_m}}$$

Thus, standard maximum likelihood techniques can be used to estimate the vector of utility parameters (λ). We estimated logistic regression models (conditioned to the $J(J-1)$=20 possible best-worst pair combinations per choice set) where the dependent variable took a value of 1 for the chosen pair of best and worst values and 0 for all other $J(J$-1)-1=19 best-worst pairs available in each choice set. The λ_j parameter estimates represented the location of item j relative to an item that was omitted to avoid the dummy variable trap and normalized to zero (i.e., we omitted the attribute impact for a pet's life expectancy from the regression). The normalized item (life expectancy attribute impact) served as the reference point for the underlying utility scale, which allowed us to directly estimate all other attribute impacts and LSVs (λ) in the same units (utility) relative to this reference point. As such, we interpreted the sign and magnitude of parameter estimates relative to the reference point.

If the coefficient value of an attribute level is twice the magnitude of another attribute level, then this implies that a respondent derives twice the utility from the preferred attribute level. We could thus identify the relative importance to pet owners of different pet traits (Flynn et al. 2007; Lusk and Briggeman 2009; Lusk and Parker 2009). For example, we could infer that pet coloration is the most preferred pet trait, but on average pet behavior (i.e., whether pets are aggressive or docile) has a higher impact on people's decision to purchase a pet. Such information provides crucial insights into why people purchase pets, and why they may choose to discard them (e.g., owners purchase a pet based on its attractive appearance but may discard the pet because they were unaware that it had an aggressive temperament).

We tested for preference heterogeneity (i.e., heterogeneity across respondents in terms of their preferences for species traits) by analyzing the BWS data using a random parameters logit model (Lusk and Briggeman 2009). Accordingly, we estimated the preference parameters for each individual i as $\tilde{\lambda}_{ij} = \bar{\lambda}_j + \sigma_j u_{ij}$, where $\bar{\lambda}_j$ and σ_j are the mean and standard deviation of λ_j, and u_{ij} is a standardized normally distributed error term with mean zero. We assumed that preferences for the attribute levels were normally distributed (Lusk and Briggeman 2009; Louviere et al. 2013). We effects coded the attributes and LSVs to separate attribute impacts and LSVs and to map their position on respondents' underlying utility scale (Suppl. material 1: table S2).

Analysis of the dichotomous choice data

Although BWS is informative, it does not provide information on whether an individual would purchase a pet with specific traits relative to the status quo of not purchasing the pet (Flynn et al. 2008). The DCE task within the BWC methodology allowed us to determine whether respondents would purchase exotic pets and how the decision to purchase pets was influenced by pet traits, the purchase price, and respondents' socio-psychological and demographic characteristics. Incorporating the DCE task allowed us to determine if certain attribute levels would make a pet undesirable to an owner, and how owners trade off between pet traits in their decision to acquire a pet.

Respondent i's utility from purchasing a pet j (U_{ij}) was represented by a systematic component (V_{ij}) and a random error component (ε_{ij}):

$$U_{ij} = V_{ij} + \varepsilon_{ij} = \mathbf{X_{ij}}\boldsymbol{\beta} + \varepsilon_{ij}$$

where $\mathbf{X_{ij}}$ is a matrix of attribute levels that describe pet j and the characteristics of individual i and $\boldsymbol{\beta}$ is the vector of estimated coefficients. We modeled the probability that individual i would purchase pet j as:

$$\Pr(\text{purchase pet } j) = \Pr(U_{ij} > U_{i0}) = \Pr(\Delta\varepsilon_{ij} < \Delta V_{ij})$$

where $\Delta\varepsilon_{ij} \equiv \varepsilon_{i0} - \varepsilon_{ij}$ is the difference in errors and $\Delta V_{ij} = V_{ij} - V_{i0}$ is the utility difference between purchasing the pet and not purchasing pet j. We specified the conditional indirect utility errors (ε_{i0} and ε_{ij}) as Type I extreme value, such that the probability that individual i would purchase pet j ('yes' response to the question 'would you purchase a [pet] with the traits above?') was:

$$\Pr(\text{purchase pet } j) = \frac{e^{\Delta V_{ij}}}{1 + e^{\Delta V_{ij}}}$$

Because respondents were presented with six choice sets that varied in pet traits and purchase price, we used a random-effects logistic regression to regress respondents' decision whether to purchase a pet (yes=1, no=0) against the pet traits, purchase price and respondents' socio-psychological and demographic characteristics. In common with the BWS task, pets' coloration, adult size, life expectancy, and behavior were effects coded. Purchase price was continuously coded, and respondents' socio-psychological and demographic characteristics were a mix of binary, continuous and effects-coded variables.

We used STATA/SE v.16.1 to estimate all models. Prior to conducting our analyses, we recoded respondents' choice of whether they would purchase an exotic pet. If the respondent indicated that their certainty that they would buy the pet was ≤ 6 then we recoded their choice as choosing not to purchase the pet (Lundhede et al. 2009). We selected best-fit DCE models based on the minimum Akaike Information Criterion (AIC). We considered coefficients to be significant at the $p \leq 0.05$ level.

Survey implementation

We initially intended to administer the survey exclusively to Florida exotic pet owners because Florida has experienced considerable adverse environmental, economic, and human wellbeing consequences, owing to species invasions that are linked to the pet trade (Russello et al. 2008; Engeman et al. 2011). We paid a survey panel provider (Qualtrics Research Services) to administer the survey to Florida residents who owned one or more of the following exotic pets: snakes; lizards; chameleons; turtles; tortoises; frogs; toads; salamanders; newts; freshwater or saltwater fish; insects; and arachnids. We instructed Qualtrics to limit the number of respondents who only owned fish to 75 respondents in total (15% of the sample) to ensure that we received surveys from owners of herpetofauna, insects and arachnids.

Qualtrics administered the survey from December 6, 2018 to January 24, 2019. A total of 5,357 individuals opened the survey, and 4,229 individuals were screened out of the survey, either because the quota of responses required for that pet type had already been reached (n=2,212) or the individual did not own our targeted pets (n=2,017). An additional 454 participants were screened out because they were not Florida residents, and 31 participants failed the attention checks in the survey. The completion rate for the survey was 72.3% (465 completed surveys; 643 surveys administered to individuals who met the study criteria.)

In addition, we emailed the link to the online survey to 44 aquarium clubs, 55 herpetological societies, 31 reptile rescues, 71 aquarium shop owners and 72 pet store owners in Florida, 391 pet adopters approved by the Florida Fish and Wildlife Conservation Commission (FWC) and 3,288 Florida Class III Wildlife for Exhibition or Public Sale permit holders and Possession or Exhibition of Venomous Reptiles or Reptiles of Concern license holders. We identified the email addresses for these survey recipients (excepting FWC approved adopters and permit holders) through online searches and social media. We administered the survey in three waves (initial email and two reminder emails) from January 8 to January 29, 2019. We received 590 completed surveys from these individuals. We could not determine a response rate for this second survey effort because we could not track how many individuals were sent the survey by hobbyist clubs, rescues, or stores. Respondents to this second survey effort were residents of the United States, and so our sample was not restricted to Florida residents. We conducted two-sample t-tests with unequal variances to test for differences in mean responses to pet ownership questions between Florida respondents and respondents from other states.

Data resources

The data underpinning the analysis reported in this paper are deposited at Zenodo, and are available at https://doi.org/10.5281/zenodo.10534609.

Results

Most respondents (n=753, 71.4%) were female (Suppl. material 1: table S3). The median age range for respondents was 35–44 years, the median education level was either an associate's or technical degree, and respondents' median gross household income was \$50,000–99,999/year. A total of 416 respondents (39.4%) had individuals ≤ 18 years old living in their household. Most respondents (n=720, 68.2%) lived in a single-family home, and 617 respondents (58.5%) were Florida residents. Because the population of exotic pet owners in the United States has not been described we could not ascertain whether our sample was representative of the larger population of exotic pet owners. We oversampled Florida residents relative to exotic pet owners in other states.

Over half of respondents owned dogs (n=698, 66.2%), cats (n=550, 52.1%) and lizards/chameleons (n=544, 51.6%; Suppl. material 1: table S4). Respondents from Florida were less likely to own pet snakes (28.8% of Florida respondents, 49.8% of respondents from other states, t=6.95, $p<0.001$), lizards/chameleons (Florida: 42.3%, other states: 64.6%, t=7.36, $p<0.001$), frogs/toads (Florida: 9.1%, other states: 15.1%, t=2.90, $p=0.004$), salamanders (Florida: 2.8%, other states: 6.2%, t=2.57, $p=0.010$), and insects/arachnids (Florida: 7.9%, other states: 21.0%, t=5.85, $p<0.001$). Respondents from Florida were more likely to own turtles/tortoises (Florida: 43.3%, other states: 20.8%, t=-8.08, $p<0.001$). The largest share of respondents (n=401, 38.0%) owned 2–5 exotic pets (reptiles, amphibians, fishes, insects, arachnids) at the time that the survey was implemented. In total, 369 respondents (35.0%) owned 2–5 exotic pets when they were < 18 years old, whereas 322 respondents (30.5%) owned no exotic pets when they were children. Most respondents (n=693, 65.7%) purchased their exotic pets for themselves, frequently from a commercial pet store (n=373, 35.4%), or a breeder or hobbyist (n=363, 34.4%).

Respondents stated that they were most likely to purchase a lizard or chameleon (n=499, 47.3%), a fish (n=415, 39.3%), or a snake (n=412, 39.1%) as their next pet (Suppl. material 1: table S5). Most of these respondents (63.3–71.5%) already owned this type of pet. Florida respondents were less likely to select a snake (Florida: 27.9%, other states: 54.8%, t=9.01, $p<0.001$), lizard/chameleon (Florida: 37.9%, other states: 60.5%, t=7.41, $p<0.001$), tortoise (Florida: 18.8%, other states: 24.2%, t=2.09, $p=0.037$), frog/toad (Florida: 10.9%, other states: 21.5%, t=4.55, $p<0.001$), salamander (Florida: 7.3%, other states: 12.1%, t=2.56, $p=0.011$), or insect/arachnid (Florida: 8.1%, other states: 22.8%, t=6.43, $p<0.001$) as their next pet. Florida respondents were more likely to select a turtle (Florida: 24.6%, other states: 11.2%, t=-5.85, $p<0.001$) or a fish (Florida: 43.8%, other states: 33.3%, t=-3.46, $p=0.001$) as their next pet.

When asked their preferences related to the appearance of their next pet, respondents typically selected a pet that is both colorful and patterned (snake: n=93, 50.5%; lizard: n=90, 44.6%; turtle: n=56, 43.1%; frog/toad: n=59, 60.2%; salamander: n=45, 60.0%; insect/arachnid: n=67, 75.3%; fish: n=92, 56.4%; Suppl. material 1: tables S6–S13). When asked their preferences related to the adult size of their next exotic pet, respondents tended to prefer a small turtle (n=77, 59.2%), tortoise (n=44, 38.6%), frog or toad (n=43, 43.9%), or fish (n=94, 57.7%). By contrast, respondents tended to prefer a medium-size snake (n=116, 63.0%), lizard/chameleon (n=102, 50.5%) or salamander (n=60, 80.0%). Most respondents who stated they would purchase an insect/arachnid preferred a large animal (n=75, 84.3%). Respondents preferred to own a snake for 10–25 years (n=108, 58.7%), a lizard/chameleon for 5–15 years (n=127, 62.9%), a turtle for 5–15 years (n=49, 37.7%), a tortoise for 25–60 years (n=44, 38.6%), a frog/toad for 5–12 years (n=49, 50.0%), a salamander for 5–9 years (n=31, 41.3%), an insect/arachnid for > 12 months (n=84, 94.4%), and a fish for 2–4 years (n=78, 47.9%). For almost all species, most respondents preferred a docile animal (snake: n=142, 77.2%; lizard/chameleon: n=150, 74.3%; turtle: n=87, 66.9%; tortoise: n=82, 71.9%; frog/toad: n=68, 69.4%; salamander: n=48, 64.0%; fish: n=106, 65.0%). However, respondents who stated they would purchase an insect/arachnid were equally likely to select an animal that is active and may occasionally be aggressive toward other animals (n=44, 49.4%) and a docile animal (n=42, 47.2%). The median price range for the pet snake respondents had most recently acquired was $90–140. The median price range paid by respondents for their most recent pet lizard/chameleon was $50–90. Most respondents had paid <$25 for their pet turtle and <$100 for their pet tortoise. Respondents paid an average of $20–50 for their pet toad/frog or salamander. Most respondents paid <$45 for their pet insect/arachnid, and <$25 for their pet fish.

When asked how other traits would influence their decision to acquire an exotic pet, respondents indicated that they view captive bred pets (median=very positive) and pets with a pre-historic appearance positively (median=somewhat positive; Suppl. material 1: table S14). Respondents tended to view pets being wild-caught or having expensive diets negatively (median=somewhat negative). Respondents were generally neutral in their assessment of a pet being native, rare, requiring a diet of animal products, having an unusual shape, changing in appearance as it ages, or breeding easily (median=neither positive nor negative).

Before acquiring an exotic pet, most respondents stated that they searched for information on the animal's diet (n=962, 91.2%), behavior (n=936, 88.7%), adult size (n=911, 86.4%), life span (n=906, 85.9%), costs of care such as equipment or veterinary costs (n=791, 75.0%), and whether the animal was wild-caught or captive-bred (n=681, 64.5%, Suppl. material 1: table S15). Excepting the pet's diet (n=668, 63.3%), fewer than half of respondents (≤49.5%) had been offered information on the pet's traits by the seller. Fewer than a quarter of respondents (n=254, 24.1%) had been offered information about costs of care for the pet, and 233 respondents (22.1%) stated that they were offered no information on the pet. On average, respondents rated the information they had been offered as average (3.1% of respondents rated the information as 'very poor', 5.8% as 'poor', 26.3% as 'average', 20.9% as 'good', and 21.0% as 'very good', while 0.8% of respondents did not take the information). Nonetheless, 545 respondents (51.7%) stated that there was no additional information they wished they had received prior to acquiring their pets. For those respondents who were not satisfied with the information they had received, the largest share stated that they would have valued information on the potential additional costs of owning their pet (n=207, 19.6%). In total, 924 respondents (87.6%) had looked up additional information on their pet or how to care for their pet since acquiring it (Suppl. material 1: table S16). Most frequently, respondents obtained this information from an online search engine (n=753, 71.4%). Respondents were less likely to seek out additional information by contacting hobbyists or breeders (n=271, 25.7%), veterinarians (n=228, 21.6%), or pet stores (n=109, 10.3%).

Best-worst scaling task

Attribute impacts: Negative signs on coefficients in the random parameters logit (RPL) models indicate that the variables fall on the negative side of the reference case, not a negative relationship with the dependent choice variable. For all RPL models, the life expectancy attribute was omitted and used as a reference case (attribute impact or mean utility across all levels=0; Tables 2, 3). For all pets, respondents exhibited preference heterogeneity with respect to pet coloration (statistically significant standard deviation coefficients [β^{SD}]; $1.054 \leq \beta^{SD} \leq 1.529$). However, respondents uniformly placed positive value on the color of pets (positive, significant mean coefficients [β^{M}]: $1.134 \leq \beta^{M} \leq 1.762$; $|\beta^{M}| > \beta^{SD}$) relative to the reference case (pets' life expectancy), excepting for lizards/chameleons and fish ($\beta^{SD} > |\beta^{M}|$ for the color attribute impact). Respondents placed positive value on the size of turtles (β^{M}=0.311), salamanders (β^{M}=0.294), and insects/arachnids (β^{M}=0.851) and negative value on the size of fish (β^{M}=-0.468) relative to the reference case, although respondents exhibited preference heterogeneity for the size of salamanders (β^{SD}=0.350). Respondents placed negative value on the behavior of snakes (β^{M}=-0.442), lizards/chameleons (β^{M}=-0.591), turtles (β^{M}=-0.278), tortoises (β^{M}=-0.631), frogs/toads (β^{M}=-0.405) and fish (β^{M}=-0.789) relative to the reference case, and positive value on the behavior of insects/arachnids (β^{M}=0.351). We found preference heterogeneity for pet behavior across respondents who selected snakes (β^{SD}=0.408), lizards/chameleons (β^{SD}=0.445), turtles (β^{SD}=0.492), fish (β^{SD}=0.406), and insects/arachnids (β^{SD}=0.724). The relative magnitude of the standard deviation coefficients suggested that a subset of respondents placed higher value on pet life expectancy than behavior for turtles (β^{SD}=0.492) and insects/arach-

Table 2. Random parameters logit for pet herpetofauna. Estimated coefficients * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

	Snake		Lizard/Chameleon		Turtle		Tortoise	
	Mean Coefficient	**Standard Deviation Coefficient**	**Mean Coefficient**	**Standard Deviation Coefficient**	**Mean Coefficient**	**Standard Deviation Coefficient**	**Mean Coefficient**	**Standard Deviation Coefficient**
Attribute Impacts								
Color	1.375***	1.146***	1.155***	1.303***	1.504***	1.342***	1.134***	1.054***
Size	-0.096	0.181	-0.044	0.254	0.311***	0.138	0.209*	0.111
Life expectancy	0.000		0.000		0.000		0.000	
Behavior	-0.442***	0.408***	-0.591***	0.445***	-0.278**	0.492***	-0.631***	0.246
Price	-0.779***	0.407**	-1.317***	0.388***	-1.308***	1.078***	-1.085***	0.913***
Level Scale Values								
***Color*:**								
Neither colorful nor patterned	-1.590		-1.301		-0.850		-0.841	
Colorful, not patterned	0.392***	0.470**	0.250**	0.129	0.380***	0.372	0.308**	0.562**
Patterned, not colorful	-0.472***	0.193	-0.151	0.108	-0.421***	0.306	-0.140	0.155
Both colorful and patterned	1.670***	0.961***	1.202***	0.287	0.891***	0.550*	0.672***	0.620**
***Size*:**								
Small	-0.043		-0.149		1.105		0.074	
Medium	0.778***	0.237	0.743***	0.723***	0.291**	0.859***	0.498***	0.614***
Large	-0.735***	1.824***	-0.594***	1.599***	-1.395***	1.156***	-0.572***	2.244***
***Life expectancy*:**								
Short	-1.124		-2.188		-0.444		-0.517	
Average	0.708***	0.400**	1.129***	0.002	0.402***	0.393**	0.602***	0.124
Long	0.416***	0.686***	1.059***	1.418***	0.041	1.468***	-0.085	1.100***
***Behavior*:**								
Docile	3.427		3.159		2.663		2.495	
Intermediate	0.098	0.998***	0.060	0.696***	0.233*	0.746***	0.147	0.373
Aggressive	-3.525***	1.251***	-3.219***	0.816***	-2.896***	0.254	-2.642***	1.550***
***Price*:**								
Lowest	1.631		1.898		1.775		1.242	
Price 2	0.466***	0.030	0.929***	0.024	0.579***	0.102	0.729***	0.087
Price 3	-0.581***	0.275**	-0.868***	0.214	-0.570***	0.490***	-0.336*	0.239
Highest	-1.516***	0.291*	-1.959***	0.148	-1.784***	0.227	-1.635***	0.040
Log likelihood	-2,191.13		-2,406.05		-1,610.62		-1,423.64	
AIC	4,446.252		4876.095		3,285.243		2,911.283	
BIC	4,702.329		5135.159		3,530.204		3,152.041	

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

nids (β^{SD}=0.724). Respondents uniformly placed negative value on the purchase price of snakes (β^{M}=-0.779), lizards/chameleons (β^{M}=-1.317), turtles (β^{M}=-1.308), tortoises (β^{M}=-1.085), frogs/toads (β^{M}=-0.888), and fish (β^{M}=-1.864) relative to the reference case, even taking preference heterogeneity into account ($0.388 \leq \beta^{SD} \leq 1.078$).

Level scale values: Respondents preferred colorful lizards/chameleons (β^{M}=0.250 for colorful, not patterned animals; β^{M}=1.202 for colorful, patterned animals), turtles (β^{M}=0.380 for colorful, not patterned animals; β^{M}=0.891 for colorful, patterned animals), frogs/toads (β^{M}=0.412 for colorful, not patterned animals; β^{M}=1.420 for colorful, patterned animals), salamanders (β^{M}=0.358 for colorful, not patterned animals; β^{M}=1.852 for colorful, patterned animals), and fish (β^{M}=0.505 for colorful, not patterned animals; β^{M}=2.004 for colorful, patterned animals) over animals that were not colorful (patterned or not) – even after taking preference heterogeneity into account

Table 3. Random parameters logit for pet amphibians, fish, and insects/arachnids. Estimated coefficients * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

	Frog/Toad		Salamander		Fish		Insect/Arachnid	
	Mean Coefficient	Standard Deviation Coefficient	Mean Coefficient	Standard Deviation Coefficient	Mean Coefficient	Standard Deviation Coefficient	Mean Coefficient	Standard Deviation Coefficient
Attribute Impacts								
Color	1.226***	1.160***	1.174***	1.161***	1.286***	1.529***	1.762***	1.312***
Size	0.158	0.254	0.294**	0.350**	-0.468***	0.203	0.851***	0.016
Life expectancy	0.000		0.000		0.000		0.000	
Behavior	-0.405***	0.322*	-0.103	0.259	-0.789***	0.406***	0.351**	0.724***
Price	-0.888***	0.762***	-0.313**	0.359**	-1.864***	0.894***	0.159	0.816***
Level Scale Values								
***Color*:**								
Neither colorful nor patterned	-1.424		-1.624		-1.730		-1.837	
Colorful, not patterned	0.412***	0.330	0.358**	0.295	0.505***	0.309	0.763***	1.200***
Patterned, not colorful	-0.408**	0.047	-0.586***	0.204	-0.780***	0.220	-0.703***	0.255
Both colorful and patterned	1.420***	0.760***	1.852***	1.156***	2.004***	1.360***	1.776***	1.145***
***Size*:**								
Small	-0.427		-0.613		0.969		-1.355	
Medium	0.443***	0.571**	0.990***	0.365**	0.502***	0.561***	-0.141	0.348*
Large	-0.016	2.143***	-0.377*	1.162***	-1.471***	0.903***	1.495***	0.646***
***Life expectancy*:**								
Short	-1.708		-0.478		-0.693		-2.102	
Average	0.897***	0.170	0.435***	0.347	0.343***	0.224	-0.676***	0.752***
Long	0.811***	1.421***	0.043	1.400***	0.350***	0.838***	2.778***	1.776***
***Behavior*:**								
Docile	2.184		2.595		2.169		2.600	
Intermediate	0.336**	0.046	0.018	0.298	0.317***	0.657***	-0.043	0.069
Aggressive	-2.519***	1.635***	-2.613***	1.254***	-2.486***	0.673***	-2.557***	1.612***
***Price*:**								
Lowest	1.713		1.685		2.584		1.296	
Price 2	0.233	0.265*	0.276	0.188	0.373***	0.152	0.599***	0.079
Price 3	-0.430**	0.356*	-0.475**	0.040	-1.006***	0.271	-0.529**	0.216
Highest	-1.516***	0.148	-1.486***	1.036***	-1.951***	0.867***	-1.367***	0.527***
Log likelihood	-1,238.81		-978.87		-1,925.29		-1,050.61	
AIC	2,541.627		2,021.740		3914.582		2,165.218	
BIC	2,777.546		2,249.099		4166.782		2,398.054	

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

(β^{SD}=0.760 for colorful, patterned frogs/toads; β^{SD}=1.156 for colorful, patterned salamanders; β^{SD}=1.360 for colorful, patterned fish). Respondents most preferred colorful and patterned animals for each of these pets. Respondents also preferred colorful and patterned snakes (β^{M}=1.670, β^{SD}=0.961) and insects/arachnids (β^{M}=1.776, β^{SD}=1.145) relative to animals that were not colorful (whether patterned or not). Respondents demonstrated preference heterogeneity for snakes (β^{M}=0.392, β^{SD}=0.470) and insects/arachnids (β^{M}=0.763, β^{SD}=1.200) that were colorful but not patterned, although animals with coloration were still preferred to animals that were not colorful. Respondents most preferred colorful and patterned tortoises (β^{M}=0.672). On average, respondents preferred colorful (not patterned) tortoises (β^{M}=0.308) to animals that were not colorful or patterned. However, preference heterogeneity suggested that some respondents preferred patterned, not colorful tortoises to colorful tortoises without a pattern (β^{SD}=0.562).

Respondents preferred medium-sized snakes (β^{M}=0.778), lizards/chameleons (β^{M}=0.743), and salamanders (β^{M}=0.990), even after taking preference heterogeneity into account (β^{SD}=0.723 for medium-sized lizards/chameleons; β^{SD}=0.365 for medium-sized salamanders). However, a subset of respondents preferred large snakes (β^{SD}=1.824), lizards/chameleons (β^{SD}=1.599), and salamanders (β^{SD}=1.162). On average, respondents preferred medium-sized tortoises (β^{M}=0.498) and frogs/toads (β^{M}=0.443), although preference heterogeneity indicated that respondents were not uniform in these preferences (β^{SD}=0.614 for medium-sized tortoises; β^{SD}=0.571 for medium-sized frogs/toads). Respondents appeared to prefer small turtles and fish to medium-sized animals (β^{M}=0.291 for medium-sized turtles; β^{M}=0.502 for medium-sized fish), although they were heterogeneous in these preferences (β^{SD}=0.859 for medium-sized turtles; β^{SD}=0.561 for medium-sized fish). Preference heterogeneity indicated that a subset of respondents preferred large tortoises (β^{SD}=2.244) and frogs/toads (β^{SD}=2.143). Even after accounting for preference heterogeneity, respondents did not prefer large turtles (β^{M}=-1.395, β^{SD}=1.156) or fish (β^{M}=-1.471, β^{SD}=0.903), but did prefer large insects/arachnids (β^{M}=1.495, β^{SD}=0.646).

On average, respondents most preferred snakes (β^{M}=0.708), lizards/chameleons (β^{M}=1.129), turtles (β^{M}=0.402), tortoises (β^{M}=0.602), frogs/toads (β^{M}=0.897), and salamanders (β^{M}=0.435) with a medium life expectancy, although respondents demonstrated some preference heterogeneity with respect to medium life expectancy for snakes (β^{SD}=0.400) and turtles (β^{SD}=0.393). On average, respondents most preferred fish (β^{M}=0.350) and insects/arachnids (β^{M}=2.778) with long life expectancies. Respondents were heterogeneous in their preferences for all pet types with respect to long life expectancy ($0.686 \leq \beta^{SD} \leq 1.776$).

Even after accounting for preference heterogeneity ($0.673 \leq \beta^{SD} \leq 1.635$), respondents disliked aggressive animals ($-3.525 \leq \beta^{M} \leq -2.486$) relative to docile animals. We found preference heterogeneity with regards to intermediate behavior in pet snakes (β^{SD}=0.998), lizards/chameleons (β^{SD}=0.696), turtles (β^{SD}=0.746), and fish (β^{SD}=0.657). The level scale values for the price of pets followed the theoretically expected pattern of decreasing preference ($\beta^{M}<0$) for higher prices. Although there was some evidence of preference heterogeneity, lower prices were always preferred.

Decision to purchase an exotic pet

Respondents were more likely to agree that they would purchase turtles (β=0.937), tortoises (β=0.718), frogs/toads (β=0.826), salamanders (β=0.757), fish (β=0.452), and insects/arachnids (β=1.090) if they were both colorful and patterned (Table 4). Respondents were less likely to purchase species that were colorful but not patterned (lizard/chameleon: β=-0.387, turtle: β=-0.462, fish: β=-0.371) or patterned and not colorful (tortoise: β=-0.571, salamander: β=-0.503, insect/arachnid: β=-0.537). Respondents were less likely to purchase snakes (β=-0.336), lizards/chameleons (β=-0.287), and turtles (β=-0.676) that would grow to a large adult size, but were more likely to buy insects/arachnids (β=0.380) that would grow to a large adult size. Respondents were more likely to purchase snakes (β=0.378), lizards/chameleons (β=0.510), tortoises (β=0.495), frogs/

Table 4. Logistic regression of respondents' stated decision to purchase exotic pets. Estimated coefficients * significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

	Snake	Lizard/ Chameleon	Turtle	Tortoise	Frog/Toad	Salamander	Fish	Insect/ Arachnid
Constant	2.291	2.330**	2.390	0.610	4.489***	-0.506	-1.088***	-0.317
Color:								
Neither colorful nor patterned	-0.320	0.064	-0.189	-0.264	-0.553	-0.354	-0.303	-0.621
Colorful, not patterned	0.158	-0.387***	-0.462**	0.116	0.062	0.099	-0.371**	0.067
Patterned, not colorful	-0.171	0.018	-0.286	-0.571***	-0.335*	-0.503**	0.222	-0.537**
Both colorful and patterned	0.332*	0.306*	0.937***	0.718***	0.826***	0.757**	0.452**	1.090***
Size:								
Small	0.209	0.126	0.545	0.002	0.086	0.005	0.235	-0.438
Medium	0.127	0.161	0.131	0.005	0.076	0.265	-0.041	0.058
Large	-0.336**	-0.287**	-0.676***	-0.007	-0.163	-0.270	-0.195	0.380**
Life expectancy:								
Short	-0.399	-0.565	0.168	0.064	-0.337	-0.297	-0.379	-0.879
Average	0.378***	0.510***	0.299*	0.495***	0.339**	0.682***	0.390***	0.160
Long	0.021	0.056	-0.467***	-0.559***	-0.002	-0.385*	-0.011	0.719***
Behavior:								
Docile	1.283	1.263	1.287	1.090	0.606	1.220	0.749	0.776
Intermediate	0.178	-0.042	0.118	0.145	-0.001	0.106	-0.043	0.006
Aggressive	-1.460***	-1.221***	-1.405***	-1.235***	-0.605***	-1.326***	-0.706***	-0.782***
Price	-0.004***	-0.005***	-0.006***	-0.005***	-0.018***	-0.014***	-0.031***	-0.029***
Influence of other traits on decision to purchase exotic pets:								
Captive-bed				-0.366*				
Native to area		0.422***						
Rare					-0.491***			0.390*
Expensive diet	0.339	0.428***	0.389*		0.453**	0.489*		
Unusual shape			0.461*					0.676**
Pre-historic appearance					0.606***	-0.594*	0.304*	
Appearance changes with age	0.389*					0.598**		
Breeds easily			0.785***	0.561**		0.390*		
Cost of previous pet (same taxa)	0.009***	0.004**		0.006**	0.019**	0.021**	0.029*	
Current pets:								
Fish				0.699*				
Insect				1.603**		1.450***		
Reptile	-1.128				1.693***			
Rodent			1.279***			0.716		-0.751
Type of housing:								
Apartment/ condominium	0.775*		1.038**				1.238**	
Trailer/mobile home							1.039**	
Demographics:								
Female				-0.893*	-0.792*			
Age		-0.024**		-0.024*	-0.036**	-0.038*		
Education	-0.208**	-0.148**	-0.256**		-0.278***			
Income					-0.007	0.007	-0.005	
Individuals < 18 years old living in household						0.902**		
Log likelihood	-520.063	-555.713	-342.564	-312.343	-285.488	-203.440	-438.222	-274.446
AIC	1076.469	1145.426	721.128	662.685	613.682	451.101	910.714	578.955
BIC	1161.583	1232.127	804.995	748.717	701.217	537.395	988.882	638.881
N	184	202	130	114	98	75	163	89

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

toads (β=0.339), salamanders (β=0.682), and fish (β=0.390) with an average life expectancy. They were less likely to purchase turtles (β=-0.467) and tortoises (β=-0.559) with long life expectancies, but more likely to purchase insects/arachnids (β=0.719) with long life expectancies. Across all taxa, respondents were less likely to purchase aggressive animals as pets ($-1.460 \leq \beta \leq -0.605$). The likelihood that respondents would purchase pets decreased as the price of the pet increased ($-0.031 \leq \beta \leq -0.004$). However, the likelihood that respondents would purchase snakes (β=0.009), lizards/chameleons (β=0.004), tortoises (β=0.006), frogs/toads (β=0.019), and salamanders (β=0.021) was positively correlated with the price they had paid for their previous pet from the same taxa.

Respondents who stated that an animal being native to the area would positively influence their decision to purchase a pet were more likely to purchase lizards/chameleons (β=0.422). Respondents who stated that a pet being rare would positively influence their purchase decision were less likely to purchase frogs/toads (β=-0.491). Respondents who stated that a pet having an expensive diet would negatively influence their purchase decision were less likely to purchase lizards/chameleons (β=0.428) and frogs/toads (β=0.453). Respondents who preferred a pet with an unusual shape were more likely to purchase insects/arachnids (β=0.676). Respondents who preferred animals with a pre-historic appearance were more likely to purchase frogs/toads (β=0.606), whereas respondents who preferred animals whose appearance changes with age were more likely to purchase salamanders (β=0.598). Respondents who preferred pets that breed easily were more likely to purchase turtles (β=0.785) and tortoises (β=0.561).

Respondents who currently own insects or arachnids were more likely to purchase tortoises (β=1.603) or salamanders (β=1.450), whereas respondents who currently own reptiles were more likely to purchase frogs/toads (β=1.693). Respondents who currently own rodents were more likely to purchase turtles (β=1.279). The number of exotic pets that respondents currently own and the number of exotic pets that they owned as children did not influence their stated decision to purchase another exotic pet.

Older respondents were less likely to purchase lizards/chameleons (β=-0.024) and frogs/toads (β=-0.036). More educated respondents were less likely to purchase snakes (β=-0.208), lizards/chameleons (β=-0.148), turtles (β=-0.256), and frogs/toads (β=-0.278). Respondents with children (<18 years old) living in the house were more likely to purchase salamanders (β=0.902). Respondents who lived in apartments or condominiums were more likely to purchase turtles (β=1.038) and fish (β=1.238). Respondents who lived in trailers or mobile homes were also more likely to purchase fish (β=1.039).

Discussion

The exotic pet trade poses substantial conservation, human safety, and animal welfare risks when people purchase exotic pets that they are unable or unwilling to care for, and owners subsequently release these animals. Using surveys of exotic pet owners, we found some evidence that demographics (gender, age, education) influence people's decision to acquire an exotic pet. However, pet traits were far more important determinants of respondents' stated decision to purchase a pet. We confirmed findings from studies of species in the exotic pet trade that pet owners prefer animals that are colorful, patterned, docile, and easy to handle (van Wilgen et al. 2010; Vall-llosera and Cassey 2017; Hausmann et al. 2023). We also found some evidence that exotic pet owners prefer species with distinctive morphological features (Burghardt 2017; Sung and Fong 2018; Harrington et al. 2022; Hausmann et al. 2023), specifically a prehistoric appearance or an appearance that changes with age. Our results suggest that pet owners are likely to be attracted by colorful, patterned animals with distinctive morphological features that are of medium size, especially if these animals are inexpensive to purchase. However, if pet owners subsequently discover that these species have undesirable traits (e.g., they are aggressive, have long lifespans, have expensive dietary needs) then pet owners may regret the purchase of the animal and may release pets if they cannot rehome them.

Animal behavior was a trait that clearly influenced the desirability of a pet. Pet owners preferred not to purchase animals that are aggressive or dangerous (e.g., animals that engage in defensive behaviors such as biting and scratching), which suggests that pet owners who are ill- informed about the behaviors and handling requirements of the pets they have purchased may release these animals (Warwick et al. 2018; Siriwat et al. 2019). It is thus concerning that only half of respondents (49.5%) had been given information about the behavior of exotic pets at the time of purchase. Exotic pet owners should be informed prior to purchase if pets are likely to exhibit aggressive or stressed behaviors, especially when exposed to humans and multispecies assemblages (Bush et al. 2014). For example, Tokay geckos (*Gekko gecko*) are prevalent in the pet trade because their coloration makes them attractive to pet owners who may be unaware that they are also aggressive, territorial, and have strong bites (O'Shea and Kaiser 2020), which makes them challenging to handle and keep. Tokay geckos are an excellent example of an animal that novice, ill-informed pet owners may regret purchasing, especially if they subsequently learn that Tokay geckos imported into the US pet trade carry antibiotic-resistant bacteria and pose a public health concern (Casey et al. 2015). Selective breeding practices that generate animals with unusual coloration or morphological traits, but also increase the risk of inbreeding depression and disease, further increase the risk that ill-informed pet owners who are attracted by animals' appearance will release their pets, especially if owners are unable or unwilling to pay necessary veterinary expenses (Pasmans et al. 2017). Exotic pet owners should thus be informed about potential genetic or disease risks associated with exotic pets, to reduce the likelihood that they will purchase these pets if they are unwilling to provide appropriate veterinary care (Moorhouse et al. 2017). This is particularly important, since only 24.1% of respondents were provided with information on additional costs of care (i.e., equipment and veterinary costs) for exotic pets.

Consistent with studies on invasive species that have been introduced through the pet trade, we found that exotic pet owners preferred species that do not reach a large adult size and that have an average life expectancy, unless they are purchasing insects or arachnids (van Wilgen et al. 2010; Toomes et al. 2022). Although most pet owners (56.1%) tended to be neutral about purchasing a pet that breeds easily, 17.4% of pet owners disliked this trait. Our findings suggest that if pet owners are uninformed or misinformed about the adult size, longevity, and fecundity of the species they have purchased they may release their pets. This is important because amphibians and reptiles traded as exotic pets tend to have relatively high reproductive rates and long reproductive lifespans (Toomes et al. 2022; Street et al. 2023). Yet, less than half of respondents had been provided with information on the adult size (47.0%) and life span (44.3%) of their current exotic pets at the time of purchase. We also found that pet owners prefer lower-priced exotic pets, which would reinforce the supply of lower-priced, abundant species. Thirty-six percent of respondents who owned the type of exotic pet they selected in our survey had obtained the pet for free or had purchased a cheap pet. Our findings support speculation by ecologists that the introduction bias in exotic pets towards highly fecund species is attributable to the lower cost and higher income from breeding these prolific species, and deliberate release by pet owners who are unable or unwilling to care for multiple offspring (Street et al. 2023).

Interestingly, the likelihood that respondents would purchase an exotic pet was positively correlated with the price they paid for a pet in the same taxa. This suggests that pet owners who have purchased more valuable pets are more likely to acquire another pet of the same taxa. Typically, rare, scarce, or illegally traded species are sold at higher prices (Morgan and Chng 2018; Altherr and Lameter 2020), which suggests that if respondents have purchased scarce species then they may be more likely to acquire additional exotic pets for their collection. However, although 45.1% of respondents valued rarity in exotic pets, respondents' interest in rarity did not increase the likelihood that they would purchase any of the exotic pets included in our survey. Respondents indicated that they were more concerned about whether pets were captive bred (69.1% of respondents viewed this trait positively) or wild-caught (71.7% of respondents viewed this trait negatively). However, we also found no correlation between respondents' preference for captive-bred species and their choice of whether to purchase a pet. Admittedly, we did not include rarity, whether pets were wild caught or captive bred, or the legality of owning species in our choice experiments because including these attributes would have greatly increased the cognitive burden of the survey. Nonetheless, our results suggest that exotic pet owners prefer that the pet trade does not impact wild populations. Importantly, only 43.4% of respondents were given information about whether their current exotic pets were captive bred. Pet owners should be made aware of how pets are sourced, even if statements about conservation do not directly influence pet owners' intention to purchase an exotic pet (Moorhouse et al. 2017).

Given that respondents were provided with incomplete or no information by sellers about pets' traits, diet, and cost of care when purchasing exotic pets, it is concerning that less than 10% of respondents had been provided with information on how to find a new home for their pet if they could no longer care for it. Incomplete information provided to respondents when they acquired their exotic pets reinforces concerns about pet owners' lack of understanding of the traits and husbandry needs of these animals. Regardless of their level of experience, exotic pet owners should be provided with baseline information on the behavior, adult size, lifespan, fecundity, diet, and expected veterinary and husbandry costs for exotic pets prior to purchase. Apart from providing clear information about pets' husbandry needs, pet owners should also be provided with clear information on how much social interaction and physical activity pets need

(Bush et al. 2014; Burghardt 2017; Warwick et al. 2018). Most respondents (87.6%) looked up additional information on their pets and how to care for them after they had purchased these animals. It is notable that respondents had predominantly relied on online searches and forums, rather than contacting pet stores or pet breeders and hobbyists. This may suggest that respondents did not trust sellers to provide additional, necessary information on exotic pets, especially since respondents rated the information they had received as average. However, researchers have cautioned that poor animal husbandry is compounded by inaccurate, incomplete, and poor-quality information from online searches (Pasmans et al. 2017; Warwick et al. 2018). This reinforces our suggestion that baseline information or improved education and outreach for exotic pet owners is required to prevent them acquiring and releasing undesirable pets. Pasmans et al. (2017) suggested that pet keeper education could be implemented, which would include a system of certification before individuals may acquire exotic pets. Zoological societies could assist in the design and implementation of pet keeper education programs.

Conclusion

Our study provides insights into which species are likely to be attractive to uninformed pet owners, but which will ultimately become undesirable because of behavioral traits, size, or longevity. Our results suggest that certification systems that provide critical information on exotic pets' behaviors, adult size, longevity, fecundity, and husbandry needs should be implemented to prevent pet owners acquiring animals that they will abandon (Hausmann et al. 2023). Importantly, these certification systems must be adopted by both commercial pet sellers and private breeders (Hausmann et al. 2023). Actively engaging the exotic pet trade in the design and implementation of this certification system is important to ensure widespread adoption. The alternative is to ban trade in species that pose substantial risks. However, we caution that bans can generate illegal trade (Rivalan et al. 2007), and are unlikely to be effective if species are already in the pet trade (Patoka et al. 2018). People may release pets if they are no longer legal to own (Patoka et al. 2018). Rather, our results can be used to identify which species are likely to be purchased and released (e.g., colorful and aggressive Tokay geckos), in order to help inform approved lists of pet species that are unlikely to pose invasion and disease risks.

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Supplementary material 1

Additional results for reference by readers and the reviewers

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Data type: docx

Explanation note: **table S1.** Choice sets for each of the survey versions based on the D optimal design. **table S2.** Effects coding for the attribute l evels. **table S3.** Demographic characteristics of survey respondents (n = 1,055). **table S4.** Respondent's pet ownership, and how they acquired their current exotic pets (n = 1,055). **table S5.** Respondents' choice of which exotic pet they would purchase next, and the number of respondents who already owned this type of pet (n = 1,055). **table S6.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet snakes, and the price they paid for their previous pet snake (n = 184). **table S7.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet lizards/chameleons, and the price they paid for their previous pet lizard/chameleon (n = 202). **table S8.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet turtles, and the price they paid for their previous pet turtle (n = 130). **table S9.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet tortoises, and the price they paid for their previous pet tortoise (n = 114). **table S10.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet frogs/toads, and the price they paid for their previous pet frog/toad (n = 98). **table S11.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet salamanders, and the price they paid for their previous pet salamander (n = 75). **table S12.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet insects/arachnids, and the price they paid for their previous pet insect/arachnid (n = 89). **table S13.** Respondent's stated preferences for the appearance, size, longevity, and behavior of pet fish, and the price they paid for their previous pet fish (n = 163). **table S14.** Responses to the question: 'Please indicate how the following traits would influence your decision to acquire [an exotic] pet.' **table S15.** Information that respondents obtained prior to acquiring an exotic pet (n = 1,055). **table S16.** Responses to the question: 'Since acquiring your [exotic] pet(s), have you looked up any additional information on the species or how to care for the animal?' (n = 1,055).

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