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Naturafl area vfisfitors' wfiflflfingness to pay for amphfibfian conservatfion fin a gflobafl bfiodfiversfity hotspot

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A R T I C L E I N F O

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Protected areas
Dfisturbance
Dfisease
Donatfion
Smoky mountafin

A B S T R A C T

Transfer of harmfufl pathogens from fimported pet anfimafls to naturafl popuflatfions of wfifldflfife fis a new chaflflenge fin protected area management. Understandfing vfisfitors' preferences for, and vaflue they pflace on, protectfing bfiodfiversfity from such dfisturbances fis fimportant fin deveflopfing effectfive management finterventfions. By conductfing a vfisfitor survey at two naturafl areas fin the Southern Appaflachfian regfion of the Unfited States, a gflobafl hotspot of amphfibfian bfiodfiversfity, thfis study examfined naturafl area vfisfitors' wfiflflfingness to pay (WTP) to conserve wfifld amphfibfian popuflatfions under two dfifferent assumptfions for the dfistrfibutfion of WTP – normafl and flog-transformed. Resuflts from the retafined modefl assumfing a normafl dfistrfibutfion for WTP showed that vfisfitors were wfiflflfing to pay US$10.55 (95% CI US$9.61—US$11.50) per vfisfit fin donatfion to ensure the persfistence of heaflthy amphfibfian popuflatfions. Determfinants of findfivfiduafl WTP under both modefl specfiffiicatfions fincfluded the percefived threat to amphfibfians from pathogen transmfissfion fin naturafl areas they vfisfit, thefir seflf-assessed famfiflfiarfity wfith generafl knowfledge about amphfibfians, the flevefl of fimportance they pflaced on the beneffits to humans from amphfibfian bfiodfiversfity, and annuafl househofld fincome. These ffindfings are usefufl fin understandfing the economfic vaflue of amphfibfian dfiversfity to naturafl area vfisfitors, and fin assessfing the vfiabfiflfity of a vfisfitor-supported mechanfism to fund projects mfitfigatfing anthropogenfic threats to amphfibfian bfiodfiversfity.

1. Introduction

Increasfing urbanfizatfion and growth fin human popuflatfions have resuflted fin fincreased human-wfifldflfife finteractfion fin naturafl areas. Even though naturafl areas such as natfionafl parks and reserves are set asfide for the protectfion of natfive bfiodfiversfity, frequent finteractfion wfith human popuflatfions can flead to enormous anthropogenfic pressures on the wfifldflfife therefin. Human-finduced ffires, finvasfive specfies, and poflflutfion (e.g., afir, water) have flong fimpacted bfiodfiversfity fin naturafl areas (Dodd, 2002; Caruso and Lfips, 2013; Wfiflson, 2014; Brahney et afl., 2020) but transfer of pathogens from vfisfitors to naturafl popuflatfions of wfifldflfife has emerged as a new threat fin many flandscapes that harbor gflobaflfly sfignfifficant bfiodfiversfity (Ffisher and Garner, 2007).

The centrafl and southern sectfions of the Unfited States' Appaflachfian Mountafin chafin have been fidentfiffied as a gflobafl hotspot of amphfibfian bfiodfiversfity (Dodd, 2003). The Smoky Mountafin regfion of the Appaflachfians, fin partficuflar, possesses an extraordfinarfifly hfigh dfiversfity of amphfibfians wfith 31 specfies of saflamanders and 14 specfies of frogs and toads (Dodd, 2004) known to occur finsfide the boundarfies of the Great Smoky Mountafins Natfionafl Park (GSMNP). Studfies have reveafled sfignfifficant decflfines fin saflamander popuflatfions fin GSMNP sfince the 1970 s (Dodd, 2004; Caruso and Lfips, 2013), the hypothesfized resuflt of mufltfipfle human finduced stressors fincfludfing fintroductfion of exotfic pathogens, afir poflflutfion, cflfimate change, and hfigh vfisfitatfion (Dodd, 2003; Caruso and Lfips, 2013; Sutton et afl., 2015).

Evfidence suggests decflfines fin saflamander popuflatfions fin GSMNP may be partfiaflfly attrfibutabfle to the fintroductfion of dfiseases known spread through the flfive anfimafl trade, fincfludfing ranavfirafl dfisease (*Rv*) and chytrfidfiomycosfis (Daszak et afl., 2006; Ffisher and Garner, 2007; Pficco and Coflflfins, 2008). These dfiseases can spfiflfl over from captfive to wfifld popuflatfions of amphfibfians vfia severafl human-medfiated pathways (e.g., the reflease or fintroductfion of contamfinated anfimafls or fomfites) (Peefl et afl., 2012) and have been assocfiated wfith dfie-offs of amphfibfian popuflatfions around the worfld (Berger et afl., 1999; Lfips et afl., 2006;

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Skerratt et al., 2007). The potential for human mediated spread and transmission of *Rv* and chytridiomycosis within and among amphibian populations is well established (e.g., Mutschmann et al., 2000; Raverty and Reynolds, 2001; Mazzoni, 2003; Hanselmann et al., 2004; Jancovich et al., 2005; Phillott et al., 2010).

Outdoor recreation and tourism, in particular, are believed to be major contributors to the movement and introduction of exotic pathogens in natural areas (Anderson et al., 2015) and sources of a multitude of stressors known to impact sensitive amphibian populations (Dodd, 2003). Trends in the US suggest that interest in nature-based recreation and visitation to natural areas continues to grow (Cordell, 2008). Indeed, during the period 2011–2021, annual visitation at GSMNP increased 57 % from 9 million to over 14 million, suggesting stressors impacting the parks' amphibian populations will likely continue to intensify.

The precipitous global declines in amphibian populations are concerning because humans benefit from amphibian biodiversity in a multitude of ways. Amphibians help support the stability and resilience of ecosystems via energy and food web dynamics including regulation of insect populations considered agricultural pests and vectors for disease, and by serving as a source of prey for numerous predatory species (Dodd, 2004). Amphibians are also important indicators of biodiversity and ecosystem integrity (Welsh et al., 2001), are vital to the production of numerous medicines and pharmaceutical products (Ozturk et al., 2020) and hold cultural or religious significance to some people (West, 2018). Conserving GSMNP's amphibian populations is critical to the continued provision of these benefits, global amphibian biodiversity and furthering our understanding of the causes of, and solutions to, global amphibian declines.

Individuals have been shown to derive utility from protecting wildlife, despite not using the resource at all (e.g., Stevens et al., 1991). The existence of indirect-use values for wildlife can have significant implications for natural area managers, as it suggests visitors may care about these species and assign value to the benefits they provide to society (Barde and Pearce, 1991; Tisdell,1991; Arnberger et al., 2012; Dhakal et al., 2012). As growth in visitation to GSMNP continues and pressure on sensitive amphibian populations intensifies, financial contributions from visitors may be one way to fund amphibian conservation in the Smoky Mountain region. In an effort to understand the economic value they place on species, previous studies have estimated individual willingness to pay (WTP) for biodiversity (e.g. Christie et al., 2006; Bhat and Soffi, 2021) and the conservation of individual species (e.g., Bowker and Stoll, 1988; Bednar-Friedl et al., 2009; Zambrano-Monserrate, 2020), including an endangered frog in a global amphibian biodiversity hotspot (Cerda and Losada, 2013). However, our current understanding of the value visitors place on amphibian biodiversity and their WTP in conserving amphibians at the globally significant hotspots like GSMNP is limited. The specific research questions addressed in this study is how much do protected area visitors know and care about the threats to natural populations of wild amphibians in the areas they visit and whether and how much are they willing to pay towards establishing a public fund to conserve amphibian conservation (Teisl and O'Brien, 2003). To fill this gap in knowledge, the specific objectives of this study are to: 1) estimate natural area visitors' WTP to support amphibian conservation in the Smoky Mountain region of the United States, and 2) understand whether and how psychological constructs including knowledge and values related to amphibians, perception of threats, and sociodemographic factors influence visitor WTP. The novelty of this study lies in the fact that while substantial literature exists in visitor preferences of and willingness to pay for recreational access (e.g., Clara et al., 2018), visitor services (e.g., interpretative services, facilities) and biodiversity in general (e.g., Bhat and Soffi, 2021), this is the first study to utilize a non-market valuation method to specifically quantify the non-market value of amphibian populations in terms of visitor willing-ness to pay. In the next section, we discuss the study methods, including the survey sites, survey design and administration, measurement of variables and regression model, followed by the results of the study, discussion of their implications and conclusions from the study.

2. Methods

2.1. Study sites

Data needed in this study was collected using an on-site survey of visitors at two natural areas - Great Smoky Mountains National Park (GSMNP) and Highlands Biological Station - in the Southern Appalachian region in the United States, widely recognized as a global hotspot of amphibian biodiversity. Encompassing over 2,000 sq km of forests along the North Carolina – Tennessee border, the first site (GSMNP) possesses a high diversity of amphibians (31 species of salamanders and 13 frog species) and has been designated both an International Biosphere Reserve and United Nations World Heritage Site (Dodd 2003; National Park Service, 2022a; Fig. 1). The GSMNP is one of the largest protected areas in the eastern US but faces tremendous anthropogenic pressure because of it being the nation's most visited (over 14 million visitors in 2021) national park (National Park Service 2022). Ecological threats facing GSMNP include occasional wildfire, a host of invasive species in the form of insects, pathogens, mammals, fish and plants, air pollution and the impacts of climate change (NPS 2022a). The second site, Highland Biological Station (HBS), is a 9.3 ha campus of Western Carolina University dedicated to supporting regionally focused outdoor education and research. Located in the Blue Ridge Mountains in an area noted for the diversity of its plant and animal life (Ricketts et al., 1999), the HBS nature center and botanical garden are popular destinations for day visitors primarily from the surrounding communities.

2.2. Survey design and administration

The one-page front-and-back survey questionnaire contained questions regarding familiarity with, and importance of, various aspects of amphibians and amphibian biodiversity, perceptions regarding pathogen threats, WTP for amphibian conservation and socio-demographic characteristics. The anonymous and voluntary survey instrument and protocols were approved by the University of Tennessee's Institutional Review Board for human subjects' research (Approval#: UTK IRB-21-06428-XM). A Scientific Research and Collecting Permit was obtained from the US National Park Service, and HBS on-site permission was obtained from Western Carolina University. The in-person survey was administered from mid-June to mid-September 2021 at three locations in the GSMNP (Clingman's Dome, Sugarlands Visitor Center and Oconaluftee Visitor Center) and at the HBS in Highlands, NC. Exiting visitors were requested to complete and return the survey onsite. Participants were given a small incentive (e.g., drink koozie, sunglass straps printed with the "Smoky Mountains" and a sketch of the mountains). Because this was an in-person, on-site survey, two potential limitations should be noted. First, since survey questionnaires were completed on site, some respondents may have been reluctant to skip questions they otherwise would have had no surveyor been in the proximity and, therefore, may not have provided truthful responses. We consider this to be a minor concern, however, as our survey referred only to a voluntary donation mechanism to support amphibian conservation and did not involve not any type of binding policy or regulation proposals in the questionnaire. Additionally, we did not conduct the survey in the format of an interview whereby the surveyor transcribes respondents' verbal responses; rather respondents were given the freedom to complete the questionnaires on their own and return them to claim their incentive regardless of whether, or how many, questions were skipped. The second potential limitation is that individuals who make frequent visits to the survey sites may have ended up having a higher probability of being included in the survey sample; however we have accounted for any potential endogenous stratification (e.g., avidity bias) as noted in the discussion of the regression model (Section 2.4). During the 14-week survey duration,

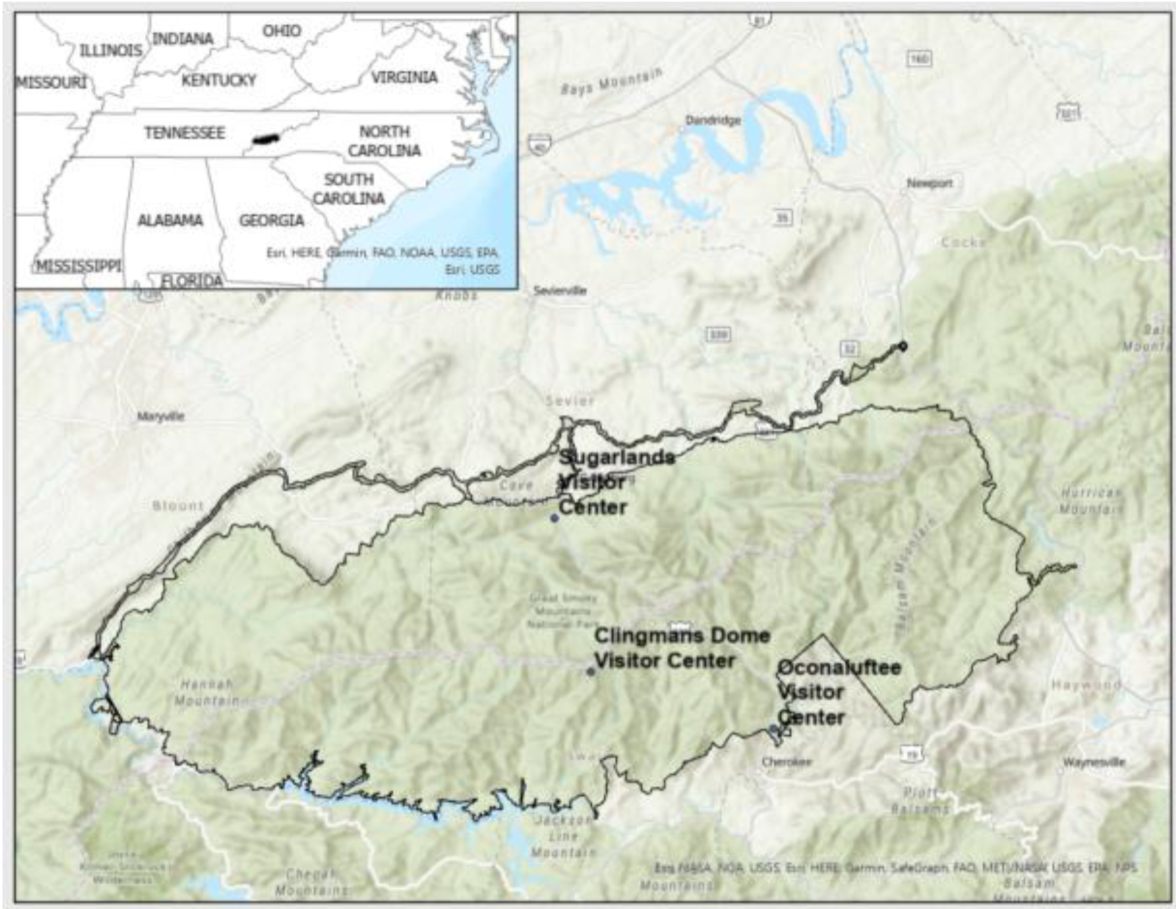

Fig. 1. Survey locations in Great Smoky Mountains National Park.

1,494 visitors completed the survey.

2.3. Measurement of variables

Respondents' self-assessed familiarity with amphibians was measured on a 3-point ordinal scale of familiarity (1-Not at all familiar, 3- Very familiar) with the question "Before reading this survey, how familiar were you with the following aspects of amphibians?" The aspects included general knowledge of amphibians (*Knowledge*), role of amphibians in the environment, benefits of amphibians to humans, and status/trends of amphibian populations. The importance of amphibian biodiversity was elicited on a five-point Likert scale of importance (1- Not important, 5- Extremely important) with the question "How important or unimportant are the following aspects of amphibian biodiversity to you?"; aspects included environmental benefits, scientific and educational value, controlling harmful insects, aesthetic value, cultural or religious significance, and medical/pharmaceutical value. The extent to which visitors engage in amphibian-related activities (*Engage*) was elicited with the question "While visiting natural areas, how often do you in engage in amphibian-related activities (e.g., searching, viewing, learning, photographing)?; possible responses included never, sometimes, frequently and regularly. Respondents' perceptions with respect to amphibian pathogen threats (*Threat*) were elicited with the statement "Transmission of pathogens to amphibians is a serious threat in natural areas I often visit." and rated on a five-point Likert scale of agreement (1 Strongly disagree 5 Strongly agree). Whether respondents had ever seen an amphibian pet released into a natural area (*Release*) was also elicited.

We hypothesized the existence of one latent variable underlying the importance of amphibian biodiversity to respondents. A factor (*Benefit*) representing the hypothesized latent variable was extracted from the six aspects of biodiversity using factor analysis, the principal-factor method, orthogonal rotation (DiStefano et al., 2009). For inclusion as an explanatory variable in our WTP model, we predicted a regression score for *Benefit* using a least squares regression approach (Thurstone, 1935) in which the regression equation independent variable is the standardized observed value of the item (i.e., respondent response) in the estimated factor (DiStefano et al., 2009). We assessed the sampling adequacy and suitability of our data for factor analysis using the Kaiser-Meyer-Olkin (KMO) test, which indicates the proportion of variance in the variables that might be caused by the underlying factor; the higher the KMO value, the more the variables share in common (Kaiser, 1974). Respondents were asked to indicate their maximum per-natural-area-visit WTP to support amphibian conservation from 17 presented values $USD (0, 1, 2, 3, 5, 7, 9, 12, 15, 20, 25, 30, 40, 50, 75, 100, >100) in a payment card (PC) format. Payment amounts were determined based on a review of similar studies examining the public's WTP for biodiversity conservation (e.g., Martín-Lopez et al., 2008). The PC method of valuation elicitation assumes that respondents select the alternative that they believe will maximize their utility. Before respondents were asked to indicate the per trip amount ($USD) they were willing to donate toward amphibian conservation, they were asked to read following script.

"Recent data suggest that if pathogens that move globally through trade are not contained, many species of amphibians in natural areas like the Smoky Mountains could be infected and disappear within the next few decades. Suppose that a non-profit fund for amphibian conservation has to be established with voluntary donations from visitors like yourself to protect amphibian populations from diseases.

Assuming this donation is per-trip and additional to your regular trip costs and would be used exclusively to ensure the persistence of healthy amphibian populations in natural areas you visit, please indicate the maximum you are willing to pay per trip to this fund."

The PC approach to eliciting WTP (Mitchell and Carson, 1981; 1984) provides information on the interval containing a respondent's per trip donation; the selected WTP value is assumed to represent the lower bound on each respondent's WTP ($\$B_{L_i}$) with the upper bound ($\$B_{U_i}$) defined as US\$0.01 less than the next highest payment card value. For example, the selection of US\$20 implies that true WTP is between US\$20 and US\$24.99. Respondents' true willingness to pay, $\$B_i$, was modeled using interval regression, where the upper and lower bounds on each interval serve as the dependent variable (Cameron and Huppert, 1989; Haab and McConnell, 2002; Ando and Reeser, 2022). Finally, questions were included in the survey questionnaire to elicit respondents' demographic characteristics, including annual household income (*Income*), gender (*Female*) and age (*Age*).

2.4. Regression model

Past studies analyzing visitor behavior have used utility theoretic demand models to estimate willingness to pay for biodiversity conservation (Martín-López et al.,2007; Wang and Jia, 2012), protected areas (Zydroń et al., 2021) and species conservation (Bowker and Stoll, 1988; Bednar-Friedl et al., 2009; Kaffashi et al., 2015; Mzek et al., 2022). The basic notion is that an individual facing an income constraint makes a choice to spend their budget based on the alternative that will maximize their utility. Accordingly, an individual will likely pay more for a good or service (e.g. protection of amphibian biodiversity) if the expected benefit from it exceeds the cost. The mean willingness to pay is then estimated in a regression model where the decision to pay a given amount for a good or service (i.e. protection amphibian biodiversity) is modeled as a function of income, demographic characteristics, knowledge, values and perception of threats.

The indirect utility functions (v) contained in Eq. 1 are used to derive the measure of compensating welfare (c) necessary to equate visitors' utility with and without protection of amphibian biodiversity; c represents how much the natural area visitor would be willing to pay for amphibian conservation Q^1 at price vector p^1 to achieve the same level of utility as they would have without protection of amphibian biodiversity (p^0, Q^0) (Boyle, 2011; Haab and McConnel 2002):

$$v(p^0, Q^0, y) = v(p^1, Q^1, y - c) \tag{1}$$

Relying on an efficient maximum likelihood interval regression technique developed by Cameron and Huppert (1989) and following Ando and Reeser (2022), individual WTP values can be estimated as

$$c_i = z_i'\beta + u_i \tag{2}$$

where c_i represents WTP for respondent i, u_i is the random error term with mean zero and standard deviation σ, z_i' is a vector of independent variables that explain response variation, and β is the vector of coefficients. Because of the payment card elicitation format, rather than directly observing c_i, we observe the interval in which it lies. The probability that a respondent's true WTP falls between the interval chosen by respondent i is given as

$$Pr\{c_i \subseteq (\$B_{li}, \$B_{u_i})\} = Pr\left[\frac{\$B_{li} - z_i'\beta}{\sigma} < t_i < \frac{\$B_{lu} - z_i'\beta}{\sigma}\right] \tag{3}$$

where t_i is the standard normal variable, $\$B_{li}$ and $\$B_{u_i}$ represent the lower and upper bounds, respectively, of the interval containing c_i and $z_i'\beta$ is the function representing the solution to Eq. 1, which defines the value being estimated (Boyle, 2011; Ando and Reeser, 2022).

Following Ando and Reeser (2022), we specified two interval regression models. The first was a linear model that assumed c_i to be normally distributed and used the actual dollar values of the interval bounds (Normal model) as the dependent variables. In the normal model, and mean WTP is estimated as $E[c] = z'\beta$. The second specification (Log Model) assumed WTP to be log-normally distributed; with the log model, mean WTP is estimated by taking the natural log transformation of the upper and lower bounds ($\$B_{li}$ $\$B_{ui}$) (Cameron and Huppert, 1989) and is found as

$$E[c] = \exp(z'\beta)\exp\left(\frac{\sigma^2}{2}\right) \tag{4}$$

Using the variables described above, we evaluated and compared the results of the four interval regression model specifications using both the normal and log distributions for WTP. Model 1 contained *Threat*, *Knowledge*, *Benefit*, *Engage* and *Release* as explanatory variables, Model 2 contained demographic variables *Income*, *Age*, and *Female* in addition to the variables evaluated in models 1. We hypothesized that *Threat*, *Knowledge*, *Benefit, Engage* and *Income* would be significantly and positively associated with WTP for amphibian conservation. We had no *a priori* expectations of whether and how *Age*, *Gender,* or *Release* would relate to WTP.

To overcome of the issue of endogenous stratification (i.e. potential of avidity bias), we used the inverse of each respondent's reported number of visits to the survey area in the previous 12 months as a regression weight (Martínez-Espiñeira and Amoako-Tuffour, 2008; Chapagain et al., 2021). We considered a result statistically significant if $p \leq 0.10$.

3. Results

Of 1,494 respondents that completed the survey, the average age reported was 46 years, and 55 % were female (Table 1). For the estimated population of 15 million annual visitors at the GSMNP and the HBS combined, this sample size is sufficient with 95 % confidence interval and 5 % margin of error (Vaske, 2019). In terms of familiarity with amphibians, only 13 % reported being very familiar with general knowledge about amphibians but another 67 % of respondents reported being slightly familiar. The remaining 20 % reported being unfamiliar. In terms of the perception of threats to amphibians, 30 % of respondents strongly agreed that transmission of pathogens is a serious threat in the natural areas they often visit, 28 % slightly agreed, and 36 % neither agreed nor disagreed; only 6 % disagreed. Over half (55 %) of respondents indicated they sometimes engage in amphibian-related activities (e.g., searching, viewing, learning, photographing) when visiting natural areas, while 16 % and 5 % reported they do so frequently and regularly, respectively; Nearly a quarter (24 %) indicated they never engage with amphibians when visiting natural areas. Only 15 % of respondents indicated they had seen a pet amphibian released into a natural area, the remainder had not. When asked to rate the importance of various aspects of amphibian biodiversity, 84 % of respondents reported controlling harmful insects as "very" or "extremely" important, 76 % of respondents reported scientific and educational value as "very" or "extremely" important, and 70 % reported environmental benefits as "very" or "extremely" important (Fig. 2). Over half (55 %) of respondents reported medicinal/pharmaceutical values as "very" or "extremely" important, 48 % reported aesthetic values as "very" or "extremely important" and only 30 % of respondents reported cultural or religious significance as "very" or "extremely" important. Of those that responded to the WTP question, 80 % indicated they would be willing to donate at least US\$1 per natural area visit to support amphibian conservation; 31 % indicated they would be willing to donate \$5 per visit, and 9 % indicated they were willing to donate \$20 per visit (Table 2).

Table 1
Descrfiptfion of varfiabfles used fin predfictfing protected-area vfisfitor wfiflflfingness to pay to support amphfibfian conservatfion.

Variable	Description	*n*	Mean
Dependent variables (Normal Model)			
Lower bound	Amount ($USD) representfing the flower bound on each respondent's wfiflflfingness to pay	1,418	9.42
Upper bound	Amount ($USD) representfing the upper bound on each respondent's wfiflflfingness to pay	1,410	11.93
Dependent variables (Log Model)			
Log Lower bound	Amount ($USD) representfing the flog-transformed flower bound on each respondent's wfiflflfingness to pay	1,418	1.50
Log Upper bound	Amount ($USD) representfing the flog-transformed upper bound on each respondent's wfiflflfingness to pay	1,410	1.77
Independent variables			
*Threat**	Varfiabfle reflectfing the flevefl of agreement wfith the statement: "Transmfissfion of pathogens to amphfibfians fis a serfious threat fin naturafl areas I often vfisfit."	1,485	3.80
*Knowfledge***	Varfiabfle reflectfing flevefl of famfiflfiarfity fin response to the questfion: "Before readfing thfis survey, how famfiflfiar were you wfith the foflflowfing aspects of amphfibfians? Generafl knowledge about amphfibfians"	1,491	1.93
Benefit	Regressfion score estfimated usfing the extracted factor *Benefit*	1,449	0.00
Engage	Varfiabfle reflectfing the frequency wfith whfich respondents engage wfith amphfibfians whfifle vfisfitfing naturafl areas, where 1 = Never, 2 = Sometfimes, 3 = Frequentfly and 4 = Reguflarfly	1,387	2.03
Reflease	Bfinary varfiabfle reflectfing whether the respondent had seen a pet amphfibfian refleased finto a naturafl area, where 1 = Yes and 0 = No.	1,426	0.14
Age	Contfinuous varfiabfle representfing respondent age	1,480	46.2
Femafle	Bfinary varfiabfle where Femafle = 1, Mafle & Bfinary/non-gender = 0	1,484	0.55
Income	Categorficafl varfiabfle representfing respondent househofld fincome. 1 $25,000 or fless, 2 $25,001—$50,000, 3 $50,001—$75,000, 4 $75,001—$100,000, 5 $100,001—$125,000, 6 $125,001—$150,000, 7 $150,001—$175,000. 8 $175,000 or more.	1,482	4.28

* 1 Strongfly dfisagree – 5 Strongfly agree, **1 Not at afll famfiflfiar – 3 Very famfiflfiar.

3.1. *Factor anaflysfis*

Afll sfix aspects of amphfibfian bfiodfiversfity had flarge posfitfive floadfings on the extracted factor (flabefled *Benefit*) (Tabfle 3). The KMO statfistfics for the sfix varfiabfles ranged from 0.732 to 0.848 wfith an overafll score of 0.804, wefll above the mfinfimum standard for conductfing factor anaflysfis (Kafiser, 1974); the rotated floadfings of the sfix varfiabfles from whfich the factors were extracted exceeded 0.50, whfich fis consfidered an acceptabfle threshofld for determfinfing whether a varfiabfle fis representatfive of the prfimary factor (Howard, 2016).

3.2. *Factors finfluencfing vfisfitor's wfiflflfingness to pay for amphfibfian conservatfion*

Of the mufltfipfle regressfion modefls, AIC scores findficated that Modefl 2 performed better than Modefl 1 fin terms of expflafinfing the factors finfluencfing vfisfitors' wfiflflfingness to pay for amphfibfian conservatfion under both specfifficatfions (Normafl and Log) (Tabfle 4). Mean vfisfitor per-trfip wfiflflfingness to pay was robust between the two Normafl modefls, rangfing from $US 10.40 (95 % CI $US 9.49—$US 11.32; Modefl 1) to

Table 2
Bfid amounts, respondent wfiflflfingness to pay (WTP) and WTP bounds (n = 1,418).

Bid amounts ($USD)	# of respondents WTP	% of respondents WTP	Lower bound	Upper bound
0	282	19.89	0	1
1	111	7.83	1	2
2	90	6.35	2	3
3	60	4.23	3	5
5	438	30.89	5	7
7	19	1.34	7	9
9	33	2.33	9	12
12	66	4.65	12	15
15	70	4.94	15	20
20	128	9.03	20	25
25	45	3.17	25	30
30	5	0.35	30	40
40	6	0.42	40	50
50	41	2.89	50	75
75	4	0.28	75	100
100	12	0.85	100	100
>100	8	0.56	101	+∞

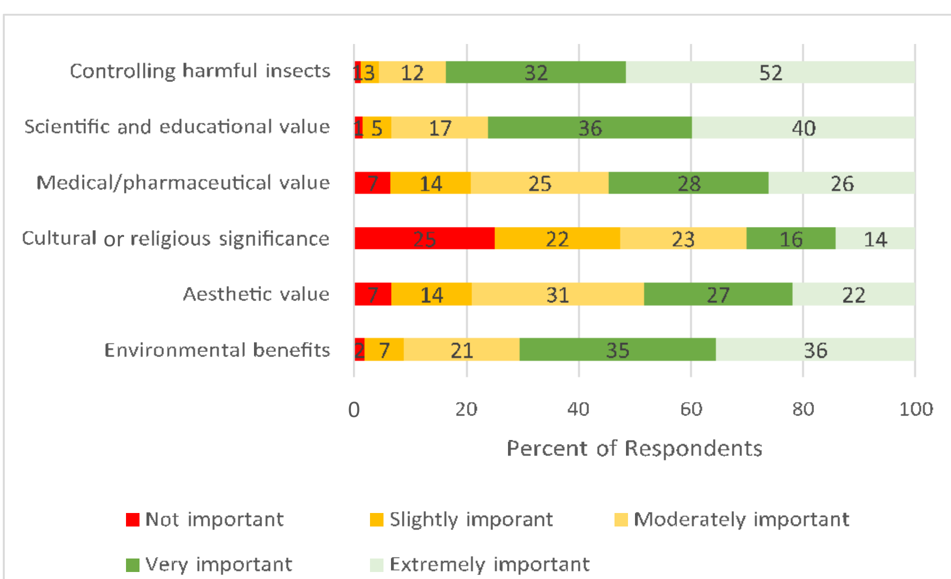

Fig. 2. Importance of varfious aspects of amphfibfian bfiodfiversfity.

Table 3
Factors extracted from survey responses to the question: "How important or unimportant are the following aspects of amphibian biodiversity to you?"*.

Factor	Biodiversity aspect	Mean	Factor Loading	KMO Statistic	Cronbach's alpha
Benefits					
	Environmental benefits	3.95	0.731	0.848	0.799
	Scientific and educational value	4.08	0.801	0.796	0.786
	Controlling harmful insects	4.30	0.663	0.817	0.816
	Cultural or religious significance	2.72	0.574	0.732	0.829
	Aesthetic value	3.43	0.644	0.816	0.814
	Medical/ pharmaceutical value	3.53	0.669	0.806	0.809

* 1 = Not important 5 = Extremely important. Factor loadings derived with factor analysis using the principal-factor method, orthogonal rotation.

Table 4
Regression estimates from alternative models explaining protected area visitors' willingness to pay for amphibian conservation.

	Normal Models		Log Models	
	Model 1	Model 2	Model 1	Model 2
Knowledge and perceptions of threats				
Threat	1.650***	1.437***	0.140***	0.112***
	(0.495)	(0.511)	(0.039)	(0.041)
Knowledge	1.352*	1.339	0.165**	0.158**
	(0.838)	(0.834)	(0.066)	(0.067)
Visitation motivation and behavior				
Benefits	1.238**	1.307**	0.127***	0.136***
	(0.548)	(0.566)	(0.044)	(0.045)
Engage	0.540	0.458	0.042	0.046
	(0.630)	(0.750)	(0.053)	(0.053)
Release	3.002*	2.675*	0.153	0.130
	(1.562)	(1.587)	(0.110)	(0.110)
Socioeconomic variables				
Age		0.023		0.004
		(0.030)		(0.002)
Female		1.552		0.122*
		(0.962)		(0.073)
Income		0.821***		0.107***
		(0.252)		(0.018)
n	1,209	1,123	1,209	1,123
p-value	0.000	0.000	0.000	0.000
Wald chi^2	39.25	55.34	58.25	98.61
AIC	7048.48	6533.96	5086.57	4715.72
ΔAIC	–	514.52	–	370.85
Mean WTP ($US)	10.40	10.55	10.32	10.22

*** $p \le 0.01$, ** $p \le 0.05$, * $p \le 0.10$; Standard error in parentheses.

$US 10.55 (95 % CI $US 9.61—$US 11.50; Model 2). Mean WTP was less robust under the log model specification and ranged from $US 10.33 (95 % CI $US 9.61-—$US 11.04; Model 2) to 10.22 (95 %CI $US 9.50—$US 10.94; Model 1). Considering that the AIC value in Log model (4715.72) was lowest of all 4 models estimated, interpretation of regression results and mean WTP are taken from this model.

As expected, respondents' perceptions regarding the threat of pathogen transmission in natural areas they often visit (*Threat*) was significantly and positively associated with WTP ($p = 0.006$) as was the importance placed on the *Benefit* of amphibian biodiversity ($p = 0.003$) and *Income* ($p < 0.01$), respectively. General *Knowledge* of amphibians was associated with WTP ($p = 0.019$). Contrary to our expectations, *Engage* ($p = 0.381$) was not significantly associated with WTP. In terms of the other demographic characteristics, *Female* was marginally negatively associated with WTP ($p = 0.095$) and (*Age*; $p = 0.116$) was not associated with WTP. Whether respondents had ever witnessed a pet amphibian being released into a natural area (*Release*; $p = 0.092$) was significantly positively associated with WTP in the normal model but not in the log model ($p = 0.238$).

4. Discussion

Visitors to protected natural areas can be a critical source of funding to generate financial support for conservation projects. However, doing so requires understanding whether and how much visitors value resources needing protection and what factors impact their willingness to contribute to their conservation. This study examined the willingness of visitors to natural areas in the southern Appalachian Mountain region of the United States, a global amphibian biodiversity hotspot, to donate money to a hypothetical non-profit amphibian conservation fund. To the authors' knowledge, this study represents the first attempt to estimate the value natural area visitors place on healthy amphibian populations in the Appalachian Mountain region and there are several key takeaways that are important to regional and global amphibian conservation. First, the overwhelming majority of natural area visitors were willing to donate at least $1 per natural area visit to support amphibian conservation with an estimated mean per visitor, per trip, WTP exceeding US $10. In a similar study, Cerda and Losada (2013) found that visitors to a protected area located in a global biodiversity hotspot in central Chile were WTP $8.20 per visit (~US$10.82 in 2022 dollars) for habitat improvements and monitoring to support populations of the endangered endemic Chilean frog (*Calyptocephalella gayi* ...) (Díaz-Paez and Ortíz, 2003). Taken together, these findings confirm protected area visitors assign value to, and are willing to pay to support, healthy amphibian populations; given the GSMNP's annual visitation, they also imply park visitors are a potentially significant source of funding to support regional amphibian conservation. Estimates from this study can be used to approximate the potential economic benefit of projects intended to protect amphibians in natural areas like GSMNP. For example, if only 21 % (i.e., the proportion of respondents that reported frequently or regularly engaging in amphibian-related activities while visiting natural areas) of the 14.1 million annual visitors that visited GSMNP in 2021 contributed $10 (estimated Mean WTP in this study) during at least one visit in the year, this would generate $29 million in financial resources. Moreover, the total benefit realized by the broader population of visitors, including those who only sometimes interact with amphibians or value amphibians without directly engaging with amphibians during the visit, will be many times greater than this. Aggregation of the benefits can be compared with cost of designing and implementing biosecurity measures in the natural areas.

Second, the importance visitors placed collectively on the benefits to humans from amphibian biodiversity were positively associated with WTP. This result sheds light on some of the values underlying visitor WTP and implies outreach and efforts to secure visitor donations to support amphibian conservation emphasize the linkages between healthy wild amphibian populations, the stability of ecosystems and human health and well-being. In a similar study, Christie et al. (2006) found that individuals valued ecosystems that had a direct impact on humans more than those which did not directly affect humans, whereas only forty-two percent of participants in the Cerda and Losada (2013) study cited direct use values, including that the Chilean frog is important for science and ecosystem functioning, as a motivation for their WTP; fifty-eight percent cited an existence value motivation and belief that the Chilean frog has the right to exist independent of any direct-use values derived by humans.

Third, visitors' familiarity with general knowledge of amphibians and perceptions regarding the severity of the threat of pathogen transmission in the natural areas they often visit were positively associated with WTP in at least one of the two model specifications. This is consistent with previous studies that have found a positive correlation between familiarity with a species and WTP for its conservation (e.g., Christie et al., 2006; Martín-López et al., 2007) and the degree of endangerment of wildlife species and individual WTP for their conservatfion (e.g., Tkac, 1998; Tfisdeflfl et afl., 2007). Thfis resuflt suggests the effectfiveness of communficatfion and outreach afimed at cufltfivatfing donor support may be enhanced through fincflusfion of generafl finformatfion about amphfibfians, thefir ecoflogficafl fimportance and the threats to regfionafl and gflobafl popuflatfions from fintroduced pathogens and dfiseases flfike chytrfidfiomycosfis and ranavfirafl dfisease.

Lastfly, the effect of demographfic characterfistfics on WTP was mfixed. Unsurprfisfingfly, fincome was sfignfifficantfly posfitfivefly assocfiated wfith WTP, whfich fis consfistent wfith the fidea that the envfironment fis a normafl, or perhaps fluxury, good to whfich findfivfiduafls are wfiflflfing to contrfibute more as thefir fincome fincreases. Aflthough some studfies have found women report stronger envfironmentafl attfitudes and behavfiors than men (e.g. Zeflezny et afl., 2000; Hunter et afl., 2004), gender dfifferences fin envfironmentafl fintentfions and behavfiors are finconsfistent fin the flfiterature (Whfite et afl., 2001; Cerda et afl., 2012; Mzek et afl., 2020). Evfidence suggests the charfisma of specfies (Metrfick and Wefitzman, 1996) and thefir percefived endangerment (Tfisdeflfl et afl., 2004), for exampfle, may finfluence the fimpact of gender on WTP for thefir conservatfion.

The reflatfionshfip between the respondent age and wfiflflfingness to pay was not sfignfifficant under efither modefl specfifficatfion fin our study. The effects of age on WTP for conservatfion are mfixed fin the flfiterature wfith some studfies concfludfing that as age fincreases, the odds of WTP fincrease (Bhandarfi and Heshmatfi, 2010; Gordfiflflo et afl., 2019) whereas others reportfing the opposfite to be true (Martín-Lо́pez; Reynfisdottfir et afl., 2008).

Wfith over 10 mfiflflfion peopfle consfistentfly vfisfitfing the GSMNP fin 2021, the resuflts of thfis study suggest the economfic vaflue assocfiated wfith regfionafl amphfibfian conservatfion fis substantfiafl and that vfisfitor donatfions coufld pflay a sfignfifficant rofle fin the conservatfion of the Appaflachfian regfion's wfifld amphfibfian popuflatfions. The fimpflementatfion of mandatory parkfing fees fin the GSMNP fin 2023, and concomfitant estabflfishment of onflfine and onsfite venues for thefir payment, may resuflt fin new opportunfitfies to engage wfith prospectfive vfisfitors regardfing the fimportance of the park's amphfibfian popuflatfions and secure donatfions for thefir support.

5. Conclusion

Wfith human-wfifldflfife finteractfions on the rfise at hfighfly vfisfited naturafl areas, natfive wfifldflfife popuflatfions, fincfludfing amphfibfians, are fincreasfingfly vuflnerabfle to anthropogenfic stressors. As protected area managers are facfing tfighter budget aflflocatfions from flegfisflators, there fis a need to expflore new fundfing streams to support projects combattfing emergfing fissues flfike pathogen transfer, finvasfive specfies, etc. However, dofing so requfires understatfing whether and how much vfisfitors themseflves care about such fissues and are wfiflflfing to pay to support such programs. Ffindfings from thfis study suggest that vfisfitors do care about and pflace vaflue on protectfing naturafl popuflatfions of amphfibfians at protected areas they vfisfit. Further, fit may be feasfibfle to estabflfish vofluntary, user-pafid, donatfion mechanfisms to rafise funds to heflp protect amphfibfian bfiodfiversfity. Such fundfing may be used to desfign and fimpflement bfiosecurfity practfices, fincrease vfisfitor awareness and educatfion regardfing the best practfices (e.g. cfleanfing, dfisfinfectfing statfions) and reguflatfion and enforcement around vuflnerabfle habfitats/popuflatfions. Our ffindfings aflso findficate that fincreasfing vfisfitor awareness of the fimportance and vaflue of amphfibfians and educatfing them on the emergfing threats to bfiodfiversfity may heflp fimprove thefir attfitudes and wfiflflfingness to support conservatfion programs. Even though thfis study was focused on amphfibfians and fin two naturafl areas fin the Southern Appaflachfian regfion, these ffindfings shed flfight on vfisfitor behavfior at protected areas. Conductfing sfimfiflar studfies of protected area vfisfitors' knowfledge, attfitudes and vaflues fin the context of amphfibfian conservatfion fin other protected areas may fincrease the generaflfizabfiflfity of these ffindfings. Moreover, the economfic beneffit estfimated may be used fin future "beneffit transfer" studfies to approxfimate the vaflue of amphfibfian conservatfion programs fin other sfimfiflar protected areas.

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Declaration of Competing Interest

The authors decflare that they have no known competfing ffinancfiafl finterests or personafl reflatfionshfips that coufld have appeared to finfluence the work reported fin thfis paper.

Data availability

The data that has been used fis conffidentfiafl.

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Ethficafl standards

Thfis study was revfiewed and approved by the Unfiversfity of Tennessee's Instfitutfionafl Revfiew Board for human subjects' research (Approvafl#: UTK-IRB-21-06494-XM).

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