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The worth of wildlife: A meta-analysis of global non-market values of threatened species

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Abstract

Clustered robust meta-regression analysis is applied to 109 willingness to pay (WTP) estimates for threatened species from 47 stated-preference studies in 19 countries. Our study updates previous meta-analyses on the topic and tests the effect of important variables not previously considered—species' threat status, use of coloured photographs of species in a survey, and a country's development status, on WTP. We also compared model results obtained from weighting observations by the inverse standard error of WTP and inverse sample size values. Inverse-standard error-weighted model results were more aligned with published research and economic theory and had a better fit than inverse-sample size-weighted model results. Average total present value of WTP was $414/household[1], but variation in reported values was large owing to the survey context. WTP was significantly higher for charismatic and threatened species. Using coloured photographs, or a country's development status did not significantly affect WTP. Average absolute within-sample- and out-of-sample transfer errors were estimated to be 17% and 48%, respectively. One-fourth out-of-sample transfers had an error of 10% or less. We discuss limitations and issues in current literature and propose recommendations that will allow future studies to be used in meta-analyses and benefit transfer.

[1] In 2016 US dollars

Keywords

Choice experiment

Contingent valuation

Endangered species

Species' charisma

Species' endangerment level

1. Introduction

The economic valuation of threatened species can provide valuable information for managers and policy makers to understand the trade-offs involved in prioritising conservation investments. Weighing the benefits and costs of conservation is, however, challenging since societal utility from pure public goods like threatened species is seldom captured in existing markets. Several non-market valuation (NMV) techniques, particularly stated-preference methods[2], have been used to quantify the *anthropocentric* benefits (Loomis and White, 1996) of threatened species. These measured benefits are largely in the form of passive-use values[3], namely, existence and bequest values. Conducting original NMV studies can, however, be expensive, time-consuming and impractical to carry out for each individual species (Richardson and Loomis, 2009). As such, the benefit transfer (BT) technique of extrapolating willingness to pay (WTP) estimates from primary studies to contextually compatible policy sites is seen as a practical and cost-saving alternative (Baker and Ruting, 2014). A meta-regression analysis is a useful BT tool that systematically combines WTP results from several comparable primary studies to estimate statistical models controlled for heterogeneity, methodological differences, and biases among primary studies, which can be applied to calculate values (WTP estimates) adjusted to the characteristics of a policy site (Lindhjem and Navrud, 2008; Richardson and Loomis, 2009; Shrestha and Loomis, 2001).

Existing meta-regression analyses of threatened-species-specific NMV literature (Loomis and White, 1996; Richardson and Loomis, 2009), are, limited in terms of their geographic focus, NMV technique used, the range of species included in the analyses, and the age of the reviews (i.e. the latest of these analyses is a decade old). Both these papers analysed contingent valuation (CV) studies from the United States with the exception of a

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[2] Contingent valuation (CV) and choice experiment (CE) studies.

[3] Spash and Vatn (2006) point out the incorrectness of the commonly used term “non-use” to denote passive-use values stating that “there are no non-use values in economics because all economic value derives from the utility it provides humans.”

single choice experiment (CE) study included in the meta-analysis of Richardson and Loomis (2009). Pandit et al. (2015) reviewed and qualitatively discussed global non-market valuation studies of threatened species, but did not conduct a meta-analysis. There are a few meta-analyses on global WTP for biodiversity conservation. However, they combine disparate valuations making it problematic to value particular species. Specifically, they either include WTP estimates for both species and habitats (wetlands, forests, deserts, agricultural lands etc.), water quality and riparian vegetation, and other biodiversity features in their analyses (Jacobsen and Hanley, 2009; Lindhjem and Tuan, 2012), or they combine disparate studies that value both individual species and groups of species, including threatened plants indistinguishable by type (Saloio, 2008). Additionally, the meta-analysis by Saloio (2008) also included studies focusing solely on use values (hunting and fishing) and policies aimed at indirectly increasing species' populations such as dam removal, in-stream flow etc. The limitations in the scope of the above studies make it difficult for a decision maker seeking non-market values for judgements about conserving threatened species to use models from these analyses to derive WTP estimates.

The primary objective of our paper, therefore, is to address the above limitations by reviewing and conducting a meta-regression analysis of NMV studies of threatened species from around the world published up until 2017, including studies that use both CV and CE survey techniques to identify global determinants of WTP for threatened species. We also test the effect of several potentially-important variables not considered in previous meta-analyses such as a species' threat status, the use of coloured photographs in the survey and a country's development status.

A secondary objective of our paper is to demonstrate the importance of using the correct metric for weighting in a meta-regression model. Weighting the values of the dependent variable (WTP estimates, in our case) ensures that within- and between-study heterogeneity can be separated, and corrects the consequences of differences in sample sizes and other effects (e.g. from the survey format), which can affect the precision of WTP estimates from the various primary studies (Gurevitch et al., 2018; Van Houtven, 2008).

While inverse-variance (or standard error) weighting is recommended and preferred (Gurevitch et al., 2018; Van Houtven, 2008), most meta-analyses (e.g., Bergstrom and Taylor, 2006; Ma et al., 2015; Van Houtven et al., 2017) use inverse-sample-size weighting since most primary studies fail to report the standard error of the WTP estimate. We, therefore, compared results from inverse-standard error-weighted and inverse-sample size weighted clustered robust regression models to determine the effect of the metric used for weighting in this paper. While not a primary objective of this paper, the significance of the weighting metric became apparent to us when conducting our meta-regression analysis. The comparison of different weighting metrics is, therefore, presented here to illustrate the importance of choosing the weighting metric appropriately. This crucial aspect has not been previously examined in the threatened species or biodiversity conservation meta-analysis literature.

We also test the validity and reliability of WTP estimates from our meta-regression model by comparing WTP estimates from our meta-regression model with those from primary NMV studies and discuss the implications of transfer errors from the model estimates.

As a consequence of the review, we also critically examined global NMV studies published to date and discuss common methodological and reporting issues that we found. We propose recommendations for reporting for future NMV studies that will enable them to be used in meta-analyses and benefit transfer.

Our paper is structured as follows: in Section 2 we describe our methodology, including literature search, moderator variables and models used. Section 3 presents model results and discusses the effect of the weighting metric on the regression results. In Section 4 we test the validity and reliability of WTP estimates from our final meta-regression model by estimating within-sample and out-of-sample transfer errors. Finally, we discuss the limitations of our data set and issues in current NMV literature of threatened species, and provide reporting recommendations for future NMV studies.

2. Methodology

We followed reporting guidelines for meta-regression analysis summarised in Nelson and Kennedy (2009) and Stanley et al. (2013). We also followed the specification and estimation guidelines for meta-functions outlined in Bergstrom and Taylor (2006) to ensure the consistency of the economic, welfare change, commodity, and study design variables used in our models.

2.1 Data sources and refinement

We searched online databases EBSCO, JSTOR, ProQuest, Scopus, Web of Science and Google Scholar for relevant NMV literature on threatened species. We also searched the Environmental Valuation Reference Inventory (EVRI) and the US Fish and Wildlife Service Conservation Library. Keywords included in the search were "non-market value" or "non-market valuation" or "non-market benefits" or "economic value" or "economic benefits" or "contingent valuation" or "choice modelling" or "choice experiment" or "conjoint analysis" or "discrete choice" or "willingness to pay" and either "endangered species" or "threatened species". Web of Science produced the greatest number of relevant peer-reviewed studies. Some studies were obtained from citations in other papers as well as from the meta-analyses of Richardson and Loomis (2009) and Saloio (2008). The search was completed on 1 May 2017 and produced 184 primary studies published between 1983 and 2017.

The 184 studies were examined and coded primarily by the first author with assistance from the other authors. Studies focusing on the total economic values of specific animal species with passive use as the dominant value were considered. Studies valuing wildlife or species in general without specifying particular species, studies valuing threatened plants, and studies that grouped different species making it difficult to calculate WTP for individual species, were also excluded. Studies focusing on use values alone (hunting, fishing or viewing) were not included. Studies that did not directly value species but instead valued environmental enhancements that would lead to a gain (or avoiding loss) in species populations were also excluded. Studies valuing gains in species' populations as enhancements to their threat status but not as specific percentages were also excluded from the analysis since it was not clear what benefit the elicited values related to. This data refinement resulted in 47 primary studies and 109 observations of WTP from 19 countries[4] on which the meta-regression was performed. Appendix I presents the characteristics of the studies included in our analysis such as species valued and survey year amongst others, along with the WTP estimates and their standard errors.

2.2 Effect size

The dependent variable, called the effect size in a meta-analysis, standardises findings across studies enabling them to be directly and easily compared (Ma et al., 2015). The effect size in our study is the respondent's (total) WTP for a certain change in the population of a threatened species (% gain/avoid % loss/avoid extinction/maintain) compared to the baseline scenario stated in the survey. Our meta-regression function therefore takes the form:

$$WTP = \sum_k \beta_k M_k \quad (1)$$

where β_k are the coefficients and M_k are the moderator variables.

Since the reported WTP values differ across studies depending on the survey location (country), survey year, and the frequency and duration of the payment, they are standardised, i.e., converted to a common metric to enable comparison. The previous meta-analyses of NMV studies of threatened species used the annual WTP in US dollars as the effect size (Jacobsen and Hanley, 2009; Lindhjem and Tuan, 2012; Loomis and White, 1996; Richardson and Loomis, 2009). We chose to use a total WTP, i.e., a lump sum payment instead of annual to enable us to straightforwardly compare respondents' valuation of the conservation scenario presented to them. The common metric in our study was, therefore,

[4] See Table S.1.in the supplementary data for a distribution of estimates based on country

the total WTP (in 2016 US dollars). It was systematically obtained for each reported estimate using the following steps:

1. Monthly or annual payments over a number of years were converted to the total present value over the proposed duration of payments using a 5% real discount rate[5] as used by Ma et al. (2015).
2. This total present value of WTP in local currency was then converted into US dollars for the survey year using the purchasing power parity (PPP)-adjusted exchange rate for the survey year from the World Bank (2017). The PPP-adjusted exchange rate equalises purchasing power across countries and is, therefore, more appropriate for currency conversion than the financial exchange rate (Ready and Navrud, 2006).
3. The total WTP in survey year US dollars was then inflated to 2016 US dollars using the consumer price index for the US (BLS, 2017).

In the case of choice experiments, we used the reported marginal WTP for the change in species' population being valued and extrapolated it to calculate the total WTP in 2016 US dollars using steps 1 through 3 described above.

2.3 Moderator variables used

The moderator variables included in our analysis (Table 1) were selected after examining our refined database as well as other meta-analyses and were included to provide consistency in study design variables, the commodity being valued, and the welfare change being measured as advocated by Bergstrom and Taylor (2006). These variables account for differences in sample characteristics, species type, the magnitude and type of change in species population being valued, differences in survey method, mode of administration, payment vehicle, and payment duration, among other things.

[5] We explored a range of discount rates for doing this but found that it made no difference to the statistical results. Discount rates used by most developed European countries and the US and Canada are between 3 and 10% (Kazlauskienė, 2015). So we used 5% for all studies with payments that extended over more than one year.

Table 1: Moderator variables used and their summary statistics

Variable	Description	Mean	Standard Deviation	Range
TWTP2016	Total WTP (per household) in 2016 US dollars	414.12	791.94	[1.28 – 4,423.88]
SE2016	Standard error of WTP in 2016 US dollars	34.83	56.408	[0.05 – 304.60]
Sample size	Number of valid survey responses	417	759	[19 – 7,376]
Survey year	Year in which the survey was conducted	2001	7	[1984 - 2012]
Income2016	Sample or national mean of annual household income in 2016 US dollars	45,781	23,131	[3,244 – 109,934]
Developed	Whether the country was developed (=0) or not (=1)	0.11	_	[0 - 1]
Species [a]	Mammal=0 (baseline); Marine mammal or Reptile (turtles) =1; Bird =2; Fish = 3; Other =4	_	_	[0 - 4]
Charisma	If the species is charismatic (=1) or not (= 0)	0.66	_	[0 - 1]
Threat Status [b]	If the species is threatened (=1) or not (=0)	0.50	_	[0 - 1]
Mode of administration	Survey administration format (mail or drop-off =0; in-person or telephone =1; online =2)	–	–	[0 - 2]
Photo [c]	If a coloured photo (=1) was used in the survey or not (=0)	0.50	_	[0 - 1]
Format [d]	DC =0 (baseline); OE =1; PC = 2; CE =3	_	_	[0 - 3]
Payment Vehicle	Tax =0; Donation =1; Fee/Surcharge/Other =2	–	–	[0 - 2]
Payment duration	One-time or Annual up to 5 years =0; Annual ≥ 6 years to perpetuity =1	0.28	_	[0 - 1]
Change	Gain =0; Avoid Loss / Avoid Extinction =1; Maintain =2	–	–	[0 - 2]
Percentage gain	Percentage of population gain presented in the survey	167	297	[10 – 1,900 [e]]

[a] Reptiles included only turtles, and were, therefore, combined with marine mammals.; [b] IUCN threat status used: baseline includes species with threat status of least concern, or data deficient, or not listed or near threatened. Threatened includes species whose threat status is vulnerable, or endangered or critically endangered. ; [b] baseline included surveys that used no photographs or black and white drawings or black and white photographs or those that did not state whether they used photographs or not; [d] DC = dichotomous choice contingent valuation (CV), OE= open-ended CV, PC = payment card CV, CE = choice experiment; [e] The Han et al. (2010) study estimated WTP for an increase from 10 to 200 Korean mountain gorals (*Naemorhedus caudatus*), which gives the percentage of 1,900.

Respondent’s income is often a significant determinant of WTP for biodiversity conservation (e.g., Jacobsen and Hanley (2009)). The effect of sample income on WTP for species was, therefore, controlled by including the mean sample household income as a moderator variable. When the mean sample income was not reported, we first tried to obtain the average income from the geographical location where the survey was conducted, failing which, we used the national mean household income obtained from the country’s government database.

Qualitative evidence from Richardson and Loomis (2012) suggests that a country’s development status influences WTP with households in developing countries willing to pay a higher percentage of their income to conserve nationally symbolic species than those in developed countries. However, in general, we expected households in developing countries to be willing to pay less in absolute terms to conserve species. Therefore, a country’s development status, taken from the World Bank website, was also included as a moderator variable.

The survey year was included to capture possible unobserved advancements in study design, methodology and changes in public attitudes over time towards threatened species (Jacobsen and Hanley, 2009; Loomis and White, 1996).

Species characteristics included as moderator variables were the type/class of animal (mammal, bird, fish, etc.), charisma, and species endangerment level (threat status). Since different countries have different criteria for classifying the threat status of species, we based the threat status of species on their IUCN threat status, which is a global criterion to classify the endangerment level of species. This ensures consistency in comparing species' threat status across countries. However, this also meant that many of the species in our meta-analysis that were threatened in particular countries or regions but not globally threatened under the IUCN criteria ended up being classified under lower threat levels unless they were recognised as being part of small and declining populations in those regions and, therefore, accorded a higher IUCN threat level. Also, some of our species were “data-deficient” according to the IUCN. This resulted in only 50% of the species in our meta-analysis being threatened according to the IUCN (i.e. having a threat status of vulnerable, or endangered or critically endangered) (Table 1). Some studies have found species' charisma to be a significant determinant of WTP (Colleony et al., 2017; Metrick and Weitzman, 1996; Richardson and Loomis, 2009) but not others (Tisdell et al., 2007). Determining the “charismatic” nature of a species is subjective, and there are various definitions of the term (Richardson and Loomis, 2009). However, it is generally agreed that charismatic species are typically large vertebrates (megafauna) that instinctively appeal to humans such as, elephants, pandas, and whales (Metrick and Weitzman, 1996). Species were treated as charismatic if they had been characterized as such in the original study, or elsewhere, for example in other studies, or other publications, including online publications. The IUCN-designated threat status of a species was used to provide an indicator of its endangerment level that is consistent across countries.

We also included moderator variables to measure the effect of the type of change in species’ population being valued—gain, avoid loss, avoid extinction and maintain with the baseline being the population at the time of the survey. We also recorded the magnitude of the percentage benefit (e.g. of gain in population size) in the expectation that greater benefits would result in higher WTP albeit at a lower marginal rate for larger gains (Loomis and White, 1996).

Lastly, we also included variables to account for differences in survey format (single or double-bounded dichotomous choice (DC), open-ended (OE), payment card (PC), choice experiment (CE)), mode of administration (online, mail, drop off, in-person and telephone), payment vehicle (tax, donation, fee and surcharge) and payment duration (one-time, annual). Survey format has been found to be a significant determinant in WTP with DC formats producing significantly higher WTP estimates compared to OE and PC formats (Jacobsen and Hanley, 2009; Reaves et al., 1999; Richardson and Loomis, 2012). Evidence about the effect of survey mode on WTP for non-market goods is mixed, with some studies finding that telephone surveys produce lower WTP values compared to in-person surveys (Maguire, 2009). To capture the diversity amongst studies regarding payment duration–with some having a single payment, and others having multiple annual payments, we included payment duration as a moderator variable as well.

WTP estimates may also be influenced by how realistically a survey questionnaire is presented including the use of photographs in the survey. The influence of photographs, especially colour photographs, on WTP estimates has been unresolved since the Arrow et al. (1993) NOAA Panel Report on contingent valuation (Shr and Ready, 2016). Since then there have been mixed findings of the influence of colour photographs (Labao et al., 2008; Subroy et al., 2018). We tested its effect on WTP by including the use of colour photographs of species in surveys as a dummy variable in the analysis.

We emailed the authors of primary studies if details about the survey including the survey year, payment vehicle, payment duration, the type or magnitude of change, the use of photographs, modelled observations, sample size or socio-demographic data, had not been provided in the article or report. Almost all authors were emailed. About 80% responded and provided answers to our questions, enabling us to use their studies in our meta-analysis.

2.4 Meta-regression models

Many NMV studies provide more than one WTP estimate. As a result, a meta-analysis dataset ends up having an unbalanced panel structure (Jacobsen and Hanley (2009), Lindhjem and Tuan (2012)). Two main methods used to account for the panel structure are fixed-effect panel data models and random-effect panel data models (Rolfe et al., 2015; Van Houtven, 2008). However, there are problematic considerations of both fixed-effects and random-effects models[6] in meta-regression analysis. Clustered robust regression can be used to address the issue of panel-effects in meta-analysis. It applies a nonparametric

[6] Both fixed-effect and random-effect considerations can be problematic in meta-analysis modelling—the former because it can be difficult to separate variables having relatively small variation and the fixed-effect constant within a group, and the latter because of the issue of regression weighing that is often required but not included in most random-effect panel models See Van Houtven (2008) for more details.

Huber-White method to correct standard errors for potential correlation within clusters and variances across clusters (Van Houtven, 2008). Clustered robust regression has been used in several prior meta-analyses (Smith and Osborne, 1996; Van Houtven et al., 2007; Van Houtven et al., 2017). We clustered by sample to correct for the correlation of errors[7] that would arise because the same set of respondents answered more than one WTP question.

Weighting each observation of the meta-dataset by different metrics is often used to separate within-study and between-study variation and also to correct for the biases in the precision of WTP estimates from multiple studies that may arise as a consequence of differences in sample sizes and other effects, such as from survey formats. Weighting using the inverse variance or standard error of the WTP estimate is recommended and preferred in meta-regression (Gurevitch et al., 2018; Van Houtven, 2008). However, many meta-analyses of NMV studies face the problem of lack of reporting of the standard errors of WTP estimates or other statistics from which the standard error can be calculated. Instead, inverse-sample size-weighting has become a common practice in meta-analysis (e.g., Bergstrom and Taylor, 2006; Ma et al., 2015; Van Houtven et al., 2017). We estimated two clustered regression models[8] to test the effect of the weighting metric on regression output—an inverse-standard error-weighted model (Model SE), and an inverse-square root of sample size-weighted model (Model SS). We anticipated different regression results from Model SE and Model SS as we found the standard errors (SEs) and the sample size (Figure 1) to only be weakly correlated (r = 0.21). For studies that did not report SEs of the WTP estimates, we calculated the SEs from other metrics if reported–either the standard deviations along with

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[7] Multiple WTP value estimates from a single primary study or from the same respondent sample cannot be treated as independent. The estimates are always dependent due to a correlation of effect size parameters or a correlation of estimation errors (Hedges et al. (2010)).

[8] Our meta-regression model esentially takes the following form based on standard practice for clustered ordinary least squares regression given by (Lindhjem and Navrud, 2015):

$$\ln(WTP_{si}) = \beta_0 + \beta_1 \ln(Income_{si}) + \sum_k \beta_k M_{si}\,(k) + \varepsilon_{si} \;\ldots\ldots\ldots\ldots(3)$$

where, ln(WTP_{si}) and ln($Income_{si}$) are the natural log of willingness to pay, and income, respectively, for estimate *i* of cluster *s*, β_0 is the constant term, and β_k the *k* coefficients of the *k* moderator/explanatory variables (*M*).

the sample size or the confidence intervals of the WTP estimates[9]. We present the results of both models (Table 2). Stata/IC 14 (Statacorp LLC, USA) was used to analyse the data.

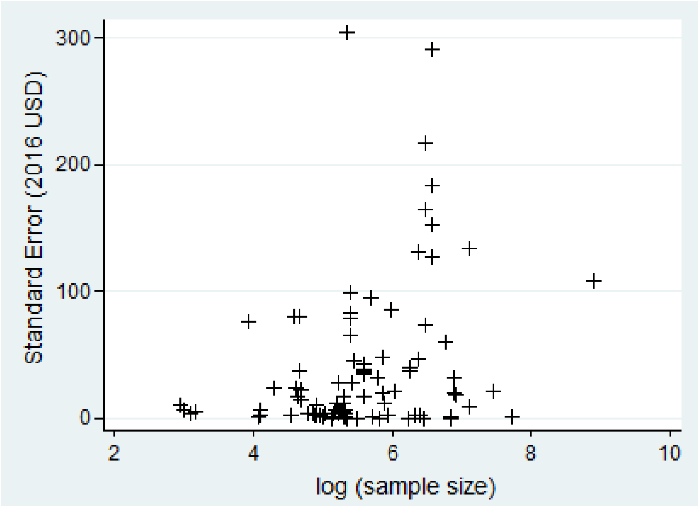

Figure 1: Scatter plot of the natural log of sample size and standard error of total WTP (in 2016 US dollars) of the studies used in the meta-analysis

3. Results

3.1 Some descriptive statistics from primary studies

Although the average total WTP (TWTP) was $414 per household, its standard deviation, which was nearly twice the TWTP value ($792), and the wide range in TWTP values (Table 1), indicate that there is a huge variation in WTP for threatened species across the globe. Charismatic species accounted for two-thirds of the observations in the data-set, while there was an equal percentage of WTP observations of threatened and non-threatened species (50%). Welch's t-tests indicated a significantly higher (*p* < 0.0001) average TWTP

[9] Studies that did not report the standard errors, standard deviations or the confidence intervals of the WTP estimates could not be included in the meta-regression analysis. Of the 165 observations from 71 stated preference studies that could possibly have been included in the meta-regression analysis, we could only include 109 observations from 47 studies in the analysis (i.e. we have excluded 56 observations from 24 studies, or about one-third of the total observations because the standard errors, standard deviations or the confidence intervals of the WTP estimates were not reported in these studies). There was no particular pattern in terms of the species that were omitted from these studies.

for charismatic species ($572) compared to non-charismatic species ($106), but no statistically significant difference in average TWTP for non-threatened species ($445) compared to threatened species ($383). Even though our dataset was skewed towards NMV studies from developed countries (89%), Welch's t-tests indicated that there was no significant difference between the average TWTP per household for threatened species in developed countries ($426) compared to developing countries ($318). Surveys with coloured photographs accounted for 50% of the observations in the dataset but t-tests[10] indicated that there were no significant differences in average total WTP values for surveys containing coloured photographs of threatened species ($499) and those that did not ($330).

3.2 Significant determinants of WTP from regression models

Though both regression models fit the data well, the higher coefficient of determination (R^2) and the lower root-mean-square error (RMSE) values of Model SE indicates that this model provides a more superior fit than Model SS (Table 2).

Species' charisma, as well as its threat status, significantly affected WTP for its conservation in Model SE (Table 2). Results from other studies highlight the importance of a species' perceived "charisma" with the general public, for example, by finding either greater conservation budgets allocated to charismatic species over endangered species (Metrick and Weitzman, 1996) or, finding participants more likely to donate money to adopt charismatic species over endangered species in zoo conservation programs (Colleony et al., 2017). In Model SS, the coefficient for a higher threat status was negative (Table 2), implying a lower willingness to pay, which is contradictory to our expectations.

WTP for marine mammals and turtles was significantly higher than for non-marine mammals, whereas WTP for birds, fish and for other species that included crustaceans and

[10] Results from t-tests can serve as indicators and are useful for initial discussions about the possible effect of various independent variables on WTP. However, the effects of multiple variables (some discrete and some continuous) from multiple studies on WTP can only be ascertained using a regression analysis. Therefore, the results of the regression analysis in section 3.2 supersede those from the t-tests.

insects was not significantly different than for non-marine mammals (SE model in Table 2). This is partly in line with the findings of the meta-analyses of Loomis and White (1996) and Richardson and Loomis (2009) who found WTP for marine mammals, birds and fish to be significantly higher compared to mammals. It is likely that species' charisma might be a bigger factor affecting WTP for conservation over the type of species on a global scale. Results from Model SS, however, implied that WTP was not species-dependent.

Model SE indicated that respondents significantly valued avoiding loss or avoiding extinction of a species, and also maintaining a species population relative to a baseline of a gain in population. In line with economic theory and findings of previous meta-analyses (Loomis and White, 1996; Richardson and Loomis, 2009), respondents positively and significantly valued higher population gains. In Model SS, however, the type of change in species' population or the magnitude of the gain in populations were insignificant factors, which are contradictory to both economic theory and our expectations.

Table 2: Clustered robust regression models results weighted by (1) the inverse of the standard error of WTP estimates (Model SE) and by (2) the inverse of the square root of sample size (Model SS).

	Model SE (1)			Model SS (2)		
Independent Variable	**Coefficient**	**Robust standard error**	**t-statistic**	**Coefficient**	**Robust standard error**	**t-statistic**
Survey context						
Survey year-2016	0.004	0.031	0.120	0.004	0.033	0.130
log [a] (Income)	0.378	0.273	1.380	0.664***	0.229	2.910
Developing country (base [b]: Developed country)	-0.572	0.808	-0.710	1.268***	0.560	2.260
Visitors (base [b]: locals)	-0.446**	0.226	-1.970	-0.570*	0.317	-1.800
Species						
Marine Mammal or Turtle (base [b]: Mammals)	1.155***	0.240	4.820	0.130	0.326	0.400
Bird (base [b]: Mammals)	-0.025	0.315	-0.080	-0.601	0.429	-1.400
Fish (base [b]: Mammals)	0.268	0.371	0.720	-0.544	0.689	-0.790
Other species type [c] (base [b]: Mammals)	-0.364	0.353	-1.030	-0.566	0.603	-0.940
Threatened species [d]	1.021***	0.202	5.040	-0.054	0.263	-0.200
Charismatic species [e]	0.539***	0.232	2.320	0.547	0.371	1.480
Survey administration						
In-person or Telephone (base [b]: Mail or Drop-off)	0.297	0.631	0.470	0.162	0.487	0.330
Online (base [b]: Mail or Drop-off)	0.965	0.842	1.150	-0.049	0.740	-0.070
Survey design [f]						
OE (base [b]: DC)	-0.852***	0.350	-2.430	-0.605***	0.299	-2.020
PC (base [b]: DC)	-1.506***	0.376	-4.000	-1.277***	0.399	-3.200
CE (base [b]: DC)	-0.616	0.642	-0.960	-0.207	0.503	-0.410
Coloured pic [g]	0.376	0.520	0.720	0.145	0.439	0.330
Payment vehicle						
Donation (base [b]: Tax)	0.128	0.297	0.430	-0.443	0.313	-1.410
Other [h] (base [b]: Tax)	-0.439	0.280	-1.570	-1.039***	0.367	-2.830
Payment duration [i]						
Annual >=6 years to perpetuity	3.881***	0.536	7.240	2.509***	0.406	6.180
Type of change						
Avoid Loss/ Avoid extinction (base [b]: Gain in population)	2.503***	0.407	6.160	0.878	0.705	1.250
Maintain population (base [b]: Gain in population)	1.031***	0.369	2.800	0.524	0.724	0.720
log [a] (Magnitude of gain)	0.389***	0.067	5.840	0.074	0.151	0.490
constant	-3.262	3.438	-0.950	-3.149	2.374	-1.330
Dependent variable	log [a] (WTP)			log [a] (WTP)		
Observations	109			109		
Clusters	71			71		
R^2	0.909			0.824		
RMSE [j]	0.326			0.753		

[a] log refers to natural log; [b] base refers to baseline; [c] Other species type include crustaceans and insects [d] Threatened includes species whose threat status is vulnerable, or endangered, or critically endangered with the baseline being species whose threat status is least concern, or data deficient, or not listed, or near threatened; [e] baseline is species that are not charismatic; [f] DC = dichotomous choice contingent valuation (CV), OE= open-ended CV, PC = payment card CV, CE = choice experiment; [g] baseline included surveys that used no photographs, or black and white drawings, or black and white photographs, or those

that did not state whether they used photographs or not; [h] Other payment vehicles included fees, surcharges and trust funds; [i] baseline for payment duration included one-time payments or annual payments up to five years; [j] RMSE = Root-mean-square error; *, **, and *** indicate significance at the 90%, 95%, and 99% and higher levels of confidence, respectively.

While respondents in developing countries had lower WTP for species' conservation compared to those in developed countries, the effect of a country's development status on WTP was not significant in Model SE. In Model SS, however, WTP for species' conservation was significantly higher in developing countries compared to those in developed countries. In both models, visitors were significantly less willing to pay for species' conservation than were local residents, which is in contrast to the findings of the meta-analyses of Loomis and White (1996) and Richardson and Loomis (2009). It could be that the values expressed by visitors were mostly use-values for the threatened species, whereas locals derived both use and passive-use values from species.

The survey year coefficient was positive but not significant for both models (Table 2). Income was found to have a positive but insignificant effect on WTP for species conservation in Model SE, similar to the findings of Richardson and Loomis (2009). In Model SS, income had a positive and significant effect on WTP similar to the findings of Jacobsen and Hanley (2009).

Survey administration was not a factor affecting WTP in this meta-analysis: the coefficients for online mode and in-person or telephone mode relative to the baseline of mail and drop-off[11] were insignificant in both models. This agrees with the findings by Olsen (2009) and Nielsen (2011) who find no significant difference in WTP between online and mail stated preference surveys, or between online and in-person stated preference surveys, respectively. However, Richardson and Loomis (2009) and Maguire (2009) found that mail surveys and telephone surveys resulted in significantly lower WTPs compared to in-person

[11] Drop-off surveys were combined with mail surveys since they can be thought of as imitating the latter in that they had to be filled on paper and in the respondent's own time. Similarly telephone and in-person surveys were combined. In models where drop-off and telephone surveys (13 and 4 WTP values in total, respectively) were assigned their separate dummy variables, the coefficients were not found to be significant. Therefore, in the interest of parsimony, variables denoting mail and drop-off and telephone and in-person surveys were combined.

surveys. In their comprehensive review comparing the internet with other modes of survey administration, (Lindhjem and Navrud, 2011) found no substantial difference in quality or validity between internet and mail or telephone or in-person modes with welfare estimates mostly equal across the administration modes, and possibly sometimes lower for internet surveys. More surveys in the future will be conducted online; therefore, it is encouraging that WTP values from online surveys were not significantly different from in-person or mail surveys.

Open-ended (OE) and payment card (PC) type contingent valuation elicited lower WTP values than dichotomous choice (DC) type contingent valuation surveys, with OE and PC eliciting significantly lower WTP values in both models (Table 2). This is consistent with the findings from many other studies (Reaves et al., 1999) as well as other meta-regressions (Jacobsen and Hanley, 2009; Richardson and Loomis, 2012). Choice experiments (CE), however, did not elicit significantly lower WTP estimates compared to DC contingent valuation surveys. This does not agree with the findings of Richardson and Loomis (2009) who found WTP estimates to be significantly higher from CE studies. However, their study included just one CE study having five WTP estimates whereas ours included 22 CE observations.

The coefficient for coloured photographs was positive but not significant in both models, indicating that the inclusion of coloured photographs of threatened species in surveys, on the whole, did not significantly affect WTP for their conservation relative to not including photographs or including black and white photographs. These findings are in line with those from Subroy et al. (2018) who found WTP to be independent of the inclusion of coloured photographs of species in their NMW survey on West Australian households' WTP for threatened native species and conservation management, but different from the findings of Labao et al. (2008) who found coloured photographs to elicit a significantly higher WTP for the preservation of the Philippine Eagle. It is possible that more studies may be necessary to resolve the issue of the influence of coloured photographs of species on WTP.

We found that other payment vehicles[12]—donations, fees or surcharges—did not elicit significantly different WTP compared to taxes in Model SE, whereas in Model SS, fees and surcharges but not donations appear to elicit a significantly lower WTP. Voluntary payment vehicles, such as donations, are usually seen to elicit lower WTP values owing to "free-riding" by many individuals who like to enjoy the benefits of public goods without having to contribute to the cost of providing the goods themselves (Stithou and Scarpa, 2012). The Jacobsen and Hanley (2009) meta-analysis on biodiversity conservation found donations to elicit a higher but not significantly higher WTP compared to taxes, while Lindhjem and Tuan (2012) found mandatory payments (taxes, etc.) to elicit significantly higher WTP than voluntary payments in their meta-analysis of species' valuation in Asia and Oceania.

Expectedly, total WTP was significantly higher for longer payment durations than for one-time payments or annual payments up to five years[13] in both models.

From our results, it is sufficiently clear that the metric used for weighting significantly alters the model output. To select the preferred model for our analysis, we consider the following arguments: first, inverse-standard error-weighting is considered more accurate than inverse-sample size-weighting owing to the incorporation of information on the precision of the effect size, which the latter weighting scheme does not provide, and also because of the possible biases that can be introduced by weighting with sample size (Gurevitch et al., 2018; Van Houtven, 2008). Second, for stated preference studies, the information from variation in experimental design and elicitation format cannot be captured using sample size, and as such, results from inverse weighting using sample size only provides an approximation, and are a practical second-best alternative when data on WTP statistics are unavailable (Van Houtven, 2008). Finally, the coefficients of several important variables

[12] In general, Johnston et al. (2017) recommend avoiding nonbinding payment vehicles that do not provide incentives for truthful demand revelation such as donations.

[13] We tested different categorical combinations of payment durations. We found no significant difference in coefficients for annual payments of 6 to 10 years than those for annual payments > 10 years to perpetuity. These two categories were therefore combined. Results also suggested no significant difference in annual payment up to 5 years compared to one-time payments resulting in just two categories as outlined in Table 1.

especially those on species' type, threat status, charisma, the type of change in population being measured (avoid loss relative to gain) and the percentage of gain being measured were not statistically significant in Model SS, which contradicts published literature and also economic theory. We, therefore, selected Model SE as our preferred model, and used it in the next section to test the reliability of the WTP estimates determined by this meta-regression.

3.3 Reliability of WTP estimates

As recommended by Bergstrom and Taylor (2006) we determined the reliability of WTP estimates from our meta-regression model (Model SE) for use in benefit transfer by comparing WTP estimates determined by the model with those derived from primary NMV studies. We estimated both within-sample and out-of-sample transfer errors using the procedure outlined in Lindhjem and Navrud (2008). To calculate within-sample transfer errors we compared the WTP from the primary study used in the meta-analysis with the WTP predicted by Model SE. Out-of-sample transfer errors were calculated by leaving study clusters out systematically, and calculating the model on the remaining clusters, then using the model to predict WTP values for the observations in the cluster that was left out, and comparing predicted WTP values with the ones estimated in the primary studies. The absolute transfer error (TE) for each observation was calculated as (Lindhjem and Navrud, 2008):

$$TE = \frac{|WTP_p - WTP_a|}{WTP_a} \text{ x } 100\% \qquad (2)$$

where subscripts *p* and *a* denote the model-*p*redicted WTP and the *a*ctual WTP values from the primary study, respectively.

Expectedly, out-of-sample TEs were found to be higher than within-sample TEs (Figure 2). Also, see Table S.2 in the supplementary data. Mean and median within-sample TEs were found to be 17%, and 14%, respectively, while mean and median out-of-sample TEs were found to be 48% and 21%, respectively. About 53 out-of-sample transfers or 48.6% of our data showed TEs of 20% or less, with 25 out-of-sample transfers or 23% of the data having TEs of 10% or less. 39.5% of in-sample transfers showed errors of 10% or less. As with the results by Lindhjem and Navrud (2008) and Brander et al. (2007), TEs were seen to be higher at the lower WTP values, and lower at higher WTP values (i.e. the meta-function over-estimates at lower values and under-estimates at higher values). Correlation between within-sample- and out-of-sample- predicted values of WTP was high (92.5%), indicating a good agreement between within-sample-predicted values of WTP and out-of-sample-predicted values of WTP in most cases (Figure 2).

TEs for our meta-model are comparable to the meta-analysis of endangered species in Asia and Oceania by Lindhjem and Tuan (2015), who found a mean out-of-sample TE to be 45% for their full model where all variables were used. Within-sample TEs from our model were lower than those determined by Richardson and Loomis (2009), who found mean within-sample TEs to vary between 34-45% depending on whether the payment was annual or lump sum. Our TEs are also in the range reported by meta-analyses in other contexts—Shrestha and Loomis (2001) reported an average absolute TEs of 28% in their meta-analysis on international outdoor recreation, Lindhjem and Navrud (2008) found mean TEs of between 39-62% in the validity testing of a meta-analysis model of non-timber benefits of CV studies from Norway, Sweden and Finland, and Brander et al. (2006) found mean transfer errors of 74% in their meta-analysis on wetland valuation. Our meta-function, therefore, provides reasonably reliable WTP estimates with TEs in the range reported by other studies.

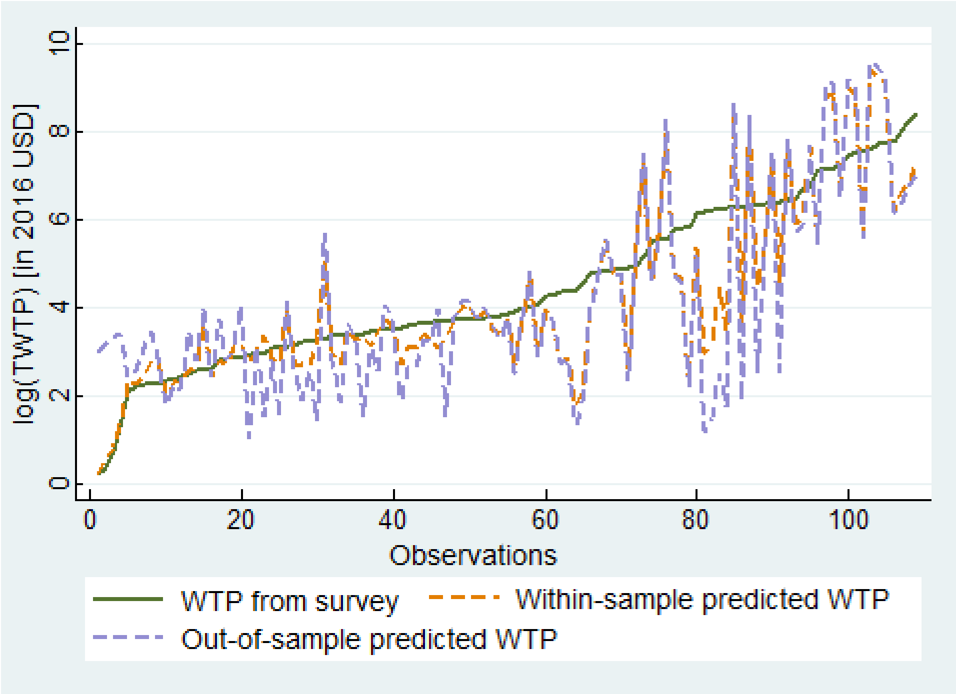

Figure 2: Plot of the natural log of total willingness to pay (log(TWTP)) estimates from the original study, and their within-sample and out-of-sample model-predicted values. TWTP values from the original studies have been sorted in ascending order. All values are in 2016 US dollars.

4. Discussions and Conclusions

Our meta-regression analysis is the first we are aware of that considers NMV studies (both contingent valuation and choice experiments) for threatened species of animals globally. Some of our findings are similar to previous meta-analyses of WTP for biodiversity conservation and individual species, namely the influence of survey format (a significant influence on WTP) and the payment vehicle (an insignificant influence). Others results such as the insignificance of income and survey year are in contrast to published meta-analyses on the topic. The average total present value of WTP for a threatened species from all primary studies in our meta-dataset was US$414 per household (in 2016 dollars). However, the large variation in the range of reported values indicate that there is a huge variation in WTP for threatened species across the globe depending on the species and the survey context.

We tested the effect of several variables not considered in prior meta-analyses—species' threat status, the use of coloured photographs of species in the survey, and a country's development status. In line with expectations and economic theory, we found endangered species to be valued significantly more highly than non-threatened species. The development status of a country, however, did not influence WTP estimates, and neither did the inclusion of coloured photographs of species in the survey.

An important contribution of this paper is the demonstration of the effect of the choice of weighting metric on the output of a regression model. We found that the inverse-standard error-weighted model provided significant coefficients of important variables that were in line with economic theory and with published literature. In agreement with the reviews of Gurevitch et al. (2018) and (Van Houtven, 2008) we recommend future meta-regression models to use inverse-standard error (or variance)-weighting rather than inverse-sample size-weighting as far as possible.

It would have been interesting to explore the influence of pro-environmental attitudes or ethical beliefs towards preservation in this meta-regression analysis, as they have been found by Kotchen and Reiling (2000), Ojea and Loureiro (2007) and Subroy et al. (2019) to significantly influence WTP for species' conservation. However, very few papers reported asking such questions. Subsequent meta-analyses may benefit if future NMV surveys of threatened species include questions about environmental attitudes or ethical beliefs of respondents.

Our meta-analysis is limited in terms of the availability of primary studies–it included a higher proportion of studies from developed countries as well as on terrestrial mammals and marine mammals compared to lesser charismatic species such as insects and crustaceans. The only NMV study on insects in our meta-analysis (Diffendorfer et al., 2014) was on a charismatic species–the Monarch butterfly, while all the reptiles in the primary studies were turtles that are also a charismatic species. Thus, even though our meta-regression model provides reasonably reliable WTP estimates, it may not always be possible to use it to estimate economic values for threatened species from developing countries or, for say, threatened insects or non-charismatic reptiles given the lack of availability of primary studies. A greater number of primary studies from developing countries as well as more studies on less charismatic species would improve the applicability of future meta-functions on WTP for threatened animal species. Also, for endemic species, particularly those having a limited geographical range, it would be more appropriate to conduct original NMV studies rather than deriving WTP estimates from a meta-regression model. Another aspect that cannot yet be accurately captured in a meta-regression model of threatened species valuation is the diminishing marginal utility of the WTP estimate. There is insufficient evidence in the existing literature to provide a general estimate of how rapidly the marginal value of a threatened species declines as the population size increases.

Limitations of current NMV studies and reporting recommendations for future studies

Preparing data for meta-analysis is challenging because relevant data needs to be extracted from original studies conducted in diverse contexts. Identifying effect-size or the commodity (here the change of species population) being valued is a difficult task when it comes to the valuation of species. Many of the reviewed studies were vague in defining the scenario being valued, stating "protection or conservation of species" or some such similarly ambiguous statement without any reference to a baseline. In the absence of a baseline, we could not know what change in species' populations was exactly being valued, and had to regrettably reject those studies from our meta-analysis. Only a few studies explicitly specified the counterfactual scenario; that is, what would happen if the conservation program was not carried out—would the species' population drop, increase or stay the same? Failure to specify the counterfactual scenario means that it is left to the respondent to guess or imagine what the counterfactual would be or to try to infer it from clues in the question. This is highly likely to introduce unnecessary randomness into the set of responses. We recommend that future non-market valuation studies of threatened species should be explicit about the counterfactual in the wording of the survey question.

Many studies failed to report essential information such as the survey year, the standard errors or confidence intervals of the WTP estimates, sociodemographic characteristics of the sample (age, income, gender, education etc.), payment vehicle and payment duration. Many studies also lacked clarity about the survey instrument including whether photographs were used, details about survey administration and survey response rate. Such information can enrich a meta-analysis and provide a more complete picture of factors affecting WTP for species.

Meta-analyses help provide a comprehensive picture of phenomena being studied and understand sources of heterogeneity (Gurevitch et al., 2018). To support future meta-analyses and benefit transfers for threatened species valuation, we urge researchers in this area to (i) explicitly define the counterfactual scenario in their survey instruments; (ii) quantitatively express the effect sizes being measured; and (iii) report these details along with essential information on the payment vehicle, payment duration, survey design (e.g. use of photographs), sample sociodemographics, and either standard errors or confidence intervals for the WTP estimates, which will allow these studies to be incorporated in future meta-analyses and benefit transfers.

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Supplementary Data

Table S.1. Country distribution of non-market valuation observations used in the meta-regression analysis

Country	Number of observations	Percentage of total (%)
Australia	3	2.75
Austria	2	1.83
Canada	8	7.34
Chile	3	2.75
China	5	4.59
Greece	6	5.5
Ireland	1	0.92
Israel	6	5.5
Nepal	1	0.92
Norway	2	1.83
Poland	1	0.92
South Korea	5	4.59
Spain	4	3.67
Sri Lanka	7	6.42
Sweden	9	8.26
Taiwan	3	2.75
UK	11	10.09
USA	31	28.44
Vietnam	1	0.92
Total	***109***	***100***

Table S.2. Natural log of total willingness to pay (ln(TWTP)) from the original study, and its corresponding within-sample and out-of-sample model-predicted ln(TWTP), along with the within-sample and out-of-sample transfer errors (TEs). All values in 2016 US$.

Observation ID	Sample ID	ln(TWTP) (from study)	Within-sample predicted ln(TWTP)	Out-of-sample predicted ln(TWTP)	TE (within-sample)	TE (out-of-sample)
1	1	8.221	6.836	6.782	16.849	17.498
2	2	7.779	6.220	6.140	20.044	21.073
3	3	3.604	3.091	2.654	14.243	26.350
4	4	2.872	3.163	4.038	10.141	40.591
5	5	6.175	2.971	1.212	51.891	80.376
6	5	6.229	3.192	1.525	48.763	75.518
7	5	6.260	3.461	1.755	44.706	71.967
8	5	6.275	3.619	1.889	42.325	69.893
9	5	6.237	4.443	2.528	28.767	59.461
10	5	6.321	4.443	2.528	29.707	59.996
11	5	6.423	4.443	2.528	30.831	60.636
12	6	2.284	2.780	2.856	21.701	25.039
13	7	5.823	2.236	2.203	61.596	62.174
14	8	2.581	2.730	2.806	5.771	8.727
15	8	2.858	2.730	2.806	4.487	1.818
16	9	2.382	2.018	1.800	15.297	24.459
17	9	2.466	2.390	2.161	3.082	12.337
18	10	2.259	2.464	3.100	9.090	37.247
19	10	2.278	2.836	3.441	24.462	51.014
20	11	2.255	2.276	2.588	0.919	14.761
21	12	2.487	2.548	3.452	2.436	38.781
22	13	5.771	4.788	4.747	17.038	17.750
23	13	4.257	3.936	3.893	7.550	8.564
24	14	0.247	0.219	3.010	11.217	1119.297
25	14	0.358	0.576	3.179	60.923	788.840
26	14	0.742	0.845	3.307	13.917	345.744
27	15	2.621	3.635	3.995	38.699	52.411
28	16	3.483	3.479	2.574	0.118	26.112
29	17	3.481	3.129	3.078	10.111	11.595
30	18	2.962	3.054	3.114	3.132	5.154
31	19	3.082	2.889	2.832	6.273	8.133
32	20	7.236	6.509	6.474	10.042	10.522
33	21	4.297	3.741	3.722	12.930	13.380
34	22	4.352	2.889	2.850	33.611	34.521
35	23	4.811	5.504	5.564	14.390	15.645
36	24	4.347	2.799	2.739	35.615	36.980
37	25	3.712	3.714	3.762	0.046	1.344
38	25	3.744	3.712	3.760	0.856	0.431
39	25	3.870	3.711	3.759	4.112	2.868
40	25	4.013	4.735	4.816	17.987	20.016

41	25	4.013	3.714	3.762	7.456	6.255
42	26	2.084	2.351	2.405	12.792	15.370
43	27	2.960	2.765	1.011	6.599	65.829
44	27	3.284	3.371	1.413	2.636	56.969
45	28	6.131	5.367	5.206	12.456	15.087
46	28	6.341	5.501	5.351	13.247	15.606
47	28	6.495	5.906	5.737	9.071	11.674
48	28	6.662	6.040	5.882	9.345	11.707
49	29	8.018	6.668	6.391	16.838	20.291
50	29	8.395	7.294	7.017	13.111	16.407
51	30	2.389	2.349	2.262	1.667	5.328
52	31	3.357	3.025	2.774	9.878	17.364
53	32	4.117	3.025	2.887	26.515	29.879
54	33	3.730	4.061	4.146	8.895	11.157
55	34	4.759	4.061	3.987	14.667	16.230
56	35	5.548	7.943	8.256	43.176	48.819
57	36	3.756	3.933	3.986	4.718	6.125
58	37	3.652	3.397	3.269	7.006	10.491
59	38	3.845	3.386	3.273	11.922	14.868
60	39	4.936	5.310	5.356	7.575	8.507
61	40	3.086	2.728	1.511	11.595	51.014
62	3	3.652	3.082	2.645	15.603	27.567
63	4	3.684	3.111	3.975	15.575	7.891
64	41	3.293	5.039	5.686	52.999	72.672
65	42	7.194	8.913	9.095	23.894	26.420
66	42	7.429	9.004	9.186	21.206	23.656
67	42	7.736	9.240	9.422	19.435	21.796
68	42	7.602	9.385	9.568	23.466	25.874
69	43	6.296	8.180	8.371	29.925	32.950
70	43	7.530	8.806	8.994	16.946	19.433
71	43	7.762	9.035	9.221	16.394	18.792
72	44	6.272	8.338	8.618	32.951	37.418
73	44	7.146	8.765	9.042	22.655	26.530
74	45	6.346	7.323	7.529	15.398	18.637
75	45	6.460	7.593	7.804	17.528	20.792
76	46	3.367	3.520	3.635	4.529	7.943
77	47	4.847	4.753	4.735	1.927	2.315
78	48	5.165	7.246	7.485	40.294	44.917
79	49	5.540	5.639	5.643	1.785	1.869
80	50	5.812	4.618	4.570	20.546	21.373
81	51	5.495	4.618	4.581	15.957	16.631
82	52	2.841	2.846	3.751	0.168	32.012
83	46	3.527	3.520	3.635	0.194	3.065
84	46	3.799	3.520	3.635	7.345	4.320
85	46	3.723	4.025	4.162	8.109	11.788
86	53	3.121	3.959	4.126	26.851	32.194

87	54	2.659	2.453	2.415	7.741	9.156
88	55	2.867	3.107	3.161	8.359	10.225
89	56	6.747	7.637	7.657	13.183	13.481
90	57	3.250	2.703	2.543	16.833	21.729
91	58	3.390	3.270	3.251	3.560	4.111
92	59	3.154	2.703	2.522	14.324	20.045
93	60	3.678	3.270	3.232	11.107	12.120
94	61	3.487	3.769	4.060	8.066	16.426
95	62	4.432	1.768	1.353	60.103	69.472
96	62	4.908	2.620	2.324	46.606	52.650
97	63	4.887	4.789	4.778	1.994	2.213
98	64	7.582	5.641	5.560	25.595	26.668
99	65	4.808	4.789	4.786	0.389	0.462
100	66	7.110	5.641	5.426	20.656	23.688
101	67	1.295	1.330	3.432	2.707	165.042
102	67	3.214	2.721	1.892	15.338	41.149
103	67	3.570	2.721	1.892	23.775	47.014
104	68	3.359	2.721	1.892	18.990	43.688
105	69	2.976	3.351	1.530	12.617	48.589
106	69	3.436	3.351	1.530	2.482	55.482
107	69	3.704	3.351	1.530	9.520	58.695
108	70	3.897	2.743	2.526	29.625	35.180
109	71	4.542	2.089	1.854	54.017	59.183

Appendix I: Studies used in the meta-analysis along with total willingness to pay (TWTP) estimates and standard errors of total WTP (SE) estimates in 2016 US dollars.

Paper	Reference	Study used in the Richardson and Loomis (2009) meta-analysis?	Document type	Country	Survey Year	Sample	Observation ID	Species	Population change measured	Magnitude of change (%)	TWTP (2016 US dollars)	SE (2016 US dollars)
1	Adamowicz et al. (1998)	No	Journal article	Canada	1995	1	1	Woodland Caribou	Gain	50	3717.58	85.8
						2	2	Woodland Caribou	Gain	50	2390.58	48.84
2	Aldrich et al. (2007)	Yes	Journal article	USA	1997	3	3	Peregrine Falcon	Gain	87.5	36.74	1.24
						4	4	Shortnose Sturgeon	Maintain		17.67	0.85
3	Bandara and Tisdell (2005)	No	Journal article	Sri Lanka	2001	5	5	Asian Elephant	Maintain		480.78	35.3
							6	Asian Elephant	Gain	25	507.4	36.79
							7	Asian Elephant	Gain	50	523.11	37.75
							8	Asian Elephant	Gain	75	531.06	38.27
							9	Asian Elephant	Loss	25	511.42	37.4
							10	Asian Elephant	Loss	50	555.93	39.45
							11	Asian Elephant	Loss	75	616.07	42.51

4	Baral et al. (2007)	No	Journal article	Nepal	2004	6	12	White-rumped Vulture	Loss	100	9.82	17.46
5	Bartczak and Meyerhoff (2013)	No	Journal article	Poland	2011	7	13	Eurasian Lynx	Gain	66.67	337.99	95.7
6	Becker et al. (2009)	No	Journal article	Israel	2003	8	14	Eurasian Griffon Vulture	Loss	60	13.21	1.02
							15	Eurasian Griffon Vulture	Loss	100	17.43	1.31
						9	16	Eurasian Griffon Vulture	Gain	100	10.83	0.85
							17	Eurasian Griffon Vulture	Gain	260	11.77	0.91
						10	18	Eurasian Griffon Vulture	Gain	100	9.57	0.78
							19	Eurasian Griffon Vulture	Gain	260	9.76	0.78
7	Bednar-Friedl et al. (2009)	No	Journal article	Austria	2006	11	20	Rock Partridge	Gain	30	9.54	0.08
						12	21	Austrian Ibex	Maintain		12.03	0.09

8	Boman and Bostedt (1994)	No	Report	Sweden	1993	13	22	Gray Wolf	Loss	100	320.98	134.78
							23	Gray Wolf	Loss	100	70.63	8.99
9	Cerda and Losada (2013)	No	Journal article	Chile	2011	14	24	Moon-toothed Degu	Gain	10	1.28	0.44
							25	Moon-toothed Degu	Gain	25	1.43	0.46
							26	Moon-toothed Degu	Gain	50	2.1	0.61
10	Cummings et al. (1994)	Yes	Journal article	USA	1994	15	27	Colorado Pikeminnow	Loss	100	13.75	2.96
11	Diffendorfer et al. (2014)	No	Journal article	USA	2012	16	28	Monarch Butterfly	Loss	100	32.57	1.41
12	Dong (2010)	No	Thesis	China	2009	17	29	Yangtze finless Porpoise	Gain	50	32.5	6.34
						18	30	Yangtze finless Porpoise	Gain	50	19.33	1.94
						19	31	Yangtze finless Porpoise	Gain	50	21.81	3.1

13	Ericsson et al. (2007)	No	Journal article	Sweden	2004	20	32	Wolverine	Gain	37	1387.88	109.07
14	Fredman (1994)	No	Thesis	Sweden	1993	21	33	White-backed Woodpecker	Loss	100	73.46	20.81
						22	34	White-backed Woodpecker	Loss	100	77.62	45.23
15	Giraud and Valcic (2004)	Yes	Journal article	USA	2000	23	35	Steller Sea Lion	Gain	100	122.9	21.27
16	Loomis and Ekstrand (1998);Giraud et al. (1999a); Giraud et al. (1999b)	Yes	Journal article	USA	1996	24	36	Mexican Spotted Owl	Gain	100	77.25	20.72
17	Hageman (1985)	Yes	Report	USA	1984	25	37	Bottlenose Dolphin	Loss	50	40.95	4.15
							38	Elephant Seal	Loss	97.5	42.25	4.26
							39	Sea Otter	Loss	93.33	47.93	4.55
							40	Blue Whale	Loss	61.24	55.32	6.03
							41	Gray Whale	Loss	91.875	55.32	6.03

18	Han and Lee (2008)	No	Journal article	South Korea	2005	26	42	Asian black Bear	Maintain		8.04	12.18
19	Han et al. (2010)	No	Journal article	South Korea	2008	27	43	Long-tailed Goral	Gain	400	19.3	0.22
							44	Long-tailed goral	Gain	1900	26.69	0.23
20	Hanley et al. (2010)	No	Journal article	United Kingdom	2009	28	45	Hen Harrier	Maintain		459.72	65.62
							46	Hen Harrier	Gain	20	567.3	79.38
							47	Golden Eagle	Maintain		661.85	83.49
							48	Golden Eagle	Gain	20	782.47	99.44
21	Harper (2012)	No	Thesis	Canada	2011	29	49	Woodland Caribou	Gain	50	3035.7	31.82
							50	Woodland Caribou	Gain	250	4423.88	20.1
22	Hynes and Hanley (2009)	No	Journal article	Ireland	2006	30	51	Corncrake	Gain	448.78	10.9	0.58

23	Jin et al. (2008)	No	Journal article	China	2005	31	52	Black faced Spoonbill	Maintain		28.7	2.81
						32	53	Black faced Spoonbill	Maintain		61.37	10.76
24	Johansson (1999)	No	Thesis	Sweden	1996	33	54	African Elephant	Loss	100	41.66	5.72
						34	55	African Elephant	Loss	100	116.67	12.04
						35	56	African Elephant	Loss	100	256.61	28.29
						36	57	African Elephant	Loss	100	42.78	5.44
25	Kim et al. (2012)	No	Journal article	South Korea	2010	37	58	Spotted Seal	Maintain		38.57	3.18
						38	59	Spotted Seal	Maintain		46.74	5.41
26	Kontogianni et al. (2012)	No	Journal article	Greece	2009	39	60	Mediterranean Monk Seal	Loss	100	139.22	12.3
27	Kontoleon and Swanson (2003)	No	Journal article	United Kingdom	1998	40	61	Giant Panda	Gain	150	21.88	1.32
28	Kotchen and Reiling (2000)	Yes	Journal article	USA	1997	3	62	Perigrine Falcon	Gain	87.5	38.56	6.46
						4	63	Shortnose Sturgeon	Maintain		39.82	17.57

29	Langford et al. (1998); Langford et al. (2001)	No	Journal article	Greece	1995	41	64	Mediterranean Monk Seal	Loss	100	26.93	7.13
30	Lew et al. (2010a)	No	Journal article	USA	2007	42	65	Steller Sea Lion	Gain	73.08	1331.48	127.4
							66	Steller Sea Lion	Gain	92.31	1683.4	153.27
							67	Steller Sea Lion	Gain	169.23	2289.53	183.23
							68	Steller Sea Lion	Gain	246.15	2001.39	290.52
						43	69	Steller Sea Lion	Gain	11.11	542.5	73.93
							70	Steller Sea Lion	Gain	55.56	1863.68	164.74
							71	Steller Sea Lion	Gain	100	2350.59	217.47
						44	72	Steller Sea Lion	Gain	16.67	529.32	46.83

							73	Steller Sea Lion	Gain	50	1269.52	132.07
31	Loomis and Larson (1994)	Yes	Journal article	USA	1991	45	74	Gray Whale	Gain	50	570.22	37.71
							75	Gray Whale	Gain	100	639.3	40.88
32	Loureiro and Ojea (2008)	No	Journal article	Spain	2005	46	76	Common murre	Gain	300	29	1.66
33	MacMillan et al. (2004)	No	Journal article	United Kingdom	2000	47	77	Wild goose	Maintain		127.33	22.23
						48	78	Wild goose	Loss	10	175.07	37.68
						49	79	Wild goose	Gain	10	254.65	80.96
						50	80	Wild goose	Gain	10	334.23	80.3
34	Macmillan et al. (2002)	No	Journal article	United Kingdom	2000	51	81	Wild goose	Gain	10	243.35	76.67
35	Myers (2014)	No	Journal article	USA	2010	52	82	Atlantic Red Knot	Gain	185.71	17.14	1.63
36	Ojea and Loureiro (2007)	No	Journal article	Spain	2005	46	83	Common murre	Gain	300	34.01	3.07
37		No		Spain	2005		84	Common murre	Gain	300	44.65	2.79

	Ojea and Loureiro (2009).		Journal article				85	Common murre	Gain	1100	41.4	3.3
38	Reaves et al. (1999)	Yes	Journal article	USA	1992	53	86	Red-cockaded Woodpecker	Gain	171.43	22.67	3.76
						54	87	Red-cockaded Woodpecker	Gain	171.43	14.28	3.66
						55	88	Red-cockaded Woodpecker	Gain	171.43	17.59	4.02
39	Stanley (2005)	Yes	Journal article	USA	2001	56	89	Riverside Fairy shrimp	Loss	100	851.59	304.6
40	Stithou and Scarpa (2012)	No	Journal article	Greece	2003	57	90	Loggerhead Turtle	Maintain		25.78	4.8
						58	91	Loggerhead Turtle	Maintain		29.68	6.89
						59	92	Monk Seal	Maintain		23.44	3.79
						60	93	Monk Seal	Maintain		39.58	11.05

41	Swanson et al. (1998); Swanson et al. (2002)	No	Thesis	United Kingdom	1996	61	94	Black Rhino	Gain	198.5	32.7	2.33
42	Syring (2003)	No	Thesis	USA	2002	62	95	Lake Sturgeon	Maintain		84.14	24.48
							96	Lake Sturgeon	Maintain		135.33	32.15
43	Tanguay (1994)	No	Thesis	Canada	1992	63	97	Woodland Caribou	Maintain		132.49	27.88
						64	98	Woodland Caribou	Maintain		1961.79	60.82
						65	99	Woodland Caribou	Maintain		122.46	17.51
						66	100	Woodland Caribou	Maintain		1223.78	19.12
44	Tisdell et al. (2005)	No	Journal article	Australia	2002	67	101	Mahogany Glider	Maintain		24.88	4.01
							102	Mahogany Glider	Maintain		35.51	6.47

							103	Mahogany Glider	Maintain		28.76	3.7
45	Truong (2005)	No	Thesis	Vietnam	2004	68	104	Javan Rhino	Maintain		3.65	0.07
46	Tseng and Chen (2008)	No	Journal article	Taiwan (China)	2006	69	105	Taiwan trout	Loss	39.58	19.6	0.09
							106	Taiwan trout	Loss	65.26	31.07	0.05
							107	Taiwan trout	Loss	90.94	40.59	0.12
47	Veisten et al. (2004)	No	Journal article	Norway	1992	70	108	White-backed Woodpecker	Loss	100	49.26	15.12
						71	109	White-backed Woodpecker	Loss	100	93.89	24.15

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