How much are US households prepared to pay to manage and protect whitebark pine (*Pinus albicaulis* Engelm.)?

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The whitebark pine (*Pinus albicaulis* Engelm.) tree species faces precipitously declining populations in many locations. It is a keystone species found primarily in high-elevation forests across the Western US. The species is an early responder to climate change and qualifies for endangered species protection. We use contingent valuation to estimate the public's willingness to pay for management of the whitebark pine species. In contrast, previous work centres on valuing broader aspects of forest ecosystems or threats to multiple tree species. While only approximately half of the survey respondents have seen whitebark pine, the mean willingness to pay for whitebark pine management is \$135 per household. When aggregated across all households from the three sampled states, willingness to pay totals \$163 million. This information is valuable to forest managers who must make difficult decisions in times of resource constraints and climate change.

Introduction

Whitebark pine (*Pinus albicaulis* Engelm.) is an early responder to climate change whose precipitous population decline qualifies it for endangered species protection (See the opinion of the United States Court of Appeals for the Ninth Circuit at <http://cdn.ca9.uscourts.gov/datastore/opinions/2017/04/28/14-35431.pdf>, last accessed August 30, 2018). Eighty per cent of adult whitebark pine (WBP) in areas of the Northern Rockies have died in the past two decades, and climate change models suggest a severe reduction in suitable habitat in the Greater Yellowstone Ecosystem (GYE) by century's end (Chang *et al.*, 2014). Unfortunately for the ecosystem as a whole, WBP is also a keystone species, meaning that other plant and animal species critically depend on it for survival. WBP acts as a food source, stabilizes soil and moderates snow runoff in the ecosystem (Iglesias *et al.*, 2015).

Developing management strategies to reduce threats to endangered species is often an arduous and expensive task. Issues of jurisdiction, ecosystem linkages and uncertainty over the impacts of climate change all contribute to a complicated problem in the case of WBP (Hansen *et al.*, 2016). WBP in the Northern Rockies face a variety of threats. Climate change enhances mortality rates via the proliferation of native mountain pine beetles, lesser water availability and increased high-severity wildfires (Iglesias *et al.*, 2015; Bureau of Land Management, 2016; Hansen *et al.*, 2016; Shanahan *et al.*, 2016; Whitlock *et al.*, 2018). White pine blister rust is also a tremendous threat to WBP, though the precise relationships between

climate change and white pine blister rust are not yet fully understood (Hansen *et al.*, 2016).

This study assesses public support for WBP management activities on federal lands generally and more specifically in wilderness areas through a contingent valuation survey of willingness to pay (WTP) for WBP management. We find the mean willingness to pay for WBP management is \$135 per household, even though approximately half of respondents have not seen the species. When aggregated across all households from the three sampled states, willingness to pay totals \$163 million.

We include analysis of public support for management schemes. Only 8.1 per cent of WBP distribution in the GYE is within lands where active management (i.e. protection against ecosystem threats or restoration of the ecosystem to a previous condition) is possible. Most of the WBP distribution in the GYE lies within areas designated as wilderness (68.2 per cent), in which active management is dissuaded, or within inventoried roadless areas (23.4 per cent), in which active management is logistically infeasible. As discussed later, views about management in such areas have broader implications.

The literature on economic valuation of environmental and natural resources that captures non-market values is extensive. However, most work centres on forest valuation as whole rather than on individual species (see Barrio and Loureiro, 2010; Holmes *et al.*, 2015). The economic valuations of particular species that have been conducted rarely focus on plant species (see Loomis and White, 1996; Richardson and Loomis, 2009). Yet some contingent valuation studies do assess ecosystems

with an emphasis on particular species or do assess threats that affect certain species. Examples of the former include contingent valuations of the health, quality and extent of forest ecosystems (see a summary in [Kramer et al., 2003](#)), including contingent valuation of the protection or quality of spruce-fir forests (e.g. [Haefele et al., 1992](#); [Holmes and Kramer, 1995](#); [Aldy et al., 1999](#)). Examples of threat-based studies include those aimed at contingent valuation of managing white pine blister rust, which affects five-needle pine species ([Meldrum et al., 2011, 2013](#); [Meldrum, 2015](#)), and contingent valuation of control programmes for hemlock woolly adelgid, which damages eastern hemlock and Carolina hemlock ([Moore et al., 2011](#); [Poudyal et al., 2016](#)). As considered later, research participants may not evaluate tree species independently in an ecosystem, but the present study does more narrowly perform a contingent valuation of managing the WBP species rather than managing an ecosystem or a broader threat.

Our work most closely follows [Meldrum et al. \(2011\)](#), which values the management of invasive white pine blister rust. This disease affects a group of five-needle pine species across high-elevation forests of the Western US. [Meldrum et al. \(2011\)](#) find that the mean WTP for management of blister rust is \$172.55 ([Meldrum et al. \(2011, p. 228\)](#) asking if survey takers were ‘willing to pay a one-time cost’ to fund the programme. Our survey used the more traditional ‘one-time tax’ language. Use of the word ‘tax’ may have reduced WTP in the present study to some extent). Additional findings from that survey, as presented in [Meldrum et al. \(2013\)](#) and [Meldrum \(2015\)](#), report a mean WTP of \$154 and ‘200 or more,’ respectively. The present study differs due to our focus on a particular tree species and a more focused geography of the tri-state area of Idaho, Montana and Wyoming.

Survey development and data collection

The contingent valuation method, which provides estimates that are either smaller or statistically equivalent to revealed preference estimates (see [Carson et al., 1996](#)), is used to measure the benefit the public derives from WBP and associated ecosystem services. Contingent valuation considers both direct and passive use, which provides an advantage over other possible valuation methods. The literature denotes the valuation from direct and passive use as ‘direct values’ and ‘passive values,’ respectively. Passive values are placed on wildlife and wilderness for their existence rather than use ([Krutilla, 1967](#)). Relatively few people visit the WBP habitat and directly use the ecosystem services offered by WBP, so much of the value of WBP comes from passive values.

Two experts on contingent valuation provided peer reviews of the survey, and their comments were incorporated. The web version of the survey was pretested with 36 individuals at Montana State University across a graduate public administration methods course, an undergraduate social science statistics course, and a small number of other persons able to provide substantive feedback. The paper version of the survey was pretested in a University of Montana introductory economics course with 46 students completing the survey. Clarifications and other improvements to the survey were then made based on the survey results and explicit feedback from pretest participants. As a consequence of the pretests, the most significant changes to the survey design involved (a) making the land designations

(e.g. national park, US forest service) on the map clearer with more distinct colours and (b) clarifying language about the one-time tax. The pretests also resulted in a variety of minor changes to language and formatting throughout the survey. Finally, feedback was sought from federal forest managers and ecologists and an array of academic researchers prior to implementation of the survey.

Sampling and data collection

The survey was mailed from Montana State University’s Human Ecology Learning and Problem Solving Lab to randomly selected addresses in Idaho, Montana and Wyoming (The addresses were obtained from Survey Sampling International, LLC (<https://www.surveysampling.com/>, last accessed August 30, 2018). Data collection was completed in two phases. The main dataset came from Phase 1, which included 9000 addresses stratified by state population. Of these mailings, 124 were either undeliverable or the addressee was deceased. From the 8876 successfully delivered surveys, 4504 were mailed to Idaho, 2788 to Montana, and 1584 to Wyoming. Three mailings occurred during this phase of data collection. The first two mailings asked the addressee to complete an online survey, and the third mailing also included a paper survey with a postage-paid return envelope. While the first mailing asked the addressee to respond, the subsequent mailings noted that any one adult in the household could respond. The use of authentication codes prevented multiple responses from one individual or household. The first mailing to 9000 addresses included randomly assigned incentives of a \$1 bill to 3000 addresses, a \$2 bill to another 3000 addresses, and no incentive for the remaining 3000 addresses. The *ex ante* incentives were used to encourage survey participation given the survey’s focus on a relatively unfamiliar species.

During Phase 1, respondents completed 1507 surveys, including 1010 surveys online and 497 mail-in surveys, which represents a 17.0 per cent survey return rate. Regression analysis excludes respondents who left relevant answers blank or chose ‘Unsure’ for their answer. The income variable was a common reason for missing data. The final usable sample included 1207 surveys. This is a 13.6 per cent effective response rate. The response rate was non-uniform throughout the states surveyed. The survey had a 20.6 per cent return rate in Montana, 15.5 per cent in Idaho and 14.7 per cent in Wyoming. The research team affiliations (Montana State University and University of Montana) were displayed on the mailings. This likely caused the higher response rate in Montana compared with Idaho and Wyoming.

After three contact points with the Phase 1 sample, the survey team chose to send mail-in surveys to 1000 new addresses using just one contact point for the Phase 2 sample. This increased the usable sample size for the WTP regressions from 1207 to 1290 observations. For Phase 2, with one undeliverable address out of the 1000, the effective response rate was a bit over 8 per cent. Additional analyses completed using these Phase 2 data with qualitatively similar results to those presented in the paper are available upon request.

Study area

The study area included the states of Idaho, Montana and Wyoming. In the survey, this tri-state area was referred to as

'the Northern Rockies.' The survey included a map of the study area with National Parks, US Forest Service lands, wilderness and WBP habitat areas highlighted (Map available upon request). While the WBP species extends outside the tri-state area to other parts of the Western US, the research team constrained the study area to these three states to provide ecological cohesiveness and respondent connection to the geographic area under consideration.

Survey design and selected descriptive results

Following a general introduction, the survey inquired about respondent experience with WBP. More than 68 per cent of respondents have heard of WBP. The remaining 32% either have not heard of WBP (25%) or are unsure (7%). 56 per cent had seen WBP prior to receiving the survey. The survey then provided a photo of whitebark pine trees along with the following background information:

Whitebark pine trees are native to the Western United States and grow primarily in harsh, high-elevation conditions. Historically, these trees have had long lifespans, often over 700 years. However, a recent mountain pine beetle epidemic and non-native diseases have resulted in up to 80 per cent of the larger whitebark pine trees dying in certain areas in the Northern Rockies. This change in the high-elevation ecosystems is important because the whitebark pine is considered a keystone species, which means that other plant and animal species depend on whitebark pine for survival.

Whitebark pine play important roles in high-elevation forest communities by:

- keeping the soil stable with roots to prevent rock slides and erosion
- decreasing flood conditions by moderating snowmelt, runoff and water flow from high to low elevations
- providing a food source for birds, squirrels and grizzly bears with their seeds
- offering a distinct aesthetic appeal to outdoor enthusiasts, as these are very old trees with a unique appearance
- contributing to our scientific understanding of historical climate conditions, given their long lifespan

About 80 per cent of larger whitebark pine in certain areas in the Northern Rockies have died in recent years due to:

- white pine blister rust, a non-native disease that infects and kills whitebark pine of all ages
- mountain pine beetle, a native insect that kills larger whitebark pine trees
- changing temperatures and precipitation, resulting in the spread of blister rust and pine beetles and the reduction of suitable habitat area

The educational piece was followed by inquiries into respondent concern for the species. Of respondents, 45 per cent are 'very concerned' and 43 per cent are 'somewhat concerned' about WBP decline in the Northern Rockies and its potential disappearance in certain areas. Provided in the educational piece were the likely effects of a decline in WBP: reduction in available food

for wildlife, loss of wildlife habitat, loss of shade and wind protection for other plants and trees, more rapid water runoff from snowpack, reduced recreational opportunities, and loss of diversity in tree species. Respondents answered questions regarding all these potential consequences. Concern is greatest for 'more rapid water runoff' (61 per cent indicate 'a great deal' of concern) and the least for 'recreational opportunities' (37 per cent indicate 'a great deal' of concern).

Mountain pine beetle outbreaks, white pine blister rust, and changing temperatures and precipitation have all affected WBP ([Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee, 2011](#)). While almost 90 per cent of respondents are aware of mountain pine beetles, fewer than 35 per cent of respondents have heard of white pine blister rust.

To identify the available strategies and determine respondent preferences for management of WBP, the survey inquired about support for management strategies on federal public lands in general and about management in wilderness areas specifically. Considered were three types of management strategies (based on the [Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee's \(2011\)](#) document outlining their WBP management strategy):

- *No management*: no intentional human interaction.
- *Protection*: active steps to reduce known threats to the ecosystem (e.g. pruning branches with blister rust, preventative chemical treatments for insects, and prescribed fires to remove competing species).
- *Restoration*: active steps to return an ecosystem to a previous condition (e.g. planting new WBP trees and removing competing trees).

Furthermore, the survey defined wilderness areas as follows:

Wilderness areas are protected to retain their natural state, free of roads and other human intervention. The Wilderness Act discourages human impacts within wilderness areas.

On federal lands in general, 80 per cent of respondents either 'strongly support' or 'support' *protection* activities. The same is true of *restoration* activities. However, only 16 per cent of respondents 'strongly support' or 'support' *no management*. In wilderness areas, the support for *protection* and *restoration* drops to 68 per cent, and support for *no management* increases to more than 22 per cent.

The survey posed other questions about environmental and political attitudes. Most relevant to this study are the questions regarding views of global climate change. Since climate change is affecting WBP habitat ([Hansen et al., 2016](#)), public support for WBP management rests in part on public views of climate change. Supplementary regression analyses reveal that individuals who believe climate change is caused by humans are significantly more likely to be willing to pay for WBP management. These results are available upon request. These potentially sensitive questions were asked at the end of the survey to encourage survey completion by as many individuals as possible. More than 62 per cent of survey respondents are either 'very concerned' or 'somewhat concerned' about climate change, with 44 per cent of respondents being concerned about 'serious impact now' and 20 per cent concerned about impact in future.

An equal proportion of survey respondents (41 per cent each) view global climate change as ‘caused mostly by human activity such as burning fossil fuels’ and ‘caused mostly by natural patterns in earth’s environment.’ Of the remaining respondents, 4 per cent do not believe climate change exists and 14 per cent are unsure.

To capture respondents’ risk aversion, the survey posed the following question, adapted from [Alberini et al. \(2010\)](#):

On a winter night with poor driving conditions, which route would you choose to return home:

- A faster route that will take 1 h but is more dangerous due to going over a mountain pass
- A slower route that will take 2 h but is safer due to using well-ploughed and well-lit road

Individuals who chose the ‘more dangerous’ route were assigned 1 in the *risky* dummy variable. The expected sign for the coefficient on *risky* is negative—those who are more risk acceptant (*risky* = 1) are less willing to pay for management of WBP to avoid potential future losses.

The survey also asked a variety of demographic questions, some of which are described below as variables included in the empirical model.

Willingness to pay survey question

The main question of interest for this study concerns respondent WTP for WBP management. The question was presented as follows:

Paying for whitebark pine management

Scientists predict that WBP will continue to decline and may disappear in certain areas entirely if no management action is taken. Suppose the government is interested in setting up a programme for WBP management in the Northern Rockies as funded by a one-time tax. Money from the tax fund would be used solely to pay for WBP protection and restoration.

There are many reasons you might choose ‘yes’ or ‘no’ as your answer to the following question. In making your decision, consider your support for the programme and affordability of the programme along with other factors. There is no wrong answer to this question.

24. Would your household be willing to pay a one-time tax of ‘\$[bid]’ to fund this WBP management programme in the Northern Rockies?

The authors considered further quantification of the potential effects of the *status quo* and of management on the landscape as suggested elsewhere (see [Johnston et al., 2012](#); [Olander et al., 2015](#)). However, the ecological models at this time are not sufficiently developed to produce meaningful information for inclusion in this type of survey. Though the survey did not provide specific predictions for WBP populations, it twice emphasized recent mortality of about 80 per cent of adult WBP trees in certain areas of the Northern Rockies to highlight the extent of the problem.

Given the multi-dimensionality of the available management strategies discussed earlier, effective application of the scope test is infeasible. Constraining the survey area to two different geographic areas (i.e. a smaller and a larger one) would have allowed the scope test but sacrificed fidelity to the issue being evaluated. The WTP question in [Meldrum et al. \(2011\)](#) included randomly selected management levels of 30 per cent, 50 per cent and 70 per cent of the high-elevation forests of the Western United States. Those authors find that the quantity of forest managed is insignificant and attribute this finding to the value placed on the continued existence of high-elevation five-needle pine species. Based on these findings and others from earlier work, the management strategies for WBP are often driven by measures other than acres managed (e.g. age of trees and genetic diversity in a forest). Therefore, while the authors made efforts at further quantification of the ecological effects of WBP management in the survey, such quantification of geographic scope was not deemed meaningful at this time.

Each survey included a randomly selected bid amount between \$10 and \$1 000, with the cost levels matching those in [Meldrum et al. \(2011\)](#). As expected, higher bid values are met with lower proportions of respondents willing to pay for WBP management. Figure 1 provides the list of different bid values along with the proportion of ‘yes’ answers to the WTP question. Compared with the [Meldrum et al. \(2011, p. 232\)](#) survey, the proportion of ‘yes’ answers is either the same (for the \$50 bid) or is lower for most bid amounts. Only for the highest bid amount (\$1 000) did our survey have a higher per cent choosing ‘yes’ (14 per cent versus 9 per cent). Based on Figure 1, the median WTP is somewhere between \$50 and \$100 and the mean WTP is greater than \$100.

Finally, the authors worked to mitigate against other potential problems in the survey design. Outcomes of ecological management actions are uncertain, especially given climate change. To evaluate the public’s potential response to this uncertainty, approximately half the (randomly chosen) surveys included the following statement regarding the uncertainty of management outcomes: ‘Management outcomes will depend on climate-driven reductions in WBP habitat.’ Further, in order to alleviate possible hypothetical bias concerns (see [Neill et al., 1994](#); [Cummings et al., 1995](#)), the survey emphasized consequentiality and realism ([Carson et al., 2014](#)). The introductory letter of the survey included a statement that funding was provided by the US Department of the Interior, in an attempt to highlight the consequence that answers would inform policy makers. The tax payment vehicle was also chosen to ensure that survey respondents would have an incentive to answer truthfully ([Carson and Groves, 2007](#)). In the WTP question, survey takers were reminded to consider programme affordability and were reminded that there was ‘no wrong answer.’

Empirical method

Estimation equation

As is standard in the contingent valuation literature, the random utility framework is used ([McFadden, 1974](#)). The utility of respondent *i* (U_i) is made up of the component that can be systematically explained by observables (V_i) and the random component (ϵ_i) distributed extreme value:

Figure 1 Bid amounts and proportion of "yes" answers to willingness to pay question.

$$U_i = V_i + \epsilon_i$$

The systematic portion of utility is estimated using binary dependent variable estimation models as follows:

$$\Pr(\text{WTP} = \text{yes}) = \frac{e^{V_i}}{1 + e^{V_i}}$$

such that

$$V_i = \beta_0 + \beta_1 \text{bid}_i + \beta_2 x_i$$

where β -s are coefficients to be estimated. *bid* is the randomly assigned bid value from the WTP for each respondent. It is expected that higher bid values in the WTP question lower the probability of 'yes' answers to the WTP question. *x* are other independent variables affecting the systematic component of a respondent's utility. The independent variable descriptions along with their sources are in Table 1, while summary statistics are in Table 2.

Estimates of central tendency of WTP, both the mean and median WTP, are considered, though the estimated mean equals the median WTP for regressions with linear bid variables (Jeanty, 2007). The regression results report the Krinsky and Robb (KR) 95 per cent confidence interval (Krinsky and Robb, 1986). The KR confidence interval allows for asymmetry around the mean/median, which is appropriate for non-linear functions used to estimate WTP measures. Jeanty's (2007) Stata code *wtpcikr* was used to estimate the KR confidence intervals.

Description of covariates

Age, income, gender, race and education variables are included in the WTP equation to control for the respondent's demographic and socio-economic characteristics. Of these, both income and education are expected to increase WTP. About 62 per cent of the respondents completed the survey online, and a

Table 1 Variable descriptions

Variables	Variable description
bid	Bid value (\$100 s) in the WTP question
age	Age in decades estimated based on birth year
inc	Approximate household income in \$100 000 s—middle point of income bracket selected ^a
female	1 if female, 0 otherwise
white	1 if white and non-Hispanic, 0 otherwise
ed_coll	1 if bachelor's degree but no graduate degree, 0 otherwise
ed_grad	1 if graduate degree, 0 otherwise
web	1 if survey completed online, 0 otherwise
stree	1 if seen whitebark pine trees, 0 otherwise
id	1 if resident of Idaho, 0 otherwise
wy	1 if resident of Wyoming, 0 otherwise

^aSurvey income brackets were '\$0–\$9999' and then each bracket increased by \$20 000 up to '\$150 000–169 999.' A choice of '\$170 000 and more' as well as 'Unsure' were provided. Of the returned surveys, for this question 129 respondents chose 'Unsure' and 142 respondents left the answer blank. The latter answers caused a large drop in the number of usable surveys for analysis. The middle point of the income bracket if a respondent selected '\$0–9 999' is \$5 000, and if they chose the bracket '\$90 000–109 999,' it is \$100 000. For those who selected income of \$170 000 or more, \$180 000 was entered for their income.

dummy variable for such completion is included in the regression equation. After observations with missing data are dropped from the dataset, the proportion of web surveys increases to almost 69 per cent, indicating a better completion rate of the surveys taken on the web. A variable describing respondent experience with the species is also included. It is expected that respondents who have seen WBP trees are more likely to be willing to pay for its management. These individuals have both a direct and a passive value associated with the species. Finally, dummy variables for the respondents' states are included to

Table 2 Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
willpay	1207	0.429	0.495	0	1
bid	1207	0.066	1.533	-2.30	2.30
age	1207	5.583	1.505	1.80	9.90
inc	1207	0.768	0.447	0.05	1.8
female	1207	0.341	0.474	0	1
white	1207	0.915	0.278	0	1
ed_coll	1207	0.519	0.500	0	1
ed_grad	1207	0.225	0.418	0	1
web	1207	0.688	0.464	0	1
stree	1207	0.570	0.495	0	1
id	1207	0.470	0.499	0	1
wy	1207	0.146	0.353	0	1

determine if values are different across states. A number of additional covariates are considered and discussed below.

Sample selection correction

The observations are evaluated for sample selection bias, since the survey had an effective response rate of 13.6 per cent. First, zip-code and county-level data for the two samples of addressees are compared. *Out of sample* addresses are those for which the survey was either not returned or incomplete. *In sample* observations are those surveys sufficiently completed to be included in the WTP equation. Second, a Heckman sample selection model similar to [Yuan et al. \(2015\)](#) is specified:

$$\Pr(R_i) = f(y_i; \theta; \vartheta_i)$$

$$\Pr(\text{WTP} = \text{yes}) = g(\text{bid}_i, x_i; \beta; \omega_i)$$

where R_i is the dummy variable taking on the value 1 if a full response is obtained for the survey of the i th individual and taking on the value 0 otherwise. y_i are exogenous characteristics associated with the survey address, θ is a vector of coefficients to be estimated and ϑ is the random error term in the selection equation. The WTP equation is described as a non-linear function of bid and x variables, the vector of coefficients β and the random error ω . This two-equation Heckman probit model is estimated using the *heckprobit* command in Stata 13. The test for presence of sample selection bias evaluates the correlation, ρ , between the error terms of the two regression equations (ϑ and ω). Sample selection bias is deemed present if the null hypothesis $H_0: \rho = 0$ is rejected. The likelihood ratio (LR) test is used to evaluate the hypothesis. The independent variables (y) included in the selection equation are briefly described in Table A-1 of Appendix A available at *Forestry* online. A variable to control for the incentive level takes on the value of \$0, \$1 or \$2 depending on the amount included in the first survey mailing. The remaining variables closely mirror the selection variables from [Yuan et al. \(2015\)](#) as exogenous predictors of selection. No statistical evidence of sample selection is found in the present analysis as discussed in Appendix A. Also considered was principal component regression analysis to

reduce multicollinearity in selection equations. Still the null hypothesis that the two equations' error terms were correlated could not be rejected. The results section, therefore, focuses on simple probit analyses.

Results

The contingent valuation model presented in Column 1 of Table 3 estimates that the average WTP for WBP management is ~\$135 per household, with the KR 95 per cent confidence interval located between \$86 and \$181 (in 2015 USD). The point estimate suggests that the total WTP for Idaho is over \$78 million given its 579 797 households (i.e. 135 times 579 797), for Montana is almost \$55 million given 405 525 households, and for Wyoming is over \$30 million given 222 846 households. Over the three states, the total WTP for management of these species is over \$163 million, given over 1.2 million households, and the KR 95 per cent confidence interval is between \$104 million and \$219 million. These estimates, qualitatively robust across different regression specifications, are based on the regression using a linear bid variable, which results in the same estimate for a mean and median WTP ([Jeanty, 2007](#)).

The estimated WTP per household of \$135 is somewhat smaller than the value found by the [Meldrum et al.](#) studies discussed earlier. A few plausible explanations for this discrepancy emerge. While [Meldrum et al.](#) evaluate the management of multiple different five-needle pine species, the present study considers just one of the five. Further, their studies focus on managing white pine blister rust rather than a collection of issues threatening the single species of WBP. The targeted population is another potential explanation for the lower estimated WTP in this study, which includes only three of the nine Western states included in [Meldrum et al.](#) The states in the present study have lower average incomes, likely leading to lower WTP.

The logged version of the linear bid variable replaces the regular version in column 3 of Table 3. This replacement allows for different mean and median WTP estimates. The mean WTP increases to ~\$187 and the median WTP is estimated at \$60 per household. This tendency for a low median WTP relative to the mean is common in the contingent valuation literature and is caused by a positively skewed WTP distribution (with a long right tail). While some argue that median WTP is a more conservative welfare measure and is a safer estimate to analyse, mean WTP is standard in the current literature and 'is the classic welfare measure most appropriate for benefit-cost analyses' ([Alberini et al., 2007](#), p. 221).

Given the median voter theorem (see [Black, 1948](#)), the estimated median WTP better represents the maximum tax level that could pass a public referendum. However, due to free riding inherent in the provision of public goods, the level of tax that would pass a referendum would collect insufficient funds to provide the efficient level of public goods. The authors here, as in related studies, focus on the results of the linear bid variable for which mean WTP equals median WTP and, therefore, is a more conservative estimate of mean WTP than the results with a logged bid variable.

Marginal effects

Using the preferred specification and sample, Table 3 displays the results for probit models with coefficient estimates in

Table 3 Probit estimates of $Pr(WTP = \text{yes})$

Variables	(1) Probit	(2) Probit marginal effects	(3) Probit	(4) Probit marginal effects
bid	−0.170*** (0.014)	−0.066*** (0.005)		
lbid			−0.381*** (0.027)	−0.148*** (0.011)
age	−0.010 (0.027)	−0.004 (0.010)	−0.013 (0.027)	−0.005 (0.010)
inc	0.302*** (0.097)	0.117*** (0.038)	0.322*** (0.098)	0.125*** (0.038)
female	0.232*** (0.087)	0.090*** (0.034)	0.225** (0.088)	0.088** (0.034)
white	−0.004 (0.140)	−0.002 (0.054)	−0.060 (0.140)	−0.024 (0.055)
ed_coll	0.188* (0.099)	0.073* (0.038)	0.210** (0.100)	0.081** (0.039)
ed_grad	0.388*** (0.122)	0.153*** (0.048)	0.364*** (0.123)	0.143*** (0.048)
web	0.264*** (0.088)	0.101*** (0.033)	0.297*** (0.089)	0.114*** (0.033)
stree	0.287*** (0.081)	0.110*** (0.031)	0.297*** (0.082)	0.115*** (0.031)
id	−0.109 (0.085)	−0.042 (0.033)	−0.117 (0.086)	−0.046 (0.033)
Wy	0.030 (0.120)	0.012 (0.047)	0.034 (0.121)	0.013 (0.047)
Constant	−0.508** (0.248)		−0.908*** (0.248)	
Observations	1207		1207	
Mean WTP	135***		187***	
KR lower bound	87		87	
KR upper bound	181		590	
Median WTP	135***		60***	
KR lower bound	87		48	
KR upper bound	181		74	

Note: KR Krinsky and Robb confidence interval bounds.

Standard errors in parentheses

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$.

column 1 and marginal effects in column 2. Logit analyses provided qualitatively similar effects and are available upon request. Given that probit models are non-linear, the coefficients are not interpretable as influences on the outcome variable. Instead, the calculated marginal effects at mean values of independent variables show the change in conditional probability of WTP given a one-unit change in the independent variable (while holding other independent variables constant). Seven independent variables have statistically significant effects on WTP for management of WBP.

Both the bid value and household income have statistically significant effects on WTP in expected directions. As the bid value increases by \$100, the approval rate decreases by ~7 percentage points (as seen in the probit marginal effect for *bid* in column 2 in Table 3). A \$10 000 rise in annual income increases approval rate

by ~12 percentage points. Corresponding income elasticity of demand is ~0.21, which is within the range (0.2–0.3) that [Kriström and Riera \(1996\)](#) find to be typical. This income elasticity suggests that the environmental good under consideration is a normal good and, more specifically, a necessity.

Gender and education level also affect WTP for management. Other studies often do not include these two independent variables in their equations, while some studies (e.g. [Moore et al., 2011](#); [Carson et al., 2014](#)) find no real influence for these variables. Females select the ‘yes’ answer to the WTP question 9 percentage points more frequently than non-females, all else constant (Non-females include males as well as those who chose not to answer the gender question or who chose ‘other’ or ‘prefer not to answer.’ The latter two categories made up fewer than 2% of respondents in the sample). A college degree

increases the probability of WTP for management by ~7 percentage points as compared to individuals with no college degree. A graduate degree increases the probability of approval by ~15 percentage points in a similar comparison. Those who completed the survey online are ~10 percentage points more likely to be willing to pay for management than those who filled out a paper survey, while holding income and other variables constant.

Finally, experience with WBP has a significant positive effect on WTP. Individuals who had seen a WBP tree prior to taking the survey are 11 percentage points more likely to be willing to pay for management of the species, suggesting that outdoor experiences increase support for ecological management.

Additional covariates considered

One worry about including incentives with surveys is that they might affect responses to the WTP question. The incentive coefficient is both statistically and economically insignificant when the variable is included in the WTP equation. Furthermore, the remaining results are qualitatively unchanged, including the estimated WTP.

Uncertain effects of climate change on WBP could also trigger different responses depending on individuals' risk aversion. In unreported regressions available upon request, the expected negative coefficient on the *risky* dummy variable is consistently found but the result is always statistically insignificant. Inclusion of this variable left the remaining results qualitatively unchanged.

Additional regressions that sequentially include variables related to respondents' views on climate change and politics are available upon request. Respondents' answers to questions about climate change, political leaning, government spending, and trust in different information sources were used to construct dummy variables. Including these dummy variables, one at a time, in the model results in expected signs. For example, holding all else constant, individuals who are 'very concerned' about climate change or think it is a serious problem right now are willing to pay more for management of WBP. On the other hand, those with 'strongly conservative' political views, those who favour 'smaller government with fewer services,' and those who believe 'too much' federal spending goes to land management are willing to pay less for WBP management. Similarly, individuals who trust information from more conservative news sources, such as 'Fox News' or 'conservative talk radio,' exhibit smaller willingness to pay on average. In contrast, individuals who trust information from more liberal news sources, such as 'MSNBC,' exhibit larger willingness to pay on average. The respondents who trust information about the environment from scientists are willing to pay more for WBP management than those who do not hold much trust in scientists. Across most of these regressions, the mean WTP remains between \$133 and \$138 per household. Only when including the dummy variable identifying individuals who believe 'too much' federal spending goes to land management does the mean WTP drop to \$116.

Finally, approximately half the surveys included the following statement in the WTP question: 'Management outcomes will depend on climate-driven reductions in WBP habitat.' Adding a dummy variable for the presence of this statement in the regression analysis results in a statistically insignificant

coefficient. This additional emphasis on uncertain management outcomes therefore does not affect the main results of the study.

Discussion

This study provides a contingent valuation of management related to a particular threatened tree species. In so doing, the study supplies forest managers with information about public values as they pertain to WBP and expands the literature on contingent valuation. As noted earlier, past contingent valuation studies have focused on ecosystems or on broader threats to trees species rather than on individual plant species themselves. Without experimental research to disentangle any confounding effects, we cannot be sure whether people value individual species separately from their ecosystems or broader threats. However, the present study does provide initial evidence for a single species that can be compared with other types of results. Information about individual species might be important for ecological managers trying to make decisions in the face of climate change. The case of WBP is particularly instructive given its function as a keystone species, its rapid decline in response to climate change, and its qualification as an endangered species.

On 28 April 2017, the US Court of Appeals for the Ninth Circuit ([Wildwest Institute v. Kurth, 2017](#)) ruled that WBP qualifies for protection under the Endangered Species Act, though this protection is subject to budgetary constraints (i.e. protection is 'warranted but precluded'). Some land managers across the WBP range find resources in their budgets to enact protection and conservation programmes for WBP, but these decisions are being made without a sense of public support. Since few, if any, land management agencies have designated funding for WBP management, estimating how much is currently spent on management each year is difficult. This WTP assessment of the tri-state area suggests that the species is highly valued and that spending on its protection is warranted.

Our study also suggests the people of the Northern Rockies favour management activities in formally designated wilderness areas, which is currently not allowed by law. This result agrees with findings that large majorities of people support active management of hemlock woolly adelgid as it affects hemlock species in backcountry or wilderness areas in the Eastern United States (see [Moore et al., 2011](#); [Poudyal et al., 2016](#)). Taken together, these findings fit with the suggestion of [Hansen et al. \(2016, p. 21\)](#) that discussion is necessary to determine 'appropriate levels of active management on restricted federal lands such as wilderness.'

The potential value of these results for managers, who must generate support for and deal with opposition to their activities, is considerable. This study provides managers of public lands in the Northern Rockies with an estimate of how important – in dollar terms – a threatened tree species is to the public. As scientific understanding and the actual effects of climate change on WBP progress, WTP information will be crucial in helping managers decide how to allocate limited resources strategically to deal with declining populations. Information about the members of the public who are most willing to pay (e.g. women, individuals with more education and higher income, those who

have seen WBP) is also valuable for efforts to build supportive coalitions for action.

For forest managers, the results of this study serve as a complement to existing research. The presented results add to work on valuations of tree disease management and valuations of other natural resources found in the region. Our results also complement research that assesses non-economic values of natural resources. Additionally, the study provides information about public views on climate change and how those views relate to valuing ecological management.

A number of potential avenues exist for extending and improving upon this study. Research on WBP might expand to the broader Western US region to assess the aggregate value of the species in the US as well as differences in valuation between regions. For that matter, having information about WTP for WBP in other regions of the US would also be useful. Further, valuations of other plant species are necessary to provide managers with sufficient information to make decisions about tradeoffs in managing different species. Finally, experiments that reveal the conditions under which people are willing to pay for management of species might also be informative. Many important management decisions await, probably sooner than hoped, and will require more information than is currently available.

Supplementary data

Supplementary data are available at *Forestry* online.

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Conflict of interest statement

None declared.

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Disclaimer

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