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Public perception and valuation of long-term ecological monitoring

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Abstract. Organizations tasked with implementing long-term ecological monitoring programs often struggle to stay funded. Government agencies are typically the only entities with sufficient capacity and motivation to support long-term scientific programs that generate data for environmental management and conservation. Taxpayers bear this funding burden, yet we know of no studies assessing public perception of government-led long-term monitoring. We present the results of a survey designed to assess willingness to pay (WTP) for the benefits resulting from long-term ecological monitoring in Southeast Alaska for residents and visitors. We hypothesized that four factors have the potential to influence preferences for long-term ecological monitoring: (1) type of ecosystem service monitored (intermediate vs. final); (2) place of residence; (3) prior knowledge of monitoring; and (4) sociodemographic characteristics. We defined final ecosystem services as ecosystem attributes that have clear relevance to human well-being and intermediate ecosystem services as those required to produce final services. We found a greater WTP for programs monitoring intermediate ecosystem services, longer-running programs, and programs covering a larger spatial extent. Respondents with higher income and conservative political preferences were more likely to choose no monitoring program at all (status quo), whereas respondents with previous knowledge of monitoring were generally more supportive of long-term monitoring programs.

Key words: choice experiment; ecological monitoring; ecosystem services; non-market valuation; public perception; willingness to pay.

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Introduction

Effectively managing natural resources requires sustained monitoring of ecosystem services to provide the foundation for assessment and decision-making. Long-term monitoring, or repeated empirical measurements collected continuously over a decade or longer (Lindenmayer and Likens 2010), can provide indicators of changes in animal abundance or environmental conditions that initiate management actions (Parr et al. 2003, Legge et al. 2018, Lindenmayer and Likens 2018). Monitoring is not only valuable for informing management actions, but also valuable for documenting long-term environmental change or anomalous events, increasing public awareness, or improving scientific understanding of an ecosystem (Burt 2003, Nichols and Williams 2006, Tulloch et al. 2013, Lindeberg et al. 2018). The rapid pace of global environmental change lends greater urgency to the development and continuation of monitoring programs for early detection of trends and tipping points (Parr et al. 2003). Programs such as the Mauna Loa Observatory time series of atmospheric CO_2 concentrations measured since the late 1950s (Keeling et al. 1995) are crucial for detecting and contextualizing future environmental change. While scientists appear to value long-term ecological monitoring, it is not clear whether the public shows a similar degree of support for these programs (Swallow and Liu 2017).

Sustaining such programs requires, among other things, ongoing funding and well-developed partnerships (Lindenmayer and Likens 2010, Sergeant et al. 2012). Some of the oldest and most influential monitoring programs, such as 400 yr of monitoring of sunspot activity initiated by Galileo (Galilei 1613), struggle to maintain funding and institutional support (Owens 2013). As long-term monitoring programs mature, the return on investment may be substantial (Lohner and Dixon 2013) and increased exposure may incite the public will necessary to create management policies based on monitoring results (Lindenmayer et al. 2018). However, the immediate benefits of long-term monitoring are not always apparent and, as a result, funding for monitoring is vulnerable as budgets for science and management shrink (Schindler and Hilborn 2015). Agency-sponsored programs that are supported by public funds are particularly important for natural resource management. For example, the U.S. National Marine Fisheries Service has been conducting trawl surveys along the Atlantic coast since the 1960s to monitor fish populations and environmental conditions in support of fishery management (Stauffer 2004). Due to the distinctive characteristics of individual ecosystems, the most effective natural resource policies are often developed at local to regional scales using specific, place-based knowledge (Yaffee 1997, Rodhouse et al. 2016, Lemieux et al. 2018). Thus, understanding public support for and knowledge of monitoring programs at a comparable spatial scale may be important for informing their sustainability. Here, we demonstrated a novel application of non-market valuation to examine public support for taxpayer-supported long-term ecological monitoring and developed a regional case study to test the approach in Alaska. Our study could inform other surveys evaluating public valuation of long-term monitoring programs in other regions throughout the world.

Since long-term monitoring programs are not bought and sold in a market, a non-market valuation approach must be used to measure the economic value people place on monitoring. Broadly, two types of preference data can be gathered in the pursuit of non-market values. One is called revealed preference, in which researchers observe actual consumer behavior. The other is called stated preference, in which the researcher elicits preference information directly from respondents and that preference information is not based upon actual behavior. Within stated preference elicitation methods, the most common are contingent valuation (Mitchell and Carson 2013) and choice experiments (Adamowicz et al. 1998). Choice experiments are useful when varying multiple attributes over multiple levels, particularly when respondents are asked to choose between different unfamiliar products. For example, Carson et al. (2015) used a choice experiment to explore which attributes are important in new park development in Malaysia. Similarly, Interis and Petrolia (2016) used a choice experiment to explore non-market values around ecosystem service improvements stemming from coral reefs, salt marshes, and mangrove forests.

We used a discrete choice experiment designed to measure willingness to pay (WTP), the maximum amount an individual will pay for a good or service, for long-term monitoring of three pairs of coupled intermediate and final ecosystem services (oceanography and whales; climate and glaciers; stream temperature and salmon). We hypothesized that four factors have the potential to influence public perception of taxpayer-supported long-term ecological monitoring: (1) type of ecosystem service monitored (Miller et al. 1998, Stankey and Shindler 2006); (2) place of residence, as a proxy for place-based relationships of individuals to natural systems (Loomis and White 1996, Kim et al. 2012); (3) prior knowledge of monitoring (Munoz et al. 2012); and (4) sociodemographic characteristics (USFWS 1994, Van den Berg and Koole 2006). We present the results of a survey assessing residents' and visitors' WTP for long-term ecological monitoring of a suite of physical and biological ecosystem components in Southeast Alaska. The results can be used to inform the public discourse on and potentially improve public support for monitoring in our study region.

Materials and Methods

Ecosystem services in the study area

Southeast Alaska is home to abundant fish and wildlife that support thriving ecotourism and seafood industries. Between October 2014 and September 2015, total visitor spending in Southeast Alaska was over $600 million (McDowell Group 2016). Humpback whale (*Megaptera novaeangliae*) viewing is a major draw for tourists visiting the coastal communities of Southeast Alaska, particularly in Juneau, where over $25 million in ticket sales revenue is generated annually (S. Teerlink, *personal communication*). Many tourists also travel to Southeast Alaska for glacier viewing; for example, the Mendenhall Glacier Visitor Center in Juneau, Alaska, has the highest visitation of all U.S. National Forest Service system visitor centers (J. Neary, *personal communication*). The seafood industry creates nearly $1 billion of economic output in Southeast Alaska, and salmon (*Onchorhynchus* spp.) account for the majority of Southeast Alaska's commercial seafood value (McDowell Group 2015). Forestry and mining are also major industries in the region, but we did not focus on them here.

For our WTP surveys, we divided monitoring programs into those measuring final or intermediate ecosystem services (Table 1). We use these terms as defined by Ringold et al. (2013), where final services are "biophysical features, quantities, and qualities that require little further translation to make clear their relevance to human well-being," and intermediate services are "those required to produce final services." Intermediate ecosystem services act as supporting services that directly or indirectly influence production of final ecosystem services (Johnston et al. 2013). Johnston et al. (2017*b*) caution against asking respondents to value intermediate ecosystem services without directly linking them to final ecosystem services, which more directly affect utility. As such, we made direct links between intermediate and final ecosystem services in the survey. For example, monitoring the abundance of humpback whales in Southeast Alaska measures a final ecosystem service that directly relates to marine mammal and tourism management. In comparison, the oceanographic conditions in areas occupied by humpback whales may determine the distribution and density of food resources for whales and thus their summertime locations, but these environmental factors are not observed or considered by most tourists. Therefore, oceanographic conditions and primary productivity can be thought of as intermediate ecosystem services supporting the final ecosystem service of whale viewing. We acknowledge that specific monitoring programs do not always have an obvious direct benefit to society (e.g., monitoring for knowledge's sake; Lindenmayer and Likens 2010), but for analytical purposes, the intermediate vs. final ecosystem service dichotomy enabled us to understand whether respondent preferences for monitoring depend on the direct benefits to humans provided by the ecosystem service. Surveys presented respondents with one of three potential intermediate/final ecosystem service pairings that are commonly measured in the Southeast Alaska: (1) oceanographic conditions/humpback whale abundance, (2) stream temperature patterns/salmon abundance, and (3) climate patterns/glacier volume change.

Respondent selection

Because of the importance of tourism in the study region, we elicited preference information from both residents of Alaska and visitors to Southeast Alaska, with the intent of obtaining responses from people who personally benefit from ecosystems in the study region (e.g., visitors that have spent money to enjoy a unique natural

Table 1. Attributes and attribute levels of the survey.

Attributes	Attribute definition	Attribute levels
Ecosystem service	Type of monitored ecosystem component	Intermediate (oceanography, climate, stream temperature) Final (whales, glaciers, salmon)
Spatial extent	Extent of area to be monitored	Port of Juneau Inside Passage
Time extent	Length of funded monitoring program	10 yr 50 yr
Price ($US)	Total price per individual taxpayer over program life	0, 10, 15, 20, 30, 50, 75,100, 150

Note: For this study, we considered the spatial extent of the "Inside Passage" to refer to the ~800-km coastline winding through the Alexander Archipelago in Alaska.

environment). The sample was therefore not representative of the taxpaying U.S. population along some sociodemographic margins (Table 2). Relative to the U.S. population, our respondents had more post-secondary education, had higher income, and were less racially diverse. To survey visitors (non-residents), we obtained a convenience sample (Johnston et al. 2017*a*) using intercept surveying of individuals disembarking various cruise ships in downtown Juneau during summer 2015. To ensure the survey effort was spread across different types of respondents, we used the publicly available cruise ship docking schedule (https://www.experienceketchikan.com/support-files/jnu_2015.pdf) to stagger both the time of day and day of the week when surveying occurred. To survey residents, we used intercept surveying to obtain a convenience sample of individuals in the departure lounge of the Juneau International Airport during summer 2016. The city of Juneau, along with nearly all communities in Southeast Alaska, is not connected to a continental road system and can only be reached by air or boat. While sampling at the airport is biased toward individuals who travel outside of Juneau, many residents regularly use air travel to commute among communities in Alaska, where the per capita rate of enplanements per year is substantial compared to other U.S. states (Northern Economics Inc. 2009, FAA 2016). We again systematically staggered the time of day and day of the week during which surveying occurred. In both years, we systematically alternated among the three different survey versions to achieve a similar number of respondents for each version.

Survey design

We surveyed peoples' preferences for the information resulting from monitoring programs using a discrete choice experiment to quantify their WTP for each of the three pairs of intermediate and final ecosystem services. Surveys provided to all respondents presented these six components, in order: (1) general introduction to long-term monitoring, (2) three questions gauging previous knowledge of long-term monitoring programs, (3) preamble and graphic illustration describing the scientific value of one of three pairs of ecosystem components, (4) one question gauging previous knowledge of one of the three pairs of ecosystem services, (5) choice scenarios, and (6) standard sociodemographic information. Only components (3) and (5) varied across surveys, while the remaining components remained static for all surveys (Appendix S1). The surveys were conducted in person by researchers at the University of Alaska Southeast, with approval from the University of Alaska Institutional Review Board (protocol #15-12).

At the beginning of each survey, respondents were asked to read a short introduction describing long-term ecological monitoring and why scientists are generally interested in collecting environmental data for many years. At the end of this introduction, respondents were told they would be presented with multiple long-term monitoring program choices and should consider their current budget and other factors affecting how their money is spent before choosing each preferred program (Fig. 1; Appendix S1). Before choosing preferred options in the discrete choice experiment, respondents were also asked to read a preamble describing the purpose of measuring one of the three ecosystem service pairs (oceanography/whales, stream temperature/salmon, or climate/glaciers; see example in Fig. 1). The expected benefits were described as the data produced by monitoring and its application to science and policy questions, as viewed by scientists and broadly supported in the long-term monitoring literature (Burt 2003, Fancy et al. 2009, Sergeant et al. 2012). This preamble distinguished our survey from other previous studies on public understanding of science (Munoz et al. 2012), which typically present questions in the absence of preceding value judgments. The preamble was a crucial link to interpreting survey results, allowing us to assess whether respondents were willing to pay for monitoring based on stated benefits. Although there may be a range of perceived benefits and costs of long-term monitoring, we described benefits solely in terms of new scientific knowledge that is generated from long-term monitoring (Appendix S1). We did not describe specific policy applications of long-term monitoring data to reduce the potential for respondents to base their valuation of long-term monitoring on whether potential resource management decisions arising from monitoring data are worthy of taxpayer support.

After the preamble, each respondent was asked to choose their most-preferred and least-

Table 2. Sociodemographic characteristics of survey respondents.

Sociodemographic characteristics	N	Mean	Percentage of respondents	Standard error	Min	Max	U.S. Pop.	Percentage of U.S. Pop.
Age (yr)	296	48		16	18	89	40	
Income (×1000 $US)	302	112		64	8	220	59	
Number of visits to federally protected lands	302	4		2	0	6	...	
Proportion belonging to environmental organization	302	0.5		0.5	0	1	...	
Female	300		47					51
Non-white	292		7					23
Unemployed	298		2					5.3
Retired	302		21					15
Politically conservative	302		24					...
Prior awareness of monitoring programs	302		64					...
Prior awareness of benefit of monitoring programs	302		57					...
Prior awareness of taxes funding monitoring programs	302		56					...
Prior awareness of monitoring programs in survey	302		51					...
Alaska resident	302		26					0.2
Bachelor's degree or higher education	302		63					30

Note: N respondents differ slightly because some respondents did not answer every question. Ellipses denote missing data.

preferred options in four different choice scenarios (Appendix S1). Within each choice scenario, each option was defined as a combination of ecosystem service type, spatial extent of monitoring, temporal extent of monitoring, and per capita cost of monitoring (Table 1). In addition to a status quo (no monitoring program) option, each choice scenario contained four long-term monitoring options. Presenting five options per choice scenario allowed us to obtain, from each respondent, preference information among four distinct goods combining ecosystem service type, spatial extent, and length of monitoring program. While including five choices per choice scenario may have increased cognitive burden and introduced incentive compatibility issues (Carson and Groves 2007), several studies (e.g., see Haider and Ewing 1990, Layton and Brown 2000, Lusk and Schroeder 2004) successfully conducted choice experiments using at least five choices per choice scenario. The three ecosystems and concomitant ecosystem service pairs were blocked into groups of 20 (n = 140 respondents for oceanography and whales; n = 140 for climate and glaciers; and n = 120 for stream temperature and salmon). We also varied the order in which respondents saw different ecosystems and spatial extents within each survey. Finally, the order of options was randomized so that the option with the highest level of public good was seen at different positions within a choice scenario. Monitoring costs were not intended to be precise, but to represent the relative differences in cost of monitoring different ecosystem services.

In two places, the survey indicated that the payment for long-term monitoring would be through a tax mechanism. First, the preamble primed respondents to think about taxes as the payment vehicle by noting that long-term monitoring programs are typically paid for using taxpayer dollars. Second, respondents were asked to "indicate the program you would choose to fund assuming you were actually going to pay the individual taxpayer cost listed." Monthly program costs ranged from $10 to $150. For a given monitoring program, costs were randomized across choice scenarios. To avoid strict dominance within choice scenarios, it was always more expensive to fund a longer-running program or a program that covered a larger spatial extent. Finally, respondents also answered 11 standardized questions on sociodemographic parameters (Appendix S1) and one open-ended question asking for any additional comments.

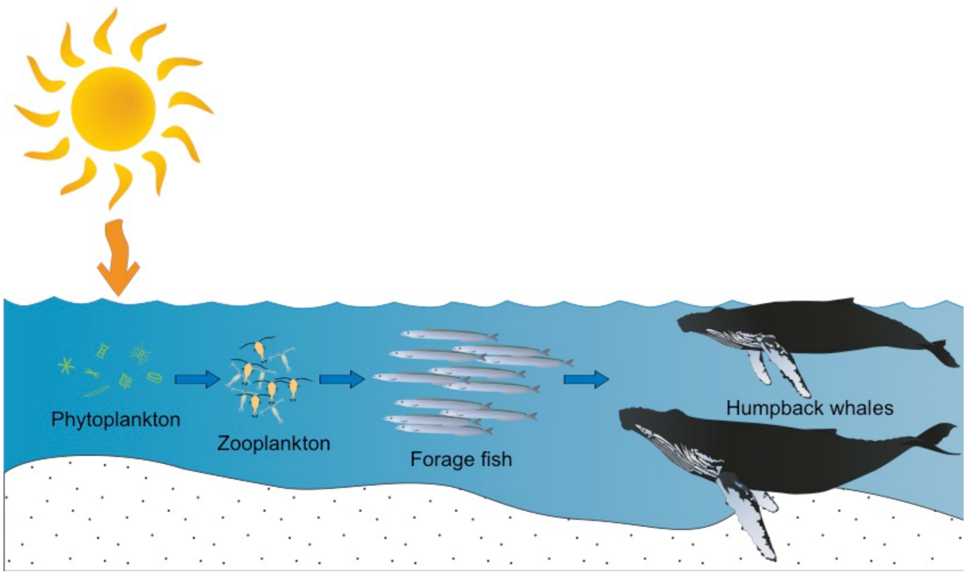
Survey response analysis

We modeled responses using the random utility model (McFadden 1974). We assumed (1)

Monitoring programs for humpback whales and oceanography

Humpback whales mainly reside in southeastern Alaska waters during the summer months. In addition to being important animals for attracting local tourism, humpback whales indicate that the surrounding environment has adequate habitat and food resources to support whale populations. Scientists would say that healthy whale populations reflect healthy marine ecosystems.

Oceanographic conditions describe the ocean environment surrounding whales. Oceanographers measure things like water temperature, salinity, and chlorophyll. Chlorophyll is an indicator of how much phytoplankton is in the water. Phytoplankton are a food source for zooplankton, which in turn feed forage fish, which in turn feed whales. Scientists have identified certain oceanographic conditions that support healthy whale populations.



Q4 Before today, did you have knowledge about long-term monitoring programs for humpback whales and the ocean environment that supports them?

☐ Yes ☐ No ☐ Uncertain

Fig. 1. An example of introductory material presented to survey respondents, including general introduction to long-term monitoring, preamble describing the scientific value of monitoring humpback whales and oceanography, and graphic illustration supporting the monitoring preamble.

each choice was a discrete event; (2) utility (well-being) derived from a choice varied randomly across individuals; and (3) each respondent selected the choice that maximized their utility. By also assuming an independent and identically extreme value distribution in the error terms, we were able to estimate the model using McFadden's conditional logit (McFadden 1974). To relax the restrictive of independence of irrelevant alternative assumption, we also estimated a random parameters logit (RPL) model to account for unobserved heterogeneity in respondent preferences. We ran five different RPL specifications using a simulated maximum likelihood routine with normally distributed random parameters. All specifications were run with 2000 Halton draws of the data (Train 2000, Bhat 2001). Halton draws are intelligent, as opposed to random, and reduce simulation error and computing time. Full correlations between the random parameters were allowed, and standard errors were calculated using the delta method (Hole 2007). All analyses were conducted in Stata 15 (StataCorp 2017).

The first RPL specification included individual attribute levels with no interactions, including a status quo dummy to control for the utility associated with choosing no monitoring program. The parameter estimates and WTP values calculated from this first specification of the RPL provide insights into how individual survey attributes (e.g., temporal extent; Table 1) influence respondents' monitoring program choices, while holding other attributes constant. The attribute-level parameter estimates are interpreted relative to a baseline attribute level. For example, interpretation of the estimated coefficient for the temporal extent attribute level of 50 yr (i.e., 50-yr monitoring program) is relative to the omitted attribute level of 10 yr. The attribute parameters, which were estimated individually while all other variables were held constant at mean values, were divided by the estimated price parameter to calculate a marginal WTP value.

Next, we ran an RPL model that interacted the full group of individual monitoring attributes with sociodemographic and attitudinal characteristics. To select the appropriate number of characteristic interactions, we ran models in which we rotated through sets of two, three, and four groups of characteristic interactions. Models with more than two groups of characteristic interactions performed poorly based on the three goodness-of-fit measures (Akaike's information criterion, log likelihood, and McFadden's adjusted R^2) and were thus excluded. To further explore status quo responses, we ran a third RPL model with baseline attributes, as well as interactions between status quo and several sociodemographic and attitudinal characteristics, including a dummy for education of at least a bachelor's degree, prior awareness of monitoring programs, membership in an environmental organization, conservative political preferences, income, and resident status.

While examining the influence of individual attribute levels is a valuable exercise for those designing and implementing monitoring programs, the first two RPL specifications have two limitations: (1) It is not possible to test for possible scope effects in WTP for the different attributes because one of the two levels of each attribute was omitted in estimation; and (2) some respondents may have made their choices based on combinations of attributes, not individual attributes. Therefore, we ran a fourth specification of the RPL using two-way interactions between spatial and temporal extent of each monitoring program so we could calculate and statistically compare incremental WTP for joint quantifiable attributes of a monitoring program. These parameter estimates are interpreted relative to the status quo (no monitoring program) choice. From the parameter estimates of the fourth RPL specification, full WTP distributions were constructed by taking 10,000 random draws of the data, multiplying by the parameter estimates from the model, and calculating WTP values. Statistical pairwise testing of the WTP distributions was conducted using the full combinatorial approach of Poe et al. (2005), in which two independent distributions obtained from simulation methods are compared for equality. By comparing the WTP distribution for a 10-yr monitoring program in the Inside Passage with the WTP distribution for a 50-yr monitoring program in the Inside Passage, for example, we can see whether there exists a statistical difference between 10- and 50-yr monitoring programs at the spatial extent of Inside Passage. Finally, to increase our confidence in the results explaining variation in the most-preferred outcomes, we also ran an RPL model explaining variation in least-preferred outcomes with baseline attributes and a status quo alternative-specific constant. We expect that the signs and significance of the covariates would be either statistically significant and the opposite sign as that of the first model, or statistically insignificant.

For all RPL specifications, N is the number of unique choices faced by all respondents. In all five specifications, a statistically significant and negative estimated coefficient for a given attribute is interpreted as negatively influencing choice probability, while a statistically significant and positive estimated coefficient positively influences choice probability. Model fits were described using McFadden's adjusted R^2, where a value between 0.2 and 0.4 represents an "extremely good fit" (Louviere et al. 2000).

Results

Description of respondents

Out of 366 surveys returned, 223 non-residents and 79 residents fully completed the choice scenario portion of the survey, answered the preliminary questions, and provided complete sociodemographic information ($N = 302$, for an 84% accuracy rate; Table 2). The majority of respondents were white (93%), high-income earners (mean = \$112,351; median income bin = \$100,000–149,999), and well educated (63% obtained a bachelor's degree or greater). Approximately one-quarter of respondents were Alaska residents (26%) or, more specifically, residents of Southeast Alaska (23%). A majority of respondents had previous knowledge of long-term monitoring programs (64%), while slightly more than half of the respondents had previous knowledge of the specific types of monitoring programs presented in the survey (51%).

Respondent choice modeling

The unit of observation for the RPL is individual i's choice c in scenario s. Each individual answered four choice scenarios, and each choice scenario contained five choices. The estimation sample was thus 302 respondents × 4 choice scenarios × 5 choices = 6040 observations. In all specifications of the RPL, respondents were less likely to choose a long-term monitoring program as price increased (Tables 3 and 4). Respondents were more likely to choose longer monitoring programs with a larger spatial extent (50-yr program for the Inside Passage; Tables 3 and 4), but less likely to choose a final ecosystem service for monitoring over intermediate ecosystem services (Table 3).

In the first RPL specification, where WTP values for individual survey attribute levels were modeled with no interaction terms, all estimated coefficients were statistically significant ($P < 0.05$, McFadden's adjusted $R^2 = 0.24$; Table 3). The average respondent was willing to pay \$383 more for a 50-yr monitoring program than a 10-yr program and \$174 more for a monitoring program spanning the Inside Passage as opposed to only the Port of Juneau (Table 3). The average respondent was willing to pay \$70 less for a monitoring program collecting data on final ecosystem services as opposed to intermediate ecosystem services (Table 3).

The results of the second RPL specification, in which we interacted sociodemographic and attitudinal characteristics with the full suite of monitoring attributes and levels, appear in the third and fourth columns of Table 3. The best-fitting model included attribute interactions between prior knowledge of long-term monitoring and conservative political preferences (McFadden's adjusted $R^2 = 0.21$). Four interaction terms were statistically significant, three with positive coefficients (prior knowledge of long-term monitoring and price, $P < 0.01$; conservative political preferences and ecosystem service type [final], $P < 0.10$; conservative political preferences and choose no monitoring program, $P < 0.05$; Table 3) and one with a negative coefficient (prior knowledge of long-term monitoring and choose no monitoring program, $P < 0.05$; Table 3). Therefore, respondents with prior knowledge of long-termed monitoring had higher marginal utility of income for long-term monitoring and were less likely to choose no monitoring program (status quo). Respondents with conservative political preferences were more likely to choose a program monitoring a final ecosystem service and were also more likely to choose no monitoring program (status quo).

We more thoroughly explored the status quo effect evident in the first two specifications (columns 5 and 6 of Table 3). Three interaction terms were statistically significant. The interactions between status quo and income, and status quo and conservative political preferences were both positive ($P < 0.10$), indicating that respondents in these groups are more likely to choose no monitoring program (status quo; Table 3). Conversely, those with prior knowledge of long-term monitoring are less likely to choose no monitoring program (status quo, $P < 0.10$; Table 3). These results corroborate our findings from the second model in Table 3.

In the RPL specification in which WTP values were estimated for two-way interactions of spatial and temporal extent of monitoring programs, all estimated coefficients were statistically significant ($P < 0.01$, McFadden's adjusted $R^2 = 0.17$; Table 4) and corroborated the results of the first RPL specification (Table 3). Positive coefficient values for the combinations of spatial and temporal monitoring program attributes demonstrated that respondents were more likely to choose any monitoring program over no monitoring program at all (status quo choice). Respondents exhibited substantial preference heterogeneity across all survey attributes (standard error around the mean effect ranged from 0.043 to 1.687; Table 4). Based on distributions of WTP values for different combinations of spatial and temporal

Table 3. Diagnostics, parameter estimates, and willingness to pay (WTP) calculations from random parameters logit (RPL) models.

Model outputs	RPL baseline			RPL interaction			RPL status quo		
	Value	β	SE	Value	β	SE	Value	β	SE
Diagnostics									
N	6,040			6,040			6,040		
Log likelihood	−1252			−1232			−1244		
McFadden's adjusted R^2	0.24			0.22			0.22		
Model parameter (attribute level)									
Price		−0.007**	0.00		−0.019***	0.01		−0.008**	0.00
Spatial extent (Inside Passage)		1.31***	0.25		1.08***	0.38		1.33***	0.25
Temporal extent (50-yr program)		2.91***	0.38		2.52***	0.53		2.94***	0.38
Ecosystem service type (final)		−0.53**	0.19		−0.35	0.29		0.50***	0.18
Choose no monitoring program		−18.59**	5.78		−21.32**	8.54		−31.45**	13.43
Prior knowledge of long-term monitoring									
×Price					0.021***	0.01			
×Spatial extent (Inside Passage)					0.67	0.45			
×Temporal extent (50-yr program)					0.96	0.64			
×Ecosystem service type (final)					−0.48	0.34			
Conservative Political Preferences									
×Price					−0.01	0.01			
×Spatial extent (Inside Passage)					−0.75	0.49			
×Temporal extent (50-yr program)					−0.99	0.66			
×Ecosystem service type (final)					0.69*	0.38			
Choose no monitoring program									
×Conservative political preferences					8.99**	4.08		8.36*	4.83
×Prior knowledge of LTM					−10.21**	4.72		−8.47*	4.41
×Membership in an environmental org.								−3.05	2.88
×Bachelor's degree or higher ed.								0.82	2.47
×Income								0.06*	0.04
×Resident								3.53	2.97

Notes: Results are pooled across all survey respondents. LTM, long-term monitoring. WTP values and 95% confidence intervals, respectively, for attribute levels are spatial extent (Inside Passage), $174 and $76–599; ecosystem service type, $70 and $386–10; and temporal extent (50-yr program), $383 and $222–866. SE, Standard error.
$^{*}P < 0.10$; $^{**}P < 0.05$; $^{***}P < 0.01$.

program extents, respondents were willing to pay significantly more for longer programs ($P < 0.05$), but there was no statistical difference in WTP for spatial extent (Fig. 2).

For the RPL specification in which the least-preferred alternative was regressed against the full suite of baseline monitoring attributes and the status quo alternative-specific constant, the model fits the data well (McFadden's $R^2 = 0.36$; Table 5). Two estimated coefficients were negative and statistically significant (spatial extent; Inside Passage, $P < 0.01$; choose no monitoring program, $P < 0.05$). No other covariates impacted respondents' choice of least-preferred monitoring program in a statistically significant fashion. The presence of mostly statistically insignificant effects, combined with the negative effect on spatial extent (Inside Passage), corroborates the results of the baseline model in Table 3.

Discussion and Conclusions

The perceived benefits of information gained by long-term monitoring must justify its costs (Caughlan and Oakley 2001). In previous studies, researchers have estimated WTP for experiencing high-quality natural environments (Samdin et al. 2010, Sekar et al. 2014) and viewing charismatic animals (Loomis et al. 2000, Rogers 2013), but we know of only one other previous study that has estimated WTP for the scientific monitoring of natural areas and their ecosystem components (Swallow and Liu 2017). We found that the average respondent had a positive WTP for long-term monitoring programs. A decomposition of

Table 4. Diagnostics, parameter estimates, and willingness to pay (WTP) calculations for the random parameters logit model with attribute-level interactions.

Model outputs	Diagnostic	β	Standard error	WTP	95% confidence interval
Diagnostics					
N	6,040				
Log likelihood	−1374				
McFadden's adjusted R^2	0.17				
Model parameter (attribute level)					
Price		−0.014***	0.00		
10-yr Port of Juneau		2.820***	0.28		
50-yr Port of Juneau		5.108***	0.38		
10-yr Inside Passage		3.251***	0.34		
50-yr Inside Passage		6.213***	0.43		
Standard error around mean effect					
Price		0.043***	0.00		
10-yr Port of Juneau		1.122***	0.26		
50-yr Port of Juneau		1.019***	0.28		
10-yr Inside Passage		1.687***	0.3		
50-yr Inside Passage		1.295***	0.43		
Attribute levels					
10-yr Port of Juneau				\$201	\$135–381
50-yr Port of Juneau				\$365	\$255–671
10-yr Inside Passage				\$232	\$156–431
50-yr Inside Passage				\$444	\$313–817

Note: Results are pooled across all survey respondents.
*** $P < 0.01$.

that positive WTP showed that intermediate ecosystem services had a higher average WTP than did final ecosystem services. Additionally, residential status did not seem to impact respondents' WTP, though prior knowledge of long-term monitoring increased WTP. Modeling with explicit sociodemographic interactions indicated that prior knowledge of long-term monitoring leads not only to higher WTP, but a lower likelihood of inaction. These results were consistent with a previous study finding that support for nature-based tourism fees increased with more education about the purpose of those fees (Laarman and Gregersen 1996). In general, respondents' WTP for environmental goods and services tends to increase with years of education (see Urama and Hodge 2006, Han et al. 2011, Liebe et al. 2011).

By presenting respondents with five options in each choice scenario, we increased the cognitive burden placed upon respondents. Economic theory indicates that asking too many choice options could, though does not necessarily, violate conditions for incentive compatibility (Carson and Groves 2007, Collins and Vossler 2009). DeShazo and Fermo (2002) found that estimation efficiency improves and then declines as the number of alternatives increases. Hensher (2006), on the other hand, found that increasing the number of alternatives in a choice experiment does not, all other design elements equal, affect mean WTP values. If respondents felt overwhelmed by the amount of information in the choice scenarios, we would have expected two potential outcomes. First, it is less likely that respondent choices would have been consistent; that is, respondent preferences could be explained by the underlying utility function, than if there had been fewer alternatives per choice scenario. The result would have been less precisely estimated coefficients (DeShazo and Fermo 2002). Second, when presented with too many choices, respondents might have been more likely to choose the status quo option (Meyerhoff and Liebe 2009, Park and Jang 2013). While we did observe increased propensity to choose status quo among conservative and higher income respondents, this behavior appears to be systematically explained by membership in those groups.

Despite the uncertainty of future societal benefits, positive WTP values demonstrated that there

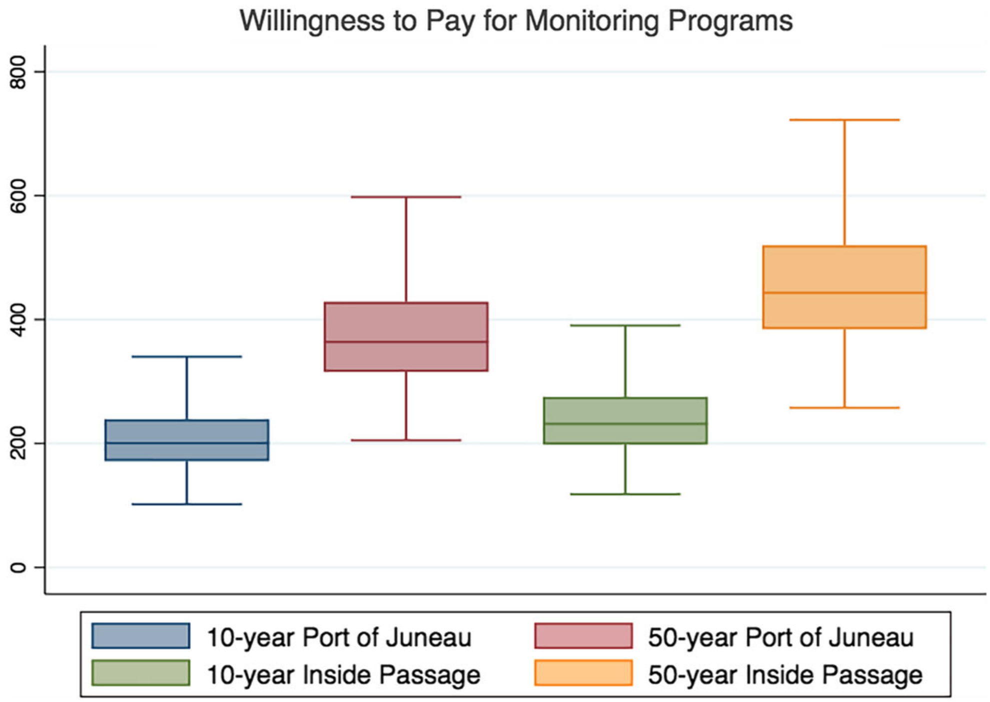


Fig. 2. Distributions of willingness to pay estimates for four combinations of spatial and temporal monitoring program extents. The horizontal lines inside each box represent median values, bottom and top edges of the boxes represent 25th and 75th percentiles, respectively, and the ends of the vertical solid lines represent 1.5× interquartile range. Individual points >1.5× interquartile range are excluded.

was strong support among respondents to commit tax dollars to long-term ecological monitoring programs that measure various ecosystem components over a decade or longer. We hypothesized that WTP for final ecosystem services would be higher than for intermediate ecosystem services. With one notable exception (politically conservative individuals), respondents were willing to pay more, on average, for monitoring intermediate services such as oceanography, stream temperature, and climate. At least two explanations may account for this result. First, monitoring of intermediate services may have been seen as a better investment, given that the information gained is more broadly informative of ecosystem processes rather than specific ecosystem components. For example, monitoring stream temperature (intermediate service) provides information about environmental changes in freshwater systems as a whole, while monitoring salmon (final service) provides information about a particular animal population. Alternatively, the wording in our survey preambles may have inadvertently led respondents to value intermediate services more highly than final services. Determining the mechanism underlying the result of higher WTP for monitoring intermediate compared to final ecosystem services would require open-ended questions that asked respondents to explain the reasoning behind their choices. Additionally, respondents were willing to pay more for longer-term monitoring programs and larger spatial extents, suggesting that they want their income to support programs with a higher probability of yielding informative results over broad spatiotemporal scales.

The demographics of our respondent group were skewed for white, highly educated, high-income earners, so future studies will need to approach a broader cross section of the taxpaying public. Non-resident respondents were similar to Juneau visitors at-large during the same time period (McDowell 2017): average age = 48 (at-large age = 56.2), 47% were female (at-large = 55%), bachelor's degree or higher = 63% (at-large = 64%), and average income = $112,351

Table 5. Least-preferred random parameters logit (RPL).

Model outputs	RPL, no interactions	β	Standard error
Diagnostics			
N	5,935		
Log likelihood	−1117		
McFadden's adjusted R^2	0.36		
Model parameter (attribute level)			
Price		−0.008	0.01
Spatial extent (Inside Passage)		−0.98***	0.38
Temporal extent (50-yr program)		−0.58	0.64
Ecosystem service type (final)		0.04	0.29
Choose no monitoring program		−3.01**	1.49

**$P < 0.05$; ***$P < 0.01$.

(at-large = $117,000). Alaska resident respondents were not representative of the state at-large (Alaska Department of Labor 2016): average age = 45.3 (at-large median age = 33.4), bachelor's degree or higher = 60% (at-large = 29.6%), and average income = $104,480 (at-large = $76,440). We acknowledge that social factors, such as place of residence and political preference, may play a much more important role for different sectors of the public not included in our survey (Spash 2006).

Willingness to pay for environmental monitoring may be related to perceptions of environmental risk and the potential for future ecological change that may be harmful to society. There is a rich body of research describing the effects of sociodemographics on perceptions of environmental risk, and the dominant view is that people with higher incomes are more willing to pay for protection from environmental risks (Lindell and Hwang 2008). However, it is also possible that many lower income families are just as concerned but may not be able to pay to mitigate the risk (Lo 2014), or respondents see long-term monitoring as an inferior good—one for which consumption declines as incomes rise. We see weak evidence of this in our data: The estimated coefficient on the interaction term between income and status quo is positive and statistically significant, indicating that as incomes rise, people are more likely to choose the status quo option associated with no long-term monitoring program at all (Table 3). In this case, respondent preference for spending money on the less clearly defined benefits associated with long-term monitoring would decrease as income increases and shift to environmental pursuits with more well-defined benefits, such as specific habitat restoration projects.

Contrary to our hypothesis, place of residence did not have a strong influence on respondent choice after controlling for income, political preference, and prior knowledge. This differs from previous research, demonstrating that place of residence has a distinct effect on society's valuation of nature (Loomis and White 1996, Miller et al. 1998, Kim et al. 2012). The Inside Passage is one of the most advertised routes in Alaska, and ecotourism activities such as dog sled rides, glacier tours, and whale watching excursions are continually increasing in popularity (Kruger 2005). As a result, visitors may be predisposed to valuing nature in a manner similar to residents. Another potential explanation is that we did not sample enough residents who are dependent on local environmental conditions. Individuals who are more dependent on local environmental conditions may perceive themselves at greater risk from environmental threats (Sullivan-Wiley and Gianotti 2017). In our analysis, prior knowledge effects dominated the place of residence effects in the absence of other controls; therefore, it is also plausible that our sample was biased toward residents with less prior knowledge of long-term monitoring.

Among the other sociodemographic characteristics, prior awareness of monitoring programs and income had the strongest influence on respondent choice. Respondents with prior knowledge of monitoring programs were consistently more willing to pay for monitoring relative to those with no prior knowledge of monitoring programs. This finding resonates with other studies that show positive relationships between ecological knowledge and conservation support. Stakeholders with knowledge about the ecology of endangered species and their habitats have demonstrated stronger support for conservation and a greater willingness to take personal action to recover those species (Beaudreau and Levin 2014, Sawchuk et al. 2015). Therefore, public education can play an important role in garnering the necessary support for conservation, and we suspect this is also true of long-term monitoring. The better-educated taxpayers are about the value of monitoring, the more willing they might be to support funding for current programs and future efforts.

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Supporting Information

Additional Supporting Information may be found online at: http://onlinelibrary.wiley.com/doi/10.1002/ecs2.2875/full

Appendix S1: Full survey instrument for whales and oceanography