Stated Preferences for Intermediate versus Final Ecosystem Services: Disentangling Willingness to Pay for Omitted Outcomes

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Stated preference scenarios often provide information on intermediate biophysical processes but omit information on the resulting final services that provide utility. This may cause respondents to speculate about the effects of intermediate outcomes on their welfare, leading to biased welfare estimates. This work clarifies distinctions between intermediate and final ecosystem services within stated preference valuation and develops a structural model by which to infer respondents' speculations when a final ecosystem service is omitted. The model also derives implications for welfare estimates. Methods and results are illustrated using an application of choice experiments to fish restoration in Rhode Island's Pawtuxet watershed.

Key Words: choice experiment, choice modeling, ecosystem service, river restoration, valuation, willingness to pay

Studies often apply stated preference valuation to quantify willingness to pay (WTP) for changes in the quantity or quality of ecosystem goods and services (henceforth, "services"). Consistent estimates of these values require careful definition of the services under consideration and how those services contribute to human welfare. Within ecosystem service analyses, final ecosystem services may be defined as ecosystem outputs that directly enhance respondents' utility. Intermediate ecosystem services may be viewed as inputs into the biophysical production of final services (Boyd and Krupnick 2009, Brown, Bergstrom, and Loomis 2007, Fisher et al. 2008, Fisher, Turner, and Morling 2009, Wallace 2007). That is, intermediate services provide benefits through their effect on final goods and services that are valued directly by people (Johnston and Russell 2011). A common example of an intermediate service is water purification or

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nutrient cycling in riparian buffers. Water purification, as it relates to a nutrient like nitrogen, is accomplished through intermediate ecological processes that generally benefit humans only through their contribution to the final, directly valued services (e.g., clean drinking water or surface waters that are valued for recreational or aesthetic purposes). Lack of attention to the distinction between intermediate and final services can lead to welfare estimates that omit, double count, or misrepresent the contributions of those services to utility. Many ecosystem processes provide both intermediate and final services, further complicating welfare analysis.

In the following case study, multiple ecosystem services are influenced by restoration of passage for migratory fish such as alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) in Rhode Island's rivers. Many of these services influence public welfare directly. An example is the abundance of fish-dependent wildlife such as otters and osprey (Johnston et al. 2012). Some of these services simultaneously influence, or provide intermediate effects on, other final services. For example, fish and wildlife abundance influences overall ecosystem condition or naturalness, which is also valued by Rhode Island residents as a final service (largely due to nonuse motivations).[1] Still other services influence welfare only through intermediate channels. For example, restoration affects the mussel species *Anodonta implicate*, which relies on migratory fish to carry its larvae. While not valued directly by the public, a healthy *Anodonta implicate* population influences overall ecosystem condition (Johnston et al. 2011, 2012). These examples illustrate three ways that individual ecosystem services can influence welfare: (i) directly as a final service, (ii) both directly as a final service and indirectly as an intermediate service, or (iii) only as an intermediate service.

Despite the importance of these distinctions for welfare estimation, surveys in the stated preference literature have rarely clarified the difference between intermediate and final services. At the same time, these surveys commonly present information on intermediate ecosystem services but omit information on the resulting final services that influence utility. This may be done to "obviate problems associated with characterizing an exact change in ecosystem services that could be expected" (Holmes et al. 2004, p. 23). Respondents often are asked to choose among scenarios that are described in terms of intermediate outcomes such as "protection of natural ecological processes" (Czajkowski, Buszko-Briggs, and Hanley 2009) or "continued decline in the functioning of ecosystem processes" (Christie et al. 2006), sometimes with no quantification of the final, welfare-relevant outcomes that would result. In other cases, respondents have been asked to value a policy intervention, another type of intermediate process, based on "vague or nonexistent information" (Boyle 2003, p. 117, cited in Provencher, Lewis, and Anderson 2012) on the resulting change in resources or final ecosystem services.

The simultaneous exclusion of final services and inclusion of intermediate services within stated preference survey scenarios can bias welfare estimates

[1] Johnston et al. (2011) verified the status of overall ecological condition as a final service in focus groups and subsequent choice experiments using criteria presented by Johnston and Russell (2011). These criteria included a central requirement that "for endpoint h to serve as a final ecosystem service for rational beneficiary j, the beneficiary must be willing to pay for increases in h, assuming that all other ecosystem outputs and conditions $i \neq h$ are held constant" (Johnston and Russell 2011, p. 2246). As detailed hereafter, this final service can be communicated with multimetric ecological indicators, including indices of biotic integrity (Johnston et al. 2011).

in at least two ways (Johnston et al. 2011, 2012). First, respondents asked to value changes in intermediate services may not be aware of resulting impacts on final services. When this occurs, the resulting WTP estimates will not fully reflect welfare contributions of the intermediate services. Second, even when respondents are aware of impacts on final services, they may have an incorrect understanding of the biophysical relationships through which the included intermediate services influence the omitted final services. Without this information, respondents cannot correctly predict the effects on welfare-relevant final services (i.e., services that they value). Survey responses and the resulting welfare estimates will be based, at least in part, on these incorrect understandings.

Simply put, omission of information on final services requires respondents to speculate about the effects of intermediate outcomes on their welfare. In such cases, respondents may look to information on intermediate outcomes presented elsewhere in the survey or choice scenario as a means by which to infer information (or speculate) on the omitted final service(s). This is particularly likely to occur in ecological resource settings about which respondents have little baseline information (Bateman et al. 2011, Spash and Hanley 1995, Johnston et al. 2011). As noted by Carson (1998, p. 23), stated preference respondents "will tend to fill in whatever details are missing in the . . . survey with default assumptions. These may differ considerably from what the researcher perceives." Blamey et al. (2002, p. 168) discussed similar concerns regarding causally related attributes: "inclusion of causally related attributes [in stated preference surveys] may stimulate some respondents to seek to understand the causal relations among them in order to assign greater meaning to the alternatives."

Such issues are commonly overlooked in stated preference valuation of ecosystem services. Yet is there any evidence that such biases—while seemingly clear in concept—occur in practice? If so, is there a model through which the resulting influences on welfare estimates could be quantified? Among the goals of such a model would be to disentangle WTP for intermediate and (potentially omitted) final ecosystem services, thereby enabling the impact of respondents' speculations to be estimated.

This work clarifies distinctions between intermediate and final ecosystem services in stated preference valuation and develops a structural model to infer speculations made by respondents when a final ecosystem service is omitted. Results enable analysts to estimate the relationship that respondents assume between intermediate and final ecosystem services (i.e., speculated biophysical production functions). By comparing these assumptions with parallel biophysical functions defined by ecologists, we are able to quantify the implications of respondents' speculation on welfare estimates. We illustrate the model using an application of choice experiments to migratory fish restoration in Rhode Island's Pawtuxet watershed. Model results provide evidence that omission of a final ecosystem service from survey scenarios leads to speculation by respondents with quantifiable impacts on resulting welfare estimates.

A Conceptual Model of Final versus Intermediate Ecosystem Services

We begin with the general definition of ecosystem services provided by Fisher et al. (2009, p. 645), "the aspects of ecosystems utilized (actively or passively) to produce human well-being." Grounded in this definition, the distinction between intermediate and final ecosystem services may be clarified as described by Johnston and Russell (2011)[2] based on the provision of natural outputs (goods and services) through systems of ecological production. The final outputs of these systems—final ecosystem services—are biophysical outcomes that directly enhance the utility of at least one human beneficiary.[3] Intermediate services are conditions or processes that benefit humans through effects on other, final services. These may be viewed as inputs into the production of final services.[4]

We illustrate the distinction between intermediate and final services using a simple conceptual model. Suppose household h has a utility function of the form $U_h(X, Y(X, Z))$ in which $\partial U / \partial X > 0$, $\partial U / \partial Y > 0$, $\partial Y / \partial Z > 0$, and $\partial Y / \partial X > 0$ and in which X and Y are measurable ecological processes or conditions. Both X and Y are direct arguments in $U_h(\cdot)$; they do not require further ecological production or transformation to influence human benefits and are hence classified as final ecosystem services. In contrast, Z is an intermediate service. Its influence on $U_h(\cdot)$ occurs entirely through its effect on Y, which is realized through the biophysical production function $Y(\cdot)$. This simple framework also illustrates that an ecological outcome, X, can, in principle, affect utility both directly (and hence be a final service) and indirectly through its contribution to the production of another final service, Y (and hence simultaneously be an intermediate service).

The marginal utility of a change in X is calculated as

$$dU/dX = \partial U/\partial X + (\partial U/\partial Y) \cdot (\partial Y/\partial X) > 0, \tag{1}$$

which reflects both the direct and the indirect effects of the change. From a theoretical perspective, WTP estimated using stated preference methods provides a money metric of this change. Equation (1) further clarifies the status of X as both a final and an intermediate service with both direct and indirect influences on utility.

Equation (1) also informs the corresponding specification of stated preference scenarios. To express informed preferences based on equation (1), a respondent requires two pieces of information: she must know the change in X to evaluate $\partial U/\partial X$ and she must know the change in Y to evaluate $\partial U/\partial Y$. If either piece of information is missing, the respondent cannot accurately quantify dU/dX. More generally, when an outcome is simultaneously a final and an intermediate service (X in this case), the ability to evaluate a change in utility requires information on *both* the change in X and resulting changes in other final services (Y in this case). Survey scenarios, therefore, must provide information on *all final services involved regardless of whether any of these final services also provide intermediate services*. If the respondent is given the change in Y directly, she has no need to know or speculate about the ecological production function $\partial Y/\partial X$ and no need to know about outcomes that are purely intermediate (e.g., Z). Scenarios designed in this way provide all of the information required for a respondent to evaluate dU/dX and thus allow for unbiased WTP estimation.

[2] See also Boyd and Banzhaf (2007), Boyd and Krupnick (2009), Fisher et al. (2008, 2009), Turner and Daily (2008), and Wallace (2007), among others.

[3] Boyd and Krupnick (2009) define a closely related concept of "ecological endpoints."

[4] The status of an ecological condition or process as a final versus intermediate service may vary across beneficiaries (Johnston and Russell 2011, Turner and Daily 2008).

In some cases, however, the information necessary to quantify Y may be difficult or impossible to obtain. In such cases, survey designers might provide information only on X and/or Z and allow respondents to draw their own conclusions regarding Y. However, a survey respondent with no ecological expertise is unlikely to be aware of the true relationship, $Y(X, Z)$, through which changes in X and Z influence Y. If a stated preference scenario omits information on Y and includes information on X and Z, respondents will hence condition their responses on likely erroneous speculations about this ecological production function. Survey responses and associated welfare estimates will reflect these speculations.

The Theoretical Model

To model the effects of an omitted final ecosystem service on respondent speculation and stated preferences, we begin with a simple theoretical framework followed by an empirical case study that quantifies and tests hypothesized results. The theoretical model for the choice experiment begins with a standard random utility specification in which household h chooses among three policy options ($k = A, B, N$) for ecosystem service restoration. These include two multi-attribute restoration options (A, B) and a status quo (N) option with no restoration and zero household cost. Each policy option is characterized by a vector of variables, $\mathbf{X} = [X_1 \ldots X_J]$, representing policy outcomes. We define $X_1 \ldots X_{J-1}$ as variables representing ecological outcomes of restoration (i.e., effects on ecosystem services) and X_J as a variable representing unavoidable household cost. Following standard notation, we represent the utility of household h from option k as

$$(2) \qquad U_{hk}(X_1 \ldots X_{J-1}, I_h - X_J) = v_{hk}(X_1 \ldots X_{J-1}, I_h - X_J) + \varepsilon_{hk},$$

where

I_h = disposable income of household h;

$v_{hk}(\cdot)$ = a function representing the empirically measurable component of utility; and

ε_{hk} = the unobservable component of utility modeled as econometric error.

Such models are typically specified with a linear functional form for observable utility, $v_{hk}(X_1 \ldots X_{J-1}, I_h - X_J)$, such that

$$(3) \qquad v_{hk}(X_1 \ldots X_{J-1}, I_h - X_J) = \mathbf{XA}$$

where $\mathbf{A} = [\alpha_1, \alpha_2, \ldots \alpha_J]'$ is a conforming vector of coefficients to be estimated. When choosing between policy options $k = A, B, N$ with utility specified per equations (2) and (3), the household is assumed to choose the option that offers the greatest expected utility. This enables the parameters of $\mathbf{A}$ to be estimated using maximum likelihood models for discrete outcomes (e.g., a mixed logit model) with likelihood functions determined by assumptions regarding factors that include the unobservable component of utility ε_{hk} and preference heterogeneity among respondents (Train 2009).

Calculation of WTP for a particular restoration outcome (or choice attribute) follows standard approaches (e.g., Boxall et al. 1996, Haab and McConnell 2002): WTP is the negative ratio of the parameter estimate for the attribute (α_j) to the parameter estimate on program cost (α_J) so that $WTP_j = -(\alpha_j / \alpha_J)$.[5] This is the implicit price of attribute *j*. To streamline notation,

(4) $$\beta_j = -(\alpha_j / \alpha_J)$$

represents implicit prices for all $j = 1 \ldots J-1$ restoration outcomes in the model.

Based on (2) through (4), total compensating surplus (or WTP) for a multi-attribute restoration program may be specified as a linear function of the implicit prices,

(5) $$CS = \sum_{j=1}^{J-1} X_j \beta_j.$$

A similar foundation for WTP estimation is applied in most random utility choice models within the stated preference literature.

Omitting a Utility-relevant Ecosystem Service Outcome

We now extend the preceding model to represent omission of a final ecosystem service from stated preference scenarios. To simplify notation, we illustrate a case for which there are only three non-cost attributes in the survey (X_1, X_2, and X_3) plus a constant, ASC_p, that is associated with all of the policy alternatives except the status quo. This implies that $ASC_p = 1 - ASC_n$ where ASC_n is the alternative-specific constant for neither plan ($k = N$). Although these simplifications streamline the notation, they are not necessary; parallel results hold for more complex specifications.

Given these simplifications, compensating surplus (WTP) for any given policy alternative may be expressed as

(6) $$CS = \beta_0 ASC_p + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3.$$

Assuming that X_1, X_2, and X_3 are included in survey scenarios using an appropriate experimental design (Louviere, Hensher, and Swait 2000), the component implicit prices ($\beta_0 \ldots \beta_3$) can be calculated from stated preference results as in (4).

Assume now that a stated preference survey is implemented in which the scenarios omit the non-cost attribute X_3—this outcome is neither mentioned in the survey materials nor included as an attribute in the choice scenarios.[6] Further assume that survey respondents, lacking information on this omitted but valued final ecosystem service, make assumptions regarding X_3 from the information provided on ASC_p, X_1, and X_2. That is, absent information on X_3, respondents use information on ASC_p, X_1, and X_2 to provide insight into the

[5] If a mixed logit model is used for estimation, one generally simulates a WTP distribution based on draws from an estimated parameter distribution (Hensher and Greene 2003). However, the fundamental definition of WTP as the ratio of parameter estimates remains unchanged.

[6] This is not equivalent to omitted variables in an econometric model. Rather, the survey itself fails to illustrate the effects of an attribute for which respondents might otherwise express a positive WTP.

biophysical production of X_3. We represent this *assumed* (most likely inaccurate) biophysical production function using a linear approximation:

$$X_{3(assumed)} = \gamma_0 ASC_p + \gamma_1 X_1 + \gamma_2 X_2, \tag{7}$$

where γ_0, γ_1, and γ_2 are parameters determined by respondents' internal assumptions.[7] These parameters are not observable by the researcher. We assume that the respondent population remains unchanged with the same preference parameters reflected in (6). Hence, respondents use (7) to infer $X_{3(assumed)}$ when X_3 is omitted and answer survey questions based on the underlying welfare function (6).

If one combines (6) and (7) when X_3 is omitted from survey scenarios, the result is

$$CS = \beta_0 ASC_p + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_{3(assumed)} \tag{8}$$

$$= \beta_0 ASC_p + \beta_1 X_1 + \beta_2 X_2 + \beta_3(\gamma_0 ASC_p + \gamma_1 X_1 + \gamma_2 X_2)$$

$$= (\beta_0 + \beta_3\gamma_0)ASC_p + (\beta_1 + \beta_3\gamma_1)X_1 + (\beta_2 + \beta_3\gamma_2)X_2\,, \tag{9}$$

which may be simplified as

$$CS = \delta_0 ASC_p + \delta_1 X_1 + \delta_2 X_2, \tag{10}$$

where

$$\delta_j = \beta_j + \beta_3\gamma_j \text{ for } j = \{0, 1, 2\}. \tag{11}$$

The model reflected in (2) through (11) allows us to formalize the difference between welfare estimates that result from stated preference surveys that include X_3 and surveys that do not. When X_3 is included, compensating surplus is estimated for a representative household, following (6), as

$$\widehat{CS}_{inc} = \hat{\beta}_0 ASC_p + \hat{\beta}_1 X_1 + \hat{\beta}_2 X_2 + \hat{\beta}_3 X_3 \tag{12}$$

where the calculation of implicit prices,

$$\hat{\beta}_j = -(\hat{\alpha}_j / \hat{\alpha}_J),$$

follows (4) and the hats (^) indicate estimated parameters. This is the standard form for welfare estimation in stated preference models of this type. When X_3 is omitted, compensating surplus is estimated, following (10), as

$$\widehat{CS}_{exc} = \hat{\delta}_0 ASC_p + \hat{\delta}_1 X_1 + \hat{\delta}_2 X_2 \tag{13}$$

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[7] Given that there is no prior information on properties of the true production function that might be assumed by respondents, (7) reflects a first-degree, linear approximation. This allows the overall model in (2) through (17) to be estimated using conditional or mixed logit models that specify the observable component of utility as linear in the parameters. Alternative forms for the assumed biophysical production do not allow estimation using a linear in the parameters utility specification when incorporated into a combined discrete choice model that parallels (2) through (17). The linear form imposes a variety of well-known restrictions on the assumed biophysical production function, including fixed returns to scale and perfect substitutability among inputs.

where $\hat{\delta}_j$ are estimates of δ_j in (11) and represent implicit prices estimated in the X_3-omitted model.

Inferring Respondents' Assumptions

It is not possible to observe respondents' speculation directly. However, the structural utility model presented here enables this speculation to be inferred from differences in responses to a pair of otherwise identical stated preference surveys—one that includes and one that omits a single ecological attribute. For example, statistical comparison of the parallel implicit prices within (12) and (13) reveals whether omission of X_3 in the survey scenarios influences respondents' welfare estimates for ASC_p, X_1, and X_2. The model also provides a means to derive the coefficients of (7), the equation through which the biophysical "production" of X_3 is inferred.

First, equation (11) is restated as

$$\gamma_j = {(\delta_j - \beta_j)}\big/{\beta_3}. \tag{14}$$

Substituting the estimated coefficients from (12) and (13) into (14) yields

$$\hat{\gamma}_j = {(\hat{\delta}_j - \hat{\beta}_j)}\big/{\hat{\beta}_3}. \tag{15}$$

Note that the values for $\hat{\delta}_j$ are simply the implicit prices estimated in the X_3-omitted model, the values for $\hat{\beta}_j$ are corresponding implicit prices estimated in the X_3-included model, and $\hat{\beta}_3$ is the implicit price estimated for X_3 in the X_3-included model. Hence, the information required to calculate the parameters in equation (7) is provided by the estimated implicit prices from the two estimated models.

We use these results to obtain an empirical linear approximation of the ways that respondents use the information presented on ASC_p, X_1, and X_2 to make assumptions about X_3 when it is omitted from the survey. Substituting (15) into (7) yields

$$X_{3(assumed)} = \hat{\gamma}_0 ASC_p + \hat{\gamma}_1 X_1 + \hat{\gamma}_2 X_2. \tag{16}$$

$$= \left[{(\hat{\delta}_0 - \hat{\beta}_0)}\big/{\hat{\beta}_3}\right] ASC_p + \left[{(\hat{\delta}_1 - \hat{\beta}_1)}\big/{\hat{\beta}_3}\right] X_1 + \left[{(\hat{\delta}_2 - \hat{\beta}_2)}\big/{\hat{\beta}_3}\right] X_2. \tag{17}$$

Given the linear preference functions previously specified, a complete lack of speculation by respondents when X_3 is omitted would result in the prices in (12) and (13) being equal (i.e., $\hat{\delta}_j = \hat{\beta}_j$ for $j = \{0, 1, 2\}$). Therefore, following (17), $X_{3(assumed)} = 0$.

If the same assumptions hold and $\hat{\delta}_j \neq \hat{\beta}_j$ for $j = \{0, 1, 2\}$, then the implicit prices for ASC_p, X_1, and/or X_2 will differ when X_3 is omitted from survey scenarios. If respondents speculate that each $\gamma_j > 0$ (that ASC_p, X_1, and X_2 are positive indicators of omitted X_3), then $\hat{\delta}_j$ should be greater than $\hat{\beta}_j$ for $j = \{0, 1, 2\}$. That is, we would expect implicit prices to be greater for ASC_p, X_1, and/or X_2 when X_3 is omitted. The opposite occurs if respondents speculate that each $\gamma_j < 0$.

Regardless of the relative magnitudes of $\hat{\delta}_j$ and $\hat{\beta}_j$, the model provides a means by which to infer respondents' speculations about the omitted ecosystem service. If respondents value other attributes differently when X_3 is omitted, they are acting *as if* they speculate that $X_3 \neq 0$ and infer the magnitude of X_3 from other attributes in the survey. The model makes these implied speculations explicit. It cannot demonstrate that respondents make these speculations, but it can demonstrate whether they behave as if they do.

Empirical Application

We implemented the model using a choice experiment that addressed restoration of migratory fish populations in Rhode Island's Pawtuxet watershed. At the time of the study, the watershed provided no spawning habitat for migratory fish, access by fish to its 4,347 acres of potential habitat was blocked by 22 dams (Erkan 2002).[8] Restoration of fish passage would affect not only the populations of fish in the watershed but also other ecosystem services that rely on migratory fish. Species that can directly benefit from restoration in this area are alewife (*Alosa pseudoharengus*), blueback herring (*A. aestivalis*), shad (*A. sapidissima*), and American eel (*Anguilla rostrata*). The choice experiment questionnaire (*Rhode Island Rivers: Migratory Fishes and Dams*) was used to estimate Rhode Island residents' WTP for options that would restore fish passage to between 225 and 900 acres of historical habitat.

The structure of the choice experiment followed the theoretical model. Respondents chose from three policy options ($k = A, B, N$) for river restoration: two multi-attribute restoration options (A, B) and a status quo (N) with no restoration and zero household cost. The choice scenarios and restoration options were informed by data and restoration priorities contained in the *Strategic Plan for the Restoration of Anadromous Fishes to Rhode Island Coastal Streams* (Erkan 2002). Consistent with that plan, restoration methods presented in the survey included fish ladders and lifts (Schilt 2007) that neither require removal of dams nor cause appreciable changes in river flows.

We developed and tested the questionnaire over two and a half years in a collaborative process that included participation of economists, ecologists, resource managers, natural scientists, and members of stakeholder groups. Twelve focus groups with Rhode Island residents were used within conceptual model development and survey design. We used information from the first four focus groups (September 2006 through March 2007) and concurrent cognitive interviews (cf. Kaplowitz, Lupi, and Hoehn 2004) to characterize the structure of respondents' preferences and to differentiate final services from intermediate services. This differentiation was also informed by an understanding of ecological processes affected by migratory fish (e.g., Loesch 1987). The resulting information was used to identify final ecosystem services based on guidelines outlined by Johnston and Russell (2011). In this way, information on the ecological roles of the migratory species targeted for restoration provided the foundation of a conceptual model linking restoration to valued final services identified in the focus groups. We then linked these final services to ecological indicators used in survey scenarios (Johnston et al. 2012, Schultz et al. 2012).

[8] The first dam at the mouth of the Pawtuxet River was removed in August 2011, three years after data collection was completed.

We used the final eight focus groups and concurrent cognitive interviews (April 2007 through May 2008) to pretest and refine the resulting questionnaire. These pretests included verbal protocols (Schkade and Payne 1994) designed to assess how respondents understood and answered choice questions. Survey language and graphics were tested carefully to ensure respondent comprehension. Particular attention was paid to respondents' interpretation of ecological indicators and whether their behavior validated the postulated conceptual model. Prior to presenting the choice questions, the survey provided information that (i) described the status of Rhode Island river ecology and migratory fish compared to historical baselines, (ii) characterized affected ecological systems and linkages, (iii) described fish passage restoration methods, and (iv) provided definitions, derivations, and interpretations for the ecological indicators used in the survey scenarios. The survey conveyed the information via a combination of text, graphics (including geographic information system maps and ecosystem representations), and photographs, all of which were subjected to extensive pretesting.

Choice Experiment Attributes and Versions

Choice options were characterized by five ecological indicators, one attribute characterizing public access, and one attribute characterizing annual household cost. The initial ecological outcome of restoration is to provide migratory fish with access to additional habitat for spawning. This was quantified by the attribute *acres* based on restorable Pawtuxet watershed habitat acreage (Erkan 2002). The consequences of greater habitat acreage include a greater probability of fish runs in a given area at some future period. Within the choice experiment, this was presented as the estimated probability that the restored fish run will exist in 50 years, reflecting results calculable through applications of population viability analysis (given by the attribute *PVA*). Two other benefits of restoration are a greater abundance of non-migratory fish that are suitable for recreational harvest, which was calculated using abundance measures from statewide sampling (given by the attribute *catch*), and the abundance of fish-dependent wildlife, which was determined by the expected appearance of identifiable species within restored areas (given by the attribute *wildlife*).

As previously noted, focus groups and survey pretests suggested that Rhode Islanders were willing to pay for improvements in overall ecosystem condition or naturalness as a final ecosystem service even after accounting for all other ecological drivers of welfare change (Johnston et al. 2011). The primary stated motivation was nonuse value associated with the existence and bequest of more natural aquatic ecosystems viewed from a holistic perspective. These results motivated the inclusion of a holistic measure of the ecosystem condition in survey scenarios to quantify this final ecosystem service.[9]

As described in Johnston et al. (2011), we quantified ecosystem condition using an index of biotic integrity (IBI). This approach mirrored the prior use of an ecosystem health index in revealed preference modeling (Jakus and Shaw 2003). Biotic integrity indexes are multimetric ecological indices typically composed of indicators representing multiple levels of biological organization.

[9] This final effect of ecosystem condition on utility is *in addition to* its intermediate effect on other final ecosystem services in the model. This implies that the *IBI* attribute is akin to the variable *X* in the conceptual model in equation (1) in that it provides both final and intermediate effects on utility.

They are designed to represent "the ability to support and maintain [a] community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Jordan and Smith 2005, p. 468, citing Karr, Yant, and Fausch 1987, cf. Karr 1981, 1991). In common terms, IBIs characterize the overall condition or naturalness of an ecosystem relative to an undisturbed referent. An IBI typically includes numerous indicators of species composition, trophic role, reproductive strategy, and the abundance and/or condition of individual organisms.

Drawing from the ecological literature and focus group results, we included the attribute *IBI* in choice scenarios as a multimetric aquatic ecological condition score. This attribute was calculated as a linear sum of eight submetrics on a 0–100 relative scale as detailed in Table 1. The reference condition of 100 was based on reference values for submetrics found in the least disturbed Rhode Island watershed. This functional form follows that of Deegan et al. (1997), who developed an estuarine IBI as a linear sum of fish assemblage and habitat metrics. Because of respondents' lack of familiarity with IBIs, a separate page of the survey was devoted to a straightforward description of the index and its components, structure, and interpretation. This material was subjected to extensive focus group testing to ensure that respondents' interpretations were similar to those of natural scientists. Johnston et al. (2011) provides additional discussion of this indicator and its development.[10]

Prior models have demonstrated positive and statistically significant WTP for improvements in the *IBI* attribute, *ceteris paribus* (Johnston et al. 2011). Moreover, when *IBI* was omitted from versions of the survey tested in focus groups, responses suggested that individuals speculated regarding the effects of restoration on overall ecological condition and that these speculations influenced survey responses (Johnston et al. 2012). To evaluate the implications of these potential omissions, we used *IBI* as the omitted final ecosystem service for empirical implementation of the model. This provided a means to quantify potential impacts of *IBI* omission on respondents' speculation and, hence, on welfare estimates. We hypothesized that respondents—lacking information on the system's overall ecological condition when *IBI* is omitted—would speculate a value for this omitted attribute based on other attributes that were included in the choice scenarios. This speculation would likely inflate WTP estimates for the other attributes because these estimates would incorporate utility gain associated with assumed impacts on the omitted attribute (*IBI*). The estimated model provided a means to test this hypothesis.

Data for model implementation were drawn from two independent versions of the final survey: an unrestricted version that included all of the ecological attributes and a restricted version of the same survey that omitted the effects of restoration on overall ecological condition represented by *IBI*. The two

[10] Development of IBIs in the ecological literature has been accompanied by scrutiny of their efficacy. Guidelines have been developed and applied in various monitoring efforts (e.g., Jackson, Kurtz, and Fisher 2000, Naweedi 2005). Those guidelines emphasize (i) relevance with respect to the ecological endpoints and stressors of concern, (ii) feasibility with respect to the cost-effectiveness of routine data collection, (iii) accuracy with respect to sources of measurement and process uncertainty, and (iv) interpretability with respect to the ability to discern changes and to facilitate management decisions. While some researchers have advocated bioindices such as the IBI (e.g., Jordan and Smith 2005), critiques have pointed out the limitations of such metrics. Among the critiques is that results can be sensitive to assumed functional forms (Suter 1993, 2001). For more details and critiques of such indexes, see Schultz et al. (2012) and Suter (2001).

Table 1. Choice Experiment Attributes and Descriptive Statistics

Variable	Definition	Pawtuxet Unrestricted Model (*IBI* Included) Mean	Pawtuxet Restricted Model (*IBI* Omitted) Mean
		Standard Deviations in Parentheses[a]	
acres	The number of acres of river habitat accessible to migratory fish as a percentage of the reference Pawtuxet watershed value (Erkan 2002). Range 0–100%.	8.18 (8.16)	8.19 (8.14)
PVA	Population viability analysis (PVA) score: probability that migratory species will continue to appear in the river in 50 years. Reference condition is based on consultation of experts in fish restoration and interpreted following standard mechanisms for PVA models. Range 0–100%.	33.44 (28.12)	33.58 (28.19)
catch	The number of catchable-size fish in restored areas estimated from the number of fish per hour caught by scientific sampling crews. Presented as a percentage of the reference value, which was defined as the highest average level sampled in any Rhode Island river (from Rhode Island Department of Environmental Management sampling data). Range 0–100%.	79.91 (7.58)	79.89 (7.57)
wildlife	Number of fish-eating species that are common in restored areas (such as turtles, eagles, egrets, osprey, mink, and otters). Presented as a percentage of the reference value (from surveys of regional experts in wildlife biology). Range 0–100%.	65.01 (10.39)	65.01 (10.35)
IBI	Index of biotic integrity (IBI) score: A linear multimetric index of aquatic ecological condition that reflects the similarity of the restored area to the most undisturbed watershed area in Rhode Island. Index components include overall fish abundance, number of mussel species, number of native fish species, number of sensitive fish species, number of feeding types in fish, percentage of individual fish that are native, percentage of individual fish that are migratory, and percentage of individual fish that are tumor-free. The score is calculated as the unweighted mean of component relative values where each is calculated relative to the watershed reference condition (Johnston et al. 2011). Presented as a percentage of the reference condition. Range 0–100%.	71.69 (6.08)	—
access	Binary (dummy) variable indicating whether the restored area is accessible to the public for walking and fishing; a value of 1 indicates that the public can access the area. Range 0 or 1.	0.33 (0.47)	0.33 (0.47)
cost	Household annual cost, described as the mandatory increase in annual taxes and fees required to implement the restoration plan. Household cost for the status quo is zero. Range 0–25.	11.98 (14.10)	12.01 (14.11)
ASC_p	Alternative specific constant (*ASC*) associated with any policy option that alters the status quo ($k = A, B$).	0.67 (0.47)	0.67 (0.47)

[a] Means and standard deviations include status quo option of no restoration.

Table 2. Attribute Levels in Choice Experiment Design

Variable	Levels	Variable	Levels
acres	• 0% – 0 acres accessible to fish[a] • 5% – 225 acres accessible to fish • 10% – 450 acres accessible to fish • 20% – 900 acres accessible to fish	*IBI*	• 65% – aquatic ecological condition score[a] • 70% – aquatic ecological condition score • 75% – aquatic ecological condition score • 80% – aquatic ecological condition score
PVA	• 0% – probability of 50-year fish run survival[a] • 30% – probability of 50-year fish run survival • 50% – probability of 50-year fish run survival • 70% – probability of 50-year fish run survival	*access*	• 0 – public cannot walk and fish in area[a] • 1 – public can walk and fish in area
catch	• 70% – 102 fish/hour sampling abundance • 80% – 116 fish/hour sampling abundance[a] • 90% – 130 fish/hour sampling abundance	*cost*	• $0 – cost to household per year[a] • $5 – cost to household per year • $10 – cost to household per year • $15 – cost to household per year • $20 – cost to household per year • $25 – cost to household per year
wildlife	• 55% – 20 species common[a] • 60% – 22 species common • 70% – 25 species common • 80% – 28 species common		

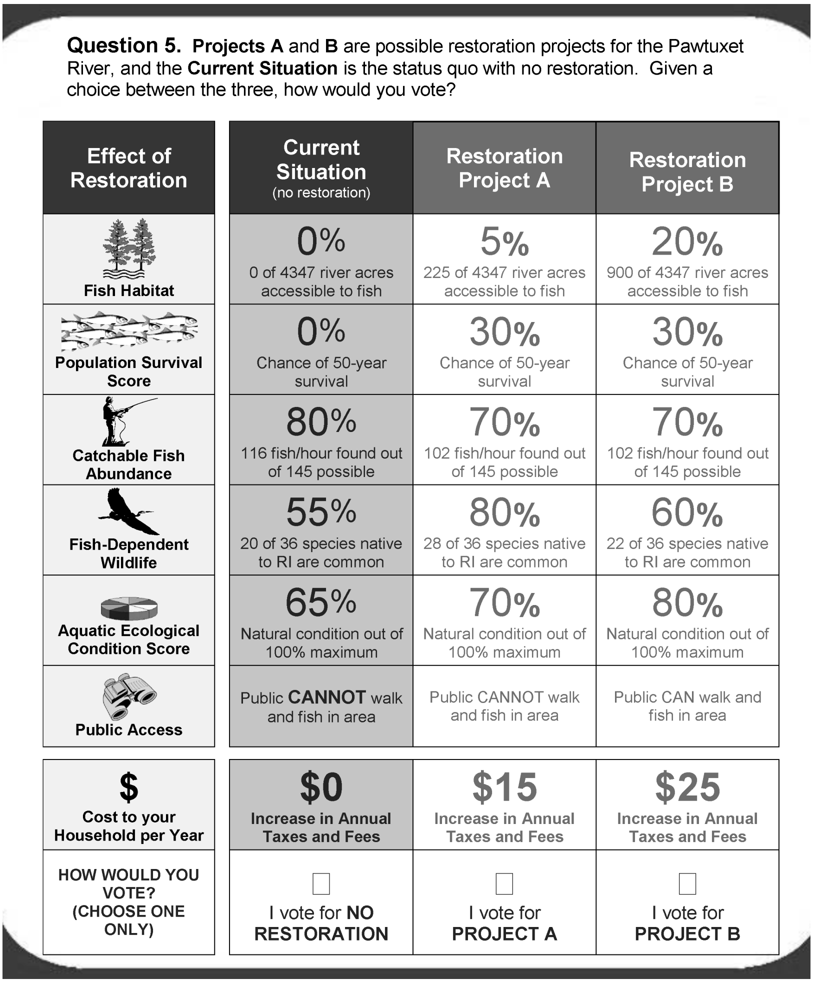
[a] Status quo value.

choice experiments were identical in all other respects. Variables included in each choice experiment are described in Table 1.

Implementation of the Choice Experiment

We assigned levels for each attribute in the experimental design (see Table 2) using feasible restoration outcomes identified by ecological models, field studies, and expert consultations. Choice scenarios represented each ecological attribute in relative terms with regard to upper and lower reference conditions (i.e., best and worst possible outcome in the Pawtuxet). Each attribute level represented percent progress toward the upper reference condition (100 percent, the best possible outcome), starting from the lower reference condition of 0 percent. The scenarios also presented the cardinal basis for these relative levels when applicable. Figure 1 provides a sample choice question.

The fractional factorial experimental design minimized D-error for a choice model covariance matrix with both main effects and selected two-way interactions (Kuhfeld 2010, Kuhfeld and Tobias 2005). The final design included 180 profiles blocked into 60 booklets. Each respondent was given three choice questions and instructed to consider each one as an independent, nonadditive choice. We implemented the surveys using a dual-wave phone-mail approach in June and August of 2008. An initial random digit dial sample of Rhode Island households was contacted via telephone and asked to participate in a survey



Question 5. **Projects A** and **B** are possible restoration projects for the Pawtuxet River, and the **Current Situation** is the status quo with no restoration. Given a choice between the three, how would you vote?

Effect of Restoration	Current Situation (no restoration)	Restoration Project A	Restoration Project B
Fish Habitat	0% 0 of 4347 river acres accessible to fish	5% 225 of 4347 river acres accessible to fish	20% 900 of 4347 river acres accessible to fish
Population Survival Score	0% Chance of 50-year survival	30% Chance of 50-year survival	30% Chance of 50-year survival
Catchable Fish Abundance	80% 116 fish/hour found out of 145 possible	70% 102 fish/hour found out of 145 possible	70% 102 fish/hour found out of 145 possible
Fish-Dependent Wildlife	55% 20 of 36 species native to RI are common	80% 28 of 36 species native to RI are common	60% 22 of 36 species native to RI are common
Aquatic Ecological Condition Score	65% Natural condition out of 100% maximum	70% Natural condition out of 100% maximum	80% Natural condition out of 100% maximum
Public Access	Public **CANNOT** walk and fish in area	Public CANNOT walk and fish in area	Public CAN walk and fish in area
$ Cost to your Household per Year	**$0** Increase in Annual Taxes and Fees	**$15** Increase in Annual Taxes and Fees	**$25** Increase in Annual Taxes and Fees
HOW WOULD YOU VOTE? (CHOOSE ONE ONLY)	☐ I vote for **NO RESTORATION**	☐ I vote for **PROJECT A**	☐ I vote for **PROJECT B**

Figure 1. Sample Choice Experiment Question in Unrestricted Survey

addressing Rhode Island "environmental issues and government programs." Those agreeing to participate were sent the questionnaire via postal mail with follow-up mailings to increase response rates (Dillman 2000). Distributed surveys were split evenly between the two versions: 600 households received the restricted survey and another 600 received the unrestricted survey. The analysis was based on 522 usable returns (277 unrestricted and 245 restricted). Returned surveys provided 1,516 complete choice responses.

Model and Welfare Estimation

We estimated the random utility model using a simulated-likelihood mixed logit (ML) with Halton draws. The model was specified to allow for correlation across multiple responses from each respondent (panel data). We chose the final model specification after the estimation of preliminary models with varying specifications of fixed and random coefficients. In the final model, coefficients on *acres*, *PVA / migrants*, *access*, and *IBI* are random with a normal distribution. The coefficient on *cost* is random with a bounded triangular distribution, ensuring positive marginal utility of income (Hensher and Greene 2003). Coefficients on ASC_p, *catch*, and *wildlife* were specified as fixed. Drawing from the model coefficients, we estimated welfare measures (implicit prices and compensating surpluses) and all derivative results using the welfare simulation described by Johnston and Duke (2007) following the general approach of Hensher and Greene (2003).[11] The presented WTP estimates reflect means of parameter simulations of mean WTP calculated over coefficient simulations. Although we illustrate empirical results only for a single model specification, results from alternative mixed logit specifications suggest that our primary findings and conclusions are robust.

Results

Table 3 reports model results. Estimated coefficients are jointly significant at $p < 0.0001$ for both models with pseudo R-squares that exceed 0.30. Coefficients on all attributes except *catch* are statistically significant, as are all of the estimated standard deviations of random parameter distributions. The signs of statistically significant coefficient estimates match prior expectations. As noted in Table 1, all of the attributes except *access* and *cost* represent percent progress toward the upper reference condition. Hence, the coefficient estimates for ecological outcomes can be interpreted as the relative marginal utility given to a one-percentage-point change in each attribute.[12] For *access*, our results indicate WTP for provision of public access in the restored area relative to the default of no access.

Table 4 contrasts the implicit prices for each attribute simulated from unrestricted and restricted survey models. The resulting estimates provide values for $\hat{\delta}_j$ and $\hat{\beta}_j$ in equations (12) and (13). The table also reports levels of statistical significance (two-tailed tests) for each of the implicit prices and implicit price differences.[13] As expected, the implicit price point estimates from the unrestricted and restricted models differ with implicit prices nearly always greater in the restricted model (which omits *IBI*). The sole exception is the implicit price point estimate for ASC_p, which is greater in the unrestricted model.[14] The implicit price difference is statistically significant for *PVA*

[11] The procedure began with a parameter simulation following the parametric bootstrap of Krinsky and Robb (1986) with R = 1,000 draws taken from the mean parameter vector and associated covariance matrix. For each draw, the resulting parameters were used to characterize asymptotically normal empirical densities for fixed and random coefficients. For each of the R draws, a coefficient simulation was then conducted for each random coefficient with S = 1,000 draws taken from simulated empirical densities (either normal or bounded triangular, depending on the assumed distribution for each coefficient). Welfare measures were calculated for each draw, resulting in a combined empirical distribution of $R \times S$ observations from which summary statistics were derived.

[12] Because choice questions provided the cardinal basis for these percentages, marginal utility may also be presented in cardinal terms (e.g., per acre, per fish).

[13] We determine the significance levels through percentiles on the empirical welfare distributions (Poe, Giraud, and Loomis 2005). These distributions account both for sampling variation reflected in the estimated covariance matrix for model parameters and for the estimated distribution of random coefficients (Hensher and Greene 2003).

[14] This finding might appear to be counterintuitive since the *ASC* variables capture systematic sources of response variability that are associated with particular choice options beyond that associated with included scenario attributes. Accordingly, one might assume that ASC_p would capture part of the utility associated with the omitted *IBI* and would hence be larger in the restricted model. However, equations (6) through (17) model a case in which the speculated outcome for the omitted *IBI* is related structurally to other ecological model attributes. As a

Table 3. Mixed Logit Results: Pawtuxet Restoration Choice Experiments

Choice Attribute	Pawtuxet Unrestricted Model (*IBI* included) Coefficient	Pawtuxet Restricted Model (*IBI* omitted) Coefficient
	Standard Errors in Parentheses	
Random Parameters		
Acres	0.0487 (0.0138)***	0.0435 (0.0130)***
PVA	0.0183 (0.0056)***	0.0302 (0.0057)***
IBI	0.0539 (0.0209)***	—
Access	1.2208 (0.2247)***	1.3759 (0.2318)***
Cost (bounded triangular, sign-reversed)	0.0623 (0.0085)***	0.0547 (0.0075)***
Nonrandom Parameters		
Catch	0.0035 (0.0092)	0.0157 (0.0087)*
Wildlife	0.0280 (0.0095)***	0.0266 (0.0087)***
ASC_p	1.6367 (0.4522)***	1.3051 (0.4162)***
Distribution of Random Parameters		
Standard deviation acres	0.0896 (0.0254)***	0.0807 (0.0195)***
Standard deviation PVA	0.0448 (0.0079)***	0.0346 (0.0060)***
Standard deviation access	1.5585 (0.3702)***	1.5075 (0.3535)***
Standard deviation IBI	0.1492 (0.0329)***	—
Spread cost (bounded triangular)	0.0623 (0.0085)***	0.0547 (0.0075)***
–2 Log Likelihood χ^2	533.62***	522.13***
Pseudo R-square	0.30	0.33
Observations (*N*)	803	713

* p ≤ 0.10, ** p ≤ 0.05, *** p ≤ 0.01.

(likelihood of a 50-year run survival) but not for other attributes. For *PVA*, the implicit price more than doubles when information on the overall ecological condition (*IBI*) is omitted. Hence, the results of the two estimated models provide evidence that respondents valued at least one other attribute more highly when information on *IBI* change was omitted from the survey. This corresponds with expectations of the theoretical model, which assumed that respondents speculated a positive relationship between other model attributes

result, it is not necessary for ASC_p to be larger in the restricted model. The outcome depends on respondents' speculations on biophysical production.

Table 4. Implicit Price Differences: Unrestricted versus Restricted Models

Choice Attribute	Implicit Prices (Mean of Median WTP): Pawtuxet Unrestricted Model ($\hat{\beta}_j$)		Implicit Prices (Mean of Median WTP): Pawtuxet Restricted Model ($\hat{\delta}_j$)		Mean Implicit Price Difference ($\hat{\delta}_j - \hat{\beta}_j$)		Implied Coefficients in Equation (16)—Speculated Biophysical Production of *IBI* [a] $\hat{\gamma}_j = (\hat{\delta}_j - \hat{\beta}_j)/\hat{\beta}_{IBI}$: Median	Mean	
ASC_p	37.0142	***	33.8589	***	−3.1553		−2.1636	−2.3446	
Acres	1.0832	***	1.1099	***	0.0266		0.0114	−0.1188	
PVA	0.4081	***	0.7695	***	0.3615	**	0.2905	0.3512	**
Access	27.2983	***	35.5050	***	8.2067		6.6587	9.7697	
IBI	1.2061	***	—		—		—	—	
Catch	0.0715		0.4069	**	0.3353		0.2748	0.3335	
Wildlife	0.6234	***	0.6883	***	0.0649		0.0544	0.1005	

* $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

[a] The reported mean (median) value represents the mean (median) over the simulated distribution of $\hat{\gamma}_j$. The p-values are calculated for the mean of the distribution.

(here, *PVA*) and overall ecological condition. It also parallels prior findings in Blamey et al. (2002) that exclusion of a causally related attribute can influence stated preference results.

Calculating Respondents' Biophysical Speculations

The rightmost columns of Table 4 present the derived parameters of equation (16). The presented values are calculated as a function of implicit prices, as shown in equation (17), and were simulated from mixed logit results in the same manner. These values provide quantitative estimates of $\hat{\gamma}_j$ in equation (16), reflecting revealed assumptions made by respondents that translate the attributes that were provided in choice scenarios into effects on the valued (but omitted) ecological condition. Table 4 reports both mean and median $\hat{\gamma}_j$ over simulated coefficient distributions. Since the use of medians precludes the calculation of traditional p-values, we report statistical significance levels only for means.

The estimate of mean $\hat{\gamma}_j$ is statistically significant only for *PVA*. This mirrors the significance levels for the implicit price differences previously reported. That is, *PVA* is the only attribute for which respondents' choices imply a statistically significant speculation-based relationship to an omitted ecological condition. Although median point estimates of $\hat{\gamma}_j$ for other attributes over the simulated distribution range from −2.16 (*ASC_p*) to 6.66 (*access*), we cannot reject the null hypothesis that these $\gamma_j = 0$. However, the signs of these point estimates are generally intuitive with most $\hat{\gamma}_j > 0$.

We interpret these results following the theoretical model previously described. Respondents' choices imply a speculated value for overall ecological condition when information on that condition is omitted. At a minimum, this speculation appears to incorporate information from *PVA* (the likelihood that migratory species will still appear in the river in 50 years). This leads to an inflated implicit price for *PVA*. Intuitively, such an assumption is reasonable for a layperson; the continued existence of migratory fish in a river implies a certain level of overall ecological quality. Respondents may have considered other relationships as well, but we cannot demonstrate their statistical significance.

To illustrate the implications of these results, consider a hypothetical restoration plan characterized by ASC_p = 1, *acres* = 10, *PVA* = 50, *catch* = 80, *wild* = 70[15], and *access* = 0. Assume that WTP for this policy is calculated using a survey that omits information on overall ecological condition. At the median $\hat{\gamma}_j$ in Table 4,[16] respondents' choices imply a speculated ecological condition (*IBI*) score of 38.27. In contrast, the no-policy status quo (ASC_p = 0) with no fish passage (*acres* = 0; *PVA* = 0) and identical levels for the other ecological outcomes (*wild* = 70; *catch* = 80) leads to a speculated ecological condition score of 25.79. Similar illustrations can be generated for other scenarios.

These speculated patterns, while perhaps intuitive in gross magnitude, do not match the mathematical structure of the actual index of aquatic ecological condition (*IBI*; see Table 1 and additional discussion in Johnston et al. (2011)). The speculated levels of ecological condition implied by model results (Table 4) are typically much smaller than the biotic index values actually observed in and predicted for the watershed (Table 2). Hence, when one omits information on a final ecosystem service from choice scenarios (here, *IBI*), respondents behave in a way that is consistent with inaccurate speculation about that service. This inaccurate speculation can bias welfare estimates.

Implications and Conclusions

This work illustrates a means by which researchers can identify assumptions made by respondents when information on a final ecosystem service is omitted from stated preference scenarios. In such cases, respondents may treat the included attributes as akin to intermediate services in the biophysical production of the omitted final service and use related speculations to inform their survey responses. To our knowledge, this is the first study that has attempted to disentangle these hypothesized effects in stated preferences. Our results provide evidence that such speculation can occur and, when present, can influence welfare estimates generated by the model.

It is possible to extend the model in numerous directions. For example, one could evaluate the model with alternative functional forms for the assumed biophysical production function. In addition, future studies could incorporate demographic interactions in the model to assess whether respondents' attributes (e.g., age, income, education) influence their preferences and assumptions about biophysical production functions. One could also evaluate heterogeneity according to observable respondent attributes—for example, whether people who engage in outdoor aquatic recreation activities such as fishing have different preferences for aquatic ecosystem services. Because these and other extensions do not affect the fundamental approach or motivation for our model, they are left to future work.

A number of caveats must also be considered when interpreting model results. First, the results of this analysis depend on the validity of the underlying structural model, including the specification of final ecosystem services. As discussed in Johnston and Russell (2011), unambiguous identification of final and intermediate ecosystem services presents a variety of challenges, and these

[15] These levels reflect median ecological outcomes from the experimental design.

[16] Medians are used rather than means because the latter are occasionally influenced by outliers in the tails of simulated distributions. Hence, medians are more robust to repeated simulations.

distinctions can vary across beneficiary groups. For example, an ecological outcome (e.g., water clarity) that provides a final service to a coastal homeowner might provide only an intermediate service to a recreational angler (Johnston and Russell 2011). Despite our exhaustive process of model and survey design, there is no way to prove unambiguously that the resulting set of final ecosystem services is both correct and comprehensive. We also imposed a number of simplifications on the model (for the sake of tractability) that could potentially influence the validity of our findings. Finally, as previously highlighted, we cannot determine whether respondents *actually* speculate regarding omitted final ecosystem services or merely behave *as if* they do. This caveat, although common, is of particular relevance here; our results are limited to statistical inferences informed by our theoretical model.

Despite such caveats, the theoretical and empirical results from our case study support a number of conclusions. First, both actual and assumed relationships between intermediate and final ecosystem services are relevant to the design and interpretation of stated preference scenarios. Unless those relationships are clarified and the scenarios are defined in terms of final ecosystem services, survey responses and associated welfare estimates will likely be influenced by respondent speculation. Second, where assumptions of the model hold, one can infer these speculations and calculate their impacts on welfare estimates. In our case, choice model results and at least some of the implicit prices are influenced by the omission of a final ecosystem service from the survey. One can thus quantify the speculated biophysical production functions, at least as linear approximations. These speculations do not comport with the expectations of ecological scientists and can hence bias welfare estimates.

Our results also highlight the broader relevance of omitted attributes within stated preference scenarios. The traditional and typically unstated assumption in stated preference survey design is that responses are conditioned solely on the attributes present in the choice scenarios and that omitted attributes or outcomes are assumed to be constant or are ignored. Our results suggest that this assumption is invalid, at least for the case of biophysically related ecological attributes. The possibility that respondents speculate values for omitted outcomes highlights the importance of focus groups and pretesting when designing stated preference surveys. Without sufficient attention to survey design, welfare estimates may be influenced by otherwise unexpected respondent speculations regarding omitted outcomes. After the fact, such speculation can be identified only through an approach of the type proposed here.

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