Spatially-Referenced Choice Experiments: Tests of Individualized Geocoding in Stated Preference Questionnaires

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Abstract

Maps in stated preference surveys rarely identify the location of respondents' homes. This standard approach is grounded in the assumption that respondents are aware of their exact household locations relative to mapped policy effects, and hence possess sufficient understanding of spatial relationships to support well-informed preference elicitation. The validity this assumption is rarely if ever tested. This paper evaluates this nearly universal practice of generic policy-area mapping in choice experiments. This is compared to a more information-intensive alternative in which individualized maps pinpoint the location of each respondent's household relative to policy effects. The latter approach requires a unique map to be generated for each respondent. Methods and results are illustrated using an application to riparian land restoration in south coastal Maine. Comparison of the results from these two approaches illustrates the implications of stated preference survey design that provides additional cartographic detail, and suggests the potential limitations of generic policy area maps.

1 Introduction

An expanding literature addresses the relevance of spatial factors for the elicitation and estimation of stated preference willingness to pay (WTP)[1]. It is now well established that welfare effects are often spatially heterogeneous, that this heterogeneity can be policy relevant, and that the form of this heterogeneity can depend on a variety of factors (Bateman et al. 2006, Campbell et al. 2009, Schaafsma et al. 2012). These include the type of good, the availability of substitutes, directionality, recognized borders or geopolitical thresholds, and whether WTP is motivated by use or non-use values (Bateman et al. 2000, 2006, Brouwer et al. 2010, Hanley et al. 2003, Johnston and Duke 2009, Jørgensen et al. 2013, Loomis 2000, Pate and Loomis 1997, Schaafsma et al. 2012)[2]. When underlying welfare effects are conditional upon such factors, valid and well-informed SP elicitation requires that respondents understand relevant spatial features of scenarios they are asked to evaluate (Johnston et al. 2002). A corollary observation is that absent sufficient information on spatial or other relevant features of a survey scenario, respondents may speculate in ways unexpected by researchers and that contribute to unknown response biases (Carson 1998, Johnston et al. 2002, 2011, 2013).

To provide information on spatial features of valuation scenarios, SP surveys often include maps of affected policy sites or affected resources (e.g., Abildtrup et al. 2013, Johnston et al. 2002, 2012, 2013, Jørgensen et al. 2013, Martin-Ortega et al. 2010, Schaafsma et al. 2012, Zhao et al. 2013). These maps typically illustrate relevant features such as affected watersheds or geographical regions (e.g., Martin-Ortega et al. 2010), water bodies (e.g., Hanley et al. 2003, Johnston et al. 2012, Jørgensen et al. 2013, Schaafsma et al. 2012), recreation sites (e.g., Abildtrup et al. 2013), conservation areas (e.g., Adamowicz et al. 1998), or the spatial layout of proposed development or conservation plans (e.g., Johnston et al. 2002; Roe et al. 2004). A small subset of these studies also ask respondents to complete survey tasks based on provided map content, such as (self-) identifying the general location of their homes (Jørgensen

[1]For example see Abildtrup et al. 2013, Bateman and Langford 1997, Bateman et al. 2006, 2011, Brouwer et al. 2010, Campbell et al. 2008, 2009, Colombo and Hanley 2008, Georgiou et al. 2000, Johnston and Duke 2009, Johnston et al. 2013, Jørgensen et al. 2013, Loomis 2000, Meyerhoff 2013, Moore et al. 2013, Morrison and Bennett 2004, Pate and Loomis 1997, Rolfe and Windle 2012, Sutherland and Walsh 1985, Yao et al. 2014

[2]These include the type of good, the availability of substitutes, directionality, recognized borders or geopolitical thresholds, and whether WTP is motivated by use or non-use motivations (Bateman et al., 2000, 2006, Brouwer et al., 2010, Hanley et al., 2003, Johnston and Duke, 2009, Jørgensen et al., 2013, Loomis, 2000, Pate and Loomis, 1997, Schaafsma et al., 2012).

et al. 2013) or visited recreation sites (Abildtrup et al. 2013).

Notwithstanding the ubiquity of maps such as these within SP questionnaires, the SP literature provides little guidance on the design of these maps, or on the systematic impact of map content on SP responses (for an exception, see Johnston et al. 2002). As a result, there is significant variation in both the design and content of maps included in published SP questionnaires, and no guidelines for minimum standards. Despite this variation, there are certain elements that are common across maps used to characterize policy effects within SP surveys. For example, maps in SP surveys are almost universally "generic" with respect to the spatial information provided to individual respondent households; the map viewed by each respondent is identical. As a result, maps of affected policy areas rarely (if ever) identify the specific location of each respondent's household within the affected area. This approach is grounded in the generally untested assumption that each respondent is aware of his/her exact household location relative to the mapped policy area, and hence possesses sufficient information on proximity and related spatial factors to support well-informed preference elicitation.

The validity of this assumption is questionable. It is well-established that "adults are not always very competent or confident in using maps" (Blades and Spencer 1987, p. 64). Hence, unless surveys provide clear information on the location of both policy effects and respondents' homes, it is possible that lay respondents may have difficulty identifying the location of their homes relative to mapped policy areas. Carson (1998, p. 23) notes that "[r]espondents will tend to fill in whatever details are missing from the CV survey with default assumptions." This general observation likely also applies to information (or lack thereof) in survey maps. As a result, the generic maps commonly used in SP surveys may encourage respondents to speculate regarding spatial factors that are potentially critical to well-informed preference elicitation, such as their proximity to policy effects. These effects may be particularly likely given the types of maps that are common within SP surveys, which often cover large areas (often hundreds of square kilometers) but provide few identifying landmarks.

The reason for the lack of individualized spatial geocoding in SP surveys (e.g., showing each respondent the specific location of his/her home on a map of policy impacts) is obvious this requires analysts to generate an individualized survey, with individualized geocoded maps, for each and every respondent. It also requires the addresses of respondents to be known prior to producing final survey materials. Until recently, the cost and computational difficulty of such efforts were prohibitive. However, recent advances in automated, high speed digital geocoding and GIS map generation now enable cost-effective production of surveys tailored to the spatial characteristics of each respondent household. For example each survey, whether printed or presented on a computer screen, can include a unique GIS map pinpointing the exact location of each household relative to affected policy areas. Such individualized geocoding of SP questionnaires could, in principle, provide information allowing more accurate welfare estimation, for example mitigating potential biases related to respondents' speculation regarding the proximity of policy effects. The empirical capacity of such individually-geocoded SP questionnaires to enhance welfare estimation, however, remains unknown.

This paper evaluates the common practice of generic policy-area mapping in SP surveys compared to a more information-intensive alternative in which survey maps pinpoint the location of each respondent household. To the knowledge of the authors, this is the first systematic evaluation of an environmental economics choice experiment (CE) that provides individually-geocoded information on the exact location of each respondent's household relative to policy effects. This required a unique survey map to be generated for each respondent household, showing both the location of policy effects (here, rivers affected by riparian land restoration) and the location of each respondent's home in the policy area. Results of these individually-geocoded CEs are compared to an otherwise identical CE with a generic map that does not pinpoint each respondent's home location; this latter survey reflects standard practice in the SP literature. Systematic comparison of the results from these two instruments illustrates the potential implications of survey design that provides additional policy-relevant spatial detail, and also suggests the potential limitations of generic policy-area maps that are now standard practice in SP survey design.

Methods are illustrated using an application of choice experiments to riparian land restoration in the Merriland, Branch Brook and Little River Watershed of south coastal Maine. Results suggest individually-geocoded surveys provide additional information that is relevant to respondents, with quantifiable implications for welfare estimates. Results also demonstrate that these effects vary intuitively across different policy outcomes. Specifically, for CE attributes whose value would not be expected to vary according to micro-level spatial proximity, WTP does not vary when households are provided with individualized maps. However, for attributes whose value is expected to vary according to proximity, results demonstrate statistically significant influence on welfare estimates. These results suggest that individually geocoded SP surveys can provide information directly relevant to well-informed preference elicitation.

2 The Relevance of Maps in Stated Preference Welfare Estimation

Over three decades of stated preference research demonstrates the relevance of spatial factors, such as proximity, to SP welfare elicitation. Recent discussions of this literature are provided by Bateman et al. (2006), Schaafsma et al. (2012), Jørgensen et al. (2013), and Abildtrup et al. (2013), among others. Within this literature, most findings are based on an assumption that maps and related material included in survey questionnaires enable respondents to accurately infer needed information on spatial relationships (e.g., their proximity to affected resources or areas). For example, models of distance decay (i.e., proximity effects on WTP) typically incorporate actual driving times or Euclidean distances between a respondent's home and an affected policy location (e.g., river, recreation site, etc.), presuming that the survey has provided sufficient information for respondents to infer these actual distances, and hence that these objective values have influenced responses.

Maps included within SP surveys are intended to provide respondents with spatial information about policy changes and outcomes, respondent proximity to policy area, and other spatial factors which might influence respondent preference elicitation. For example, the SP survey in Jørgensen et al. (2013) uses a map of the Odense River in Denmark to display where river improvements would occur if the policy scenario were to be adopted. The CE described by Martin-Ortega et al. (2010) includes a map of the Guadalquivir river basin in southern Spain. Each policy option in their experimental design has a corresponding map denoting where water quality improvements would occur. Similarly, the survey of Schaafsma et al. (2012) maps eleven lakes subject to proposed water quality improvements of different types. The CE of Johnston et al. (2011, 2012) depicts Rhodes Island rivers and tributaries that would be potentially affected by fish passage restoration scenarios. The map in Schaafsma et al. (2012, p. 24) shows the suburban region south of Amsterdam and asks respondents to evaluate possible improvements to lakes coded by water quality. Abildtrup et al. (2013), in contrast, includes an interactive mapping task in which respondents were asked to "identify on a map the forest visited most often during the last 12 months."

Each of these maps depicts a different region and environmental amenity but are otherwise similar in the type and quantity of spatial information provided. Each shows relatively large areas (i.e., hundreds of square kilometers). They each include a few points of interest. Some provide roads and town names. Despite these differences, each map is universally generic; maps do not differ across individual respondents. To be clear, maps included in SP surveys occasionally vary across survey scenarios or versions. Yet this is distinct from maps that provide unique information to individual respondents. For example, both Martin-Ortega et al. (2010) and Schaafsma et al. (2012) vary maps based on the specific policy scenarios considered by respondents. However, each responded presented with a particular CE scenario viewed an identical map of that scenario.

Map designs such as these are the norm in stated preference surveys. While the size, detail and landmarks of the illustrated policy area(s) may vary, these maps rarely if ever incorporate information that situates the individual respondent within the illustrated area, for example by illustrating the specific location of his/her place of residence relative to the illustrated policy effects. This is particularly true for printed (paper) surveys, for which the cost and effort of producing individual-specific survey booklets and maps has typically precluded such approaches. Currently, surveys do not provide even an approximate location of the respondent within these large areas.

Despite the universal use of such generic maps in SP questionnaires, it is not clear that this approach provides sufficient information to support well-informed preference elicitation. More specifically, the ability of a respondent to infer appropriate spatial information from a generic map (i.e., one that omits their home location) depends on the ability of respondents to (a) locate their own home or other relevant locations relative to affected policy areas or resources, and (b) infer appropriate spatial information contingent on this location. The ability of respondents to accomplish these tasks accurately has not been evaluated in the SP literature. Moreover, evidence from other literatures suggests that respondents may have non-trivial difficulty inferring relevant spatial information from such maps. An extensive literature demonstrates a common lack of competence with maps among lay adults, leading to unanticipated or misinformed wayfinding (Blades and Spencer 1987). This is particularly true when relevant information is omitted (MacEachren 2004).

This observation is directly relevant to stated preference welfare elicitation. If maps used to illustrate survey scenarios do not provide the information required for respondents to understand spatial factors relevant to their welfare, such as their proximity to affected resources, their responses may be influenced by speculations regarding these factors that may differ from actual conditions. The result can be responses and subsequent welfare estimates grounded in unknown respondent speculations, and hence subject to unknown biases (cf. Johnston et al. 2013). These issues have thus far been largely overlooked by the SP literature, which typically presumes that generic policy area maps provide sufficient information to motivate well-informed responses. Yet while this concern is seemingly clear in concept, there is no evidence that demonstrates systematic biases related to SP respondents' misreading of generic survey maps.

The following section continues with a theoretical model formalizing the role of spatial information in SP welfare analysis and survey design. This is followed by an empirical application grounded in this theoretical framework that enables the effect of spatial information in SP surveys to be evaluated. For example, results enable the evaluation of differences between CE welfare estimates informed by spatial information in generic scenario maps and otherwise identical estimates informed by individually-geocoded maps. Results provide direct insight into whether and how spatial information is used by respondents to inform CE responses.

3 A Theoretical Model of Geospatial Information and Preference Elicitation

Valid preference elicitation depends on individuals' ability to make well-informed and rational choices based on the information provided in a SP survey (Bergstrom et al. 1989, Hoehn and Randall 2002). Johnston et al. (2002) further demonstrates that information communicated (intentionally or unintentionally) by SP survey maps can influence preferences and WTP. Similar observations regarding the importance of mapped information on SP responses have been made in other disciplines (e.g., Yamada and Thill 2003). Combined, these observations suggest the relevance of systematic research into the informational content of SP survey maps and the adequacy of this information to support well-informed policy choices and welfare analysis. The absence research in this area has left researchers to make seemingly ad hoc choices regarding the quantity and type of geospatial information that should be incorporated within SP survey maps, with little formal insight into the potential influence of these design choices on preference elicitation.

For example, it is possible that the type of generic maps currently used within SP research provide sufficient information to enable well-informed policy choices by respondents. This would seem particularly likely for scenarios, valuation tasks and nonmarket goods for which micro-level spatial proximity is not directly relevant for welfare. Hence, the potential inability of a respondent to infer the exact location of his/her home relevant to policy effects would be largely irrelevant. An example would be a valuation task in which respondents' choices are primarily motivated by nonuse values, for which evidence regarding sensitivity to proximity and other spatial factors has been mixed (Bateman et al. 2006, Hanley et al. 2003, Johnston et al. 2013, Loomis 2000, Rolfe and Windle 2012). However, there may be other instances in which welfare effects are sensitive to micro-level spatial factors. In such cases, the additional specificity provided by maps that identify key features such as respondent's home location could be directly relevant to respondents, and could help prevent speculation and welfare biases related to inadequate spatial information. Currently, the literature provides no information to help researchers identify if and when more informative map content is directly relevant to preference elicitation and indeed, required to elicit unbiased preferences.

To formalize these issues, we begin with a simple theoretical framework in which utility for household h and policy scenario p, $U_{hp}(\cdot)$, is a function of a vector of policy outcomes $\mathbf{X_{ph}}$, household attributes $\mathbf{Y_h}$, and the cost of the policy to the household, C_{ph}. Utility is also influence by a vector of spatial policy attributes, $\mathbf{S_{ph}}$, that are considered exogenous to the household. Elements in $\mathbf{S_{ph}}$ might include, for example, proximity or direction to different types of policy outcomes. Following standard practice (Hanemann 1984), we assume that utility includes both a systematic or observable component $V_{hp}(\cdot)$ and a random component treated as an unobservable error, ε_{hp}, such that

$$U_{ph}(\cdot) = V_{ph}(\mathbf{X_{ph}}, C_{ph}, \mathbf{Y_h}, \mathbf{S_{ph}}) + \varepsilon_{ph} \tag{1}$$

Based on this specification we further partition vector $\mathbf{X_{ph}}$ into two different types of policy outcomes, x_{ph1} and x_{ph2}, where these are distinguished by the relationship of preferences to $\mathbf{S_{ph}}$. For the former,

$$\left.\frac{\partial U_{ph}(\cdot)}{\partial x_{ph1}}\right|_{\mathbf{S_{ph}}=\mathbf{S^A_{ph}}} \neq \left.\frac{\partial U_{ph}(\cdot)}{\partial x_{ph1}}\right|_{\mathbf{S_{ph}}=\mathbf{S^B_{ph}}} \forall \mathbf{S^A_{ph}} \neq \mathbf{S^B_{ph}} \tag{2}$$

where $\mathbf{S^A_{ph}}$ and $\mathbf{S^B_{ph}}$ are different values for the vector of spatial attributes $\mathbf{S_{ph}}$. That is, the marginal utility of x_{ph1}, and hence WTP, is affected by spatial policy attributes $\mathbf{S_{ph}}$. In contrast, for policy outcomes x_{ph2},

$$\left.\frac{\partial U_{ph}(\cdot)}{\partial x_{ph1}}\right|_{\mathbf{S_{ph}}=\mathbf{S^A_{ph}}} = \left.\frac{\partial U_{ph}(\cdot)}{\partial x_{ph1}}\right|_{\mathbf{S_{ph}}=\mathbf{S^B_{ph}}} \forall \mathbf{S^A_{ph}} \neq \mathbf{S^B_{ph}} \tag{3}$$

such that marginal utility is independent of spatial factors.

As implied by (3), the information on spatial attributes presented in a SP survey should be irrelevant to preference elicitation for x_{ph2}, absent other biases or related information effects. An example would be WTP for the preservation of an endangered species, where WTP is motivated entirely by nonuse values unrelated to spatial factors. For x_{ph1}, in contrast, spatial information inferred from a SP survey is directly relevant to preference elicitation, as marginal utility depends on spatial attributes. As implied by (1) above, both x_{ph1} and x_{ph2} can be included in the same SP scenario.

Now consider a situation in which an SP survey presents incomplete information on the true vector of spatial attributes $\mathbf{S^A_{ph}}$; an example might be a generic map that omits the respondent's household location relative to the area in which policy outcomes occur. Given incomplete information, the respondent must infer the welfare change due to SP policy scenarios based on an assumed vector of spatial attributes, $\mathbf{\tilde{S}^A_{ph}}$, which may or may not correspond to the true vector $\mathbf{S^A_{ph}}$. Based on (1) - (3) above, the omission of relevant spatial information will influence anticipated welfare change (and hence survey responses) under two conditions. First, the affected policy outcomes in question must be of type x_{ph1}, for which spatial attributes influence marginal utility. Second, assumed spatial attributes must diverge from actual conditions

($\tilde{\mathbf{S}}^{\mathbf{A}}_{\mathbf{ph}} \neq \mathbf{S}^{\mathbf{A}}_{\mathbf{ph}}$). If either of these conditions fail to hold, welfare estimation should remain unaffected by the presentation of incomplete spatial information. Hence, the sensitivity of estimated marginal utilities (or derived implicit prices) to systematic variations in the quantity of geospatial information in survey maps can provide direct insight into conditions under which the omission of this information is likely to be utility-neutral, and hence irrelevant to preference elicitation.

While these observations are straightforward in theory, the SP literature provides little if any empirical guidance regarding whether and when these concerns are likely to be significant for SP survey design. Specifically, when, and under what conditions, would we expect the type of generic maps used universally within SP surveys to promote respondent speculation and potential biases in welfare estimation? The remainder of this paper presents a case study grounded in the theoretical model above, explicitly designed to evaluate the potential sensitivity of welfare estimates to enhanced geospatial content in SP surveys, focusing on the potential relevance of individually-geocoded maps to well-informed preference elicitation.

4 Empirical Application and Hypothesis Tests

We address the empirical question of whether SP welfare estimates are robust the provision (or omission) of individual-specific geospatial information using a case study of riparian land restoration in the Merriland, Branch Brook, and Little River (MBLR) Watershed. This watershed overlaps the communities of Kennebunk, Sanford and Wells in south coastal Maine. The choice experiment questionnaire (*Choices for Our Land and Water: A Survey of Kennebunk, Sanford and Wells Residents*) enabled estimation of the preferences and WTP of community residents for options that would restore natural vegetation on up to 500 acres of degraded (cleared or developed) riparian land, out of 4,700 total riparian acres in the watershed. Improvement to riparian land condition could also influence other ecological conditions that focus groups identified as potentially welfare-relevant, including the ecological condition of local rivers, the abundance of recreational fish, and water quality in downstream swimming sites. In addition, survey scenarios communicated changes in riparian development restrictions identified as potentially influencing residents' welfare. Inclusion of the latter attributes follows Johnston and Duke (2007), who demonstrate the potential relevance of such attributes for welfare estimation.

As described above, our primary hypotheses of interest relate to the potential impact of individualized, geocoded information in SP survey scenarios. The information required to test these hypotheses is derived through a systematic comparison of results from two otherwise identical choice experiments: one that includes a detailed "generic" map of the type that is nearly universal in SP research, and a second that includes a map that also pinpoints the location of the respondent's home relative to affected riparian land. The theoretical model for both choice experiments is identical, and begins with a standard random utility specification outlined above, in which household h chooses among options for riparian land restoration, including two multi-attribute restoration options (p = A, B) and a status quo (p = N) option that includes no restoration and zero household cost. Each policy option i is characterized by a vector of k=6 non-cost attributes, $\mathbf{X_p} = [X_{p1}...X_{pk}]$, representing policy outcomes or methods, along with an unavoidable household cost C_p. When choosing between options p = [A,B,N] with utility specified following (1) - (3), the household is assumed to choose the option which offers the greatest utility. This enables parameters to be estimated using maximum likelihood models for discrete outcomes (e.g., mixed logit), with likelihood functions determined by assumptions regarding such factors as the unobservable component of utility and preference heterogeneity among respondents (Train, 2009).

The model and choice experiments were developed and tested over more than 3 years in a collaborative process involving scientists and other experts from the Wells National Estuarine Research Reserve. This included in-depth coordination between ecologists and economists to develop the coupled economic and ecological models and data underlying the choice experiment—along with meetings with managers and stakeholders. Nine focus groups were used to inform survey development and test questionnaire designs. Pretest focus groups included both verbal protocols (Schkade and Payne 1994) and other tests to gain insight into respondents' interpretation of questionnaires. Survey language, graphics and maps were pretested carefully to ensure respondent comprehension. Particular attention was given to the definition and interpretation of ecological and geospatial information. Prior to presenting choice questions, the survey provided information (1) describing the status of riparian land in the study area, (2) characterizing affected ecological systems and linkages, (3) describing restoration outcomes, and (4) providing definitions, derivations and interpretations of attributes used in survey scenarios. Information was conveyed via a combination of text, graphics including Geographic Information System (GIS) maps, and photographs, all of which were subject to careful pretesting.

Within both choice experiment versions, choice options were characterized by four ecological attributes, two attributes characterizing development restrictions/enforcement, and one attribute characterizing unavoidable annual household cost. Ecological attributes in the choice model were selected based on a conceptual model that coordinated ecological science with findings from focus groups (Johnston et al. 2012, Zhao et al. 2013). The initial direct effect of restoration is to increase the number of riparian acres with natural vegetation. This is communicated by the attribute *Riparian Land Condition*. The status quo and attribute values for this variable were projected using GIS raster maps showing conditions and changes in riparian land development and clearing within the study area. The predicted consequences of this restoration include (1) changes in the ecological condition of area rivers (*River Condition*), calculated using an aquatic biotic index following Johnston et al. (2011); (2) changes in the relative abundance of recreational fish (*Recreational Fish*), quantified using MBLR sampling data on brown trout; and (3) changes in the safety of water quality for swimming at area beaches (*Safe Swimming*), characterized using data on water quality testing available from the Maine Healthy Beaches Program. In addition to these ecological outcomes, policy attributes characterized the minimum width of the riparian area in the MBLR Watershed within which development would be restricted (*Development Setbacks*), and whether enforcement and inspections would be increased to prevent illegal development and clearing on riparian land (*Enforcement*). Household cost (*Cost*) was characterized as an unavoidable increase in taxes and fees required to implement each restoration plan.

Attribute definitions and summary statistics for the two choice experiment versions are presented in Table 1. Associated attribute levels within the experimental design (Table 2) were grounded in 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 in the watershed) as defined in survey materials. Relative scores represented percent progress toward the upper reference condition (100%), starting from the lower reference condition (0%). Scenarios also presented the cardinal basis for these relative scores where applicable.

A sample choice question is illustrated by Figure 1.

Generic and Individually-Geocoded Survey Versions

As described above, data for model implementation are drawn from two independent versions of the final survey. Two survey versions were distinguished only by the level of spatial detail in maps included within survey booklets. Maps in both survey versions were pretested carefully along with other survey materials to ensure respondent comprehension. The first survey version included a detailed generic map of the policy area, including landmarks, roads and potentially affected riparian land in the watershed (Figure 2). The policy area was illustrated at three different (nested) magnifications and included a distance scale (in miles) to enable respondents to infer proximities. This version follows common practice in the SP literature.

The second, geocoded version of the survey was identical in all aspects, with the exception of additional information provided on the survey map. Specifically, the geocoded survey map also identified the specific location of the respondent's household using a bright yellow dot (Figure 3). This was accompanied by the text, "Where do you live in this area? This survey was mailed to a neighborhood within $^1/_4$ mile of the yellow dot." The map was developed to enable respondents to visualize the location of their home relative to rivers and riparian land in the watershed to within $^1/_4$ mile, while still maintaining respondent confidentiality (i.e., respondents cannot be uniquely identified using the information in the map).

Production of the geocoded surveys required the generation of individualized booklets for each respondent. Randomly sampled respondent addresses within the three sampled towns (Kennebunk, Sanford and Wells) were first geocoded using an online application programming interface. An automated ArcGIS python script was then used to generate individual maps by iterating over each of these addresses and updating the area map with a unique location marker. Custom software was then written to embed each of these maps within a unique survey for each individual respondent. A barcode system (one number per household) was devised to track each survey, thereby ensuring receipt of the correct geocoded survey by each household. This process allowed the generation of thousands of surveys, each with an individual identifier and unique geocoded map targeting an individual household.

Experimental Design and Implementation

The fractional factorial experimental design minimized D-error for a choice model covariance matrix with both main effects and selected two-way interactions (Rose and Bliemer 2008, Bliemer et al. 2009). The final design included 72 profiles optimally blocked into 24 booklets, and was identical for both versions of the choice experiment. Each respondent was provided with three choice questions and instructed to consider each as an independent, non-additive choice. The resulting mail surveys were implemented from December 2013 through January 2014. Surveys were mailed to 2,544 randomly-selected households in the three towns (1,272 per version), oversampling those residing within the MBLR watershed itself (all watershed residents were sampled). To ensure that the geocoded survey version targeted a residential location, surveys were only mailed to those with physical addresses (i.e., surveys were not mailed to PO boxes). Survey implementation followed Dillman et al. (2009), with multiple follow-up mailings to increase response rates. Of deliverable surveys, 366 completed surveys were returned from the generic map version and 368 were returned from the geocoded version, for a nearly identical response rate of 34% (of deliverable surveys) in both cases.

Model and Welfare Estimation

The random utility model for both choice experiment versions was estimated using mixed logit (ML) with 100 Halton draws. Identical models specifications are estimated for versions. The model is specified to allow for correlations across multiple responses from each respondent (panel data). The final specification was chosen after the estimation of preliminary models with varying specifications of fixed and random coefficients. Within the final model, coefficients on an alternative specific constant for the status quo (*ASC*), *Recreational Fish*, *Safe Swimming*, *Development Setbacks*, and *Enforcement* are specified as random with a normal distribution. The coefficient on *Cost* (sign-reversed) is random with a bounded triangular distribution, ensuring positive marginal utility of income (Hensher and Greene 2003). The coefficients on *Riparian Land Condition* and *River Condition* are specified as non-random. Drawing from model coefficients, we estimate welfare measures (implicit prices and compensating surplus) using the welfare simulation described by Johnston and Duke (2007), following the general approach of Hensher and Greene (2003)[3]. Presented WTP estimates reflect the mean over the parameter simulation of mean WTP calculated over the coefficient simulation. While we illustrate results only for one model specification, evaluations with alternative specifications suggest that the results presented below are robust.

Hypothesis tests directly follow equations (2) and (3) above. Specifically, we evaluate the extent to which choice experiment results and implicit prices vary systematically between the two survey versions, and the extent to which variations across different attributes reflect theoretically expected patterns. Because the confounding role of the scale parameter prevents naive comparison of coefficient estimates across models (Swait and Louviere 1993), we focus the analysis on an evaluation of implicit prices (or marginal WTP for individual attributes), which are not confounded by scale. We also assess differences in primary, policy-relevant model conclusions, for example inferences regarding the statistical significance of relative marginal utilities (reflected by mixed logit coefficients on main effects) and welfare effects.

5 Results

Results for the two independent models are reported in Table 3; we refer to these as results of the generic and individually-geocoded versions. As noted above, the two choice experiments differed only in the presentation of information on the respondent's home location within the map included in the individually-geocoded version. This variation appeared on a single page of the survey booklet—all other elements of the choice experiment were identical. Both of the resulting models are statistically significant at $p<0.0001$, with pseudo-R2 statistics in excess of 0.21. Coefficient estimates on all ecological and policy process main effects are statistically significant at $p<0.01$ in all models. The sole exception is the coefficient estimate on *Riparian Land Condition* within the individually-geocoded version; this result is discussed below.

In all cases, signs of statistically significant coefficients match prior expectations derived from focus groups. For example, among the relevant results of both choice experiments is that increases in develop-

[3] The procedure begins with a parameter simulation following the parametric bootstrap of Krinsky and Robb (1986), with R=1000 draws taken from the mean parameter vector and associated covariance matrix. For each draw, the resulting parameters are used to characterize asymptotically normal empirical densities for fixed and random coefficients. For each of these R draws, a coefficient simulation is then conducted for each random coefficient, with S=1000 draws taken from simulated empirical densities (either normal or bounded triangular, depending on the assumed distribution for each coefficient). Welfare measures are calculated for each draw, resulting in a combined empirical distribution of R×S observations from which summary statistics are derived.

ment restrictions are associated with positive marginal utility. That is, coefficient estimates for *Development Setbacks* and *Enforcement* are both positive and statistically significant at $p<0.01$. These findings are consistent with a preference for more stringent regulation of both legal and illegal development on riparian land within the watershed, *ceteris paribus*, as suggested by preliminary focus group results. Both random coefficients also have statistically significant estimated standard deviations. This implies that while the average preference among residents is for more stringent regulation, there is also statistically significant heterogeneity in these preferences across the sample, such that in both cases a non-trivial proportion of the estimated coefficient distribution is in the negative domain.

Effects of Individually-Geocoded Maps on Choice Experiment Results

These and other policy-related findings aside, we focus the remainder of the discussion on hypotheses related to the impact of individually-geocoded information within choice experiments. Among the initial findings here is the difference in coefficient sign and statistical significance for *Riparian Land Condition*. This attribute is associated with a positive and statistically significant mean coefficient estimate in the generic choice experiment model, but is associated with a non-significant (and trivially negative) coefficient estimate in the individually-geocoded choice experiment model. This result alone suggests that different inferences would be drawn from the two choice experiment versions regarding respondents' preferences for changes in *Riparian Land Condition*, and that the incorporation of individualized maps within a choice experiment is not preference neutral (i.e., it affects model results).

Beyond this difference in statistical significance, comparison of the coefficient estimates across the two models is not directly informative; the confounding role of the logit scale parameter prevents naive comparison of unadjusted coefficient estimates across models (Swait and Louviere 1993). Instead, we continue the analysis through an evaluation of implicit prices, which are more directly relevant for policy and not confounded by scale.

Implicit price results are shown in table 4, simulated from mixed logit results as described above. As noted above, all variables except *Development Setbacks*, *Enforcement* and *Cost* represent percent progress towards the upper ecological reference condition (100%) from the status quo. Hence, implicit prices for all ecological attributes may be directly interpreted as the marginal WTP for a one percentage point change in each attribute. For *Development Setbacks*, results reflect marginal WTP per additional foot of required setback, whereas the implicit price for *Enforcement* reflects the marginal WTP associated with the presence of additional enforcement activity (*Enforcement* = 1) compared to the status quo (*Enforcement* = 0). The rightmost column of Table 4 illustrates the difference between implicit prices estimated from the two models. We calculate statistical significance levels (p-values for two-tailed tests) for each of the implicit prices and differences. Significance levels are determined through percentiles on the empirical welfare distributions (Poe et al. 2005), with these distributions accounting both for sampling variation reflected in the estimated covariance matrix for model parameters and the estimated distribution of random coefficients (Hensher and Greene 2003).

In all cases except one, implicit prices from both choice experiment versions are statistically significant at $p<0.01$. Moreover, as expected, most implicit prices are the same across both choice experiment versions. For all attributes except *Riparian Land Condition* and *Enforcement*, we find nearly identical point estimates of WTP and no statistically significant differences. This is a promising result for the standard practice of generic maps within stated preference surveys as most welfare estimates are unaffected by the additional information provided by an individually-geocoded map.

However, results for *Riparian Land Condition* show a statistically significant and potentially policy relevant difference between the two choice experiment versions, mirroring differences in parameter estimates discussed above. Specifically, when respondents are provided with a generic map, choice experiment results suggest positive and statistically significant WTP for increases in the percentage of riparian land in the watershed covered by natural vegetation—$1.41 per percentage point increase, or 47 additional vegetated acres. When respondents are presented with an individually-geocoded map showing their home location, however, choice experiment results suggest that WTP is not statistically significant. This is a statistically significant and directly policy-relevant divergence between results of the two choice experiments, purely related to the difference in provided cartographic information.

Implicit prices for *Enforcement* also show a relatively large point estimate change—from $16.62 (generic version) to $27.28 (individually-geocoded version), or a 64% increase. After accounting for the estimated coefficient distributions, however, this difference does not meet the threshold for statistical significance ($p<0.12$). Hence, while the result for this attribute is not definitive, it does suggest that there might have been some influence of the individually-geocoded map on preferences.

Additional insight may be gained by interpreting these empirical results within the context of our theoretical model. Recall, our primary hypothesis is that generic maps may exclude information that is necessary for respondents to accurately assess their welfare change. As shown by (2) and (3) above, two conditions must hold for the omission of spatial information to influence choice experiment welfare estimates. First, spatial attributes must be relevant—they must influence marginal utility for at least some valued outcomes. Second, the excluded information must be relevant. Here, for example, the geocoded maps must enable respondents to more accurately infer needed spatial information, compared to generic maps.

These theoretical conditions, combined with the results in Table 4, provide evidence that generic maps can lead to misguided welfare inferences. They also provide insight into reasons why only some welfare estimates are affected. Specifically, the statistically significant variation in WTP for *Riparian Land Condition* implies that (1) the geocoded-maps provided information that differed from the generic map, and (2) that this difference was relevant to WTP, at least for this attribute. The fact that WTP for other attributes was unaffected further implies that WTP for these outcomes was not sensitive to the (additional) spatial information provided by the individually-geocoded maps. These results have intuitive appeal, particularly in light of focus group results. For example, focus group results suggested that many area residents did not know the micro-level proximity of their homes to riparian land in the watershed—but that this did not affect their preferences for most restoration outcomes. For example, preferences for recreational fish abundance (*Recreational Fish*), to the extent that they were affected by spatial factors, appeared to be motivated primarily by proximity to popular fishing areas. Proximities to these areas were already known by anglers, irrespective of information provided in survey maps. Similarly, *Safe Swimming* reflects changes that would occur at popular area beaches where the locations and proximity of which are already well-known by area residents. Finally, focus group results suggested that preferences for the ecological condition of area rivers (*River Condition*) were motivated primarily by nonuse values unrelated to spatial proximity within the surrounding communities. For attributes such as these, one would not expect an individually-geocoded map to provide additional information relevant to preferences.

However, for other types of attributes, additional spatial information is likely relevant. For example, *Riparian Land Condition* reflects changes in the vegetation and aesthetics of riverside land, the preferences for which could be influenced by proximity to that land. This possibility, combined with respondents' lack of prior knowledge concerning the proximity of their homes to this land, could lead to the welfare-relevance of a map that directly illustrates this proximity. This welfare-relevance is supported by choice experiment results showing statistically significant differences in WTP for this outcome, when individually-geocoded maps are provided. The direction of this difference implies that respondents, when provided with only a generic map, speculate a closer proximity to riparian land than is actually the case, leading to larger and more statistically significant marginal WTP. When given an individually-geocoded map that allows them to correctly infer this proximity, marginal WTP diminishes—in this case becoming statistically insignificant. While intuition such as this is suggestive, however, it cannot be directly verified using model results alone.

The validity of such intuition notwithstanding, empirical results suggest the potential relevance of individualized cartographic information in stated preference surveys. These results lead to two primary conclusions. First, individualized information on the location of respondents' homes relative to policy effects influences choice experiment results and welfare estimation. Second, this information only affects welfare estimates for a subset of policy outcomes (or model attributes). Practical implications for the common use of generic survey maps are mixed. Where attribute preferences are not sensitive to micro-level spatial factors, generic maps might lead to the same (or similar) welfare inferences as the more informative, individualized maps tested here. In such cases, analysts might be justified in using less informative generic maps. However, present results also suggest the risks of omitting individualized spatial information when attribute values might be sensitive to micro-level spatial factors. In such cases, results can lead to misguided welfare inferences.

6 Conclusions

This paper presents the first systematic comparison of stated preference results informed by individualized cartographic information, compared to results from otherwise identical surveys using traditional generic maps. Results provide evidence that generic maps may provide insufficient information to support fully-informed preference elicitation. Results also suggest that the role of spatial information within stated preferences may be more nuanced than is typically assumed, with individualized cartographic detail only influential for a subset of policy outcomes. Hence, although our results suggest welfare estimates are sometimes (perhaps even often) robust to the use of alternative levels of spatial detail, greater attention is needed to potential relationships between the sufficiency of cartographic/spatial information in stated preference surveys, the specific types of policy outcomes for which welfare estimates are desired, and the interpretation and validity of empirical results.

These issues are particularly salient given the additional resources required to incorporate individually-geocoded maps within stated preference surveys. While advances in GIS mapping technology make such approaches increasingly feasible, they nonetheless require greater cost, time and expertise than survey designs using traditional generic maps. Researchers must balance these additional requirements against the risk of misinformed welfare estimates that might result if respondents draw inappropriate spatial inferences from generic maps. The present results suggest that effects on welfare estimates, while perhaps only relevant for a subset of model attributes, can be significant. The extent to which these effects are prevalent beyond the present case study, and hence justify additional survey design cost, has yet to be determined. Results here suggest the importance of future research in this area.

The results presented here must be viewed within the context of the present case study, along with all implied assumptions and possible empirical limitations. Moreover, this paper only addresses a few of the many challenges involved in the potentially complex role of spatial information within stated preference welfare analysis. These and other caveats aside, model results highlight the potential relevance of omitted spatial information within stated preference surveys. The traditional and typically unstated assumption in survey design is that generic maps provide sufficient information to support informed and unbiased preference elicitation, and will not lead to respondent speculation regarding welfare-relevant but omitted spatial information. Results here suggest that this assumption may be invalid, at least for some policy outcomes.

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Tables

Table 1: Attributes Description and Descriptive Statistics

Attribute: Description	Generic Map Mean (Std. Dev.)	Geocoded Map Mean (Std. Dev.)
ASC: Alternative specific constant (ASC) associated with the status quo, or a choice of neither plan.	.333333 (.471478)	.333333 (.471478)
Riparian Land Condition: The percentage of riparian land covered by natural vegetation, quantified using GIS land cover data layers for the Merriland, Branch Brook and Little River Watershed. Presented as a percentage of the reference condition. Range 0-100%.	89.13290 (4.049063)	89.11651 (4.034072)
River Condition: A multimetric index of aquatic ecological condition, reflecting the similarity of the restored area to the most undisturbed watershed area possible in south coastal Maine. Index components include the mass and variety of different macroinvertebrates distinguished by pollution tolerance. Presented as a percentage of the reference condition. Range 0-100%.	61.77611 (8.255039)	61.58879 (8.142299)
Recreational Fish: Average abundance of recreational fish within the Merriland, Branch Brook and Little River Watershed. Measured as the number of brook trout per 1000 feet of river. Presented as a percentage of the reference value for the region (30 fish per 1000 feet), defined as the highest average level sampled in any area of the Watershed. Range 0-100%.	61.63852 (8.142539)	61.60748 (8.127134)
Safe Swimming: The percentage of days during which water quality tests show safe levels of bacteria colony forming formations in samples at area beaches (Laudholm, Drakes Island, Crescent Surf, and Parson Beach). Calculated using data provided by Maine Healthy Beach Initiative. Range 0-100%.	86.56754 (2.022157)	86.54860 (1.998669)
Development Setbacks: The minimum width of the riparian area where development is restricted around rivers, in feet. Range 100-200 feet.	136.1789 (41.58686)	135.7321 (41.17899)
Enforcement: Binary (dummy) variable indicating whether enforcement is increased to prevent illegal development or clearing on riparian land. This could include inspections on private land if violations are suspected. A value of 1 indicates increased enforcement activity. Range 0-1.	.334897 (.472028)	.328349 (.469686)
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 0-60.	20.63164 (21.86148)	20.71028 (21.75625)

Table 2: Attribute Values

Attribute	Values[1]
Riparian Land Condition	**85% - 4000 acres** 87% - 4100 acres 90% - 4200 acres 95% - 4500 acres
River Condition[2]	**55%** 65% 75%
Recreational Fish	**55% - 17 Fish per 1000 Feet** 65% - 20 Fish per 1000 Feet 75% - 23 Fish per 1000 Feet
Safe Swimming[3]	**85%** 87% 90%
Development Setbacks[4]	**100 ft (river) / 25 ft (stream)** 150 ft / 75 ft 200 ft / 125 ft
Enforcement	**False** True
Cost	**$0** $5 $15 $30 $45 $60

[1] Bold denotes status quo values.
[2] Measured using an IBI (indicator of biotic integrity) score on 0%-100%
[3] The percentage of days area beaches are safe to swim

Table 3: Mixed Logit Regression Results: South Coastal Maine Riparian Land Restoration

Choice Attribute	Generic Map Recipients (Standard Error)	Geocoded Map Recipients (Standard Error)
Random Parameters		
ASC	-3.68727*** (0.71385)	-2.29846*** (0.50534)
Recreational Fish	0.04030*** (0.00844)	0.02908*** (0.00901)
Safe Swimming	0.10881*** (0.02609)	0.06766*** (0.02565)
Development Setbacks	0.00706*** (0.00284)	0.00659*** (0.00250)
Enforcement	0.76194*** (0.15624)	0.81205*** (0.15710)
Cost	-0.06428*** (0.00785)	-0.04214*** (0.00636)
Nonrandom Parameters		
Riparian Land Condition	0.06508*** (0.02275)	0.00856 (0.02215)
River Condition	0.05014*** (0.00905)	0.03183*** (0.00794)
Distributions of Random Parameters		
Standard Deviation ASC	5.91556*** (0.75916)	5.27222*** (0.69600)
Standard Deviation Recreational Fish	0.03273 (0.02902)	0.06716*** (0.01865)
Standard Deviation Safe Swimming	0.02148 (0.05290)	0.05123 (0.10220)
Standard Deviation Development Setbacks	0.02672*** (0.00529)	0.02158*** (0.00454)
Standard Deviation Enforcement	0.88917** (0.36023)	0.72187* (0.39681)
Spread Cost	0.06428*** (0.00785)	0.04214*** (0.00636)
χ^2	614.12735	499.63156
Pseudo R^2	0.2621964	0.2125160
Observations (N)	1,066	1,070
Respondents (N)	366	368

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

Table 4: Implicit Price Differences: Generic versus Geocoded Map Recipients

Choice Attribute	Generic Map Recipients (WTP_1) (Standard Error)	Geocoded Map Recipients (WTP_2) (Standard Error)	Mean Implicit Price Difference ($WTP_2 - WTP_1$) (Standard Error)
ASC	-79.82508*** (17.91017)	-76.54282*** (21.89749)	3.282261 (28.27499)
Riparian Land Condition	1.4091*** (0.4709791)	-0.3186554 (0.7334651)	-1.727755** (0.8712252)
River Condition	1.088973*** (0.1800713)	1.050705*** (0.2653499)	-0.0382678 (0.3205207)
Recreational Fish	0.8727871*** (0.1810518)	0.9634613*** (0.2977053)	0.0906742 (0.3482627)
Safe Swimming	2.37766*** (0.5946574)	2.237423*** (0.8866537)	-0.1402363 (1.067068)
Development Setbacks	0.152898*** (0.0713289)	0.2209538*** (0.0933744)	0.0680558 (0.1174427)
Enforcement	16.62064*** (3.914806)	27.28155*** (6.26838)	10.6609 (7.386727)

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

Figures

QUESTION 4

OPTION A and **OPTION B** are possible protection options for the area surrounding the Merriland, Branch Brook, and Little River. The current situation is the status quo with **NO NEW PROTECTION**.

Given a choice between the three, how would you vote?

Method or Effect of Protection	In 5-10 years under the Current Situation	In 5-10 years under Option A	In 5-10 years under Option B
Riparian Land Condition	**85%** 4000 out of 4700 riparian acres covered by natural vegetation	**90%** 4200 out of 4700 riparian acres covered by natural vegetation	**87%** 4100 out of 4700 riparian acres covered by natural vegetation
River Ecology	**55%** of best possible (100%) ecological condition	**65%** of best possible (100%) ecological condition	**65%** of best possible (100%) ecological condition
Recreational Fish	**55%** 17 out of 30 possible fish per 1000 sq. feet	**65%** 20 out of 30 possible fish per 1000 sq. feet	**65%** 20 out of 30 possible fish per 1000 sq. feet
Safe Swimming	**85%** of beach tests meet safe swimming guidelines	**87%** of beach tests meet safe swimming guidelines	**87%** of beach tests meet safe swimming guidelines
Development Setback	**100 feet** required between development and rivers; 25 feet for streams	**200 feet** required between development and rivers; 125 feet for streams	**100 feet** required between development and rivers; 25 feet for streams
Enforcement	**No Change** in enforcement and inspections	**Increased** enforcement and inspections	**Increased** enforcement and inspections
$ **Cost to your Household per Year**	**$0** Increase in Annual Taxes or Fees	**$30** Increase in Annual Taxes or Fees	**$60** Increase in Annual Taxes or Fees
HOW WOULD YOU VOTE? (CHOOSE ONLY ONE) I vote for	☐ **NO NEW PROTECTION**	☐ I vote for **OPTION A**	☐ I vote for **OPTION B**

38728

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Figure 1: Example Choice Question

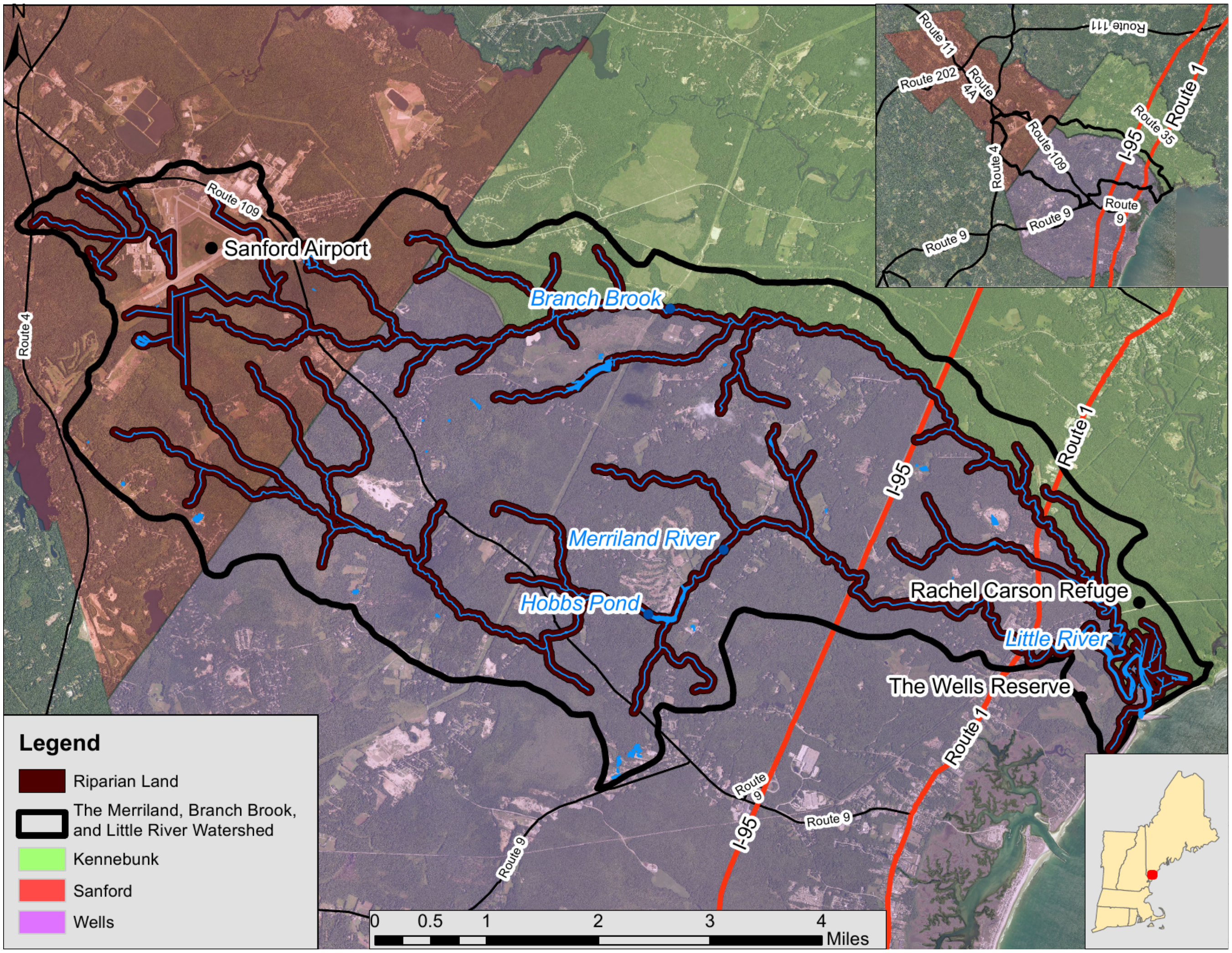

Figure 2: Choice Experiment Generic Map: Affected Policy Area in the Merriland, Branch Brook and Little River Watershed.

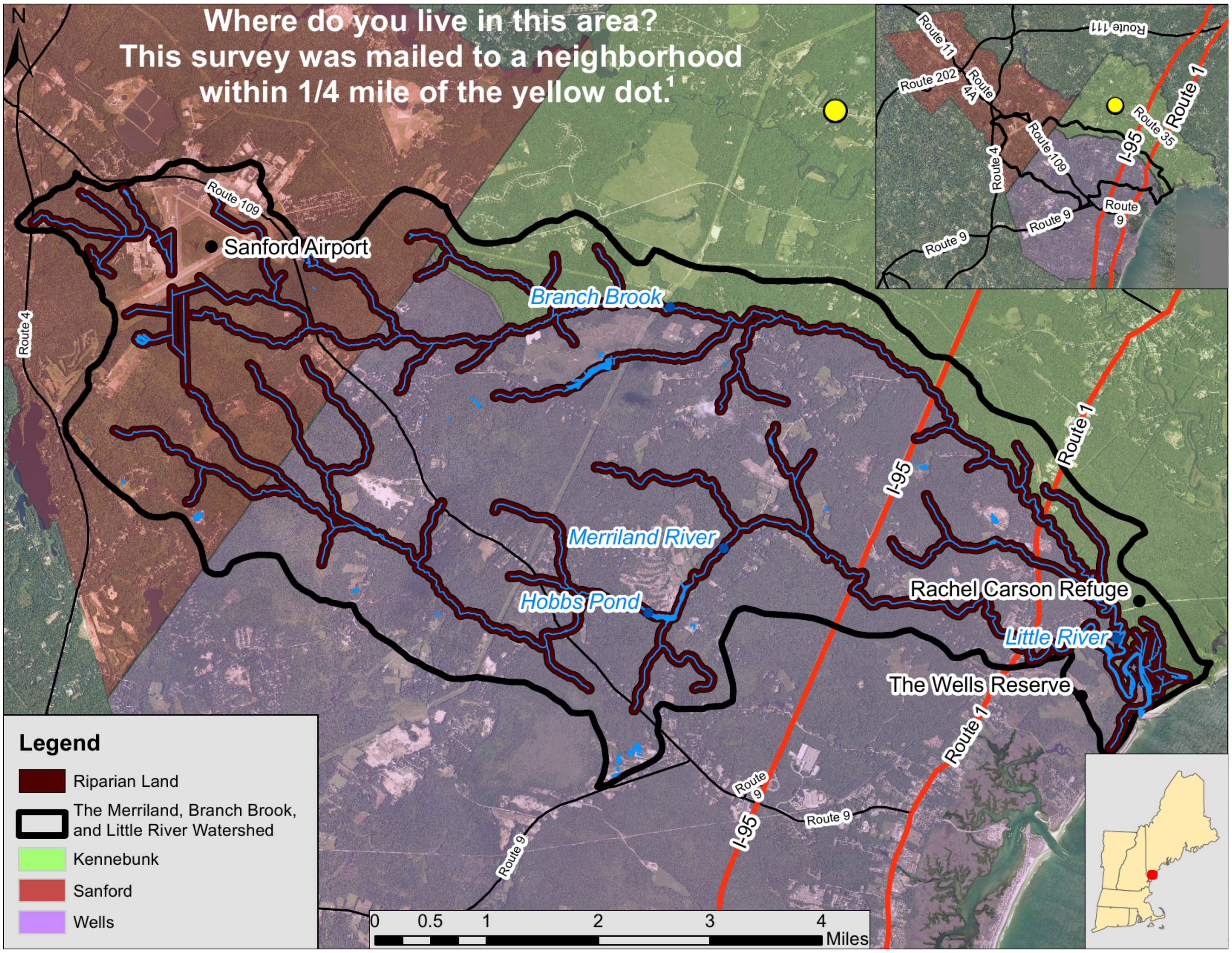

Figure 3: Choice Experiment Individually-Geocoded Map: Affected Policy Area in the Merriland, Branch Brook and Little River Watershed.