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At the Confluence of Data Streams: Mapping Paired Social and Biophysical Landscapes on the Puget Sound's Edge

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ABSTRACT

We seek to expand interdisciplinary insights into coastal management by pairing survey data from the general public with attendant landscape data in the Puget Sound region. Our social survey gathered information regarding attitudes and perceptions of changing social and environmental conditions in the Puget Sound Basin as well as views regarding possible management interventions. We mapped the survey data to US zip code regions and spatially overlaid the survey response data with existing geospatial data layers of biophysical conditions. Using mixed-effects logistic regression we examine the relationships between urban development trajectories and individual views about both environmental problems and possible policy responses. We found significant relationships between people's responses and the physical conditions within their residence zip code, as well as social variables, which illustrated the importance of developing new analytical approaches that consider the relationships between both biophysical and social features and individual attitudes about coastal environmental concerns.

KEYWORDS

environmental attitudes; environmental policy; landscape ecology; Puget Sound; social survey

Introduction

Puget Sound, USA exemplifies a complex coastal and estuarine ecosystem that necessitates research integrating the natural and social sciences (Berkes, Colding, and Folke 2003; Machlis, Force, and Burch 1997). For at least 13,000 years the Puget Sound's islands and inland watersheds have been home to peoples who have made use of its diverse marine and estuarine resources, and the Sound itself remains at the center of a region that is home to some 3.7 million people (Croes et al. 2008; U.S. Census Bureau 2010). Regional planners and governments do not anticipate any cessation in the sustained population growth that has come to define the area's recent past.

The interconnected waterways, basins, estuaries, and inland watersheds that support the system's hydrology provide habitat for a range of species of established cultural, economic, and ecological importance (Plummer et al. 2013). Many of these species, however, have faced

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population declines as the region's human populations and accompanying activities have increased, placing elements of the Sound's ecological integrity at risk (Williams, Levin, and Palsson 2010). Urbanization and the accompanying loss of coastal habitat are threats to the Sound's environment and affect the quality of life for residents across the region as well (Cereghino et al. 2012; Feely et al. 2010). Individuals and institutions inside and outside of the region recognize the importance of both the ecosystem's specific components, as well as the whole of the Puget Sound ecosystem—as the sum of these parts—for the rural and urban communities at its edge. Forestry, fishing, and agriculture feature prominently in the present and past of the region, and the Sound's scenic beauty has been an attraction for both tourist interests and the newer residents underpinning the region's growth. For long resident Coast Salish peoples, the Sound and its salmon (*Oncorhynchus* spp.), in particular, take on a unique cultural and spiritual importance (Pritzker 2000). The Puget Sound, then, is ultimately a saltwater estuary for which the potential benefits of interdisciplinary and collaborative research, analyses, and policy solutions are apparent.

Declines in marine species populations and risks to the biophysical quality of its estuarine waters have impelled Puget Sound environmental management entities to begin ecological restoration research and planning efforts in earnest. Many of these efforts have been coordinated through the regional institution embodied by the Puget Sound Partnership. The Partnership is a state level agency designed to coordinate among Puget Sound tribes, citizens, governments, researchers, businesses, and nonprofit organizations to develop and implement recovery priorities and actions, with the ultimate aim of restoring the health of the Puget Sound ecosystem. To its credit, the Partnership has evolved to recognize both the social and biophysical realities of the Sound, the challenges unique to understanding each, and has generally embraced the notion that the recovery of the Puget Sound ecosystem involves goals and research that are both social and ecological in nature (Puget Sound Partnership 2011). An overarching challenge for the Partnership and other Sound-oriented institutions interested in interdisciplinary questions lies in finding ways to integrate different types of social and biophysical research, data, and analyses. Successful integration of this kind could provide scientific insights into the relationships between social and environmental change. Indeed, integrated research, and the ecosystem-based management (EBM) it is meant to serve, require not only interdisciplinary collaboration, between riparian ecologists and oceanographers for example, but also collaboration and integration across methodological and data-related boundaries that have traditionally separated the social and natural sciences (Leslie et al. 2015).

In this study, we put forward an approach for integrating social and natural science efforts and tools by examining a confluence of data specific to the Puget Sound's social and biophysical landscapes, and by mapping, both analytically and visually, the relationships within these data. In particular, we consider how pairing data across the terrestrial portions of the Sound's environs might establish quantitatively the relationships between socially derived perceptions of the environment and actual physical measures of environmental conditions. Which sociodemographic characteristics relate to views on environmental concerns and interventions? Do patterns in perceptions of the environment, problems, and possible management solutions reflect on-the-ground biophysical characteristics of the Puget Sound region? Can we employ quantitative methodologies to disentangle possible relationships between sociodemographics, urban growth trajectories, landscape changes, and attitudes toward environmental policy? In order to consider these questions, we make use of data obtained through a large-scale telephone survey of a random sample of Puget Sound residents, and pair these responses with place-level data on the environments in which these respondents live.

Social versus biophysical data/primary versus secondary data

Social and natural scientific work in support of the broad goals of integrated marine, coastal, and estuarine management has often relied on existing data and ongoing monitoring efforts, particularly in efforts to develop assessments and indicators (Halpern et al. 2014; Sepez et al. 2006). In this regard the Puget Sound is no exception (Kershner et al. 2011). Indeed, though such secondary data analyses are sometimes the products of research and policy environments constrained by time and funding, they may still yield useful results and insights. For example, the work in landscape ecology necessary for understanding the Puget Sound's freshwater watersheds and nearshore environments is exemplified by a consortium of organizations behind the Puget Sound Nearshore Ecosystem Restoration Project (Anchor 2009; PSNERP 2010). This well-coordinated effort generated new geospatial data layers and synthesized existing data and monitoring efforts into a powerful, unified analysis and management tool. It provides detailed, spatially explicit information about conditions in the nearshore and its associated watersheds, including change analysis.

Social science efforts to support natural resource management have creatively used extant data because primary data collection efforts are often funded for short-term research periods or are organized as one-time surveys and field visits (Abbott-Jamieson and Clay 2010). Efforts within the National Marine Fisheries Service (NMFS) to develop geographically broad community-level indicators of social vulnerability vis-à-vis the marine environment have integrated demographic data from the U.S. Census Bureau's American Community Survey (ACS), county-level crime statistics, and other extant sources (Colburn and Jepson 2012; Himes-Cornell and Kasperski 2015; Jepson and Colburn 2013). Nevertheless, primary data collection in the form of one-time social surveys provides an invaluable baseline of information (Ward et al. 2014). They may also help characterize broader-level social networks (Hoelting et al. 2014). The information provided in such surveys can be of value to the development of natural resource management policy (Ward et al. 2014). Our social survey of the Puget Sound was similarly beneficial (Safford et al. 2014a).

Building on these integrated research experiences, we examine relationships between attitudes, perceptions, and beliefs about the Sound and its management in conjunction with landscape details specific to the spatial units from which these social views emerge. In this respect, this study presents an interdisciplinary collaboration between social scientists and a landscape ecologist, pairing data typically used in discipline-specific social science research with data often utilized in landscape ecology. The project further presents an alternative approach to combining an analysis of *primary* social data with spatially organized *secondary* landscape data in order to illustrate the linkages between socially situated policy views and local environments.

Methods

To investigate our central questions, we utilized data from a 2012 telephone survey of Puget Sound residents conducted by the National Oceanic and Atmospheric Administration

(NOAA) in partnership with the University of New Hampshire (UNH)'s Carsey Institute and Survey Center. This survey queried 1,980 individuals in King, Kitsap, Pierce, Mason, Skagit, and Whatcom counties about their views regarding environmental concerns and possible management actions (Safford et al. 2012a, 2012b, 2012c, 2014a). Counties chosen for the study include rural, urban, and suburban areas as well as locations across the diverse physical geography of the Sound (Figure 1).

Respondents were selected randomly from listed telephone numbers and among adult members of the target households. Survey results were then weighted to make minor adjustments so that the respondent pool's demographic characteristics (age, race, and sex) mirrored those recorded in the 2010 U.S. Census for each included county. Each of the 1,980 survey respondents were asked 45 questions, which included both basic demographic

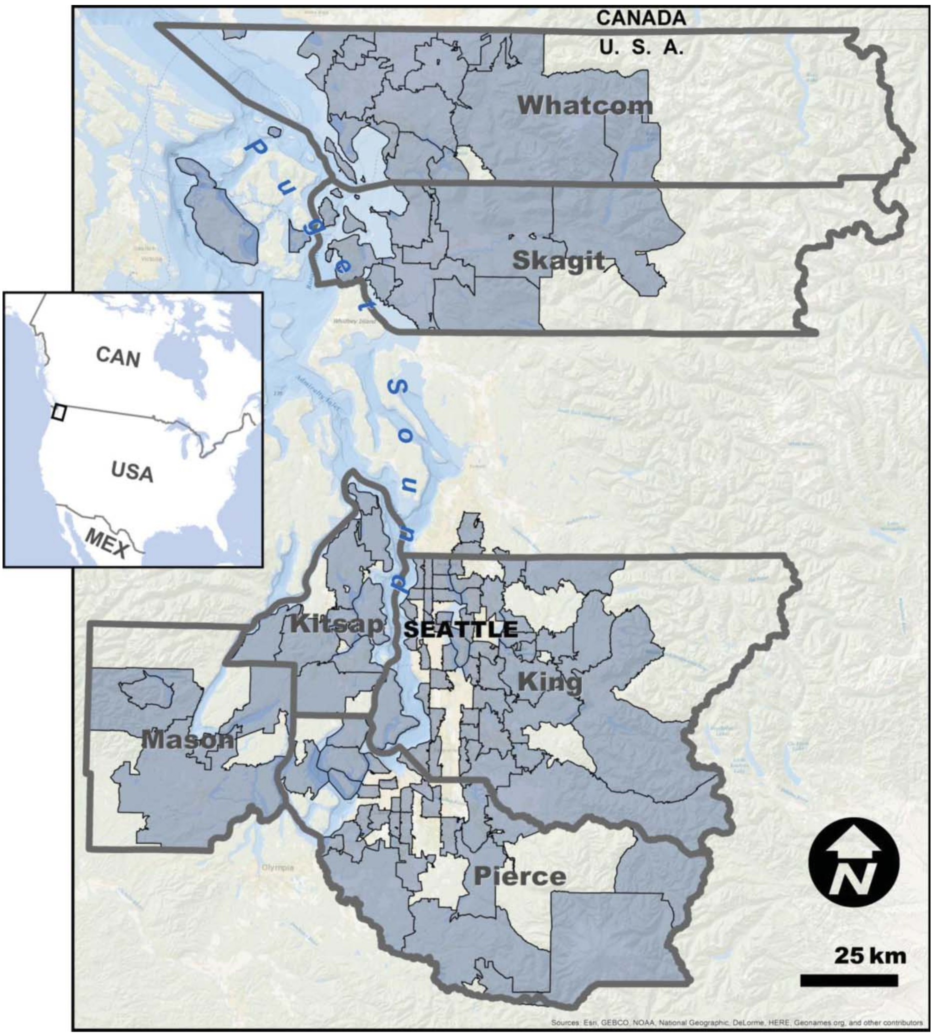

Figure 1. Map highlighting Puget Sound counties represented in the 2012 NOAA-UNH social survey (dark gray outlines) and the targeted Puget Sound zip codes for paired social survey and landscape data (light blue shaded regions).

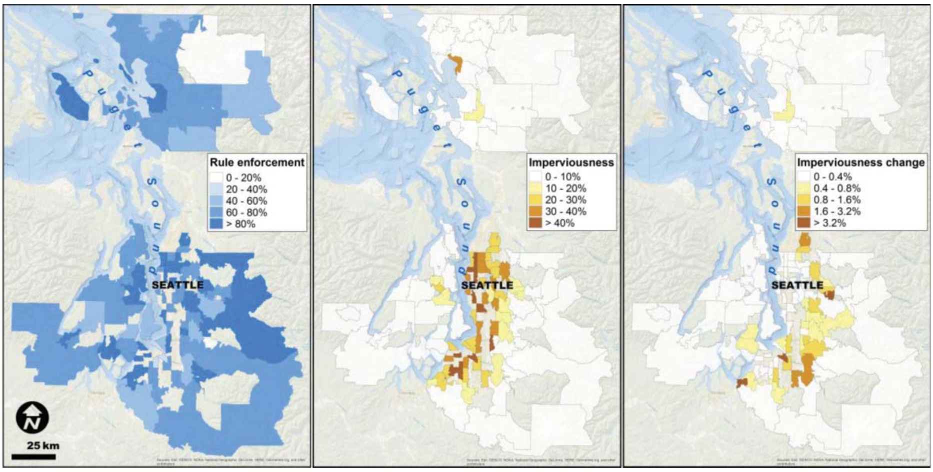

Figure 2. Support for environmental rule enforcement mapped across surveyed Puget Sound zip codes (left) as compared to levels of imperviousness (center) and levels of imperviousness change (right) mapped across the same zip codes.

questions and questions on a variety of topics related to social and environmental concerns in the Puget Sound. Initial analyses occurred at the county level (Safford et al. 2014a). In subsequent analyses, including the analyses at the center of the research presented here, zip codes were matched to survey responses to allow for a spatial scale of analysis at the finer zip code tabulation area (ZCTA) level (Figure 2).

For this study, we primarily used two of these social survey questions in order to analyze the integrated effects of social and biophysical characteristics on attitudes and beliefs about environment-related concerns. Survey respondents were presented with a series of potential concerns that might affect their community. One of these concerns focused on perceptions of rapid development or sprawl. "I'm going to read a list of issues that might be problems in some places in Washington. For each of these issues, please indicate whether you think it is or is not an important problem facing your community today: 'Too-rapid development, growth, or sprawl'." Fifty-three percent of respondents said sprawl was an important problem facing their community while forty-seven percent felt it was not.

The survey also included a set of questions assessing support for different environmental management or policy proposals. One of these options assessed support for increased enforcement of existing environmental rules. "I am going to read some specific environmental proposals. Please say whether you generally favor or oppose it: 'more strongly enforcing existing environmental regulations'." Eighty percent indicated they favor stronger enforcement of environmental regulations while twenty percent opposed these types of environmental interventions.

In this study we examine possible predictors of Puget Sound residents' responses to survey questions about development and enforcement of environmental regulations. In the pertinent literature, sociodemographic characteristics as well as length of residence often explain responses to these types of environment-related questions (Guagnano and Markee 1995; Hamilton et al. 2014; Krannich, Luloff, and Field 2011; Safford et al. 2014b; Steel, Lach, and Fomenko 2005). To consider these types of effects, we include demographic variables such as gender, age, level of educational attainment, and length of residence in our regression models. Numerous studies also demonstrate that political party affiliation is a strong predictor of attitudes and beliefs about environmental problems (Dietz et al. 2007; Hamilton 2011; McCright and Dunlap 2011; Safford et al. 2014a; Xiao and McCright 2007). To consider all possible effects of party affiliation, we examined whether self-identified Republicans, Democrats, and Independents, as well individuals who had no affiliation (or chose not to identify with a party), varied in their responses to the survey questions. Preliminary analyses showed no significant differences among Democrats, Independents, and the non-affiliated. However, Republicans varied significantly from all other affiliations. For this reason, we used self-identified Republicans as the referent in our models and then analyzed how they differed from those of other affiliations and the non-affiliated.

While the principal objective of this investigation was to test the related effects of social and biophysical characteristics on views about environmental change, we also hypothesized that respondents' views about the effectiveness of existing restrictions on development might also shape beliefs about sprawl and their support for increased enforcement of environmental rules. We used an additional question from the NOAA survey to investigate these possible effects. "Have conservation or environmental rules that restrict development generally been a good thing for your community, a bad thing, have they had no effect—or, are you unsure?" Residents were mixed in their assessments with forty-seven percent saying rules had been good for their community, thirteen percent felt they had negative effects, and the remaining forty-one percent were unsure or felt these rules had neither good or bad effects. We created a dummy variable from these results and included it in our regression models.

Finally, we examined how physical place-related characteristics might predict responses to our questions about sprawl and enforcement of environmental regulations. Sample data from the NOAA survey enabled us to analyze these relationships down to the level of the zip code area. We used the Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) Database (MTDB) for our zip code boundaries in the study (U.S. Census Bureau 2012). All survey data and environmental conditions were quantified and summarized for each zip code boundary that received survey responses.

We used the mean imperviousness in 2006 (Fry et al. 2011) and imperviousness change from 2001 to 2006 (Xian et al. 2011) data layers as a proxy for degree of urbanization in each of our zip code regions, where imperviousness is a measure of the area of impermeable surfaces such as building roofs; concrete or asphalt roads and parking lots; concrete, asphalt or brick sidewalks, pedestrian walkways, and malls. Imperviousness data were downloaded (http://www.mrlc.gov/finddata.php) from the Multi-Resolution Land Characterization (MRLC) Consortium National Land Cover Database (NLCD, May 2011 edition). The NLCD characterizes and tracks changes in land use and land cover for the entire United States, including Puerto Rico, by classifying LANDSAT TM (Land Remote-Sensing Satellite (System) Thematic Mapper) satellite imagery. The classified imagery is available at a spatial grain of 30 m, and the classifications are run every 5–7 years, beginning in 1992. The NLCD offers a variety of land use and land cover products based on their classifications of LANDSAT imagery, with mean imperviousness and imperviousness change as data layers of particular value for this study.

We calculated an area-weighted mean (AWM) imperviousness value for each of the surveyed zip code regions using ArcGIS (v. 9.3). The AWM approach facilitates quantification of regularly gridded data that occur over an irregularly shaped region. Specifically, we converted each of the two NLCD raster grids to vector format, and then we intersected (using

ArcGIS) each of these vector representations of imperviousness with the vector polygon outlines of the zip code regions in the survey. We used the information from this intersection to calculate an AWM imperviousness value (both for the year 2006 and for the change that occurred from 2001 to 2006) for each zip code polygon using the following equation:

$$I_{awm} = \left[\sum_{1}^{n} i_n(a_n) \right] \Big/ A$$

where i is the imperviousness value for a given grid cell or portion of a grid cell, a is the corresponding area of that given grid cell or portion of a grid cell, and A is the total area of the zip code polygon that contains said grid cell or portion of a grid cell. This equation effectively weights imperviousness values for a grid cell or portion of a grid cell based on the proportion of a given grid cell that falls within any given zip code polygon.

Quantifying the degree of imperviousness allowed us to assess whether characteristics of the built environment and recent changes in imperviousness might relate to responses to our core questions of interest. To account for the marked differences in the size of zip code areas, the estimates for these two variables are weighted by area to create equivalence for analysis. To account for the positive skew that was present in our data, and is common to environmental measures such as these, we use the log base 10 of these two variables in our regression models (Hamilton and Safford 2014). Taking the logarithm helps create symmetry and assists with the transformation of biophysical data that can have values that range several orders of magnitudes.

We use mixed-effects logistic regression to assess the estimated fixed effects of our independent variables, plus a random intercept that could differ for each zip code area. The random intercepts allow us to examine place-to-place differences in the mean logit or log odds that are not explained by predictors in our models. Random slope coefficients are allowed in mixed-effects models, but we did not find any with significant variation. This consideration of other place effects is important given our focus on assessing how on-the-ground features of the built environmental may relate to individual attitudes and beliefs.

Results

Results from our first model show a number of significant predictors of respondents' views about development. Women are more likely than men to see sprawl as a problem in their community, which is consistent with gender as a predictor for other views and attitudes in our survey (Safford et al. 2014a). Also, the longer the residents have lived in the region the more likely they are to see rapid growth as a concern. Views about development are also strongly related to political party affiliation. Self-identified Democrats, Independents, and those with no affiliation are more likely than Republicans to believe sprawl is a serious problem facing their community. We find that neither residents' beliefs about existing environmental rules nor their age or level of education are significant predictors. Finally, respondents living in areas with higher percentages of impervious surface are more likely to believe sprawl is a serious problem (Table 1).

In our second model we find both similarities and differences in the predictors of support for increased enforcement of environmental rules. As with beliefs about sprawl, length of

Table 1. Coefficients (with standard errors) from mixed-effects logistic regressions, predicting impact of socio-demographic factors, opinions about environmental rules, party affiliation, and imperviousness on beliefs about sprawl and enforcement of the existing environmental rules with random intercepts for each zip code area.

	Dependent variables	
	Too rapid growth is a problem	Favor stronger enforcement of environmental rules
	Coeff. (std. error)	Coeff. (std. error)
Individual-level fixed effects		
Demographic characteristics		
Gender (female)	0.21 (0.10)*	0.21 (0.13)
Age (years)	−0.01 (0.003)	−0.01 (0.004)*
Education (low to high)	0.02 (0.05)	0.01 (0.07)
Length of residence (years)	0.01 (0.003)***	−0.01 (0.003)**
Opinion on environmental rules		
Existing rules good for community	0.11 (0.07)	0.87 (0.09)***
Political affiliation (ref = Republican)		
Democrat	0.80 (0.15)***	2.45 (0.23)***
Independent	0.59 (0.14)***	0.77 (0.15)***
No affiliation/not specified	0.60 (0.18)**	0.80 (0.21)***
Zip code-level fixed effects		
% imperviousness	**0.39 (0.15)****	**0.44 (0.20)***
% increase in imperviousness 2001–2006	**0.13 (0.51)**	**−1.39 (0.61)***
Fixed intercept	−1.27 (0.31)***	−1.18 (0.38)**
Random intercept (estimate | std. error)	0.22 (0.09)	0.12 (0.22)
Number of respondents	1,821	1,751

Note. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

residence is related to respondents' views. However, in this instance the longer the individuals have resided in the region the less likely they are to see a need for increased enforcement. In addition, older individuals are less likely to favor stronger enforcement, but neither gender nor education is a significant predictor. We also find that individuals who see environmental rules as benefiting their community have increased odds of supporting more enforcement (Table 1).

Finally, we see intriguing patterns in both of our built environment variables. Our regression analysis shows that residents in zip code areas with a higher percentage of imperviousness are more likely to support increased enforcement of environmental regulations. These residents were more concerned about rapid growth and sprawl, and were more interested in enforcement of environmental regulations as a possible policy intervention. Conversely, residents living in areas with increasing rates of imperviousness—zip codes that have seen a particularly rapid increase in imperviousness over the 5-year period of 2001–2006—are less likely to place an emphasis on environmental rule enforcement (highlighted in bold as "zip code-level fixed effects" in Table 1). In the case of both of our models, the random intercepts are not significant. This suggests that our two imperviousness-related variables are effectively capturing place-level effects.

These correlations are spatially illustrated with a map highlighting zip code-level support for environmental rule enforcement juxtaposed against landscape conditions, in terms of both imperviousness and imperviousness change, in Figure 2. The latter two items, mean imperviousness for a zip code and imperviousness change in the same zip code areas, are mapped in the center and right of Figure 2, respectively, and serve to visually highlight the urbanized core of the Puget Sound (center of Figure 2) as distinct from its suburban and exurban areas (right of Figure 2). Put more simply, highly urbanized areas in the Puget Sound tend to be home to residents concerned about sprawl and invested in environmental rule enforcement, and areas that are in the midst of development tend to be home to residents who do not support expanded rule enforcement, with statistically significant results evident in both of these opposing directions.

Discussion

While sociodemographic variables and preexisting attitudes are interesting predictors of residents' beliefs about environmental management approaches, these results are in line with prior research and literature including earlier analyses drawn from the NOAA survey data (Safford et al. 2014a). The strong influence of political party affiliation in our regression models also reaffirms findings in the extant literature that environmental concerns have become politicized and attitudes are closely linked to political ideology (Hamilton and Safford 2014; Xiao and McCright 2012). As such, they allow for a robust model of socially and demographically situated beliefs and perceptions about the Puget Sound and its management. Beyond these specific results, including these social predictors as controls in our models is important for contextualizing our findings related to the relationship between biophysical characteristics and individual attitudes and beliefs.

Of particular interest, however, are the contrasting results with respect to the built environment variables for places in the Sound and their possible links to the lived experiences of residents. The degree of impervious surface in an area can serve as a measure of urbanization, and is also important in this context particularly because impervious surfaces are indicative of habitat degradation concerns in urbanized ecosystems like the Sound (Arnold and Gibbons 1996; Booth, Hartley, and Jackson 2002; Schueler 1994). Larger areas of impervious surface cover indicate areas where there is greater residential density and accordant infrastructure. For these reasons, our results may have captured some surprising differences between Puget Sound residents of already highly urbanized areas and those who reside in areas where urban development is ongoing. In addition, the relationships between length of residence and individual attitudes add further insights into these findings.

These decidedly contrasting results in our mixed-effects model were unexpected, and suggest an opportunity for interpretation. One possible explanation for the difference is the value residents of highly urbanized areas may place on green spaces, as well as their maintenance and protection (Conedera et al. 2015). Residents of urban areas enjoy the benefits of urban development but, as our results demonstrate, are concerned about urban sprawl encroaching on those areas of the Sound that have not yet seen new layers of pavement and concrete. One possible means of protection for these areas lies in an emphasis on environmental rule enforcement, and curbs on development, which these same urban respondents tend to support.

In contrast, residents of areas that have faced more rapid increases in imperviousness during the 2001–2006 period of our analysis are neither more or less likely than other residents to see sprawl as a problem. Initially, this appeared to be a surprising result because of the presumption that, in those zip codes where impervious development is rapidly increasing, residents would identify sprawl as a tangible concern or a local environmental condition that is emerging rapidly around them. Instead, our analysis revealed a different result. These same individuals are significantly less likely to support expanded environmental rule enforcement. This suggests that individuals in these areas may be primarily interested in the benefits of ongoing development such as job creation, affordable housing, and increased access to commercial establishments. Expanded rule enforcement may be regarded locally as an impediment to ongoing development activities, and these development activities may be associated with general improvements in well-being in areas that are decreasingly rural. Where many urban residents may see sprawl as a concern, residents of developing areas may regard sprawl as the unremarkable corollary of the opportunities afforded by development.

An alternative explanation of our unexpected result lies in the notion that some residents of rapidly developing areas see development and dramatic landscape change as a *fait accompli*, and are accordingly pessimistic about the potential of environmental rule-making to alter the course of development trajectories (Macnaghten and Jacobs 1997). Although we found that individuals who see conservation rules as beneficial have increased odds of supporting more enforcement, the analytical picture on rule effectiveness is less clear. In order to separate residents' neutrality or uncertainty on environmental rule impacts from their potential cynicism about their efficacy in controlling development, we would need to probe further, with greater nuance, within that survey topic. These surprising quantitative results of our paired analyses around rule enforcement allow for several possible explanations. For that reason, these are preliminary interpretations. Only through more directed survey and social science fieldwork in the region could we confirm and more fully explain these findings.

Conclusions

The predictors of views regarding sprawl and support for increased environmental rule enforcement are clearly distinct. While each of the significant variables offers interesting possibilities for interpretation, the more salient emphasis in our work is on the importance of including both biophysical and social variables in investigations of problems important to coastal restoration and management. Our study demonstrates that biophysical characteristics can be related to patterns in individual views about both environmental problems and policy measures.

Rural zip codes in our study were present mostly in Mason County and, in the Puget Sound, trajectories of rural development identified elsewhere are not reflected in the data. We were surprised by prior analyses generated by the large-scale social survey at the center of this work, in that efforts to examine established rural, suburban, and urban indicators in concert with environmental views did not yield significant results (Safford et al. 2014a). Therefore, integrating the work and data of landscape ecology with our social analyses enabled more nuanced results and demonstrated significant local environmental place effects on views of environmental problems and management responses.

Indeed, our analysis indicates that patterns in the predictors of concern about an environmental problem do not naturally parallel patterns in views about environmental policy options, which is an important consideration for Puget Sound managers interested in successful coastal management. Regional policymakers interested in educating constituents on the value of particular management measures may be interested in the geographic distribution of environmental concerns and views, and in environmental factors influencing these views.

In addition to regional policymakers, local institutions might use these results to anticipate how invested their stakeholders may be in the environmental goals of Puget Sound restoration, which may in turn offer a metric of institutional health or capacity vis-à-vis coastal management goals. As we note in our introduction, the structure of the Puget Sound Partnership allows for a multiplicity of local institutions to be involved in restoring the Sound's ecosystem health. Some of these institutions are responsible for implementing restoration activities, and, as we discussed separately, institutional capacities, behaviors, and structures vary throughout the Sound according to local cultural and normative forces (Safford and Norman 2011; Safford, Carlson, and Hart 2009).

Socio-demographic characteristics of Puget Sound residents prove to be salient in suggesting how various Puget Sound environmental concerns and interventions might be regarded in the region. The abundance and relative dominance of socio-demographic predictors may be a comfort to social science researchers long interested in the ways that normative and cultural processes, and socio-demographic characteristics, shape environmental attitudes and perceptions (van Riper and Kyle 2014; Whitmarsh and O'Neill 2010). Nevertheless, the results of our interdisciplinary collaboration, which integrates biophysical and social survey data into mixed-effects logistic regression models, suggests the ways in which some local environmental conditions might still serve as predictors of social views on environmental issues and associated management options. Beyond these conclusions, however, the particularly valuable research lesson in these paired analyses is that integrating biophysical and social predictors gives more nuance and power to prior and ongoing sociodemographic analyses (Safford et al. 2014a), providing a clearer picture to management. Obviously, the clearest picture of all comes through visual representations of social and biophysical landscapes. Maps of ecosystem characteristics or biophysical conditions are regularly used to convey information about environmental concerns, highlighting the value of Geographic Information System (GIS) and visual representations (Levin, Wells, and Sheer 2013; Rahman et al. 2013). Mapping social data, and pairing these data with biophysical data, may be an even more powerful way to visualize and convey the integrated nature of biophysical conditions and individual attitudes and beliefs about environmental problems and policy measures.

We identified relationships between individuals' environmental beliefs and the conditions within their residence zip codes, and these were relationships that ultimately modified our interpretations of both our sociological and landscape data. However, one of the constraints that may have affected our capacity to find conclusive results in some of our related analyses is that the biophysical data available for our paired analyses were secondary data collected for other purposes. Indeed, although this collaborative research may present a first step in mapping the relationships between the biophysical and social landscapes of the Puget Sound, such interdisciplinary efforts would benefit from data collections carefully coordinated at the outset. We recognize that truly integrated research depends not merely on the confluence of separate data streams, but on the assertion of truly integrated research plans within the formative turbulence of the headwaters.

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