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Toward an integrated understanding of perceived biodiversity values and environmental conditions in a national park

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ABSTRACT

In spatial planning and management of protected areas, increased priority is being given to research that integrates social and ecological data. However, public viewpoints of the benefits provided by ecosystems are not easily quantified and often implicitly folded into natural resource management decisions. Drawing on a spatially explicit participatory mapping exercise and a Social Values for Ecosystem Services (SolVES) analysis tool, the present study empirically examined and integrated social values for ecosystem services and environmental conditions within Channel Islands National Park, California. Specifically, a social value indicator of perceived biodiversity was examined using on-site survey data collected from a sample of people who visited the park. This information was modeled alongside eight environmental conditions including faunal species richness for six taxa, vegetation density, categories of marine and terrestrial land cover, and distance to features relevant for decision-makers. Results showed that biodiversity value points assigned to places by the pooled sample of respondents were widely and unevenly mapped, which reflected the belief that biodiversity was embodied to varying degrees by multiple locations in the park. Models generated for two survey subgroups defined by their self-reported knowledge of the Channels Islands revealed distinct spatial patterns of these perceived values. Specifically, respondents with high knowledge valued large spaces that were publicly inaccessible and unlikely to contain on-ground biodiversity, whereas respondents with low knowledge valued places that were experienced first-hand. Accessibility and infrastructure were also important considerations for anticipating how and where people valued the protected land and seascapes of Channel Islands National Park.

1. Introduction

The ecosystem services framework has enhanced understanding of the multiple benefits that nature provides to society. Since publication of the Millennium Ecosystem Assessment (2005), progress has been made to illustrate how ecosystem structures and functions provide benefits to sustain human health and well-being (Carpenter et al., 2009; Costanza et al., 1997; Daily, 1997). Within this literature, scholars have largely focused on economic valuation, ecosystem service policies and programs, and various aspects of ecological change (Schröter et al., 2014). However, the socio-cultural domain of ecosystem services, requiring a range of social science tools and alternative evaluation approaches, has been underrepresented in the literature (Chan et al., 2012a). Moreover, there is growing recognition that assigning monetary values to stocks and flows of ecosystem services risks commodification of the environment (Daniel et al., 2012), overemphasizing tangible values in research may neglect cultural benefits that are ecologically and ethically important (Chan et al., 2012b) and disregarding the moral and normative concerns of stakeholders decreases the odds of reaching open, deliberative solutions to conservation problems (Raymond et al., 2013). Research on “social values for ecosystem services,” defined as the social aggregation of diverse benefits that ecosystems provide to society (Ives and Kendal 2015; Kenter et al., 2015; Sherrouse et al., 2011), is crucial because unlike other services, social values are directly experienced by individuals and

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tied to intrinsic motivations for people to own, manage, and protect natural resources (Brown and Fagerholm, 2015; Milcu et al., 2013; Plieninger et al., 2015). This information not only advances knowledge of the reasons why people feel compelled to appreciate and act on nature's behalf, it provides a platform to democratize decision-making and engage people in environmental planning and management (Gould et al., 2015; Klain and Chan 2012; Martín-López et al., 2009).

Geographic Information System (GIS) techniques have facilitated integration between social and ecological data to determine spatial priorities for management of people and the ecosystems on which they rely (Villa et al., 2014; Hein et al., 2006; St. Martin and Hall-Arber, 2008; Whitehead et al., 2014). Particularly within coastal and marine contexts, a substantive body of past work has examined public interests across spatial and temporal scales to provide insight into how people and their environments evolve together over space and time (Cogan et al., 2009; McLeod and Leslie, 2009; Pollnac et al., 2010). One method that has become particularly useful for eliciting and analyzing social value indicators in relation to environmental conditions is known as Public Participation GIS (PPGIS) (Sieber, 2006). This tool has been used to map values that characterize collective expressions of meaning and place-based knowledge (Fagerholm et al., 2012), frame potential conflicts between science and policy (Cutts et al., 2011), and better understand ecosystem services to inform environmental planning and management (Brown et al., 2012; Raymond et al., 2009). Particularly in the context of protected areas (Brown and Weber 2011; Palomo et al., 2014), PPGIS research has helped to identify socially acceptable and defensible planning outcomes (e.g., Bryan et al., 2011), and address recent calls by initiatives such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) for the co-production of knowledge on ecosystem services (Díaz et al., 2015).

Within the PPGIS literature, particular attention has been paid to the social value indicator of "perceived biodiversity" that reflects the importance of a place because of the variety of plants, wildlife, marine life, and other living organisms provided therein (Brown et al., 2004). Although past research has suggested the public is largely unfamiliar with the number of species encountered (Dallimer et al., 2012; Lindemann-Matthies and Bose 2008), this body of literature has offered helpful insights into synergies and conflicts between stakeholder interests and natural resource management conditions (Bagstad et al., 2015). In particular, perceived biodiversity can be conceptualized as an "assigned" value that indicates individual beliefs and suppositions about qualities that exist in an environment, as opposed to "held" values that refer to more stable psychological processes and orientations (Brown, 1984), and "relational" values that reflect virtuous, eudemonic pursuits that underline environmental behavior (Chan et al., 2016). These different types of values reflect what people care about and can be distinguished from objectively defined metrics that indicate what exists in the physical world (Ives and Kendal, 2014). In this body of literature, several studies have focused exclusively on the assigned value of perceived biodiversity. For example, Alessa et al. (2008) found that perceived biodiversity values ascribed to the Kenai Peninsula, Alaska correlated with measures of net primary productivity for three of six communities surveyed. Also under a PPGIS methodological frame, Bryan et al. (2011) mapped a suite of social values elicited through interviews with residents in the Southern Australia Murray-Darling Basin and identified conservation strategies on the basis of different value configurations. This research activity signals a growing interest in PPGIS, particularly its ability to provide insight into perceived biodiversity, and its potential to blend social, ecological, and economic data that can inform natural resource management decisions (Martín-López et al., 2014).

Public engagement in environmental planning is increasingly prioritized by management agencies; however, stakeholder groups are often varied and require different intervention strategies which can complicate decision-making (Flint et al., 2013). Consequently, previous studies have aimed to account for variation in preferences for resource conditions by investigating psychological processes such as attitudes (Sherrouse et al., 2011) and environmental worldviews (van Riper and Kyle, 2014) that shape ecosystem service valuation. Tailoring research questions to address place-based concerns and considering characteristics of particular constituencies are critical steps to ensure the relevance and salience of research outcomes (Kyttä et al., 2013). One factor that is particularly difficult to account for in PPGIS research is knowledge, which we define as individual awareness and familiarity of one's surroundings. Knowledge propels human behavior that affects the environment and lies at the heart of individual decisions and ownership over places (Olli et al., 2001). Although knowledge is an inherently complex and multi-faceted concept (Raymond et al., 2010), previous research has offered insights into how self-reported knowledge can help frame communications that foster environmental stewardship (Kollmuss and Agyeman 2002; D'Antonio et al., 2013), promote psychological restoration from nature (Fuller et al., 2007), and address questions about the co-production of different forms of knowledge in relation to the provision of ecosystem services (Díaz et al., 2015). Additionally, past research has established a linkage between knowledge and concerns about biodiversity (Holl et al., 1995; Hunter and Rinner 2004); however, this relationship has yet to be empirically tested across spatial scales.

The present study examined the relationship between perceived biodiversity values and environmental conditions on Santa Cruz Island for two survey subgroups defined by their self-reported knowledge of Channel Islands National Park. Survey data from a PPGIS mapping exercise and a Social Values for Ecosystem Services analysis tool were used to address three objectives: 1) determine the spatial dynamics of perceived biodiversity value points assigned to places by survey respondents; 2) examine the relationship between perceived biodiversity and eight landscape metrics that reflected environmental conditions in the protected area; and 3) compare social and environmental data for two survey subgroups that reported different degrees of self-reported knowledge. This paper aims to create space for discourse on the multiple values of protected areas and stimulate thinking about how self-reported knowledge can be more effectively integrated into resource management decisions.

2. Methods

2.1. Study area

This research was conducted on Santa Cruz Island, which is the largest (25,000 ha) of five islands within Channel Islands National Park. It is situated 30 km off the coast of southern California, including nearly 22 million inhabitants from metropolitan areas such as Los Angeles and San Diego. Santa Cruz has a Mediterranean climate and mountainous terrain reaching an elevation of 747 m at its highest point. The island has landforms such as a central valley, canyons, and year-round streams, as well as a 77-mile coastline of cliffs, giant sea caves, sandy beaches, and tidepools. The Channel Islands National Marine Sanctuary surrounds Santa Cruz and protects a rich and biologically diverse marine environment (Davis, 2005). Landing permits are available for use of the island's coastline, while the island's adjacent waters are utilized by commercial and recreational fishers, boaters and divers, and maritime shipping operations.

Table 1
Typology presented to survey respondents during the social value for ecosystem services mapping exercise, number of mapped points associated with each category, and maximum Value Index scores.

Social Value Indicators	*Number of Mapped Points*	*Maximum Value Index*
Perceived Biodiversity. I value Channel Islands National Park because it provides for a variety of plants, wildlife, marine life, and other living organisms	535	7
Aesthetic. I value Channel Islands National Park for the attractive scenery, sights, sounds, or smells	510	10
Recreation. I value Channel Islands National Park because it provides a place for my favorite outdoor recreation activities	428	8
Scientific. I value Channel Islands National Park because it provides an opportunity for scientific observation or experimentation	259	3
Learning. I value Channel Islands National Park because I can learn about natural and cultural resources	246	8
Therapeutic. I value Channel Islands National Park because it makes me feel better, physically and/or mentally	161	3
Future. I value Channel Islands National Park because it allows future generations to experience this place	119	4
Intrinsic. I value Channel Islands National Park in and of itself for its existence	102	3
Spiritual. I value Channel Islands National Park because it is spiritually significant to me	101	2
Cultural. I value Channel Islands National Park because it preserves historic places and archaeological sites that reflect human history of the island	97	4
Life Sustaining. I value Channel Islands National Park because it helps produce, preserve, clean, and renew air, soil, and water	53	2
Economic. I value Channel Islands National Park because it provides fisheries, recreation, or tourism opportunities that provide economic benefits	20	1

Note. The Value Index score is calculated by SolVES and it represents the intensity of preferences for social value indicator in the typology. It ranges from 0 to 10, where 10 indicates the greatest relative importance of a category.

Despite the Channel Islands' close proximity to a densely populated region in southern California, their isolated location provides suitable habitat for over 2000 species of marine and terrestrial organisms. There are species on the islands listed as threatened and endangered by the U.S. Fish and Wildlife Service, several of which are found nowhere else on earth (National Park Service (NPS, 2006). For example, the island provides habitat for terrestrial organisms such as the charismatic Island Scrub Jay (*Aphelocoma insularis*) and Island Fox (*Urocyon littoralis*), as well as native Bald Eagles (*Haliaeetus leucocephalus*) that have been reintroduced from extinction. Multiple agencies such as the US National Park Service (NPS), The Nature Conservancy, and National Oceanic Atmospheric Administration work in cooperation to actively manage, restore, and monitor the recovery of these organisms in response to pressures such as invasive species, habitat destruction, and predation (Davis, 2005). The National Park Service manages visitor use on the eastern portion of Santa Cruz (including 24% of the island), whereas the western side is managed by The Nature Conservancy and largely reserved for scientific research and environmental preservation.

Visitor use on Santa Cruz contributes to local economies, supports human well-being through the provision of recreational opportunities, and promotes environmental stewardship. Most people become familiar with the park through outlets such as the Channel Islands Harbor which includes shops, dive centers, boat charters, and companies that provide whale watching tours in the Santa Barbara Channel. Of the 300,000 people that see the park's mainland educational center, a mere 10% visit the islands and 20% visit the marine waters annually (LaFranchi and Pendleton, 2008). Visitors to the islands use public transportation provided by an external contractor that offers small doses of interpretation during the 45 min journey from Ventura, CA. The cost of visiting Santa Cruz for an afternoon in 2012 was $59 for one adult. A ticket for camping was $79 per adult, plus a $15 fee to reserve a campsite for one night. On the island, most people saw interpretive signage, hiked along trails and through campgrounds, and learned about biological and cultural resources from volunteer-led tours. That is, there were multiple opportunities for visitors to learn how indigenous communities (i.e., Chumash Native Americans), ranching operations, recreational activities, and scientific research have shaped the island's social and environmental conditions over time (Faulkner and Kessler, 2011).

2.2. Survey administration and design

On-site survey data were collected from a representative sample of people over the age of 18 who visited Santa Cruz Island during the high use season (June–August) in 2012 ($n = 323$; response rate = 94%). After visitors had experienced the island and before boarding a boat to return to the mainland, they were approached by trained survey administrators and asked to participate in the study. For groups, the individual with the most recent birthday was asked to complete the survey to minimize potential group leader bias. The sampling frame was stratified by day of the week and time of day to ensure sampling events were not biased towards times throughout the study period (Dillman et al., 2014). Data were collected using ASUS Transformer TF3000T tablets and Droid Survey off-line software (http://droidsurvey.android.informer.com/) Version 1.4.1. All encounters and observable descriptive characteristics of people who refused the survey were recorded in contact logs to calculate potential sampling bias, none of which was detected on the basis of gender ($\chi^2 = 0.065$) and group size ($t = 1.256$, $df = 335$).

During the survey, the administrator and respondent engaged in a participatory mapping exercise that required visitors to allocate 100 "preference points" in increments that reflected the importance they ascribed to one of 12 social values for ecosystem services listed in a typology adapted from past research (Brown and

Reed, 2000) and tailored to the study context in consultation with NPS staff (Table 1). Following the allocation of preference points, respondents were asked to identify up to five areas that embodied the values to which preference points were assigned, using a 34″ by 13″ map of the Channel Islands created by the National Geographic Society and displayed at the survey station. The map of Santa Cruz had an approximate scale of 1:50,000 and served as a visual basis for dialogue with respondents. During data collection, the points marked by respondents were recorded on digital maps and then generated at an output resolution of 50 m based on the scale of the map. Perceived biodiversity value was one of 12 categories examined during this participatory mapping exercise (Table 1). This value category was selected for the purpose of this paper, because of its relative importance for managers of the Channel Islands, prominence in past research, and the array of biologically diverse locations that were mapped by survey respondents (Alessa et al., 2008).

Self-reported knowledge of the Channel Islands was measured in the survey questionnaire to account for variation in preferences for social values for ecosystem services. In the on-site survey before completing the participatory mapping exercise, self-reported knowledge was measured using one item on a Likert scale (1 = "Very Low" to 5 = "Very High"). This item asked, "How would you rate your knowledge of Channel Islands National Park?" A median split (Median = 3) was performed to divide the sample into *Low Knowledge* (n = 129; 40%) and *High Knowledge* (n = 194; 60%) subgroups. This approach to segmenting the sample into two subgroups identified two distinguishable types of visitors that could be targeted in education and outreach programs designed by public land management agencies (*Low: M* = 1.65; *SD* = 0.48; min/max = 1/2; *High: M* = 3.53; *SD* = 0.69; min/max = 3/5) (Ozuru et al., 2009). This measure likely reflected an accumulation of experiences including firsthand accounts of on-site conditions and responses to various forms of interpretation communicated with the public.

2.3. Preparing spatial and survey data

All locations that were assigned social values were digitized in an ArcGIS[1] geodatabase as a point feature class (n = 2245). The preference points allocated to each social value indicator were also loaded into the geodatabase and related to digitized points using a unique identifier. The geodatabase also included eight environmental conditions that were identified in consultation with NPS staff as having the potential to explain spatial variations in social value intensity (Table 2). For the purpose of this analysis, the variables were not assessed for multi-collinearity. Building on past PPGIS research (Sherrouse et al., 2011; van Riper et al., 2012), our first three environmental conditions were distance to features relevant for visitor use in the park, including management infrastructure, viewshed and Marine Protected Areas (MPAs) created using tools available in the Spatial Analyst extension of ArcGIS. These variables reflected the shortest straight-line distance of each cell to the feature of interest such as areas in view of the coastline (i.e., viewshed). Next, measures of soil and vegetation carbon storage were combined to indicate tons of carbon stored per square meter across the island. To represent our environmental condition of elevation, we used raster elevation data of Santa Cruz Island generated in 2007.

Given that biodiversity is a multi-faceted concept, we represented on-ground biodiversity using two surrogates of species richness and vegetation cover (Purvis and Hector, 2000). Using data from National Oceanic and Atmospheric Administration's Office of Response and Restoration, we developed a species richness layer to reflect range data for 25 species across five taxonomic groups of organisms sensitive to environmental impacts. Next, we estimated a layer indicating vegetation cover on the island whereby average values within six categories developed in past research (Cohen et al., 2009) were reclassified into an index (1 = > 60%; 2 = 40–60%; 3 = 25-40%; 4 = 10–25%; 5 = 2–10%; and 6 = N/A). The original vegetation categories were created by TNC using plot and transect data, ground sampling, and verification fieldwork. Building on past work that has compared spatially-anchored measures of human perception to land cover and land use change (Brown, 2013; Palomo et al., 2014), we used a 16-class categorical layer drawn from the National Land Cover Database (NLCD-2006) (Fry et al., 2011). There were 13 of 16 NLCD categories represented on Santa Cruz and we added one category to represent predominant marine vegetation (i.e., presence of kelp forests and eelgrass).

2.4. Analysis of social values indicators and environmental conditions

We examined the relationship between mapped social value points and our eight environmental conditions for the *Low Knowledge* and *High Knowledge* subgroups as well as the pooled sample with a GIS mapping application developed by the U.S. Geological Survey, Social Values for Ecosystem Services (SolVES), Version 2.0 (http://solves.cr.usgs.gov) (Fig. 1). SolVES calculated a standardized 10-point Value Index that was a quantitative, spatially explicit indicator of social values for ecosystem services (Sherrouse et al., 2011, 2014). The Value Index allowed for consistent expression of the relative intensity and spatial distribution of our perceived biodiversity measure. We also used SolVES to create a measure of the relative dispersion, clustering, or randomness of all mapped points using Completely Spatially Random (CSR) hypothesis testing, which was based on the calculation of average nearest neighbor statistics (Brown et al., 2002). As described by Sherrouse et al. (2011), SolVES used the digitized points weighted by the total preference points allocated to each value indicator to generate weighted kernel density surfaces. Each surface was normalized and standardized to determine the relative intensity of social values within our typology.

Our eight environmental conditions were analyzed by Maximum Entropy software (MaxEnt) (Phillips et al., 2006). Although MaxEnt was originally developed for the purpose of modeling the geographic distribution of species, we applied this tool to a social values context. MaxEnt worked in conjunction with SolVES to generate a logistic surface layer, which provided a relative indicator of locations to which respondents would assign social value given the spatial distribution of points and the underlying environmental characteristics of those locations (Sherrouse et al., 2014). The logistic surfaces and accompanying models generated by MaxEnt provided spatial predictions of socially valued locations on the basis of point data that we collected using PPGIS methods. That is, this procedure yielded maps predicting the locations that respondents thought were associated with biodiversity. Geographic zones delineated by the integer values (0–10) of the Value Index were used to generate zonal statistics that summarized the relationship between assigned value and our eight underlying environmental conditions. These zonal statistics (mean values for continuous data; majority values for categorical data) were then compared using independent sample *t*-tests that were subject to Bonferroni tests to counteract the effect of multiple comparisons.

To evaluate goodness of fit and the predictive power of the MaxEnt models estimated for our *Low Knowledge* and *High Knowledge* subgroups, the digitized points were partitioned into "training" and "test" data (Phillips et al., 2006). MaxEnt parameters were set to withhold 25% of the digitized points of each social value indica-

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[1] Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table 2
Description and sources of environmental conditions. Data were processed at a 50-m spatial resolution.

Environmental Variable	Description	Source
Distance to Infrastructure	Distance between perceived biodiversity value points and infrastructure that facilitated recreational activities, including trails, educational centers, boat ramps, and harbors.	Derived from U.S. National Park Service spatial data
Distance to Viewshed	Distance between perceived biodiversity value points and areas on Santa Cruz within view of the coastline.	Derived from U.S. National Park Service spatial data
Distance to MPAs	Distance between perceived biodiversity value points and Marine Protected Areas surrounding Santa Cruz, including two Marine Reserves and one Marine Conservation Area.	Derived from U.S. National Park Service spatial data
Carbon Storage	Extent to which soil and vegetation on Santa Cruz capture and store atmospheric carbon dioxide. Data are in 30-m spatial resolution for the year 2000.	U.S. Department of Agriculture Soil Survey Geographic (SSURGO) Database and National Biomass and Carbon Dataset
Species Richness	Total species richness across six taxonomic groups: (1) birds, (2) fish, (3) invertebrates, (4) mammals (terrestrial and marine); and (5) reptiles.	National Oceanic and Atmospheric Administration's Office of Response and Restoration
Elevation	Digital elevation model of Santa Cruz Island.	U.S. Geological Survey's National Elevation Dataset
Terrestrial Vegetation	Vegetation cover of predominant plant life (conifers, hardwoods, and shrubs) on Santa Cruz Island in 2007.	Derived from The Nature Conservancy spatial data
Marine and Terrestrial Land Cover	A 16-class NLCD-2006 classification scheme, including one category added to indicate giant kelp forest and eelgrass bed extents identified in surveys conducted from 1982–2009.	National Land Cover Database (NLCD-2006) and National Oceanic and Atmospheric Administration's Office of Response and Restoration

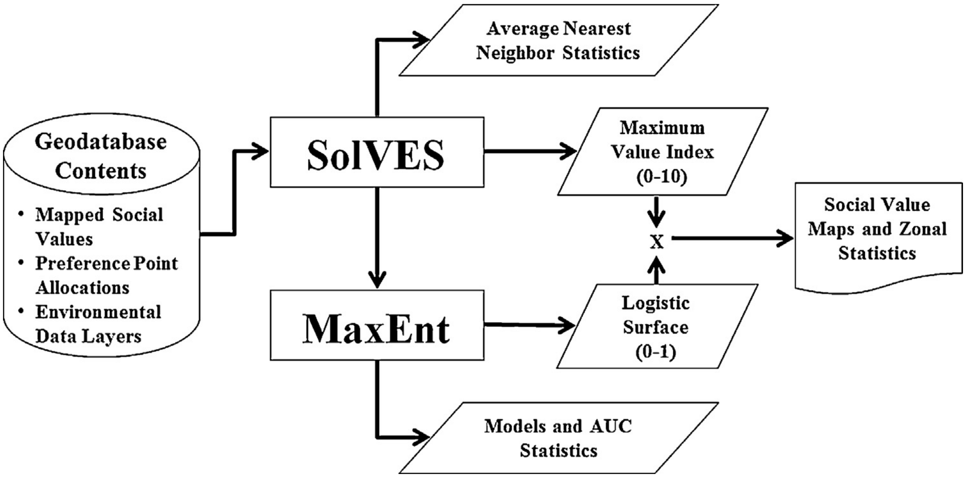

Fig. 1. Schematic of steps in SolVES-MaxEnt modeling process.

tor as test data (Sherrouse and Semmens, 2014). Area Under the Curve (AUC) statistics were calculated by MaxEnt, which reflected the total area under the receiver-operating characteristic plot (ROC) for the training and test data (Fielding and Bell, 1997). Training AUC indicates the goodness of fit of the model to the study area, while the test AUC indicates the model's potential predictive capability. To determine whether our models fit the sample data and possessed adequate predictive potential, we followed Swets (1988): $\text{AUC} \geq 0.90$ = good; $\text{AUC} \geq 0.70$ = useful; and $\text{AUC} \leq 0.70$ = poor.

3. Results

Survey respondents mapped points at numerous locations that were not randomly distributed, indicating that Channel Islands National park was valued to different degrees for a multitude of reasons such as biodiversity (20.3% of preference point allocations), aesthetics (19.4%), recreation (16.3%), and scientific values (9.8%) (Table 1). Focusing particular attention on perceived biodiversity, nearest neighbor statistics showed non-random spatial clustering of points along the coastline and within MPA boundaries. Self-reported knowledge was evaluated for the pooled sample ($M = 2.77$, $SD = 1.11$), *Low Knowledge* ($M = 1.65$, $SD = 0.48$) and *High Knowledge* ($M = 3.53$, $SD = 0.69$) subgroups of respondents who mapped perceived biodiversity. The corresponding maximum Value Index scores for these two subgroups' ratings were 6 and 10 suggesting the park was considered less important for harboring biodiversity by respondents assigned to the *Low Knowledge* subgroup (Table 3).

Table 3
Mean values and standard deviations of self-reported knowledge and nearest neighbor statistics including R-values (observed versus expected distance between points) and Z-scores (number of standard deviations from the mean). Data are presented for the pooled sample, *Low Knowledge* (n = 194), and *High Knowledge* (n = 129) subgroups.

	Knowledge[a] *M (SD)*	*R-value*	*Z-score*
Pooled Sample	2.77 (1.11)	0.506	−19.26
Low Knowledge	1.65 (.48)	0.483	−11.50
High Knowledge	3.53 (.69)	0.569	−13.84

[a] Knowledge was measured on a five-point Likert scale ranging from 1 (Low Knowledge) to 5 (High Knowledge).

Next, in response to our second study objective, we examined the relationship between eight environmental conditions

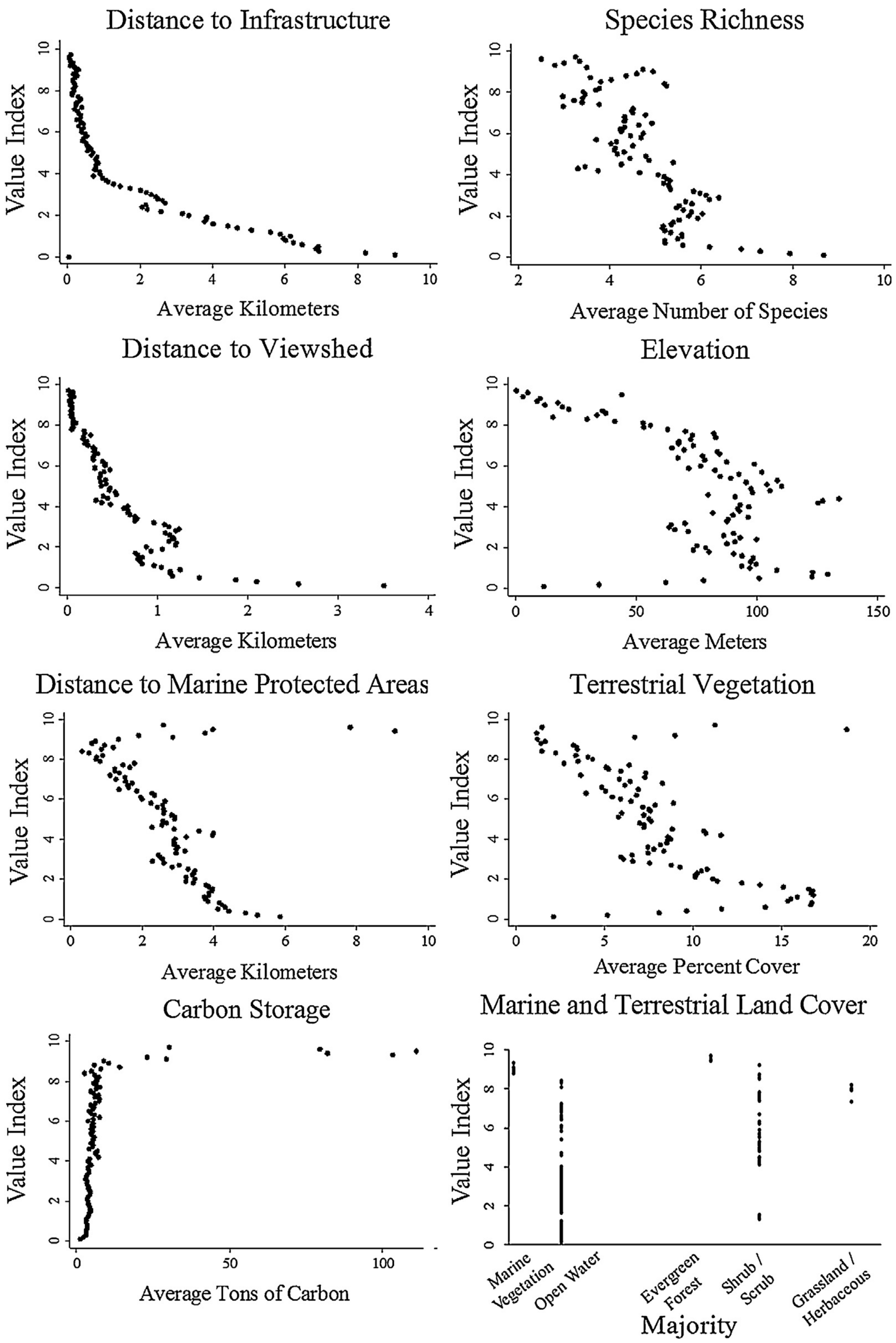

Fig. 2. Zonal statistics (based on zones defined by integer values in the Value Index) for the pooled sample showing the relationships between the average or majority value of environmental condition on the x-axis and Value Index scores for perceived biodiversity on the y-axis.

and our social value indicator of perceived biodiversity. Good fitting models, as indicated by training AUC, were found for the pooled sample (AUC = 0.919), *Low Knowledge* (AUC = 0.941), and *High Knowledge* (AUC = 0.914) subgroups. These models had useful predictive capacities given corresponding test AUC values (0.880, 0.971, and 0.880) (Swets, 1988). Varied directional relationships emerged in the comparison between environmental conditions and the Value Index score reflecting the pooled sample's evaluation of biodiversity (Fig. 2). Specifically, the intensity of preferences for our social value indicator decreased as: (a) distance to infrastructure, viewshed, and MPAs increased; (b) species richness and terrestrial vegetation cover increased; and (c) at areas of higher elevation. Conversely, as carbon storage increased, so too did value assignments. Our analysis of categorical data showed that higher levels of our social value indicator were associated with locations where the majority of land cover was classified as marine vegetation, open water, evergreen forest, shrub/scrub, and grassland/herbaceous.

This research revealed variation in stakeholder interests on the basis of self-reported knowledge in response to the third study objective. More specifically, perceived biodiversity values reported by respondents in the *Low Knowledge* and *High Knowledge* subgroups were associated with measurable differences in the underlying environmental conditions. Significant differences between survey subgroups were found in the mean values of six of seven continuous variables including distance to infrastructure ($t = -2.98$, $df = 156$), distance to viewshed ($t = -2.41$, $df = 153$), carbon storage ($t = 3.95$, $df = 156$), species richness ($t = -5.09$, $df = 150$), elevation ($t = 2.06$, $df = 82.53$), and terrestrial vegetation ($t = 3.26$, $df = 76$), as indicated by similar superscripts in Table 4. However, the direction of Pearson correlations describing the relationship between perceived biodiversity value and six of seven environmental conditions did not change between subgroups. Finally, as indicated by the percentages describing the relative contribution of each environmental variable to the model, distance to management infrastructure, viewshed, and MPAs were the most influential whereas carbon storage was the least influential predictor.

For the pooled sample, perceived biodiversity value points were clustered in the northeast corner of the island. Transportation, camping, and outreach activities occurred within this region indicating an existing priority for management of visitor use. Value points also aligned with the provision of opportunities for recreation on trails and near launching points (e.g., piers) for water-based activities. Additionally, areas along the coastline and within MPA boundaries were rated highly for valued *and* on-ground biodiversity (Davis, 2005). For the two subgroups, differences emerged in point assignments and the configuration of underlying environmental conditions that supported social values for ecosystem services (Fig. 3). Respondents in the *Low Knowledge* subgroup (Fig. 3b) assigned points across a smaller geographic gradient that covered the eastern side of Santa Cruz and that was accessible to the public. Conversely, the *High Knowledge* subgroup (Fig. 3c) associated biodiversity with a larger space encompassing the eastern *and* the western portion of the island where public use was prohibited. These findings showed that the characteristics of places, particularly the spatial distribution of social values for ecosystem services, were valued for biodiversity in relation to the level of reported knowledge within two subgroups. Although respondents likely obtained knowledge from multiple sources, a significantly higher number of previous visits were reported by the *High Knowledge* ($M = 7.51$, $SD = 20.09$) than the *Low Knowledge* ($M = 1.01$, $SD = 0.69$) subgroups ($t = -4.316$, $df = 178$).

4. Discussion

4.1. Understanding indicator performance for research and practice

Results from this study provide a roadmap for prioritizing decisions about the provision of social values for ecosystem services and environmental conditions on Santa Cruz Island within Channel Islands National Park, CA. Findings also extend past research that has identified “hotspots” or areas of value abundance on the basis of mapped points that cluster around particular features and/or the convergence of social and ecological data (Alessa et al., 2008; Bryan et al., 2011). According to visual assessments of the perceived biodiversity value maps generated by the pooled sample and two subgroups, more intensely valued locations including the northeast corner of Santa Cruz Island and areas along the coastline can be considered high priority given their capacity to provide benefits to the public and represent meaningful places. Moreover, results indicated that respondents were not attuned to on-ground biodiversity that was assessed using the surrogates of species richness and vegetation cover. This finding aligns with past research suggesting the public is unfamiliar with the number of species encountered (Dallimer et al., 2012; Lindemann-Matthies and Bose, 2008) and may be unable to distinguish between healthy versus degraded environments (White et al., 2008). As such, “coldspots” where on-ground biodiversity is not within the public eye should be considered an inroad for visitor education needs and spatial priorities for decision-makers (Bagstad et al., 2015; Bryan et al., 2011; Alessa et al., 2008). Although heightened levels of awareness can evoke appreciation for landscape aesthetics and psychological restoration from nature (Dallimer et al., 2014), factors such as accessibility and infrastructure might be more important than knowledge, considering the negative correlations between on-ground biodiversity and assignments of social values for ecosystem services.

This study used SolVES and MaxEnt to investigate the relationship between a social value indicator and a suite of environmental conditions, and in turn, identify biological resources on Santa Cruz that underpinned the delivery of ecosystem services (de Groot et al., 2010). Framing the provision of these resources as a coupled human and natural system will be most likely to foster social support toward conservation policies (Mascia et al., 2003) and provide information that reflects the complexities in tradeoffs made among the biophysical, socio-cultural, and economic values of nature (Martín-López et al., 2014). The variables reflecting distance to several features relevant for park management were the strongest predictors of point assignments and can be applied in future research to identify social-ecological spaces (Sherrouse et al., 2014; van Riper and Kyle, 2014). Respondents valued areas closer to: (a) MPAs possibly due to agency outreach about biodiversity hotspots; (b) infrastructure given that many park volunteers and managers imparted knowledge to visitors in this context; and (c) the coastline viewshed given the prominence of trail systems and infrastructure in these regions. Other natural features that provided social values for ecosystem services included evergreen forests and open water (Brown and Brabyn, 2012), as well as the shrub/scrub and grassland/herbaceous categories of the NLCD-2006 layer. These findings can be used to formulate place-based conservation strategies that afford greater consideration to the multiple meanings of places (Adger et al., 2011), consider contextual factors when strategizing how to achieve socially acceptable environmental management goals and objectives (Kyttä et al., 2013), and give a voice to diverse stakeholder groups most affected by policy change (Martín-López et al., 2009). Consequently, resource management agencies will be better equipped to gauge the efficacy of current outreach activities and determine whether the expressed values of places align with stakeholder interpretations of the goods and services provided by protected areas.

We analyzed our data across two subgroups defined by self-reported knowledge of the Channel Islands and revealed variation that may have otherwise gone undetected. Respondents in the *High Knowledge* subgroup assigned biodiversity values across a larger spatial gradient that covered the privately owned, western portion of Santa Cruz that cannot be experienced by most visitors, whereas the *Low Knowledge* subgroup valued a smaller geographic area evidenced by values concentrated solely on the eastern side of the island. In this sense, the knowledge variable used in this study accounted for variation in what people believed to be important across large expanses of the protected area. It could be that *High Knowledge* respondents assigned value points to the TNC-side of

Table 4
Mean values and standard deviations of environmental conditions and results from independent samples *t*-tests comparing two subgroups of survey respondents. Pearson correlation coefficients (r) indicating each continuous variable's relationship to perceived biodiversity and percentages describing the relative contribution of each environmental condition to perceived biodiversity.

	Low Knowledge Subgroup			High Knowledge Subgroup		
	M(SD)	*r*	*Percent Contribution*	*M(SD)*	*r*	*Percent Contribution*
Distance to Infrastructure	1.76 (1.93)^{a}	−0.78*	49.70	2.94 (3.05)^{a}	−0.89*	47.06
Distance to Viewshed	0.43 (0.40)^{b}	−0.75*	15.86	0.62 (0.59)^{b}	−0.81*	14.81
Distance to MPAs	2.15 (1.60)	−0.78*	20.84	2.46 (1.25)	−0.78*	24.01
Carbon Storage	8.84 (11.18)^{c}	0.45*	0.74	4.13 (3.08)^{c}	0.45*	0.29
Species Richness	4.14 (0.97)^{d}	0.03	3.89	5.08 (1.34)^{d}	−0.62*	3.47
Elevation	87.51 (52.57)^{e}	−0.81*	4.91	72.05 (31.06)^{e}	−0.23*	3.56
Terrestrial Vegetation	9.47 (7.07)^{f}	−0.77*	0.64	6.25 (3.59)^{f}	−0.56*	0.90
Marine and Terrestrial Land Cover	–	–	3.42	–	–	5.91

Note. Like superscripts indicate significant differences at $p \leq 0.05$.

* p-value ≤ 0.05.

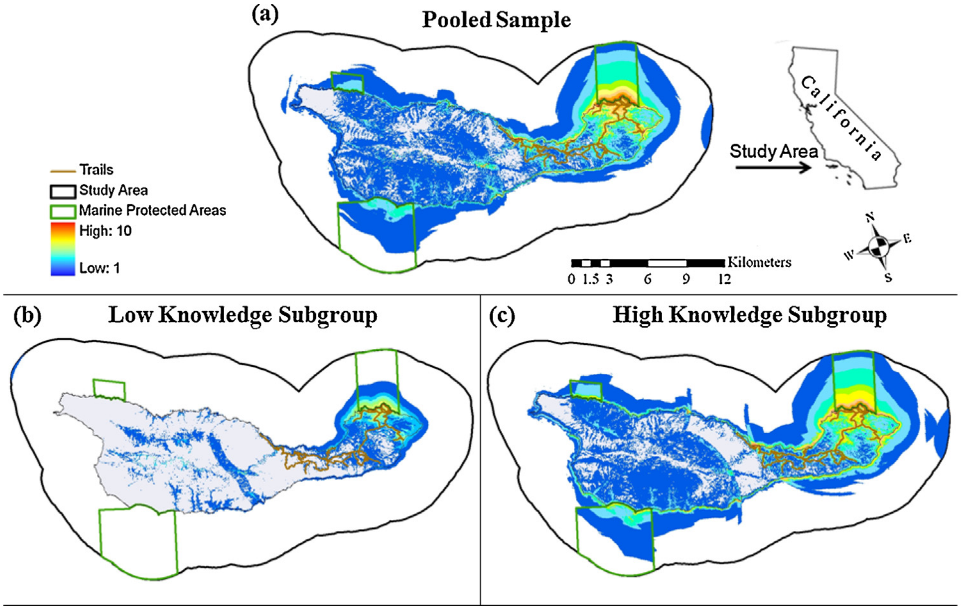

Fig. 3. Distribution of perceived biodiversity value points on Santa Cruz Island for the (a) pooled sample, (b) Low Knowledge, and (c) High Knowledge subgroups.

Santa Cruz despite limited access, because they were more familiar and had learned about the importance of this region through previous experience. These findings extend past research suggesting that smaller places are likely to be valued on the basis of personal experience and specific features, whereas larger places are known in a different way – through recreation and scientific analyses (Cheng and Daniels, 2003). We contend that perceived biodiversity value assignments may be attributable to knowledge from direct experience (Allan et al., 2015) or other sources of information (e.g., NPS interpretation) that foster public appreciation of natural and cultural resources.

4.2. Improving future research on social values for ecosystem services

The findings presented herein should be considered in light of several limitations. First, these results cannot be generalized to all protected areas; however, the sample obtained for this study was representative of people who used public transportation to visit Channel Islands National Park during the high use season in 2012. Residents engaged in water-based, consumptive activities were not included in the sample despite the relevance of this stakeholder group for management decisions that affected terrestrial and aquatic ecosystems (Brownlee et al., 2013) and the likelihood that these individuals expressed diverse spatially-anchored social values for ecosystem services (van Riper et al., 2012). Given that protected area management decision-making is a complex process that relies on multiple forms of information, this paper offers insights on the perspectives of one stakeholder group that can help inform that process. Secondly, respondents valued objects that moved within the protected area (e.g., Santa Cruz Island Fox, *Urocyon littoralis*), while the mapping exercise generated spatially-fixed results. Future research should investigate values at different, changing spatial and temporal scales to better understand the nuanced and geographically changing reasons why places resonate with stakeholders (Klain and Chan, 2012; St. Martin and Hall-Arber, 2008; Tratalos et al., 2016).

A third area for future research is centered on the idea of knowledge as a multi-dimensional concept (Raymond et al., 2010), which was measured in this study using only one variable. The median split technique used in this study accounted for preference heterogeneity in two subgroups' preferences for social values for ecosystem services on the basis of self-reported knowledge (Ozuru et al., 2009). However, more complete and multi-faceted measures of knowledge should be considered for future use. Finally, observed spatial patterns were likely influenced by the method of assessment used to examine social values for ecosystem services in this study (Martín-López et al., 2014). Specifically, during the mapping exercise, some respondents may have indicated that a single location (e.g., one campground) was biologically diverse, whereas others may have associated biodiversity with larger spaces (e.g., trail systems). The multiple points associated with these larger spaces could be interpreted to indicate stronger preferences, although both of these destinations were equally valued. However, past research has suggest that point data converge with polygon data given an adequate sample size (Brown and Pullar, 2012). Greater specificity in range data and the use of multiple forms of information to document social values for ecosystem services should be considered a priority for future research.

5. Conclusions

Compelling evidence of ecological and economic values has been gathered to better understand changing resource conditions across the globe, whilst social value indicators have received considerably less attention. This study brings the social value indicator of perceived biodiversity to bear in an investigation that integrates social values for ecosystem services and environmental conditions across spatial scales. Results illustrate the locations and reasons why stakeholders believed they derived values and benefits from biological resource conditions in a national park, and present these findings in light of diverse perspectives that were defined according to levels of self-reported knowledge. Given that social value indicators are sometimes sidelined in decision-making, this study elevates the importance of these metrics to support the spatial prioritization of conservation and provide insight into how social and ecological data can be blended to inform natural resource management decisions.

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