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Mapping outdoor recreationists' perceived social values for ecosystem services at Hinchinbrook Island National Park, Australia

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A B S T R A C T

Coastal ecosystems are increasingly faced with human impacts. To better understand these changing conditions, biophysical and economic values of nature have been used to prioritize spatial planning efforts and ecosystem-based management of human activities. Less is known, however, about how to characterize and represent non-material values in decision-making. We collected on-site and mailback survey data ($n = 209$), and analyzed these data using the Social Values for Ecosystem Services (SolVES) GIS application to incorporate measures of social value and natural resource conditions on Hinchinbrook Island National Park, Australia. Our objectives in this paper are to: 1) determine the spatial distribution and point density of social values for ecosystem services; 2) examine the relationship between social values and natural resource conditions; and 3) compare social value allocations between two subgroups of outdoor recreationists. Results suggest that high priority areas exist on Hinchinbrook's land and seascapes according to the multiple values assigned to places by outdoor recreationists engaged in consumptive (e.g., fishing) and non-consumptive (e.g., hiking) activities. We examine statistically significant spatial clustering across two subgroups of the survey population for three value types that reflect Recreation, Biological Diversity, and Aesthetic qualities. The relationship between the relative importance of social values for ecosystem services and spatially-defined ecological data is explored to guide management decision-making in the context of an island national park setting.

Introduction

Ecological and economic values of nature are increasingly used to define high priority areas for planning and management of coastal settings. Social values rooted in human perceptions of ecosystem goods and services, however, are rarely considered (Chan, Satterfield, & Goldstein, 2012; Kumar & Kumar, 2008; Raymond et al., 2009; Tyrväinen, Mäkinen, & Schipperijn, 2007). It is critical that multiple values, including those that are social in nature, be recognized in conservation at the landscape level to offer a more comprehensive understanding of the processes that lead to change in social-ecological systems (Berkes, Colding, & Folke, 2003; Brown, Montag, & Lyon, 2011; Liu et al., 2007; Ostrom, 2009). We define social values for ecosystem services as the perceived qualities carried by a natural environment that provides benefits (e.g., recreational, aesthetic, spiritual) to support human well-being (Millennium Ecosystem Assessment, 2005). A stronger understanding of social values can lend insight on what is or is not considered important (Kyle, Graefe, Manning, & Bacon, 2004), help decision-makers gauge how receptive their constituents will be to changing policies (Stern, 2000), and anticipate points of conflict over potentially competing uses through engagement in consumptive (e.g., fishing) and non-consumptive (e.g., diving) activities (Yung, Freimund, & Belsky, 2003).

Various frameworks associated with valuing and understanding people's relationships with places have encouraged holistic thinking that integrates considerations of ecosystem health and functioning, as well as human perceptions (Sherrouse, Clement, & Semmens, 2011; St. Martin & Hall-Arber, 2008). Fundamental to this body of work are "ecosystem services" defined as the characteristics and functional processes of the natural environment that provide benefits to sustain and fulfill human life (Costanza et al., 1997; Daily, 1997; de Groot, Wilson, & Boumans, 2002). In marine and coastal settings in particular, a number of valid and robust spatial planning tools that employ Geographic Information Systems

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(GIS) have been developed to determine the relative importance of environmental conditions and the tradeoffs people are willing to make among ecosystem services (Cogan, Todd, Lawton, & Noji, 2009; McLeod & Leslie, 2009; Nelson et al., 2009; Norse, 2010; Roff & Taylor, 2000). Despite increased attention to minimize environmental impacts across spatial and temporal scales, few of these frameworks address the social and/or cultural landscapes of coastal settings. Integrating social values for ecosystem services with ecological and economic considerations of valuing nature will yield equitable and efficient policy outcomes that can increase the resilience of social-ecological systems (Berkes et al., 2003).

Several studies have documented a procedure built on "Public Participation in Geographic Information Systems" (PPGIS) (Sawicki & Peterman, 2002; Sieber, 2006). This procedure identifies the geographic locations of social values for ecosystem services defined in the Millennium Ecosystem Assessment (2005) as "cultural services" that contribute to quality of life and human well-being. The PPGIS method can be used to capture diverse kinds of values that inform managers of the preferences and beliefs held by their public constituents (Brown, 2005; Clement & Cheng, 2011; Raymond et al., 2009). Conceptually, this work is grounded within the meta-theory of "transactionalism" that emerged in the field of environmental psychology (Ittelson, 1973). This rationale suggests that people and their environments evolve together over space and time. Not only are people embedded within an environment, they give shape to it and respond to its changing conditions (Zube, 1987). Previous research has extended this line of thinking to environmental values and place-based theories that underpin processes related to different forms of land use (Brown, Reed, & Harris, 2002; Nielson-Pincus, 2011). These ideas have contributed to greater concern for non-material values that frame human–environment interactions in terms of symbolic values rather than a commodities view of nature (Williams, Patterson, Roggenbuck, & Watson, 1992).

Previous scholarship has developed typologies that characterize perceptions of the natural environment (Bengston & Xu, 1995; Rolston & Coufal, 1991). These typologies draw on the idea of "assigned value" to reflect the relative importance of landscape features (Brown, 1984; McIntyre, Moore, & Yuan, 2008). An object's assigned value indicates an anthropocentric view of an object's relative importance or worth for a particular purpose. "The marina has great economic value" and "the forest has recreation value" are statements that reflect assigned values. Building on this line of work, Brown and Reed (2000) developed 13 conceptually distinct categories of value in a robust typology that has been applied to: (a) the spatial relationships among places of management importance (Brown, Smith, Alessa, & Kliskey, 2004); (b) personal attachment formed between people and geographic locales (Brown & Raymond, 2007); and (c) correspondence between human perception and ecosystems services (Brown et al., 2011; Raymond et al., 2009; Sherrouse et al., 2011). Similar research approaches have mapped place meanings that residents and indigenous groups associate with important places (Black & Liljeblad, 2006; Carver et al., 2009).

Alessa, Kliskey, and Brown (2008) drew on Brown & Reed's (2000) typology and used PPGIS to identify "hotspots" or areas of spatial convergence between socially defined areas of importance and net primary productivity as a surrogate for species diversity in the Kenai Peninsula, Alaska. Their results directed managerial attention toward areas that accommodated human activities and biological productivity, thus, helping to prioritize decisions about places vulnerable to overuse. Nielson-Pincus (2011) also applied a form of PPGIS to better understand social conflicts over land use among rural area residents in Idaho and Oregon. Using a density-based cluster analysis, the author found that Brown & Reed's (2000) value typology encompassed two broader dimensions of material and postmaterial value. This body of past research has provided a toolset for systematically incorporating human perceptions of a landscape into environmental planning and management decisions. However, little is known about how PPGIS methods apply to coastal environments that encompass terrestrial and aquatic systems and correspond to landscape features such as management infrastructure (e.g., trail systems) and derivatives of elevation (e.g., slope). The present study addresses these gaps in an effort to direct managerial attention toward high priority places in the context of an island national park setting.

More specifically, our research was guided by three objectives. The first objective was to determine the spatial distribution and density of social value points assigned to places on Hinchinbrook Island National Park (HINP), Australia. To meet this objective, we tested for "hotspots" or high priority areas that emerged based on the presence of 12 of the 13 values identified by Brown and Reed (2000). Although 13 value types were included in the survey questionnaire, one (i.e., Subsistence value) was excluded from our analysis due to a low sample size for this value type and restrictions in the GIS application utilized for this research. The second objective was to examine the relationship between social values for ecosystem services and natural resource conditions in the underlying landscape. For this objective, we analyzed the relative importance of 12 values in relation to features of HINP's land and seascapes. The third objective was to compare between two subgroups defined by the activity types of consumptive (e.g., fishing, crabbing) and non-consumptive (e.g., hiking, kayaking) use. We examined social values for ecosystem services assigned to places by these two subgroups and determined the proximity of value points to three landscape metrics. These analyses produced graphical representations of social and ecological data and allowed us to account for heterogeneity in the survey population.

Methods

Study site

This research was conducted on the HINP, which is an uninhabited island located between one and eight km off the northeastern coast of Queensland, Australia. This protected area is situated within the Great Barrier Reef World Heritage Area. The state agency, Queensland Parks and Wildlife Service (QPWS), is charged to oversee the terrestrial island system and the Hinchinbrook Channel, which runs between the western side of the island and the mainland. The QPWS works in cooperation with the Great Barrier Reef Marine Park Authority, which has jurisdiction over the waters to the east of the island (Osmond, Airame, Caldwell, & Day, 2010). The island's topography is highly variable with elevation ranging from sea level to peaks as high as 1121 m. The highest peak, Mt. Bowen, is part of a granite crag that runs like a backbone protruding from the southern to northern ends of the island. The climate on the HINP is considered tropical with annual temperatures ranging from 32 °C to 13 °C. The taller peaks on the island receive freezing temperatures and periodic snowfall during the winter (June–August). This area has wet and dry seasons with variable rainfall averaging 2143 mm and on occasion, up to 3500 mm per year. Most of the heavy rain events occur during the summer (December–April). As a tropical system, the annual amount of biomass productivity averages between 400 and 700 metric tons per hectare (QPWS, in press).

The HINP hosts extraordinarily diverse ecosystems that support species of conservation concern including estuarine crocodiles (*Crocodylas porosus*), dugong (*Dugong dugon*), and beach stone curlew (*Esacus magnirstris*). Dominant flora species include large fruit bearing dicots (*Buchanania mangoides*), mangroves (*Avicennia marina*), fern (*Huperzia phlegmaria*), eucalyptus (*Eucalyptus raveretiana*), and palms (*Livistona drudei*). Habitat types range from sea grass beds to mangrove forests and inland eucalyptus woodlands, as well as streams and riparian corridors that run throughout the inland and lead to two waterfalls on the southeast end of the island (QPWS, in press).

Recreational activities on the HINP primarily include fishing and hiking. Most fishing is undertaken on private boats and occurs in the Hinchinbrook Channel. The perimeter of the Channel is largely encompassed by mangrove estuaries home to barramundi (*Lates calcarifer*) and mangrove jack (*Lutjanus argentimaculatus*), making this one of the most popular fishing destinations in the state of Queensland. Most hiking activities occur on the 32-km Thorsborne Trail that runs along the northeastern coast of the island and includes few facilities (e.g., campground areas) that maintain a wilderness-like experience for recreational visitors. Permits are required to visit parts of the island (i.e., Thorsborne Trail, Mt. Bowen, and a crash site of a B-24 liberator, the *Texas Terror*, on Mt. Straloch) and are secured as much as one year in advance (maximum of 40 visitors permitted per day on the island). No permit is required for boating and fishing activities that occur in the waters surrounding the island, including the Hinchinbrook Channel.

Visitor use on the HINP occurs through day use and overnight activities (e.g., sea kayaking, snorkeling/diving, traditional hunting, spear fishing, recreational fishing in mangrove estuaries) (QPWS, in press, pp. 1–155). The island was originally inhabited by the Bandjin people, and although no Aborigines reside on the island, they maintain exclusive rights to a ceremonial ground named Muhr Amalee. Visitation is largely comprised of individuals that travel from national and international destinations to hike the Thorsborne Trail, and individuals, many of whom reside in nearby communities and/or stay for long periods in caravan parks on the mainland, that engage in water-based recreation activities. Most visitors that access the waters surrounding the HINP use private vessels. There are two primary access points including boat ramps in the towns of Lucinda (south end) and Cardwell (north end).

Survey approach

Self-administered survey questionnaires were distributed to a representative sample of adult visitors from June through October, 2011. A total of 400 visitors were contacted and asked to participate in the study. The on-site survey was administered over a six-week period mid-June through July. Survey days were stratified by day of the week (weekend vs. weekday) and time of the day (a.m. vs. p.m.). Respondents were contacted at various sampling points, including two boat ramps, a fishing pier, two ferries that provide transportation to and from the island, a caravan park, and the Hinchinbrook Sports Fishing Club meeting in the town of Ingham. During these sample periods, respondents were approached and asked to reflect on their most recent visit to the island and/or surrounding waters. For groups, the individual with the most recent birthday (and over the age of 18 years) was asked to participate (Battaglia, Link, Frankel, Osborn, & Mokdad, 2008). Contact logs were used to estimate response rates. Data were also collected via a mailback survey distributed by local ferry operators on the primary investigator's behalf. Surveys were given to two ferry operator companies following methods outlined in Young (2006). The ferry operators asked respondents to complete the survey at the conclusion of their visit and return it in a postage paid envelope. A total of 59 of 200 survey questionnaires were returned by mail. The on-site and mailback surveys resulted in an overall sample size of 209 and a response rate of 52%.

The questionnaire included a series of closed and open-ended survey items, as well as a map of the study area. Three sections of the survey questionnaire were analyzed for this paper: 1) trip characteristics, 2) a value mapping exercise, and 3) socio-demographics. First, we asked respondents to provide information about their current visit to the HINP (e.g., duration of stay, activities undertaken, group composition) and history of visitation (e.g., year of first visit, frequency of visitation). Second we explored social values for ecosystem services that respondents assigned to places. Adapting Brown & Reed's (2000) value typology, we asked respondents to complete two related tasks: (a) assign 100 hypothetical "preference points" across 12 value types (see Table 1). Respondents were asked to distribute their preference points in increments that reflected the importance they ascribed to each value with the understanding that they would only have 100 points to distribute; and (b) spatially locate values by marking points on a map of the HINP (Brown & Pullar, 2011). Finally, respondents were requested to provide information on several socio-demographic indicators (e.g., age, education, income, etc.).

Analysis

Our study examined the relationship between social values for ecosystem services and existing natural resource conditions on the HINP. There were two stages of analysis that corresponded to the first two study objectives. The third objective, comparing between two subgroups defined by the activity types of consumptive (e.g., fishing, crabbing, prawning) and non-consumptive (e.g., hiking, camping, kayaking) uses, was addressed throughout our two stages of analysis. We anticipated a heterogeneous sample based on activity type so our results are reported for the pooled sample and the two subgroups. Our social and ecological data were derived from various sources and all analyses were performed in SPSS V20.0 and ArcGIS V9.3.1[1] (see Table 2). We also drew on a GIS application, Social Values for Ecosystem Services (SolVES), developed by the USGS (Sherrouse et al., 2011). This tool provided a programmed framework that linked survey data regarding social values for ecosystem services to three landscape metrics.

We digitized the social value points situated across the HINP in an ArcGIS geodatabase using ArcMap ($n = 1748$). Each digitized point was associated with a value type, such that one respondent could mark various points on the map and indicate that these locations embodied different value types. The hypothetical preference points survey respondents assigned to each value type were also loaded into the geodatabase with a unique identifier allowing them to be joined to digitized points of the same value type. Three spatial layers representing natural resource conditions were then loaded into the geodatabase. These spatial layers included: 1) distance to water (i.e., the shortest straight-line distance of each cell to water features including the coastline, wetlands, and mangroves estimated with the Euclidian Distance tool included in the ArcGIS Spatial Analyst extension); 2) distance to trails (i.e., shortest straight-line distance of each cell to the primary trail system, The Thorsborne Trail, using Spatial Analyst); and 3) slope (i.e., percent slope using the Surface Analysis tool in Spatial Analyst).

Prior to applying SolVES to the contents of the ArcGIS geodatabase, we calculated a single kernel density surface including all digitized points to observe the overall spatial pattern of survey responses from which SolVES would ultimately derive a 10-point social values metric, the Value Index. The kernel density analysis followed an approach based on a quadratic kernel function (Silverman, 1986), which defines a smoothly curved surface that fits over each point and extends out to a defined search radius. The volume below each surface is determined by a weight assigned to each point; in this case all points were assigned the default

[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 1
Definitions of 12 social value types assigned to places by outdoor recreationists.

Aesthetic Value. I value these places because I enjoy the scenery, sights, sounds, smells, etc.
Biological Diversity Value. I value these places because they provide a variety of fish, wildlife, plant life, etc.
Cultural Value. I value these places because they allow me to continue and pass down the wisdom and knowledge, traditions, and way of life of my ancestors.
Economic Value. I value these places because they provide useful resources (e.g., fisheries, tourism opportunities).
Future Value. I value these places because they allow future generations to know and experience Hinchinbrook as it is now.
Historic Value. I value these places because they have natural and human historical significance that matters to me, others, or the country.
Intrinsic Value. I value these places in and of themselves, whether people are present or not.
Learning Value. I value these places because we can learn about the environment through scientific observation or experimentation.
Life Sustaining Value. I value these places because they help produce, preserve, clean, and renew air, soil and water.
Recreation Value. I value these places because they provide opportunities for outdoor recreation.
Spiritual Value. I value these places because they are sacred, religious, or spiritually special to me or because I feel reverence and respect for nature there.
Therapeutic Value. I value these places because they make me feel better physically or mentally.

weighting of 1. A kernel density output cell size of 120 m was selected based on the scale of the original survey map, which was just over 1:111,111. The search radius used for the kernel density analysis was specified at 1200 m.

For the first stage of analysis, we applied SolVES to the HINP survey data to determine the spatial distribution and density of social value points assigned to places on the HINP. First, drawing on Completely Spatially Random (CSR) hypothesis testing (Brown et al., 2002), the relative dispersion, clustering, and randomness of the digitized points associated with each social value type were determined through the calculation of average nearest neighborhood statistics. Next, kernel density surfaces were generated for each social value type with each surface weighted by the total amount of hypothetical preference points assigned to its corresponding social value type by survey respondents. Because SolVES did not provide the option to modify its kernel density parameters, the surfaces were generated using its pre-set values of a 450-m output cell size and a 5000-m search radius. These surfaces were then normalized against the highest overall weighted kernel density value and standardized to generate a Value Index integer surface for each value type. This allowed us to calculate the magnitude of value differences for the two subgroups and produce maps that compared the Value Index scores for the 12 value types to our three raster layers of the natural environment.

For the second stage of analysis, we analyzed the relationship between social and ecological data by comparing the Value Index scores that reflected the relative importance of social values for ecosystem services related to natural resource conditions represented by the three landscape metrics. The SolVES tool used the Value Index surface for each social value type to calculate zonal statistics from the three landscape metrics using the Value Index integer values to define zones for the 12 mapped social value types. Each integer value contained in the Value Index surface defined a separate zone for which the mean value of each landscape metric was calculated.

Results

Socio-demographic characteristics

Overall, respondents included more men (59%) than women and the average age was 65 years. Respondents were well educated, in that the average visitor had earned at least a college degree. The average annual income before taxes was approximately $100,000. A total of 71% were born in Australia and 88% lived in Australia. Regarding racial identification, 98% of on-site visitors engaged in this study did not consider themselves to be of Aboriginal or Torres Strait Islander descent. The average number of people per household was just under three and the average number of people per group was approximately four adults and two children. Respondents were asked to rate their level of satisfaction with a variety of programs, facilities, and services, and were generally satisfied with their park

Table 2
Social and ecological data utilized to examine social values for ecosystem services and natural resource conditions on Hinchinbrook Island National Park.

Data	Description	Source
Social value points	Values assigned to places by survey respondents. These points illustrated the distribution and point density of social values for ecosystem services across HINP's land and seascapes.	On-site and mailback surveys administered by Primary Investigator and Hinchinbrook Island ferry operators, respectively.
ASTER-GDEM	Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) was a product of METI and NASA. This layer was used as the base underlay to compare social and ecological data.	http://gcmd.gsfc.nasa.gov/index.html
Slope	Percent slope.	Derived from Global Digital Elevation Model.
Distance to Trails	Distance between social value points and the Thorsborne Trail.	Calculated from digitized features.
Distance to Water	Distance between social value points and all bodies of water including wetlands, the Hinchinbrook Channel, and the open ocean.	Calculated from digitized features.
Hillshade	Grayscale background used for illustration purposes.	Derived from Global Digital Elevation Model.
Wetlands	All wetlands found on the island. Used to calculate distance to water.	http://dds.information.qld.gov.au/dds/
Landsat	Satellite imagery (2005) of the HINP used for illustration purposes.	http://www.derm.qld.gov.au/services_resources/category.php%3fclass_id%3d8
Great Barrier Reef Marine Park waters	The open ocean surrounding Hinchinbrook Island. Used to calculate distance to water.	http://www.gbrmpa.gov.au/resources-and-publications/spatial-data-information-services/spatial-data-information
Queensland Parks and Wildlife Service waters	The Hinchinbrook Channel next to Hinchinbrook Island. Used to calculate distance to water.	http://www.derm.qld.gov.au/services_resources/category.php%3fclass_id%3d8
Roads	The Bruce Highway running along the Cassowary Coast.	http://www.derm.qld.gov.au/services_resources/category.php%3fclass_id%3d8
Hinchinbrook Towns	Data points for the two ports that lead to Hinchinbrook Island, including Cardwell and Lucinda.	http://www.derm.qld.gov.au/services_resources/category.php%3fclass_id%3d8
Coastline	Boundary of Hinchinbrook Island and the adjacent coastline.	http://www.gbrmpa.gov.au/resources-and-publications/spatial-data-information-services/spatial-data-information

experience ($M = 4.48$, SD = 0.80). For individuals (41%) that took ferries to and from the island, these experiences were also viewed as satisfactory ($M = 4.25$, SD = 0.94). On average, respondents made 23 visits in the previous 12 months, which included people in caravan parks and local residents that counted each boat trip as a visit. Visitors had been frequenting the area for 13 years and over half traveled in a family group type. Day users' visits lasted for an average of 6 h and overnight visits for approximately 20 days. It should be noted that overnight visits included people staying in a caravan park for several months at a time, as well as hikers staying on the HINP for several day backpacking trips. The most common recreation activities were hiking (51%), fishing (57%), camping (51%), taking photographs (52%), and wildlife viewing (41%). In contrast, few respondents reported kayaking (2%) and birding (10%).

Distribution and intensity of social value points

The first phase of our analysis examined how social value points marked by survey respondents were situated across the HINP and its adjacent waters. Our results suggested 12 social value types were unevenly distributed, thus indicating places of particular importance identified by the pooled sample of survey respondents. In other words, there was evidence of spatial clustering that supported the idea of "hotspots" or high priority areas that emerged according to outdoor recreationists' perceptions of places that embodied relatively important social values for ecosystem services. The most intensely valued places were Sunken Reef Bay and Zoe Bay located on the southern end of the Thorsborne Trail, the Hinchinbrook Channel, and the Missionary Bay Creeks nestled within mangrove estuaries at the north end of the island. These areas accommodated multiple visitor activities such as fishing, kayaking, hiking, and swimming in freshwater falls (see Fig. 1).

Both subgroups (i.e., consumptive and non-consumptive users) assigned multiple value types to HINP's land and seascapes, the most important of which reflected Aesthetic, Biological Diversity, and Recreation qualities. There were 236, 236, and 400 digitized points respectively assigned to these three value types. Using the SolVES application, average nearest neighbor statistics including R values (i.e., ratio of the observed versus expected distance among points) and Z scores (i.e., number of standard deviations from the mean of each R value) were reported to illustrate statistically significant spatial clustering of social value points (see Table 3). According to these statistics, our results suggested these three social value types, as well as Therapeutic value, illustrated significant clustering of value points across the two subgroups and the pooled sample. Places thought to embody Therapeutic value were relatively less important (i.e., ranked 5th) according to the total number of assigned points so our analysis focused only on the three most important value types. We generated Value Index scores to illustrate the relative importance of value types, and found that the

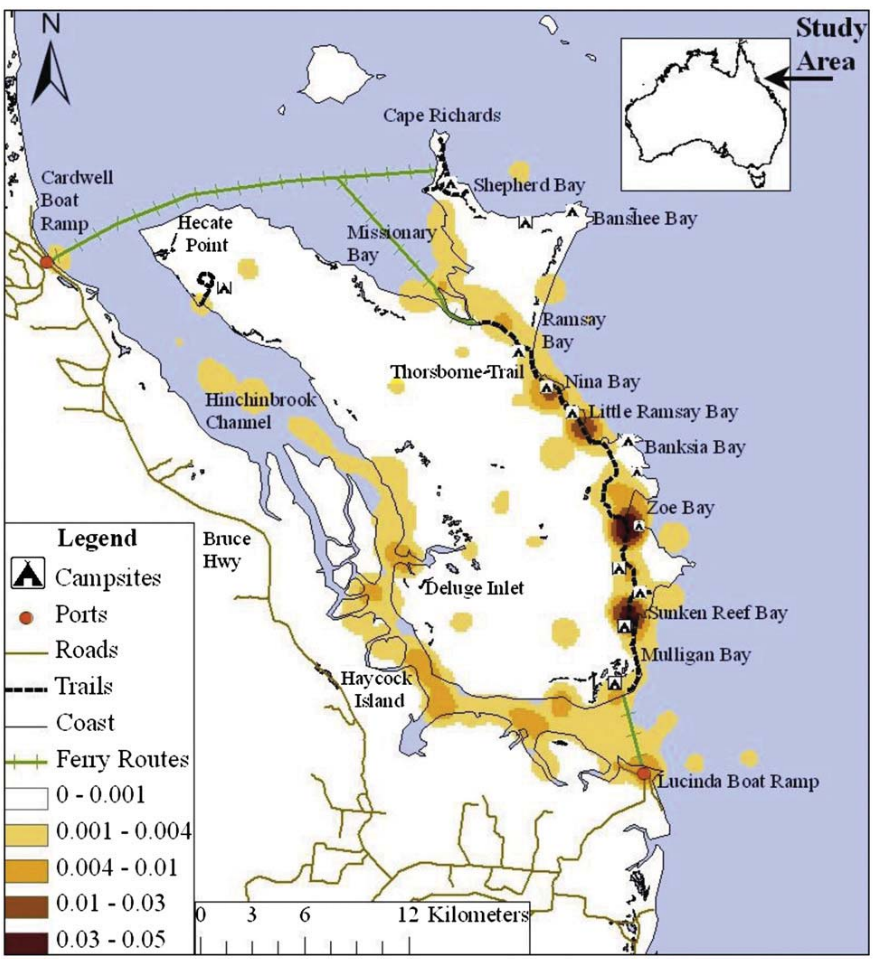

Fig. 1. Results from the kernel density analysis of social value points assigned to places by the pooled sample of outdoor recreationists on Hinchinbrook Island National Park.

Table 3
Average nearest neighbor statistics for 12 social value types among two subgroups and the pooled sample of outdoor recreationists on Hinchinbrook Island National Park.

Value type	Non-consumptive subgroup		Consumptive subgroup		Pooled sample	
	Rank (n)	R value (Z score)	Rank (n)	R value (Z score)	Rank (n)	R value (Z score)
Aesthetic	2nd (134)	0.5 (−10.7)*	3rd (102)	0.6 (−8.7)*	3rd (236)	0.4 (−16.5)*
Biological diversity	3rd (95)	0.6 (−7.3)*	2nd (131)	0.9 (−3.0)*	2nd (236)	0.7 (−9.5)*
Cultural	12th (5)	0.6 (−7.3)*	12th (6)	1.6 (2.8)	12th (11)	0.8 (−1.4)*
Economic	9th (13)	1.4 (2.4)	7th (24)	0.9 (−1.2)*	7th (37)	0.7 (−3.7)*
Future	4th (49)	0.8 (−2.8)*	4th (51)	1.1 (1.0)	4th (100)	0.7 (−5.1)*
Historic	7th (17)	1.0 (0.1)	9th (16)	1.4 (3.1)	8th (33)	1.0 (−0.5)
Intrinsic	6th (39)	1.0 (0.3)	6th (47)	1.0 (−0.6)	6th (86)	0.8 (−3.0)*
Learning	11th (8)	2.1 (5.9)	8th (19)	1.1 (0.5)	9th (27)	1.1 (0.6)
Life sustaining	8th (14)	1.8 (5.8)	11th (6)	3.3 (10.8)	10th (20)	1.0 (0.1)
Recreation	1st (147)	0.5 (−10.9)*	1st (253)	0.5 (−14.8)*	1st (400)	0.5 (−19.3)*
Spiritual	10th (12)	1.3 (2.2)	10th (8)	1.4 (2.1)	11th (20)	0.9 (−0.5)*
Therapeutic	5th (48)	0.6 (−5.4)*	5th (49)	0.8 (−2.3)*	5th (97)	0.7 (−5.8)*

* = statistically significant spatial clustering at $p < 0.01$.

scores for Aesthetic, Biological Diversity, and Recreation value types were five or greater. The pooled sample and the two subgroups reported differing ranked preferences for the importance of social values for ecosystem services.

Social values related to natural resource conditions

The second phase of the analysis tested the spatial relationships between social values and characteristics of the natural environment using SolVES. Three GIS raster layers were created to represent natural resource conditions and link social data points to spatially explicit locales (see Fig. 2). The relationship between the Value Index scores for the three most important social value types (i.e., Aesthetic, Biological Diversity, and Recreation) and our three landscape metrics (i.e., distance to water, distance to trails, and slope) were examined for the consumptive and non-consumptive subgroups.

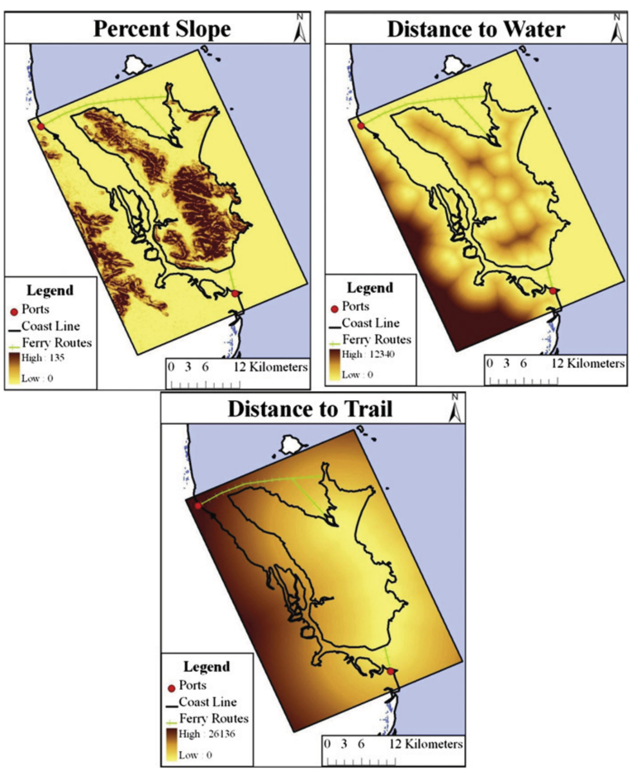

Fig. 2. Raster layers of three landscape metrics, including the percent slope, distance to bodies of water on and around the island, and distance to the Thorsborne Trail on Hinchinbrook Island National Park.

Different visual spatial relationships emerged in the comparison between the Aesthetic Value Index for the consumptive and non-consumptive subgroups and the three landscape metrics (see Fig. 3). On one hand, the consumptive subgroup associated Aesthetic value with a broader area that spanned across the terrestrial and aquatic environments of the HINP (Value Index = 4). This subgroup assigned Aesthetic value to places near the water and the island's walking track. No discernible trend emerged in the relationship between slope and the consumptive subgroups' assignments of Aesthetic value. In comparison, the non-consumptive subgroup more intensely valued a smaller area on the east side of the island (Value Index = 10). Places considered most important to this subgroup had steeper slopes, were closer to the trail, and farther from bodies of water on and around the island.

Biological Diversity values were spread across a larger area indicated by low Value Index scores of 5 for both subgroups. Similar to the differences found in the allocation of Aesthetic value points, the consumptive subgroup assigned Biological Diversity values to an area that covered most of the HINP study area. There was variation in the relationship between social and ecological data, though the general trend suggested places with less steep slopes, closer to the trail, and closer to the water carried Biological Diversity value. The non-consumptive subgroup felt that the east side of the HINP primarily embodied Biological Diversity value, as did areas with steeper slopes and in closer proximity to the trail.

Pronounced differences emerged in the two subgroups' allocations of Recreation values, as well as the relationship between Value Index scores and the three landscape metrics. On one hand, the consumptive subgroup most intensely valued the Hinchinbrook Channel and preferred places for recreational activities with less steep slopes, closer to the water, and closer to the trail. The relationship between the Recreation Value Index and distance to the trail for the consumptive subgroup was not strongly pronounced. On the other hand, the non-consumptive subgroup assigned Recreation value to places with steeper slopes, farther from the water, and closer to the Thorsborne Trail. Thus, contrasting relationships between the two Recreation Value Index scores and landscape metrics emerged. The subgroup engaged in consumptive activities attained a Value Index score of 10 and the subgroup engaged in non-consumptive activities attained a score of 9.

Discussion

Our study linked elements of a social-ecological system including the perceptions of a heterogeneous sample of outdoor

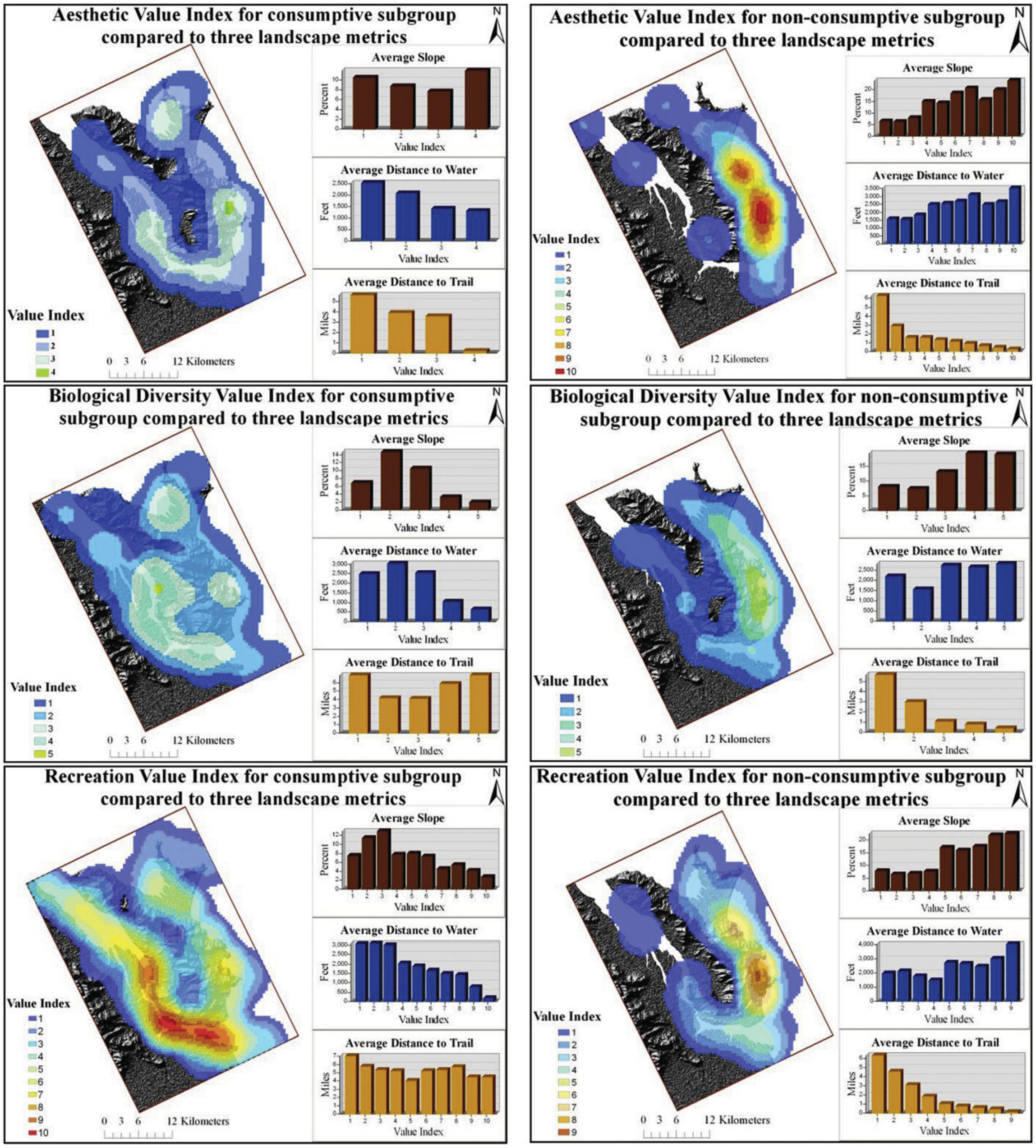

Fig. 3. Value Index scores for the Aesthetic, Recreation and Biological diversity value types reported by the two subgroups of outdoor recreationists on Hinchinbrook Island National Park. Graphical representations of the Value Index scores are overlaid on maps of the study area to illustrate which places were most and least intensely valued. The three charts within each figure illustrate the relationship between the Value Index scores and three landscape metrics including slope, distance to water, and distance to trail generated using the SolVES GIS application.

recreationists and characteristics of a biologically diverse island national park setting in Australia. We identified places of perceived importance based on significant spatial clustering of social values for ecosystem services and explored how the relative importance of these social values interacted with three landscape metrics to inform environmental planning and management. Our findings supported the utility of PPGIS methods and the SolVES GIS application to guide decision-making based on the perceived relationships outdoor recreationists shared with the natural environment.

Distribution and intensity of social value points

Several high priority areas emerged in our analysis of social values for ecosystem services that fell under the "cultural services" category of the Millennium Ecosystem Assessment (2005). These findings directed managerial attention toward places (e.g., camping sites along the Thorsborne Trail, the Hinchinbrook Channel, Missionary Bay Creeks) that embodied Aesthetic, Biological Diversity, and Recreation values. In response to these results, one management option would be to focus conservation efforts on "hotspots" or places of value abundance considered important by different user groups (Alessa et al., 2008; Chan, Shaw, Cameron, Underwood, & Daily, 2006). Alternatively, high priority settings could be identified based on the diversity, scarcity, rarity, and/or conflict of value assignments (Bryan, Raymond, Crossman, & King, 2011).

The density of social value points and the types of values that congregate in places can help decision-makers anticipate conflict among user groups (Nielson-Pincus, 2011; Yung et al., 2003). Areas of perceived importance for recreational purposes are inherently linked to human activities, whereas areas of perceived biological diversity value imply ecological importance irrespective of human use. These differing value types may reflect tensions among competing activities. However, our findings indicated that outdoor recreationists assigned Recreation and Biological Diversity values to opposite sides of the HINP, perhaps suggesting that outdoor recreationists believed these values could co-exist within the same protected area setting. Resource managers should keep in mind that outdoor recreationists maintain a diversity of tastes and preferences in their evaluations of recreation conditions and that social values assigned to places often relate to existing use histories (van Riper, Manning, Monz, & Goonan, 2011). Differing value assignments can be used as a guide to better understand which places within island national parks are considered important and are associated with different forms of consumptive and non-consumptive human activities (Duffus & Dearden, 1990).

Another approach would be to target "cold spots," or places that hold qualities not currently recognized by outdoor recreationists. Managers might consider increasing awareness of existing resources and/or distributing human use and associated impacts to less frequented areas (Manning, 2011). However, it should be noted that drawing attention to coldspots can lead to increased use and potential degradation of sensitive environments. For example, several places on the HINP (e.g., mangrove estuaries, sea grass beds) replete with biological importance were not associated with Biological Diversity value according to survey respondents. It would enhance the recreational experience and help encourage environmentally responsible behavior around fragile ecological conditions to educate the public about existing natural resource conditions in protected area settings (Powell & Ham, 2008). Interpretive boards could be constructed to provide information on the importance of sea grass for the threatened dugong, as well as their sensitivity to disturbance by boats. Other interpretive messages could focus on how mangrove forests provide nursery habitats for species that support environmental preservation and the fishing industry (see Jones, Walter, Brooks, & Serafy, 2010; Laegdsgaard & Johnson, 1995). These management options apply to protected area settings that harbor unrecognized biological diversity values (Gowdy, 1997).

Environmental interpretation was one area of improvement mentioned by visitors in their general feedback, offered anecdotally, and indicated by value types absent from important places such as a restricted access ceremonial ground on the north end of the island. It could be argued that Cultural or Therapeutic value types would have been associated with this area if visitors were more familiar with on-site conditions and/or if more Aborigines were represented in the sample. It may behoove managers to offer more educational interpretation to teach visitors about the history of the island, cultural context, geomorphology, wildlife, and/or management tactics such as controlled burning and invasive species eradication. Although there is signage about former Aboriginal presence on the island, and an informational center at one town on the mainland, more active on-site interpretation could help to increase appreciation and awareness while maintaining the wilderness qualities of the HINP. Managers should keep in mind that greater knowledge of a protected area setting can lead to supportive attitudes and behavior (Powell & Ham, 2008), which carries implications for broader environmental issues such as marine park designation in the Australian context.

Social values related to natural resource conditions

We assessed correspondence between social values assigned to places and natural resource conditions to gain a better understanding of how to link elements of a social-ecological system (Bryan et al., 2011; Sherrouse et al., 2011; St. Martin & Hall-Arber, 2008). Three managerially-relevant landscape metrics were selected to guide decision-making toward features of the environment that could be coupled with spatial data reflecting human perceptions. Future research should develop alternative metrics that can be targeted by managers to facilitate the provision of benefits provided to people by natural landscapes. For example, research in protected areas highly impacted by visitor use could test for correspondence between value assignments and intensity of impact to determine whether increased environmental degradation affects the degree and type of value assigned to places. This could be helpful to determine whether people recognize changing ecological conditions (White, Virden, & van Riper, 2008), examine how public understanding aligns with management prescriptions (Kyle et al., 2004), and gauge attitudes toward temporary closures for resource protection and/or restoration (Mayer & Wallace, 2007).

Marked differences emerged in our comparison between the two subgroups, which illustrated the utility of segmenting survey populations to account for preference heterogeneity (Lawson, Roggenbuck, Hall, & Moldovanyi, 2006; Needham, 2010). In general, the consumptive subgroup assigned social values across a broader expanse than did the non-consumptive subgroup. This may be due to the degree of access permitted within the context of various activities, in that individuals within the consumptive subgroup primarily engaged in fishing activities that involved traveling to different destinations across a large body of water. On the other hand, the non-consumptive subgroup traveled within the bounds of a state-issued permit and primarily experienced a concentrated area. Management infrastructure (e.g., hiking and camping amenities), dense vegetation on the island, and rugged terrain may have further restricted non-consumptive visitors from traveling beyond the confines of established trail systems. The differences that emerged in our comparison suggested that distinct subgroups were utilizing and/or appreciating different natural resource conditions for the benefits provided by terrestrial and aquatic environments.

There was sufficient evidence to suggest that consumptive and non-consumptive activities shaped outdoor recreationists' opinions about which places on the HINP embodied social values for ecosystem services (Duffus & Dearden, 1990). The nature of this variation illustrated diverse views of human–environment interactions according to respondents' engagement with environmental preservation versus conservation-oriented activities. Future research should identify similar divisions in visitor populations that hold different preferences for recreation conditions. With this information, managers will be better able to tailor their practices toward naturally occurring segments of their constituency. This research approach will also lend insight into the efficacy of educational efforts to maintain visitor compliance and the extent to which regulations can achieve management objectives (Dawson & Hendee, 2009).

Conclusion

This study extends various conceptual frameworks including social-ecological systems (Berkes et al., 2003; Liu et al., 2007;

Ostrom, 2009), ecosystem-based management (Cogan et al., 2009; de Groot et al., 2002; McLeod & Leslie, 2009), and Public Participation in Geographic Information Systems (Alessa et al., 2008; Brown, 2005; Brown & Raymond, 2007) to gain a better understanding of social values for ecosystem services in the context of an island national park setting in Australia. The two phases of our analysis – calculating the spatial distribution and point density of values assigned to places and determining their relationships with three landscape metrics using SolVES – help to make operational the human dimensions of natural resources management and fill the missing cartographic layer of human perception. Our findings illustrate the relative importance of 12 social values assigned to places by outdoor recreationists and identify high priority settings. We also elucidate how activity type can be used to indicate preferences for resource management activities. These findings help tailor management practices to a heterogeneous population and increase efficacy in decision-making to provide high quality visitor experiences while minimizing human impacts on the natural environment.

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