Manuscript submitted to: *Climatic Change*

Assessing spatial associations between perceptions of landscape value and climate change risk for use in climate change planning

[Approximately 6,860 words including abstract]

Christopher M. Raymond[*]

Gregory Brown[+]

[*] Christopher Raymond is Senior Project Officer, Natural Resources Management Social Applications, within the Department of Water, Land and Biodiversity Conservation (DWLBC), South Australia
(Email: raymond.chris@saugov.sa.gov.au)

[+] Correspondence author. Gregory Brown is Program Director for Environmental Studies, Department of Geography, Central Washington University, 400 E. University Way, Ellensburg, WA 98926 Phone: 509-963-1188,
(Email: browng@cwu.edu)

Assessing spatial associations between perceptions of landscape value and climate change risk for use in climate change planning

Abstract

This study examines spatially referenced perceived landscape values and climate change risks collected through public participatory geographic information systems (PPGIS) for potential use in climate change planning. Using survey data from the Southern Fleurieu Peninsula, South Australia, we present a method for identifying perceived landscape values and climate change risks to describe and quantify their spatial associations. Two spatial data models—vector and raster—and two analytical methods—Jaccard coefficients and spatial cross-correlations were used to describe the spatial associations. Results indicate that perceptions of climate change risk are driven, in part, by the values people assign or hold for places on the landscape. Biodiversity and intrinsic landscape values have strong spatial association with biodiversity loss risk while recreation values have strong spatial association with riparian flooding, sea-level rise and wave action risks. Other landscape values show weak to no spatial association with perceived climate change risks. The methodology described in this research provides a mechanism for government agencies to develop place-based adaptation strategies based on these associations.

1 Introduction

The impacts of climate change on human well-being and ecosystem condition is of increasing concern to scientists, policy-makers and the general public. While the science community has an important role in identifying climate change risks, current scientific knowledge of adaptation is insufficient for rigorous evaluation of planned adaptation options (Smit el al. 2001; Yohe et al. 2007). Public perception of climate change and ecosystem risks play an important role in assisting local communities' response to climate change risks and in shaping environmental policy and programs in the light of this scientific uncertainty.

While a large amount of research has examined public perceptions of climate change, few studies have examined the role of place in shaping risk perception. Researchers have focused on the role of attitudinal, psychometric and socioeconomic characteristics on risk perception (e.g., McDaniels et al. 1995; Dietz 2001; Stedman 2004; Leiserowitz 2006; Slimak and Dietz 2006) while generally excluding physical or social characteristics associated with the local environment. Only recently have researchers begun to investigate the relationships between the physical attributes of place and risk perception. Brody et al. (2008) examined the role of proximity variables such as distance to coast, relative elevation, sea level rise risk and 100-year floodplain on climate change risk perception. They found that survey participants tend to calculate their risk level based on a limited understanding of climate change risk—only select physical vulnerability variables such as elevation significantly influenced risk perception. It is possible that ascription of climate change risks are influenced by additional dimensions of place, including the values individuals and communities assign or hold for place. Such values may be symbolic in that they reflect ideas or indirect use values (e.g., intrinsic, life sustaining, future values) or instrumental in that they are linked to a direct use of the landscape (e.g., economic or recreation values). We refer to these place values as perceived landscape values.

In this study, we present a spatial method, referred to as the landscape values methodology (LVM), for identifying and measuring public perceived landscape values and climate change risks. The spatial method is based on transactional concept of human-landscape relationships (Zube 1987) where humans are active participants in the landscape – thinking, feeling and acting – leading to the attribution of meaning and the valuing of specific landscapes and places. The method is also a type of public participatory geographic information system (PPGIS) because it engages broader public audiences with geographic information systems technology for land use planning (see Sieber 2006 for a review of PPGIS methods). The method has been tested and validated in eight North American natural resource management applications (see Brown 2005; Beverly et al. 2008) and four Australian applications (Brown 2006; Raymond and Brown 2006; Pfueller et al. 2008; Raymond 2008).

In this study, we include spatial measures of perceived climate change risk for places that are vulnerable to: 1) biodiversity loss; 2) land erosion; 3) bushfire; 4) sea-level rise; 5) riparian flooding; and 6) storm surges as a result of projected climate change by 2030. We use the LVM to examine the spatial associations between public perceptions of landscape value and climate change risk. After a preliminary investigation of the distribution and intensity of values and risks across the Southern Fleurieu Peninsula, South Australia (Southern Fleurieu), we use Jaccard and spatial cross-correlation analyses to determine the extent of spatial overlap between landscape values and climate change risks on the landscape. From our findings, we demonstrate the potential for integrating spatial measures of landscape value and climate change risk for climate change adaptation planning in the Southern Fleurieu and elsewhere.

1.1 Values, socio-cultural variables and climate change risk

Environmental value orientations have been found to be a significant predictor of people's assessment of environmental risks (Stedman 2004; Leiserowitz 2006; Slimak and Dietz 2006; Etkin and Ho 2007). For example, a study of lay public, experienced public, risk assessors and risk managers within the United States Environment Protection Authority revealed that the New Ecological Paradigm scale (comprising of personal values and world views related to the sacredness of nature) is a strong predictor of global risks such as global warming, ozone depletion, acid rain and human population growth (Slimak and Dietz 2006). These results support earlier studies which indicated persons with pro-environmental attitudes were more supportive of risk reduction efforts related to greenhouse gas emissions (O'Connor et al. 2002) and support for policies that address climate change risks (Bord et al. 1998).

Researchers have also examined the relationships between underlying values, world views, sociodemographic variables and specific beliefs about climate change risks. Analyses found that negative affect and egalitarian values were consistently stronger predictors of risk perception than sociodemographic variables (Leiserowitz 2006), and that world views and broad social values are greater predictors of perceived climate change risk than specific beliefs about climate change impacts (Stedman 2004). However, there is some disagreement on the contribution of values to risk perception. Studies have revealed that socio-cultural variables, such as familiarity with biodiversity issues, may amplify the relationships between values and risk perception (McFarlane 2005) and thus alternative paths of influence need to be considered.

Socio-demographic correlates of risk perception are one such path. One of the consistent findings is that older individuals and people with higher levels of education and income tend to be less concerned about environmental risks (Savage 1993; Kraus et al. 2000; Slovic 2000). In relation to gender differences, women are more aware of environmental risks and show greater support for environmental and climate change initiatives (Barkan 2004; Zelezny et al. 2000; Dietz et al. 1998).

1.2 Landscape values and risk perception

Relatively little research has examined the role of physical and social characteristics of place on risk perception. Brody et al. (2008) tested the degree to which a person's level of physical vulnerability to climate change influences his or her perception of risk. The physical vulnerability variables only explained 4% of the variance in risk perception. Survey respondents who lived in areas most vulnerable to sea-level rise (low-lying areas close to the coast) or within the 100-year floodplain had significantly higher risk perceptions than those who lived in other areas, but six other physical vulnerability variables did not significantly predict risk perception. The authors attribute the low explanatory power of the risk perception model to the way in which the general public calculates risk. They suggest risk calculation is based on a limited understanding of the impacts of climate change and that education programs may increase public awareness about a broader range of physical vulnerability characteristics.

While Brody's work examined the relationships between physical place variables and risk perception, we examine the extent to which the social and psychological construction of place influences risk perception. Landscape values are a component of the 'sense of place' construct (Brown 2005). 'Sense of place' reflects an entire suite of thoughts (cognitions) and emotional (affective) sentiments held regarding a particular geographic locale (Altman and Low 1992; Jorgensen and Stedman 2001) and the meanings one attributes to such areas (Relph 1976; Fishwick and Vining 1992; Kaltenborn 1998; Stedman 2003a, 2003b). A large body of work has shown that people who are strongly attached to place are more likely to show high levels of environmental concern (e.g., Vorkinn and Riese 2001; Kyle et al. 2004); however, few studies have examined the relationships between environmental risks and 'sense of place' and none to our knowledge have attempted to spatially quantify these associations. To fill this knowledge gap, this study explores the spatial relationships between eight perceived landscape values and areas perceived to be vulnerable to the following climate change risks by 2030: 1) biodiversity loss; 2) land erosion; 3) bushfire; 4) sea-level rise; 5) riparian flooding; 6) storm surges. An integrated assessment of climate change impacts in the Adelaide and Mount Lofty Ranges (AMLR) region (Bardsley 2006) was the starting point for the selection of these climate change risks.

Brown (2005) and colleagues developed the concept of landscape values as an operational bridge between the geography of place and 'sense of place'. The starting point for the selection of landscape values was work by Rolston and Coufal (1991) who identified ten basic landscape values: life support, economic, scientific, recreation, aesthetic, wildlife, biotic diversity, natural history, spiritual and intrinsic. The typology was modified to include subsistence, cultural and therapeutic values (Brown and Reed 2000). In this study, a subset of the landscape value typology was used and included the following landscape value measures: 1) aesthetic; 2) recreation; 3) biological diversity; 4) learning; 5) heritage; 6) intrinsic; and 7) future values.

1.3 Research hypotheses – comparing perceived landscape values and climate change risks

We first test the hypothesis that there are significant spatial associations between perceived landscape values and climate change risks. With rejection of the null hypothesis for some value/risk pairings, we determine the strength of the association using two different methods of spatial analysis – Jaccard coefficients for determining the degree of spatial overlap between landscape value and climate change risk polygons (vector approach), and spatial cross-correlation analysis for determining the spatial relationships between landscape value and climate change risk grid cells (raster approach). We then examine whether the method of analysis (i.e., vector vs. raster) affects the degree of spatial overlap of landscape values and climate change risks. Finally, we generate a map to illustrate the associations between places of low, medium and high landscape value and climate change risks and show how the results may be used to prioritise climate change adaptation responses.

2 Methods

2.1 Study Location – Southern Fleurieu Peninsula, South Australia

The Southern Fleurieu Peninsula region, as defined in this study, is a plateau bordered by the townships of Mount Compass, Cape Jervis and Goolwa (Figure 1). While the Goolwa, Hindmarsh Island and Coorong sub-regions are not formally part of the Southern Fleurieu, they were included considering the important natural resource management (NRM) and climate change issues being experienced in these places. The region contains 10.3% of its pre-European (pre-1788) vegetation cover, and 85.0% of the remaining vegetation is fragmented into patches of less than 1,000 ha (National Land and Water Resources Audit 2001). The Fleurieu Peninsula swamps are rated as a nationally threatened plant community under the Environment Protection and Biodiversity Conservation Act (EPBC) Act 1999 and are home to populations of the nationally endangered Mount Lofty Ranges Southern Emu-wren (Hill and Duffield 2002).

The region has a mosaic of land uses. Farming activities comprise approximately 73% of the total land use, followed by conservation (21%) and residential living (6%) (DWLBC 2006). Residential development is undergoing major growth along the coastal fringe. The regional hub of Victor Harbor, for example, is amongst the fastest growing communities in the State, with an average growth in excess of 3% per annum for the past 10 years and a population of 30,000 at peak tourist season from December to February (City of Victor

Harbor 2007). A total of 13 individual conservation and recreation parks and reserves are encompassed by the study boundary. The most popular park in the region is Deep Creek Conservation Park with approximately 32,104 visitors in 2003 (Urban and Regional Planning Solutions 2007).

[Insert Figure 1]

2.2 Sampling

Two sampling techniques were used in this study – a snowball sampling technique to identify workshop participants and a systematic random sampling technique to identify postal survey participants. In the snowball sampling technique, a list of key NRM organisations was obtained from the AMLR NRM Board. Organisations were grouped and then selected by interest (i.e., coastal development, education, conservation, primary production). Each organisation was invited to participate in the study through the chair or secretary. Additionally, the chair or secretary was asked to suggest names and contact details of other individuals and groups who may have been interested in participating in the study. Victor Harbor, Goolwa, Mount Compass and Yankalilla secondary school students were invited to participate in the study through the school principal. Only Years 10-12 Geography and Society and Environment Studies were asked to complete the surveys because the LVM assumes basic skills in map reading and the climate change concept requires some understanding of world climate systems. The snowball sample is not assumed to be representative of the Southern Fleurieu resident population; however, it does represent the major NRM interest groups in the region, all of whom are critical to engage in climate change issues and adaptation responses, and the ongoing management of natural resources, especially biodiversity.

A random sample of Southern Fleurieu property owners was collected by examining the 2007 cadastral file (DEH 2007) cropped using GIS to the exact dimension of the study area. Property owners were selected from 14 Southern Fleurieu communities at an interval of 120 and from a random starting point. A census of property owners in Delamere and Clayton communities was attempted because a proportional sample of each community would have not yielded enough observations for subsample statistical analysis. All selections with company or trust names were removed from the database because the postal survey was tailored to individuals and their families. The sampling frame was representative of most residents over the age of 18; but it under-represented residential and commercial lessees whose details were omitted from the cadastral file.

2.3 Survey Instruments

Workshop and postal surveys were administered during this study to encourage response from a broad cross-section of the Southern Fleurieu community.

2.3.1 Workshop Survey

Between March and May 2007, 15 workshops were conducted with school students and adults residing in the Southern Fleurieu region. Workshops occurred in all major townships across the region, including Goolwa, Victor Harbor, Mount Compass, Normanville, Yankalilla and Second Valley. We conducted two workshops in each township, except for Victor Harbor (four workshops). The number of participants involved in each workshop ranged from 5 to 30, with a median attendance of 17 people. A total of 16 workshop surveys were completed with an equal spread of responses across each major township except Victor Harbor considering its high population.

The workshop survey contained questions in five sections: 1) familiarity with the Southern Fleurieu and perceived threats to quality of life; 2) climate change knowledge and level of concern; 3) preferred climate change adaptation responses; 4) respondent characteristics (e.g., interest group, age, gender, level of formal education, employment category); and 5) identification of landscape values and climate change risks. To encourage attendance, workshop participants were provided a 20 minute presentation on recent climate change trends. International climate change trends were distilled from the 2007 IPCC report (IPCC 2007), and the national and state trends from two CSIRO reports (McInnes et al. 2003; Suppiah et al. 2006). The potential regional and local climate change risks and associated adaptation options were not discussed during the workshop to minimise response bias.

Most relevant to this study was participant identification of perceived landscape values and climate change risks. During the workshop, participants were provided a map legend and 1:125,000 greyscale map of the Southern Fleurieu region. The map legend included 17 rows of sticker dots for use in identifying the location of landscape values, development preferences and perceived climate change risks (Figure 2). An operational definition for each value and risk appeared adjacent to the respective row of sticker dots. Each value and risk was assigned six sticker dots weighted from 50 to 5, with the larger numbers reflecting subjectively more of the landscape attribute, e.g., more scenic, more recreation value, higher biodiversity loss or higher bushfire risk. Participants were requested to place their sticker dots on the map locations that held the landscape values or climate change risks. They could place as many or as few dots on the map as they liked.

The six perceived climate change risks—biodiversity loss, land erosion, bushfire, riparian flooding, sea-level rise and wave action or storm surge—were identified from a literature review and integrated assessment of climate change risks in the AMLR region (Bardsley 2006). The final list of risks was reviewed and refined by a project steering committee comprising of scientists and policy makers within the Department of Water, Land and Biodiversity Conservation and AMLR NRM Board.

[Insert Figure 2]

2.3.2 Postal Survey

In May 2005, a postal survey of Southern Fleurieu property owners was conducted using a modified Total Design Method (Dillman 1978). Survey administration involved four mailings: 1) introductory letter informing of the purpose of the research; 2) complete survey packet; 3) handwritten reminder postcard; and 4) second complete survey packet to non-respondents from the first round.

The postal survey contained the same questions as the workshop survey, with the exception being the length of residence, interest group affiliation and community of residence questions. The postal survey participants were not provided a presentation on climate change and its risks.

2.4 Analysis Techniques

When the maps and questionnaires were returned, we entered the data into SPSS® Version 16 and digitised the landscape value and climate change risk points into ESRI ArcMap® software. We then ‘joined’ the spatial data to the table data using a unique identifier, enabling descriptive and inferential statistics to be performed on both data sets.

2.4.1 Landscape values, climate change risks and respondent variables.

After comparing respondent characteristics from the survey sample to 2006 Australian Bureau of Statistics regional census data (ABS 2006), we used a combination of t-tests and ANOVA in SPSS® to examine differences in the mean number of landscape values and climate change risk points (0-6) mapped by survey participants across age and knowledge sub-groupings. We divided participants into school student and adult groupings. School students were under the age of 18 and were enrolled in Geography or Environmental Studies courses. Additionally, we asked all participants to rate their knowledge of places of the Southern Fleurieu on an 'Excellent', 'Good' and 'Fair' scale and to identify their level of attention paid to climate change issues facing South Australia on a 'no attention', 'little attention', 'moderate attention' and 'close and constant attention' scale.

2.4.2 General distribution of landscape values and climate change risks

We examined hypotheses about the general distribution of landscape value and climate change risk points using Nearest Neighbour Analysis. Specifically, hypotheses were testing whether specific sets of point locations were completely spatially random (CSR) on the landscape. The nearest-neighbour statistic (R) is a simple measure of the spatial distribution of points. It is calculated by dividing the average Euclidean distance of all points within a specified polygon by the expected distance of points under an assumption of random distribution. The more clustered the points, the closer to 0 the value of R will be. The more randomly distributed the points are, the closer the R value is to 1.

After identification of significant spatial clusters, we sought to compare and contrast the values and risks assigned to general land use classifications: residential areas, conservation reserves, plantation areas and irrigated pastures. We intersected the landscape values and climate change risk layer to the land-use layers for cross-tabulation analyses. The actual numbers of landscape value and climate change risk points falling within each of the identified land-uses were compared to an expected distribution.

2.4.3 Spatial and non-spatial associations between landscape values and climate change risks

Because participants were instructed to map as few (i.e., 0) or as many values and risk locations (i.e., up to 6 points per value or risk), participants had choice in the mapping activity. One empirical question is whether there exists a latent non-spatial association between an individual's choice of landscape values and climate change risks to be mapped. We examined this potential non-spatial relationship between landscape values and climate change risks using multiple regression analyses. In the regression model, the landscape value counts (0-6) for all respondents were treated as independent, predictor variables and the climate change risk counts (0-6) for all respondents were treated as the dependent variables. We used the "enter" method to force all landscape value counts into the regression model.

We used vector and raster analyses to determine the spatial overlap of each landscape value and perceived climate change risk. In the vector approach, we used the Jaccard coefficient (van Jaarsveld et al. 1998; Leroux et al. 2007) where:

J = area of intersection between value and risk polygons/((area of value polygon + area of risk polygon) - area of intersection).

Calculation of the J coefficient required some preliminary spatial analysis. Because the J coefficient is sensitive to scale effects, we generated 95% and 75% probability polygons for each of the value and risk layers using the kernel home range function available within Hawth's Tools (Worton 1987). The kernel home range mathematically converts the points into areas with varying probabilities of use and presents these graphically. In this study, it represents the minimum area in which 95% and 75% of the value or risk points are likely to be located. We then calculated the areas of each value and risk polygon at 95% and 75% intervals. To determine the area of intersection, we intersected each value and risk polygon and appended the area of intersected polygons to the table.

In the raster approach, we examined the spatial relationships between landscape value and climate change risk densities using spatial cross-correlation analysis. Cross-correlation analysis calculates the Pearson's product-moment correlation between the density of two raster coverages at randomly selected points, in this case 1000 points. Calculation of the r values also required some preliminary data analysis. We used Hawth's tools in ArcMap® to generate a kernel density for each value and risk coverage using a 500 m grid cell size with no search radius. We then extracted and associated the density values at the 1000 points to calculate Pearson's coefficients.

To identify priority areas for climate change adaptation, we generated a map displaying the associations between high, medium and low point densities for the aggregated landscape value and climate change risk point themes. We first generated density grids for the eight landscape values and six climate change risks using a 500 m grid cell and 3 km search radius. The landscape value and climate change risk themes were classified using the standard deviation classification method. This method places class breaks above and below the mean grid cell density at intervals of one standard deviation until all the data values are contained within the classes. Values that are beyond the three standard deviations from the mean were aggregated into two classes; greater than three standard deviation above the mean and less than three standard deviation below the mean. We then reclassified the landscape value and risk themes into high (> 2 standard deviations) and low (≤ 2 standard deviations) grids and used the raster calculator to generate spatial intersections between low and high value and risks. The result is a new raster layer with 4 classifications: low value, low risk; low value, high risk; high value, low risk; and high value, high risk. We developed a climate change adaptation priority matrix by associating planning options with the value/risk landscape classifications.

3 Results

3.1 Survey Response

We ran two surveys concurrently as part of the Southern Fleurieu study – a workshop survey and postal survey. We received 245 workshop surveys consisting of 127 secondary school student and 118 adult responses.

A total of 210 postal surveys were sent to a random sample of Southern Fleurieu property owners. Property owners were defined as people over the age of 18 who either lived in the Southern Fleurieu (n = 153) or owned one or more properties in the region (n = 57). We received 130 postal survey responses for a response rate of 61%. Overall, we received 375 workshop and postal survey responses, resulting in a spatial data set of 16,025 digitised points.

3.2 Respondent Profile

To facilitate comparison with regional data (ABS 2006), we separated the adult survey population into resident and non-resident sub-groups (Table 1). There were more males (65.8%) in the resident sample compared to ABS statistics for the region (48.8%). The majority of resident survey respondents were over 40 years of age (53.6%) which is consistent with the region (60.0% ABS). However, there were proportionately fewer respondents 21-40 years of age (5.6% resident sample vs. 17.1% ABS) and proportionately more youth respondents younger than 20 years of age (40.8% resident sample vs. 22.9% ABS). The high number of youth respondents is to be expected considering school students were targeted as part of the snowball sample.

The majority of the sample had completed either primary or secondary school (54.7%). Of the resident sample, 28.4% had completed secondary education, 14.5% tertiary education and 10.4% postgraduate education, all higher than the regional education profile. Non-residents were more educated than residents with 34.6% having completed tertiary and 32.7% postgraduate education. All participants identified with education (32.3%), conservation (21.7%) or primary production (21.2%).

Overall, the demographic profile of respondents indicates that the sample was skewed towards male respondents who were better educated than the regional population and aligned with education, conservation or primary production interests.

[Insert Table 1]

3.3 Relationships between respondent variables and the number of value and risk points assigned to the Southern Fleurieu

We ran independent samples t-tests and one-way ANOVAs to compare the mean number of value and risk locations assigned to the Southern Fleurieu map across different age and knowledge level sub-groups. The variables of life stage (student or adult), level of formal education (primary/secondary or tertiary), knowledge of region (fair, good, or excellent) and attention paid to climate change (little, moderate, or close) had no significant effect on the number of landscape value or risk points assigned by respondents. However, there are some trends in the relative frequency of value and risk assignment. Aesthetic values were most frequently assigned to the Southern Fleurieu region by all respondent sub groups ($\bar{x}$ = 4.07), followed by economic ($\bar{x}$ = 3.38) and recreation ($\bar{x}$ = 3.32). Bushfire was the most frequently assigned risk across most sub-groups ($\bar{x}$ = 3.33), followed by sea-level rise ($\bar{x}$ = 2.88) and wave action ($\bar{x}$ = 2.86).

3.4 Spatial distribution of landscape values and climate change risks in the Southern Fleurieu region

Table 2 shows the results of nearest neighbour analysis. For each value or risk, the null hypothesis of complete spatial randomness is rejected, indicating significant clustering of points. Heritage, aesthetic and recreation values are the most clustered on the landscape (R = 0.46, 0.48 and 0.48 respectively), while intrinsic, learning and future values are the most randomly distributed (R = 0.55, 0.52 and 0.51 respectively). In relation to climate change risks, sea-level rise, wave action and bushfire risks (R = 0.43, 0.44 and 0.54 respectively) are more clustered than land erosion, biodiversity loss and riparian flooding risks (0.62, 0.60 and 0.54 respectively). Overall, landscape values tend to be more clustered than climate change risks.

[Insert Table 2]

We then examined the distribution of landscape values and climate change risks by general land–use classification (Table 3). The general land-use classification system consisted of 4 categories (residential, conservation, irrigated pasture and plantation). While the overall observed distribution of landscape values by land-use do not deviate from expected results ($X^{2 =}$ 19.83, p >0.05), there were statistically significant associations between land-use classification and perceived climate change risks ($X^{2 =}$ 36.1, p < 0.05). The perceived climate change risks of biodiversity loss and bushfire are proportionately more associated with “conservation” land use, while biodiversity loss is least associated with “plantation” land use. Also noteworthy is the relatively high proportion of wave action risk associated with “residential” (coastal) areas.

[Insert Table 3]

3.5 Relationships between landscape values and climate change risks

We used a regression model to help identify the landscape values that might be non-spatially associated with measures of perceived climate change risk (Table 4). The number of mapped landscape values were moderate predictors of the number of mapped climate change risks, regardless of spatial location (R^2 ranges from 0.36 to 0.62). For example, individuals who mapped more intrinsic, aesthetic and recreation landscape values also tended to map more biodiversity loss risk locations. Similarly, individuals who mapped more recreation, historic, economic and aesthetic values also tended to map more riparian flooding risk locations. The number of mapped intrinsic values was the most significant predictor of the number of mapped biodiversity loss ($\beta = 0.37$) and bushfire risks ($\beta = 0.32$); and the number of mapped recreation values was the most significant predictor of the number of mapped riparian flooding ($\beta = -0.48$) and sea-level rise risks ($\beta = -0.32$). The collinearity diagnostics on the regression models suggest a tolerable level of multicollinearity in the independent variables with diagnostics for four of the six models having VIF values below the general threshold of 10 for obvious concern (Myers 1990). The maximum VIF value in the other two models was 10.6.

[Insert Table 4]

3.6 Spatial overlap of landscape values and climate change risk places

Jaccard's coefficients were calculated to quantify the degree of spatial overlap between landscape values and climate change risk vector-based polygons that were created to capture 95% and 75% of the mapped points, respectively (Tables 5a, 5b). At both intervals, biodiversity and intrinsic values were most strongly associated with biodiversity loss and bushfire risks, aesthetic and intrinsic values were most strongly associated with land erosion risk, and recreation and aesthetic values were most closely associated with sea-level rise and wave action risks. The size of the polygons, reflected in the percentage of points included, did not have a major influence on the spatial associations, with few changes in the rank order of Jaccard coefficients across 95% and 75% polygons.

[Insert Tables 5a and 5b]

The spatial relationships between landscape value and climate change risk was also examined using a raster spatial model. Spatial cross-correlation analysis was performed on density grids generated for landscape values and climate change risks. Pearson's product-moment correlations between the density of raster coverages were calculated for 1000 randomly selected points (Table 6). There are larger, significant spatial associations between perceptions of biological diversity value and risk of biodiversity loss (r = 0.81), learning value and biodiversity loss (r = 0.75), future value and risk of biodiversity loss (r = 0.73), recreation value with risk of wave action (r = 0.71), intrinsic value with risk of biodiversity loss (r = 0.69) and recreation value with risk of sea-level rise (r = 0.67).

In comparing the vector and raster analyses, there is more consistency than difference in the results. In both spatial approaches, there are significant spatial associations between biodiversity value and biodiversity loss risk and intrinsic value and biodiversity loss risk. The relatively strong spatial associations between recreation value and the risks from wave-action and sea-level rise are also consistent. The weakest spatial associations between heritage and recreation values and bushfire risks are also consistent in both analyses. One difference in the results is that the spatial association between economic value and the risk of riparian flooding is relatively high in the raster analysis, but less in the vector analysis.

[Insert Table 6]

3.7 Mapping of landscape value and perceived climate change risk associations

In Figure 3, we present a map to illustrate the spatial associations between landscape values and perceived climate change risk point densities. Deep Creek and Newland Head Conservation Parks, and Victor Harbor, Goolwa, Cape Jervis, Second Valley, Normanville and Mount Compass townships were identified as landscapes of high perceived value and risk at the 95% confidence level. The neighbouring townships of Delamere are Myponga were perceived as areas of low value and high risk, whereas the majority of lands were identified as low value and low risk.

We then generated a climate change adaptation priority matrix (Table 7) which translates the associations between perceptions of landscape value and climate change risk into potential agency responses. Areas of high landscape values and high climate change risks are priority areas for climate change adaptation and agency resources need to be directed to these areas. Conversely, areas of low landscape value and low climate change risks are discount areas where agency resources can be reallocated or diverted from these sites. Areas of high landscape value and low risk are maintenance areas and areas of low landscape values and high risks are sacrifice areas.

[Insert Figure 3]

[Insert Table 7]

4 Discussion

The purpose of this study was to present a method for identifying and measuring the spatial relationships between public perceived landscape values and climate change risks for climate change adaptation planning. Analysis of the data suggests that perceptions of climate change risk are, in part, spatially related to the values people assign to or hold for places on the landscape in the Southern Fleurieu region. This finding may prove useful to assess climate change risk in Australia and elsewhere. Previous international research indicates that risk perception is correlated with an individual's physical location (Brody et al. 2008) and environmental value orientations (Stedman et al. 2004; Leiserowitz 2006; Slimak and Dietz 2006; Etkin and Ho 2007). Our findings suggest that researchers need to expand the list of variables to include psychological correlates of risk perception at the place-specific scale when undertaking climate change adaptation studies to gain a more comprehensive understanding of risk drivers and their management.

Although there is a high degree of variability in the mapping process among individuals, collective spatial patterns do emerge from the mapping process. Perceived landscape values and risks are not randomly distributed across the landscape, but rather cluster to varying degrees. Significant spatial associations exist between some climate change risk perceptions and major land-use classifications, as well as some geographic areas with higher perceived landscape values.

The respondent decision to map more of certain types of landscape value yielded moderately predictive results about the number of certain climate change risks mapped. However, the landscape values that best predict the number of climate change risk locations mapped such as recreation value (Table 4), were seldom the same landscape values with the highest level of geographic spatial association with the mapped climate change risks, such as biodiversity or intrinsic values (Tables 5 and 6). These results suggest that the participant choice about the number and type of values and risks to map involves a different or unrelated cognitive process to the choice of where to map the value and risk locations.

Not all landscape values were strongly associated with perceived climate change risks. For example, we found weak spatial associations between all eight landscape values and bushfire and land erosion risks. Historic events may explain this particular finding. In recent years, there have been a series of bushfires across inland conservation parks and forestry reserves on the Southern Fleurieu peninsula, possibly leading to the assignment of high bushfire risk to inland areas.

The bushfire example raises an interesting question for scientists and policy makers: do people assign risks to the landscape based on their understanding of likely climate change by 2030 or are they based on past experience/interaction with the landscape? Brody et al. (2008) suggest that the general public assigns risk based on a limited set of vulnerability variables. Similarly, our results suggest that respondent characteristics such as the level of attention paid to climate change, formal education level and perceived knowledge of the study area do not significantly influence the number of climate change risk points assigned to the map. These findings are consistent with a number of American studies on climate change where members of the public tend to calculate their risk level based on a limited understanding of the impacts of climate change (Bell 1994; Kempton 1991).

One methods-related research question in this study is whether the type of analysis (vector or raster) influences the spatial associations between perceived values and risks. Both data models, vector and raster, produced similar spatial associations with Jaccard coefficients and spatial cross-correlation analyses and thus appear to provide reasonable measures of spatial association. However, because there is inherent uncertainty and variance associated with the extrapolation of point data for both landscape values and climate change risks, we suggest conducting both vector and raster analysis to assess the reliability of the resulting spatial associations.

4.1 Implications for government agencies and land managers

Government agencies and land managers should engage in proactive land use planning which we would define as: 1) identifying lands with significant ecological, economic and social values; 2) identifying potential risks to these values; and 3) planning and coordinating activities to minimize the risks to these values. The growing awareness of the risks from climate change has accelerated the need for agencies to expand their temporal planning horizons. The method identified in this research provides a mechanism for agencies to identify landscape values and climate change risks to develop place-based planning strategies.

Government resources are limited and choices must be made regarding how planning and management resources will be targeted. The mix of landscape value and climate risk scenarios (see Table 7) is suggestive of the allocation of land use planning and management resources for government agencies under the new reality of climate change. Agency planning resources should be directed to priority areas—landscapes that have both high levels of value as well as risk from climate change—and away from areas that have high risk, but relatively low value. In this study, areas of high priority include the landscape between Victor Harbor and Middleton, the Lower Murray, Newland Head and Deep Creek Conservation Parks. An area of low value includes the Finniss township. Areas that currently have high value but are at lower risk for climate change should be managed to maintain the quality of landscape values, which generally translates into managing these lands to reduce human conflict over existing landscape values. Landscapes that have relatively low value and low risk may be sacrificed at the present as a necessary resource trade-off.

The prioritisation and reallocation of agency planning and management resources based on this type of LVM analysis will be controversial because it explicitly seeks public engagement in the climate change planning process while acknowledging the limited resources of government to addresses public needs. The prioritisation of agency resources is viewed by many as best reserved for political and administrative systems that are informed by expert opinion. But public participation in climate change planning to this point has been ‘shallow’ in that there has been a tendency to focus on informing the public rather than seeking their advice and direction through collaborative planning outcomes. The landscape values methodology presented in this study provides a tool for soliciting a wide variety of values and risks at the place-specific scale early in the planning process.

While we believe PPGIS mapping of landscape values and climate change risks offers the potential to improve climate change planning, especially at the local and regional planning levels of government, the method should not be viewed as supplanting the need for expert opinion, especially regarding the assessment of risks from climate change. The methods presented herein should be viewed as part of an iterative and transactive planning process wherein both public and expert knowledge coalesce into a shared understanding of the risks and value tradeoffs involved in climate change. Soliciting landscape values early in the planning process may increase trust in agency decision-making and increase community support for and involvement in climate change adaptation responses, particularly when current expert knowledge of adaptation at local and regional scales is insufficient for planned adaptation responses.

To develop a comprehensive understanding of climate change adaptation priorities, future research could examine the spatial relationships between locally perceived and expert assessed landscape values and climate change risks similar to the method used to compare lay and expert biological diversity conservation priorities (see Brown et al. 2004). Land managers could use the results to develop and refine their community engagement strategies. Information and consultation programs, for example, may need to be established in places of high expert assessed value and risk but low public perceived value or risk. Conversely, collaboration and empowerment programs may be required in areas of low expert assessed value and risk but high public perceived value or risk if the goal is to encourage local involvement in climate change adaptation planning. Perhaps most important, the methods described herein provide a reasonable operational bridge between perceived landscape values and climate change risks that can be used in a collaborative planning process to rationally allocate limited public resources.

Acknowledgements

We would like to thank the Department of Water, Land and Biodiversity Conservation (SA), Adelaide and Mount Lofty Ranges NRM Board and the Department of Climate Change (Cwlth) for funding this research project upon which this paper is based.

References

Altman IA, Low SM (eds) (1992) Place attachment. Plenum, New York

Australian Bureau of Statistics (2006) Census Tables for the Fleurieu Statistical Subdivision. Australian Bureau of Statistics, Canberra. http://www.censusdata.abs.gov.au. Cited 5 May 2008.

Bardsley D (2006) There's a change on the way — An initial integrated assessment of projected climate change impacts and adaptation options for natural resource management in the Adelaide and Mount Lofty Ranges region, DWLBC Report 2006/06, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide

Barkan SE (2004) Explaining public support for the environmental movement: A civic voluntarism model. Social Science Quarterly 85:913-937.

Bell A (1994) Climate of opinion: Public and media discourse on the global environment. Discourse and Society 5(1):33-64.

Beverly JL, Uto K, Wilkes J, Bothwell P (2008) Assessing spatial attributes of forest landscape values: An internet-based participatory mapping approach. Canadian Journal of Forest Research 38:289-303

Bord RJ, Fisher A, O’Connor R (1998) Public perceptions of global warming: United States and international perspectives. Climate Research 11:75-84.

Brody SD, Zahran S, Vedlitz A, Grover H (2008) Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States. Environment and Behavior 40(1):72-95

Brown G (2005) Mapping spatial attributes in survey research for natural resource management: Methods and applications. Society and Natural Resources 18(1):17-39

Brown G (2006). Mapping landscape values and development preferences: A method for tourism and residential development planning. International Journal of Tourism Research 8(2):101–113.

Brown G, Reed P (2000) Validation of a forest values typology for use in national forest planning. Forest Science 46(2):240-247.

Brown G, Smith C, Alessa L, Kliskey A. (2004) A comparison of perceptions of biological value with scientific assessment of biological importance. Applied Geography 24(2):161-180.

City of Victor Harbor (2007) A community portrait of the City of Victor Harbor, Public Practice, Adelaide

DEH (2007) DCDB Parcel, Land Services Group. Department for Transport, Energy and Infrastructure, Adelaide

Dietz T (2001) Thinking about environmental conflict. In: Kadous L (ed) Celebrating Scholarship. Fairfax, George Mason University, Virginia, p 31-54

Dietz T, Stern PC, Guagnano GA (1998) Social structural and social psychological bases for environmental concern. Environment and Behaviour 30(4):450-471

Dillman D (1978) Mail and telephone surveys. John Wiley and Sons, New York

Etkin D, Ho E (2007) Climate change: Perceptions and discourses of risk. Journal of Risk Research 10(5):623-641

Fishwick L, Vining, J (1992) Toward a phenomenology of recreation place. Journal of Environmental Psychology 12:57–63

Hill B, Duffield R (2002) Swamp Management Guidelines for the Fleurieu Peninsula. Conservation Council of South Australia, Adelaide

Jorgensen BS, Stedman RC (2001) Sense of place as an attitude: Lakeshore owners attitudes toward their properties. Journal of Environmental Psychology 21(3):233-248

Kaltenborn, BP (1998) Effects of sense of place on responses to environmental impact: A case study among residents in an Arctic community. Applied Geography 18(2):169–189

Kempton W (1991) Lay perspectives on global climate change. Global Environmental Change 1(3): 183-208.

Kraus N, Malmfors T, Slovic P (2000). Intuitive toxicology: Expert and lay judgements of chemical risks. In: Slovic P (ed) The Perception of Risk. Earthscan Publications, Virginia, p 285-315

Kyle G, Graefe A, Manning R, Bacon J (2004) Effects of place attachment on users' perceptions of social and environmental conditions in a natural setting. Journal of Environmental Psychology 24:213-225

Leiserowitz A (2006) Climate change risk perception and policy preferences: The role of affect, imagery and values. Climatic Change 77:45-72

Leroux SJ, Schmiegelow FKA, Nagy JA (2007) Potential spatial overlap of heritage sites and protected areas in a Boreal Region of Northern Canada. Conservation Biology 21(2):376-386

McDaniels T, Axelrod LJ, Slovic P (1995) Characterizing perception of ecological risk. Risk Analysis 15(5):575-588

McFarlane BL (2005) Public perceptions of risk to forest biodiversity. Risk Analysis 25(3):543-553

McInnes KL, Suppiah R, Whetton H, Hennessy KJ, Jones RN (2003) Climate change in South Australia. CSIRO Atmospheric Research, Melbourne

O'Connor RE, Bord RJ, Yarnal B, Wiefek N (2002) Who wants to reduce greenhouse gas emissions? Social Science Quarterly 83:1–17

Pfueller S, Zhu X, Whitelaw P, Winter C (2008) Community Values for Murray River Forest Reserves in Victoria. Sustainable Tourism CRC, Queensland

Raymond C, Brown G (2006) A method for assessing protected area allocations using a typology of landscape values. Journal of Environmental Planning and Management 49(6):797-812

Raymond C (2008) Mapping landscape values and perceived climate change risks for natural resources management: A study of the Southern Fleurieu Peninsula region, DWLBC Report 2008/07, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide

Relph E (1976) Place and placelessness. Pion Limited, London

Rolston H, Coufal J (1991) A forest ethic and multivalue forest management. Journal of Forestry 80(4):35-40

Savage I (1993) Demographic influences on risk perceptions. Risk Analysis 13(4):413-420

Sieber R (2006) Public participation and geographic information systems: A literature review and framework. Annals of the American Association of Geographers 96(3):491-507

Slimak MW, Dietz T (2006) Personal values, beliefs and ecological risk perception. Risk Analysis 26(6):1689-1705

Slovic P (2000) Do adolescent smokers know the risks? In: Slovic P (ed). The Perception of Risk. Earthscan Publications, Virginia, p 364-371

Smit B, Pilifosova O, Burton I, Challenger B, Huq S, Klein RJT, Yuoge G (2001) Adaptation to climate change in the context of sustainable development and equity. In: McCarthy JJ, Canziani OF, Leary NA, Dokken DJ. White KS (eds) Climate change 2001: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 877-912

Stedman R (2003a) Is it really just a social construction? The contribution of the physical environment to sense of place. Society and Natural Resources 16:671–685

Stedman R (2003b) Sense of place and forest science: Toward a program of quantitative research. Forest Science 49(6):822–829.

Stedman RC (2004) Risk and climate change: Perceptions of key policy actors in Canada. Risk Analysis 24(5):1395-1406

Suppiah R, Preston B, Whetton PH, McInnes KL, Jones RN, Macadam I, Bathols J, Kirono D (2006) Climate change under enhanced greenhouse conditions in SA. Climate Impacts and Risk Group, CSIRO Marine and Atmospheric Research, Melbourne

Urban and Regional Planning Solutions (2007) Fleurieu Peninsula region integrated strategic tourism plan 2007-2012. Urban and Regional Planning Solutions, Adelaide van Jaarsveld AS**,** Freitag S, Chown SL, Muller C, Koch S, Hull H, Bellamy C, Krüger M, Endrödy-Younga S, Mansell MW, Scholtz CH (1998) Biodiversity assessment and conservation strategies. Science 279:2106-2108

Vorkinn M, Riese H (2001) Environmental concern in a local context: The significance of place attachment. Environment and Behavior 33(2):249-263

Worton BJ (1987) A review of models of home range for animal movement. Ecological Modelling 38:277-298

Yohe GW, Lasco RD, Ahmad QK, Arnell NW, Cohen SJ, Hope C, Janetos AC, Perez RT (2007) Perspectives on climate change and sustainability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ Hanson, CE (eds) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, p 811-841

Zelezny L, Poh-Pheng Chua C, Aldrich C (2000) Elaborating on gender differences in environmentalism. Journal of Social Issues 56:443-457.

Zube EH (1987) Perceived land use patterns and landscape values. Landscape Ecology 1(1):37-45.

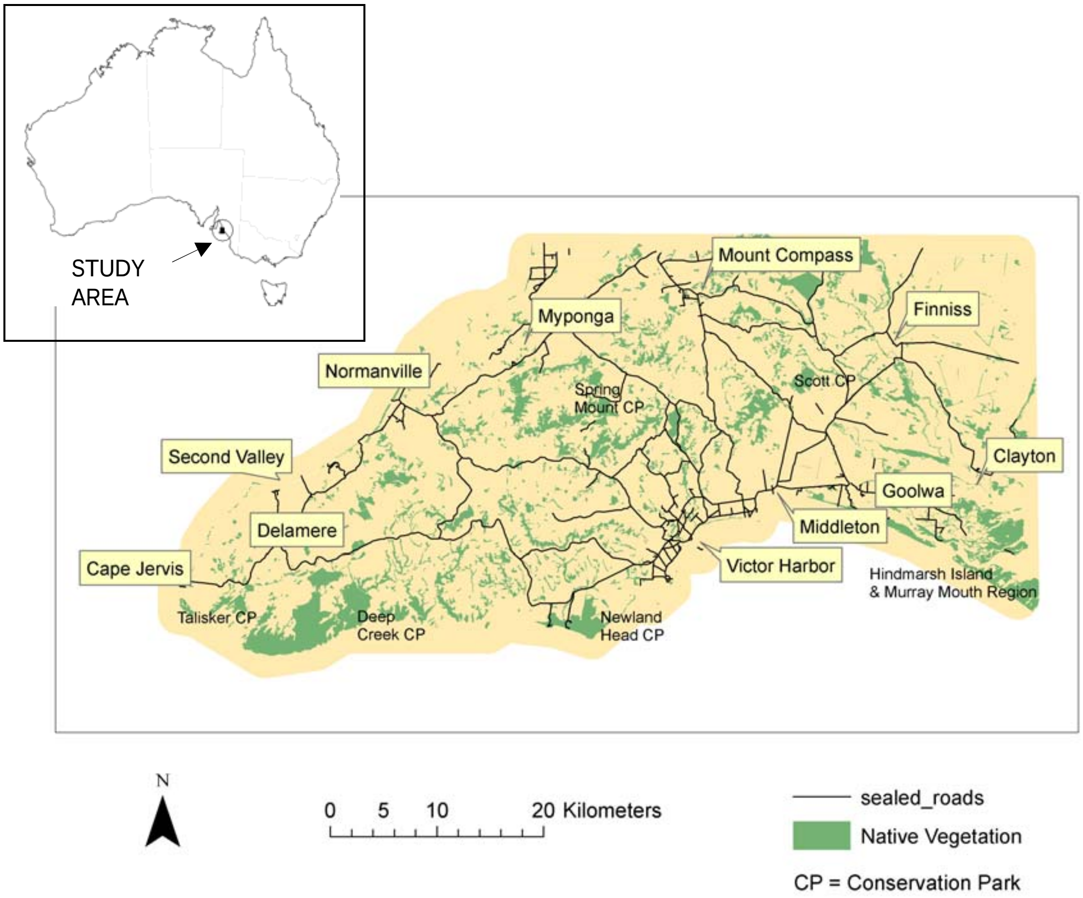
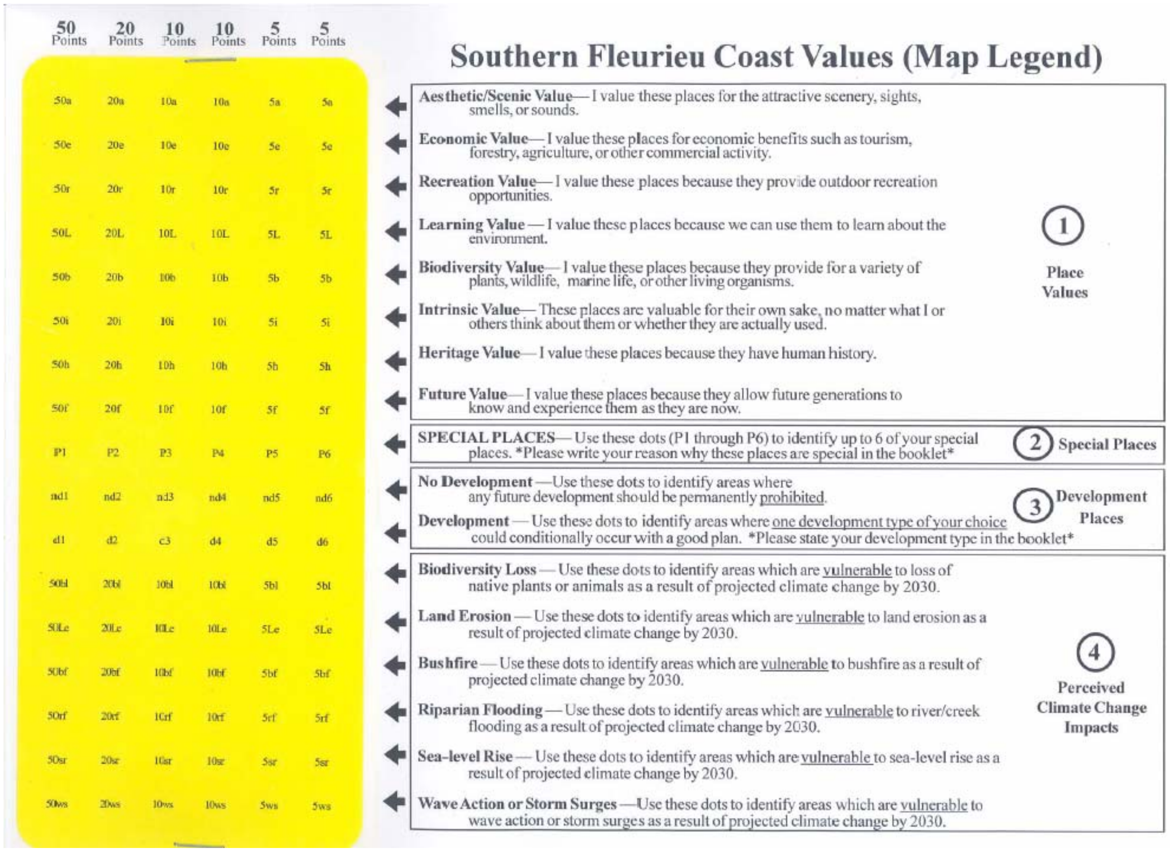


Figure 1. The Southern Fleurieu Peninsula Region (Southern Fleurieu) as defined in this study.



50 Points	20 Points	10 Points	10 Points	5 Points	5 Points
50a	20a	10a	10a	5a	5a
50e	20e	10e	10e	5e	5e
50r	20r	10r	10r	5r	5r
50L	20L	10L	10L	5L	5L
50b	20b	10b	10b	5b	5b
50i	20i	10i	10i	5i	5i
50h	20h	10h	10h	5h	5h
50f	20f	10f	10f	5f	5f
P1	P2	P3	P4	P5	P6
nd1	nd2	nd3	nd4	nd5	nd6
d1	d2	c3	d4	d5	d6
50bl	20bl	10bl	10bl	5bl	5bl
50Le	20Le	10Le	10Le	5Le	5Le
50bf	20bf	10bf	10bf	5bf	5bf
50rf	20rf	10rf	10rf	5rf	5rf
50sr	20sr	10sr	10sr	5sr	5sr
50ws	20ws	10ws	10ws	5ws	5ws

Southern Fleurieu Coast Values (Map Legend)

① Place Values

Aesthetic/Scenic Value—I value these places for the attractive scenery, sights, smells, or sounds.

Economic Value—I value these places for economic benefits such as tourism, forestry, agriculture, or other commercial activity.

Recreation Value—I value these places because they provide outdoor recreation opportunities.

Learning Value—I value these places because we can use them to learn about the environment.

Biodiversity Value—I value these places because they provide for a variety of plants, wildlife, marine life, or other living organisms.

Intrinsic Value—These places are valuable for their own sake, no matter what I or others think about them or whether they are actually used.

Heritage Value—I value these places because they have human history.

Future Value—I value these places because they allow future generations to know and experience them as they are now.

② Special Places

SPECIAL PLACES—Use these dots (P1 through P6) to identify up to 6 of your special places. *Please write your reason why these places are special in the booklet*

③ Development Places

No Development—Use these dots to identify areas where any future development should be permanently prohibited.

Development—Use these dots to identify areas where one development type of your choice could conditionally occur with a good plan. *Please state your development type in the booklet*

④ Perceived Climate Change Impacts

Biodiversity Loss—Use these dots to identify areas which are vulnerable to loss of native plants or animals as a result of projected climate change by 2030.

Land Erosion—Use these dots to identify areas which are vulnerable to land erosion as a result of projected climate change by 2030.

Bushfire—Use these dots to identify areas which are vulnerable to bushfire as a result of projected climate change by 2030.

Riparian Flooding—Use these dots to identify areas which are vulnerable to river/creek flooding as a result of projected climate change by 2030.

Sea-level Rise—Use these dots to identify areas which are vulnerable to sea-level rise as a result of projected climate change by 2030.

Wave Action or Storm Surges—Use these dots to identify areas which are vulnerable to wave action or storm surges as a result of projected climate change by 2030.

Figure 2. The map legend containing eight landscape values and six perceived climate change risks.

Table 1. The socio-demographic profile of school students and adults compared to the resident and non-resident survey population.

Socio-demographic characteristics	N	Overall (%)	Students (%)	Adults (%)	Resident Overall (%)	Non-resident Overall (%)	ABS Regional Results[1] (%)
Sex							
Male	235	65.9	67.5	65.0	65.8	71.4	48.8
Female	118	34.1	32.5	35.0	34.2	28.6	51.2
Total	353	100.0	100.0	100.0	100.0	100.0	100.0
Age							
Younger than 20 yrs	127	34.6	100.0	0.0	40.8	2.0	22.9
21 to 40 yrs	21	5.7	0.0	8.8	5.6	2.0	17.1
41 to 60 yrs	114	31.1	0.0	47.5	26.3	57.1	29.2
60 years+	105	28.6	0.0	43.7	27.3	38.9	30.8
Total	367	100.0	100.0	100.0	100.0	100.0	100.0
Education Level							
Primary	97	27.8	0.0	6.7	30.9	8.2	8.1
Secondary	94	26.9	93.5	26.8	28.4	18.4	17.9
Vocational	40	11.6	0.0	17.2	12.5	6.1	55.4
Tertiary	60	17.3	0.0	27.2	14.5	34.6	13.1
Postgraduate	47	13.5	0.0	21.3	10.4	32.7	2.2
No response	10	2.9	6.5	0.8	3.3	0.0	3.3
Total	348	100.0	100.0	100.0	100.0	100.0	100.0
Interest Group							
Coastal Development	25	11.1	12.3	9.7	11.1		
Conservation	49	21.7	7.3	38.8	21.7		
Primary Production	48	21.2	8.1	36.9	21.2		
Recreation/ Tourism	31	13.7	20.3	5.8	13.7		
Education	73	32.3	52.0	8.8	32.3		
Total	226	100.0	100.0	100.0	100.0		

[1] ABS results based on the 2006 Census for the Fleurieu Statistical Subdivision (ABS 2006)

Table 2. Completely spatially random (CSR) hypothesis testing of landscape values and risks by value and risk using nearest neighbour analysis.

	N	R-value (rank)	z-value	Ho: Values are CSR
Landscape Value				
Aesthetic	1377	0.48 (2)	-36.4	Reject
Economic	1072	0.50 (5)	-31.0	Reject
Recreation	1137	0.48 (3)	-33.0	Reject
Learning	929	0.52 (7)	-27.9	Reject
Biodiversity	1006	0.49 (4)	-30.4	Reject
Intrinsic	831	0.55 (8)	-24.3	Reject
Heritage	909	0.46 (1)	-31.2	Reject
Future	876	0.51 (6)	-27.7	Reject
Climate change risk				
Biodiversity Loss	817	0.60 (5)	-21.8	Reject
Land Erosion	704	0.62 (6)	-19.1	Reject
Bushfire	938	0.54 (3)	-27.0	Reject
Riparian Flooding	618	0.54 (4)	-21.5	Reject
Sea-level Rise	793	0.43 (1)	-30.4	Reject
Wave Action	799	0.44 (2)	-30.0	Reject

Table 3. Relative proportion of landscape values and climate change risks by land-use classification.

		Land Use Classification (% by category)			
	N	Residential	Conservation	Irrigated Pasture	Plantation
Landscape Values					
Aesthetic	496	16.8	16.2	15.3	14.4
Economic	384	12.5	11.7	12.3	16.4
Recreation	398	14.0	12.1	14.3	12.4
Learning	344	11.6	10.7	12.3	10.4
Biodiversity	420	13.1	14.5	11.9	12.4
Intrinsic	349	11.9	11.0	12.3	9.7
Heritage	335	10.6	10.7	10.6	12.8
Future	364	9.5	13.1	10.9	11.4
	3090	100	100	100	100
					$X^{2} =$ 19.83, $p > 0.05$
Climate change risks					
Biodiversity Loss	315	15.6	21.0	21.4	11.9
Land Erosion	220	12.4	12.3	17.5	14.1
Bushfire	355	16.3	22.9	21.8	22.6
Riparian Flooding	207	14.6	10.7	14.1	13.6
Sea-level Rise	276	18.8	16.1	11.2	19.2
Wave Action	303	22.3	17.0	14.1	18.6
	1676	100	100	100	100
					$X^{2} =$ 36.1, $p < 0.05$

Table 4. Linear regression results for the number of mapped landscape values regressed against the number of mapped perceived climate change risks.

Landscape Values (As Predictor Variables)	Perceived Climate Change Risks (As Dependent Variables) (Standardized Beta Coefficients)					
	Biodiversity Loss	Land Erosion	Bushfire	Riparian Flooding	Sea-Level Rise	Wave Action
Aesthetic	0.25	NS	NS	0.22	NS	NS
Economic	NS	NS	NS	0.23	NS	0.28
Recreation	-0.25	NS	NS	-0.48	-0.32	-0.27
Learning	NS	NS	NS	NS	NS	NS
Biodiversity	NS	NS	NS	NS	NS	0.34
Intrinsic	0.37	NS	0.32	NS	NS	NS
History	NS	NS	0.25	0.35	NS	0.25
Future	NS	NS	NS	NS	NS	NS
R	0.79	0.75	0.63	0,75	0.60	0.70
R^2	0.62	0.56	0.39	0.57	0.36	0.46
F	33.3	24.4	13.1	22.1	10.7	18.7
P	0.000	0.000	0.000	0.000	0.000	0.000

NS = not significant (p >0.05)

Table 5a. Jaccard coefficients for 95% landscape value and climate change risk polygons.

	Biodiversity Loss	Land Erosion	Bushfire	Riparian Flooding	Sea-level Rise	Wave Action
Aesthetic	0.499	0.510 (1)	0.343	0.395	0.400 (2)	0.411 (2)
Economic	0.438	0.425	0.350	0.396	0.313	0.306
Recreation	0.480	0.453	0.315	0.408	0.411 (1)	0.417 (1)
Learning	0.523	0.463	0.372	0.418 (1)	0.381	0.384
Biodiversity	0.572 (1)	0.443	0.377 (2)	0.402	0.360	0.361
Intrinsic	0.541 (2)	0.497 (2)	0.382 (1)	0.408	0.364	0.367
Heritage	0.426	0.425	0.274	0.379	0.379	0.351
Future	0.505	0.460	0.336	0.414 (2)	0.397	0.392

Table 5b. Jaccard coefficients for 75% landscape value and climate change risk polygons[1].

	Biodiversity Loss	Land Erosion	Bushfire	Riparian Flooding	Sea-level Rise	Wave Action
Aesthetic	0.376	0.379 (1)	0.153	0.239	0.376 (2)	0.385 (2)
Economic	0.308	0.270	0.184	0.277	0.305	0.266
Recreation	0.376	0.331	0.126	0.309 (1)	0.430 (1)	0.408 (1)
Learning	0.490	0.338	0.250	0.262	0.306	0.284
Biodiversity	0.505 (1)	0.304	0.269 (1)	0.215	0.257	0.269
Intrinsic	0.485 (2)	0.362 (2)	0.242 (2)	0.278 (2)	0.298	0.290
Heritage	0.287	0.278	0.063	0.268	0.364	0.320
Future	0.455	0.329	0.210	0.247	0.323	0.317

[1] Ranks appear in parentheses

Table 6. Spatial cross correlations (r-values) between densities of landscape values and climate change risks with 1000 randomly generated points in study area. Grid values (500m) were generated from kernal density using kernel density method.

	biodiversity loss	land erosion	bushfire	riparian flooding	sea-level rise	wave action
aesthetic	0.47	0.54 (2)	NS	0.29	0.54	0.63 (2)
economic	0.40	0.39	0.09	0.55 (1)	0.47	0.43
recreation	0.50	0.64 (1)	0.10	0.48	0.67 (1)	0.71 (1)
learning	0.75 (2)	0.460	0.30 (2)	0.40	0.41	0.38
biodiversity	0.81 (1)	0.33	0.45 (1)	0.20	0.29	0.30
intrinsic	0.69	0.53	0.24	0.38	0.48	0.52
heritage	0.38	0.46	NS	0.54 (2)	0.56 (2)	0.54
future	0.73	0.55	0.23	0.47	0.55	0.54

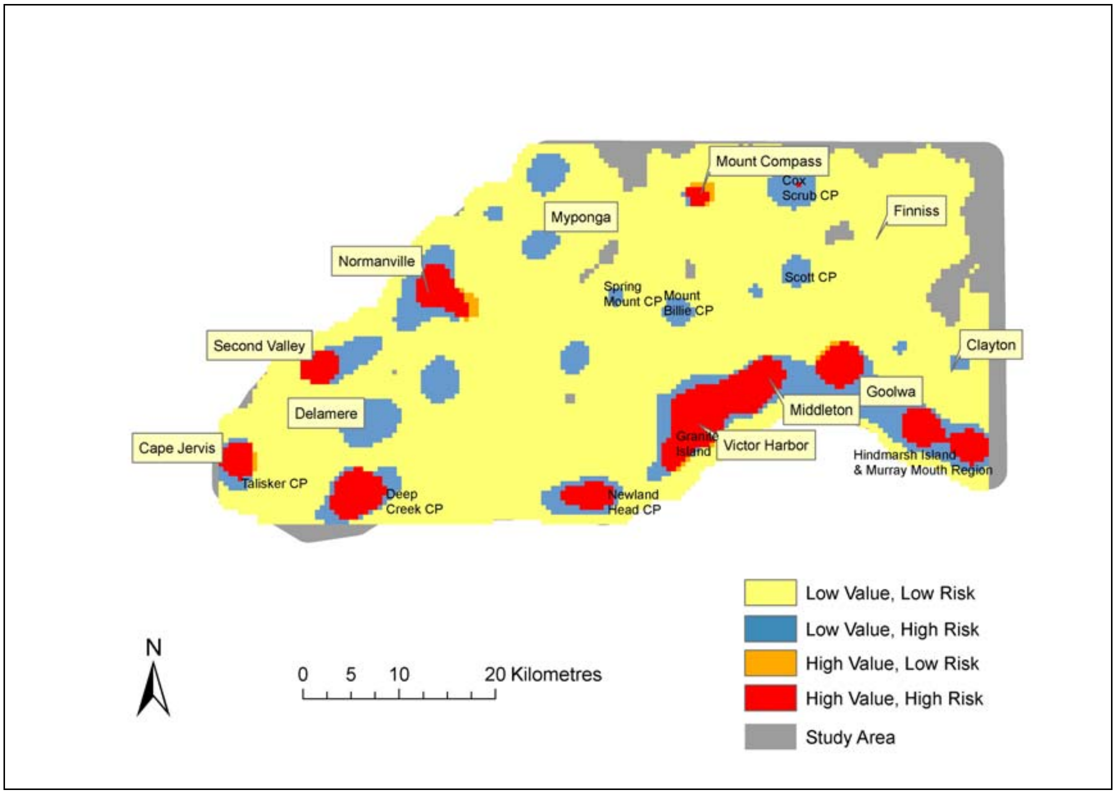


Figure 3. Density map showing the spatial associations between areas of low and high perceived landscape value and climate change risk.

Table 7. Potential agency responses to landscape value and climate change risk scenarios.

	Low Climate Change Risks	**High Climate Change Risks**
High Landscape Values	Maintenance areas: maintain agency resources sufficient to protect existing landscape values	Priority areas: direct agency resources to these areas
Low Landscape Values	Discount areas: reallocate agency resources away from these areas	Sacrifice areas: reallocate or divert agency resources away from these areas