Resilient Hills & Coasts

A Climate Change Adaptation Plan for the Adelaide Hills, Fleurieu & Kangaroo Island

Integrated Vulnerability Assessment for Kangaroo Island

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Adelaide Hills, Fleurieu & Kangaroo Island

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Department of Environment, Water and Natural Resources

37 Dauncey Street, Kingscote, SA, 5223.
Phone (08) 8553 4444.

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Authors: Siebentritt, M.A. and Garden, J. – Seed Consulting Services

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Table of Contents

Table of Figures

Table of Tables

Executive summary

An Integrated Vulnerability Assessment (IVA) was conducted for Kangaroo Island using indicators related to environmental, financial, human, physical and social capitals of the region. The IVA method followed the approach outlined in the Local Government Association of South Australia's climate change planning guidelines and was undertaken with input from stakeholders during interviews and then at workshops held in Kingscote, supplemented with additional information from the project team and relevant literature.

Analysis of the indicators suggest that various aspects of the region's capitals are likely to be vulnerable to future climate change because of the high potential impact of factors like increasing bushfire frequency, heatwaves, increasing temperatures, and declining rainfall combined with current low adaptive capacity to respond. The areas of highest vulnerability include (in no order of priority):

- Impact of pest plants and animals on the terrestrial environment;
- Abundance and diversity of frogs;
- Area of native forest vegetation cover;
- Quality of surface water;
- Area of native vegetation outside of DEWNR reserves;
- Seabirds;
- Property values;
- Level of production in wild-catch fisheries;
- Condition and performance of energy and telecommunications network infrastructure;
- Condition of roads;
- Geographically isolated people;
- Participation in industry associations and organised community groups/activities; and
- Impact on people aged over 65 years.

Overwhelmingly, climate changes associated with increasing extreme events (specifically bushfires and heatwaves) were considered to have the most significant impacts on all of the region's capitals; with increasing ocean temperatures and acidity being most significant for marine-related indicators.

For environmental capital, adaptation planning will need to focus on managing bushfires and maintaining the quality of available water in order to ensure suitable habitats and resources are protected and managed.

Analysis of human and social capital indicators suggest a need for adaptation planning to focus on how to maintain the health of vulnerable people in the community, as well as maintenance of community connectedness and emergency services, the demand for which is expected to rise.

A rise in the demand for emergency services will require consideration of the availability of volunteers, who are already stretched for time and come from an aging population.

Improving adaptation of physical capital to climate change will generally relate to maintaining service networks, primarily energy and telecommunications supply and the road network, much of which is currently unsealed.

The most vulnerable financial capital indicator was local government services (specifically, property values), followed by levels of primary production for various industries. Adaptation planning for government services will depend primarily on protecting properties and assets at-risk from extreme events, such as bushfire and sea level rise. Management of bushfires will also need to be a key consideration for adaptation planning relating to the Island's land-based primary production industries. Comparatively, measures for facilitating the adaptation of the Island's marine-based primary production industries (i.e. wild-catch fisheries) to climate change may require a more lateral approach, given the limited ability to be able to directly address increasing oceanic temperatures and acidity.

While there appears to be a high level of vulnerability across all capitals and numerous indicators, it should be noted that impacts are generally attributable to similar climate change impacts. Accordingly, many of the assets in the region will require a similar adaptation response. For example, a number of indicators across all capitals may be addressed by ensuring adequate adaptation planning for increasing bushfire risk.

1. Introduction

1.1 Adaptation planning in South Australia

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading international body for the assessment of climate change. Its Fifth Assessment Report was released in October 2013 and included the following conclusions (Intergovernmental Panel on Climate Change, 2013):

- warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased;
- continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system; and
- limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

While work continues in an attempt to reach substantial binding targets to reduce greenhouse gas emissions internationally (i.e. mitigation), governments and communities around the world now recognise the need to respond, or adapt, to some level of climate change in their region. This will be a change to climatic conditions experienced on the land such as through changing temperature and rainfall, or in the ocean through changing acidity, sea surface temperatures and rising sea levels.

The Climate Change Adaption Framework for South Australia provides a consistent approach to adaption planning. Regional steering committees are tasked with coordinating the development of an adaptation plan for the region. In accordance with the guidelines for developing a climate change adaptation plan published by the Local Government Association (LGA), an Integrated Vulnerability Assessment (IVA) is conducted to identify those parts of the environment, society or economy that are most vulnerable. Following completion of the IVA the information reported can be used to create an adaptation plan which prioritises adaptation options to address the vulnerabilities identified.

1.2 Adaptation planning for Kangaroo Island

In response to the South Australian Government's Climate Change Adaptation Framework, representatives of natural resource management, local government, regional development, emergency services management, and health care are developing a Climate Change Adaptation Plan for the Adelaide Hills, Fleurieu Peninsula and Kangaroo Island (AHFKI) region. Developing an Adaptation Plan will guide how the region can limit the impacts of climate change

and move to take advantage of any opportunities that may arise. It will also work to increase the region's adaptive capacity.

This report presents the results of an Integrated Vulnerability Assessment (IVA) conducted for the Kangaroo Island part of the region. Although the Adaptation Plan will cover the AHFKI region as a whole, given distinct differences attributable to the inherent geographically isolated nature of Kangaroo Island, it was decided that the IVA would be conducted specifically for the Island and these results later merged with an independent mainland IVA to produce an overall IVA for the region.

The Kangaroo Island IVA has been developed through a workshop based process using indicators selected to represent values and key decisions understood to be important to the region (Resilient Hills and Coast, 2014). This report identifies priority areas of vulnerability for Kangaroo Island that need to be considered in developing the region wide Adaptation Plan.

2. Approach to conducting an IVA

An IVA is a tool that helps to assess the vulnerability of assets, services and values to climate change. It is an evolution of risk-based approaches to climate change adaptation and considers both the potential impact (exposure and sensitivity) of climate change on sectors and systems in an area, as well as the adaptive capacity of those elements (Figure 1). By identifying the most vulnerable sectors and systems, and understanding the connections between the components used to calculate vulnerability scores, appropriate adaptive responses can be planned, prioritised and programmed into investment strategies (Department of Environment, Water and Natural Resources, 2012).

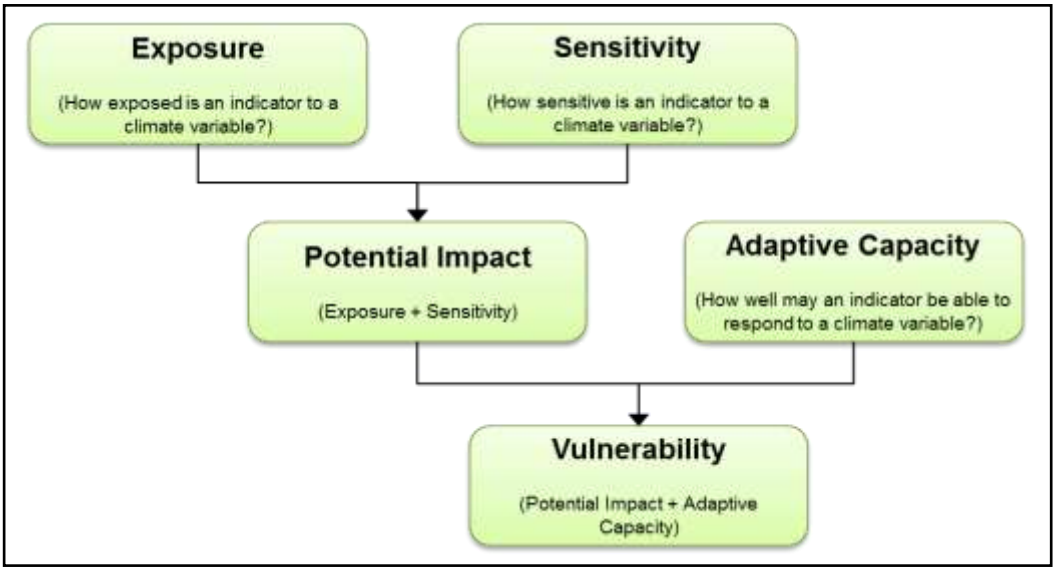

Figure 1. Conceptual diagram of integrated vulnerability approach, indicating the relationships between components used to calculate vulnerability scores. Each indicator of vulnerable sectors/systems in a region is scored for each component to provide the final vulnerability score per indicator (Allen Consulting Group, 2005).

2.1 Indicators

An essential step in undertaking an IVA is identifying appropriate indicators for which exposure, sensitivity and adaptive capacity to climate change can be considered. An indicator is a factor that describes the sectors, industries and communities of a study region (Local Government Association of South Australia, 2012) and provides information about the condition of a given capital or domain. The following two general classifications are used to group indicators:

- *Triple bottom line*: economic, social and environmental; and
- *Five capitals*: human, social, physical, financial, and environmental capital.

Each indicator is made up of a primary indicator, which refers to a variable within the given capital or domain and a secondary indicator, which refers to a sub-component that provides a measure of the condition of the primary indicator and subsequently the domain. For example, “education” may be a primary indicator for human capital; a secondary indicator of “education” may be “access to education facilities”. It is the vulnerability of this secondary indicator which is assessed as part of an IVA.

2.2 Climate variables

Climate variables describe key elements of the future climate, such as:

- average maximum and minimum temperatures;
- temperature at different times of the year e.g. summer versus winter;
- frequency of heatwaves;
- quantity and timing of rainfall;
- frequency of severe (or worse) fire danger days; and
- risk of coastal inundation.

For each indicator selected to represent sectors and capitals in a region the climate variables that are most likely to have an impact are selected for assessment. For example, a climate variable related to sea level rise will be relevant to an indicator about beach erosion, but not an indicator about the quality of Eucalypt forest woodland located away from the coast. Scoring of exposure, sensitivity and adaptive capacity is then is then done for each combination of secondary indicator and climate variable.

The specific climate data used for an IVA is determined by the selected climate projection, which indicates the expected trend in climate variables under various emissions scenarios. The main characteristics of a projection are the emissions scenario chosen (e.g. low, medium or high), the climate model output (e.g. median) and the year of the projection (e.g. 2030, 2070, 2100). Shorter projection timeframes, such as 2030, may be easier to relate to by stakeholders, but the impacts of climate change can be harder to identify in an IVA. On the other hand, longer term projections such as 2100 may present strong changes in climate variables but be at a time scale that is not meaningful to stakeholders.

2.3 Scoring

Two main scoring steps are undertaken for each pair of secondary indicator and relevant climate variable in order to determine vulnerability of each indicator to climate change. The first step is to determine the potential impact of the climate variable on the indicator. This is calculated according to the following formula (Local Government Association of South Australia, 2012):

$$\text{Potential impact} = \text{Exposure} + \text{Sensitivity}$$

Where:

- Exposure (score out of 5, Table 1) relates to the influences or stimuli that impact on a system. It captures the important weather events and patterns that affect the system, but can also represent broader influences such as changes in related systems brought about by climate change (Allen Consulting Group, 2005); and

- Sensitivity (score out of 5, Table 1) reflects the responsiveness of a system to climatic influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes (Allen Consulting Group, 2005).

The second step is to assess the adaptive capacity of the indicator to the climate variable and then calculate vulnerability according to the following formula (Local Government Association of South Australia, 2012):

$$\text{Vulnerability} = \text{Potential impact} - \text{Adaptive capacity} + 10$$

Where:

- Adaptive capacity (score out of 10, Table 2) is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. The more adaptive a system, the less vulnerable it is; and

- Vulnerability (score out of 19) to climate change is the degree to which systems are susceptible to, and unable to cope with, adverse impacts.

Table 1. Scale for the allocation of climate exposure and sensitivity scores for the vulnerability (Local Government Association of South Australia, 2012).

	SCALE				
	1	**2**	**3**	**4**	**5**
Description for qualitative data	Very Low	Low	Medium	High	Very High
	Rare	Unlikely	Possible	Likely	Very Likely
General description for quantitative data (%)	0 – 20%	21 – 40%	41 – 60%	61 – 80%	81 – 100%
Absolute change in temperature (°C)	0.01 – 0.4	0.41 – 0.8	0.81 – 1.2	1.21 – 1.6	1.61 – 2.0
Change in rainfall from baseline (%)	1 – 5%	5 – 10%	10 – 15%	15 – 20%	20 – 25%
Increase in sea level (m)	0.0 – 0.1	0.11 – 0.2	0.21 – 0.3	0.31 – 0.4	0.41 – 0.5

Table 2. Scale for the allocation of adaptive capacity scores for the vulnerability assessment (Local Government Association of South Australia, 2012).

	SCALE				
	1 - 2	**3 - 4**	**4-5**	**7 - 8**	**9 - 10**
Description for qualitative data	Very Low	Low	Medium	High	Very High
	Rare	Unlikely	Possible	Likely	Very Likely
Species adaptive capacity	Endangered	Very Rare	Rare	Threatened	Common
% for quantitative data	81 – 100%	61 – 80%	41 – 60%	21 – 40%	0 – 20%
Vegetation communities	Primarily found in relictual landscapes (<10% remaining)	Primarily found in fragmented landscapes (10 – 30% remaining)	Primarily found in fragmented landscapes (30 – 60% remaining)	Primarily found in variegated landscapes (60 – 90% remaining)	Primarily found in intact landscapes (>90% remaining)

2.4 Approach to the Kangaroo Island IVA

An IVA was undertaken for whole of Kangaroo Island, including the near shore marine environment. The approach used was consistent with the method described in the Local Government Association of South Australia's Guidelines (Local Government Association of South Australia, 2012). The assessment commenced by conducting a knowledge audit of the region's environment, economy, and community values (Resilient Hills and Coast, 2014), including a review of the "Envisioning to Empower Your Action" report produced by The Partnership (Resilient Hills and Coast, 2014) which was based on the outputs from an "envisioning" workshop aimed at identifying the Island's values across different sectors.

Following the knowledge audit and review of the values held by people on the Island, climate variables relevant to the Island were selected (Section 2.4.1), as were primary and secondary indicators (Section 2.4.2). The next step was to hold a one-day workshop on Kangaroo Island (in August 2014) to bring together key stakeholders, managers and experts to discuss and refine the indicator scoring, including the need for any changes in indicators and climate variables selected. Finally, the outputs from the workshop were analysed (Section 2.4.3) to determine the vulnerability scoring for each indicator (Section 3). The following sections provide a summary of the climate variables and indicators used in the scoring workshop, the outputs from the scoring workshop, and a summary of the scoring analyses used to produce the IVA.

2.4.1 Climate variables

Climate variables used for this analysis are based on a 2070 timeframe and the IPCC's B1 SRES future scenario which predicts a moderate emissions growth. Thirteen climate variables were selected as being relevant to Kangaroo Island, including measures of: atmospheric temperature and rainfall regimes, oceanic temperatures, chemistry and sea level rise, CO2 and evaporation levels, bushfire and heatwave frequencies, and frost occurrences (Table 3). Where information has not been available for Kangaroo Island, the trend for a climate variable has been inferred from other studies in a nearby region. Future work for Kangaroo Island may therefore include obtaining a broader array of projections, such as for heatwave frequency and bushfire risk.

Table 3. Projection descriptions (2070) for climate variables selected as relevant to Kangaroo Island.

CLIMATE VARIABLE	DESCRIPTION
Temperature increases: Winter-spring	An increase of 1.8°C (1.3-3.5°C) is projected in winter-spring across the region (no seasonal differences are projected, with average temperatures increasing by the same amount in all seasons) (Department of Environment and Natural Resources, 2010).
Temperature increases: Summer-autumn	An increase of 1.8°C (1.3-3.5°C) is projected in summer-autumn across the region (no seasonal differences are projected, with average temperatures increasing by the same amount in all seasons) (Department of Environment and Natural Resources, 2010).
Rainfall Reduction: Winter-spring	Winter-spring rainfall predicted to decrease by 15% (0-30%) for Kangaroo Island below 1990 levels by 2070 (Department of Environment and Natural Resources, 2010).
Rainfall Reduction: Summer-autumn	Summer-autumn rainfall predicted to decrease by 8% (+15% to -30% for autumn) for Kangaroo Island below 1990 levels by 2070 (Department of Environment and Natural Resources, 2010).
Sea level rise	Sea level has been rising at about 4.5 mm/year in South Australia since the 1990s. The recent IPCC 5th Assessment Report (Intergovernmental Panel on Climate Change, 2013) suggests global mean sea level rise for 2046–2065 relative to 1986–2005 could be 0.26 m for more moderate emissions outlooks and up to 0.48 m by 2081–2100.
Increased ocean temperatures	Annual sea surface temperatures may increase by 1.5-2.0°C around southern Australia (CSIRO and Bureau of Meteorology, 2007).
Increased ocean acidity	Projections for decreasing pH range from 0.06 to 0.32 by 2100, with a best estimate more likely to be in the order of a 0.2 pH unit decrease (Intergovernmental Panel on Climate Change, 2013).
Increased heatwave frequency and intensity	In Adelaide the frequency of 2 or more days greater than 40°C will increase from 0.09 per year to 0.7 to 1.3 per year. 3 days with temperatures greater than an average of 32°C will increase from 0.02 per year to 0.2 to 0.65 per year (Resilient South, 2014).
CO_2 Increases	Atmospheric CO_2 is currently at 397ppm and rising. Under medium emissions outlooks CO_2 concentrations in the atmosphere will increase to 700 ppm by 2070 (Hardy, 2003).
Increased bushfire frequency and intensity	Increased likelihood of more frequent, higher intensity bushfires, and longer bushfire seasons due to increased heatwaves, temperatures and wind speeds, combined with decreased rainfall. For example, the incidence of severe (or worse) fire danger rating days (FFDI ≥ 50), based on Adelaide Airport's weather, is projected to increase from 2 per year in 1980-1999 to 10 per year in 2070 (Resilient South, 2014).
Increased evaporation	Potential evapotranspiration is projected to increase in autumn, spring and summer by 6.5% and in winter by 10.5% (Department of Environment and Natural Resources, 2010).
Increased intensity rainfall	Climate models suggest that for each degree of global warming, extreme daily rainfall may increase by 7% (Westra, Alexander, & Zwiers, 2012).

2.4.2 Indicator selection

Based on the knowledge audit and the "Envisioning to Empower you Action" report (Resilient Hills and Coast, 2014), together with existing local knowledge, an iterative selection process was undertaken by Seed Consulting, together with the Kangaroo Island NRM Board, to identify the primary and secondary indicators and climate variables most relevant to Kangaroo Island's environment, community and economy. Indicators were selected initially from a list of indicators common to IVAs conducted in other regions of the State. From this list, some indicators were further modified to suit conditions specific to Kangaroo Island; additional indicators not included in the standard list, but specific to Kangaroo Island, were also added. A total of 22 primary indicators and 54 secondary indicators were selected (Table 4).

Table 4. Primary and secondary indicators assessed for the Kangaroo Island IVA showing how the indicators relate to each other and to the five capitals.

PRIMARY INDICATOR	SECONDARY INDICATOR
Environmental Capital	
Biodiversity	• Abundance and diversity of freshwater fish • Abundance and diversity of frogs • Abundance and diversity of marine mammals • Abundance and diversity of other mammals • Abundance and diversity of reptiles • Aquatic invertebrates • Area of native vegetation cover by vegetation type (Forest) • Area of native vegetation cover by vegetation type (Mallee) • Area of native vegetation cover by vegetation type (Shrubland) • Area of native vegetation cover by vegetation type (Woodland) • Area of native vegetation cover outside of DEWNR reserves • Birds of prey • Condition of major river systems (e.g. Cygnet River) • Number of native fauna species that are threatened (regional, state) • Number of native flora species/communities that are threatened (regional, state) • Seabirds • Waders • Condition of wetland plant communities
Land condition	• Condition of soil
Landscape fragmentation	• Availability of ecological linkages
Pest plants and animals	• Impact of pest plant and animal threats to the riverine/floodplain environment • Impact of pest plant and animal threats to the terrestrial environment
Water	• Quality of surface water • Quantity of surface water
Financial Capital	
Biosecurity	• Impact of pest plants and animals (on primary production & terrestrial ecosystems)
Intensive livestock production	• Level of production - intensive agriculture

PRIMARY INDICATOR	SECONDARY INDICATOR
(e.g. chickens, pigs)	
Local government services	• Property values
Primary production	• Level of production (aquaculture - freshwater) • Level of production (aquaculture - marine) • Level of production (bee keeping/honey production) • Level of production (cropping) • Level of production (horticulture e.g. wine production, seed potatoes) • Level of production (livestock and wool) • Level of production (wild catch fisheries)
Tourism	• GRP from tourism (e.g. accommodation and food service)
Waste management	• Cost of waste management
Human Capital	
Education	• Access to education facilities (including schools and TAFE)
Health	• Access to medical care and support services • Impact on children < 12 years of age • Impact on people aged over 65 years • Impact on people who require assistance for core activities
Physical Capital	
Buildings	• Condition of public buildings (e.g. schools, hospitals, sporting and recreational facilities)
Essential services	• Condition and performance of energy and telecommunications network infrastructure • Delivery of potable water (condition of pipes and water quality)
Recreation	• Condition of open spaces (e.g. parks and gardens)
Transport services	• Condition of roads
Social Capital	
Community connectedness	• Participation in industry associations • Participation in organised sport, church or community group in local area • Sense of belonging to community • Support from family, friends and neighbours
Community planning and development	• Low income households
Emergency management	• Emergency services (demand and access)
Social inclusion/exclusion	• Impact on people geographically isolated from transport services

2.4.3 Approach to scoring

The general approach to scoring follows the method outlined in the Local Government Association of South Australia Guidelines (Local Government Association of South Australia, 2012). It should be noted that the scores represent an understanding of the impacts of climate change on the selected indicators for Kangaroo Island at the point in time at which the analysis

was conducted. The results may differ in the future if more information becomes available to further inform the analysis.

Scores for exposure, sensitivity and adaptive capacity were initially assigned by the project team and then reviewed and refined with input from participants at the stakeholder workshop. Because of the limited number of studies that specifically consider climate change impacts on Kangaroo Island, the majority of this assessment draws on expert input.

This IVA viewed adaptive capacity as an inherent property of a system or existing management actions already in place to which an indicator relates rather than the potential to adopt adaptive measures that may not currently be in place. The latter are viewed as being relevant to identifying appropriate adaptation actions and if scored here, could give a misleading measure of the inherent adaptive capacity of a system.

3. Results of the IVA

The results of the Kangaroo Island IVA have been summarised for primary indicators and secondary indicators in Tables 5 and 6. The workshop scores (including exposure, sensitivity, and adaptive capacity) for primary and secondary indicators are summarised in Appendices A and B, respectively.

When interpreting vulnerability scores they should be used more so as a measure of relative vulnerability amongst indicators rather than a score that can be used to assess relative vulnerability of issues in different regions where separate IVA (or similar processes) have been applied.

3.1 Primary indicators

Six indicators representing all capitals, except the human capital, were found to fall into the top 25th percentile of vulnerability scores (Table 5):

- Environmental capital
  - pest plants and animals;
- Financial capital
  - local government services;
  - intensive livestock production (e.g. chickens, pigs);
- Physical capital
  - transport services;
- Social capital
  - social inclusion/exclusion; and
  - emergency management.

When considering the average of indicator scores for each capital, the social capital was the most vulnerable overall (average = 13.93), followed by physical (13.28), environmental (12.83), financial (12.65), and human (12.33). Most indicators (76%) were classed as highly or very highly vulnerable, with the remaining 24% classed as having medium vulnerability..

Amongst the primary indicators most vulnerable to climate change (i.e. the top 10% most vulnerable) were local government services (financial capital), transport services (physical capital), and social inclusion/exclusion (social capital). These indicators may be seen to relate to the condition of physical assets and community connectedness and involvement on the Island. The relative ranking of these indicators was due to a high potential impact of climate change, combined with medium to very high sensitivity and very low to low adaptive capacity.

The other primary indicators comprising the top 25% most vulnerable on the Island were: emergency management (social capital), pest plants and animals (environmental capital), and intensive livestock production (financial capital), which may be seen to relate to measures of livelihood risk on the Island. These indicators generally had a high potential impact of climate

Table 5. Primary indicators relevant to Kangaroo Island and their vulnerability scores, listed under their respective capital. For each indicator, their vulnerability scores (ordered highest to lowest per capital) are shown with grey shading indicating the top 25% most vulnerable indicators and the top 10% shown in bold. Vulnerability scores have also been classed in accordance with the categories: very low (<4), low (=4 > 8), medium (=8 > 12), high (=12 > 16), or very high (≥16).

PRIMARY INDICATOR	VULNERABILITY	
	Score	Class
Environmental Capital		
Pest plants and animals	**14.00**	**High**
Landscape fragmentation	13.60	High
Biodiversity	13.28	High
Water	13.25	High
Land condition	10.00	Medium
Financial Capital		
Local government services	**17.50**	**Very high**
Intensive livestock production (e.g. chickens, pigs)	13.75	High
Primary production	12.71	High
Tourism	11.00	Medium
Waste management	10.60	Medium
Biosecurity	10.33	Medium
Human Capital		
Health	13.07	High
Education	11.60	Medium
Physical Capital		
Transport services	**15.00**	**High**
Essential services	13.63	High
Recreation	12.50	High
Buildings	12.00	High
Social Capital		
Social inclusion/exclusion	14.33	High
Emergency management	14.25	High
Community connectedness	13.63	High
Community planning and development	13.50	High

change, combined with medium to very high sensitivity to climate variables, yet they had slightly better adaptive capacity, scoring mostly low to medium adaptive capacity.

The average vulnerability scores for indicators offer a relative ranking and highlight those indicators that are substantially impacted by a number of climate variables. However, the

relative influence of a single climate variable may potentially be masked using this approach. Accordingly, we also investigated whether any indicators were significantly vulnerable to individual climate variables, yet did not rank in the top 25% most vulnerable using the averaging approach. Four such primary indicators were identified: biodiversity, tourism, health, and community planning and development, with these indicators being found to be very highly vulnerable to one or more of three variables (bushfires, heatwaves, and/or summer-autumn temperatures). These will be further discussed in relation to the specific relevant secondary indicators in Section 3.2.

3.2 Secondary indicators

Based on average vulnerability scores, 14 indicators (of a total of 54), representing all capitals, were found to fall into the top 25th percentile of indicators (Table 6):

- Environmental capital
  - Area of native vegetation cover by vegetation type (forest);
  - Impact of pest plant and animal threats to the terrestrial environment;
  - Abundance and diversity of frogs;
  - Seabirds;
  - Area of native vegetation cover outside of DEWNR reserves;
  - Quality of surface water;
  -
- Financial capital
  - Property values;
  - Level of production (wild-catch fisheries);
- Human capital
  - Impact on people aged over 65 years;
- Physical capital
  - Condition and performance of energy and telecommunications network infrastructure;
  - Condition of roads;
- Social capital
  - Participation in industry associations;
  - Participation in organised sport, church or community group in local area; and

Impact on people geographically isolated from transport services.

All indicators were classed as either moderately, highly, or very highly vulnerable to climate change impacts, suggesting that all sectors in the region will be impacted by climate change. When considering average vulnerability scores based on secondary indicators within each capital, social capital is the most vulnerable in the region (average vulnerability = 13.81). The physical capital was the next most vulnerable overall (13.41), closely followed by environmental (13.34), financial (12.80) and, human (12.72). The following sections briefly discuss the vulnerability scores and classes of secondary indicators within each capital. These analyses are the foundation for identifying key areas of decision making (Section 4).

3.2.1 Environmental capital

The environmental capital contained the most number of secondary indicators (24) and the most number of indicators (6) scoring in the top 25% most vulnerable across all capitals; with three of these scoring in the top 10%(Table 6). Most of the environmental indicators were classed as being highly vulnerable to climate change impacts, though three were classed as having medium vulnerability, and two were classed as being very highly vulnerable.

Environmental indicators predominantly refer to terrestrial systems, with aquatic and marine systems having fewer indicators assessed. None-the-less, the top 25% most vulnerable environmental indicators represented all three systems, indicating the impacts of climate change on the Island's diverse environments will be wide-ranging. The highest scoring environmental indicators were the area of native forest cover, the impacts of pest plant and animal threats to the terrestrial environment, and the abundance and diversity of frogs.

The geographical isolation of Kangaroo Island helps to maintain its current low diversity of pest species, yet it is expected that the Island's environments and species will be highly vulnerable if pests are able to reach the Island. It is widely recognised on the mainland that climate change will facilitate the spread and abundance of pest species adapted to drier and warmer conditions, leading to significant impacts on affected systems and species. In addition to impacts on the environment, invasions of Kangaroo Island by pest species would also have substantial implications for other sectors, such as primary production and tourism.

The importance of surface water to the environmental indicators was represented by the high vulnerability of water quality and quantity to climate change impacts. For environmental indicators, the quality of surface water scored higher than the quantity, with bushfire and increased intensity of rainfall events and subsequent run-off to waterways being identified as critical factors likely to degrade available surface water[1]. The quantity of surface water, although not ranking in the top 25% most vulnerable indicators, was still classed as being highly vulnerable to climate change impacts given its very high sensitivity to declining rainfall and increasing evaporation coupled. Impacts on water availability and quality will also have significant flow-on effects for other elements of the environment, particularly if changes in water alter habitat and resource availability and quality. For instance, the abundance and diversity of frogs scored as the third highest most vulnerable indicator for the environment. This results from mostly high sensitivity to certain climate variables (e.g. increasing heatwaves and bushfire events), together with very low adaptive capacity; all of which will have direct impacts on individual frogs (e.g. desiccation), as well as indirect impacts on populations through decreasing suitable habitat amounts and quality.

Aspects of water availability, will also impact areas of native [land-based] vegetation cover, with forest vegetation types considered more vulnerable than others on the Island given its very low adaptive capacity to relevant climate change impacts, but particularly to decreased rainfall and altered bushfire regimes, both of which are likely to impact mature trees and seedlings alike and

[1] The impact of climate change on surface water availability is also relevant to primary production. However, this is addressed through considering the impacts of declining rainfall on level of primary production indicators.

potentially result in a conversion of forest to more open, grassy woodland communities. In addition, such climate change impacts may be more difficult to manage outside of formal State reserves (e.g. through regulated management burns) and so areas of native vegetation cover outside of DEWNR reserves are considered to have a lower adaptive capacity and higher vulnerability. Impacts on native vegetation communities and water availability will likely have flow-on effects for many threatened flora and fauna species reliant on specific habitat attributes for foraging, breeding, or sheltering.

The diversity and quality of habitat types on Kangaroo Island support a number of threatened species, and it has been suggested that the Island could potentially act as a refuge for species that may be lost from the mainland. Consequently, the total number of regionally and State threatened species on Kangaroo Island may increase. The ability to protect these species on the Island and to prevent additional species becoming threatened will rely largely on protecting suitable habitat areas, as well as managing pest species that may further threaten native species and their habitats.

The impact of climate change variables on marine systems was represented in the top 25% most vulnerable indicators by the seabirds indicator, though the abundance and diversity of marine mammals was also classed as being highly vulnerable, despite not falling in the top 25% most vulnerable (Table 6). These marine environment indicators cover a wide range of species including: seagulls, terns, pelicans, and penguins, as well as coastal raptors (e.g. ospreys), seals, dolphins, and whales. Although these species may differ in terms of their nesting and shelter habitat requirements, they were considered together here given their reliance on similar prey such as fish, jellyfish, crustaceans and plankton. Accordingly, their high vulnerability to climate change impacts was due primarily to flow-on impacts of expected very high sensitivity and low adaptive capacity of prey species to increasing oceanic temperatures and acidity. Such impacts on marine species will also have significant effects on other sectors, such as marine-based primary production industries (Section 3.2.2).

3.2.2 Financial capital

All indicators of financial capital were classed as being moderately, highly, or very highly vulnerable to climate change impacts, with two indicators (property values and level of production in wild-catch fisheries) scoring in the top 25% most vulnerable across all capitals (Table 6). The highest scoring indicator was property values, which was also the only financial indicator classed as having very high vulnerability. Property located in areas at high risk from sea level rise and bushfire, are expected to experience a decline in their market value, as reflected by their sensitivity to both of these climate variables being very high and adaptive capacity very low.

All sources of primary production on the Island were found to be highly vulnerable to climate changes, though particularly wild-catch fisheries which depend on target species that are considered highly sensitive to increasing oceanic acidity and temperature, yet are expected to have little capacity to adapt to such changes (e.g. crustacean species). Concerns regarding the impacts of climate change on marine species such as crustaceans, will not be limited to industries, but will also have conservation implications to the species itself, as well as any

dependent predatory species (e.g. sea lions and seabirds; Section 3.2.1). There is likely to be little scope to improve the adaptive capacity of species to these impacts.

On land, primary production will be highly vulnerable as a result of increasing temperatures, heatwaves and bushfires, as well as decreasing rainfall, to which they are considered to be generally highly sensitive with very low to medium adaptive capacity, depending on the industry and climate variable being considered. For example, the Island's freshwater aquaculture and cropping industries are considered to have high to very high sensitivities to rainfall reduction, yet due to differences in their respective water requirements, freshwater aquaculture is considered to have a medium adaptive capacity to rainfall reduction, whereas the adaptive capacity of cropping is considered to be very low. It should be noted that although the level of production relating to the horticulture and livestock and wool industries were both considered to have the lowest vulnerability of production industries to climate changes overall, they were the two industries with the highest vulnerability to increasing bushfire; the relative impact of bushfire though is masked in the average scoring due to the lower sensitivity and better adaptive capacity (and so lower vulnerability) to other climate variables.

Similarly, the GRP from tourism ranked as one of the least vulnerable financial capital indicators to climate change impacts. However, this average vulnerability score masks the expected impact of bushfire on tourism which, when considered independently, scores as very highly vulnerable.

3.2.3 Human capital

Indicators of human capital were mostly classed as having either medium or high vulnerability to climate change impacts, though the impact on people aged over 65 years scored in the top 10% most vulnerable of all indicators assessed. This impact on people aged over 65 years was due primarily to their perceived high exposure, high sensitivity, and low adaptive capacity to increased heatwaves and bushfires, resulting in a very high vulnerability. . The main impacts of heatwaves and bushfires is considered to be to the general health and well-being of people aged over 65 years (e.g. smoke inhalation during bushfires).

3.2.4 Physical capital

Most of the indicators of physical capital were highly vulnerable to climate change impacts, with the condition of roads scoring in the top 25% most vulnerable of all indicators assessed. However, the condition and performance of energy and telecommunications network infrastructure scored the highest and fell within the top 10% most vulnerable across capitals. The vulnerability of energy and telecommunications networks was driven equally by their high exposure and sensitivity together with their very low adaptive capacity to increasing temperatures, heatwaves and bushfires. Energy and telecommunications networks will be under increasing demand during increasing summer temperature and heatwave periods which may exceed their capacity and lead to unreliable supplies. In addition, during severe (or worse) fire danger periods, energy networks may be shut down to minimise sparking risk, thereby further influencing supply reliability. Such impacts will have flow-on effects to other sectors, such as health services and local businesses (e.g. if air-conditioning and refrigeration is unavailable during extreme temperature periods).

In comparison, the high vulnerability of road conditions is primarily due to impacts of increasing sea levels together with increasing heatwaves, followed to a lesser degree by increasing temperatures and greater rainfall intensity. Issues associated with road conditions on Kangaroo Island differ from most populated regions on the mainland as the roads on Kangaroo Island are predominantly unsealed; with approximately 1100km unsealed, compared to approximately 200km of sealed roads.

Recent examples of the impact of localised flooding on roads can be seen in the MacGillivray/Haines area, where flooding has caused damage to roads and inhibited access.. On the other hand, increased heatwaves will also impact road condition directly by destabilising binder, cracking bitumen, and causing unsealed roads to break up. Such impacts may be exacerbated by potential low availability of maintenance crews during extreme events. Climate related impacts could be further exacerbated if more road users visit the Island, thus increasing wear and tear.

3.2.5 Social capital

All secondary indicators of social capital were classed as being highly vulnerable to climate change impacts, and three scored in the top 25% most vulnerable across all capitals (Table 6). The most vulnerable indicators were related to participation in industry associations and sport/community groups, and impact on people who are geographically isolated from transport services. These indicators were predominantly very highly vulnerable to increasing bushfire and heatwave impacts, having a very high exposure yet a high to very sensitivity and low to very low adaptive capacity.

The impact on geographically isolated people (i.e. those without access to reliable transport) scores highly in relation to increasing bushfire and heatwave and, to a lesser degree, sea level rise. These changes will pose significant risk to the disruption of access routes and communication networks which may be required in extreme situations. However, the majority of residents on the Island without reliable access to transport live in, or within close proximity to, the Island's main settlement of Kingscote. As such, this indicator has not been prioritised as a key area of decision making in its own right. Instead it has been incorporated into a combined key area of decision making which considers the impacts of extreme events on vulnerable memebrs of the community.

Related to geographic isolation is the high vulnerability of demand and access to emergency services, which also was classed as having a high vulnerability to climate change impacts. As well as a high or very high sensitivity to heatwaves, bushfires and intense rainfall, the adaptive capacity of this indicator was generally considered to be quite low. During extreme events, particularly bushfires, the demand for emergency services will likely increase, yet if required in geographically remote locations on the Island, then access to and by, such services may be difficult. Furthermore, the geographic isolation of the Island itself from the mainland means that during an extreme event, if additional emergency resources are required to support existing Island services (e.g. additional firefighters and resources), there will often be a delay of potentially 24 hours or more. Such situations are already experienced (at least once per year, by some accounts) and this frequency is anticipated to increase under climate change.

Table 6. Secondary indicators relevant to Kangaroo Island and their vulnerability score, listed under their respective capital. For each indicator, their relevant primary indicator and vulnerability scores (ordered highest to lowest per capital) are shown with grey shading indicating the top 25% most vulnerable indicators and the top 10% shown in bold. Vulnerability scores have also been classed in accordance with the categories: very low (<4), low (=4 > 8), medium (=8 > 12), high (=12 > 16), or very high (≥16).

PRIMARY INDICATOR	SECONDARY INDICATOR	VULNERABILITY	
		Score	Class
Environmental Capital			
Biodiversity	Area of native vegetation cover by vegetation type (Forest)	**16.20**	**Very high**
Pest plants and animals	Impact of pest plant and animal threats to the terrestrial environment	**16.00**	**Very high**
Biodiversity	Abundance and diversity of frogs	**15.43**	**High**
Biodiversity	Seabirds	14.60	High
Biodiversity	Area of native vegetation cover outside of DEWNR reserves	14.40	High
Water	Quality of surface water	14.33	High
Biodiversity	Number of native flora species/communities that are threatened (regional, state)	14.22	High
Biodiversity	Abundance and diversity of reptiles	14.17	High
Biodiversity	Abundance and diversity of freshwater fish	13.88	High
Biodiversity	Abundance and diversity of marine mammals	13.75	High
Biodiversity	Area of native vegetation cover by vegetation type (Mallee)	13.60	High
Landscape fragmentation	Availability of ecological linkages	13.60	High
Biodiversity	Condition of major river systems (e.g. Cygnet River)	13.00	High
Biodiversity	Waders	13.00	High
Pest plants and animals	Impact of pest plant and animal threats to the riverine/floodplain environment	13.00	High
Water	Quantity of surface water	13.00	High
Biodiversity	Number of native fauna species that are threatened (regional, state)	12.67	High
Biodiversity	Area of native vegetation cover by vegetation type (Shrubland)	12.60	High
Biodiversity	Abundance and diversity of other mammals	12.33	High
Biodiversity	Condition of wetland plant communities	12.29	High
Biodiversity	Area of native vegetation cover by vegetation type (Woodland)	12.00	High
Biodiversity	Aquatic invertebrates	11.57	Medium
Biodiversity	Birds of prey	10.63	Medium
Land condition	Condition of soil	10.00	Medium

PRIMARY INDICATOR	SECONDARY INDICATOR	VULNERABILITY	
		Score	Class
Financial Capital			
Local government services	Property values	17.50	**Very high**
Primary production	Level of production (wild catch fisheries)	14.50	High
Intensive livestock production (e.g. chickens, pigs)	Level of production - intensive agriculture	13.75	High
Primary production	Level of production (aquaculture - marine)	13.50	High
Primary production	Level of production (bee keeping/honey production)	13.00	High
Primary production	Level of production (cropping)	12.67	High
Primary production	Level of production (aquaculture - freshwater)	12.50	High
Primary production	Level of production (horticulture e.g. wine production, seed potatoes)	12.29	High
Primary production	Level of production (livestock and wool)	12.00	High
Tourism	GRP from tourism (accommodation and food service)	11.00	Medium
Waste management	Cost of waste management	10.60	Medium
Biosecurity	Impact of pest plants and animals (on primary production & terrestrial ecosystems)	10.33	Medium
Human Capital			
Health	Impact on people aged over 65 years	**15.25**	**High**
Health	Impact on people who require assistance for core activities	13.00	High
Health	Access to medical care and support services	12.00	High
Health	Impact on children < 12 years of age	11.75	Medium
Education	Access to education facilities (including schools and TAFE)	11.60	Medium
Physical Capital			
Essential services	Condition and performance of energy and telecommunications network infrastructure	17.00	**Very high**
Transport services	Condition of roads	15.00	High
Recreation	Condition of open spaces (e.g. parks and gardens)	12.50	High
Water	Condition of sewage and stormwater management assets	12.33	High
Buildings	Condition of public buildings (e.g. schools, hospitals, sporting and recreational facilities)	12.00	High
Essential services	Delivery of potable water (condition of pipes and water quality)	11.60	Medium

PRIMARY INDICATOR	SECONDARY INDICATOR	VULNERABILITY	
		Score	Class
Social Capital			
Community connectedness	Participation in industry associations	14.50	High
Community connectedness	Participation in organised sport, church or community group in local area	14.50	High
Social inclusion/exclusion	Impact on people geographically isolated from transport services	14.33	High
Emergency Management	Emergency services (demand and access)	14.25	High
Community planning and development	Low income households	13.50	High
Community connectedness	Support from family, friends and neighbours	13.00	High
Community connectedness	Sense of belonging to community	12.60	High

The ability to meet increasing demands on emergency services will be affected by the availability of volunteers. It is understood that, although having the highest rate of volunteering (relative to population size) in the Adelaide Hills, Fleurieu and Kangaroo Island RDA region, the people volunteering for emergency services are largely the same as those who participate in industry and community associations or groups. The size of the volunteer pool is also expected to decline due to the Island's aging population. Addressing issues of community connectedness and geographic isolation will be a particularly difficult, yet necessary, challenge in facilitating the adaptive capacity of the Kangaroo Island community to climate change extremes.

3.3 Climate variables

The 13 climate variables used in the IVA were assessed to identify which had the greatest relative influence on indicator scoring. For each climate variable, the indicators influenced by that variable were identified and the average indicator vulnerability score calculated to provide a score across all capitals for each climate variable (Table 7). The vulnerability scores grouped against climate variables is presented in Appendix C.

Three of the climate variables were scored as being in the top 25th percentile of variables with the most influence on vulnerability:

- increased bushfire frequency and intensity;
- increased heatwave frequency and intensity; and
- increased ocean temperatures.

The remaining 10 variables were classed as either medium or high.

As well as being the most significant climate variable across capitals, increasing bushfire was the most significant influencer on indicator vulnerability within each capital, followed by increasing heatwaves in all but the environmental capital, where heatwaves ranked third below increasing ocean temperatures (Appendix C). Sea level rise ranked third most significant for the

Table 7. Climate variables ordered by average indicator vulnerability scores (highest to lowest across all capitals). Vulnerability scores here represent the average scores for all indicators considered vulnerable to the respective variable. Those shown with grey shading indicate the top 25% climate variables that had the most impact on indicators, with the top 10% shown in bold. Vulnerability scores have also been classed in accordance with the categories: very low (<4), low (=4 > 8), medium (=8 > 12), high (=12 > 16), or very high (≥16).

CLIMATE VARIABLE	VULNERABILITY (INFLUENCE)	
	Score	Class
Increased bushfire frequency and intensity	15.69	**High**
Increased heatwave frequency and intensity	14.56	**High**
Increased ocean temperatures	14.33	High
Temperature increases: Summer-autumn	13.62	High
Sea level rise	12.69	High
Rainfall Reduction: Winter-spring	12.69	High
Increased ocean acidity	12.57	High
Temperature increases: Winter-spring	11.79	Medium
Increased Evaporation	11.75	Medium
Rainfall Reduction: Summer-autumn	11.06	Medium
Increased intensity rainfall	9.79	Medium
CO2 Increases	9.00	Medium

financial, physical and human capitals. Despite the high importance of surface water on the Island, reductions in rainfall and increased evaporation did not rank in the most significant variables (Appendix C), which reflects the finding that water quality (influenced by bushfires and heatwaves) was more important for various sectors on the Island than water quantity, *per se*. This does not mean, however, that water availability is unimportant.

4. Discussion

4.1 Integrated Vulnerability Assessment Outputs

The IVA suggests that all sectors on Kangaroo Island will be affected by climate change, though particularly those which form the basis of the Island's social, physical and environmental capital. Most indicators were assessed as being highly sensitive to climate change variables yet with low adaptive capacity, such as:

- impact of pest plant and animal threats, particularly to terrestrial environments;
- abundance and diversity of native fauna species, particularly those dependent on water resources (e.g. frogs) and marine prey (e.g. seabirds, marine mammals);
- area of different native vegetation types (particularly forest);
- quality of available surface water;
- property values, particularly those in high-risk locations (e.g. low-lying coastal or bushfire prone areas); and
- primary production industries, particularly marine-based;
- health of vulnerable community members, particularly those aged over 65;
- the condition of energy, telecommunications and road infrastructure; and
- participation in industry and community activities;

Whether adaptation options exist in relation to all of these indicators will be explored during development of the adaptation plan. For example, marine fishes and crustaceans will be impacted by increasing ocean temperatures and acidity, having implications not only for the conservation of individual species, but also for dependent predatory species (e.g. seabirds and marine mammals) and primary production industries (e.g. wild-catch fisheries). However, there is little that can be done to directly limit changing oceanic conditions in the local marine environment. Local actions may therefore be restricted to measures such as managing onshore habitats and resources for seabirds, or potentially reassessing fishing quotas or target species for wild-catch fisheries.. By contrast, impacts on property values could be actively managed to better protecting current at-risk properties from rising sea levels.

While it is important to consider independent indicators or capitals, the inter-relations between indicators and capital should not be overlooked. Many of the environmental assets in the region, for instance, may be addressed through adaptation responses to bushfire management. Furthermore, social and financial values rely on a healthy and diverse natural landscape and so addressing one capital may also provide beneficial outcomes for other capitals. For example, managing the increasing risk from pest species introductions under warmer and drier conditions will have beneficial implications for native flora and fauna communities, as well as primary production industries on the Island.

Addressing climate change impacts should not just be limited to those indicators ranked in the top 10% or 25% most vulnerable. Rather, these should be used as a guide whilst also considering other indicators classed as highly vulnerable to specific climate change impacts. For example, based on the relative average vulnerability scores, horticulture and livestock/wool production were the least vulnerable to climate change impacts. However, when climate change impacts were assessed individually, these two industries were the most highly vulnerable to increasing bushfire. Furthermore, cropping scored very high vulnerability to decreased rainfall, yet this impact was masked by the lower vulnerability to some other climate variables. Accordingly, although not ranked or classed very highly overall, such impacts on these indicators warrant further consideration in the adaptation plan, particularly given the Island's economic reliance on these industries. Similarly, overall, GRP from tourism ranked as the third least vulnerable financial indicator to climate change impacts. However, this indicator was amongst the most vulnerable of indicators, across all capitals, to increasing bushfire, indicating the need to consider this risk in the adaptation plan for the Island.

4.2 Key Areas of Decision Making for Kangaroo Island

Based on the vulnerability scoring and classes, together with comments and discussions during the workshop, the following nine key areas of decision making are proposed as the basis further adaptation planning:

1. How can the current diversity of vegetation communities be maintained, particularly those providing important habitats and resources for threatened species (e.g. forest communities)?

2. How can suitable habitats be maintained for aquatic dependent species (e.g. frogs and freshwater fishes) given future predicted drier and hotter conditions that will influence the availability of high quality fresh surface water.

3. How can the Island manage the impacts of pest and plant animal threats?

4. How can levels of production in wild-catch fisheries be maintained given changing oceanic conditions?

5. How can built assets along the coast be managed in the face of sea level rise and coastal inundation?

6. How can the condition and performance of energy and telecommunications networks be improved given the expected increasing frequency and intensity of extreme climatic events such as heatwaves and bushfires?

7. How can the condition of sealed and unsealed roads be managed in the face of altered climate conditions such as increasing rainfall intensity and sea level rise, as well as increasing use?

8. How can we better protect natural environments, farming assets and built infrastructure against more frequent and intense bushfires, particularly given the limited residential volunteer pool coupled with geographic isolation from the mainland?

9. How can we maintain the well-being of vulnerable members of the community given the increasing risk of extreme conditions such as heatwaves and bushfires?

10. How do we maintain levels of crop, horticulture, and wool production, given projections of declining rainfall and higher average temperatures?.

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Appendices

Appendix A. Workshop Scores for Primary Indicators

Workshop scores for primary indicators relevant to the IVA analysis for Kangaroo Island. E = exposure; S = sensitivity; PI = potential impact; AC = adaptive capacity; V = vulnerability. Vulnerability is calculated as (potential impact – adaptive capacity + 10), where potential impact = (exposure sensitivity). Vulnerability scores shaded grey indicate the top 25% most vulnerable indicators, with the top 10% shown in bold.

PRIMARY INDICATOR	E	S	PI	AC	V
Environmental Capital					
Pest plants and animals	3.17	4.50	7.67	3.67	14.00
Landscape fragmentation	4.00	3.60	7.60	4.00	13.60
Biodiversity	3.79	3.60	7.39	4.11	13.28
Water	3.13	3.75	6.88	3.63	13.25
Land condition	2.00	4.00	6.00	6.00	10.00
Financial Capital					
Local government services	4.50	5.00	9.50	2.00	**17.50**
Intensive livestock production (e.g. chickens, pigs)	5.00	3.50	8.50	4.75	13.75
Primary production	4.03	3.29	7.31	4.60	12.71
Tourism	4.11	2.56	6.67	5.67	11.00
Waste management	3.20	2.40	5.60	5.00	10.60
Biosecurity	3.33	3.67	7.00	6.67	10.33
Human Capital					
Health	4.73	3.33	8.07	5.00	13.07
Education	4.20	3.40	7.60	6.00	11.60
Physical Capital					
Transport services	3.40	3.60	7.00	2.00	**15.00**
Essential services	3.88	3.63	7.50	3.88	13.63
Recreation	4.50	4.00	8.50	6.00	12.50
Buildings	3.50	3.50	7.00	5.00	12.00
Social Capital					
Social inclusion/exclusion	4.67	3.33	8.00	3.67	**14.33**
Emergency Management	3.75	4.25	8.00	3.75	14.25
Community connectedness	4.63	3.25	7.88	4.25	13.63
Community planning and development	5.00	3.00	8.00	4.50	13.50

Appendix B. Workshop Scores for Secondary Indicators

Workshop scores for secondary indicators relevant to the IVA analysis for Kangaroo Island. E = exposure; S = sensitivity; PI = potential impact; AC = adaptive capacity; V = vulnerability. Vulnerability is calculated as (potential impact – adaptive capacity + 10), where potential impact = (exposure sensitivity). Vulnerability scores shaded grey indicate the top 25% most vulnerable indicators, with the top 10% shown in bold.

PRIMARY INDICATOR	SECONDARY INDICATOR	E	S	PI	AC	V
Environmental Capital						
Biodiversity	Area of native vegetation cover by vegetation type (Forest)	4.00	4.20	8.20	2.00	**16.20**
Pest plants and animals	Impact of pest plant and animal threats to the terrestrial environment	4.00	5.00	9.00	3.00	**16.00**
Biodiversity	Abundance and diversity of frogs	3.71	3.86	7.57	2.14	**15.43**
Biodiversity	Seabirds	4.40	4.20	8.60	4.00	14.60
Biodiversity	Area of native vegetation cover outside of DEWNR reserves	4.00	4.00	8.00	3.60	14.40
Water	Quality of surface water	3.83	3.50	7.33	3.00	14.33
Biodiversity	Number of native flora species/communities that are threatened (regional, state)	4.22	3.78	8.00	3.78	14.22
Biodiversity	Abundance and diversity of reptiles	4.17	3.00	7.17	3.00	14.17
Biodiversity	Abundance and diversity of freshwater fish	3.75	3.63	7.38	3.50	13.88
Biodiversity	Abundance and diversity of marine mammals	4.25	3.75	8.00	4.25	13.75
Biodiversity	Area of native vegetation cover by vegetation type (Mallee)	4.00	3.60	7.60	4.00	13.60
Landscape fragmentation	Availability of ecological linkages	4.00	3.60	7.60	4.00	13.60
Biodiversity	Condition of major river systems (e.g. Cygnet River)	3.25	4.00	7.25	4.25	13.00
Biodiversity	Waders	3.29	3.57	6.86	3.86	13.00

PRIMARY INDICATOR	SECONDARY INDICATOR	E	S	PI	AC	V
Pest plants and animals	Impact of pest plant and animal threats to the riverine/floodplain environment	2.75	4.25	7.00	4.00	13.00
Water	Quantity of surface water	1.75	4.25	6.00	3.00	13.00
Biodiversity	Number of native fauna species that are threatened (regional, state)	4.17	3.00	7.17	4.50	12.67
Biodiversity	Area of native vegetation cover by vegetation type (Shrubland)	4.00	3.80	7.80	5.20	12.60
Biodiversity	Abundance and diversity of other mammals	4.00	3.33	7.33	5.00	12.33
Biodiversity	Condition of wetland plant communities	3.00	3.86	6.86	4.57	12.29
Biodiversity	Area of native vegetation cover by vegetation type (Woodland)	4.00	3.20	7.20	5.20	12.00
Biodiversity	Aquatic invertebrates	3.14	3.43	6.57	5.00	11.57
Biodiversity	Birds of prey	3.63	2.88	6.50	5.88	10.63
Land condition	Condition of soil	2.00	4.00	6.00	6.00	10.00
Financial Capital						
Local government services	Property values	4.50	5.00	9.50	2.00	**17.50**
Primary production	Level of production (wild catch fisheries)	4.00	4.50	8.50	4.00	14.50
Intensive livestock production (e.g. chickens, pigs)	Level of production - intensive agriculture	5.00	3.50	8.50	4.75	13.75
Primary production	Level of production (aquaculture - marine)	4.25	3.75	8.00	4.50	13.50
Primary production	Level of production (bee keeping/honey production)	4.17	3.00	7.17	4.17	13.00
Primary production	Level of production (cropping)	3.83	3.00	6.83	4.17	12.67
Primary production	Level of production (aquaculture - freshwater)	3.75	3.75	7.50	5.00	12.50
Primary production	Level of production (horticulture e.g. wine	4.14	3.14	7.29	5.00	12.29

PRIMARY INDICATOR	SECONDARY INDICATOR	E	S	PI	AC	V
	production, seed potatoes)					
Primary production	Level of production (livestock and wool)	4.00	3.00	7.00	5.00	12.00
Tourism	GRP from tourism (accommodation and food service)	4.11	2.56	6.67	5.67	11.00
Waste management	Cost of waste management	3.20	2.40	5.60	5.00	10.60
Biosecurity	Impact of pest plants and animals (on primary production & terrestrial ecosystems)	3.33	3.67	7.00	6.67	10.33
Human Capital						
Health	Impact on people aged over 65 years	4.75	4.25	9.00	3.75	**15.25**
Health	Impact on people who require assistance for core activities	4.75	3.25	8.00	5.00	13.00
Health	Access to medical care and support services	4.67	2.67	7.33	5.33	12.00
Health	Impact on children < 12 years of age	4.75	3.00	7.75	6.00	11.75
Education	Access to education facilities (including schools and TAFE)	4.20	3.40	7.60	6.00	11.60
Physical Capital						
Essential services	Condition and performance of energy and telecommunications network infrastructure	5.00	4.00	9.00	2.00	**17.00**
Transport services	Condition of roads	3.40	3.60	7.00	2.00	15.00
Recreation	Condition of open spaces (e.g. parks and gardens)	4.50	4.00	8.50	6.00	12.50
Water	Condition of sewage and stormwater management assets	3.33	3.67	7.00	4.67	12.33
Buildings	Condition of public buildings (e.g. schools, hospitals, sporting and recreational facilities)	3.50	3.50	7.00	5.00	12.00

PRIMARY INDICATOR	SECONDARY INDICATOR	E	S	PI	AC	V
Essential services	Delivery of potable water (condition of pipes and water quality)	3.20	3.40	6.60	5.00	11.60
Social Capital						
Community connectedness	Participation in industry associations	4.75	3.25	8.00	3.50	14.50
Community connectedness	Participation in organised sport, church or community group in local area	4.75	3.25	8.00	3.50	14.50
Social inclusion/exclusion	Impact on people geographically isolated from transport services	4.67	3.33	8.00	3.67	14.33
Emergency Management	Emergency services (demand and access)	3.75	4.25	8.00	3.75	14.25
Community planning and development	Low income households	5.00	3.00	8.00	4.50	13.50
Community connectedness	Support from family, friends and neighbours	4.67	3.33	8.00	5.00	13.00
Community connectedness	Sense of belonging to community	4.40	3.20	7.60	5.00	12.60

Appendix C. Relative Influence of Climate Variables per Capital

For each relevant climate variable within each capital, the indicators impacted by that variable were identified and the average indicator vulnerability score calculated. In this sense, "vulnerability" scores for climate variables are considered a proxy for relative influence of the climate variable. Vulnerability scores shaded grey are the top 25% of climate variables having the highest relative influence within each capital, with the top 10% shown in bold.

CLIMATE VARIABLE	RELATIVE CLIMATE VARIABLE INFLUENCE
Environmental Capital	
Increased bushfire frequency and intensity	**15.53**
Increased ocean temperatures	15.00
Increased heatwave frequency and intensity	14.67
Temperature increases: Summer-autumn	14.25
Rainfall Reduction: Winter-spring	13.32
Increased ocean acidity	13.00
Temperature increases: Winter-spring	13.00
CO2 Increases	13.00
Sea level rise	12.22
Rainfall Reduction: Summer-autumn	12.10
Increased Evaporation	11.71
Increased intensity rainfall	9.63
Financial Capital	
Increased bushfire frequency and intensity	**16.10**
Increased heatwave frequency and intensity	14.33
Sea level rise	14.33
Increased ocean temperatures	13.67
Temperature increases: Summer-autumn	13.00
Increased Evaporation	12.00
Increased ocean acidity	12.00
Rainfall Reduction: Winter-spring	11.75
Temperature increases: Winter-spring	10.17
Rainfall Reduction: Summer-autumn	8.29
Increased intensity rainfall	8.00
CO2 Increases	7.67
Human Capital	
Increased bushfire frequency and intensity	14.20
Increased heatwave frequency and intensity	13.80
Sea level rise	12.00
Temperature increases: Summer-autumn	11.75

CLIMATE VARIABLE	RELATIVE CLIMATE VARIABLE INFLUENCE
Temperature increases: Winter-spring	11.00
Increased intensity rainfall	8.00
Physical Capital	
Increased bushfire frequency and intensity	**15.50**
Increased heatwave frequency and intensity	**15.25**
Sea level rise	15.00
Temperature increases: Summer-autumn	14.00
Rainfall Reduction: Winter-spring	11.25
Rainfall Reduction: Summer-autumn	10.75
Increased intensity rainfall	10.67
Temperature increases: Winter-spring	8.00
Social Capital	
Increased bushfire frequency and intensity	**16.71**
Increased heatwave frequency and intensity	14.86
Temperature increases: Summer-autumn	12.50
Rainfall Reduction: Winter-spring	12.00
Increased intensity rainfall	12.00
Sea level rise	11.50
Temperature increases: Winter-spring	8.00