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Climate Change Threats to Coastal Biodiversity in the Southern Fleurieu Region

Report prepared for Hills and Fleurieu Landscape Board as part of the review of the Southern Fleurieu Coastal Action Plan and Conservation Priority study (2007).

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Contents

1 Introduction

The Hills and Fleurieu region covers a 6700 km^2 area of land, ocean and offshore islands, including approximately 170 km of coastline, spanning from Kersbrook in the Adelaide Hills in the north to Cape Jervis on the Fleurieu Peninsula in the south, and as far as the Onkaparinga River in the west and the Murray Mouth in the east (Figure 1.1). The Hills and Fleurieu region are the traditional lands of the Ngarrindjeri, Peramangk and Kaurna Nations.

The region's ecosystems are diverse and include one of Australia's 15 biodiversity hotspots in the Mount Lofty Ranges with the Coorong and Lower Lakes system having international significance as Ramsar listed wetlands. The local marine region is part of the larger Great Southern Reef ecosystem which supports high levels of species endemism and is an important biodiversity hotspot. The coast and marine areas are particularly valuable from an ecosystem services perspective, providing tourism opportunities and important marine resources which support high fisheries, habitat and biodiversity values, including resident and migratory shorebirds. Efforts to protect coastal dune habitat for endangered shorebirds, such as the hooded plover, are an important conservation focus in the region.

The region is vulnerable to widespread impacts of climate change, which could potentially threaten its unique environment, economy, and communities. As temperatures rise and weather patterns become more unpredictable, the region is expected to experience an increase in heatwaves, droughts, and bushfire risks. These changes may strain agricultural productivity and disrupt natural ecosystems. Groundwater and surface water underpin the regions agricultural productivity, public water supply for local communities and metropolitan Adelaide, and water dependent ecosystems, which could be particularly vulnerable to climate change impacts. Additionally, the health and well-being of local populations may be compromised by extreme weather events and the long-term effects of a changing climate. The region's coastal areas face rising sea levels, potentially putting local infrastructure and biodiversity at risk. Adaptation and mitigation strategies that guide action plans are crucial in addressing these challenges and ensuring the long-term resilience of the Hills and Fleurieu region.

The south of this region is renowned for its diversity of coastal habitats with the Southern Fleurieu region comprising a diversity of coastal environments, including high to medium energy cliff coast from Sellicks Beach to the Bluff, (this section includes two large beaches at Normanville and Tunkalilla); the urbanised south coast plain, with beaches and headlands, from Victor Harbor to Goolwa; and the Murray Mouth estuary and the Sir Richard Peninsula. The last Southern Fleurieu Coastal Action Plan (SFCAP) was published more than 17 years ago in 2007. The SFCAP focuses on the coastal regions which encompass the District Council of Yankallila, The City of Victor Harbor, and Alexandrina Council. The 2007 document contains a summary of climate change projections for the region, including background from the 2007 Intergovernmental Panel on Climate Change's (IPCC) Third Assessment Report and the 2007 CSIRO projections. Since the release of the SFCAP, a number of publications have updated earlier climate change projections with increased certainty. Three iterations of climate reports from the IPCC have been released since development of the SFCAP. The developments reflect both an acceleration in observed climate change and a deepening understanding of climate systems, resulting in more specific and refined climate change projections.

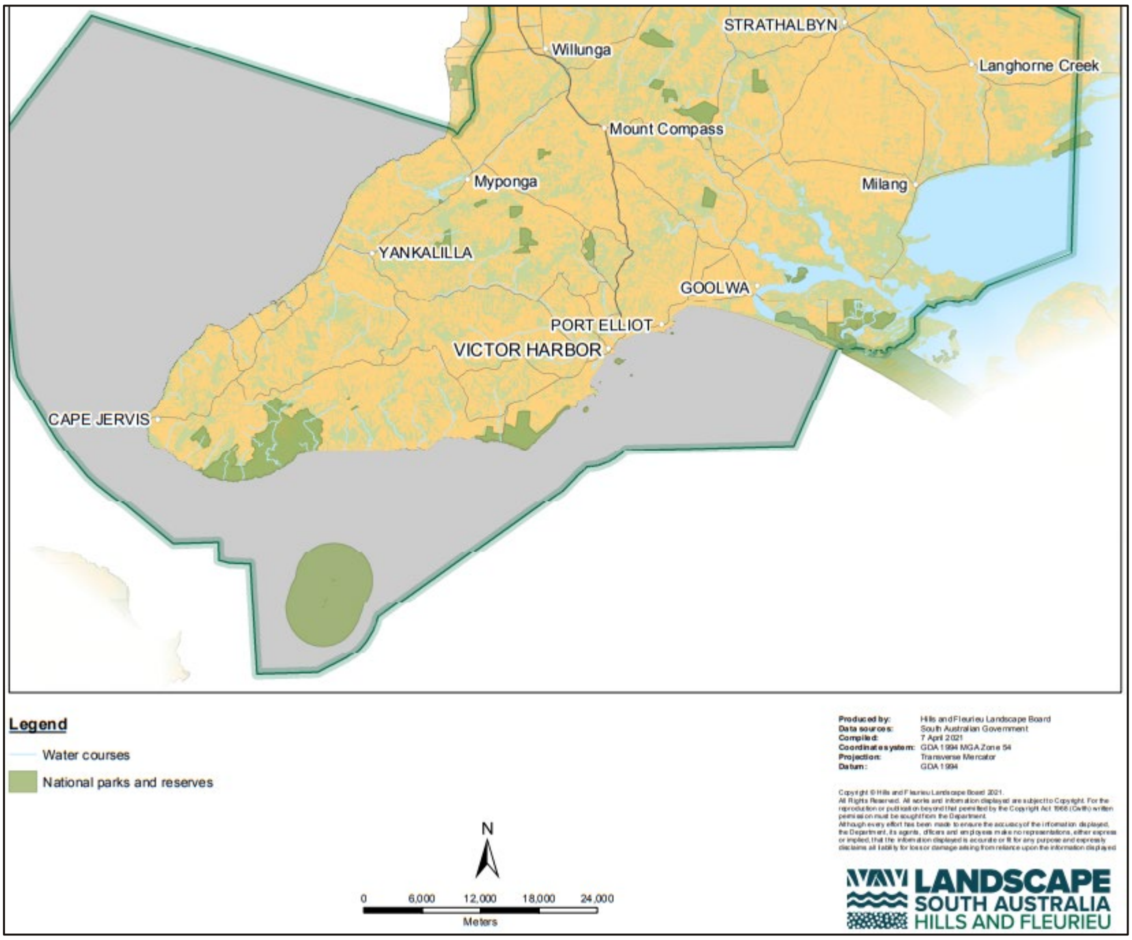

Figure 1.1 Hills and Fleurieu Coastal Region inclusive of the coastline and coastal waters

To align with this updated climate change information, a revised regional review addressing potential climate change threats to coastal biodiversity of the Landscapes Hills and Fleurieu region is required. This study provides a high-level review of recent coastal literature. No modelling or spatial analysis has been conducted as a part of this review.

The definition of ‘coast’ for this study follows the previous SFCAP and includes nearshore coastal marine waters and lands above mean high-water mark that are influenced by coastal processes and/or support natural coastal features, such as, dunes and salt marshes. Where coastal influences are not clearly defined, e.g. on sea cliffs, the boundary has been taken as 500 m from low water springs (low water mark). For ease of analysis, the coastal zone was divided into ‘cells’ or sub-regional landform units with an average mapping length of 6 kilometres.

The main coastal ecosystems within each cell have been mapped and described. A data review of current climate change projections for South Australia was undertaken to identify possible climate change threats to coastal biodiversity in the Hills and Fleurieu region. Potential climate change threats to coastal biodiversity for each cell along the regions coast was assessed addressing the following key areas:

a. Sea level rise, storm surge & coastal erosion
b. Increasing average temperatures and aridity
c. Changed run-off regimes
d. Changes to Southern Ocean and Gulf waters
e. Changes to groundwater aspects of the hydrological cycle

Based on the data review and discussions with Landscape Hills and Fleurieu, a table of recommended actions and priorities for each cell was developed identifying key actions to protect or improve resilience of coastal habitats vulnerable to climate change threats.

2 Climate change threats to biodiversity

2.1 Climate change

We are experiencing profound planetary changes due to anthropogenic activities. At a global scale, greenhouse gas emissions are causing warming at a pace that is unprecedented in the past 2,000 years, and the Earth is warmer than it has been in 125,000 years (Tollefson, 2021). At regional land use scales, the use of fossil fuel powered processes has led to more rapid modification of natural habitats for agriculture, mining, and urbanisation compared to the pre-industrial era (Vitousek et al., 1997). The multiple stressors of global climate change and regional landscape modification, both reduce ecosystem resilience at a local scale (Kendrick et al., 2019).

The effects of climate change are being observed across the landscape and seascape. Climate change is adding a substantial pressure to all landscapes, whether they are modified or in pristine natural condition. The climate is generally becoming warmer and drier with increasing heatwaves and bushfire risk, higher sea levels and increased storm surge (IPCC, 2021). Coastal regions are generally experiencing changes to runoff regimes through less frequent, but more intense storms, increasing runoff and subsequent pollutant loads from the catchment (Huq & Abdul-Aziz, 2021). Sea level rise is causing salinization of some groundwater coastal regions through direct lateral infiltration of saline water into the subsurface as well as by changes in groundwater pressure balance (Zamrsky et al., 2024). Oceans absorb much of the atmospheric heat and warmer oceans are predicted to lead to changing ocean circulation patterns and currents (Li et al., 2023). As carbon dioxide dissolves into seawater, oceans are becoming more acidic, posing a significant threat to marine and coastal ecosystems (SotC, 2024).

2.2 Climate change impacts on biodiversity

Climate change impacts are often described with a focus on managing primary production (agriculture and fisheries) (SotE, 2022) as well as the impacts of predicted sea level rise on coastal human populations (McMichael et al., 2020). Relatively little focus is directed at how climate change will impact Australia's biodiversity (Biodiversity Council 2023).

Biodiversity, or biological diversity, refers to the variety of species in a place, including animals, plants, and microorganisms, as well as the ecosystems—terrestrial, marine, and freshwater—that they inhabit.

The ecosystem services provided by biodiversity are integral to the environment and human health and well-being. Aside from the benefits for recreation, cultural and spiritual nourishment that maintain our own personal and social wellbeing, biodiversity also provides critical ecosystem services such as, pollination, water purification, soil fertility, disease control, climate regulation and coastal protection.

While it is widely recognised that climate change is an increasing global driver of biodiversity loss, other stressors such as land use change, pollution, and overexploitation may have a more immediate influence at local levels (Caro et al., 2022). Loss, fragmentation and degradation of habitat, spread of invasive species, unsustainable use of natural resources, and changes to aquatic and environmental water flows over the last 200 years in Australia has led to the largest documented decline in biodiversity of any continent (SOE, 2021). These additional stressors can influence a species or habitats resilience to climate change threats. Understanding biodiversity vulnerability to climate change threats in the context of other local pressures therefore needs to be considered in environmental planning and management to enhance biodiversity resilience to a changing climate.

Accounting for the impacts of climate change on biodiversity is also essential for identifying a range of climate change adaptation actions that can target multiple environmental services.

2.3 Climate change impacts on coastal biodiversity

Coastal habitats in Australia are highly vulnerable to the impacts of climate change and land use pressures. Coastal regions are the most densely populated areas in Australia and are subject to the ongoing pressures of urbanisation and other land uses as well as from the climate change-related impacts of sea level rise, storm surge, coastal erosion, increased ocean acidification and changes in run-off regimes.

The impacts of climate change and habitat loss and degradation not only threaten coastal ecosystem extent but can also disrupt species composition and behaviour. For example, marine gastropods with low mobility may have a low ability to leave one area of habitat to find a more favourable site. Species with a high dependency on their immediate habitat may be particularly vulnerable to changes in seascape condition. In contrast, animals with high mobility may be able to relocate to other areas of suitable habitat. However, this may disrupt some species behaviour associated with essential life cycle stages, e.g. breeding habitat used by migratory waders for part of the year.

While slowing climate change through reducing emissions necessitates international action, increasing climate change resilience of biodiversity needs to be implemented at local scales. Actions to enhance climate change resilience for biodiversity can include nature-based solutions, such as, ecosystem restoration, conservation of ecosystems and sustainable land management. Nature-based solutions can serve as creating and preserving climate refugia where species might find suitable habitats in a changing climate. These solutions can be key to both mitigating climate change (e.g. restoration of blue carbon ecosystems) and enhancing biodiversity resilience to a changing climate.

2.4 The Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has released assessment reports regularly since 1992. The reports summarise the state of knowledge of climate change, its widespread impacts and risks, and climate mitigation and adaptation measures. Each report provides updates and integration of new knowledge. As understanding of climate science has grown, so too has confidence in the model projections for future climate impacts.

Projections of future climate impacts are based on different emissions scenarios, that is, different quantities of greenhouse gases being released into the atmosphere. Termed, Representative Concentration Pathways (RCPs), the scenarios were developed by the IPCC to represent plausible future trends of greenhouse gas emission rates and the consequent concentrations of greenhouse gas in the atmosphere. The four commonly referenced RCPs range from very low (RCP2.6) through medium (RCP4.5 and RCP6.0) to high (RCP8.5) future concentrations and are based on possible global responses to manage the emissions of greenhouse gases.

The IPCC released its Sixth Synthesis Report (AR6) in 2023. The previous version of the Coastal Action Plan (2007) was based on information available from the Third Assessment Report (TAR) (2001). The increased specificity of AR6 reflects significant advances in scientific understanding, greater attention to ecosystem dynamics, and more detailed assessments of the impacts of climate change on biodiversity.

Between the TAR and AR6, the IPCC's global predictions and projections on climate change have evolved significantly due to advancements in scientific understanding, improved models, and more comprehensive data. These advancements have led to:

- **More precise predictions**: Temperature projections, sea level rise, and regional impacts are more refined, with better models and data.
- **Increased confidence in extreme weather**: There is now higher certainty that extreme events will increase with warming.
- **Better understanding of feedbacks**: Feedbacks like melting ice and permafrost thaw are now more fully integrated into models, leading to higher estimates of warming under certain scenarios.
- **Focus on 1.5°C and carbon budgets**: The AR6 emphasizes how close we are to exceeding the 1.5°C threshold and provides clear carbon budgets to guide mitigation efforts.

The projections for global changes in AR6 reflect both an acceleration in observed climate change and a deepening understanding of climate systems, resulting in more specific and refined predictions compared to the TAR. Table 2.1 shows a comparison of information referenced from TAR in the previous Coastal Action Plan (2007) compared with AR6.

Table 2.1 Comparison of conclusions from the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR), Sixth Assessment Report (AR6).

Impact	Southern Fleurieu Coastal Action Plan 2007	TAR	AR6
Climate Sensitivity (temperature response to CO2 emissions)	Collectively, observations show the world is warming. Most of the warming of the last 50 years is attributable to human activities. Emissions of greenhouse gases have altered the composition of the atmosphere and will continue to do so throughout the present century. Emissions of greenhouse gases and aerosols due to human activities continue to alter the atmosphere in ways that affect the climate system. Confidence in the ability of models to project future climates has increased.	The global temperature increase due to a doubling of CO_2 was projected to range from 1.5°C to 4.5°C, with a best estimate of around 2.5°C.	The likely range for the climate sensitivity has been narrowed to 2.0°C to 5.0°C, and the best estimate is still around 3.0°C.
Projected Temperature Rise	Global average temperature is projected to rise. The global average surface temperature has increased by 0.7°C during the last century. The unusual nature of the warming of the past 50 years, relative to the past 1,000 – 2,000 years, has been supported by many other independent studies.	The projected global temperature rise by 2100 was between 1.4°C and 5.8°C, depending on different greenhouse gas emissions scenarios.	The likely temperature rise by 2100 under different emissions scenarios is more specific: Very low emissions (SSP1-1.9): ~1.0°C to 1.8°C, Intermediate emissions (SSP2-4.5): ~2.5°C to 4.2°C, High emissions (SSP5-8.5): ~3.3°C to 5.7°C. These updated ranges reflect more sophisticated models, including more detailed data on climate feedbacks, aerosols, and regional patterns.
Carbon Budget and Likelihood of Exceeding 1.5°C		The TAR did not emphasize a carbon budget or the likelihood of exceeding specific temperature	The AR6 provides a carbon budget for limiting global warming to 1.5°C or 2°C. It quantifies how much CO_2 we

Impact	Southern Fleurieu Coastal Action Plan 2007	TAR	AR6
		thresholds in the way that the AR6 does. The focus was more on long-term projections, with less precision on the timing of specific temperature thresholds.	can still emit to stay within these limits: To stay below 1.5°C, the remaining carbon budget is roughly 400 Gt CO_2 (with a 50% chance). The AR6 emphasizes that we are likely to exceed 1.5°C of warming within the next two decades unless substantial emissions reductions occur. AR6 also highlights the higher probability of exceeding the 1.5°C threshold, especially under high emissions scenarios (SSP5-8.5).
Regional Changes	Heatwaves and heavy rainfall have increased in many regions, while glaciers, ice sheets and frosts have decreased	Predictions for regional impacts were more general, and there was less confidence in understanding how different regions would specifically respond to global warming. For example, the TAR described increases in temperature and changes in precipitation but did not provide detailed projections for individual regions.	The AR6 provides high-resolution regional projections and is much more specific in terms of how different regions will be affected. For instance: Polar regions are predicted to warm faster than the global average (more than twice as fast in many cases). Arid and semi-arid regions will see an increase in heatwaves and droughts. The Arctic is projected to warm by 3°C to 5°C by 2100, compared to a global average of 1.5°C to 4.0°C.
Sea Level Rise	Global average sea level is projected to rise. The global average sea level has risen 1.7mm per year since 1900.	Projected sea level rise by 2100 was between 0.09 m and 0.88 m, with a central estimate of about 0.48 m.	Projections for sea level rise are now more precise due to improved models of ice sheet dynamics and other factors. AR6 projects: 0.29 m to 0.59 m (for low emissions scenarios, such as SSP1-2.6), 0.44 m to 0.76 m (for intermediate scenarios, such as SSP2-4.5), 0.63 m to 1.01 m (for high emissions scenarios, such as SSP5-8.5). There is also an acknowledgment that rapid ice sheet disintegration could lead to higher sea-level rise than earlier estimates, particularly under high emissions scenarios.
Extreme Events (Heatwaves, Floods, Droughts)		Predicted an increase in extreme weather events, but the confidence in these projections was lower, and the understanding of their dynamics was less advanced.	There is higher certainty that extreme events like heatwaves, floods, droughts, and storm surges will increase in frequency and intensity as the world warms. The AR6 also highlights that the global

Impact	Southern Fleurieu Coastal Action Plan 2007	TAR	AR6
			increase in extreme weather will be highly dependent on regional climate systems.
Carbon Cycle and Feedbacks	New information about climate feedbacks indicates a greater likelihood of warming at the higher end of the uncertainty range.	Feedback mechanisms such as carbon cycle feedbacks (e.g., permafrost thaw, forest fires) were less understood and were not incorporated in detail in the models.	The AR6 incorporates a greater understanding of feedbacks. For example: Permafrost thaw and the release of methane are now considered more likely to contribute significantly to future warming. Forest dieback and the potential for reduced carbon sinks have been shown to amplify climate change.

2.5 Climate observations in South Australia

Observations of South Australia's weather from the Bureau of Meteorology (2024) show that average annual temperature across the state has increased by 1.6 °C since 1910. Increased temperatures are leading to an increase in the number of days with dangerous weather conditions for bushfires across the state.

Changes in rainfall regimes have occurred, with declines in winter rainfall and increases in summer rainfall over most of South Australia, however, the states southern regions have experienced a persistent decline in rainfall (BOM, 2024). Rainfall for the year 2022-2023 in South Australia was 12.5% below average, making it the state's driest year since 2019. Storms brought heavy rain at times in November and December, with some sites having their highest daily rainfall on record (BOM, 2024).

Sea levels rose 17 cm from 1901 to 2000. Sea levels are projected to rise by a further 22 to 25 cm by 2050, exacerbating shoreline erosion and putting at risk coastal communities (DEW, 2022a).

CSIRO collection of ocean acidification data as part of the Integrated Marine Observing System (IMOS) network shows that the acidity of marine waters around Australia has increased more than 30% over the past 140 years (SotC, 2024).

2.6 Climate projections for South Australia

Climate change projections for South Australia are delivered by the Government of South Australia through the SA Climate Ready initiative. These state-based projections are provided for individual weather stations across South Australia and may better represent local climate. Global Climate Models (GCM) that represent the State's climate drivers such as the Indian Ocean Dipole and the El Niño Southern Oscillation are used to generate climate projections at a local scale. Data are available at the regional scale for the following six climate variables:

- Rainfall
- Temperature maximum
- Temperature minimum

- Potential evapotranspiration
- Solar radiation
- Vapour pressure deficit.

The state's climate projections are a flexible resource that provides data at local and aggregated spatial scales.

The Department for Environment and Water published a guide to climate projections for risk assessment and planning in South Australia (The Guide) (DEW, 2022a). The report summarises climate projections from the NSW Australian Regional Climate Modelling Project stage 1.5. The NARCliM 1.5 regional-scale climate modelling is based on Coupled Model Intercomparison Project Phase 5 (CMIP5) models that informed the IPCC 5th Assessment Report (IPCC, 2014). NARCliM 2.0 regional-scale climate modelling, currently in progress, will provide higher resolution gridded climate projections for South Australia based on the CMIP6 models of the IPCC 6th Assessment Report (IPCC, 2021).Figure 2.1 provides a summary of climate trends projected for South Australia to 2050 and beyond.

Higher temperatures	Maximum, minimum and average temperatures will increase.
Warmer spring temperatures	Warming in spring is likely to be greater than in any other season.
Hotter and more frequent hot days	The frequency of very hot days will continue to increase, and periods of hot weather will get longer and hotter.
Fewer frosts	The frequency of frost events will remain comparable until 2030. In the longer-term, frosts are expected to decrease as the climate warms.
Declining rainfall	Average annual rainfall will decline.
Lower spring rainfall	Spring rainfall declines will be greater than any other season.
More drought	Time spent in drought will increase.
More intense heavy rainfall events	The number and intensity of heavy rainfall events will increase.
Increased potential evapotranspiration	Potential evapotranspiration is projected to increase across all seasons.
Wind	Wind speeds will remain comparable until 2030. In the longer-term, a pattern of winter wind speed decrease is likely.
More dangerous fire weather	Harsher fire weather will be experienced, and fuels will be drier and more ready to burn.
Rising sea levels	Sea levels will continue to rise.
Warmer and more acidic ocean waters	Sea surface temperatures will continue to rise, and acidity will continue to increase.

Figure 2.1 Summary of climate trends projected for South Australia to 2050 and beyond (source: DEW 2022a).

The following summaries of projected climate trends have been extracted from The Guide (2022):

Increasing temperature

Annual mean daily maximum and minimum temperatures will increase across all South Australian regions. By 2030 annual mean daily maximum temperatures are projected to increase by up to 1.3°C with greater increases projected for northern parts of the state. For the Kangaroo Island and Hills and Fleurieu Landscape Regions, mean daily maximum temperatures are projected to increase by 1.0°C. By 2050 annual mean maximum temperatures are projected to increase by up to 2.2°C.

Decreasing rainfall

Annual rainfall will decline across all South Australian regions. By 2030 annual rainfall across the state is projected to decline by 1.7 – 6.8%, from the baseline period of 1986 – 2005, with smaller declines in the south. By 2050 annual rainfall is projected to decline by 4.0 – 23.0%.

Seasonal rainfall

Across all South Australian regions, rainfall declines in Spring are likely to be greater than any other season. By 2030, declines in Spring rainfall are projected to be as high as 13.2% in the Kangaroo Island landscape region. By 2050 rainfall declines are projected for all regions in all seasons. Projected declines in Spring rainfall are the greatest.

Extreme rainfall events

South Australia faces increasing impacts from extreme rainfall events that will affect runoff regimes to aquatic and marine ecosystems. The amount of rain falling in extreme rainfall events will increase in all South Australian regions and the frequency of extreme rainfall events will increase.

Drought

The amount of time spent in drought will increase for all South Australian regions. By 2030, time spent in drought (over a 20-year period) is projected to nearly double in the Hills and Fleurieu and Kangaroo Island Landscape Regions. This means that up to 65% of time could be in drought by 2030. By 2030, the frequency of extreme drought will more than double. By 2050, time spent in drought is projected to more than double in the Hills and Fleurieu, Eyre Peninsula and Kangaroo Island Landscape Regions. This means that up to 70% of time could be in drought by 2050.

Fire weather

All of South Australia is projected to experience harsher fire weather. Projected warming and drying across the state will lead to fuels that are drier and more ready-to-burn. South Australia faces increasing impacts from more dangerous fire weather including increases in bushfire risk and expansion of bushfire-prone areas.

Sea level

Sea levels along the South Australian coasts are projected to continue to rise. The height of extreme sea level events will also increase. By 2030, a sea level rise of around 13 cm is projected compared with the average level during 1986 – 2005. By 2050, a sea level rise of 22 – 25 cm is projected compared with the average level during 1986 – 2005. Sea level rise will cause increased extent and frequency of coastal flooding to estuaries, and low-lying coastal habitat. Higher sea levels may lead to erosion of beaches and rising groundwater or coastal inundation.

Sea surface temperature

By 2030, mean sea surface temperatures are projected to increase by 0.5°C at Victor Harbor. Warming oceans, together with an increase in the frequency, intensity and duration of marine heatwaves, pose a significant threat to the long-term health and resilience of South Australia's coastal ecosystems. South Australia faces increasing impacts associated with rising sea surface temperatures including, changes in nutrient cycling in marine waters, adverse impacts on the condition and extent of suitable habitat for coastal fisheries, adverse impacts on shell-forming organisms including molluscs, crustaceans and foraminifera (single-celled organisms), adverse impacts on fisheries, aquaculture and tourism.

Ocean acidification

In Australia, the greatest acidity increases have occurred in the Southern Ocean (21%) and in the Coral Sea (19%), with the smallest increases to the north-west of Australia (15%). The pH changes tend to be greater at higher latitudes where there is more total dissolved CO_2 in the surface waters, which reduces their capacity to buffer against pH change (SotC, 2024). South Australian marine species may experience higher stress because the pH changes tend to be greater at higher latitudes where there is more total dissolved CO_2 in the surface waters, which reduces their capacity to buffer against pH change (SotC, 2024).

Summary

Projected climate trends vary across the region. For example, the mainland areas of the Hills and Fleurieu are projected to experience greater increases in mean temperatures and have a greater decline in rainfall than Kangaroo Island (Table 2.2). Adaptation and actionable responses to climate change impacts will need to be locally specific to suit the varying magnitudes of change projected for each area.

Table 2.2 RCP4.5 and RCP8.5 projections of climate change between the Fleurieu mainland and Kangaroo Island by 2070.

Projected change	Mainland Hills and Fleurieu		Kangaroo Island	
	RCP4.5	**RCP8.5**	**RCP4.5**	**RCP8.5**
Rainfall	Decline by 6%	Decline by 20-30%	Decline by 7.9%	15-25%
Rainfall intensity	Increase by 11%		Increase by 8%	
Minimum temperatures	Increase by 1.2°C	2.5-3.5°C	Increase by 1.0°C	2.5-3.5°C
Maximum temperatures	Increase by 1.2°C	3-4°C	Increase by 1.0°C	3-4°C
Sea level rise	0.3-0.4 m	0.4-0.5 m	0.3-0.4 m	0.4-0.5 m

3 Implications of climate change on coastal biodiversity in the Hills and Fleurieu region

South Australia's biodiversity is declining rapidly; it suffers from a legacy of past and current anthropogenic pressures (Bradshaw, 2018). The coastline of South Australia is replete with examples of how changed land use, including industrial discharges and increased stormwater have contributed to substantial loss of foundational, benthic marine habitats (Fox et al., 2007), impacting associated biodiversity, ecological function, and ecosystem services provision (Smith et al., 2024). Climate change impacts are additional stressors of consequence for biodiversity (Caro et al., 2022).

The Hills and Fleurieu region of South Australia, renowned for its diverse coastal and marine ecosystems, faces significant threats from climate change that could jeopardize its rich biodiversity. Rising sea levels, increasing ocean temperatures, and more frequent extreme weather events are contributing to habitat loss, and disruptions to the migratory patterns of marine and coastally dependent species. Additionally, ocean acidification threatens the functioning of marine food webs, while altered rainfall patterns impact stormwater inputs into coastal systems. These changes not only endanger the region's unique biodiverse coastal and marine life but also disrupt the balance of ecosystems that support local communities and economies. Protecting and restoring these habitats requires urgent and adaptive conservation efforts to help mitigate the accelerating impacts of climate change.

The Hills and Fleurieu region is divided into three councils: Yankalilla, Victor Harbor and Alexandrina. Yankalilla hosts the smallest population of permanent residents, followed by Alexandrina, and Victor Harbor. The entire Hills and Fleurieu region experiences substantial population influx during holiday periods, and future growth of the permanent population is anticipated for all three councils. The holiday popularity and permanent population growth is in part, due to the regions natural surroundings which are treasured by residents and visitors. Councils have an important role and vested interest in ensuring that biodiversity is protected from the threats of anthropogenic activities including climate change, within their boundaries.

Population growth has strategic planning implications that need to accommodate future housing and employment opportunities together with associated infrastructure and services whilst protecting biodiversity, heritage and, creating a desirable and sustainable lifestyle for the community. Updates to council plans are an integral part in ensuring that growth and development are informed by contemporary information on the condition of supporting ecosystems. Plans should consider that the impacts from anthropogenic activity can appear far from the source and are often intertwined with impacts from climate change. Land use within a terrestrial catchment area will often have consequences for coastal and marine ecosystem health via runoff, while climate change impacts such as sea level rise, and increasing storm intensity can have consequences for communities.

Pollutants in stormwater and runoff, such as nutrients, sediment, herbicides and pesticides from agricultural or urban land use can cause the loss of nearshore seagrasses and macroalgae (Fox et al., 2007). Climate change can increase the pollutant loads as less frequent and more intense rainfall events will result in higher concentrations of pollutants in the first flush from rain. Seagrasses and macroalgal reefs, as part of their ecosystem services, accrete and stabilise sediment and dampen wave energy (Denny, 2021). Loss of benthic marine flora can result in loss of sediment bound by the plants, liberation of stored carbon in the plants and sediments, deepening of the seabed and diminished wave attenuation properties. Without the seagrasses and macroalgae, and associated trapped sediment, beaches and dunes may be eroded more rapidly. Hence, improving water quality or quantity of runoff and stormwater can help mitigate losses of seagrasses and macroalgae and provide better coastal protection from climate change induced sea level rise and storms (Saunders et al., 2013).

Seeking solutions to climate impacts on communities that also protect and enhance biodiversity can help create resilient communities and ecosystems. Nature-based solutions are strategies that use natural processes and ecosystems to address climate change, disaster risk, and biodiversity loss. For example, modified designs of stormwater drainage systems that incorporate native vegetation and better retention areas for flooding events provide refuges for native species and prevent direct discharge of polluted stormwater into marine waters. Protecting the sensitive nearshore algal reefs and seagrass meadows from the impacts of urban and agricultural stormwater, retains the substantial coastal erosion benefits and biodiversity of these important habitats. Nature-based solutions can offer cost-effective, sustainable alternatives to traditional engineering solutions, helping to both protect and restore biodiversity while benefiting people.

Classification of local coastal habitats and an understanding of their composition, condition, essential habitat requirements and ecosystem services provided can assist in understanding how climate change pressures may impact each habitat and if local action can be taken to increase resilience to global and local pressures.

The coastal and marine ecosystems of the Hills and Fleurieu region broadly comprise, algal reefs and seagrasses, rivers, creeks, estuaries and wetlands, beaches and rocky shores, cliffs and sand dunes, and groundwater. The vulnerabilities of each ecosystem will be specific to each climate change impact and to local conditions, presenting potentially complex challenges for conservation and management strategies.

The following section provides an overview of coastal ecosystems in the study area and a high-level assessment of potential climate change impacts to these broad habitat types.

3.1 Algal reefs and seagrasses

Algal reefs and seagrass ecosystems extend from the intertidal zone to depths of more than 20 m along the coastlines and offshore islands of the Hills & Fleurieu region. Often occurring in mixed beds, a diverse composition of temperate macro algae and seagrass species occur. Reefs in the Hills and Fleurieu region also support large canopy forming brown macroalgae that form dense, often closed canopies or 'kelp forests' which are a critical component of nearshore rocky ecosystems that span the entire southern coastline of Australia (Brock et al., 2023).

The algae reefs and seagrasses attenuate waves and currents, capture sediment, assimilate and store carbon, are an integral component of nutrient cycling and provide habitat for marine fauna including nursery habitat.

The algae and seagrass species making up these communities are generally susceptible to poor water quality and changes in water quality, particularly, decreases in light levels, increases in sedimentation and increases in nutrients or other pollutants (e.g. herbicides and pesticides in stormwater). Natural recolonisation of algal and seagrasses can take decades and relies on abatement of stressors that caused the loss.

a) Sea level rise, storm surge & coastal erosion – Rising sea levels will increase water depth across reefs and seagrasses. This may impact on the deepest extent of the current ecosystem range through light reduction that may hinder the growth of some species. Conversely, some species may be able to spread into areas that were formerly too shallow to support the ecosystem. However, shoreward migration of marine flora may be limited by coastal erosion. The predicted increase in wave heights (Perry et al., 2024) and faster currents could also cause dislodgement of seagrasses and algae from the benthos.

b) Increasing average temperatures and aridity - Higher atmospheric temperatures are likely to lead to an increase in marine heatwaves. Higher temperatures may cause stress in temperate reef and seagrass species. Aridity may reduce freshwater inflows and affect the salinity of coastal ecosystems. These conditions could result in the dieback of species in the intertidal and subtidal zones. Recovery or migration of these ecosystems may be restricted by other stressors e.g. loss of sediment due to coastal erosion. Higher sea surface temperatures also increase the potential for toxic and exotic algal blooms which may outcompete locally native species.

c) Changed run-off regimes – Changes in runoff patterns, such as heavier rainfall followed by dry periods, may lead to increased sedimentation and nutrient loading in coastal waters, smother seagrasses and macroalgae, promote harmful algal blooms, and reduce local oxygen levels that could impact reef and seagrass ecosystems.

d) Changes to Southern Ocean and Gulf waters – Changes in local ocean temperatures, salinity, and acidity (from increased CO_2 levels) may directly affect the health of temperate reefs and seagrasses. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton. Projections suggest that the Southern Oscillation Index will also become more variable in the future, leading to more extreme winter and spring wave conditions in the Gulf St Vincent (Perry et al., 2024) which may impact on the ability for some species to grow and colonise.

Reductions in seagrass populations could have cascading impacts resulting in short term deposition of wrack on beaches and longer-term loss of nearshore seagrass, leading to losses to nearshore sand and deepening seabed. This could result in increased wave heights and impacts on shore leading to increased erosion rates and changes to beach profiles.

e) Changes to groundwater aspects of the hydrological cycle - Groundwater changes may indirectly impact temperate reefs and seagrasses if coastal aquifers are linked to surface water. Reduced groundwater flow may impact freshwater input to estuaries, affecting salinity and water quality conditions suitable for local algal and seagrass species.

3.2 Rivers, creeks, estuaries and wetlands

Estuaries are low energy environments that receive terrestrial runoff from connected streams or rivers, as well as being connected to the marine environment either continually or during high tides and storm surge flows. Within the Hills and Fleurieu region estuaries are narrow in extent but relatively open systems. Whilst the flora and fauna species in these variable systems can typically tolerate the often extreme conditions of wetting, drying, salinity and temperature fluctuations, exposure to sun and submersion, they may also be vulnerable to climate change impacts.

a) Sea level rise, storm surge & coastal erosion - Sea level rise may cause erosion and increased inundation of these coastal habitats. Saltmarshes and mangroves which typically occur in these environments within specific tidal hydrological zones may become submerged and may be displaced if unable to migrate further inland.

b) Increasing average temperatures and aridity – Increased aridity may lead to reduced freshwater availability, changing the salinity levels in these ecosystems. Higher temperatures may also increase evaporation rates, further stressing these habitats. Hotter drier conditions may place increased stress during dry periods. Increased evaporation could lead to higher soil salinities beyond the tolerance of native species. Higher temperatures may impact shallow estuarine water more severely than well-flushed open coastal waters potentially leading to increased incidence of algal blooms.

c) Changed run-off regimes – More intense storm events and longer periods of aridity will change run-off regimes. The first flush of stormwater runoff after prolonged dry periods may lead to increased pollutant loads reaching mudflats and saltmarshes, negatively impacting water quality and the health of these habitats. Changes in sedimentation patterns may affect the stability and growth of saltmarshes.

Acid sulfate soils are naturally occurring soils with significant percentages of iron sulphide. These soils commonly occur in low lying coastal areas where the water table is at or close to the surface. Soils that remain below the water table are relatively stable. However, when these soils are exposed to the air (for example as a result of changes in water levels), oxidation can occur, and sulfuric acid is formed. The acid may simply react with carbonates and clay within the soil, but if a build-up of acidic soil water occurs or is retained in a shallow estuary, biodiversity may be adversely impacted.

d) Changes to Southern Ocean and Gulf waters – While connected to marine waters estuarine habitats may be largely sheltered from direct impacts from changes to Southern Ocean and Gulf waters.

e) Changes to groundwater aspects of the hydrological cycle – Changes in groundwater levels can alter the salinity and water quality of coastal wetlands, leading to stress or loss of species in these habitats. Groundwater may become more saline and pollutants in groundwater may be driven upwards due to saline ocean water displacing freshwater in sediments.

3.3 Beaches and rocky shores

Beaches and rocky shores are important feeding, breeding, and nursery areas for many marine and coastal species in the Hills and Fleurieu region. The region is also an important breeding site for a range of beach-nesting shorebirds including the nationally vulnerable hooded plover and for migratory wading birds, both freshwater based and shorebirds.

a) Sea level rise, storm surge & coastal erosion - Coastal erosion can become more pronounced with sea level rise, leading to the retreat of beaches and the submersion of low-lying rocky shore areas. Increased wave heights predicted (Perry et al., 2024) will contribute to erosion and impact the intertidal zone for example cause dislodgement seagrasses and algae from the benthos. Rocky shores may also be eroded, damaging the natural habitat for organisms like barnacles, molluscs, and algae. Rising sea levels will see increased storm damage to the beach and causing recession into foredunes.

b) Increasing average temperatures and aridity – Higher temperatures can lead to shifts in species distributions, potentially reducing biodiversity on beaches and rocky shores. Many species might not be able to adapt to the increasing temperatures resulting in a loss of species diversity in these habitats.

c) Changed run-off regimes - Increased runoff, particularly after heavy rains, can lead to erosion of beaches and rocky shores. Excessive sedimentation (from land-based sources) can also reduce biodiversity and disrupt local ecosystems through burial, increased nutrient loads, and reduction in light.

d) Changes to Southern Ocean and Gulf waters - Changes in ocean temperatures, salinity, and acidity (from increased CO_2 levels) can directly affect the health of temperate species associated with beaches and rocky shores. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton. Projections suggest that the Southern Oscillation Index will become more variable in the future, leading to more extreme winter and spring wave conditions in the Gulf St Vincent (Perry et al., 2024). The reduction in seagrass could also have cascading impacts resulting in short term deposition of wrack on beaches, longer-term loss of nearshore seagrass, losses to nearshore sand and deepening seabed. This could result in increased wave heights and impacts on shore leading to increased erosion rates and changes to beach profiles.

e) Changes to groundwater aspects of the hydrological cycle - Groundwater flow can influence the moisture levels in the coastal environment, affecting the vegetation and organisms that inhabit these zones. Lower groundwater levels could increase vulnerability to drought and erosion.

3.4 Cliffs

Cliffs of the Hills and Fleurieu region may be comprised of fossiliferous limestone, shales, sandstones, granite, slate and sandstone (Daily et al., 1988). The type of rock will determine how climate change impacts will affect each habitat type. The inaccessibility of many of these cliffs typically makes them of high importance to many bird, mammal and reptile species.

a) Sea level rise, storm surge & coastal erosion - Increased Sea levels contribute to more frequent and intense wave action, which may accelerate cliff erosion. This may lead to the collapse of cliff faces, reducing the available habitat for cliff-dwelling plants and animals.

b) Increasing average temperatures and aridity – Warmer temperatures may affect the flora and fauna of cliffs, making them less hospitable for some species, particularly those dependent on cooler or more stable conditions. Hotter drier conditions will place increased stress during dry periods. Increased evaporation could lead to higher soil salinities beyond the tolerance of native species.

c) Changed run-off regimes – Changes in runoff may lead to increased erosion around cliffs, contributing to their destabilization and may impact cliff-side vegetation and habitat values.

d) Changes to Southern Ocean and Gulf waters - Oceanic changes, including sea level rise and storm intensity, may lead to increased erosion of cliffs. The effects of coastal waters on cliff stability will be intensified during extreme weather events.

e) Changes to groundwater aspects of the hydrological cycle – Groundwater in cliffs helps stabilize the soil and rock. Fluctuating groundwater levels may lead to instability and increased erosion, possibly contributing to cliff collapses.

3.5 Sand dunes

The Hills and Fleurieu region has some of the most significant sand dunes in the greater Adelaide region. Dunes provide coastal protection and habitat for a diverse range of species of animals and plants. On high-energy sandy coasts storm damage to the foredune is common, and through natural or anthropogenic causes this damage may develop to a single or series of large blowouts. Primary colonising dune plants may, over time, reclaim these areas.

a) Sea level rise, storm surge & coastal erosion - Rising sea levels can cause increased erosion of sand dunes, which serve as vital buffers against storms and high tides. The loss of dunes would reduce coastal protection and increase coastal habitat vulnerability to extreme weather. In coastal ecosystems where dunes are unable to retreat landward due to hard infrastructure, there may be localised loss of dune and coastal habitats and biodiversity, with potential regional implications to critical habitats and ecosystems.

b) Increasing average temperatures and aridity – Increased temperatures can lead to greater evaporation and aridity, potentially leading to desertification of sand dune habitats. Hotter drier conditions may increase plant stress during dry periods which may affect plant cover and habitat availability. Increased evaporation could lead to higher soil salinities beyond the tolerance of native species. These conditions could increase the range and promote migration of pest plants and animals.

c) Changed run-off regimes – Runoff changes may contribute to the erosion or deposition of sediment on sand dunes. If the runoff is more intense it could erode dunes reducing their effectiveness in protecting coastal areas.

d) Changes to Southern Ocean and Gulf waters - Coastal water changes can lead to shifts in sediment deposition patterns on sand dunes. If waves and tides change, dunes may be eroded, displaced or may build up depending on the coastal processes. These changes could impact on component flora and fauna.

e) Changes to groundwater aspects of the hydrological cycle – Groundwater can be an important part of maintaining the stability of sand dunes. A drop in groundwater levels may weaken dune vegetation and formation, making them more vulnerable to erosion.

3.6 Groundwater

The Hills and Fleurieu region is underlain by a variety of basement rocks and unconsolidated sediments that have shaped the occurrence of groundwater resources which influence the composition and location of groundwater dependent ecosystems.

a) Sea level rise, storm surge & coastal erosion - Rising sea levels may lead to increased saltwater intrusion into freshwater aquifers, affecting the quality and availability of groundwater that may impact on the location and composition of groundwater dependant ecosystems.

b) Increasing average temperatures and aridity - Higher temperatures can exacerbate evaporation from the soil, reducing groundwater recharge. Increased aridity may put stress on local water systems, potentially reducing water availability for ecosystems and human use.

c) Changed run-off regimes - Changes in runoff can affect the recharge rate of groundwater systems. Increased rainfall followed by dry periods may affect the filtration of water through the soil, potentially leading to contamination or reduced ground water quality.

d) Changes to Southern Ocean and Gulf waters – groundwater inputs are not likely to heavily impact the Southern Ocean or receiving gulf waters. However, impacts could include nutrient inputs and saltwater-freshwater interactions both potentially changing salinity levels and water chemistry.

e) Changes to groundwater aspects of the hydrological cycle - Changes in coastal water levels can affect the pressure on aquifers, especially those near the coast. This can lead to saltwater intrusion or alterations in groundwater flow, impacting the region's water supply.

4 Climate change threats to coastal and marine biodiversity by cell

The following section outlines the climate change threats to biodiversity for each cell for the Hills and Fleurieu coastline. These potential impacts have been informed by recent coastal literature and local coastal adaptation plans. Coastal Adaptation Plans have been recently published for the Alexandrina Council and City of Victor Harbour (limited to Chiton to the Bluff), with an absence of plan for Yankalilla Council. These plans have been used as supporting material to infer coastal inundation and erosion predictions to areas of coastal habitats under threat from sea level rise and other coastal hazards, however, it should be noted that these plans have a focus on asset and infrastructure and do not directly align with all cells used in this study.

4.1 Summary of threats to biodiversity by cell

Many of the potential threats to coastal and marine biodiversity and ecosystems are common between cells. Potential climate change threats include coastal erosion, increased storm activity, sea level rise, increased temperatures, and inundation and flooding. These climate change threats can directly contribute and exacerbate impacts to ecosystems through increased aridity, geomorphological changes to coastlines, changes and potential loss of habitats, and saltwater intrusion.

Sea level rise not only impacts coastlines directly it is the main driver for other coastal hazards, indirectly enabling an increase in their frequency and severity. As sea level rises, habitats will be required to adapt causing habitat migration inland (where this is possible) or loss (where this is not possible due to ‘coastal squeeze’). Ecosystems at risk include coastal freshwater wetlands, intertidal ecosystems, coastal dunes and vegetation habitats.

Storm activity is predicted to increase in both frequency and intensity as a result of climate change. The potential cause of greatest immediate threat to coastlines are the impacts of storm surges. These events will impact on coastal geomorphology and function, as it directly increases the rate of coastal erosion and inundation of land. More intense storm events coupled with longer periods of aridity will change run-off regimes. For example, heavier rainfall after dry periods can influence sedimentation and nutrient loading in coastal waters, potentially smothering algal reefs and seagrasses. Additionally, the first flush of stormwater runoff after prolonged dry periods may lead to increased pollutant loads reaching mudflats, saltmarshes, mangroves, seagrasses and sediment infauna negatively impacting water quality and the health of these habitats. Changes in sedimentation patterns may affect the stability and growth of saltmarshes and mangroves. Alternatively, changes to rainfall patterns and temperatures will have impacts on ecosystems such as wetlands due to changes in water availability and function, where wetlands could become more seasonal rather than permanent.

Increased aridity will also impact on ecosystems which rely on water availability, particularly impacting the cells in the Alexandrina Council due to its proximity to the Murray Darling catchment and wetland environments. A reduction or change in flow regimes will have cascading effects downstream in the lower Murray and on the freshwater coastal ecosystems (such as wetlands). Longer periods of aridity will also increase the risk of drought conditions and fires.

Higher temperatures may also increase evaporation rates, further stressing coastal habitats. Hotter drier conditions will place increased stress during dry periods. Increased evaporation could lead to higher soil salinities beyond the tolerance of native species. Higher temperatures will impact shallow estuarine water more severely than well-flushed open coastal waters potentially leading to increased incidence of algal blooms. Higher temperatures can lead to shifts in species distributions, potentially reducing biodiversity on beaches and rocky shores. Many species might not be able to adapt to the increasing temperatures.

Flooding and inundation as a direct result from sea level rise and rainfall/storm activity is an increasing threat to low-lying coastlines. These events are predicted to occur more frequently and can range from short term or temporary flooding to permanent inundation of land. The risk from flooding and inundation is the temporary or permanent loss of habitats and saltwater intrusion impacting both flora and fauna species, and coastal freshwater ecosystems. Changes in rainfall activity and flooding can also impact groundwater recharge rates impacting on water quality. Changes in groundwater levels can alter the salinity and water quality of coastal wetlands, leading to stress or loss of species in these habitats. Groundwater may become more saline and pollutants in groundwater may be driven upwards due to saline ocean water displacing freshwater in sediments.

Coastal erosion is also an increasing risk to this region causing soft shorelines to recede at accelerated rates. Coastal erosion is influenced by changes in sediment supply and wave energy and direction. The most vulnerable coastlines consist of soft sediments such as beaches, dunes and sand cliffs, which are all present in this region. Hard coastlines such as cliffs are also a risk to erosion or collapse from intense storm and wave activity. Coastal erosion impacts include loss or reduction of sandy beaches, dunes, dune vegetation, and cliff recession, in turn a loss of habitat to fauna species which rely on them such as beach nesting birds.

4.2 The Hills and Fleurieu coastal cells

Cell F1 Murray Mouth, southern shore of Hindmarsh Island

Potential climate change threats to coastal biodiversity

Cell F1 includes estuarine, saltwater, and wetland (freshwater) habitats associated with the Murray Mouth. These ecosystems are supported by native vegetation including dune, saltmarsh, and mangrove habitats.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Ramsar wetland of international importance
- Lower Murray River entrance
- Coastal groundwater dependent ecosystem (GDE)

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, increased drought, higher temperatures and more intense storms as described above.

In this cell, intertidal mudflat, mangrove and saltmarsh are closely dependent on tide heights and may need to migrate upslope. Supratidal samphire and swamp paperbark stands may be similarly affected.

Climate change may also impact this cell indirectly. For example, the Coorong district is underlaid by aquifers of varying suitability for domestic and agricultural uses. Increased extraction of groundwater for these uses due to longer periods of aridity under climate change projections could result in changes in groundwater levels that may alter the salinity and water quality of coastal wetlands, leading to stress or loss of species in these habitats.

Component	Issue	Proposed Action	Priority of Action	Key Players
Estuary & Wetlands	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality for pollutants that may contribute to algal blooms.	High (hazard)	• LHF • Council • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality for pollutants that may contribute to algal blooms.	Medium (threat)	• LHF • Council • Landowners
	Sea level rise will threaten tidally dependent species.	Monitor topography of low-lying land. Review buffer zones for species migration in development plans.	High (cons/threat)	• LHF • Council • Coast Protection Board • Landowners
	Groundwater may become more saline and pollutants in groundwater may be driven upwards due to saline ocean water displacing freshwater in sediments.	Undertake assessment of groundwater use	High (hazard)	• LHF • DEW • Council • Landowners

Cell F2 Goolwa (Beach Road) to the Murray Mouth the Sir Richard Peninsula

Potential climate change threats to coastal biodiversity

Cell F2 includes sheltered estuarine habitats and open coastal beaches and dunes. Native vegetation consists of extensive dune grassland, shrubs and trees.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Biodiversity of wetlands
- Coastal dunes

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on. The biodiversity of dune and sandy beaches will be affected through increasing storm intensity and sea level rise, resulting in increased erosion of beaches and dunes. The recession of the beach and dunes could range from 5 to 30 m, though this range would be affected by littoral drift factors.

Rising sea level affecting the estuarine shore may well be above average, assuming continuation of tectonic sinking in this area. Intertidal mudflat and saltmarsh are closely dependent on tide heights and will need to migrate upslope to survive; supratidal samphire and swamp paperbark stands will be similarly affected. In response, high resolution topographic land survey is needed to detail this threat. It will be necessary to review opportunities for recession of tide-dependent species on the landward side of the peninsula.

Component	Issue	Proposed Action	Priority of Action	Key Players
Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality for pollutants that may contribute to algal blooms.	High (hazard)	• LHF • Council • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality for pollutants that may contribute to algal blooms.	Medium (threat)	• LHF • Council • Landowners
	Sea level rise will threaten tidally dependent species.	Monitor topography of low-lying land. Review buffer zones for species migration in development plans.	High (cons/threat)	• LHF • Council • Coast Protection Board • DEW
	Groundwater may become more saline and pollutants in groundwater may be driven upwards due to saline ocean water	Undertake assessment of groundwater use.	High (hazard)	• LHF • DEW • Council

Component	Issue	Proposed Action	Priority of Action	Key Players
	displacing freshwater in sediments.			
Beach and Dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes.	High (cons/threat)	• LHF • SA Water • Council
		Implement restoration of native plant species.		
		Monitor recession rate of beaches and sand dunes.		

Cell F3 Goolwa Beach Road to Treleaven Avenue

Potential climate change threats to coastal biodiversity

Cell F3 includes a relatively narrow section of dunes. The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes
- Bird nesting habitats
- Native vegetation

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 10 – 20m over 50 years could be likely, given current IPCC forecasts. Likely increases in the low period swell component of wave climate and a possible increase in the magnitude of peak storm events increase the uncertainty in seasonal changes of beach state.

Sea-flood and routine high tide modelling indicates increased impact on dunes. Certainly 2100 scenarios indicate of the sea in alignment with the former shoreline. Erosion assessment is difficult and estimates of shoreline recession is up to 100 m by 2100, impacting dunes (Western et al. 2019).

Component	Issue	Proposed Action	Priority of Action	Key Players
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes	High (cons/threat)	• LHF • Coastal community groups • Council
		Implement restoration of native plant species.		
		Monitor recession rate of beaches and sand dunes.		

Cell F4 Tokuremoar Reserve

Potential climate change threats to coastal biodiversity

Cell F4 includes beaches and dunes that extend inland into low lying dunes. The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes
- Bird nesting habitats
- Native vegetation

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation and compounds the pressure of lack of floodwaters on the *Melaleuca halmaturorum* paperbark swamp. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 10 – 20m over 50 years are likely, given current IPCC forecasts. Probable increases in the low period swell component of wave climate and a projected increase in the magnitude of peak storm events increase the uncertainty in seasonal changes of beach state.

The dunes in this location are relatively low (at around 6-8m) and range in width landward between 40m and 80m. The land behind the dunes is at low elevation (around 2m) and forms part of the paperbark swamp. With the existing predictions of coastline recession at 70 to 100m, it is obvious that the narrow sections of dune are at high risk of erosion and marine transgression. Sea water inundation and potential flow around and behind remaining dunes through low lying land presents a risk and may accelerate the rate of erosion. Without intervention, the dune system would recede and likely breakdown on the western end (adjacent subdivision) and sea water flow behind the settlement. If this were to occur the ecology of the Reserve would change irreversibly (Western et al. 2019).

Component	Issue	Proposed Action	Priority of Action	Key Players
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species. Monitor recession rate of beaches and sand dunes.	High (cons/threat)	• LHF • National Parks Wildlife Service SA (NPWSSA) • Council • Coastal community groups
	Potential impact of increased development within cell and adjacent land for housing i.e. increase of stormwater directed into Tokuremoar Reserve			• Council • Coast Protection Board

Cell F5 Surfers Beach, Middleton

Potential climate change threats to coastal biodiversity

Cell F5 includes cliffs, beach, dunes and the nearshore algal reef. The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Intertidal ecosystems
- Native vegetation
- Beach nesting birds
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 10 – 20 m over 50 years could be likely, given current IPCC forecasts. Changes in wave climate which increased the long period swell component would increase the likelihood of foredune damage. Where dunes are eroded in front of aeolianite cliffs, these will be undermined at varied rates, depending on their local composition.

The 1 in 100 ARI storm event would significantly impact the beach and dune, especially in the southern areas. High tides 1 m greater than today would also routinely impact the dunes and the areas behind the dunes. Routine tidal action 1 m higher than present will cause the dune escarpment to recede. The extent of the recession is unknown but modelling in other areas indicates that the esplanade road would come under attack within 2050 – 2100 (Western et al., 2019).

In the context of a high energy sand dominated beach it is unlikely that protecting the base of the cliffs will be viable in the second half of this century. Therefore, a managed retreat strategy should be employed. This does not mean ‘surrender’ but rather monitor and adapt to the recession when it begins to occur. While a cliff collapse is unlikely, if the dunes eroded away in a storm event, and this was followed by another storm event, direct impact could come on the base of the cliffs. Over the longer term, it is also expected that routine action will impact the base of the cliffs (Western et al., 2019).

Erosion modelling suggests that in the second half of this century these sand dunes may have eroded away, and erosion is impacting urban settlement in this region. Note: The area behind the dunes is not flooded by sea water in this scenario. However, if the dune system broke down in SF4, then flooding is possible (Western et al., 2019).

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes and implement restoration of native plant species.	Medium (threat)	• Council • Coastal community groups • Coast Protection Board • LHF
		Implement restoration of native plant species.		
		Monitor recession rate of beaches and sand dunes.		

Cell F6 Middleton

Potential climate change threats to coastal biodiversity

Cell F6 includes cliffs east of Middleton Creek, beach and dunes. The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Estuary ecosystem
- Freshwater creek ecosystem
- Native vegetation
- Beach nesting birds
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

At Middleton Creek, the overall level of the beach south of the creek has dropped as a result of stormwater outflow across the beach. This will continue to occur if the speed of flow is not reduced through upstream intervention measures.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 10 – 20m over 50 years could be likely, given current IPCC forecasts. Changes in wave climate which accentuate the long period swell component would increase the likelihood of foredune damage. Cliffs will be eroded at varied rates, depending on their local composition: the ancient metamorphics of the Middleton headland will be little affected; however, the marl bluff between the Middleton Creek and Chapman Road is vulnerable to tidal sapping at its base.

The dunes east of Middleton Creek will be subject to sea-flood and routine high tide modelling indicates increased impact on dunes. Erosion assessment is difficult due to the presence of a substantial offshore reef and lack of sediment data. The 1 in 100 ARI storm event would significantly impact the beach and dune causing recession of the alluvial cliffs. High tidal action 1 m greater than today would also routinely impact the dunes (probably removing them) and directly attacking the base of the alluvial cliffs. Erosion modelling indicates a possible recession of 100 m by 2100 (Western et al., 2019).

Increased runoff, particularly after heavy rains, can lead to erosion of beaches and rocky shores. Excessive sedimentation can also reduce biodiversity and disrupt the biodiversity of local ecosystems.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • Coastal community groups • Coast Protection Board • LHF
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and estuary condition.	Medium (threat)	• LHF • Council • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes and implement restoration of native plant species. Implement restoration of native plant species. Monitor recession rate of beaches and sand dunes.	Medium (threat)	• Council • Coastal community groups • Coast Protection Board • LHF
Algal reefs	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality to reduce stressors on benthic flora	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

Component	Issue	Proposed Action	Priority of Action	Key Players
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Improve stormwater quality to reduce stressors on benthic flora. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF

Cell F7 Bashams Regional Park

Potential climate change threats to coastal biodiversity

Cell F7 includes beach and dunes. Ratalang (Basham's beach) reserve supports coastal dunes without substantial development at the rear of the dunes which is uncommon across the south coast of the Fleurieu Peninsula. Resulting in larger, taller dunes in this cell compared to adjoining areas. The dunes support native vegetation of importance for flora and fauna, the beach is an important nesting area for birds and the intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Native vegetation
- Beach nesting birds
- Beach ecosystem
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations suggest beach and dune recession of the order 5 – 30 m over 50 years could be likely, given current IPCC forecasts. Western et al (2020) suggests sea-flood and routine high tide modelling indicates increased impact on dunes. Certainly 2100 scenarios indicate impact of the sea in alignment with the former shoreline. Erosion assessment is made difficult by the presence of a substantial offshore reef and lack of sediment data. Estimates of shoreline recession range between 36 and 70 m by 2100. Recession distances of approximately 36 m by 2100 if the dune system stays intact, this extends to approximately 60 – 70 m recession by 2100 if the dune system breaks down (Western et al., 2019).

Within the dunes approximately halfway along the cell, a narrow entry point (access point 3) to the beach limits the amount of foot traffic to the beach and therefore limits potential sand erosion. The area to the east is vulnerable to inundation and erosion. Evidence exists that seawater is making small incursions through the dune system now. Sea level rise and changes in wave climate will exacerbate this problem. Should water penetrate the dunes for any length of time then the ecology of this region may be significantly impacted. Incursions through the dunes will likely see a breakdown of the foredunes. Incursions of seawater will irreversibly change the ecology behind the dunes (Western et al., 2019).

Increased runoff, particularly after heavy rains, can lead to erosion of beaches and rocky shores. Excessive sedimentation can also reduce biodiversity and disrupt the biodiversity of local ecosystems.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal Community groups • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species. Monitor recession rate of beaches and sand dunes.	Medium (threat)	• Council • Coastal community groups • Coast Protection Board • LHF
Algal reefs	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• LHF • Council
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• DEW • LHF • Council
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• DEW • LHF • Council
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• DEW • LHF • Council

Cell F8 Commodore Point, Horseshoe Bay and Freemans Knob

Potential climate change threats to coastal biodiversity

Cell F8 includes beaches, dunes, algal reef and seagrasses. Much of this cell is protected from direct ocean swells by Pullen Island, an important refuge for seabird species. The geomorphology of the bay will restrict flushing and may make it more susceptible to pollutants in stormwater that will occur under more intense rainfall events.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Native vegetation
- Reef and seagrass ecosystems
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to the small areas of dune vegetation. Rising sea levels will see increased storm damage to beaches and foredunes; Bruun Rule calculations of beach recession suggest an order 5 – 30m over 50 years could be likely, given current IPCC forecasts. Changes in wave climate which increased the long period swell component would increase the likelihood of foredune damage. This cell is resilient to projected changes due to the massive headlands and lack of floodable land; however, the lack of a buffer zone allowing the recession of Horseshoe Bay beach creates a potential long-term threat of beach loss.

Green Bay assessment by Western et al. (2019) identifies no formal evaluation methodologies exist to estimate the rate of erosion at the rear of Green Bay. Modelling demonstrates that should sea levels rise as projected the embankment at the rear of the bay will come under increasing pressure from impacts of the sea. The boulders and cobbles at the rear of the bay are unlikely to be sufficient to prevent the undermining of the embankment.

At Crockery Bay, the modelling for 2100 does show increased impact at the back of the bay which is likely to cause the breakdown of the embankment (likely to also include imported fill). However, even in the worst-case scenario, recession of the backshore would be limited by the nature of the geological layout (rocky outcrops and rocky beach). Recession beyond 5 – 10 m is unlikely (Western et al., 2019).

Within Horseshoe Bay, the storm flood scenarios and high tide scenarios indicate that the existing dune/embankment will come under increasing pressure. If sea level rises by the projected 1 m it is very unlikely that the bay could retain its existing formation (dune line and position of assets). Using two erosion methodologies it is estimated ~26 m to 29 m erosion by 2100 (with projected rises of 1 m), and ~8 m by 2050 (with projected rises of 0.3 m) (Western et al., 2019).

Increased runoff, particularly after heavy rains, can lead to erosion of beaches, rocky shores and reefs. Excessive sedimentation can also reduce biodiversity and disrupt the biodiversity of local ecosystems.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal Community groups • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Monitor recession rate of beaches and sand dunes. Implement restoration of native plant species.	Medium (threat)	• Council • Coast Protection Board • Coastal Community groups • LHF
Algal reefs	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • LHF • DEW
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • LHF • DEW
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • LHF • DEW
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • LHF • DEW

Cell F9 Knights Beach and Boomer Beach

Potential climate change threats to coastal biodiversity

Cell F9 includes dunes and beach. The dunes support native vegetation of importance for flora and fauna, the beach is an important foraging area for birds and the intertidal areas support infauna that birds feed on.
Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Coastal cliffs
- Native vegetation
- Beach nesting birds
- Beach ecosystem

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 5 – 15m over 50 years could be likely, given current IPCC sea level forecasts.

For this section of coastal dunes two evaluation methods have been utilised to provide the basis for an estimate of shoreline recession. Sea-flood and routine high tide modelling also indicate increased impact on dunes. Erosion assessment is made difficult by the presence of a reef at -5 m. Estimates of shoreline recession range between 18 m and 23 m by 2100. Estimate of shoreline recession by 2050 range between 5 m and 7 m (Western et al., 2019).

The trainline from Goolwa to Victor Harbor emerges towards the coast in this cell and is located at the top of the escarpment effectively dissecting the dune. As this is a fixed line, it will not be possible for the dune to translate landwards, and therefore the slope of the dune must increase. This slope will become increasingly unstable, and successive collapses will tend to make the escarpment increasingly vertical, and increasingly more unstable (Western et al., 2019).

Knights beach (eastern end of cell) modelling shows that the backshore would be more significantly impacted by 2100 by storm events but appears less significant with routine tidal action. However, it is important to note that modelling is conducted on current sand levels, and it isn't possible to establish the likely sand environment in 2100. The modelling demonstrates that the impact would be higher on the eastern side of the bay (Western et al., 2019).

Changes in wave climate which increased the long period swell component would increase the likelihood of foredune damage, as well as changing mean littoral drift speeds and possibly direction. For beaches such as this, where refraction of long period swell will be important, change in wave climate will greatly increase unpredictability in beach response.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal Community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal Community groups • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • Coastal Community groups • LHF
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • DEW • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species.	Medium (threat)	• Council • Coastal Community groups • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

Component	Issue	Proposed Action	Priority of Action	Key Players
	seagrasses, reducing biodiversity.			
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF

Cell F10 Watson's Gap to the Hindmarsh River

Potential climate change threats to coastal biodiversity

Cell F10 includes an estuary, dunes, and beach. The dunes support native vegetation of importance for flora and fauna. The beach is an important foraging area for birds and intertidal areas support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Native vegetation
- Beach nesting birds
- Beach and intertidal reef ecosystem
- Estuary ecosystem

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to dune vegetation. Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach recession could be compromised by active littoral drift values here, however, recession of the order 5 – 15m over 50 years could be likely, given current IPCC sea level forecasts. Rising sea levels threaten tidal inundation of low-lying land at Watson's Gap.

Western et al. 2021, identifies threats for this cell including coastal areas which are habitats for shore nesting birds are likely to be disturbed by retreating shorelines. The impact is likely to be the greatest in locations where shorelines are unable to retreat naturally due to human intervention. In this cell, the trainline will prevent a natural recession of the coastline and rising sea levels are likely to impact bird habitats so that they are disturbed or lost. Additional risks relate to the location of storm water outlets which is already interacting with actions of the sea. Lower sand levels here will also increase potential for actions of the sea to erode the embankment behind.

Increased runoff, particularly after heavy rains, can lead to erosion of beaches, rocky shores and reefs. Excessive sedimentation can also reduce biodiversity and disrupt the biodiversity of local ecosystems.

Changes in wave climate, which increased the long period, swell component would increase the likelihood of foredune damage, as well as changing mean littoral drift speeds and possibly direction. For beaches such as this, where refraction of long period swell will be important, change in wave climate will greatly increase unpredictability in beach response.

Changes in ocean temperatures, salinity, and acidity (from increased CO_2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • DEW • Landowners • LHF
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • DEW • Landowners • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes.	Medium (threat)	• Council • DEW • LHF • Coastal community groups
		Implement restoration of native plant species.		
	Storm water is scouring the beach, reducing sand levels around outlets, and in some locations preventing the dune from establishing.	Conduct a feasibility study and cost estimates to reduce the flow of storm water to the beach from two outlets adjacent Hayward Court.	Medium	• Council
		Upgrade storm water outlet at Yandra Terrace with design able to be adjusted for cycles of erosion / accretion.	High	• Council
Algal reefs	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF

Cell F11 Hindmarsh River to Inman River

Potential climate change threats to coastal biodiversity

Cell F11 includes two estuaries, coastal dunes and beach ecosystems. The beach and dunes are important areas for nesting birds. The dunes also support native vegetation of importance for flora and fauna. The intertidal areas including the estuary support infauna that birds feed on and a reef ecosystem.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Native vegetation
- Beach nesting birds
- Beach ecosystem
- Reef ecosystem
- Estuary ecosystem

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Analysis of climate change projections suggest that the low-lying parts of the coastal plain will be subject to both flooding and erosion in the medium term. Rising sea levels will lead to increased foredune damage and recession. Where recession is not possible, beaches in front of hard protection will narrow and may be lost. In the interim beach response to seasonal changes may become more unpredictable. The shoreline is controlled by reef protection; however, this may suffer radical re-alignment following sea level rise. Changes in wave climate, such that an increasing proportion of energetic long period swell occurs, would have a marked impact on the narrow medium energy beaches and low dunes of this cell, due to refraction effects on long period waves.

Western et al., 2021 summarises the main threat from sea level rise having an increasing impact to backshores so that the dune system will recede resulting in permanent recession of the sand dunes. Unless room is made landward of the sand dunes, they will be unable to retreat and will be lost to the foreshore. As the protected backshore is unable to recede, sand levels will continue to lower on the beach which may in time be lost for community use. Community concern may cause social disruption and ecosystem disruption is likely to occur in some freshwater ecologies in reserves/parks and within the two estuaries. Sea water flooding through to low-lying land that is currently freshwater ecology would be irreversibly disrupted with incursion of saltwater. Habitats of shore nesting birds are likely to be disturbed or lost. The impact is likely to be the greatest in locations where shorelines are unable to retreat naturally due to human intervention (Western et al., 2021).

Groundwater flow can influence the moisture levels in the coastal environment, affecting the vegetation and organisms that inhabit these zones. Lower groundwater levels could increase vulnerability to drought and erosion. As sea levels rise, groundwater salt intrusion is likely to occur.

Component	Issue	Proposed Action	Priority of Action	Key Players
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • DEW • LHF
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species. Monitor recession rate of beaches and sand dunes.	Medium (threat)	• Council • Coastal community groups • DEW • LHF
	Impacts of sea level rise combined with existing stormwater and pedestrian access threaten the integrity and protection values of dunes at Victor Central.	Design and implement a program to consolidate and vegetate the dune system from the Inman River to the causeway. Remove gaps (storm water outlets and pedestrian points)	High (threat)	• Council • Coastal community groups • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF

Cell F12 Inman River to Rosetta Harbour

Potential climate change threats to coastal biodiversity

Cell F12 includes an estuary, coastal dunes and beach. The beach and dunes are important areas for nesting birds. The dunes also support native vegetation of importance for flora and fauna. The intertidal areas including the estuary support infauna that birds feed on.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes and vegetation
- Native vegetation
- Beach nesting birds
- Beach ecosystem
- Estuary ecosystem

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Analysis of climate change projections suggest that the low-lying parts of the coastal plain will be subject to both flooding and erosion in the medium term. Rising sea levels will lead to increased foredune damage and recession. Where recession is not possible, beaches in front of hard protection will narrow and may be lost. In the interim beach response to seasonal changes may become more unpredictable. Where the plan form of the shoreline is controlled by reef protection this may suffer radical re-alignment following sea level rise.

Changes in wave climate, such that an increasing proportion of energetic long period swell occurs, would have marked impact on the narrow medium energy beaches and low dunes near the mouth of the Inman, due to refraction effects on long period waves.

Sea level rise is predicted to cause increasing impacts to backshores causing unprotected areas recede and are likely to threaten the integrity of protected areas. Coastal areas which are habitats for shore nesting birds are likely to be disturbed by retreating shorelines. The impact is likely to be the greatest in locations where shorelines are unable to retreat naturally due to human intervention. In this cell, the cycleway and Franklin Parade will prevent the shoreline from retreating naturally and habitats are likely to be disturbed or lost (Western et al., 2021).

Groundwater flow can influence the moisture levels in the coastal environment, affecting the vegetation and organisms that inhabit these zones. Lower groundwater levels could increase vulnerability to drought and erosion.

Component	Issue	Proposed Action	Priority of Action	Key Players
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater estuary condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater estuary condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes and implement restoration of native plant species.	Medium (threat)	• Council • Coastal community groups • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality. Undertake restoration and monitoring of benthic flora.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF

Cell F13 The Bluff

Potential climate change threats to coastal biodiversity

Cell F13 is a granite headland that supports algal habitats relatively remote from urban stormwater inputs that may discharge higher pollutant loads under increased storm intensities under climate change projections. This cell is outside the area of the Coastal Adaptation Plan for the City of Victor Harbor (Western et al., 2021)

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Algal habitats
- Temperate reefs
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, increased drought, higher temperatures and more intense storms as described above.

Seasonal surface run-off on slopes will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off on slopes. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches and to talus slopes at the base of cliffs.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

	Increased storm surge can cause dislodgment of algae and seagrasses.	Undertake benthic flora mapping to determine areas or opportunities for restoration. Undertake benthic flora restoration.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF

Cell F14 Petrel Cove to Newland Head

Potential climate change threats to coastal biodiversity

Cell F14 includes dissected plateau, cliffs and reef of Kanmantoo Series sediments. Some clifftop dunes and calcarenite. Inshore sane and pebble beach and offshore platform reef. The reef supports a number of a number of temperate species of fauna and flora including seagrasses.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Algal habitats
- Temperate reefs and seagrasses
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches and to talus slopes at the base of cliffs.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • LHF

Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Implement restoration of native plant species.	Medium (threat)	• Council • Coastal community groups • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• LHF • Council

Cell F15 Newland Head to Parsons Beach

Potential climate change threats to coastal biodiversity

Cell F15 includes coastal cliffs of calcarenite and dunes, with inshore sand with platform reef offshore. The reef supports a number of a number of temperate species of fauna and flora including seagrasses.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native vegetation
- Creek and estuary ecosystems
- Coastal cliffs
- Reef ecosystems

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation and some species may be unable to adapt to reduced soil water levels and die out. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores at Waitpinga and Parsons Beaches. Given the IPCC projections of sea level rise, beach recession of an order of 5 to 15 metres in 50 years could be expected. Some low-lying areas adjacent to the Waitpinga Creek estuary, appear to be vulnerable to flooding following sea level rise. Tide and water depth dependent habitats on reefs will be impacted by sea level rise.

Changes in runoff can lead to increased erosion around cliffs, contributing to their destabilization. The movement of water may also impact cliff-side vegetation. Changes in rainfall will potentially lead to higher pollutant loads during first flush events.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs (rocky headlands)	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • LHF

	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • NPWSSA • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and estuary condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species.	Medium (threat)	• Council • Coastal community groups • NPWSSA • LHF
Algal reefs	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Increased storm surge can cause dislodgment of algae.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • NPWSSA • DEW • LHF

Cell F16 Parsons Beach to Tunk Head

Potential climate change threats to coastal biodiversity

Cell F16 includes high cliffs, sloping boulder strewn platforms and sandy beach pockets, as well as inshore reef ecosystems. The reef supports a number of a number of temperate species of fauna and flora; however, this is generally a high energy shore.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native vegetation
- Creek and estuary ecosystems
- Cliffs
- Reef ecosystems

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will stress remnant vegetation and slow natural recovery from damage. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes, however, unpredictable intense rainstorms will locally cause fast runoff in small catchments.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • DEW • LHF
	Increased sea levels contribute to more frequent and intense	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • NPWSSA

	wave action, which accelerates cliff erosion.			• DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners • EPA
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Implement restoration of native plant species.	Medium (threat)	• LHF • Council
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • NPWSSA • DEW • LHF

Cell F17 Tunk Head to Deep Creek CP

Potential climate change threats to coastal biodiversity

Cell F17 includes coastal cliffs and dunes which support native vegetation and nesting areas for birds. there are several small catchments draining to this coast as well as the Tunkalilla Creek. This cells also includes intertidal and reef ecosystems inshore supporting infauna for birds to feed on and other temperate flora and fauna.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek ecosystems
- Intertidal and reef ecosystems
- Coastal cliffs
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Rising sea level will lead to recession of the ocean beach and barrier dune areas; this could be of an order of 5 to 30 metres, though this range would be affected by littoral drift factors. Likely increases in the low period swell component of wave climate and a possible increase in the magnitude of peak storm events increase the uncertainty in seasonal changes of beach state. Nearshore reef species will be threatened by sea level rise.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Council • Coastal community groups • NPWSSA • DEW

				• LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Council • Coastal community groups • NPWSSA • DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on creek/estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • NPWSSA • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Implement restoration of native plant species.	Medium (threat)	• Council • Coastal community groups • NPWSSA • DEW • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality.	Medium (threat)	• Council • NPWSSA • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • NPWSSA • DEW • LHF

Cell F18 Deep Creek CP to Fishery Beach

Potential climate change threats to coastal biodiversity

Cell F18 includes steep coastal cliffs with beach pockets and small creeks and estuaries. There are narrow inshore reef and small areas of seagrass. The inshore reef supports several temperate flora and fauna species while the terrestrial zone supports native vegetation.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will stress remnant vegetation and slow natural recovery from damage. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast runoff in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO_2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • NPWSSA • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • NPWSSA • DEW • LHF
	Increased sea levels contribute to more frequent and intense wave action, which	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Coastal community groups • NPWSSA

	accelerates cliff erosion.			• DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on creek fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • NPWSSA • DEW • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• NPWSSA • DEW • LHF

Cell F19 Fishery Beach to Cape Jervis

Potential climate change threats to coastal biodiversity

Cell F19 includes coastal cliffs and slopes which support native vegetation particularly around the creek and estuary. Rocky reef platforms inshore as well as a mixed sand and reef habitat seaward of the platform also makes up this cell. These reefs and intertidal zones support a number of temperate flora and fauna.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Beach habitat
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • NPWSSA • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • NPWSSA • DEW • LHF

	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Coastal community groups • NPWSSA • DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF • Council • Landowners • EPA
	Higher temperatures likely to lead to increased algal blooms with impacts on creek fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • NPWSSA • DEW • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• NPWSSA • DEW • LHF
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• NPWSSA • DEW • LHF

Cell F20 Cape Jervis to Rapid Head

Potential climate change threats to coastal biodiversity

Cell F20 includes high coastal sloped cliffs and pocket beaches, backed by foredunes and dunes. Granite boulders are also present on the adjacent shore platform. There is a heavy limestone inshore reef and intertidal ecosystems supporting temperate flora and fauna species. The coastal dunes and creek and estuary ecosystems support native vegetation, and nesting and foraging areas for birds.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes
- Native vegetation
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Coastal cliffs
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches. Given the range of sea level rise projected by the IPCC (2001), many talus slopes at the base of sea cliffs will be trimmed back.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • DEW • LHF
	Increased sea levels contribute to more frequent and intense wave action, which accelerates cliff erosion.	Restoration of native plant species to assist soil stabilisation	Medium (threat)	• Coastal community groups • Council • DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • DEW • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners

	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F21 Rapid Bay

Potential climate change threats to coastal biodiversity

Cell F21 includes coastal cliffs, creek and estuary ecosystems, supported by native vegetation, as well as intertidal and reef ecosystems supported by dense seagrass meadows and other temperate flora and fauna.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

A projected rise of 0.3 m in 50 years would cause minor recession to the gravel beach face and minor flooding to low ground near the creek. The water table under the broad gravel plain would directly reflect tide heights. Flow in the creek would become irregular, mainly occurring following unpredictable intense rainstorms.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • DEW • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species.	High (Cons/threat)	• Coastal community groups • Council • DEW • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA

	flush from the landward end.			
	Higher temperatures likely to lead to increased algal blooms with impacts on creek fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to fragile dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • DEW • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F22 Second Valley to Lady Bay

Potential climate change threats to coastal biodiversity

Cell F22 includes high coastal cliffs and discontinuous boulder pocket beaches, with small creeks incised. Native vegetation occurs within the beach and creek ecosystems. There are intertidal and temperate reef ecosystems supported by dense seagrass.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native vegetation
- Coastal dunes
- Intertidal and reef ecosystems
- Coastal cliffs
- Creek and estuary ecosystems

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Increasing plant and animal resilience to progressive climate change is important for this area and can be assisted by improving connectivity between remnant vegetation patches. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches. Given the range of sea level rise projected by the IPCC (2001), many talus slopes at the base of sea cliffs will be trimmed back. Tide and water depth dependent habitats on reefs will be impacted by sea level rise. Some intertidal sloping reefs will accommodate species migration. Flat low tide reef platforms will see species change.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO_2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF
	Increased aridity likely to make growing conditions less suitable	Restoration of native plant species.	High (Cons/threat)	• Coastal community groups • Council

	to native vegetation fragments.			• LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the creek/estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F23 Lady Bay to Bungala River

Potential climate change threats to coastal biodiversity

Cell F23 includes the Yankalilla river estuary ecosystem, and beach and dune ecosystems backed by coastal cliffs. These ecosystems are supported by native vegetation and dune scrub and well as providing nesting areas for birds. Intertidal ecosystems with infauna for birds to feed, and temperate reef ecosystems including dense seagrass.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Coastal dunes
- Native vegetation
- River, creek and estuary ecosystems
- Intertidal and reef ecosystems
- Coastal cliffs
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach change suggest a recession of the order 5 – 30m over 50 years could be likely, given current IPCC sea level forecasts. Both beach and dune recede under this process and over time consideration will have to be given to dune recession. CSIRO forecasts suggest fewer storms, but a small increase in storm magnitude, increasing the level of unpredictability of seasonal beach change. Rising sea levels threaten tidal inundation, ground water inundation behind the dunes (in low lying areas), and erosion of the former dune area south of Yankalilla River. All climate models project drier conditions for southern South Australia, together with increased evapotranspiration: it is clear that in some years soil field capacity may not be reached in winter and seasonal runoff in the Yankalilla River may be greatly reduced; however, fast run off from intense storms in summer may give irregular flows. Over time, increasing aridity will slow natural recovery from damage to dune vegetation.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on creek/estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species. Investigate and implement monitoring plan for planned dune retreat	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners

	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F24 Bungala River to SW bank of Carrickalinga Creek

Potential climate change threats to coastal biodiversity

Cell F24 includes an estuarine ecosystem of the Bungala River, beach and dunes. The dunes support native vegetation including coastal shrubland and grasses There is an inshore limestone reef with intertidal and reef ecosystems supporting a number of flora and fauna species, as well as extensive dense seagrass offshore.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Rising sea levels will see increased storm damage to foredunes; Bruun Rule calculations of beach change suggest a recession of the order 5 – 30m over 50 years could be likely, given current IPCC sea level forecasts. Both beach and dune recede under this process and over time consideration will have to be given to dune recession. CSIRO forecasts suggest fewer storms, but a small increase in storm magnitude, increasing the level of unpredictability of seasonal beach change. Rising sea levels threaten tidal inundation of small areas of low-lying land adjacent to Bungala Creek and ground water intrusion risk between Bungala River and Carrickalinga Creek. All climate models project drier conditions for southern South Australia, together with increased evapotranspiration: it is clear that in some years soil field capacity may not be reached in winter and seasonal runoff in the Bungala River may be greatly reduced; however, fast run-off from intense storms in summer may give irregular flows. Over time, increasing aridity will slow natural recovery from damage to dune vegetation.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA

	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species. Investigate and implement monitoring plan for planned dune retreat.	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F25 Carrickalinga Creek to Carrickalinga Head

Potential climate change threats to coastal biodiversity

Cell F25 includes sandy beach, low dunes and an estuarine and creek ecosystem of the Carrickalinga Creek. This cell contains extensive dense seagrass ecosystems as well as inshore reef and intertidal ecosystems. The dunes are supported by native vegetation including dune shrubland and grasses.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native dune vegetation
- Creek and estuary ecosystems
- Coastal cliffs
- Intertidal and reef ecosystems
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Acceleration of current sea level rise will see increased storm damage to foredunes; Bruun Rule calculations of beach change suggest a recession of the order 5 – 30m over 50 years could be likely, given current IPCC sea level forecasts. CSIRO forecasts suggest fewer storms, but a small increase in storm magnitude, increasing the level of unpredictability of seasonal beach change. Rising sea levels threaten tidal inundation of low-lying land adjacent to Carrickalinga Creek.

All climate models project drier conditions for southern South Australia, together with increased evapotranspiration: it is clear that in some years soil field capacity may not be reached in winter and seasonal runoff in the Carrickalinga Creek may be greatly reduced; however, fast run-off from intense storms in summer may give irregular flows. Over time increasing aridity will slow natural recovery from damage to dune vegetation.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF

	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F26 Carrickalinga Head to Myponga Head

Potential climate change threats to coastal biodiversity

Cell F26 includes high bedrock cliffs and pocket beaches, with an inshore limestone reef and dense seagrass ecosystems offshore. The clifftops and pocket beaches are supported by native vegetation, while the reef is supported by intertidal flora and fauna.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native vegetation
- Intertidal and reef ecosystems
- Pocket beach ecosystems
- Coastal cliffs
- Beach nesting birds

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Changes in wave climate, likely to increase the long period swell component, would accentuate high tide changes to backshores in pocket beaches. Given the range of sea level rise projected by the IPCC (2001), many talus slopes at the base of sea cliffs will be trimmed back. Tide and water depth dependent habitats on reefs will be impacted by sea level rise; some intertidal sloping reefs will accommodate species migration; flat low tide reef platforms will see species change.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean acidity (from increased CO2 levels) can directly affect the health of temperate reefs. Increased acidification may impact the life history of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation	High (Cons/threat)	• Coastal community groups • Council • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species.	High (Cons/threat)	• Coastal community groups • Council • LHF

Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners • EPA
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Monitor stormwater quality and creek condition. Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

Cell F27 Myponga to Sellicks

Potential climate change threats to coastal biodiversity

Cell F27 includes coastal cliffs, the Myponga estuary and creek ecosystem, and beach backed by low dunes. There is an intertidal rocky shore reef ecosystem and dense seagrass ecosystem offshore. The coastal cliffs, dunes, and estuary are supported by native vegetation, while the rocky shore and beach supports beach nesting birds and a number of intertidal fauna species.

Biodiversity Assets potentially vulnerable to climate change in this cell include:

- Native vegetation
- Coastal dunes
- Creek and estuary ecosystems
- Intertidal and reef ecosystems
- Beach nesting birds
- Beach ecosystems
- Coastal cliffs

These ecosystems may be particularly vulnerable to the direct impacts of climate change particularly sea level rise, coastal erosion, increased drought, higher temperatures and more intense storms as described above.

Over time increasing aridity will slow natural recovery from damage to remnant vegetation. Seasonal run-off in small creeks will be drastically reduced by soil water budget changes; however, unpredictable intense rainstorms will locally cause fast run-off in small catchments. Myponga Beach and the dune will recede in the face of sea level rise. This is likely to occur in widely spaced storm events. Approximate Bruun Rule calculations would put recession at 5 to 30m for a 0.3m sea level rise over 50 years. Change of this order would require protection or relocation of the houses built on the dunes. Changes in wave climate, likely to increase the long period swell component, would increase the unpredictability of seasonal change to the beach. Given the significance of the low narrow dune as a buffer and first line of defence against storm damage, improved dune management is a priority. Tide and water depth dependent habitats on reefs will be impacted by sea level rise. Those reef platforms sloping through the tidal range could allow some species migration.

Marine heatwaves place further stress temperate reefs and seagrasses, reducing biodiversity. Higher atmospheric temperatures will lead to increased marine heatwaves, loss of species in the intertidal with longer than experience to grow back due to increased stressors e.g. loss of sediment. Higher sea surface temperatures increase the potential for algal blooms.

Changes in ocean temperatures, salinity, and acidity (from increased CO_2 levels) can directly affect the health of temperate reefs. Warmer waters and increased acidification may hinder the growth of calcareous organisms, such as marine molluscs and phytoplankton.

Component	Issue	Proposed Action	Priority of Action	Key Players
Cliffs	More intense rainfall events likely to cause soil erosion.	Restoration of native plant species to assist soil stabilisation.	High (cons/threat)	• Coastal community groups • Council • LHF
	Increased aridity likely to make growing conditions less suitable to native vegetation fragments.	Restoration of native plant species.	High (cons/threat)	• Coastal Community groups • Council • LHF
Creek/Estuary	More intense rainfall events likely to lead to increased pollutants washed into the estuary during first flush from the landward end.	Monitor stormwater quality and creek condition.	Medium (hazard)	• Council • DEW • LHF • Landowners
	Higher temperatures likely to lead to increased algal blooms with impacts on estuarine fauna.	Monitor stormwater quality and creek condition.	Medium (hazard)	• Council • DEW • LHF • Landowners
Beach and dunes	Increased sea levels contribute to more frequent and intense wave action, which accelerates beach and dune erosion.	Restrict public access to dunes. Implement restoration of native plant species.	Medium (threat)	• Coastal community groups • Council • LHF
Algal reefs and seagrasses	More intense rainfall events likely to lead to increased pollutants washed into coastal waters during first flush.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Increased storm surge can cause dislodgment of algae and seagrasses.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Higher temperatures can lead marine heatwaves and increased stress on temperate reefs and seagrasses, reducing biodiversity.	Monitor stormwater quality and creek condition.	Medium (threat)	• Council • DEW • LHF • Landowners
	Ocean acidification can impact the life history of marine species.	Undertake benthic flora mapping to determine areas or opportunities for restoration.	Medium (threat)	• Council • DEW • LHF • Landowners

5 Conclusion and Recommendations

Climate projections for the Hills and Fleurieu region to 2100 indicate significant changes for land and seascapes, including rising temperatures, more frequent and intense heatwaves, and shifting rainfall patterns. Average temperatures are increasing, with hotter summers and milder winters. Rainfall is projected to decrease during the cooler months, exacerbating drought conditions and reducing water availability. Extreme weather events such as bushfires and storms are likely to become more intense and frequent. Coastal areas are experiencing rising sea levels, leading to increased erosion and inundation risks. These changes are having significant impacts on coastal ecosystems, and the biodiversity.

Changing climatic conditions exacerbate the pressures on natural systems that occur due to widespread landscape modification for industrial, agricultural or urban development in turn reducing the area for natural systems to adapt to changes. The alteration of natural landscapes disrupts ecosystems, reduces biodiversity, and increases vulnerability to extreme weather events. Urban sprawl and changes in land use also increase the risk of flooding and erosion, as natural water runoff patterns are altered, and stormwater management systems are often inadequate.

Planning for further growth of the Hills and Fleurieu population a geographical spread of development should prioritise the protection and restoration of biodiversity. Biodiverse ecosystems enhance the ability of natural habitats to adapt to changing conditions, potentially reducing the need for costly engineered solutions. Integrating biodiversity protection into urban and coastal planning not only ensures long-term environmental sustainability but also improves the quality of life for communities by promoting cleaner air, water, and more liveable spaces. Where possible biodiversity protection and restoration should be incorporated into urban and peri urban planning and coastal adaptation plans.

Nature-based solutions (NbS) can be incorporated into urban planning and coastal adaptation plans by utilizing natural systems and processes to address climate change challenges, enhance resilience, provide climate refuges, and promote sustainability. In urban areas, this can include integrating green infrastructure such as green roofs, urban forests, permeable pavements, and rain gardens to manage stormwater, reduce heat island effects, and improve air quality. In coastal areas, NbS might involve restoring wetlands, saltmarsh, samphire, and seagrass meadows, which can reduce coastal erosion, enhance biodiversity, and act as natural buffers against storm surges and rising sea levels. Additionally, urban planners and land managers can prioritize the protection and expansion of natural habitats like forests, dunes, and reefs, which can mitigate flood risks and enhance carbon sequestration. By incorporating these strategies into planning processes, cities and coastal regions can not only mitigate the impacts of climate change but also improve ecosystem health, enhance community well-being, and potentially reduce reliance on expensive, engineered solutions.

Monitoring provides an evidence base for planning decisions. Monitoring should be incorporated into urban and coastal planning and restoration activities to ensure the effectiveness of implemented strategies, track environmental changes, and adapt to evolving climate conditions. Regular monitoring allows for the assessment of ecosystem health, the success of restoration efforts, and the identification of emerging challenges, such as habitat degradation or increased vulnerability to climate impacts. It provides critical data that can inform adaptive management, enabling planners and land managers to adjust strategies in real-time based on observed outcomes. Monitoring also helps measure the progress of biodiversity conservation and climate resilience goals, ensuring that urban and coastal areas remain sustainable and resilient. Additionally, it fosters transparency and accountability, supporting informed decision-making and community engagement, which are essential for long-term success. By integrating monitoring into planning and restoration activities, regions can proactively respond to change, maximize the benefits of nature-based solutions, and safeguard both human and ecological well-being.

This report offers a high-level assessment of climate change threats to biodiversity in the Hills and Fleurieu region, based on recent coastal literature and consultations with Landscape Hills and Fleurieu. For each cell, the report discusses the potential risks posed by climate change and outlines proposed actions. However, it is recommended that a comprehensive risk assessment and coastal hazard spatial analysis be conducted to further evaluate the region's risks and vulnerabilities. This process would enable a more robust evaluation of risks, particularly in relation to coastal erosion and inundation projections, allowing for better prioritization of actions and more effective management including potential adaptation strategies.

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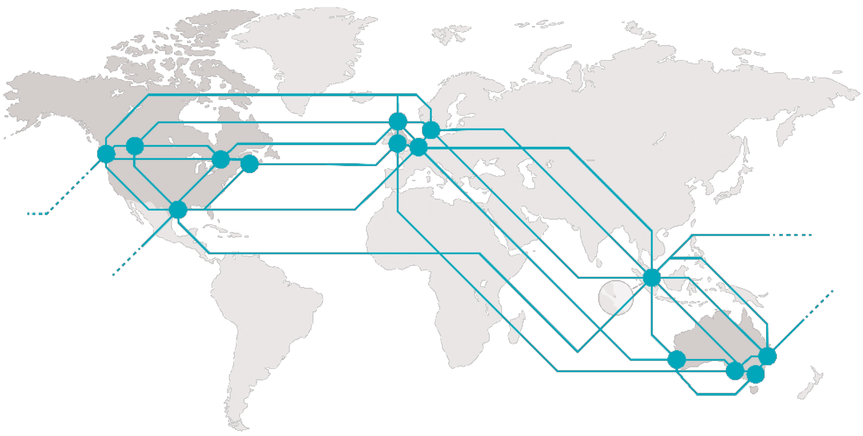

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