Goode Beach, Albany. Photo: Peter Morris.

Climate Change Adaptation Coastal & Marine

South Coast Region of Western Australia

A background paper for the Climate Adaptation Addendum to *Southern Prospects 2011-2016*. Prepared by Aurora Environmental for South Coast NRM.

SOUTHCOAST NATURAL RESOURCE MANAGEMENT

Australian Government

National Landcare Programme

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Abbreviations

ACECRC	Antarctic Climate and Ecosystems Cooperative Research Centre
AHD	Australian height datum
CO_2-eq	Carbon Dioxide Equivalent
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DPaW	Department of Parks and Wildlife
ENSO	El Nino Southern Oscillation
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
LGA	Local Government Authority
NRM	Natural Resource Management
ppm	Parts per million
SCMG	South Coast Management Group
UCL	Unallocated Crown Land
WALGA	Western Australian Local Government Association

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Contents

Figures & Tables

1 - Foreword

The background papers to the *Climate Adaptation Addendum of Southern Prospects 2011-16* are a series of detailed technical documents on the potential impacts of the South Coast region's changing climate and how people are adapting to it.

The papers were commissioned by South Coast NRM in 2014 and were part of the Regional Natural Resource Management Planning for Climate Change - Stream 1 project of the Australian Government.

The background papers synthesise the current information on the effect of climate change on each natural resource theme, community capacity to adapt and how people are already adapting. They also document some of the gaps. The papers provide useful background for community consultation through South Coast NRM reference groups. The reference groups have used the papers to develop climate adaptation goals and outcomes for *Southern Prospects 2011-2016.*

South Coast NRM recommends the papers are best read in conjunction with *Fry (2015) A Changing Climate - South Coast of Western Australia* and information on the CSIRO and Bureau of Meteorology Climate Change in Australia website *www.climatechangeinaustralia.gov.au/en/.*

Climate change planning at South Coast NRM will be flexible and adaptive and so information on climate and its impacts will be continually reviewed.

- Kaylene Parker, Climate Change Project Leader, 2015

2 - Introduction

"It's not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change." **- Charles Darwin**

The potential impacts of climate change in the South Coast region are likely to be far-reaching. However, by considering adaptive activities as early as possible, South Coast NRM hopes to build resilience in the natural resource management (NRM) sector and to reduce impacts to the economy, the community and the environment.

This discussion paper provides information to assist South Coast NRM and its partners to outline the aspirations, goals and desired outcomes for the coastal and marine zones of the South Coast NRM region, with respect to climate change and its potential impacts.

This information will be used strategically to target the top priorities for action through funding and other support. To provide background information for key stakeholders, this document contains the following:

- An update on potential impacts identified in South Coast NRM's Climate Change: Whole of Landscape Analysis of the Impacts and Options for the South Coast Region (*Coffey Environments et al., 2009).*
- A broad description of coastal and marine assets.
- Information that we know relating to values, risks and threats as they apply to climate change.
- Current community and organisation capacity
- Gaps.
- Examples of adaptation best practice from Australia and around the world.
- A starting point for a program logic to outline aspirations, goals (10+ years), outcomes (1-5 years) (including possible options for measuring and monitoring, on-ground actions, capacity building and planning and policy framework development).
- Potential measures and indicators for climate change.
- Trade-offs for climate change impacts
- Useful links to information and organisations.

Further discussion papers are currently being developed to consider the other theme areas of *Southern Prospects 2011 – 2016, the South Coast's regional strategy for NRM.*

These areas include: Land, Biodiversity, Water and Cultural heritage.

Estuaries have generally been considered part of the Water theme. Goals and outcomes in the Biodiversity theme will also contribute to addressing targets for the coastal zone and are not repeated here. *Southern Prospects 2011 - 2016* outlines its aspirations, goals and desired outcomes in a program logic.

The overarching aspiration for the Coastal and Marine theme is: *Our Coastal and Marine systems are maintained and/or improved through the community embracing social, cultural, economic and ecological values.*

This document provides a starting point for discussion.

3 - Principles

The principles for managing coastal and marine resources are:

- Increasing the understanding of coastal and marine environments by sharing research and information.
- Maintaining the functional integrity and health of coastal and marine systems.
- Reducing conflicts between users through engagement, collaboration and consultation.
- Using adaptive management and best practice methods for on-ground works.

4 - What We Know - Values & Threats

4.1 - Coastal & Marine Asset Values

The South Coast's coastal and marine environment is richly diverse, beautiful and valued by the community. A moderately sized commercial fishery (compared to other areas of WA) is directly dependent on the resources within the region's marine environment.

Information included in this chapter has been sourced from a wide range of documentation as referenced and through consultation with key stakeholders.

4.2 - The South Coast

The region includes approximately 1,000km of coastline, taking in the coastal settlements of Albany, Esperance, Denmark, Bremer Bay, Hopetoun and Walpole which support the majority of the region's population.

The coastline is spectacular and diverse, alternating between sandy beaches, granite headlands, limestone cliffs, vegetated coastal dunes and includes numerous inlets and more than 500 offshore islands, shoals and bomboras.

The Recherché Archipelago contains the majority of these features and is an important marine and terrestrial environment in WA. About 70 per cent of the terrestrial coastal environment is contained in the conservation estate with the majority of the remainder being either managed by Local Government Authorities for recreation or is unvested crown land (largely unmanaged).

The coastline is a high energy environment, heavily influenced by large swells generated in the Southern Ocean *(Fletcher and Santoro, 2012)*. There are few large areas of protected waterways, the exceptions being estuaries (e.g. Wilson Inlet), embayments (Princess Royal Harbour and King George Sound) and areas protected by islands (eg. the Recherché Archipelago).

Tenure of the marine environment is complex and the Western Australian State limit of jurisdiction extends from the coastline for three nautical miles, including waters to three nautical miles off the coast of offshore islands. For South Coast NRM, the state waters comprise a substantial area of around 1,000,000 ha and more than 1,000km of marine/coastal interface (the coastal zone).

The region's state marine waters extend in places to approximately 70km off the mainland around Esperance and at a broad-scale include a range of major benthic habitats within the continental shelf.

South Coast marine waters are directly influenced by large-scale ocean currents such as the Leeuwin Current, localised hydrological variations and inputs (e.g. river mouths), climatic conditions and Southern Ocean current and swell regime. Annually, more than 800,000 local people and tourists visit the region's coastal national parks and conservation reserves, contributing to the economic stability of the region through overnight stays and retail trade in residential centres.

In some areas the level of management and available facilities are limited. Under these circumstances, these areas are sometimes unable to sustainably cater for the influx of locals and visitors. When the effects arising from climate change become more apparent at a local scale, some areas may not be able to support the current level of visitation (especially during peak periods).

4.3 - Coastal & Marine Biodiversity

The coastal (terrestrial and marine) environment contains much of the region's most intact ecosystems, a high proportion of reserved land and a high degree of species endemism.

The South Coast's almost continuous strip of intact coastal native vegetation is the major east-west link in the region's macro corridor network *(Wilkins et al., 2006)*.

The coastal corridor is a very high priority linkage, significant in spatial scale and its links between high conservation value protected areas. It is only broken at the major towns of Albany and Esperance and to a lesser extent at Denmark, Bremer Bay and Hopetoun *(Wilkins et al., 2006)*. The integrity of the corridor is threatened by dieback and degradation from recreational and other land use pressures (such as development).

The coastal terrestrial reserves, in particular Two Peoples Bay Nature Reserve, Cape Arid and Fitzgerald River national parks, represent very significant habitat refuges for threatened indigenous fauna, such as Gilbert's potoroo, the dibbler, western ground parrot and western whipbird.

The coastal wetland systems of Lake Warden in Esperance and nearby Lake Gore are registered as Ramsar sites, due to their high significance as a major

refuge for migrant and resident water birds of the region during the dry season.

Offshore islands provide important habitat, breeding and resting sites for many species of seabirds (albatross, petrels, shearwaters, penguins and the endangered Cape Barren goose) and two species of marine mammals (the Australian sea-lion and New Zealand fur seal).

The region's offshore islands have high cultural values, from Indigenous and European perspectives. Nature-based tourism and visitor pressure on offshore islands is currently increasing. An area recently recognised for marine biodiversity values is the ocean encompassing Bremer Bay Canyon, located 70km offshore from Bremer Bay townsite.

The deep water rifts in this area exude hydrocarbons which are converted by bacteria into a nitrogen-based food source which fuels a complex food chain ranging from phytoplankton to killer whales *(Riggs Australia, 2014).* In this way, the marine environment in this area mirrors the biodiversity of its terrestrial counterpart, the Fitzgerald River Biosphere.

4.4 - Coastal & Marine Resource Use

The oligotrophic waters of the region are not highly productive compared with other parts of the country and similar marine environments around the world.

The marine habitats of the South Coast are similar to the coastline, having fine, clear sand sea floors interspersed with occasional granite outcrops and limestone shoreline platforms and sub-surface reefs *(Fletcher and Santoro, 2012).*

Department of Fisheries has identified the major commercial fisheries of the South Coast bio-region include abalone, the purse seine targeting pilchards and other small pelagic organisms and a demersal gillnet for sharks *(Fletcher and Santoro, 2012).*

Other smaller commercial fisheries include long-standing beach seine for WA, salmon and herring, a trap fishery targeting southern rock lobsters and deep-water crabs and the intermittent scallop fishery.

There is also a commercial net fishery for finfish operating in several estuaries. South Coast commercial fishing vessel operators often hold a number of licences to create a viable year-round fishing operation.

As much of the region is remote or difficult to access, recreational beach and boat fishing tends to concentrated around main population and holiday centres. Major target species for beach and rock anglers are salmon, herring, whiting and trevally, while boat anglers target pink snapper, queen snapper, bight redfish, several shark species, samson fish and King George whiting.

The third major recreational fishery component is dinghy and shoreline fishing off estuaries and rivers focused in the western half of the bioregion. Here the main angling targets are black bream and whiting (including King George whiting). Recreational netting, primarily targeting mullet, also occurs in these estuaries. The small statewide Marine Aquarium Fish Fishery and Specimen Shell Fishery also fish in the region.

The predominant aquaculture activity undertaken on the South Coast includes the production of mussels and oysters from Oyster Harbour at Albany. This activity is restricted to this locality where there are sufficient nutrients (related to terrestrial run-off) in the water to provide the planktonic food necessary to promote growth of filter-feeding bivalves.

Other forms of aquaculture (eg. sea cage farming) are restricted on the South Coast due to limited availability of protected deep waters typically required by this sector. The commercial South Coast fishery is significantly smaller than those on the west coast of WA.

Fishing along the coast has traditionally been practised by Aboriginal people for thousands of years and remains an important cultural activity. A draft Aboriginal fishing strategy *(Aboriginal Fishing Strategy Working Group, 2003)* has recognised the interests of Aboriginal people in the protection and use of fish resources.

The Walpole–Nornalup Marine Park was declared on May 8, 2009 and is the first marine protected area on the South Coast. The Department of Fisheries is developing a research and monitoring plan for the Walpole-Nornalup Marine Park, which forms one component of the department's research and monitoring strategy within the broader bioregion.

Collectively, this monitoring information is used to assess the effectiveness of management strategies applied to ensure sustainable management of the state's fish resources at the bioregional level.

The Department of Fisheries State of the Fisheries document *(Fletcher and Santoro, 2012)* states the risks to South Coast fisheries from climate change are likely to be low in the medium term. Introduced marine pests are considered to be a major threat to the marine environment throughout the world's oceans *(McDonald and Travers, 2008)*. A snapshot study that deployed settlement figures for six months in 2007/08 found 25 pests in Albany and 15 in Esperance *(Wells, 2008)*.
Further introductions that have the potential to devastate the marine environment of the region could come from the west coast of WA, eastern Australia and overseas. The influence of climate change impacts on the risk of recruitment of invasive species is not known.

5 - What We Know Predictions, Risks & Threats

Climate change risks and impacts for the South Coast have been described in *Climate Change: Whole of Landscape Analysis of the Impacts and Options for the South Coast Region (Coffey Environments et al. 2009)*.

5.1 - Observed & Predicted Impacts

The Australian Government (2013) has provided a fact sheet to outline the most up to date predictions from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, released in sections during 2013 and 2014.

Some of the new or updated information related to coastal and marine systems includes the following:

- Ocean heat content has risen. More than 90 per cent of the extra heat trapped by greenhouse gases has been absorbed by the ocean, causing the ocean temperature to increase.
- Glaciers and ice sheets worldwide are shrinking and losing mass.
- Acidification of the marine environment may impact on vulnerable species.
- The extent of Artic sea ice has decreased at rates unprecedented in the past 1,450 years.
- If emissions continue to track at the top of IPCC scenarios, by 2100 global average sea-level could rise by 1m (0.52-0.98m from a 1986 - 2005 baseline).
- If emissions track along the lowest scenario, then global average sea level could rise by 0.28-0.60m by 2100 (from a 1986-2005 baseline).
- Possible modification of the Leeuwin Current could be experienced with implications for the life cycle and distribution of marine fauna (including species of commercial interest as well as marine pests).

The Australian Government (2009, 2011) stated more general climate change risks and impacts associated with coastal and marine environments will be variable but are likely to involve the following:

- Shoreline recession and realignment.
- Vertical accretion.
- Increased saline inundation of wetlands and estuaries.
- Modification and southward shift of habitat.
- Coastal squeeze, where built obstacles (roads or settlements) prevent the migration of some ecosystems such as salt marshes.
- Mobilisation of pollutants from near coastal dump sites and rubbish tips due to salt water intrusion.
- Nationally and internationally significant coastal environments at risk, including habitat for migratory birds.
- Impacts on estuaries, associated wetlands, coral reefs, constrained tidal flat communities and beaches where there is a lack of sediment replenishment.
- Cumulative impacts of individual stressors could tip coastal and marine systems to a point beyond which the ecosystem cannot function in a predictable or sustainable way.

These impacts present considerable risks. There is a need to develop and implement strategies to mitigate or adapt over future decades *(Coffey Environments et al., 2009)*.

One of the most challenging aspects of climate change is that due to complex interactions and the difficulty of scaling predictions to a regional level, it's unclear whether all these impacts will be of relevance to the region and indeed, how exactly these impacts will manifest.

5.2 - Sea-Level Rise

Sea-level has varied greatly over geologicalw time and is currently close to the lowest level attained since the Permian-Triassic about 250 million years ago (*Figure 1; Ross and Ross, 1988).*

During the most recent ice age (at its maximum about 20,000 years ago) the world's sea-level was about 130m lower than today *(Figure 2, Milne et al. 2005),* due to the large amount of seawater evaporated and deposited as snow and ice in ice sheets. Most of this had melted by around 10,000 years ago.

The use of satellite altimetry has provided more accurate observations of recent global sea-level rise and indicates between 1880 and 2012, the global-averaged sea-level rose about 21 cm, with an average rate of rise of about 1.6 mm per year over the 20th century *(CSIRO, 2014a; Figure 3).*

The sea-level record indicates a statistically significant increase in the rate of rise between 1880 and 2009 *(CSIRO, 2014a).* In recent decades, the rate of sea-level increase has been an order of magnitude faster than the average rate of rise over the previous several thousand years. From 1993 - 2003 global sea-level rose by about 3.1mm per year, compared to 1.8mm per year when averaged from 1961 - 2003 *(Australian Government, 2011).*

Global average sea-level rise during the 20th century was 1.7mm per year, slightly higher than the 1.2mm per year relative rise recorded around Australia for the period.

While long-term estimates of sea-level rise may differ, nearly all the uncertainties in sea-level rise projections operate to increase estimates of sea-level rise.

Projections for global mean sea-level rise relative to 1986 - 2005 have been predicted by the IPCC Fifth Assessment Report, with the likely range shown in *Figure 4* and *Table 1 (Church et al., 2013).*

Contributions from various factors (eg. thermal expansion, melting of ice sheets) are shown separately.

Representative concentration pathways (RCP) have been used to compile the models and are based on projections for levels of greenhouse gases

Median and Likely Ranges for Projections of Global Mean Sea-Level	SRESA1B*	Lowest Predictions RCP 2.6 Assuming less than 500 ppm CO_2-eq	Highest Predictions RCP 8.5 Assuming >700 <1500 ppm CO_2-eq
Global mean sea-level rise in 2081–2100	0.52 [0.37 to 0.69]	0.40 [0.26 to 0.55]	0.63 [0.45 to 0.82]
Rate of global mean sea-level rise	8.1 [5.1 to 11.4]	4.4 [2.0 to 6.8]	11.2 [7.5 to 15.7]
Global mean sea-level rise in 2046–2065	0.27 [0.19 to 0.34]	0.24 [0.17 to 0.32]	0.30 [0.22 to 0.38]
Global mean sea-level rise in 2100	0.60 [0.42 to 0.80]	0.44 [0.28 to 0.61]	0.74 [0.52 to 0.98]

Table 1: Median and likely ranges for projections of global mean sea-level rise to 2100. Source: *Church et al. 2013, Table 13.5.* *SRESA1B was predicted in Special Report on Emissions Scenarios (IPCC, 2000) and represents higher adaptation, lower CO2 emissions. CO2-eq = Carbon dioxide equivalents.

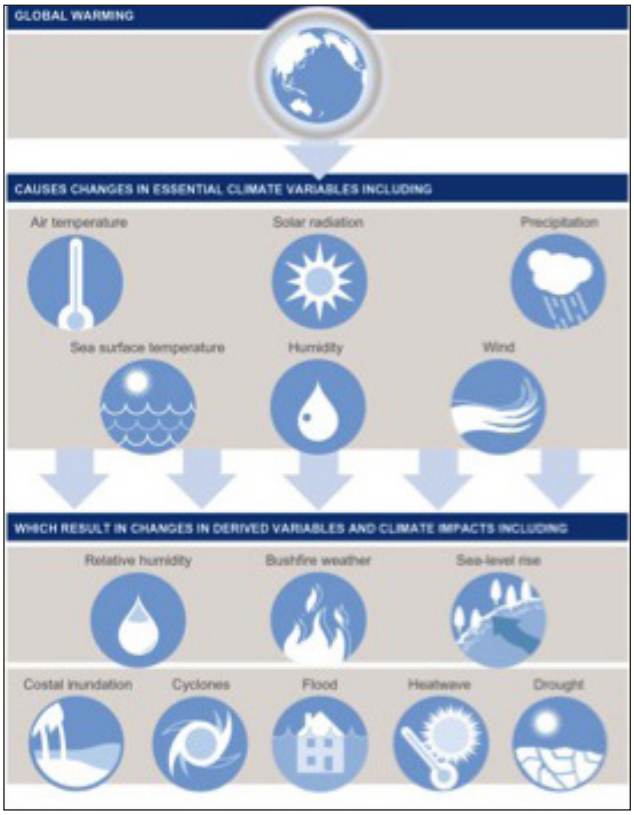

Figure 1: Global level sea fluctuations - geological time-frame (*Ross and Ross 1988).*

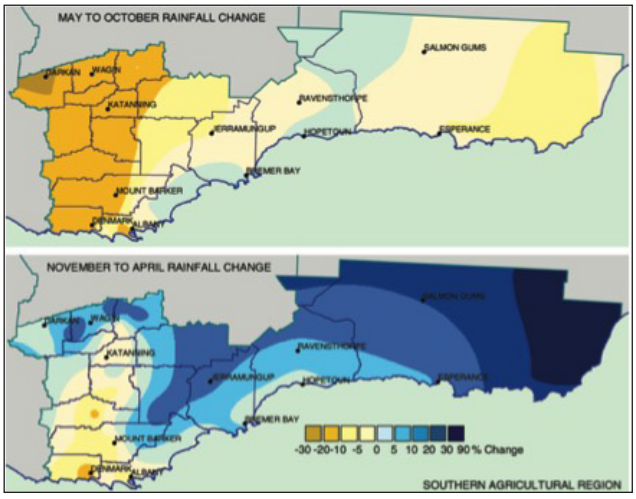

Figure 2: Post glacial sea-level rise, (*Milne et al, 2005).*

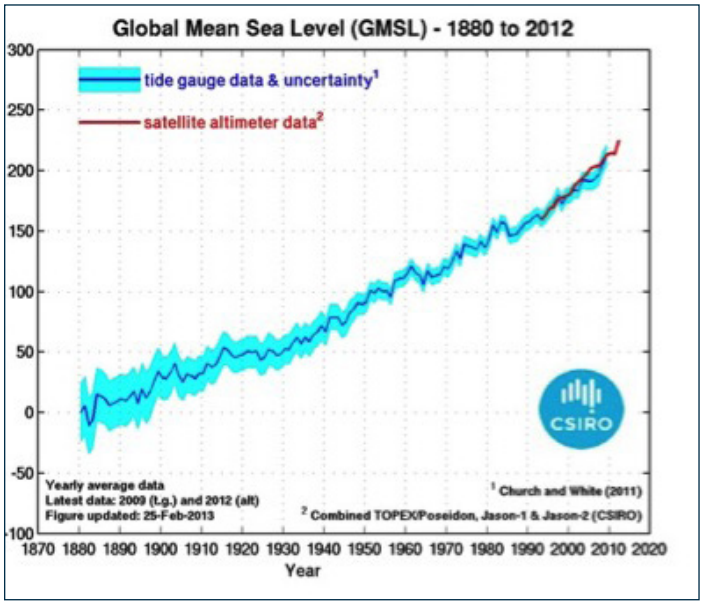

Figure 3: Global mean sea-level rise, 1880 - 2012 (*CSIRO, 2014a).*

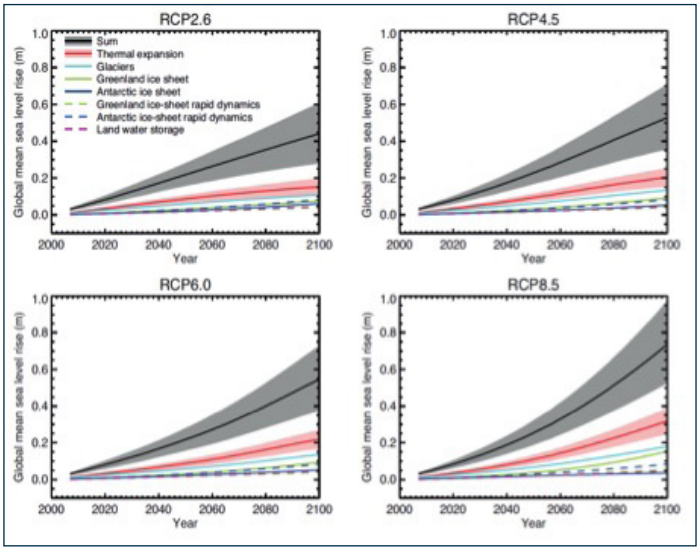

Figure 4: Projections for sea-level rise to 2100 (*Church et al. 2013, figure 13.11*).
Note: Figures represent median values and likely ranges or global mean sea-level in metres.

RCP 2.6 *(Figure 4)* represents a relatively low RCP, while RCP 8.5 represents much higher concentrations of greenhouse gases. IPCC *(Church et al., 2013)* indicate the collapse of the Antarctic ice sheet, if initiated, could cause global mean sea-level to rise substantially above the likely range during the 21st century.

The few available process-based models going beyond 2100 indicate global mean sea-level rise above the pre-industrial level to be less than 1m by 2300 for greenhouse gas concentrations that peak and decline and remain below 500 ppm CO_2-eq, as in scenario RCP2.6. For a radiative forcing that corresponds to above 700 ppm CO_2-eq but below 1500 ppm, as in the scenario RCP8.5, the projected rise is 1m to more than 3m. One of the worst case scenarios, based on the melting of glaciers, is of Greenland and Antarctica ice sheets predicted sea-level rise of 6.5m (compared to current levels) by 2500 *(Church et al. 2013).*

Sea-level change has not been uniform across the globe *(Bicknell, 2010; Church et al., 2013).* In fact, regional trends are significantly different from global averages *(National Tidal Centre, 2010).* For example, sea-level rise from the early 1990s to 2010 has not been geographically uniform, with the largest trends observed around the north and west Australian coastline adjacent to the Indian Ocean *(Figure 5).*

The South Coast had a 4.6mm per year sea-level rise at Esperance compared to 7.4mm at Hillarys, 2.1mm at Sydney (Port Kembla), 2.6mm at Melbourne and 7mm at Darwin *(National Tidal Centre, 2010)*. This pattern, based on less than 20 years of observation, is in agreement with maps of sea-level change derived from satellite altimetry data over an equivalent time period .

With ongoing sea-level monitoring, the National Tidal Centre predicts better estimates of the longer-term sea-level change signal will increasingly emerge from the 'noise' of decadal fluctuations.

In coastal areas and waterways connected to the ocean, erosion and inundation are likely to be key impacts from rising sea-levels leading to loss of coastal and near coastal foreshores and associated assets. Saltwater intrusion into groundwater and freshwater bodies could also have a significant impact on ecosystems and potable water availability *(Ozcoasts, 2014)*.

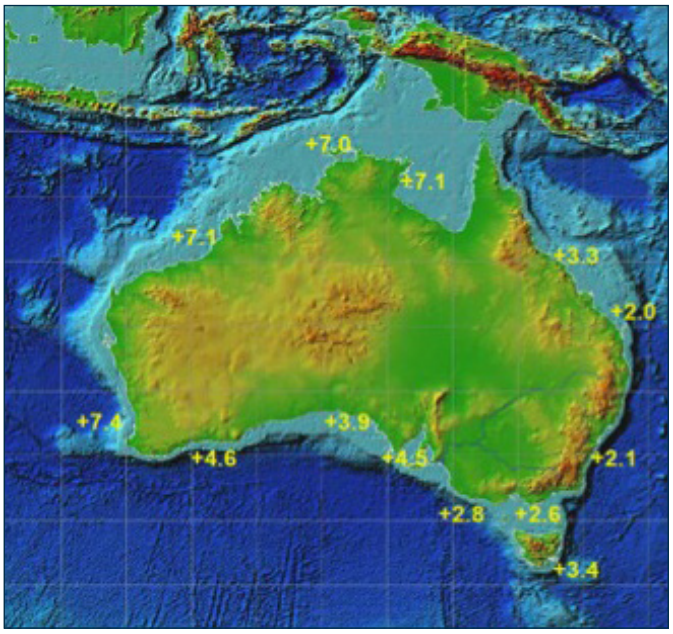

Figure 5: Net relative sea-level trends around Australia, 1990s to 2010. Source: National Tidal Centre (2010).
Note: The net relative sea-level trend in mm/year after subtracting effects related to barometric pressure and measuring devices.

5.3 - Storms & Storm Surges

A storm surge is the rising of the sea as a result of wind and atmospheric pressure changes associated with a storm.

Changes in sea-level generated by extreme meteorological events, such as winter storms and cyclones, may be positive or negative depending on whether the sea level is higher or lower than predicted. The effect of storm surge is most severe when these extreme meteorological events occur in conjunction with high tide.

Sea-level rise and the occurrence of extreme storm events are likely to exacerbate erosion, inundation and damage to existing infrastructure. SPP 2.6 *(WAPC, 2013)* and Department of Transport use an allowance for erosion caused by future sea-level rise on sandy coast by calculating 100 times the predicted sea-level rise value (currently 0.9m for WA over a 100-year timeframe) which equates to 90m. SPP 2.6 also considers historic erosion and storm erosion and a 0.2m per year allowance for uncertainty.

There is scientific evidence to indicate climate change could amplify the impacts of storm surge due to an elevated sea-level and warmer ocean temperature which are likely to intensify storm activity *(Dasgupta et al., 2009; Grinsted, et al., 2013)*.

This impact could lead to more damaging flood conditions in coastal zones and adjoining low-lying areas. The destructive impact will be greatest in areas where settlements are located in these high risk areas.

However, there is currently little evidence to suggest storms and storm surge are likely to be significantly exacerbated on the South Coast (*Coffey Environments et al., 2009*).

5.4- Climatic Zone Shift

Average climate zones have shifted south (e.g. by 100 - 200km in north-eastern and north-western Australia; *IPCC, 2014*). Due to elevated rates of ocean temperature increase, south-west and south-east Australia are recognised as global warming hotspots *(IPCC, 2014)*. Modelling indicates with high confidence *(IPCC, 2014)* that pelagics such as sharks, tuna and billfish are likely to move further south on the east and west coasts. These changes depend on sensitivity to water temperature and may lead to shifts in species-overlap with implications for by-catch management. Poleward movements are also projected for WA coastal fish species and complex impacts are expected for marine mammals *(IPCC, 2014)*.

5.5 - Acidification

One quarter of humankind's current annual emissions of carbon dioxide (CO_2) are absorbed by the oceans *(Antarctic Climate and Ecosystems Cooperative Research Centre (ACECRC), 2010).*

The uptake of CO_2 is driving a change in ocean chemistry by increasing the amount of carbonate ions to form carbonic acid.

The average pre-industrial pH of oceans was 8.2 and the current average is 8.1, with predictions of a drop to 7.8 by 2100 (*ACECRC, 2010).* Because the pH scale is logarithmic, a drop in pH of 1 unit represents ten times the increase in hydrogen ions. Lowered pH could have serious impacts within the 21st century for the sustainability and management of marine and coastal ecosystems and fisheries.

The Southern Ocean absorbs 40 per cent of the oceanic inventory of anthropogenic CO_2 and acidification is strongest there *(ACECRC, 2010).* Studies by ACECRC scientists have found a reduction in the shell-forming ability of small zooplankton in the Southern Ocean, including planktonic foraminifera and planktonic snails, known as pteropods.

Pteropod shells are made of a more soluble form of calcium carbonate (aragonite), which is likely to put them at greater risk of ocean acidification.

Foraminifera and pteropods are important food sources for marine predators in the Antarctic food web. Observing impacts on these calcium carbonate-based organisms in this environment will help to predict global impacts of acidification.

The IPCC (2014) has a medium level of confidence that an increasing ocean acidification will affect many species including corals, coralline algae, calcareous plankton, reef fishes, bryozoans and other benthic organisms with a calcareous structure.

Deep-sea corals are also expected to decline with ocean acidification. Different species may have varying degrees of vulnerability at different stages of their life-cycle (e.g. spawning or recruitment).

5.6 - Warming Ocean & Impacts on Currents

The Leeuwin Current runs south along the west and south coasts of Australia, drawing warm water from the northern Indian Ocean.

Strength of the current is influenced by the El Niño Southern Oscillation (ENSO) which manifests as anomalously warm ocean water temperatures. Leeuwin Current is usually strongest from March to November coinciding with the southern hemisphere winter.

The Leeuwin Current warms the continental shelf waters off WA which results in a warmer winter and cooler summer than the western coasts of other continents. It is also responsible for the presence of the most southerly true corals at the Abrolhos Islands and the transport of tropical marine species down the west coast and across the Great Australian Bight.

There has been a weakening trend in the Leeuwin Current which may be due to the combined effect of global warming and natural variability (*Feng et al. 2009).* As the physical and marine ecosystems associated with the western and southern Australian coasts are sensitive to climate variability, long term trends in the Leeuwin Current induced by climate change will be superimposed on interannual and decadal variations which may overwhelm trend signals.

During the summer of 2010/2011, when near record La Nina conditions were prevailing, there was an anomalously high sea-level in the equatorial western Pacific Ocean. This resulted in a strengthening of the Leeuwin Current, above average sea surface temperatures, fish deaths, coral bleaching and southward migration of warm water organisms (e.g. whale sharks and manta rays) *(IPCC, 2014; Feng et al. 2009 and Pearce and Feng, 2013).*

While the effects of the heatwave lasted just a few weeks, terrestrial temperatures were higher and the impacts on marine species were marked.

It is possible major warming events of this nature will occur from time-to-time in the future and this heatwave demonstrated some of the potential implications for the local marine ecology and fisheries *(Pearce and Feng, 2014).*

5.7 - Combined Effects

While any one of the potential impacts of climate change is of concern, the increasing vulnerability of the world's coastlines and oceans from multiple anthropogenic stressors is likely to amplify the effects from any single stressor.

Stressors include changes to ocean thermal structure, increasing acidification, pollution, sedimentation and unsustainable harvesting of some fisheries. Estuarine habitats are likely to be affected by changing rainfall or sediment discharges, as well as greater connectivity to the ocean through rising sea levels and coastal inundation. The loss of coastal habitats and declines in some species will result in substantial impacts on coastal settlements, infrastructure (e.g. from storm surge) and may affect tourism *(IPCC, 2013)*.

Changes in temperature, rainfall and sea-level rise are expected to lead to secondary effects, including erosion, landslips and flooding, affecting coastal habitats and their dependent species, e.g. loss of habitat for nesting birds *(high confidence; IPCC, 2014)*.

6 - Current Community Capacity

Many projects initiated by the South Coast NRM community contribute to baseline knowledge and build resilience.

As funding opportunities become fewer, more competitive priorities need to be considered, ensuring the greatest benefit is achieved. South Coast NRM believes best outcomes are achieved by maintaining strategic partnerships, sharing information and building community capacity. Current projects include:

- Fisheries Redmap database allows the community to spot, log and map marine species in Australia, leading to better understanding of species and possible changes in their distribution.
- The Recherché Advisory Group and the University of Western Australia research program with community marine surveys.
- Monitoring programs for species distribution and fish movements (Saltwater Treasures Program, Murdoch University and Recfishwest).
- Education-based monitoring (eg juvenile fish data) by local schools.
- Education and information sharing by a South Coast marine education officer.
- Region-wide coastal school holiday education and school-based programs implemented by South Coast NRM and partners.
- Partnerships with OceanWatch, SeaNet, the WA Fishing Industry Council and Dept of Fisheries.

6.1 - Australian Government

The Australian Government's comprehensive review *Managing our Coastal Zone in a Changing Climate (Standing Committee on Climate Change, Water, Environment and the Arts, 2009)* has recommendations relating to adaptation to climate change impacts including insurance, planning and legal issues. The review discusses current governance arrangements and the role of stakeholders in managing the coastal zone.

In light of potential climate change impacts, the review recommends the development and adoption of an intergovernmental agreement through the *Council of Australian Governments (COAG)*. A review of policies and legislation and the development of adaptation strategies and building resilience in coastal communities is also recommended.

The document recommends the government should:

- Lead the development of regional-scale climate change projections to ensure consistency of approach and avoid duplication of effort, as well as a set of nationally consistent default climate change scenarios for use in planning, particularly for sea-level rise.
- Coordinate and provide financial assistance for the development of nationally consistent, high resolution merged topographic and bathymetric digital elevation models for the coast and develop nationally consistent definitions for coastal/marine terminology.
- Lead development of nationally consistent methods to assess climate change risk and/or vulnerability.
- Collaborate and provide financial support for states and/or local government to undertake a suite of vulnerability assessments.

The document also recommended key roles for the State Government should include:

- Preparing land use planning systems for change.
- Protecting public assets.
- Building knowledge of climate change science and impacts and sharing info between stakeholders.
- Identifying and managing risk.
- Reducing risk taking.
- Facilitating change on a large scale.
- Providing emergency response and recovery arrangements.
- Increasing local capacity to adapt to climate change.

The document recommended key roles for local governments should include:

- Understanding local vulnerabilities to climate change.
- Informing local communities of the impacts of climate change.
- Supporting local community groups.
- Implementing statutory planning decisions.
- Ensuring planning schemes take account of vulnerabilities.

The Australian Government has worked with stakeholders to prepare a marine bioregional plan for Commonwealth waters in the south-west marine region under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Australian Government, 2012). The south-west marine region covers more than 1.3 million km2 of ocean adjacent to the eastern tip of Kangaroo Island off the South Australian coast to waters off Shark Bay. The plan aims to strengthen the operation of the EPBC Act to help ensure that the marine environment of the region remains healthy and resilient.

The bioregional plan describes the marine environment and conservation values, broad objectives for the protection of its biodiversity, identifies regional priorities and outlines strategies and actions for implementation.

The program also produced a series of conservation value report cards to present a summary of scientific information for the marine environment, existing heritage places and a range of species. They also provide information about existing management arrangements.

The NRM Element 1 Team, an Australian Government initiative involving CSIRO and the Bureau of Meteorology is working to downscale climate change predictions for NRM regions. The South Coast is included in the *Southern and South-west Flatlands* region. Preliminary projections have been prepared for the South Coast NRM region *(CSIRO, 2013)* for parameters such as temperature and rainfall.

However, predictions related to coastal and marine impacts are yet to be developed.

6.2 - The Government of Western Australia

Government of WA agencies and other organisations are responsibile for the coastal and marine environment. While not directly responsible for coastal and marine areas, some have an interest via funding and other programs. Key organisations include:

- Dept of Planning and WA Planning Commission: planning legislation, state planning policies and guidelines. The State Coastal Planning Policy 2.6 *(WAPC, 2013)* has been updated to recognise predicted sea-level rise over the next 100 years.Setbacks which allow for this rise only apply to new developments.
- Environmental Protection Authority and Dept of Environment Regulation: Environmental Protection Act 1986, policies and guidelines.
- Dept of Parks and Wildlife: conservation estate and marine park strategic planning.
- Dept of Water: information on groundwater, estuaries, inlets and wetlands.
- Dept of Transport: coastal facilities and infrastructure protection.
- Dept of Fisheries: management of fisheries (commercial and recreational) and sustainable management of aquatic biodiversity.
- Dept of Regional Development and Lands.
- Dept of Aboriginal Affairs.
- Goldfields Esperance Development Commission and Great Southern Development Commission.

DPaW has facilitated a regional marine strategic planning process on behalf of the Marine Parks and Reserves Authority. In September 2010, the WA Government released the *Draft Regional Marine Strategic Plan for the South Coast (Gov of WA, 2010a)* and the accompanying reference report; *Oceans Opportunity: a proposed strategic framework for the marine waters off WA's South Coast (Gov of WA,2010b; http://rmp.dec.wa.gov.au).*

The state-coordinated process has been undertaken concurrently and cooperatively with marine planning for south-west commonwealth waters further offshore.

The one marine park in the South Coast marine bioregion, the Walpole and Nornalup Inlets Marine Park was gazetted in May 2009. DPaW also plans for and manages the terrestrial conservation reserve system on behalf of the Conservation Commission of WA.

DPaW and LGAs carry out a significant amount of joint planning where reserves are adjacent.
The Department of Fisheries is collecting baseline data for the distribution of certain fish species.

6.3 - South Coast - Regional

The South Coast community has actively planned for coastal and marine environments, including:

- South Coast NRM: *Southern Prospects 2011 - 2016, The South Coast Regional Strategy for Natural Resource Management (South Coast NRM Inc., 2011).*
- South Coast Management Group: *Southern Shores – A strategy to guide coastal zone planning and management in the South Coast Region of Western Australia (Coffey Environments and South Coast Management Group, 2009).*

These strategies have led to direct investment in coastal and marine environments. The five coastal LGAs within the region support and are members of the South Coast Management Group (SCMG), a regional local government and community group. SCMG has prepared Southern Shores *(Coffey Environments and SCMG, 2009)* which outlines regional objectives, management actions and opportunities for collaboration between stakeholders to better manage the coast, including the impacts of climate change.

The Department of Planning is considering how to initiate coastal vulnerability studies in the Great Southern (between the shires of Denmark and Jerramungup), as outlined in the draft Great Southern Regional Planning and Infrastructure Framework *(WAPC, 2014).*

6.4 - Local Government Authorities

The high value attached to coastal areas and corresponding pressure from recreational use, means management of coastal reserves is high on local government natural resource management priorities.

The five coastal LGAs in the South Coast region are the shires of Denmark, Esperance, Ravensthorpe, Jerramungup and the City of Albany. Numerous local-level coastal planning and management documents have been developed for local government coastal reserves (shires of Denmark, Jerramungup, Ravensthorpe and Esperance).Communities from inland local government areas visit and actively use coastal and marine areas.

LGAs are supported by the WA Local Government Association (WALGA) which has created a tool box to assist in the identification of risks and preparation of priorities for climate change adaptation planning.

6.5 - Community Groups & Other Organisations

The South Coast NRM region has many community groups and organisations helping to manage coastal and marine areas. Stakeholders include:

- Green Skills, Esperance Regional Forum, Fitzgerald Biosphere Group, Ravensthorpe Agricultural Initiative Network, Oyster Harbour Catchment Group, Wilson Inlet Catchment Committee, Regional Development Australia Great Southern, UWA and Centre for Excellence in NRM and schools/tertiary institutions.
- Native Title claimants, Aboriginal reference groups and corporations, Goldfields Land and Sea Council, Southern Agricultural Indigenous Landholder Service and South West Aboriginal Land and Sea Council, Gondwana Link.

Community members have been involved in local-level coastal management projects with support through partnerships with LGAs, state agency land managers and South Coast NRM coastal and marine theme staff.

7 - Adaptation

Adaptation to the impacts of climate change will be essential if the South Coast community and its natural resources are going to thrive in the future.

For adaption to be most effective, planning for change needs to be undertaken as soon as possible, based on the best available information *(Department of Environment, 2014)*.

Broad consultation is essential to determine priorities and the plan needs to be adopted by stakeholders with influence over implementation of actions.

Planned adaptation options in response to impacts in coastal and marine areas may include:

- Avoidance of activity or development, e.g. foreshore setbacks.
- Temporary relocation or discontinuation of activity, eg recreation.
- Permanent relocation of activity, e.g. foreshore caravan parks.
- Changes to form and/or nature of development, e.g. building design.
- Changes to use of land, e.g. agriculture, fisheries, urban expansion.
- Physical protection, e.g. coastal engineering, building standards.
- Upgrading of public infrastructure, e.g. dams, pipelines, roads.
- Adjustment to activity and lifestyle, e.g. re-scheduling of outdoor sports.
- Emergency response, e.g. storms, bushfires, heatwaves.
- Awareness and expectation, e.g. information/ understanding/education.
- Removal of human barriers to landward migration of species.
- Beach nourishment.
- Management of environmental flows to maintain estuaries;
- Habitat provision.
- Assisted colonisation of species.

South Coast NRM and its partners have the potential to launch a range of climate change adaptation strategies. which may fall under the following categories:

- Collection of baseline data and monitoring.
- Capacity building including coordination, advocacy, awareness raising and education.
- On-ground works.
- Facilitation of planning and policy development.

Organisations should consider its jurisdiction, available resources and ability to sustain a particular action.

8 - Gaps

The following gaps currently exist in coastal and marine climate change adaptation:

- Lack of coastal and marine baseline data (e.g. digital elevation models, bathymetric and other datasets).
- Regional downscaling of predictions to improve resolution of factors related to climate change.
- Vulnerability assessment of settlements, cultural features and key natural assets.
- Incorporation of vulnerability assessments in planning and policy instruments.
- Prioritising works based on long term implications of climate change risks and impacts.
- Community education and awareness programs related to climate change risks, impacts and adaptation strategies.
- Decisions related to management of coastal and marine related infrastructure, such as retreat, protect, defend.
- Knowledge related to likely impacts associated with potential risks associated with coastal and marine environments.

8.1 - Possible Actions

The following actions have been outlined as potentially important for the region:

- Vulnerability assessment of high value assets or strategic locations (eg. settlements and some natural features). The WA Planning Commission recommends approaches based on the Coastal Hazard Risk Management and Adaptation Plan process *(WA Planning Commission, 2013; Figure 6).*
- Examples consistent with this process include the vulnerability assessments undertaken in the Pilbara *(Eliot et al., 2013)* and Cockburn Coast *(Cockburn Sound Coastal Alliance, in preparation).* The Dept of Planning in the Great Southern would like to initiate this process for priority areas in the region, pending funding and departmental priorities.
- Prioritising on-ground actions with consideration of options (eg. planned retreat).
- Maintain action plan coordinator and establish cross links between reference groups.
- Action plans to cover necessary functions and activities of stakeholders for a timeframe of 50 – 100 years. This includes project areas, biodiversity management and community use.
- Identify and engage with stakeholders.
- Identify instruments appropriate for use by different stakeholders.
- Undertake risk analysis and develop appropriate responses.
- Develop instruments for local governments (e.g. with WALGA, Department of Planning).
- Evaluation via report cards/state of the environment reporting.

Other ideas:

- Consider potential health risks associated with climate change, such as increased mosquito breeding habitat.
- Formation of umbrella group e.g. climate change or sustainability task force.

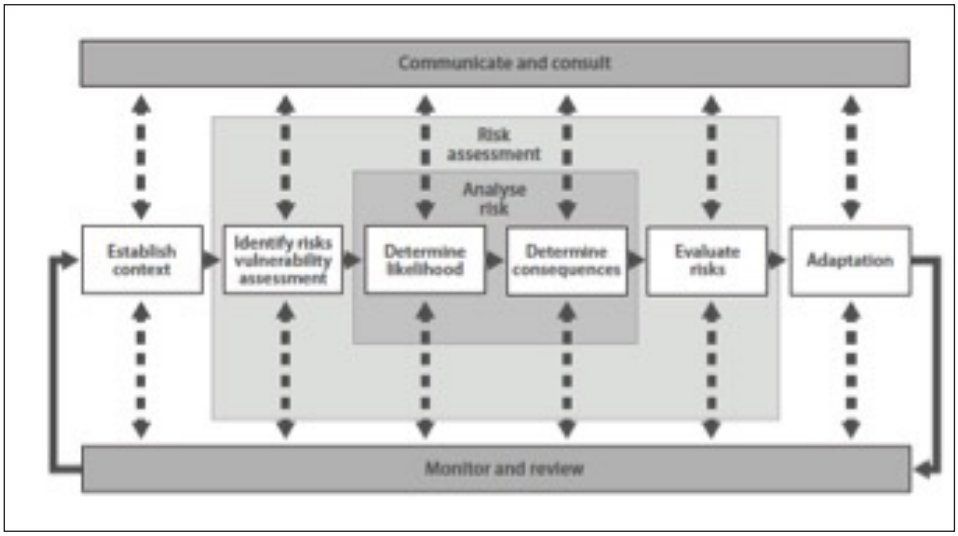

Figure 6: Coastal hazard risk management and adaptation planning process, *(Western Australian Planning Commission 2012).*

8.2 - Priority Areas

Areas which could be starting points as priorities for the analysis of potential impacts and associated adaptation planning include:

- Macro-corridors.
- Conservation estate and adjacent marine areas (e.g. Bremer Bay Canyon).
- Areas identified in vulnerability assessments.
- Areas which are important for a number of reasons (e.g. cultural heritage, biodiversity, recreation).

9 - Measures & Indicators

Use of the following indicators and measures *(Table 2)* as a guide will assist in setting targets for projects and programs and allow for standard approaches to measurement.

These indicators should be selected according to the principles of cost, simplicity, consistency, practicality and the capacity to deliver information across the region.

Table 2: Measures and Indicators, coastal and marine climate change. Based on *DEWHA, 2007.*

Asset	Indicator Heading	Recommended Indicators
Estuarine, coastal and marine habitat.	Estuarine, coastal and marine habitat extent and distribution.	• Beach erosion or accretion. • Dune vegetation. • Seagrass. • Sediment. • Terrestrial and marine species (native and introduced).
	Estuarine, coastal and marine habitat condition.	**Biological condition:** • Mass mortality events • Pest species (number, density, distribution). **Physical/chemical condition:** • Dissolved oxygen. • Nutrients. • pH. • Sedimentation and erosion rates. • Shoreline position. • Temperature.

10 - Trade-offs

The South Coast coastal and marine area is an environmentally, economically, socially and culturally important asset.

Pressures on coastal and marine environments from climate change will be exacerbated by existing stressors. Not all coastal areas may be able to be protected from impacts such as sea-level rise and some may need to be left to find a new equilibrium, without intervention.

Stakeholder consultation will be essential to determine the priorities for action and therefore where funding for projects should be focused. Climate change and its associated threats and impacts are difficult to predict with certainty due to the many complex interactions between multiple elements.

Adaptation trade-offs related to possible changes in the coastal and marine zone need to be considered by the community (including loss or modification of foreshore reserves, private land and other NRM assets).

Some opportunities may arise with the southward migration of marine species that are valued commercial resources.

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12 - Useful Links

- Department of Environment Regulation (Western Australia) Climate Change Unit: www.der.wa.gov.au/your-environment/climate-change.
- Western Australian Local Government Association Climate Change Management Toolkit: www.walgaclimatechange.com.au/
- www.walgaclimatechange.com.au/adaptation-and-responses.htm.
- IPCC: www.ipcc.ch.
- UNFCCC: unfccc.int.
- Australian Government Department of Climate Change: www.climatechange.gov.au.
- Tyndall Centre for Climate Change Research: www.tyndall.ac.uk.
- UK Climate Impacts Program: www.ukcip.org.uk.
- Stockholm Environment Institute: http://sei-international.org.

Climate Change Adaptation

- UNFCC on adaptation unfccc.int/adaptation/items/4159.php.
- CSIRO Climate Adaptation Flagship: www.csiro.au/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/ClimateAdaptationFlagshipOverview.aspx.
- Resilience Alliance: www.resalliance.org.
- WeADAPT: www.weadapt.org.
- Eldis page on climate change: www.eldis.org/go/topics/resource-guides/climate-change#.U3BL7IGSx8E.
- Community based adaptation exchange: Eldis: community.eldis.org/.59b70e3d/.
- Department of Foreign Affairs and Trade (Australia) webpage on adaptation: http://aid.dfat.gov.au/aidissues/climatechange/Pages/adaptation.aspx.
- World Bank webpage on adaptation: beta.worldbank.org/overview/climate-change-adaptation.
- OECD work on adaptation: http://www.oecd.org/env/cc/adaptation.htm.
- Google Earth – Sea-Level Rise: https://sites.google.com/a/glaciology.net/grinsted/Home/Miscellaneous-Debris/Visualize-the-impact-of-sea-level-rise-in-google-earth.

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