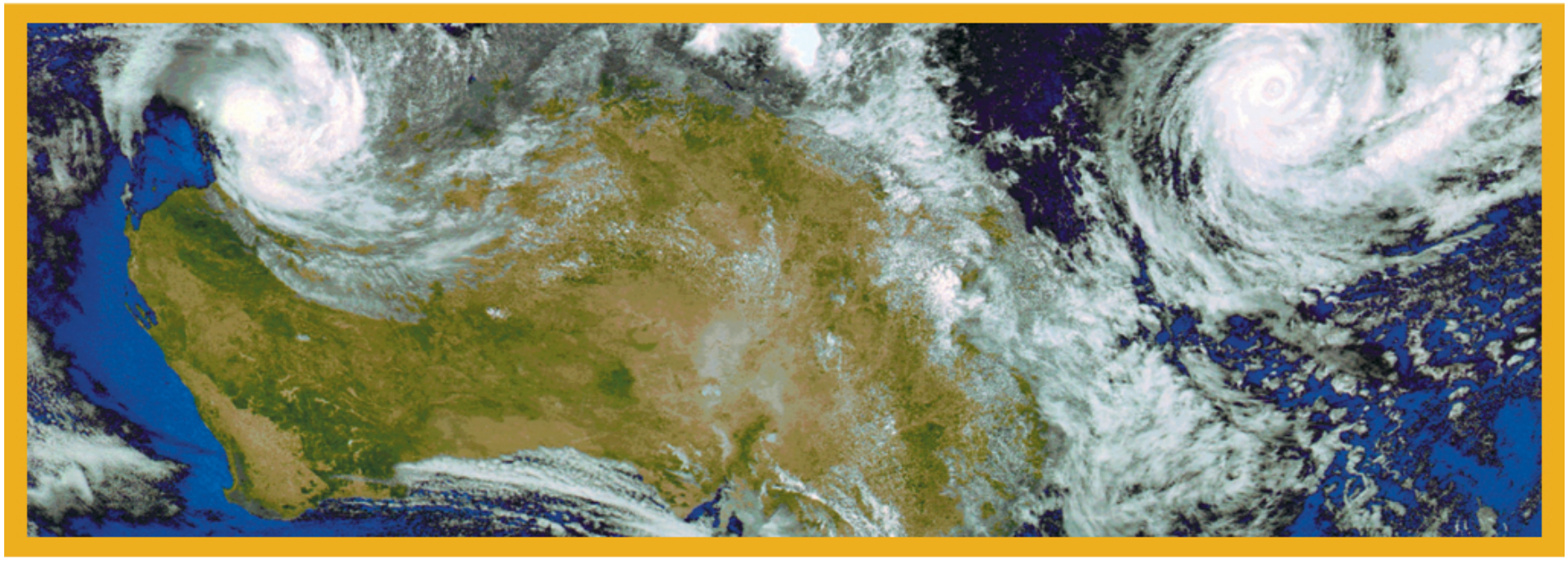
Seeing Change

Climate related resource information for the marine environment



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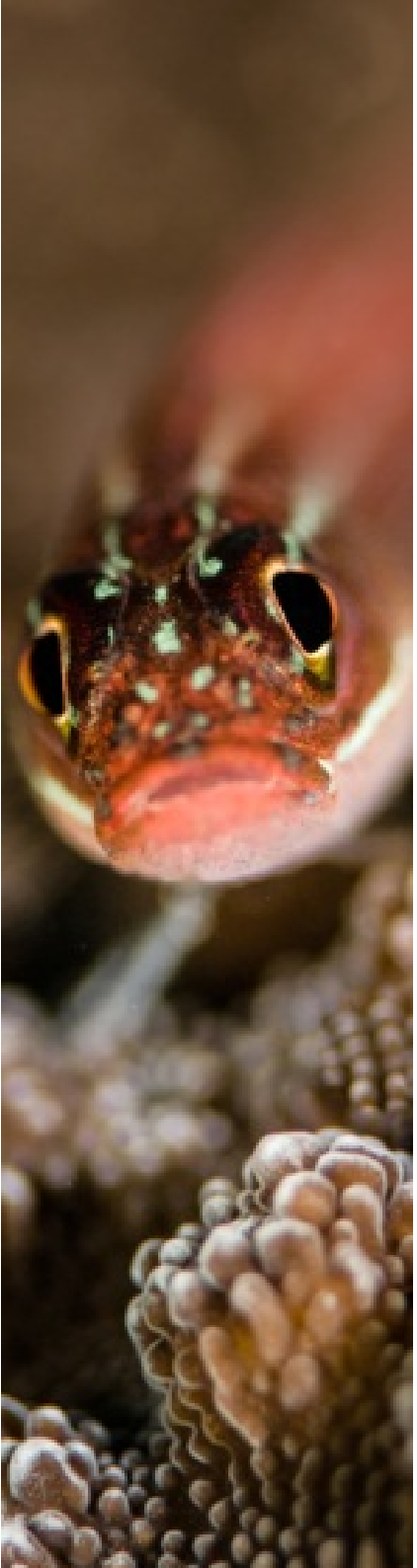

About this document

This PDF includes a variety of climate-related information resources for the marine environment. The materials contained in the PDF provide links to easily access a range of marine climate science in a variety of formats and levels of detail. It deals with key issues of climate change, possible impacts, and opportunities for action and adaptation.

The original DVD was produced to focus on the 3 geographic areas around Australia, thus the printed materials are divided into the southwest, the southeast and the tropical regions respectively. Note that some of the materials have been removed from this PDF version, because the content was not available online and also to limit the size of this document.

The resources describe trends in the oceans around Australia drawing on a range of data and on the experiences of fishers and scientists. Included are visualisations of ocean currents, simplified explanations of impacts using animations, graphic videos, published booklets, information sheets, research papers, PowerPoint presentations and teacher plans. Links to relevant websites and further resources are also provided.

This PDF includes resources provided by many organisations around Australia. It was produced by the Western Australian Marine Science Institution (WAMSI) and funded by the Fisheries Research and Development Corporation (FRDC) as part of the project: *Climate Change Adaptation - Building Community and Industry Knowledge*.

Please note that the links in this PDF document were valid at the time this document was produced in August 2013.
WAMSI cannot guarantee the accuracy of the content of the websites.

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Acknowledgements

Australia General

Climate Commission (CC)

The Critical Decade: Climate science, risks and responses

The Critical Decade: Key messages

The Critical Decade: Extreme weather - key facts

Extreme Weather and Climate Change in Australia: today and into the future

National Climate Change Adaptation Research Facility (NCCARF)

Species Response to Climate Change in the Ocean

Ecosystem responses to climate change in the ocean

Climate Change and the Marine Environment: South Australia

Developing a toolkit for economic instruments to facilitate marine climate change adaptation

Adaptive Management of Temperate Reefs for Climate Change: new approaches for ecological monitoring and predictive modelling

Fisheries Research and Development Corporation (FRDC)

Preparation, the best business practice

Climate change, marine biodiversity and the fishing and aquaculture industries

Climate change adaptation: building industry and community knowledge

Changing currents in marine biodiversity governance and management: responding to climate change

An adaptation blueprint for coastal communities

Estuaries and Coasts: adaptation options for a changing climate

Growth opportunities & critical elements in the value chain for wild fisheries & aquaculture in a changing climate

Developing adaptation options for seabirds and marine mammals impacted by climate change

Marine Report Card 2012

Marine report Card 2012: Marine Climate Change in Australia - Impacts and Adaptation Responses

Australia General South West South East Tropics Videos Animations Gallery Presentations Opportunities Related Resources

South West

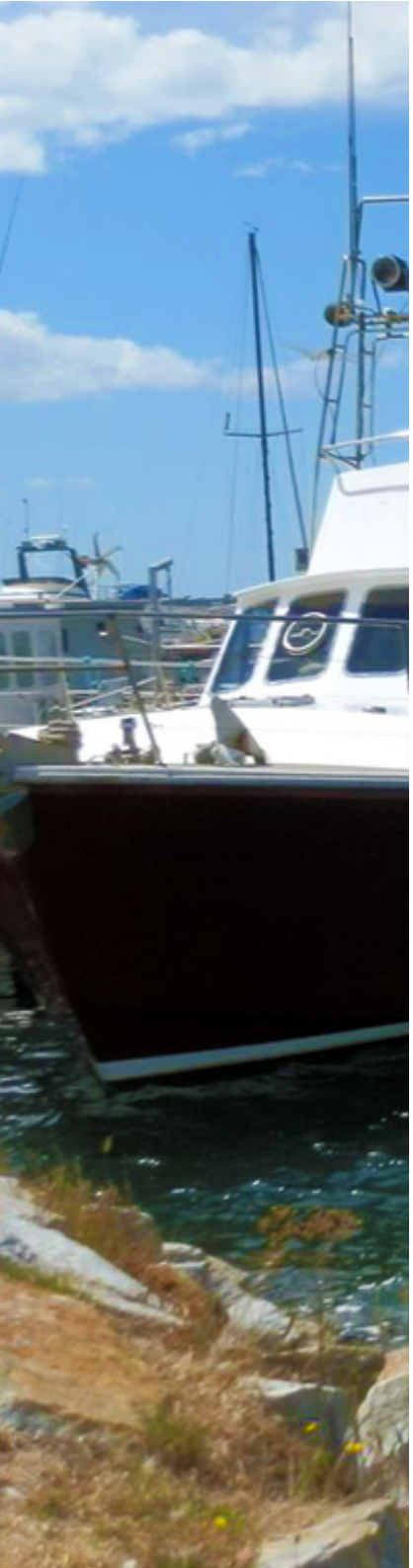
Climate Commission (CC)
The Critical Decade: Western Australia climate change impacts

National Climate Change Adaptation Research Facility (NCCARF)
Climate change effects on the marine environment and fisheries: WA

Indian Ocean Climate Initiative (IOCI)
How WA's Climate Has Changed
The Future of WA's Climate
The Role of IOCI in Understanding WA's Changing Climate
WA Rainfall – What the past can tell us, and what the future may hold
Summary for Policymakers

Fisheries Research and Development Corporation (FRDC)
Management implications of climate change effects on fisheries in Western Australia
Change in coastal fishing communities: Geraldton, Western Australia

Research Papers
La Nina forces unprecedented Leeuwin Current warming in 2011 Feng, M., McPhaden, J. M., Xie S. and Hafner, J. (2013)
The "marine heat wave" off Western Australia during the summer of 2010/11 Pearce, A., Lenanton, R., Jackson, G., Moore, J., Feng, M. and Gaughan, D. (2011)
Fisheries-dependent indicators of climate change in Western Australia. Caputi, N., Pearce, A. and Lenanton, R. (2010)
Observations of warming on the Western Australian continental shelf Pearce, A.F. and Feng, M. (2007)



South East

Tasmania

Climate Commission (CC)
The Critical Decade: Tasmanian impacts and opportunities

Antarctic Climate & Ecosystems CRC (ACE CRC)
Climate futures for Tasmania: Extreme events or here
Climate futures for Tasmania: General climate impacts
Climate futures for Tasmania: Break O'Day Municipality

Fisheries Research and Development Corporation (FRDC)
Change in coastal fishing communities: St Helens, Tasmania

National Climate Change Adaptation Research Facility (NCCARF)
Climate change impacts on Tasmania's marine life
Pre-adapting Tasmanian Coastal Reefs to Climate Change

Tasmanian Climate Change Office
Projected Climate Change Impacts for Tasmania

Tasmanian Seafood Industry Council (TSIC)
Seaing Change: Catch up on changes in our marine environment

Research Papers
The East coast Tasmanian rock lobster fishery – vulnerability to climate change impacts and adaptation response options Pecl, G., Frusher, S., Gardner, C., Haward, M., Hobday, A., Jennings, S., Nursey-Bray, M., Punt, A., Revill, H., van Putten, I. (2009)

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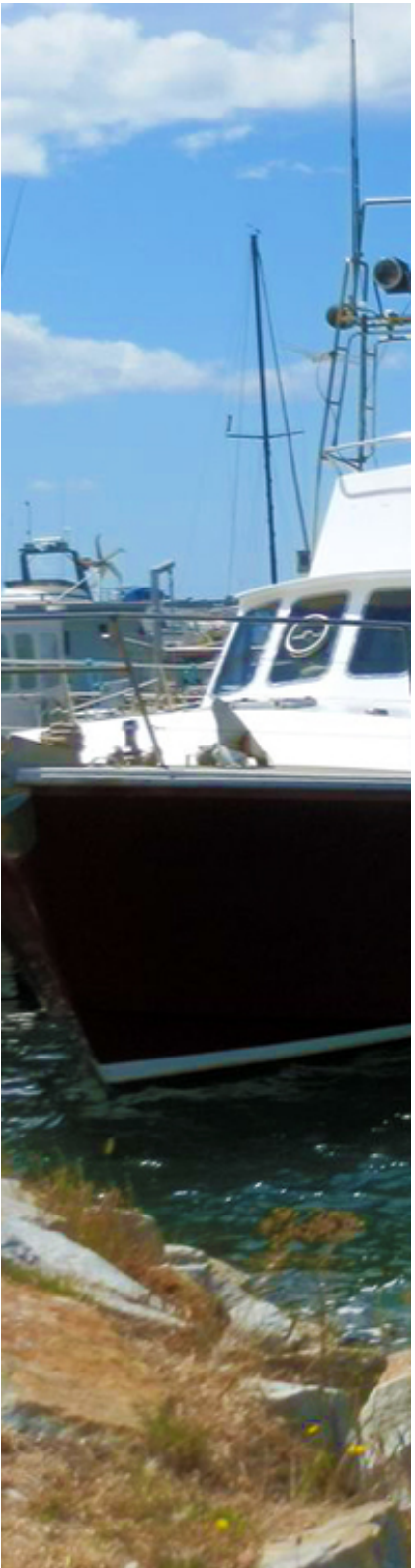


Victoria & NSW

National Climate Change Adaptation Research Facility (NCCARF)

Climate Change, the Marine Environment and Fisheries Adaptation: Victoria

Changes in community composition and distribution under climate change: New South Wales

Fisheries Research and Development Corporation (FRDC)

An Information Portal for the Oyster Industry

Department of Primary Industries Victoria (DPI VIC)

Abalone Fisheries

The Impact on SE Australian Blue Grenadier Fishery

Blue Mussel Aquaculture

Pacific Oyster Aquaculture

Atlantic Salmon Aquaculture

Snapper Fisheries

Southern Rock Lobster Fisheries

Tropics

Climate Commission (CC)
The Critical Decade: Queensland climate change impacts and opportunities

CRC Reef Research Centre
Coral bleaching and global climate change

Fisheries Research and Development Corporation (FRDC)
Effects of climate change on reproduction, larval development, and population growth of coral trout
The vulnerability of an iconic Australian finfish to an altered climate: Barramundi
Change in coastal fishing communities: Bowen, Queensland

Great Barrier Reef Marine Parks Authority (GBRMPA)
Impacts of tropical cyclone Yasi on the Great Barrier Reef
Climate change adaptation principles

Videos

Climate Variability
Dr Ivan Haigh considers the consequences of Climate Change on population, erosion and sea level rise.

ABC Catalyst: Taking Our Temperature
A special report covering a hundred years of weather records from around Australia and what it means to the way we live.

Pelagic Fish
Dr Alistair Hobday discusses the main climate drivers, water temperature and increases in upwelling-favourable winds that will impact pelagic fishes around Australia.

Measuring Marine Climate Change
Rising sea temperatures and sea levels, changing currents and acidity levels all have a huge impact on our oceans inhabitants. But scientists in Tasmania have discovered it's not all bad news for our fisheries.

Marine Report Card Provides a Benchmark for Climate Impacts
The Marine Climate Change Impacts and Adaptation Report Card for Australia provide details of the observed and projected impacts of climate change on marine ecosystems.

Arctic Report Card
This report card provides multiple observations of strong evidence for widespread, sustained change driving Arctic environmental system into new state.

Climate Change Fuelling Wilder Weather
When extreme weather events occur there are questions asked about the link to climate change. This video describes some of the causes of extreme weather events.

Piecing Together the Temperature Puzzle
The past decade has been the hottest ever recorded since global temperature records began 150 years ago. This video discusses the impacts of the sun's energy, Earth's reflectance and greenhouse gasses on global warming.

Sea Level Rise
Sea levels are rising around Australia, with fastest rates currently in northern Australia. Sedimentary records from Tasmania confirm slow sea-level change over 1000s of years until the early 20th century, when there was a significant acceleration in the rate of sea-level rise.

Stories from the Abrolohos

PhotoVoice the Abrolhos project

The Abrolhos Islands with Dave McCann

Never put them on lumps on the moon

Snorkel dive with Jenny

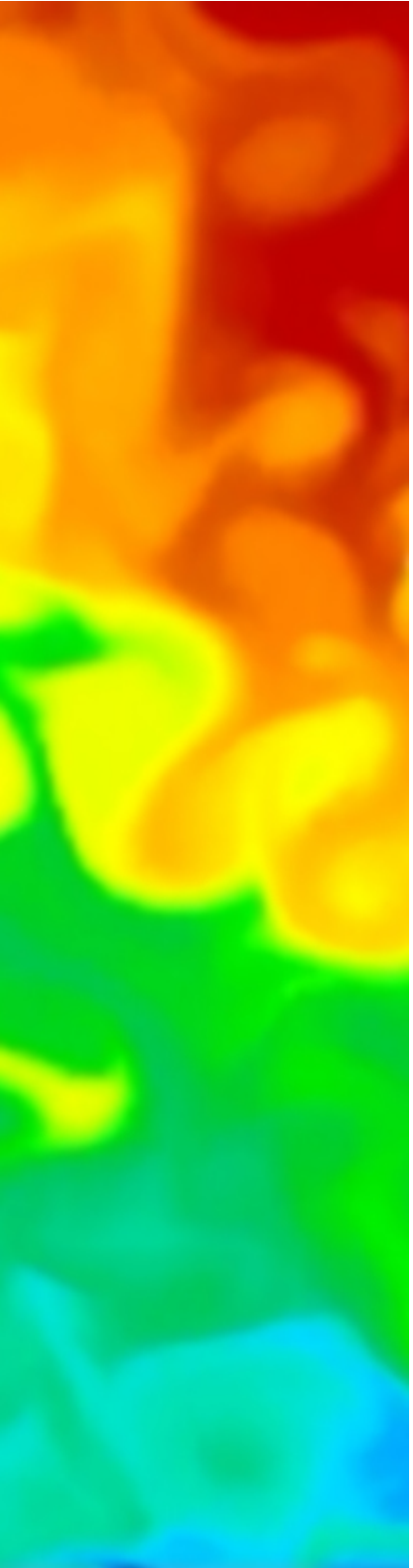
Island life

Abrolhos Islands timelapse

A chat with the Basile's

A chat with Sam

A chat with Karen



Animations

Australian Currents

Follow the ocean currents around Australia. This animation shows the ocean circulation in the Australian region. (9M)

West Australia's Leeuwin Current

This southward flowing current forms in the Indo-Pacific region and moves along the coast of Western Australia. The Leeuwin Current is a warm, low nutrient current that is stronger during winter months and weaker in summer months. (110M – slow loading)

Ocean Current Flows with Sea Surface Temperatures (SST)

This visualization shows the ocean current flows on a flat map. The flows are coloured by sea surface temperatures with blues being cooler waters and yellows/reds warmer waters. The time period for this visualization is 10 January 2005 through to 2006. Each second that passes in the visualization is about 2.5 days. (12M – slow loading)

What is Coral Bleaching?

As the climate changes, coral bleaching is predicted to become more frequent and severe. Sea temperature increases and coral stress from other impacts may increase corals' vulnerability to bleaching.

Impacts of Climate Change

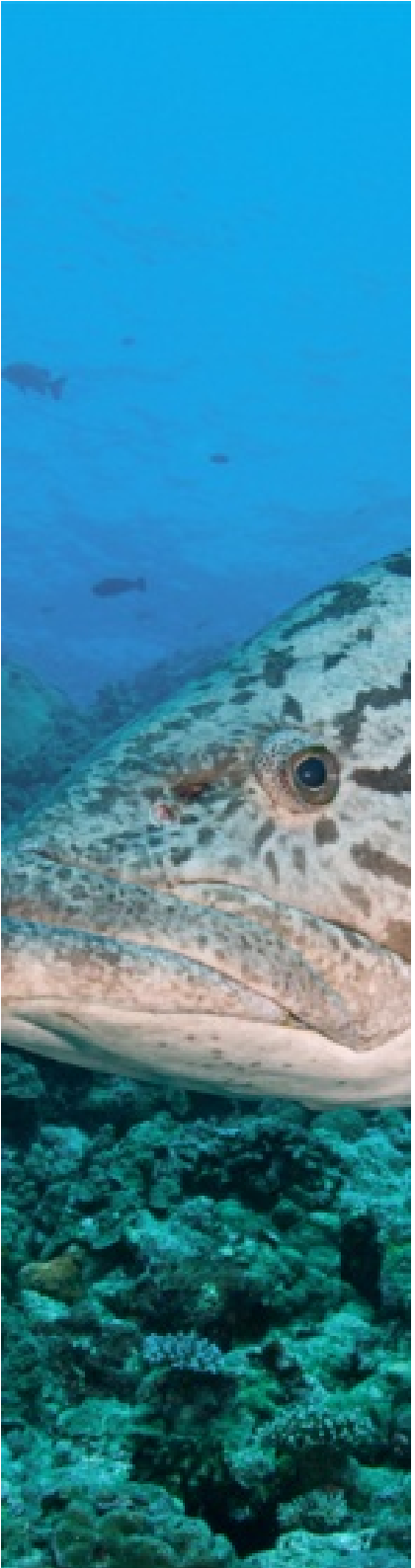
Climate change is now considered to be the greatest threat to the Great Barrier Reef. This animation is designed to help people understand the impacts climate change could have on the Reef and how their individual choices can influence the degree of impact.

Ocean Acidification

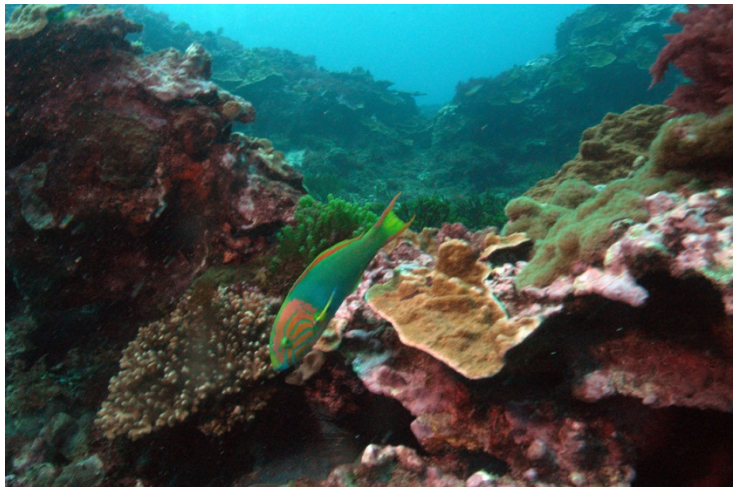
A simplified animation to a complex topic which does not explain the process in detail, rather it uses a characters experience to illicit an understanding of the effect of acidification on coral reefs.

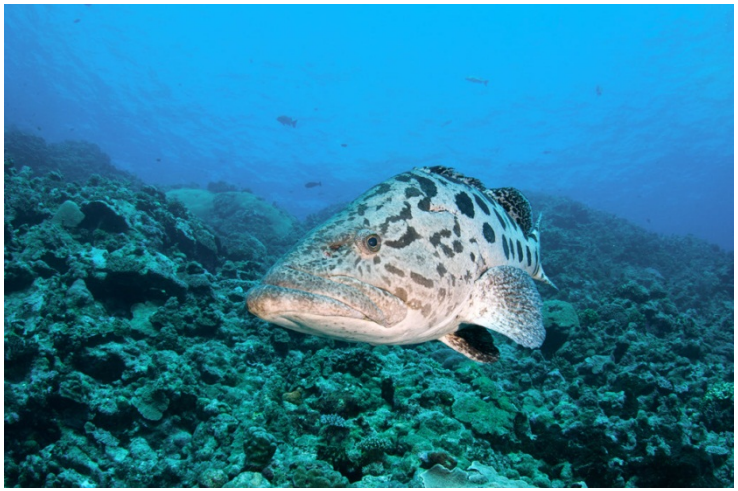
Five-Year Global Temperature Anomalies from 1880 to 2012

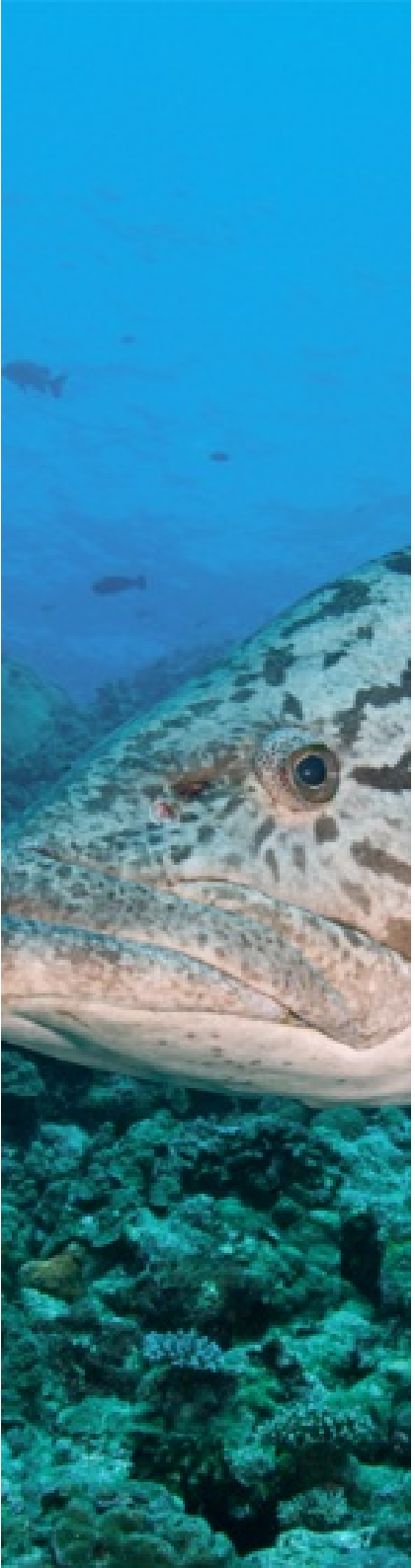
This color-coded map displays a progression of changing global surface temperatures anomalies from 1880 through 2012. Higher than normal temperatures are shown in red and lower than normal temperatures are shown in blue. (9.3M – slow loading)

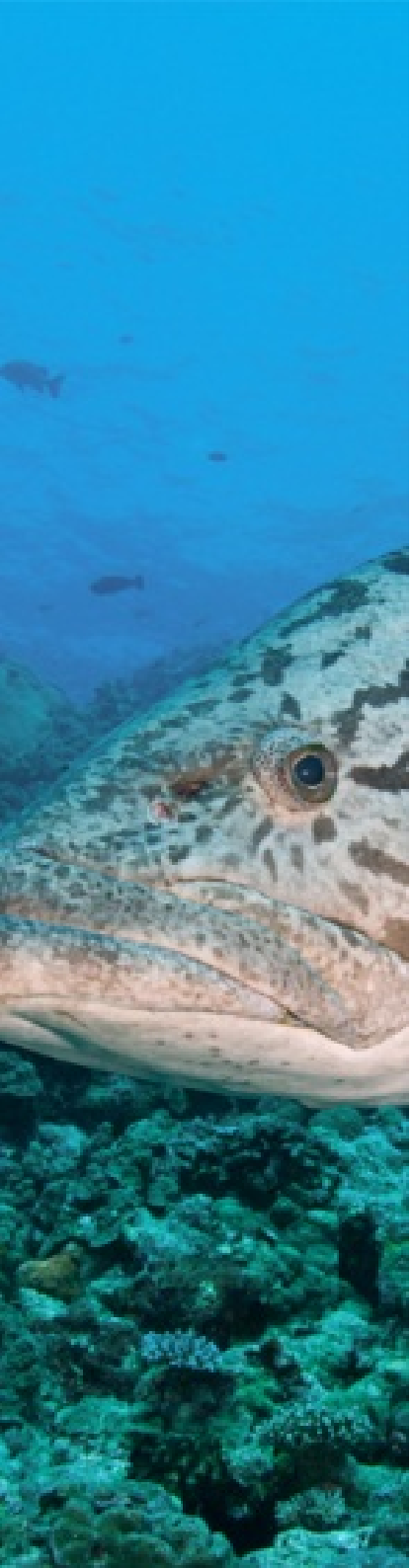


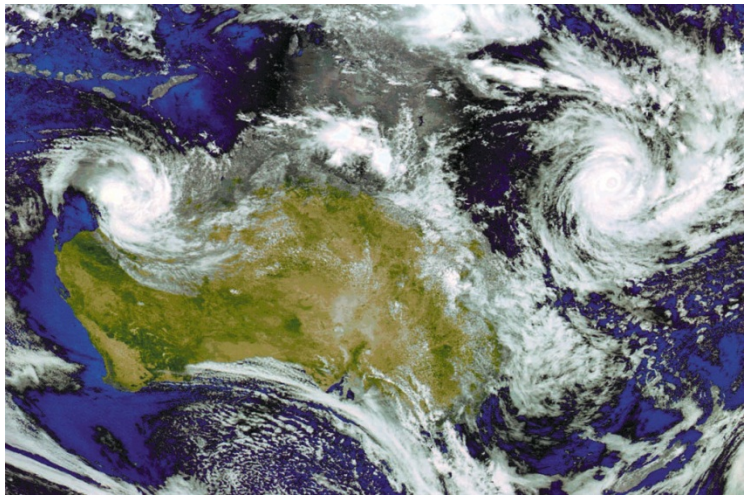
Gallery

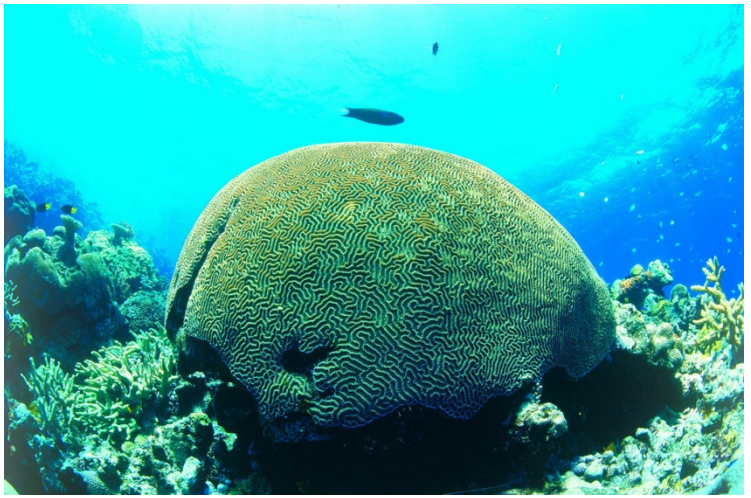


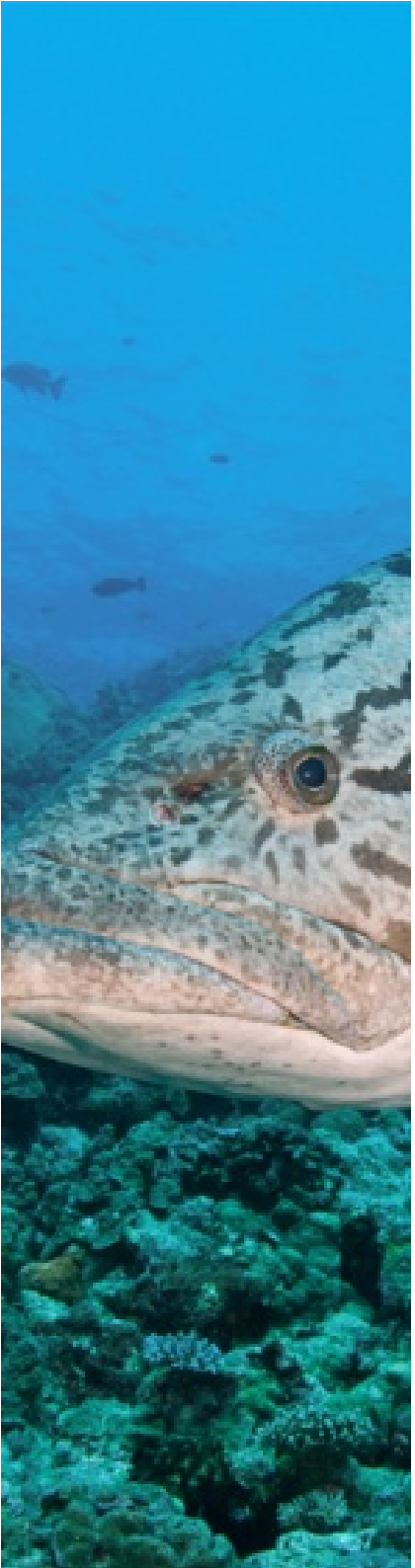


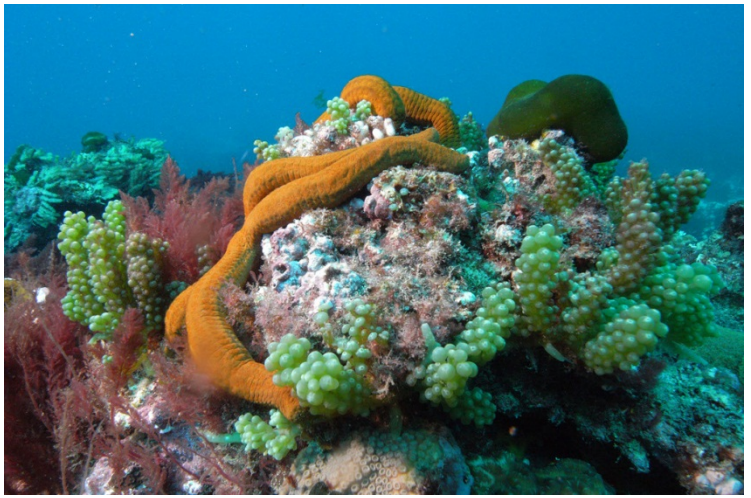


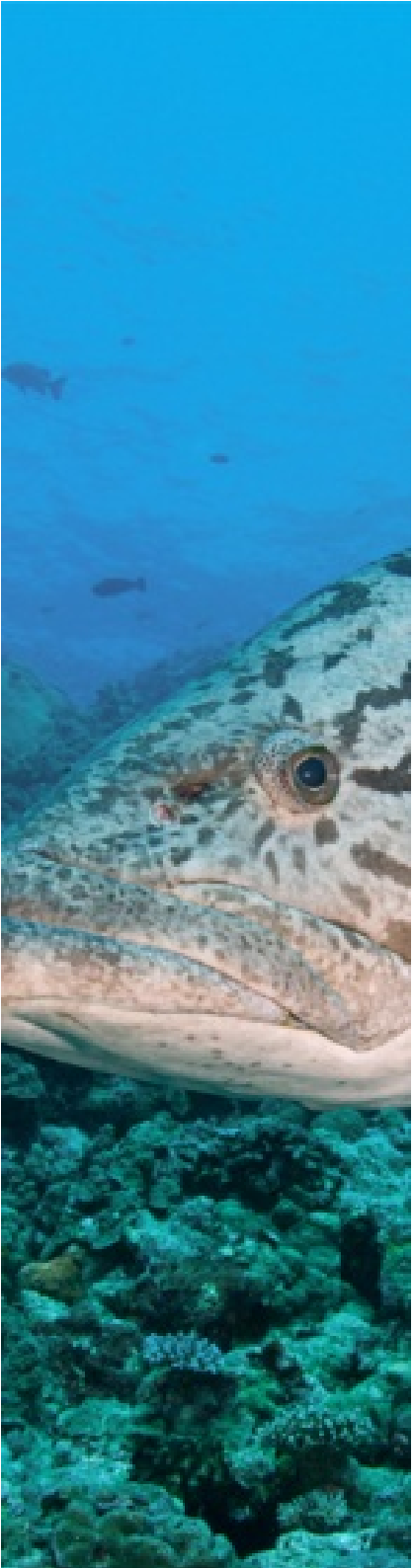


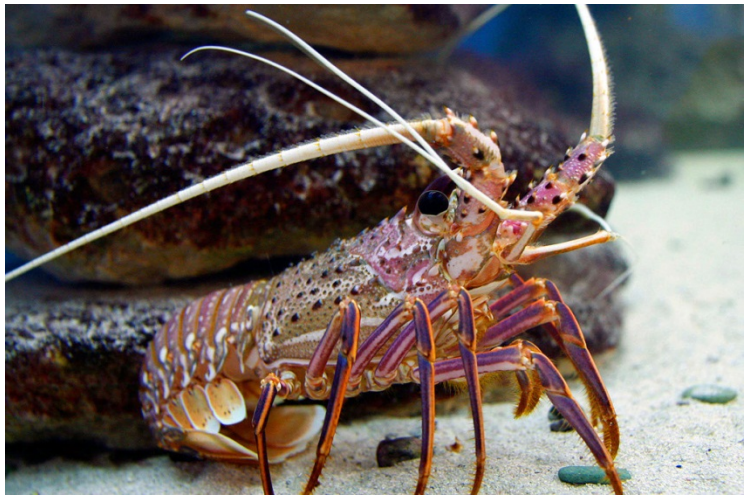












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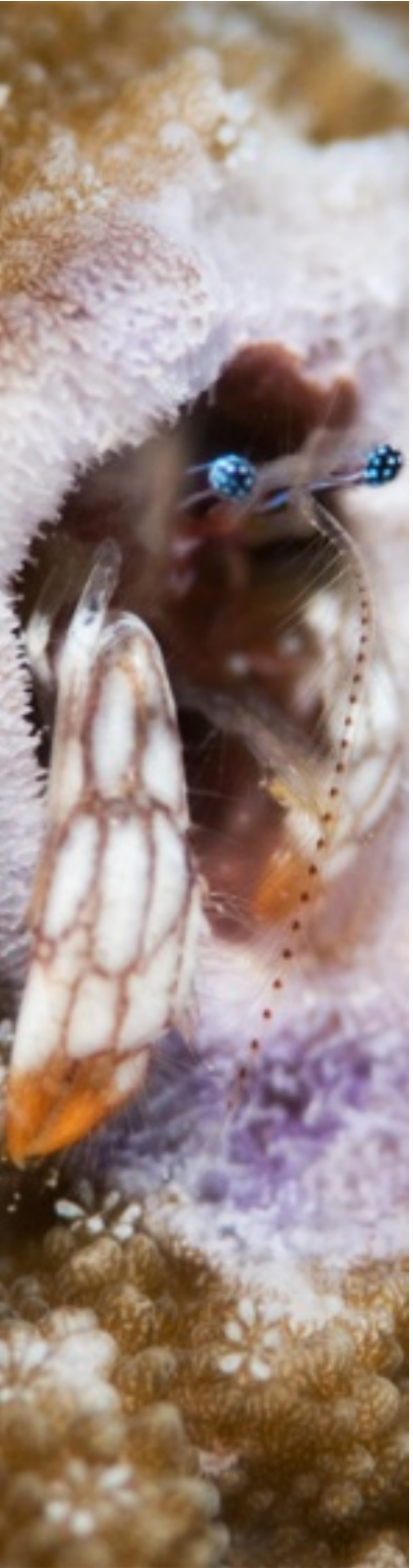


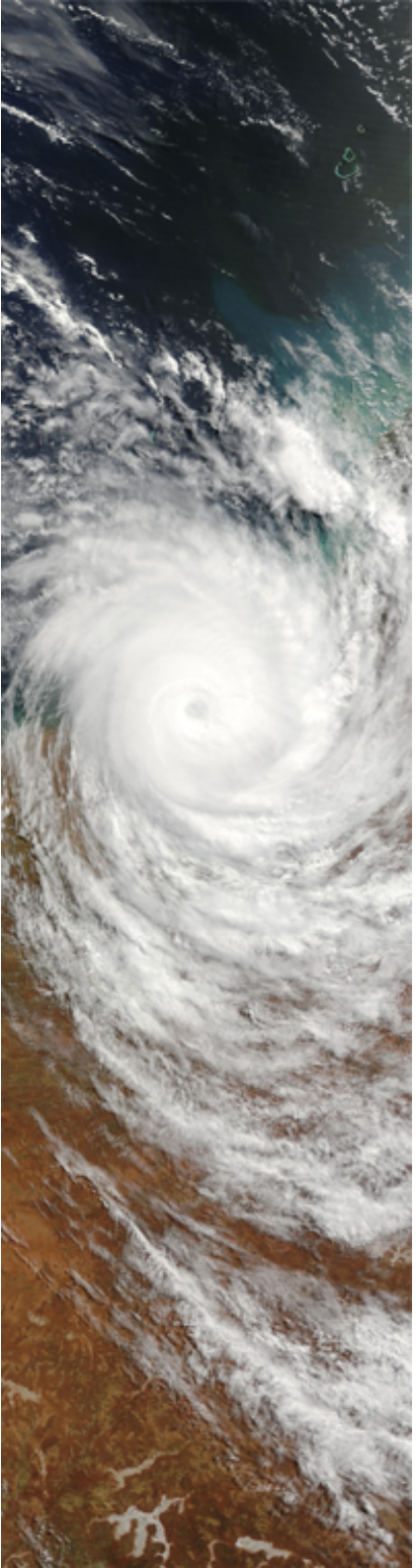
Presentations

2011 Costal Conservations Series, Geraldton WA Session 3
Dr Alistair Hobday

Lessons learned from conducting adaptation research
Dr Gretta Pecl

Taking the adaptation message to the commercial fishing industry
Mr Eric Perez

Skin in the Game
Mr Ryan Donnelly



Opportunities for Action

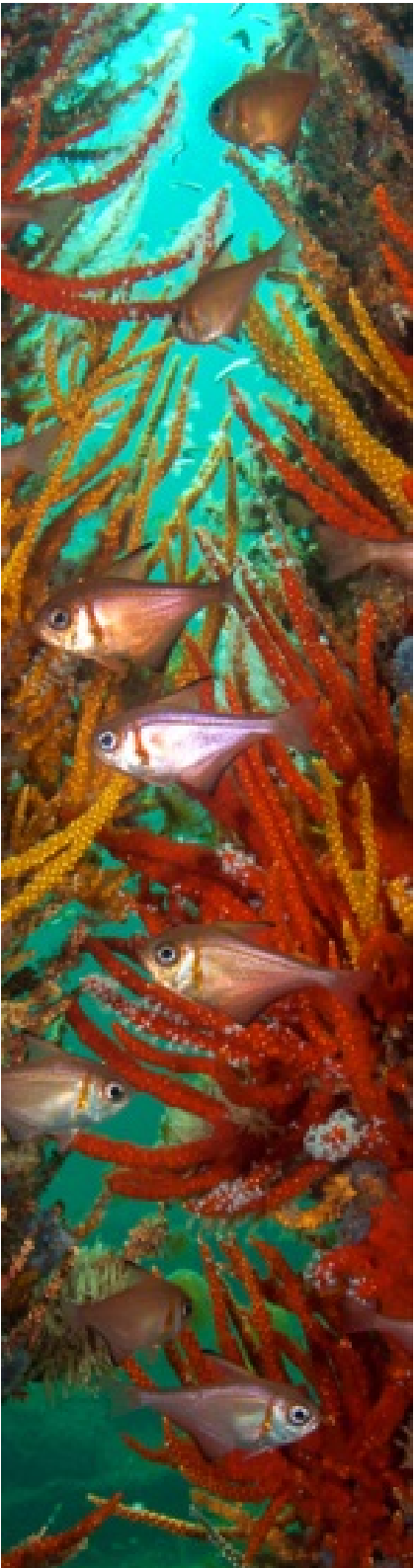
Teachers Resources

- Teacher Guide: Climate Change and the Marine Environment
- A Climate for Change page 2
- What can we do to protect our coral reefs from climate change?
- Monitoring Coral Bleaching on Christmas Island
- Management for a Sustainable Future
- Little drifters are beacons of climate change
- Who goes with the flow?: The Leeuwin Current

Redmap: What's on the move around Australia?

Redmap: What's on the move around Western Australia?

Fuel Efficiency Guide



Related Resources

General Information

- Glossary of Terms
- Climate Change Links
- Organisation Abbreviations
- Unlocking lobster secrets

Acknowledgements

Contributers

Dr Alistair Hobday - CSIRO Climate Adaptation National Research Flagship
Mr Chris Lewis - ABC Open
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Dr Ingrid van Putten - CSIRO Marine and Atmospheric Research
Dr Ivan Haig - University of Western Australia
Dr John Church - CSIRO Marine and Atmospheric Research
Ms Laura Purcell - Adaptation Research Network for Marine Biodiversity and Resources (UTAS)
Dr Laura Stocker - Curtin University Sustainable Policy Institute
Dr Lynda Bellchambers - Department of Fisheries, Government of Western Australia
Mr Mike Burgess - Department of Fisheries, Government of Western Australia
Dr Ming Feng - CSIRO Marine & Atmospheric Research
Mr Neil E. Stump - Tasmanian Seafood Industry Council
Dr Nick Caputi - Department of Fisheries, Government of Western Australia
Mr Ryan Donnelly - Reef & Rainforest Research Centre
Dr Sarah Metcalf - Murdoch University

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Clay Bryce
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Department of Environment and Conservation
Great Barrier Reef Marine Park Authority
Japan Meteorological Agency and Bureau of Meteorology

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Organisations

ABC Open
Adaptation Research Network for Marine Biodiversity & Resources
Antarctic Climate & Ecosystems CRC
Australian Broadcasting Corporation
Australian Institute of Marine Science
Australian Marine Protection Association
Bureau of Meteorology
Climate Commission
Commonwealth Scientific and Industrial Research Organisation
Department of Climate Change and Energy Efficiency
Department of Fisheries, Government of Western Australia
Department of Primary Industries, Victoria
Fisheries Research and Development Corporation
Great Barrier Reef Marine Park Authority
Green Cross Australia
Institute for Marine and Antarctic Studies
Indian Ocean Climate Initiative
Marine Education Society of Australasia
Murdoch University
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National Climate Change Adaptation Research Facility
National Oceanic and Atmospheric Administration PMEL
Northern Agricultural Catchments Council
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Tasmanian Climate Change Office
Tasmanian Seafood Industry Council
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Project Leader

Jenny Shaw

western australian marine science institution

Designer

Michael D'Silva

www.wamsi.org.au

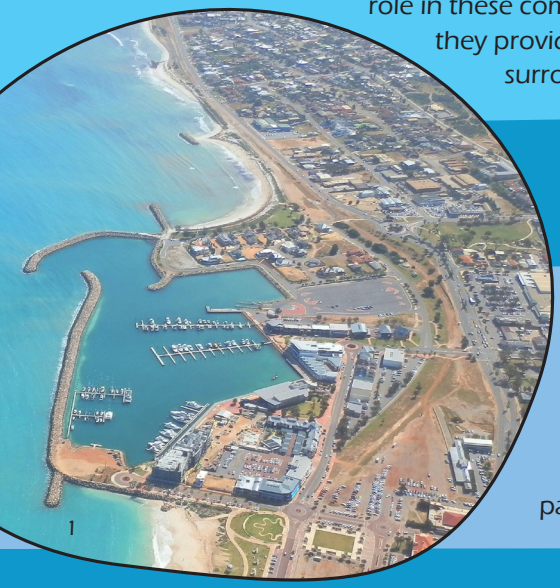
info@wamsi.org.au

Change in coastal fishing communities: Geraldton, Western Australia

What's unique about Geraldton and small coastal communities

Although a relatively large regional town at a just over 30,000 people, in some aspects Geraldton is typical of Australian coastal towns that are beyond commuting distances. For instance, the health services and retail sectors assume a larger role in these communities as they provide services to the surrounding areas.

However, large coastal communities in Western Australia, like Geraldton are different to other States in that the construction sector associated with the mining industry is particularly important. Even though Geraldton has traditionally been characterised as a fishing town, commercial fishing also has a much greater role in smaller coastal communities in Western Australia when compared with other Australian communities.



1

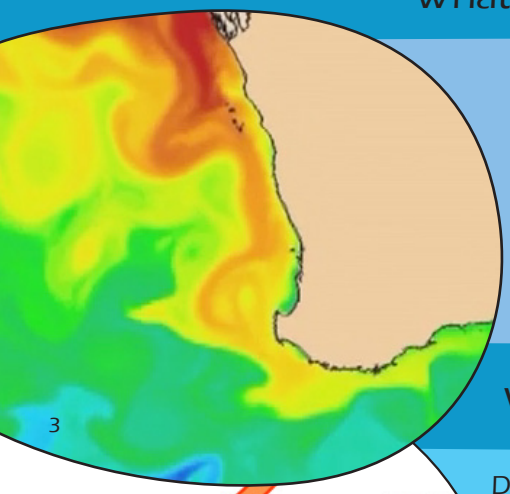
The marine sector in a small coastal community

Australian coastal communities traditionally have major industry sectors that harvest resources from the sea. Recreational fishing and charter fishing are often locally very important with increasing participation rates fuelled by higher disposable incomes. Generally, tourism related activities (like restaurants and accommodation), some of which can be linked to marine activities, are of greater relative economic importance in small coastal communities compared to the larger centres.

The flow-on effects of the marine sector

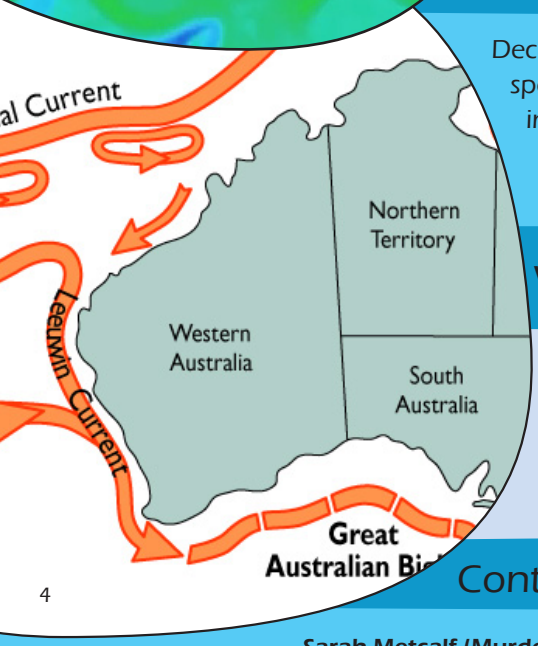
The link between the marine sector and other economic sectors in the community are constantly changing. For instance, there is a noticeable impact of a decline in active local fishing boats over the last 4 years on associated marine industries such as slipway operators, vessel maintenance and marine chandlery as well as fish outlets, restaurants, and processing facilities. Even though employment in fisheries has been impacted, many have found alternative employment in the mining and oil and gas sector. Although there have been negative flow on effects from the smaller commercial fishing sector, the recreational fishing sector provides some economic benefits to associated industries such as fishing and tackle shops. The aquaculture sector has many flow-on benefits including local employment and direct pearl sales to tourists help promote Geraldton as a tourism destination.

What you said: Changes in the marine sector



The size of the local commercial fishing fleet had declined. The social implication of a declining fleet and change in fishing behaviour and timing has had noticeable social implications. Further growth in aquaculture was thought to be primarily through venturing into new species, as there were currently limited area expansion possibilities for existing farms. However, aquaculture start-up costs are relatively high. Use of the local area for recreational boating and charter fishing was affected by onshore winds. Even though charter fishing was taking place in the area, the operators were generally from other coastal centres.

What you said: Changes in the marine environment



Decline in abundance of several commercial species was due to a number factors including: commercial and recreational fishing pressure and climate related factors (temperature and ocean current related). Some new commercial fishing opportunities could present themselves from new (range shifting) species. New net based aquaculture in the Geraldton area could be based on warmer water species.

What the Scientists Say

The sea surface temperature on the west coast is increasing. The currents are bringing warmer waters further south into different areas. Marine species respond differently to the warmer waters and current changes are likely to affect larval movement in some species. Some species may move to more suitable places further south and become less abundant in Geraldton.

Contact

Sarah Metcalf (Murdoch University)
Email: s.metcalf@murdoch.edu.au
Phone: (08) 9360 7833

Malcolm Tull (Murdoch University)
Email: m.tull@ murdoch.edu.au
Phone: (08) 9360 2481

Photo credits: 1, 2 & 5. J. Shaw; 3.© BLUElink a partnership between CSIRO and Bureau of Meteorology; 4. Diagram from Richardson and Poloczanska 2009

Census and other existing research information were combined with information collected from 3 coastal towns in Australia, St Helens TAS, Bowen QLD and Geraldton WA. The information presented here is preliminary and should not be considered final for the 'blueprint for coastal community adaptation planning' project. The 'blueprint for coastal community adaptation planning' project will be finalised by the end of 2013.

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NCCARF
National Climate Change Adaptation Research Facility
Adaptation Research Network
MARINE BIODIVERSITY AND RESOURCES

Change in coastal fishing communities: St Helens Tasmania

What's unique about St Helens and small coastal communities?

Although a relatively small town at less than 4,000 people, St Helens is typical of the many small coastal towns in Tasmania that are beyond commuting distances, that makes up nearly 30% of the population. Secondary industries such as accommodation and food services are increasingly dominating St Helens economy over commercial fishing. But despite a decline in the primary industries nationally, small coastal communities like St Helens still have a higher proportion of people in the aquaculture and fishing industries. Like other small coastal communities, St Helens has a greater proportion of older people, average household incomes are lower, and work opportunities are limited. St Helens is unique in the fact that it is in a marine hotspot, meaning that climate driven changes in the marine environment are happening relatively fast.

1

The marine sector in a small coastal community

Coastal communities traditionally have major industry sectors that harvest resources from the sea. Recreational fishing and charter fishing have become locally very important and the charter fishing sector has built increasing presence and reputation. Moreover, Tasmania has a high participation rate in recreational fishing which is also evident in St Helens. The charter and recreational fishing sectors are predicted to remain an important tourist activity in St Helens and potentially increase as more "game fish" move adjacent to the coast with warming waters. Generally, tourism related activities (like restaurants and accommodation), some of which can be linked to marine activities, are of greater economic importance in small coastal communities compared to the larger centres.

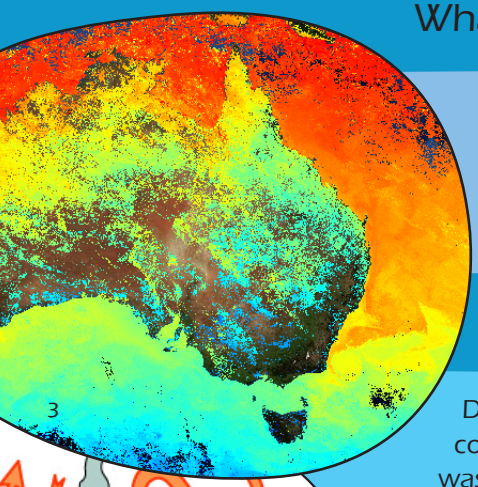
The flow-on effects of the marine sector

The link between the marine sector and other economic sectors in the community are constantly changing. For instance, the impact of a nearly 70% decline in active local fishing boats over the last 20 years on associated marine industries such as slipway operators, vessel maintenance and marine chandlery as well as fish outlets, restaurants, and processing facilities, has been great. Although there has been a negative impact from a smaller local commercial fishing sector, there is increased seasonal activity associated with the charter fishing and recreational fishing sectors providing economic benefits to associated industries such as fishing and tackle shops and accommodation and restaurant business. The aquaculture sector has many flow-on benefits including local employment, equipment maintenance and transport operations. Direct sales to tourists and restaurants help promote St Helen's as a marine tourism destination.

2

What you said: Changes in the marine sector

The size of the local commercial fishing fleet had declined. Further growth in the aquaculture was thought to be primarily through changes in productivity and marketing, as there were limited area expansion possibilities. The charter fishing, and to some extent the dive sector, had grown with potential for further expansion. Use of the local St Helens area for recreational boating was increasing.



What you said: Changes in the marine environment

Decline in abundance of several commercial species (also in the Bay) was due to a number factors including: commercial and recreational fishing pressure and climate related factors. New commercial fishing opportunities were presented by new (range shifting) species like the urchins.

Charter (and recreational) fishing opportunities were presented by increasing presence of new game fish species and also abundance increases of some species present in the Bay. Aquaculture was being affected by increased frequency of extreme rainfall events and associated terrestrial run-off in catchment regions.

What the Scientists Say

The sea surface temperature on the east coast is increasing. The currents are bringing warm water further south (especially in summer). Marine species respond differently to the warmer waters – some will move to more suitable places further south and thus be less abundant in St Helens, while species moving from northern regions will become more abundant. Rainfall events have been more intense and frequent in the past years affecting run-off and the nutrient load of the inshore waters.

Contact

Ingrid van Putten (CSIRO)
Email: Ingrid.vanputten@csiro.au
Phone: (03) 6232 5048

Stewart Frusher (IMAS, University of Tasmania)
Email: stewart.frusher@utas.edu.au
Phone: (03) 6227 7271 or (03) 6226 1771

Photo credits: 1, 2 & 5. J. Shaw; 3. IMOS-L3P Legacy 14 Days Composite 2011 GHRSST subskin; 4. Diagram from Richardson and Poloczanska 2009

Disclaimer: The information presented is from a range of sources including Census data, published reports, and interviews held for the Blueprint project. The aim of the flyer is to present some preliminary and highly simplified information. Further details will be provided after the full project finishes at the end of 2013.

Census and other existing research information were combined with information collected from 3 coastal towns in Australia, St Helens TAS, Bowen QLD and Geraldton WA. The information presented here is preliminary and should not be considered final for the 'blueprint for coastal community adaptation planning' project. The 'blueprint for coastal community adaptation planning' project will be finalised by the end of 2013.

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Fisheries Research and Development Corporation
CSIRO
UTAS
IMAS
INSTITUTE FOR MARINE AND ANTARCTIC STUDIES
NCCARF
National Climate Change Adaptation Research Facility

Change in coastal fishing communities: Bowen, Queensland

What's unique about Bowen and small coastal communities?

Bowen is a medium sized coastal town of just over 10,000 people. In some aspects Bowen is typical of Australian coastal towns that are beyond commuting distances. For instance, secondary industries such as accommodation and food services are increasingly dominating the economy over commercial fishing. But despite a decline in the primary industries nationally, coastal communities like Bowen still have a higher proportion of people in the aquaculture and fishing industries. Reef line fishing, especially for coral trout, is the main commercial fishery in Bowen and prawns and barramundi form the backbone of land based aquaculture industries. Recreational fishing and dive operators make up the marine tourism sector.

The marine sector in a small coastal community

Coastal communities traditionally have major industry sectors that harvest resources from the sea or invest in recreational marine pursuits. Most people (32%) who work in fishing and aquaculture in Queensland live in coastal communities of up to 30,000 residents. Recreational fishing, charter fishing, and the dive sector are often locally very important with increasing participation rates fuelled by higher disposable incomes. Generally, tourism related activities (like restaurants and accommodation), some of which can be linked to marine activities, are of greater relative economic importance in small coastal communities compared to the larger centres, especially in Queensland.

The flow-on effects of the marine sector

The link between the marine sector and other economic sectors in the community are constantly changing. For instance, there is a noticeable impact from a decline in active local fishing boats over the last decade on associated marine industries such as slipway operators, vessel maintenance and marine chandlery as well as fish outlets, restaurants, and processing facilities. Even though employment in fisheries has been impacted, some have found alternative employment in the mining sector. Although there has been a negative impact from a dwindling local commercial fishing sector, the growing recreational fishing sectors provides some economic benefits to associated industries such as fishing and tackle shops. The aquaculture sector has many flow-on benefits particularly with respect to local full-time and part-time employment.

What you said: Changes in the marine sector

The size of the local commercial fishing fleet has declined significantly to around 10 active boats. Marine park zoning and changes in management partly explained this decline. The social implication of a declining fleet and change in fishing behaviour has been noticeable in the local community. The dive sector has remained relatively stable and has been consistently present in the area for a number of years. Even though there had been a charter fishing operator in the area it was difficult to operate without cross-subsidisation from other business (much like the dive sector).

What you said: Changes in the marine environment

Decline in abundance of several commercial species was due to a number factors including: commercial and recreational fishing pressure and climate related factors (especially the effect of cyclones and storms but also coral bleaching). Misinformation about the physical infrastructure and marine environment destruction after cyclonic events was responsible for prolonged economic hardships in the local community with tourists staying away. However, at present the local marine environment seemed to be 'repairing' benefitting the dive charters.

What the Scientists Say

There have been a number of cyclonic weather events that have had destructive effects on the marine environment in the past years. Marine species respond differently to these destructive effects with the recovery rate of some species being higher than others and the ability of some species to move to more suitable places.

Contact

Nadine Marshall (CSIRO)
Email: Nadine.Marshall@csiro.au
Phone: (07) 4753 8537

Photo credits: 1, 2, 3 & 5. J. Shaw; 4. Diagram from Richardson and Poloczanska 2009

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MARINE BIODIVERSITY AND RESOURCES

Teacher Guide: Climate Change and the Marine Environment

1. Overview

This teacher guide has been provided to assist teachers to begin developing a teaching-learning program studying the effects of climate change on the marine environment and connecting them with relevant background information and credible resources.

The teacher guide has been specifically developed to highlight key resources provided on the DVD resource *Seeing Change: Climate related resource information for the marine environment*, published by the Western Australian Marine Science Institute (WAMSI). This DVD resource has been developed to facilitate the distribution of the latest scientific findings and aids in the interpretation of how a changing climate is affecting, and could affect, Australia's marine environment.

Additional online resources have also been identified in this teacher guide.

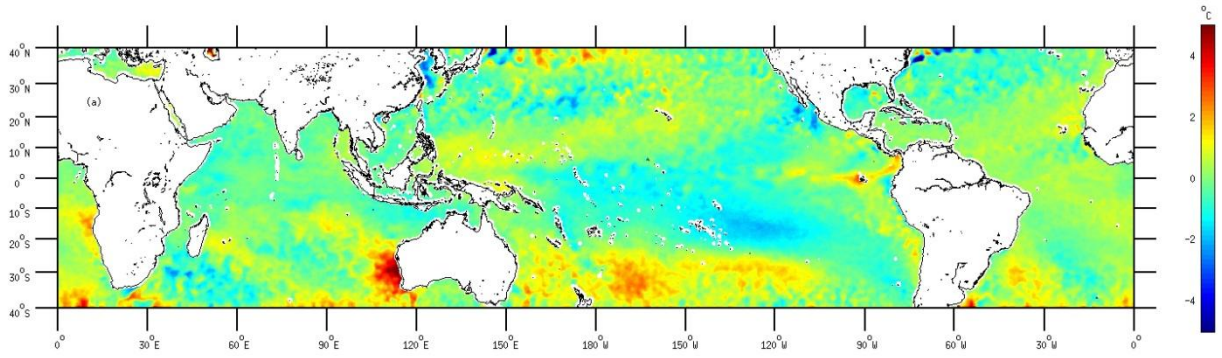


Figure 1: Sea surface temperature anomalies during the Western Australian "marine heatwave" during summer of 2010/2011 (Source: CSIRO)

2. Objectives of a teaching-learning program

Any proposed teaching-learning program relating to climate change should consider that students will:

- Recognise that the marine environment is a complex and biologically diverse system that contains critical ecosystems.
- Recognise that these ecosystems are under added threats from warming oceans, sea level rise, more intense climatic events and increasingly acidic seawater.
- Gain both global and regional perspectives of how a changing climate can impact on the marine environment.

- Understand the flow-on effects of climate change on fisheries and the functions of marine ecosystems.
- Identify various causes and impacts of climate change, including poor environmental practices, habitat loss and extreme climatic events?
- Focus on ways that people can help reduce the impact of climate change, including reducing emissions and protecting and preserving biodiversity, coastal and marine landscapes and threatened species.
- Participate in and promote active citizenship of what individuals and the school community can do, at home and at school, to cut greenhouse emissions and increase resilience to the effects of climate change.

3. Links to National Curriculum

AUSTRALIAN CURRICULUM		CODE
Strand	**Sub-strand**	
SCIENCE		
Science Understanding	Biological sciences	ACSSU043 ACSSU094 ACSSU175 ACSSU176
	Earth and space sciences	ACSSU096 ACSSU189
Science as a Human Endeavour	Use and Influence of science	ACSHE220 ACSHE121 ACSHE135 ACSHE136 ACSHE160
	Nature and development of science	ACSHE191
ENGLISH		
Language	Expressing and developing ideas	ACELA1498
Literacy	Interacting with others	ACELY1688 ACELY1677
	Creating texts	ACELY1694 ACELY1704
	Interpreting, analysing, evaluating	ACELY1733 ACELY1703 ACELY1712

4. Teacher Background Information

The impacts of potential climate change and extreme climatic events are being detected globally within the world's marine ecosystems and fisheries. Until recently, the effect of climate

change on our oceans has been described in terms of rising sea levels and increased sea surface temperature. Research has now provided a wealth of information and contributed to a greater understanding of the potential impacts and consequences of climate change on the marine environment and fisheries. Some of the key observations include:

- A trend of rising seas levels. Global average mean sea level for 2011 was 210 mm above the level in 1880.
- Sea surface temperatures in Australia have increased by about 0.8 °C since 1910.
- Decline in the amount of rainfall with an increase in extreme weather events.
- Likelihood of more tropical cyclones further south.
- Changes in behaviour and intensity of ocean currents, such as the Leeuwin Current and the East Australian Current.
- Changes in the wind direction and strength.
- Some marine species extending their range further south.

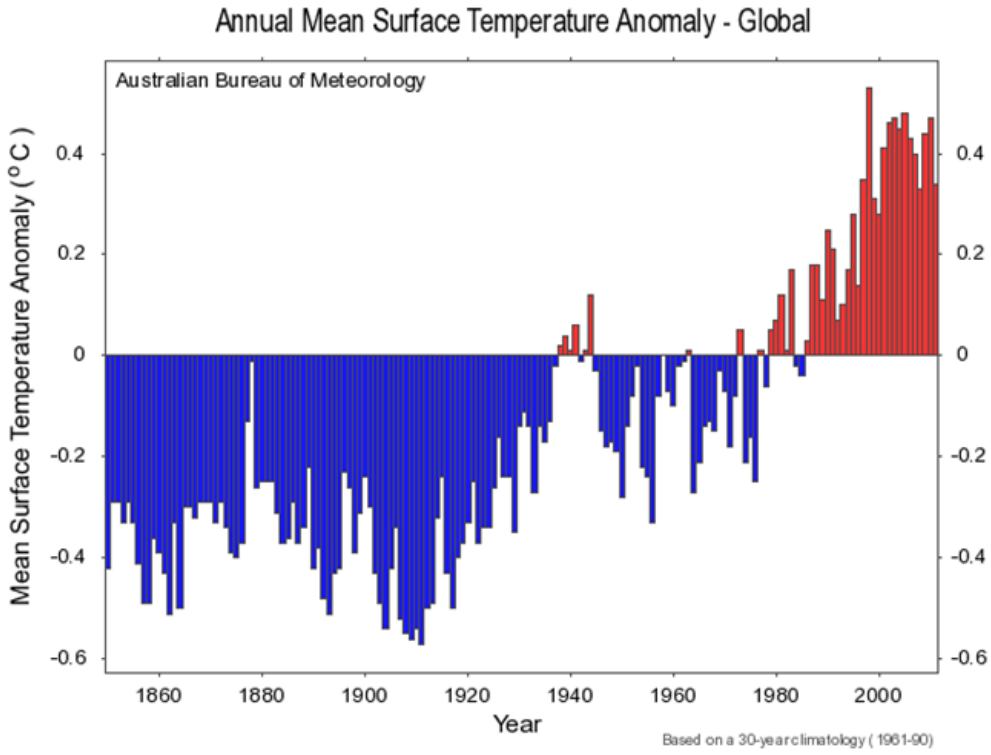


Figure 2: Global annual mean surface temperature anomaly (Source: Bureau of Meteorology)

5. *Seeing Change DVD* (WAMSI)

The *Seeing Change* DVD brings together an extensive range of information and published resource materials on climate change, specifically relating to the Australian marine environment. There are videos, animations, technical presentations, fact sheets, links to other materials and much more.

Marine Climate Change in Australia 2012 Report Card

The *Marine Climate Change in Australia 2012 Report Card* provides a comprehensive overview of the current understanding of marine climate change across Australia. The impacts on climatic variables and ecological values (as per Figure 3) are divided across three areas:

1. What is happening?
2. What is expected?
3. What we are doing about it?

The *Marine Climate Change in Australia 2012 Report Card* is found in the Published Information section on the *Seeing Change* DVD.

This material can be used as an environmental scan to help recognise the current understanding of climate change and variations, expected impacts and relevance to local marine ecosystems and fisheries.

A video interview with Dr Alistair Hobday (*CSIRO: Marine report card provides a benchmark for Climate Change*, duration 04:21m) explains some of the key findings of the report card and is available on the *Seeing Change* DVD.

MARINE CLIMATE

- Temperature
- Sea level
- East Australian Current
- Leeuwin Current
- El Nino- Southern Oscillation
- Ocean acidification

IMPACTS ON MARINE BIODIVERSITY

- Mangroves and tidal wetlands
- Seagrass
- Macroalgae
- Marine microbes
- Phytoplankton
- Zooplankton
- Coral Reefs
- Tropical Fish
- Marine Mammals
- Marine reptiles
- Seabirds

Figure 3: Marine climatic variables and environmental values covered in the *Marine Climate Change in Australia 2012 Report Card*

Video Resources

Videos included on the DVD are very useful in complementing a teaching-learning program, through demonstrating the science being conducted around Australia to detect changes in the marine environment and climate generally. They are all targeted to a general audience and can complement lesson plans referred to in this Teacher Guide.

- **Taking Our Temperature (Catalyst, ABC TV)**
  Dr. Jonica Newby travels around Australia to investigate if the weather has changed through presenting a quirky and engaging a 100 year weather report. This video provides an excellent resource for students to obtain a comprehensive overview of studying and observing climate change. Includes discussion on temperature, snow cover, rainfall and rising sea levels. Duration approximately 27 minutes.

- **Measuring Marine Climate Change (FRDC)**
  This video investigates how warming oceans may affect recreational and commercial fishing. The video begins on board a CSIRO vessel conducting water sampling for temperature, salinity, nutrients, carbon and alkalinity in a research program that has been running since 1944. Data has seen ocean temperatures rise, which corresponds with around 40 new fish species reported for the first time in Tasmanian waters. The video describes that a changing climate will affect fisheries both positively and negatively and as a result marine, management will need to be more flexible and adaptive. Duration 03:33 minutes.

- **Climate Variability (WAMSI)**
  This video contemplates the potential implications of rising sea levels and extreme weather events for the Perth Metropolitan Region. Includes an interview with Dr. Ivan Haigh of the University of Western Australia (UWA). Duration 02:32 minutes.

Animations

Animations included on the DVD help to demonstrate the behaviour of Australia's ocean currents and their influence on transporting warmer waters southwards. Animations developed by the Great Barrier Reef Marine Park Authority (GBRMPA) have been specifically produced to interpret the impact of climate change on the Great Barrier Reef and complex processes of coral bleaching and ocean acidification. Again, these resources can be used to complement lesson plans referred to in this Teacher Guide.

- **Australian Currents**
  Ride the ocean currents around Australia. This animation shows the ocean circulation in the Australian region.

- **Western Australia's Leeuwin Current**
  This southward flowing current forms in the Indo-Pacific region and moves along the coast of WA. The Leeuwin Current is a warm, low nutrient current that is stronger during winter months and weaker in summer months.

- **Ocean Current Flows with Sea Surface Temperature (SST)**
  Visualisation shows ocean current flows on a flat map of Australia. The flows are coloured to show sea surface temperatures, with blue being cooler waters and yellow/reds warmer waters. The time period for this visualisation is from 10 January 2005 through to 2006. Each second that passes in this visualisation is equivalent to about 2.5 days.

- **Western Australia's Heat Wave**
  This is an animation showing the movement of an unusually warm body of water that was 2 degrees Celsius above the average (yellow) in November 2010, peaking to 3+ degrees Celsius above average (orange) in February 2011, before dissipating in March.

- **What is Coral Bleaching (GBRMPA)**
  As the climate changes, coral bleaching is predicted to become more frequent and severe. Sea temperature increases and stress from other factors may increase corals' vulnerability to bleaching.

- **Impacts of Climate Change (GBRMPA)**
  Climate change is now considered to be the greatest threat to the Great Barrier Reef. This animation is designed to help people understand the impacts climate change could have on the Reef and how their individual choices can influence the degree of this impact on the Reef.

- **Ocean Acidification (GBRMPA)**
  Ocean acidification is one of the most worrying impacts climate change will have on the Great Barrier Reef. This animation uses a cartoon character to experience this phenomenon, which leads to a greater understanding how life on coral reefs could be affected by ocean acidification.

Getting Involved

- **Redmap Australia -** www.redmap.org.au

  Redmap Australia, or Range Extension Database and Mapping Project, invites fishers and divers to report captures and sightings of unusual or uncommon marine species at their favourite fishing and diving spots. Data is being collected over the long-term to help reveal whether marine species are shifting their range due to warming oceans and extreme climatic events.

The engaging website displays photographs and data contributed by the Australian community, allowing students to explore what is on the move in Australian waters. Biological information and known distribution is presented for a number of marine species that have been selected on Redmap's 'watch list'. In addition to these species potentially shifting their range, they have also been selected as a species that can be easily verified by scientists from a quality photograph.

The website is a very useful interface to access the latest information on climate change science and marine environment observations. It also demonstrates the partnership between 'citizen scientists' and marine scientists to collect quality and robust data over the long-term.

6. Marine WATERs Education Resources

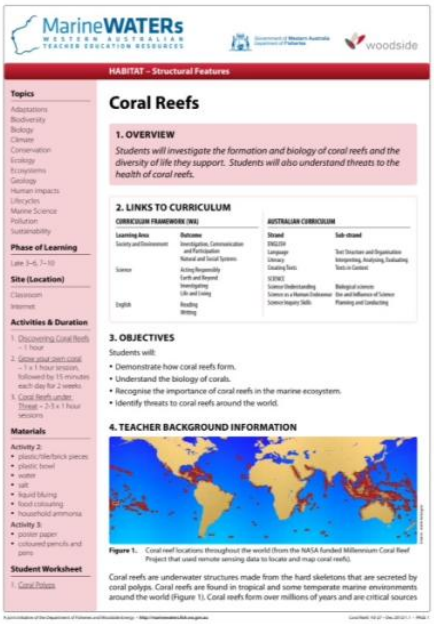
marinewaters.fish.wa.gov.au

Marine Western Australian Teacher Education Resources (Marine WATERs) is an interactive online resource connecting educators with materials specific to study our aquatic environment and fisheries.

Marine WATERs is an initiative of the Department of Fisheries Western Australia and Woodside Energy.

Comprehensive education resources are available on Marine WATERS and include lesson plans, student worksheets, fact sheets, posters, articles, case studies, presentations and games. These materials have been linked to the Australian Curriculum, enabling Marine WATERs resources to be relevant in all Australian States and all K – 12 students.

Following is a selection of Marine WATERs resources relevant to studying a changing climate and its impact in the marine environment. These have been provided within the *Seeing Change* DVD in an 'offline mode' for your accessibility. Educators can register for free on the Marine WATERs' website to access several other suitable resources, search the vast catalogue of materials and be kept up-to-date as new resources are produced.



Lesson Plans

- Acid Test
  Students will investigate the phenomena of ocean acidification and test the effects of increasing acidity on shell-forming marine organisms.

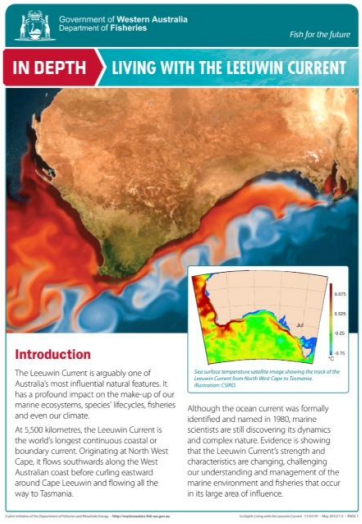
- Getting to Know Your Reef
  Students will participate in a field excursion to investigate their local temperate or coral reef ecosystem.

- Coral Reefs
  Students will investigate the formation and biology of coral reefs and the diversity of life they support. Students will also understand threats to the health of coral reefs.

- Marine Connections
  Students will investigate marine ecosystems by examining the structure of marine food chains and food webs for Shark Bay. The activities can be conducted in the context of climate change impacts such as the poor recruitment of one species, loss of seagrass, or other marine species extending their range.

- The Tide is High
  Students will understand the forces that influence tides and the significance of the lunar cycle. Students will interpret tidal movement by analysing tidal patterns and predicted tide tables. This lesson plan can be used as a foundation to discussing the implications of rising sea levels, storm surge scenarios and coastal planning considerations.

In Depth



- Living with the Leeuwin Current
  At 5,500 kilometres, the Leeuwin Current is the world's longest continuous coastal or boundary current. This publication outlines the characteristics of the current, influences on inter-annual variation and the effect on southern Australia's marine ecosystems and fisheries.

- Houtman Abrolhos System
  The Houtman Abrolhos, commonly referred to as "The Abrolhos", consist of 122 islands lying 60 kilometres west of Geraldton on Western Australia's mid-west coast. This island group sits directly in the path of the southward flowing Leeuwin Current and profoundly influences the unique marine ecology of the area.

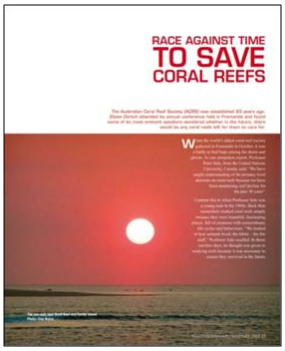
Poster

- Who goes with the flow?
  This poster interprets the effect that the Leeuwin Current has on marine species. This resource can be used in conjunction with the animations contained on the *Seeing Change* DVD and Redmap Australia information.

Case Study

- Monitoring Coral Bleaching on Christmas Island
  Coral bleaching is the number one threat to reefs worldwide. In early 2010, a coral bleaching event occurred on Christmas Island for the first time in 15 years.

Articles



- Assessment of Human Activity Impacts on Abrolhos Reefs
- Fact Sheet: Western Rock Lobster – Unlocking Lobster Secrets
- Hunt for Missing Puerulus
- Little Drifters are Beacons of Climate Change
- Predicting the Leeuwin System
- Race Against Time to Save Coral Reefs

7. Other Activity Ideas

- Visit the Redmap Australia website (www.redmap.org.au) and view the logged marine species that have been reported as uncommon along the Australian coastline. Review species biology information and known range data. Discuss the terms ‘range’, ‘distribution’, ‘migration’ and ‘abundance’. Students can take their investigation further by choosing a species of interest and prepare a report or presentation on the known biology, distribution, where the species has been recently spotted and discuss possible explanations why this species has been reported outside their known range.

- Source national and regional newspapers and digital media articles relating to climate change in the marine environment. Visit the latest news section of the Redmap Australia website, as this can be rich source of the latest information across Australia. Your school library may also have access to other nature or environmental magazines. Ask students to choose an article of interest to them or relevant to the local/regional area. Analyse these articles for key words, images used, headlines and the argument or scientific findings presented.

- Discuss the needs and specific preferences of a marine organism to survive such as food, habitat, water temperature, salinity and oxygen. As a comparison, contrast the strategies employed by humans and marine organisms that help them survive or cope with fluctuating parameters. For example, to control temperature humans use air conditioners and heaters, compared to a marine organism which may swim to waters

that meets their temperature preference. Consider the how sedentary marine organisms such as corals, other invertebrates and macroalgae could be effected.

- Set students, individually or in groups, the task of investigating one of the following possible impacts of climate change or fluctuations in the marine environment.
  a) Change of ocean currents.
  b) Rising sea level.
  c) Coral bleaching.
  d) Extreme climatic events i.e. WA marine heatwave.
  e) Increase in the frequency and intensity of tropical cyclones.
  f) Aquatic pest incursions.
  g) Ocean acidification.
  h) Other.

  Ask students to consider what is happening; what is expected for the future; and what we are doing about it? Their findings could be presented through a mind map, poster, report, presentation or a website.

- Ask a local expert to speak to the students about climate change, its causes, effects and consequences. Invite a primary producer or commercial fisher as guest speaker to provide their personal perspectives and observations of how the weather and climate affects their livelihood and their industry.

- Develop or enhance a school-wide sustainability program. Ask students to reflect on issues that concern them and discuss how individuals, the class or the school can contribute to address the issue. Draw up an action plan and implement it. Include public awareness actions that can deliver literacy outcomes, such as writing letters to the local newspaper, speaking at a school assembly, or developing posters and other media as part of a campaign. Include practical actions within the school, home or local community that help to reduce emission of greenhouse gases or efficient use of resources.

8. Additional Online Teacher Information

Teaching Materials

- Marine Education Society of Australasia (MESA) - www.mesa.edu.au

- Australian Marine Environment Protection Association (AUSMEPA) - www.ausmepa.org.au

- Australian Sustainable Schools Initiative (AuSSI) - http://www.environment.gov.au/education/aussi/
- Bureau of Meteorology (BOM) - www.bom.gov.au/lam/Students_Teachers/learnact.htm
- CSIRO Carbon Kids - www.csiro.au/carbonkids
- Coral Watch - www.coralwatch.org
- Great Barrier Reef Marine Park Authority (GBRMPA) – www.gbrmpa.gov.au
- NASA – http://climate.nasa.gov/education
- Reef ED – www.reefed.edu.au

e-Books

Australian Academy of Science. (2010). The Science of Climate Change: questions and answers, see: http://www.science.org.au/policy/climatechange.html

Cleugh, H., Stafford-Smith, M., Battaglia, M., Graham, Paul. Eds. (2011). Climate Change: Science and Solutions for Australia, CSIRO, see: http://www.csiro.au/Climate-Change-Book

Cook, J. (2010). The Scientific Guide to Global Warming Skepticism, Skeptical Science, see: http://www.skepticalscience.com/The-Scientific-Guide-to-Global-Warming-Skepticism.html

Stephen, W. (2013). The Angry Summer, Climate Commission, see: http://climatecommission.gov.au/report/the-angry-summer/

9. Useful Terms

Acid
A substance that yields a relatively high concentration of hydrogen ions when dissolved in water and has a pH less than 7.

Adaptation
Evolutionary process whereby an individual or a population becomes better suited to its habitat or changing environment.

AIMS
Australian Institute of Marine Science.

Algae
Aquatic plant-like organisms.

Baseline data
Information collected to comprise a reference set for comparison of a second set of data collected at a later time; used to interpret changes over time usually after some condition has been changed.

Biodiversity
Number and variety of life forms, including different species, the genes they contain and the ecosystems they form.

Buffering capacity
The relative ability of a buffer solution to resist pH change upon addition of an acid or a base.

Carbon dioxide (CO_2)
An odourless, colourless atmospheric gas composed of one carbon and two oxygen atoms.

Carbonic acid (H_2CO_3)
A weak, unstable acid formed when CO2 is dissolved in water.

Climate
Typical weather conditions at a particular time.

Climate change
Long-term change in global weather patterns attributed directly or indirectly to human activity, which is in addition to natural climate variability.

Coastal (Coast)
The geographical area of contact between land and marine environments.

Coastal erosion
The permanent loss of land along the shoreline. This is observed as the landward movement of the shoreline vegetation.

Conservation
The management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Coral
Colonies of tiny tubular animals called polyps and are generally classified as either hard or soft corals.

Coral bleaching
The loss of zooxanthellae from a coral, through either expulsion or loss of algal pigmentation. Corals may expel their zooxanthallae when under stress, which leads to a lighter or completely white appearance, hence the term "bleached”.

Coral reef
A reef composed mainly of coral and other organic matter of which parts have solidified into limestone.

CSIRO
Commonwealth Scientific and Industrial Research Organisation.

Ecosystem
A complex set of relationships among the living resources, habitats and residents of an area.

Ecosystem integrity
The capability of an ecosystem to support ad maintain key ecological processes and organisms.

Eddy
A water (or air) current moving against the direction of the main current, especially in a circular motion, i.e. whirlpool.

Endemic
A species that occurs only in a confined area; referred to as a native species.

Environment
The living things, their physical, biological and social surroundings, and interactions between all of these.

Erosion
Wearing away of a shoreline by constant wave action.

Eutrophication
The process of enrichment of water with nutrients that increase plant growth and generally resulting in depletion of dissolved oxygen. A natural process that can be caused/enhanced by an increase in nutrient loads or decreased flushing rates resulting from human activity.

Evaporation
Convert or change into a vapour.

Evolution
A change in the genetic makeup of a species, usually as a result of natural selection favouring some individual characteristics over others.

Fish kill
Mass and sudden death of fish or aquatic animals, usually in a restricted area.

Fisheries Management
The combinations of rules and regulations used to protect, conserve the aquatic environment and ensure sustainability of aquatic organisms.

Food web
Several interconnected food chains in an ecosystem.

GBRMPA
Great Barrier Reef Marine Park Authority.

Gyre
A circular system of ocean currents rotating clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

Habitat
Area or environment in which an organism normally lives or occurs.

Habitat preference
A measure to explain the preference of organisms to a particular habitat.

Heat
Energy which is spontaneously flowing from an object with a high temperature to an object with a lower temperature.

Indonesian Throughflow
Water flow through the Indonesian Archipelago to the Indian Ocean driven by South East trade winds in the Pacific Ocean.

Introduced species
A species living outside its native distributional range, which has arrived there by human activity, either deliberate or accidental.

Juvenile (fish)
Young fish not yet capable of breeding.

Larvae (larva)
The immature form of animals which undergo metamorphosis (a change in form) before becoming a juvenile or adult.

Leeuwin Current
Warm ocean current that flows southward along the west and south coast of Australia.

Macroalga (macroalgae pl.)
Large alga that grows attached to the seabed (commonly known as a seaweed).

Marine
Pertaining to the sea, from the open oceans to high water mark and into estuaries.

Migration
To move from one habitat to another, usually for purposes of breeding or spawning.

Ningaloo Reef
A fringing coral reef system along the west coast of Western Australia, approximately 300 km long (from Exmouth to just north of Carnarvon).

Nutrient
A substance that provides nourishment.

Ocean
Continuous body of saltwater covering the majority of the earth's surface, geographically divided into the Pacific, Atlantic, Indian, Southern and Arctic oceans.

Ocean acidification
The ongoing decrease in the pH of the world's oceans attributed to excess human-induced carbon dioxide emissions.

Ocean current
Continuous steady movement of ocean water in a prevailing direction and defined area.

pH
A measure of the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in a solution, measured on a scale from 0 to 14 units.

Photosynthesis
Process by which green plants convert carbon dioxide to carbohydrates and oxygen using sunlight for energy.

Plankton
Tiny, free-floating aquatic plants and other photosynthetic organisms.

Population
Animals inhabiting a specified area.

Range
Geographic area or location in which a species is recorded, even if only rare or single sightings.

Run-off
Water from rainfall that is not absorbed into the ground, instead flowing into streams or other surface waters or land depressions

Salinity
The amount of salt dissolved in water. The average salinity of seawater is about 35 parts per thousand, or 3.5 per cent.

Sea surface salinity (SSS)
A common measure of ocean salinity is the concentration of dissolved salts in the upper layer of the ocean surface.

Seaweed
Red, green or brown marine algae.

Sedentary
Non-migratory, or tending to stay in one location.

Sediment
Organic and inorganic matter that falls to and lies at the bottom of the ocean.

Southern Oscillation Index
Measure of the atmospheric pressure fluctuations between Darwin and Tahiti in an attempt to indicate El Niño and La Niña episodes.

Storm surge
A rise above the normal water level along a shore resulting from strong onshore winds and / or reduced atmospheric pressure, usually associated with intense low pressure systems such as tropical cyclones.

Subtropical
Bordering on tropical areas.

Temperate
In the southern hemisphere, seas that lie between the Antarctic and the Tropic of Capricorn.

Tide
The rhythmic rise and fall of the sea level caused by the gravitational pull of the moon and sun and by the centrifugal force caused by the rotations of the earth, moon and sun.

Tropical
In the southern hemisphere, the seas that lie between the Equator and Tropic of Capricorn.

Turbid
Clouded, not clear or transparent, because of stirred-up sediment or particles suspended in the water

Turbidity
The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases. Turbidity is measured in nephelometric turbidity units (NTU).

Turtle
Aquatic or terrestrial reptiles, with webbed feet or flippers and a bony or leathery shell.

Upwelling
The movement of colder, nutrient-rich, sub-surface waters toward the surface of the ocean.

Variable
Likely to change or vary.

Vector
The physical means, agent or mechanism which facilitates the translocation of organisms from one place to another.

WAFMRL
Western Australian Fisheries and Marine Research Laboratories

WAMSI
Western Australian Marine Science Institute

Weather
The state of the atmosphere at a given time in terms of such phenomena as temperature, wind, clouds and precipitation.

Zooplankton
Small free-floating or weak-swimming animals.

Zooxanthellae
Single-celled algae that lives in the tissues of invertebrates such as corals, clams and some sponges and carries out photosynthesis.

Climate Change Links

Commonwealth Government

- Department of Climate Change and Energy Efficiency
- GBPRMA - Climate Change
- The Garnaut Climate Change Review

State Governments

- NSW Government Climate Change Adaptation
- NT Government Climate Change
- QLD Office of Climate Change
- South Australian Climate Change Office
- Tasmanian Climate Change Office
- The Climate dogs: The four drivers that influence Victoria's climate
- Vic Government Climate Change
- Victorian Climate Change Adaptation Program
- WA Office of Climate Change

Australian Research Organisations and Other Resources

- ABC Climate Change News
- ARC Centre of Excellence, Coral Reef Studies
- Australian Academy of Science
- Australian Institute of Marine Science Climate Change Information
- Bureau of Meteorology Climate Change page
- Climate Adaptation Knowledge Exchange
- Climate Change in Australia - a CSIRO and Bureau of Meteorology report
- Climate Commission
- CSIRO Climate Change
- FRDC: El Nemo
- Green Cross Australia
- Indian Ocean Climate initiative
- Integrated Marine Observing System (IMOS)

- Marine Climate Change Adaptation Report Card
- Marine Climate Change: Impacts and adaptation
- National Climate Change Adaptation Research Facility
- NCCARF Marine Adaptation Research Network
- Organisation for Economic Co-operation and Development - Adaptation to Climate Change
- Ozclim - Exploring climate change scenarios for Australia(CSIRO)
- Planning Institute of Australia Climate Change Page
- Queensland Seafood Climate Change
- Redmap
- The Climate Institute
- The National Climate Change Research Strategy for Primary Industries
- Victorian Centre for Climate Change Adaptation Research
- Western Australian Marine Science Institution

International Climate Change Links

- European Climate Adaptation platform
- European Environmental Agency - National Adaptation Strategies
- IPCC Working Group II - Impacts and Adaptation
- NASA Global Climate Change
- UK Climate Impacts Programme
- UN Framework Convention on Climate Change

western australian
marine science institution

Abbreviations

ABC – Australian Broadcasting Corporation

ACE CRC - Antarctic Climate & Ecosystems CRC

AIMS - Australian Institute of Marine Science

ANDS - Australian National Data Service

AUSMEPA - Australian Marine Environment Protection Association

CC - Climate Commission

CRC - Cooperative Research Centre

CSIRO - Commonwealth Scientific and Industrial Research Organisation

DEC - Department of Environment and Conservation

DOF - Department of Fisheries

FRDC - Fisheries Research and Development Corporation

GBRMPA - Great Barrier Reef Marine Parks Authority

IMAS - Institute for Marine and Antarctic Studies

IOCI - Indian Ocean Climate Initiative

MESA - Marine Education Society of Australasia

NASA - National Aeronautics and Space Administration

NCCARF - National Climate Change Adaptation Research Facility

NOAA - National Oceanic Atmospheric Administration

REDMAP - Range Extension Database and Mapping Project

TSIC - Tasmanian Seafood Industry Council

UTAS - University of Tasmania

WAMSI - Western Australian Marine Science Institution

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