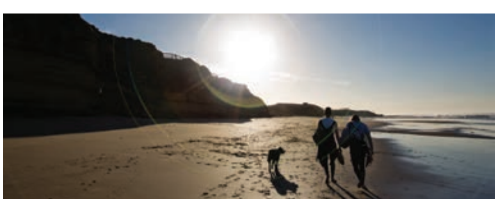
TEACHER RESOURCE

OCEANS



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Introduction to the guide

This Student Learning Resource is designed to assist secondary school teachers to engage students in Years 7 to 10 in the study of marine environment and the direct influence oceans have on weather, climate and marine ecosystems. It is supported by the use of the CSIRO text *Oceans: Science and Solutions for Australia*, edited by Bruce Mapstone, and links to the Australian Curriculum with a flexible matrix of activities based on the 'Five Es' model.

The resource explores elements of Years 7 to 10 science and geography curricula, covering the cross-curriculum priorities of Sustainability and Aboriginal and Torres Strait Islander Histories and Cultures. For science, it more specifically covers the areas of: Science Understanding; Science as a Human Endeavour, and Science Inquiry Skills. For geography, it covers the area of geographical knowledge and understanding, and geographical inquiry and skills.

The main concepts covered are:

- The seven main challenges we face when managing our marine estate.
- Aspects of our marine estate, such as currents, marine organisms, geology, climate, recreation, the economy and governance.
- Uses of the ocean, such as coastal development, security, search and rescue, pollution, research tools and technology, managing multiple uses of the oceans.
- The future of science and technology.

How to use the guide

The notes in this study guide offer both variety and flexibility of use for the differentiated classroom. You and your students can choose to use all or any of the five sections – although it is recommended to use them in sequence, along with all or a few of the activities within each section.

The 'Five Es' model

This resource employs the 'Five Es' instructional model designed by Biological Sciences Curriculum Study, an educational research group in Colorado in the US. It has been found to be extremely effective in engaging students in learning science and technology. It follows a constructivist or inquiry-based approach to learning, in which students build new ideas on top of the information they have acquired through previous experience.

ABOUT

Its components are:

Engage
Students are asked to make connections between past and present learning experiences and become fully engaged in the topic to be learned.

Explore
Students actively explore the concept or topic being taught. It is an informal process where the students should have fun manipulating ideas or equipment and discovering things about the topic.

Explain
This is a more formal phase where the theory behind the concept is taught. Terms are defined and explanations are given about the models and theories.

Elaborate
Students have the opportunity to develop a deeper understanding of sections of the topic.

Evaluate
Both the teacher and the students evaluate what they have learned in each section.

WARNING: Aboriginal and Torres Strait Islander people are warned that this document may contain images of deceased persons.

PUBLISHER Karen Taylor
EDITOR Heather Catchpole
PRODUCTION EDITOR John Roper
DESIGNER Jon Wolfgang Miller
WRITERS Sally Parker, Gemma Conroy

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ABOUT

Section and Activity	CSIRO Oceans book – Pages
Engage	Facts taken from pages 2, 18, 64, 68, 77, 130
Explore	
Air temperature over water	Pages 22, 53, 56, 57, 59, 121, 125, 138, 139, 141, 142, 160, 170, 171
Convection currents	Pages 13-17, 22-24, 178
Water pressure	Pages 30, 45, 48, 122
Ocean expeditions	Pages 43, 121
Desalination	Pages 51, 75
Beach use	Pages 65, 72, 109-112, 150, 154
Ocean acidification	Pages 10, 37, 51, 60, 154, 169, 173-174, 177-178, 180
Food chains	Pages 28, 132
Major currents	Pages 2, 18-21
Coastal erosion	Pages 51, 65
Explain	
Article 1	Pages, 112, 114, 149
Article 2	Chapter 1
Article 3	Pages 11, 137-148
Elaborate First-hand investigation Both developing and extending	Chapter 14, Pages 137-148
Engineering and Making	
Developing	Chapter 14, Pages 137-148
Extending	Chapter 18, Pages 169-178
Ethical Thinking	
Developing	Chapter 15, Pages 149-158
Extending	Chapter 17, Pages 169-178
ICT	
Developing	Chapter 4, Pages 39-50
Extending	Chapter 11, Pages 107-116

ABOUT

Section and Activity	CSIRO Oceans book – Pages
Personal and Social Capabilities Developing Extending	 Chapter13, Pages 127-136 Chapter 6, Pages 63-68
Creative and Critical Thinking Developing Extending	 Page 130 Chapter 1, Pages 1-12
Time Travel Developing Extending	 Chapter 6, Pages 63-68 and Chapter 8, Pages 77-86 Chapter 3, Pages 25-38

Science

Cross-curriculum priorities

Sustainability

Aboriginal and Torres Strait Islander histories and cultures.

Year 7-10 Science

Science Understanding:

<table>
<tr><th colspan="3">Year 7</th></tr>
<tr><td>Predictable phenomena on Earth, including seasons and eclipses, are caused by the relative positions of the sun, Earth and the moon (ACSSU115)</td><td>Some of the Earth's resources are renewable, but others are non-renewable (ACSSU116)</td><td>Interactions between organisms, including the effects of human activities can be represented by food chains and food webs (ACSSU112)</td></tr>
<tr><th colspan="3">Year 8</th></tr>
<tr><td colspan="3">Energy appears in different forms, including movement (kinetic energy), heat and potential energy, and energy transformations and transfers cause change within systems (ACSSU155)</td></tr>
<tr><th colspan="3">Year 9</th></tr>
<tr><td colspan="2">Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176)</td><td>Chemical reactions, including combustion and the reactions of acids, are important in both non-living and living systems and involve energy transfer (ACSSU179)</td></tr>
<tr><th colspan="3">Year 10</th></tr>
<tr><td colspan="2">Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere (ACSSU189)</td><td>Energy transfer through different mediums can be explained using wave and particle models (ACSSU182)</td></tr>
</table>

Science

Cross-curriculum priorities

Sustainability

Aboriginal and Torres Strait Islander histories and cultures.

Year 7-10 Science

Science as a Human Endeavour:

Years 7 & 8			
Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available (ACSHE119, ACSHE134)	Science knowledge can develop through collaboration across the disciplines of science and the contributions of people from a range of cultures (ACSHE223, ACSHE226)	Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120, ACSHE135)	People use science understanding and skills in their occupations and these have influenced the development of practices in areas of human activity (ACSHE121, ACSHE136)
Years 9 & 10			
Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157, ACSHE191)	Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158, ACSHE192)	People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people's lives, including generating new career opportunities (ACSHE160, ACSHE194)	Values and needs of contemporary society can influence the focus of scientific research (ACSHE228, ACSHE230)

Science Inquiry Skills:

All Year 7-10 science inquiry skills are relevant.

Geography

Cross-curriculum priorities

Sustainability

Aboriginal and Torres Strait Islander histories and cultures.

Geographical Knowledge and Understanding

Year 7 Unit 1: Water in the world					
Classification of environmental resources and the forms that water takes as a resource (ACHGK037)	The way that flows of water connects places as it moves through the environment and the way this affects places (ACHGK038)	The quantity and variability of Australia's water resources compared with other continents (ACHGK039)	The nature of water scarcity and ways of overcoming it, including studies drawn from Australia and West Asia and/or North Africa (ACHGK040)	Economic, cultural, spiritual and aesthetic value of water for people, including Aboriginal and Torres Strait Islander Peoples and peoples of the Asia region (ACHGK041)	Causes, impacts and responses to an atmospheric or hydrological hazard (ACHGK042)
Year 9 Unit 1: Biomes and food security					
Distribution and characteristics of biomes as regions with distinctive climates, soils, vegetation and productivity (ACHGK060)	Human alteration of biomes to produce food, industrial materials and fibres, and the use of systems thinking to analyse the environmental effects of these alterations (ACHGK061)		Environmental, economic and technological factors that influence crop yields in Australia and across the world (ACHGK062)	Challenges to food production, including land and water degradation, shortage of fresh water, competing land uses, and climate change, for Australia and other areas of the world (ACHGK063)	The capacity of the world's environments to sustainably feed the projected future global population (ACHGK064)

Geography

Cross-curriculum priorities

Sustainability

Aboriginal and Torres Strait Islander histories and cultures.

Geographical Knowledge and Understanding

Year 9 Unit 2 Geographies of interconnections					
The perceptions people have of place, and how these influence their connections to different places (ACHGK065)	The way transportation, information and communication technologies are used to connect people to services, information and people in other places (ACHGK066)		The ways that places and people are interconnected with other places through trade in goods and services, at all scales (ACHGK067)	The effects of the production and consumption of goods on places and environments throughout the world, including a country from North-East Asia (ACHGK068)	The effects of people's travel, recreational, cultural or leisure choices on places, and the implications for the future of these places (ACHGK069)
Year 10 Unit 1: Environment and change management					
Human-induced environmental changes that challenge sustainability (ACHGK070)	Environmental world views of people and their implications for environmental management (ACHGK071)	The Aboriginal and Torres Strait Islander Peoples' approaches to custodial responsibility and environmental management in different regions of Australia (ACHGK072)	The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated (ACHGK073)	The application of geographical concepts and methods to the management of the environmental change being investigated (ACHGK074)	The application of environmental economic and social criteria in evaluating management responses to the change (ACHGK075)

Geography Inquiry Skills:

All Year 7-10 geographical inquiry skills are relevant.

Preserving our oceans

Mibu Fischer is helping governments and communities in the South Pacific manage their marine resources more sustainably.

Fishing is a central part of Australian culture, with one in five of us saying we enjoy catching fish for fun. As one of the largest fishing zones in the world, spanning 14 million square kilometres, Australian waters are also a hotspot for commercial fishing.

But fishing activities have an enormous impact on marine ecosystems and fish populations, from the Spanish mackerel to the endangered southern bluefin tuna.

To ensure our ocean ecosystems are preserved for future generations, marine ecologists like CSIRO's Mibu Fischer (pictured above) gather and analyse information on ocean resources to help communities use marine environments more sustainably.

"I quickly came to realise how important it is for those in influential positions to understand the impacts of their choices and what that can mean for the environment, society and culture," says Mibu.

Mibu's passion for the ocean stemmed from growing up in Moreton Bay, Queensland, where she spent her weekends at the beach with her mother's family on Stradbroke Island. Mibu's heritage includes the Noonuccal, Ngugi and Gorenpul clans of Quandamooka (Moreton Bay and its southern bay islands, including parts of the adjacent mainland from the Brisbane River down to the Logan River).

She realised she wanted to explore marine biology during a high school field trip, where she looked at seawater under the microscope for the first time.

"I saw all the tiny organisms that spend their entire lives floating in the sea and how most people don't realise that the seawater they swallow at the beach is filled with these microscopic creatures," says Mibu. "I was fascinated to learn more about the marine environment."

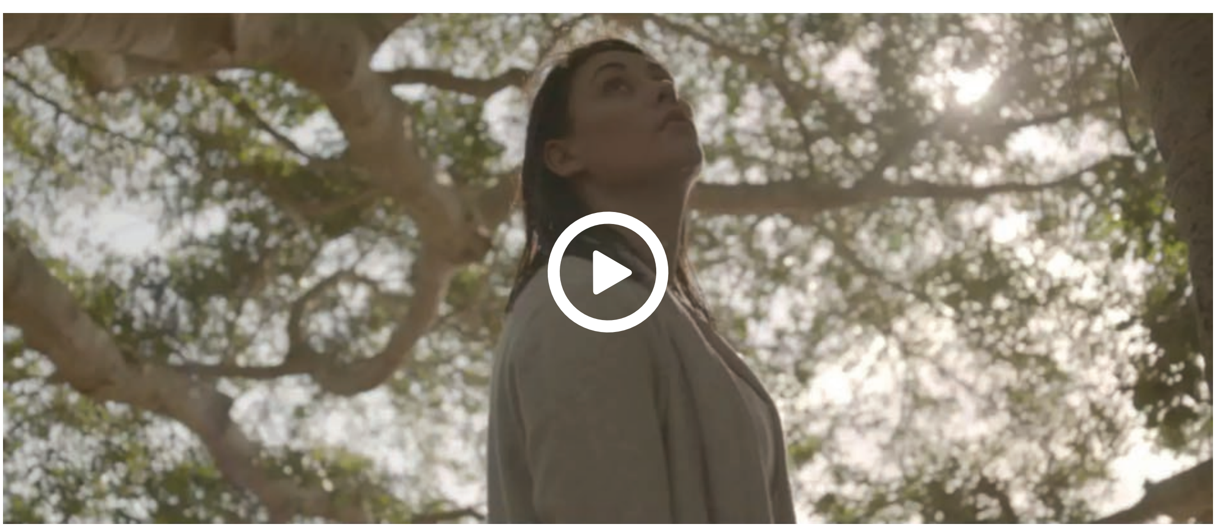
When she embarked on her career in marine ecology at the CSIRO, Mibu gathered data on recreational fishing to gain a more accurate idea of how it was impacting fish populations. She also worked closely with Torres Strait Island communities collecting information on traditional fishing, which was not closely monitored previously.

The information was used to develop an interactive map that showed how a fish population changed over time.

This research led Mibu to developing tools and natural resource databases for governments in Papua New Guinea and the Solomon Islands. The easy-to-use databases provide information on an ecosystem's economic, social and environmental value to help governments manage their marine resources more effectively.

Mibu says that it is important for natural resource information to be easily accessible to decision-makers so they can get a clearer idea about environmental threats and which ecosystems to prioritise.

"Climate change is a real and current threat, and people need information from marine scientists to guide their decisions," she says.



http://seven.csiro.au/Mibu

Pin the fact on the infographic

What to do:

Finish this infographic on our marine estate by adding the amazing facts about our oceans to the images on the next page.

How to do it:

1. Cut out each of the six facts and place them on the infographic where you think they are most appropriate.
2. Check with your teacher before sticking them down.
3. Store the infographic in your work book or folder.
4. Write down what the ocean means to you and your family. Think of all the ways you might use the ocean.

An estimated quarter of a million tonnes of seafood is produced by Australian Fisheries and aquaculture annually.

Australia's marine estate is 13.86 million km^2 (approximately 1.8 times the size of Australian sovereign land territories).

The 'Blue Economy' is worth tens of billions of dollars a year.

Ghost fishing causes harm to marine organisms long after humans have lost or abandoned their fishing equipment.

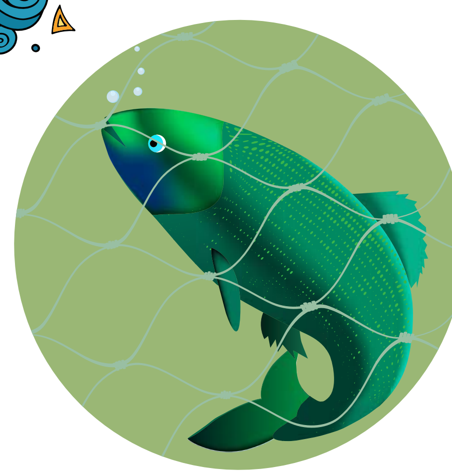
Marine plants produce between 50-80% of the world's oxygen.

Due to global warming, the East Australian Current has been extending south towards Antarctica.

ENGAGE

13.86 million km²

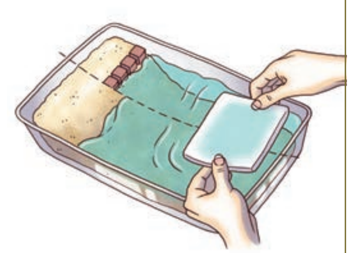
50-80%



Teacher Information

The aim of the Explore section is for the students to investigate some of the ideas around oceans. It is intended that the students make their own discoveries as they work around the stations in the room and should be encouraged to record their questions as they ask them.

The equipment table below lists the equipment and preparation required.

Station#	**Materials List**
1. Testing the air temperature over warm and cold water	Kettle, beakers, ice, thermometers.
2. Making convection currents with warm water	Four small recycled plastic drinks bottles, large plastic tray or sink over which to conduct the activity, blue food dye, yellow food dye, kettle, playing card.
3. Water pressure	A couple of Cartesian divers pre-prepared. To make a Cartesian dive, visit bit.ly/Cartesiandiver.
4. Ocean expeditions	Computer and access to the International Oceans Discovery Program (IODP) website www.iodp.org.
5. Desalinating salt water	5ml samples of salt water, filter paper, beakers, funnels, evaporating dishes and basins, Bunsen burner, tripod, flasks, ice, measuring cylinders.
6. Beach use	Computer and access to North Bondi webcam at bit.ly/NBbeachcam.
7. Ocean acidification cause and effect	Straws, water, beaker, universal indicator solution and colour chart, dilute hydrochloric acid, marble chips.
8. Conducting ocean food chains	Images of ocean dwelling organisms – provided in following pages.
9. Australia's major ocean currents	Image of currents – provided in following pages.
10. Paying for coastal erosion	Paper towel, one plastic tray, sand, water, flat Perspex wave maker, building blocks. Prepare one or more model coastlines, each inside a plastic tray. Use sand to make a beach and water to represent the sea. A wave maker, such as a piece of Perspex, can be 'pushed' back and forth to create water waves onto the sand. If one model is made, the sea wall must be removed so students can compare the effect of the waves on the sand with and without the sea wall. Otherwise, it is necessary to make two identical models, one with a sea wall and one without. 

Oceans Activities

Work around each of the stations in any order. As you go, write any questions you have here. Include questions about the science behind the activities in the stations, how the ideas are related to oceans, and how they relate to your life.

Questions

Station One

Testing the air temperature over warm and cold water

What to do:

1. Prepare a beaker of warm water and a beaker of iced water.
2. Measure the temperature above the water. Increase distance between thermometer and water in 1cm increments until there is no difference in the temperature between the two water samples.

Distance over surface of the water (cm)	**Temperature over warm water (°C)**	**Temperature over warm water (°C)**
1		
2		
3 (etc)		

What to think about:

1. What effect does the temperature of the water have on the air temperature above it?

____

____

2. If ocean temperatures change, what might happen to the air temperature over the oceans?

____

____

____

3. If the air temperature over the ocean changes, what knock-on effect might this have on the weather?

____

____

____

____

Station Two

Making convection currents with hot water

Caution:

- Always exercise caution when using boiling water. It can cause serious burns if it gets on your skin.
- Do not pour boiling water from the kettle directly in the bottle. Instead, mix some warm water in a large beaker and use that.
- Use a lab coat and other protective clothing to avoid stains from the food colouring.
- Conduct this activity over the top of a plastic tray or sink so that any water spillage will be contained and not end up over the bench and floor.

What to do:

1. Place five drops of blue food colouring in two of the bottles.
2. Place five drops of yellow food colouring in the other two bottles.
3. Fill the bottles with the blue food colouring with cold water. The water should reach right up to the rim of the bottle.
4. Fill the bottles with the yellow food colouring with hot water. The water should reach right up to the rim of the bottle.
5. Place the playing card over the top of one of the yellow bottles.
6. Turn the yellow bottle over, with the card in place, and place it on top of one blue bottle.
7. Slowly remove the card and observe what happens to the water.
8. Place the card on top of the other blue bottle.
9. Turn the blue bottle over, with the card in place, and place it on top of the second yellow bottle.
10. Slowly remove the card and observe what happens.
11. Record your observations.

____

____

Station Two

Making convection currents with hot water

What to think about:

1. What might be a consequence of different bodies of water in the ocean having different temperatures on:

a. water movement/ocean currents

____

____

____

b. air temperature

____

____

____

c. weather

____

____

____

____

Station Three

Water pressure

What to do:

1. Squeeze the side of the plastic bottle and observe what happens to the 'diver'.
2. Can you control the height of the diver up and down the bottle? For example can you make the diver hover half way up the bottle? Can you make the diver sink all the way to the bottom?

What to think about:

1. What do you think squeezing the bottle does to the air inside the 'diver'?

   ____

   ____

   ____

2. With a smaller volume of air inside the diver it becomes less buoyant and sinks. How might this phenomenon relate to real life in the following situations:

   a. A marine biologist moving up and down a wall of coral when scuba diving in the ocean.

   ____

   ____

   b. An unmanned submarine descending and ascending.

   ____

   ____

   c. The air spaces in the human body (ie in the ear, blood, lungs) when a diver is at depth.

   ____

   ____

3. Why do you think the oceans are such a difficult place for humans to conduct research?

   ____

   ____

   ____

Station Four

Ocean expeditions

What to do:

1. Go to the International Oceans Discovery Program (IODP) at www.iodp.org and click on ‘Expeditions’.
2. On the drop-down menu click on current expeditions.

What to think about:

1. If you had to choose one of the expeditions, which would you put your name down for? Why did you choose this one?

   ____

   ____

   ____

   ____

   ____

Station Five

Desalinating salt water

Caution:

- Remove all combustible materials from the area where the Bunsen burner is being used.
- Tie-back any long hair, dangling jewellery, or loose clothing.
- Do not leave open flames unattended. Shut off gas when it is not in use.

What to do:

1. Use the equipment provided to attempt to desalinate one of the 5ml samples of salt water. Plan your experiment and show your plan to your teacher before starting.
2. How much desalinated water have you managed to harvest from the 5ml sample of salt water?
3. How much water was 'lost' in the process? How was this water lost?
4. Evaporate desalinated water in a clean evaporating basin to see if there is any salty residue in it.

What to think about:

1. Comment on your success and the difficulties you had when trying to desalinate salt water.

____

____

____

2. Why might desalination be a process that some organisations would want to carry out?

____

____

____

3. Would you describe 'fresh water' as a resource from the ocean? Why or why not?

____

____

____

Station Six

Beach use

What to do:

1. Log onto the North Bondi webcam at bit.ly/NBbeachcam

What to think about:

1. What are people doing at the beach? How are they interacting with the environment? Is there any evidence of pollution?

 ____

 ____

 ____

2. List the positive and negative impacts of beach use.

Positive impacts	**Negative impacts**

3. How can local councils reduce the negative impacts? Choose a couple from your list and address how humans can reduce their 'footprint' on the coastline.

 ____

 ____

 ____

 ____

 ____

Station Seven

Ocean acidification cause and effect

What to do:

Cause

1. Add a few drops of universal indicator to a few mls of tap water. Note the colour of the water with the universal indicator and record the corresponding pH in the table below.
2. Use a clean straw to blow bubbles carefully into the water for 1 minute. The carbon dioxide in your breath will be bubbled into the water. Do not suck the water into the straw.
3. Note the colour of water after 1 minute of blowing bubbles into it and record the corresponding pH in the table below.

	Colour	**pH**
Normal tap water + Universal indicator		
Normal tap water + Universal indicator with carbon dioxide bubbled through		

Effect

1. Place a few drops of dilute acid onto the carbonate stones and observe what happens to the stone.

What to think about:

1. What effect did carbon dioxide have on the acidity of the water?

____

2. What effect did the acid have on the carbonate?

____

3. Using the evidence from this activity, suggest what the effect of an increased amount of carbon dioxide in our ocean might have on organisms that require calcium carbonate in their daily lives, for example creatures that protect themselves from predators with carbonate shells.

____

____

____

Station Eight

Ocean food chains






Photograph of Marbled Rockcod © David Fleetham/OceanwideImages.com

What to do:

1. Place the following organisms into a possible food chain starting with a producer and ending with a top order consumer.

____

____

What to think about:

1. If one of the species in your food chain was over-fished, suggest what could happen to each of the other organisms in your food chain.

____

____

____

2. How would the changes you have suggested impact on the everyday lives of humans?

____

____

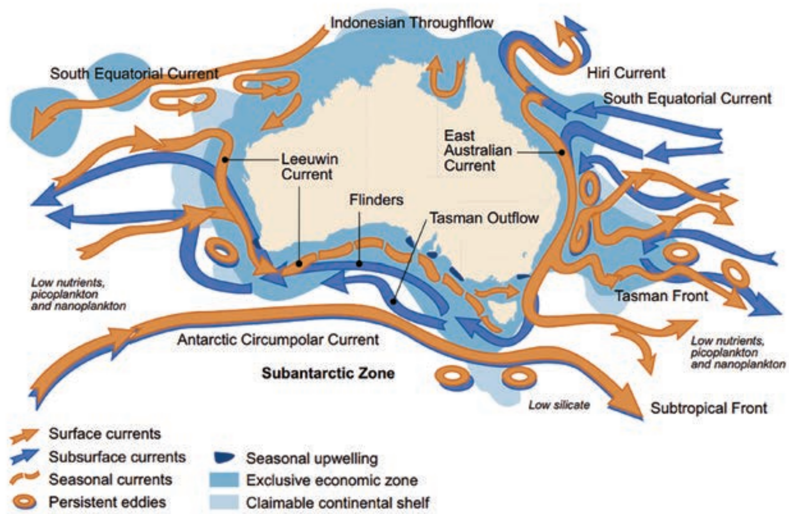
____

Station Nine

Australia's major ocean currents

What to do:

1. Examine the following map showing the major currents flowing around Australian coastlines:



What to think about:

1. Which current could an animal travel down the east coast of Australia on?

____

2. For an animal that is circulating in the water south of Australia:

a. Which current could they travel east on? ______________________________

b. Which current could they travel west on? ______________________________

c. Which current would they have to surface to travel on? ______________________

3. Apart from helping to transport marine organisms, what other role might the movement of large bodies of cold or warm water have?

____

____

____

Station Ten

Paying for coastal erosion

What to do:

1. Being careful not to splash any water, use the wave maker to create gentle and even waves that break onto the model sandy beach.
2. Record the effect of the waves on the distribution and movement of the sand in Column A.

Observations of sand	A. Effect of waves on model beach with no sea wall	B. Effect of waves on model beach with sea wall in place
Distribution		
Movement		

3. Repeat steps 1 and 2 above, but use a sea wall between the generation of the waves and the model sandy beach.
4. What is the effect of the sea wall on the distribution and movement of the sand? Record your observations in Column B.
5. Clean up any spilt water.

What to think about:

1. What is the general effect of the sea wall on coastal erosion in this model?

 ____

2. Identify one strength and one limitation of this model to predict the effect of a real sea wall on a real coastline.

Strength	Limitation

3. Sea walls can be costly so who should pay for them, the local council, federal government, home owners? Justify your response.

 ____

 ____

Student Literacy Activities

In this section, we introduce and explain the science of oceans by summarising three key areas, each with its own article.

The three articles are:

- Article One – An introduction to our relationship with our oceans
  Here, a couple of case studies introduce and outline examples of the complexities of our relationship with the ocean.

- Article Two – The seven grand challenges
  The Australian National Marine Science Committee (ANMSC) has developed seven grand challenges for our continued and sustainable relationship with our marine estate.
  Those seven challenges and the research in each area are outlined here.

- Article Three – Ocean science now and the future
  This article provides a snapshot of the research topics, the research tools and future directions of our knowledge and understanding of our marine estate to meet the seven challenges outlined by the ANMSC.

Student Literacy Activities

1. **Getting started:** To help gather ideas and elicit focus areas for discussion around our marine estate, a mind-map template is provided for students to record and then share what they already know about our oceans before they start reading the articles. A finished mind-map can also provide a starting point for examining the relationship between the different areas of marine science.
2. **Engaging with the articles:** For each of the three articles there are three separate literacy activities, including:
   - Glossary
   - Comprehension questions
   - Questioning toolkit
3. **Bringing it all together:** After reading the articles students identify important focus questions related to our marine estate.

Getting Started

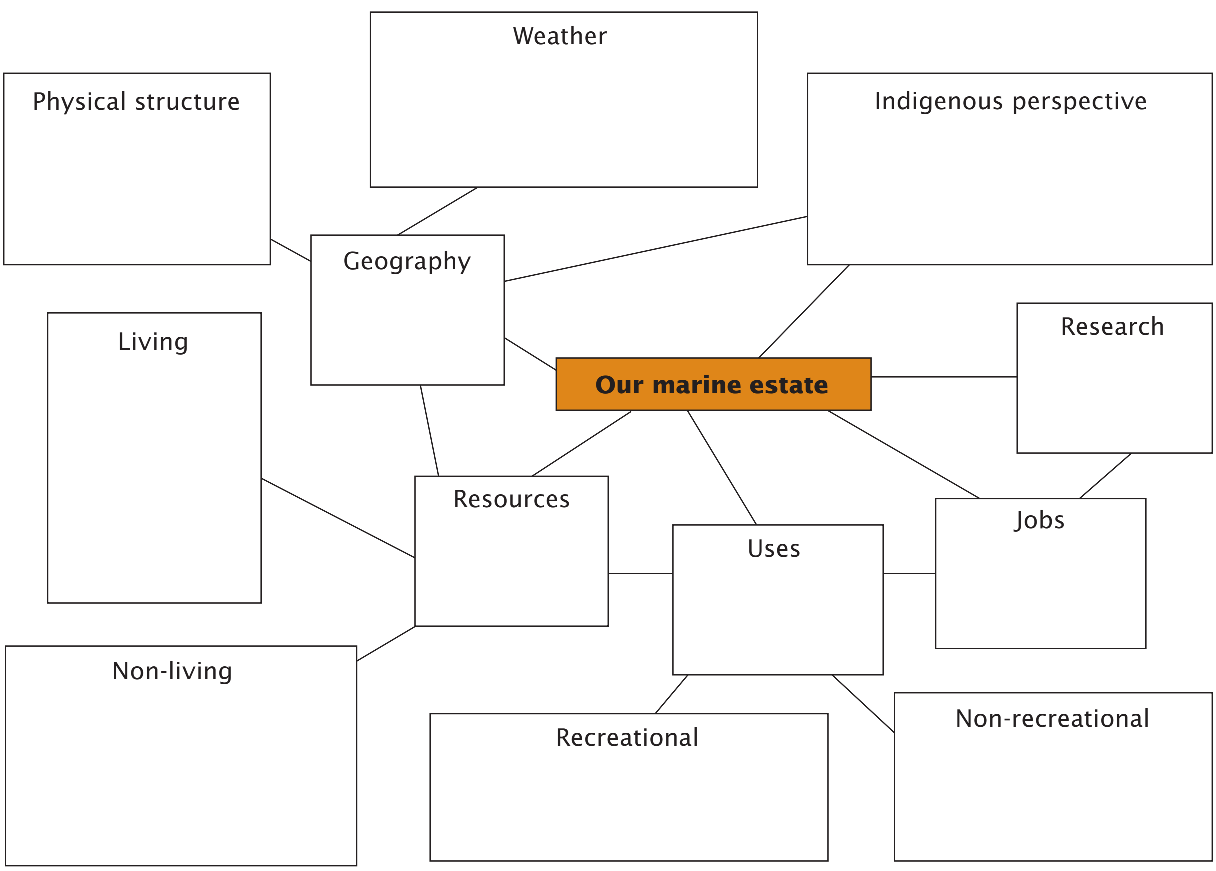
What does the ocean mean to you?

The oceans around us affect almost all aspects of our lives, including the weather and climate, our food and energy supplies, international security, cities and infrastructure, and wellbeing.

Before reading any of the articles, think about what you already know about our oceans; how we use them, what we know about them, and how we can continue to learn from them.

Use the headings and subheadings below to write down ideas, information and questions you have about the oceans. Use your own personal experience and knowledge gained from what you have already learnt.

Write in the boxes, create new boxes, add images and write along the links. When you are done you can share your ideas with the rest of the class.



An Introduction To Our Relationship With Our Oceans

Australia is a nation that loves the sea. Coasts, and oceans more broadly, are important as loci of human activity and attract many competing human users, often with conflicting objectives. Little of the oceans is completely untouched by human influences, although most human activities are concentrated along coastlines. Near-shore waters are also where most ocean production and food webs are concentrated.

Marine and coastal systems are complicated and changeable, and management decisions need to account for uncertainty as well as political and social acceptability. Examine the following case studies from the CSIRO Oceans book of popular coastlines that have a focus on the challenges and the scientific tools available to support improved decision-making for their sustainable management.

Figure 1: Scuba diving is one of the many recreational activities taking place on the Great Barrier Reef

CASE STUDY 1: eReefs: an information management system for the future of the Great Barrier Reef

The iconic Great Barrier Reef (GBR) is the largest living system in the world. The catchments adjacent to the GBR are home to more than one million people. This coastal environment provides local communities with beach access for numerous recreational opportunities such as fishing and boating. The GBR is also a major tourism drawcard for the region, responsible for more than 80% of the area's overnight visitors. Tourists, like residents, enjoy spending time at the beach and more than 60% go to the offshore islands or reefs. Tourists also come to the region for specialist activities including scuba diving and whale-watching.

As well as tourism, the GBR is under threat from a number of sources including the impacts of climate change, declining water quality and coastal development. eReefs is the first project in the world to attempt to address the complexity of these impacts on such a large scale and does this by studying the various stresses on the GBR itself.

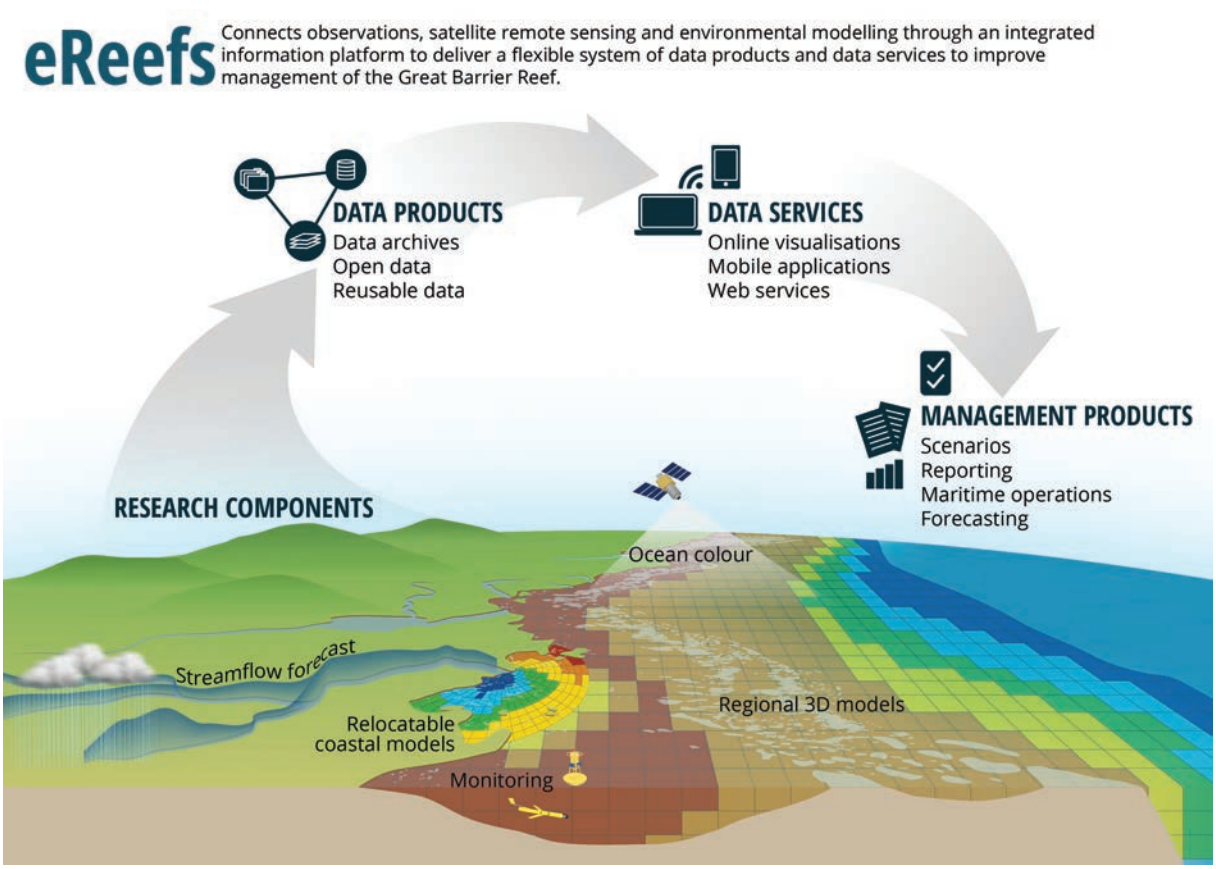


Figure 2: eReefs is an online platform where raw data can be analysed for specific purposes

eReefs is a collaborative project that primarily contributes to the protection and preservation of the Great Barrier Reef. It provides the first comprehensive information platform capable of meeting the many and varied needs of users for access to improved environmental intelligence, allowing them to assess past, present, and future conditions and management options to mitigate the risks associated with multiple, and sometimes competing, uses of the GBR and adjacent land areas. Importantly, it also forms the first step in building comprehensive coastal information systems for Australia.

eReefs is built upon an integrated system of data, catchment and marine models, visualisation, reporting and decision-support tools that span the entire GBR and adjacent coastal areas – from paddock to catchment, estuary, reef lagoon and ocean.

The centrepiece of the eReefs information platform is a whole-of-region, shelf-scale, numerical marine modelling system. The modelling system comprises hydrodynamic models to predict the physical state of the GBR, sediment transport models predicting the fate of suspended fine sediments and a biogeochemical model to predict water column and benthic production, water quality and nutrient cycling.

Automated sensors are used that can make near-continuous measurements of water quality and quantity variables to provide better data for users and for models. Access to satellite-derived synoptic daily maps of water quality for the GBR is available through a marine water quality dashboard (www.bom.gov.au/marinewaterquality/).

The backbone of the eReefs information platform is an innovative information architecture that enables access to data from a range of data custodians. This information can be discovered dynamically, making it much easier to develop end-user products. Access to these models and datasets allows users to interact with eReefs products easily via the web.

CASE STUDY 2: Ningaloo Reef: where municipal, state, federal and international governance meet

Ningaloo Reef is a large fringing coral reef system on Australia's west coast and a hotspot where the challenges of balancing the interests of conservation, recreation and economic opportunity are intense. Ningaloo is a World Heritage Area and a marine park under both Western Australian and federal legislation. It attracts hundreds of thousands of visitors each year who participate in activities, such as swimming with whale sharks and recreational fishing. Fishing, along with climate change, is considered one of the main threats to the conservation values of Ningaloo. Production wells for oil and gas not far from the boundary of the World Heritage Area add to the complexity of managing the system.

The information needed to manage the needs of conservation, recreation, industry and the local economy is significant. Several large research initiatives have been undertaken, including within the Western Australian Marine Science Institution, the Ningaloo Collaboration Cluster, the Pilbara

Figure 3: Tourists come from all over the world to swim with whale sharks at Ningaloo

Marine Conservation Partnership and Ningaloo Outlook. This research investment has provided maps of the seabed and seabed communities, understanding of the ways that ocean currents move, assessments of the state of valued and ecologically important species, and the pressures on their populations. This information has been brought together in evaluations of the trade-offs among various management actions; from size and placement of sanctuary zones to modified bag limits for recreational fishers to the social and environmental impact of different types of tourist accommodation.

Figure 4: The whale shark is just one of the species of mega fauna that are characteristic of this World Heritage Area (Source: Mat Vanderklift, CSIRO)

Activity 1 – Glossary

Creating a glossary. Use the table to define some of the science terms in this article.

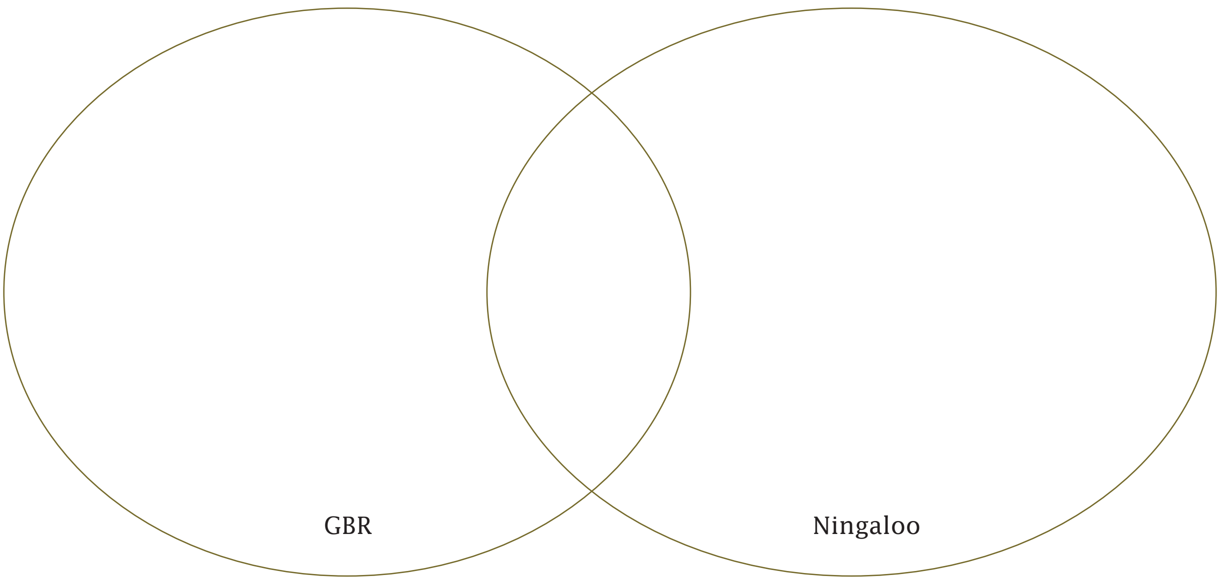
Word	Definition
Food webs	
Sustainable management	
Environmental intelligence	
Information systems	
Modelling system	
Benthic production	
Automated sensors	
Satellite derived	
Synoptic map	
Information architecture	
Data custodians	
Data product	
Data service	
Management product	
World Heritage Area	
Legislation	

Activity 2 – Summarising

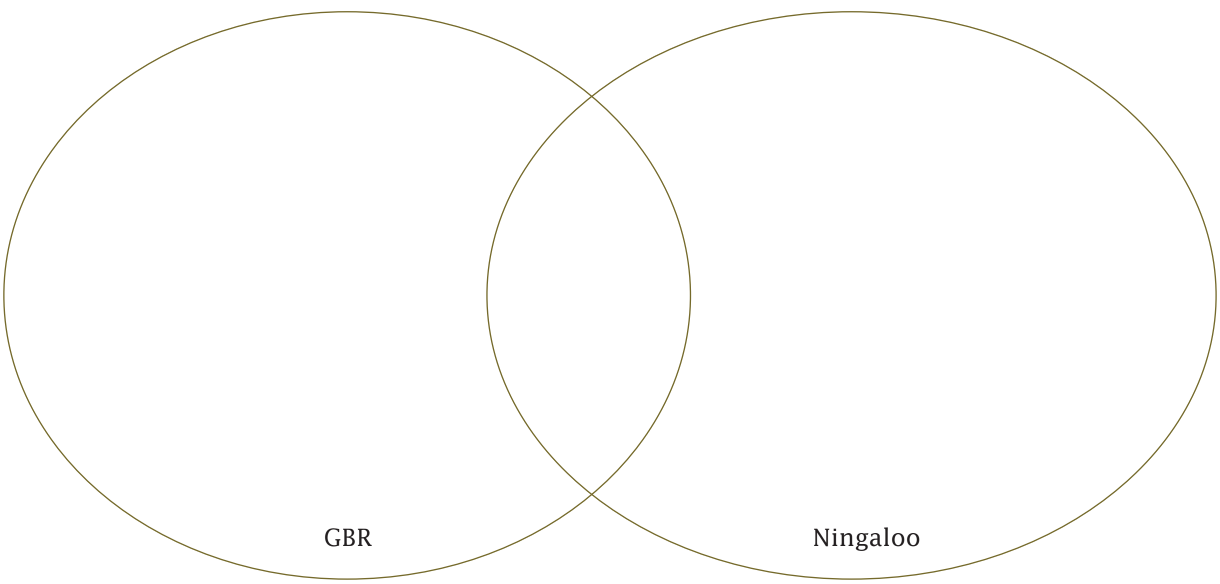
Summarise the information in Article 1 by responding to the following questions:

1. Draw Venn diagrams to compare

- The main ways humans interact with the GBR and Ningaloo.



- Some of the sources of stress on the GBR and Ningaloo.



2. What are some of the ways that data is collected to help analysts understand the impacts on the GBR and Ningaloo?

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____

3. a. What is a model and why is it a useful scientific tool?

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____

b. Distinguish between hydrodynamic models, sediment transport models and biogeochemical models by completing the following table.

Type of modelling	Definition	Application

c. Why do you think it might be important for scientists to study each model individually, and together?

____

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d. Identify the information that research has provided about Ningaloo.

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4. In summary, write a sentence or two to outline what the eReef is and what it does. Visit the eReef website at ereefs.org.au/ereefs for help.

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5. What do you see as some of the greatest challenges related to managing coastal environments around Australia's marine estate? List some ideas here.

____

____

Activity 3 – Questioning Toolkit

We have provided a series of discussion questions in the form of a questioning toolkit.

Choose some or all of the questions to answer, or ask some of your own.

Further reading on questioning toolkits:

- McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. Questions ▪ Why is the GBR important to preserve? ▪ How is eReefs going to contribute to the sustainable management of the GBR?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. Questions ▪ What is one example of how people or organisations might have conflicting uses of coastal areas? ▪ What are some possible impacts of climate change, declining water quality and coastal development on coastal areas? ▪ Who will use the data products and data services available on the eReefs website?	

EXPLAIN (ARTICLE ONE)

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the what-ifs? They are useful when we want to test our hunches. Questions ▪ What if tourists could only have a positive impact on the coastal areas they visit, what might a sustainable holiday look like? ▪ What if Ningaloo had its own eReefs platform?	
Provocative questions Questions to challenge convention. Questions ▪ Should we be focusing research on coastal areas that we use for recreation or on all areas? ▪ Is the damage already done to our coastal areas reversible?	

The Seven Grand Challenges

Australia's marine territory is the third largest marine estate on Earth. It covers 13.86 million km^2, ~1.8 times the area of Australian sovereign land territories and includes substantial areas of three of the world's four major oceans, with territory in the Indian, Pacific and Southern Oceans (see Figure 5). It extends from equatorial waters just south of New Guinea to Antarctica and spans over one-third of the Southern Hemisphere, from 40˚E to 170˚E longitude. Our marine waters reach from coastal estuaries, lagoons and intertidal areas to abyssal plains at over 5,000m depth.

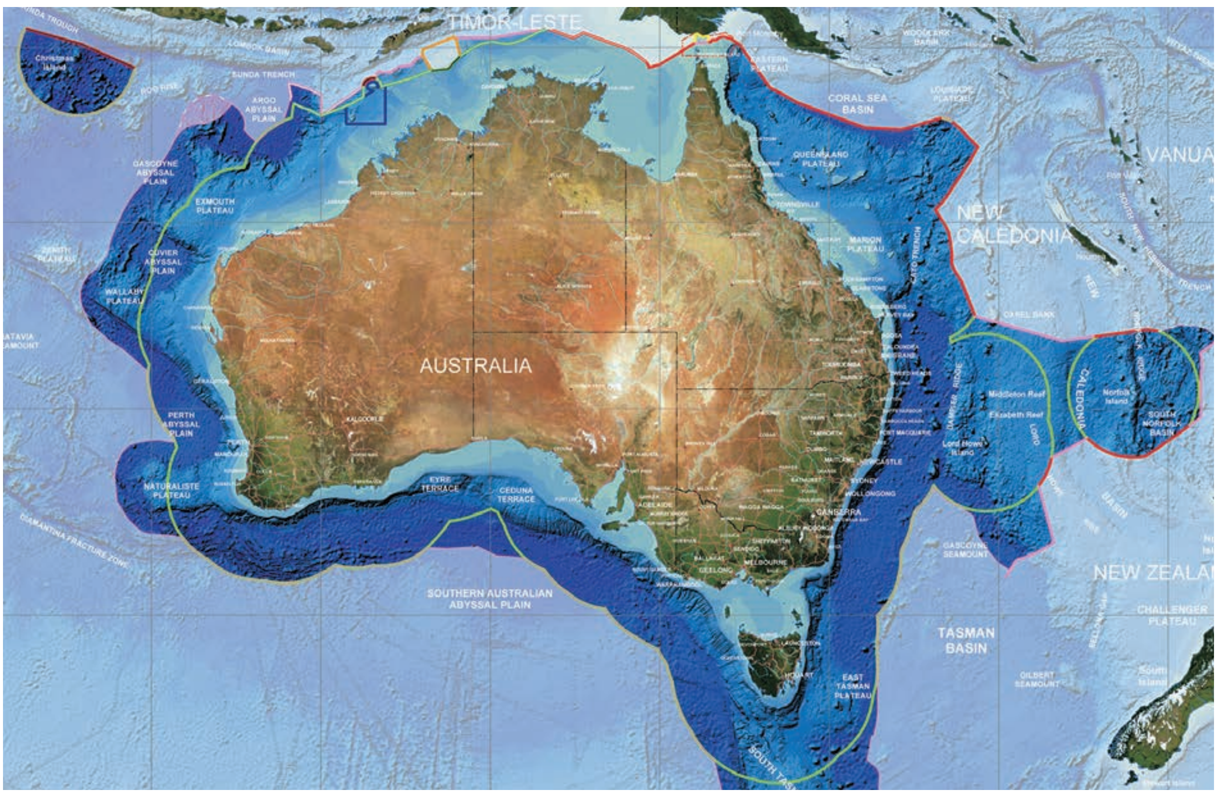

Figure 5: Australia's marine territory

Our marine estate includes a tremendous diversity of plants and animals (see CSIRO Oceans book, Chapter 3) and energy and mineral resources (Chapter 4). The major currents flowing around Australia (Chapter 2) have profound effects on biological productivity and the weather and climate we experience in our region and globally (Chapter 5). Australians derive diverse social, cultural and community benefits from our affinity with the oceans (Chapter 6) and national economic contribution from activities depending on our marine estate (the 'Blue Economy', Chapter 7) was valued at $47.2 billion in 2012.

The Australian National Marine Science Committee identified seven grand challenges facing Australia for which the marine environment is central. Each challenge is considered here.

1. Sovereignty, security and safety

Australia's economy depends on the maritime operations of many industries across a vast region of the globe. Australia's security depends on the efficient operation of naval and coastal regulatory authorities across vast areas of ocean. The country also has search and rescue responsibility over a huge area of maritime domain.

The Australasian Indo-Pacific region comprises many developing nation states with extensive coastlines and high dependence on marine food resources (Chapter 9). However, Australia can provide vital regional research leadership to help these countries. Australian research is essential to the prognosis for climate change effects across the region and important for assisting nations to prepare for, and adapt to, changes now considered to be inevitable.

Australia plays a leading role in various international agreements to ensure our southern maritime boundary, which includes the Antarctic, remains an area of peace and international cooperation. Research is a key currency for our participation in such agreements.

Ocean surveillance, defence and search and rescue are essential parts of Australia's international responsibilities for the vast Australian marine estate and depend heavily on up-to-date ocean research and forecasts and international cooperation.

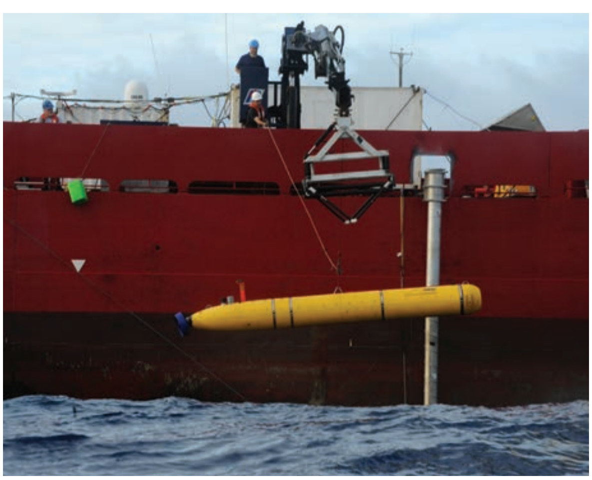

Figure 6: (Source: Peter D. Blair, USA Department of Defense 140426-N-OV358–019, Public domain, via Wikimedia Commons)

Figure 7: Australian Border Force Cutter (ABFC) Cape Wessel on patrol with the BAKAMLA vessel Ular Laut 4805 (Source: Australian Department of Immigration and Border Protection, CC BY 3.0)

2. Energy

Australia's marine estate sits over vast non-living resources of economic and social importance, including oil, gas, mineral sands and ore-bearing features (Chapter 4). Sub-seabed oil and natural gas are vital for Australia's energy security and natural gas is set to be a major export from Australia over coming decades. However, the oceans of our marine estate also have great potential to supply renewable wave and tidal energy (Chapter 10).

Harvesting these massive energy resources is a future necessity requiring research now to understand the options, technologies and challenges of harvesting ocean renewable energy in addition to conventional fossil fuels. Discovery of new resources, and the technologies for exploitation and innovations in handling and transport of these resources, are important areas of research, together with exploration of the oceans and sub-seabed for potential new resources. There is a high expectation socially that the extraction and transport of these resources will have negligible effect on Australia's marine environment, with clear recognition of the potential for significant impacts from accidents such as oil spills.

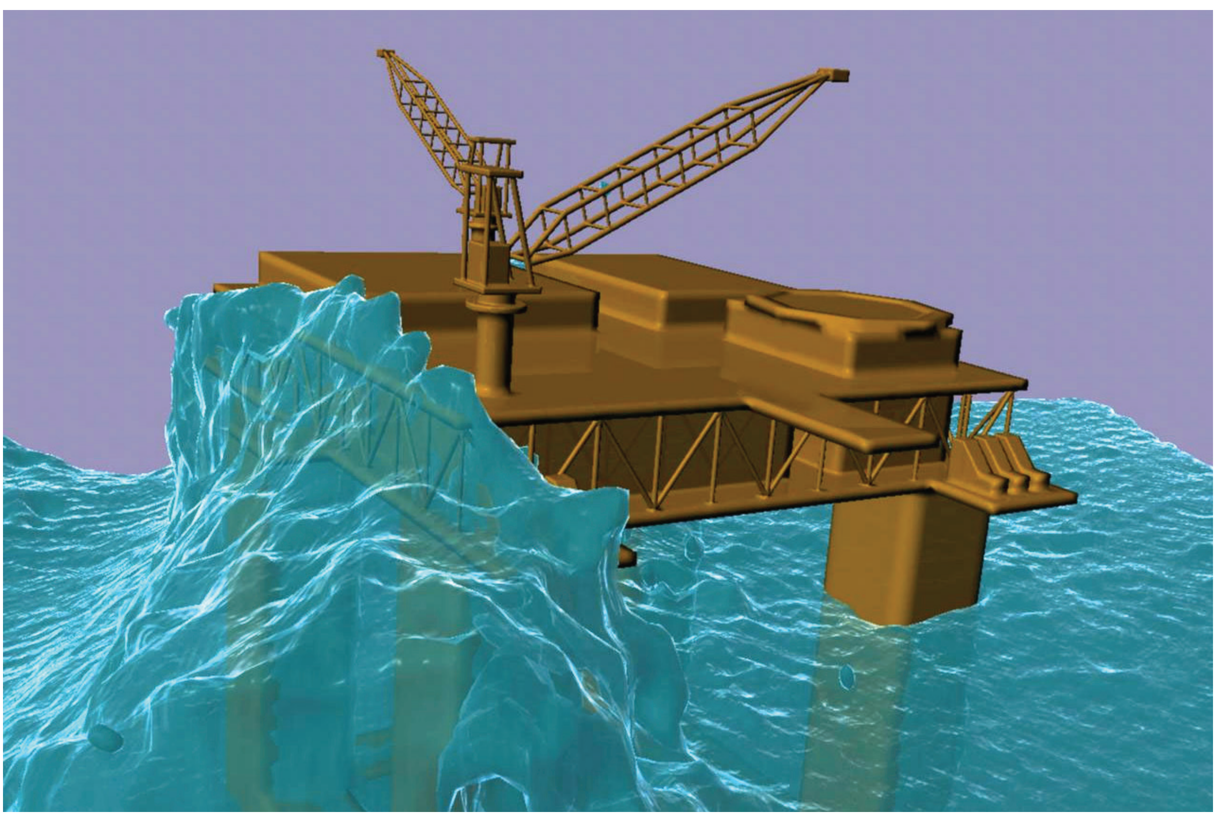

Figure 8: Offshore oil and gas have been essential for Australia's development, but efficiency, safety and environmental effects of exploration and extraction rely on ocean research (Source: CSIRO)

3. Marine biodiversity

Our marine estate has unique biodiversity over a huge geographic range (Chapter 3). Balancing the consequences of exploitation with the demands for conservation of the marine estate represents a major policy and regulatory challenge that rests heavily on robust research across the breadth of the marine estate.

Figure 9: Australia's marine estate is rich in a great diversity of plants and animals, from tropical to Antarctic seas (Source: CSIRO – Matt Curnock, Steve Rintoul)

4. Food

Australian commercial fisheries and aquaculture industries harvest marine animals and plants, mostly for food, with benefits for the Australian economy and society (Chapter 9). Fishing is an important recreation across Australia and an essential part of the culture and food of many Indigenous Australians (Chapter 6). The direct and indirect effects of all fishing and aquaculture on the status of the marine estate, however, is of material concern nationally and internationally. Research plays major roles in the efficiency and management of these activities in ways that reassure an increasingly concerned community that they are ecologically safe and sustainable.

Figure 10: Fishing is important commercially and for recreation and cultural heritage for many Australians (Source: CSIRO)

5. Coasts

Much of Australia's coast is low-lying and sandy or muddy. Near-shore marine processes regularly flush estuaries, rework and redistribute coastal sediments and modify the shape of our coasts.

Over 80% of Australians live in coastal communities with associated industries and infrastructure (Chapter 11), and shipping, which is essential for the national economy and requires ongoing port development.

Managing coastal development is a profound challenge for Australia and our regional neighbours. Rising sea levels will increasingly affect Australia's coastal environments, assets and communities (Chapter 17).

Policy and regulatory responses to these effects are shared across national, state and local jurisdictions and adaptation to coastal risks and changes will be required by diverse communities and industries (Chapters 15-16). Responses by individuals and communities will hinge on underpinning information about coastal processes and uses delivered at national scale by targeted, large-scale marine research.

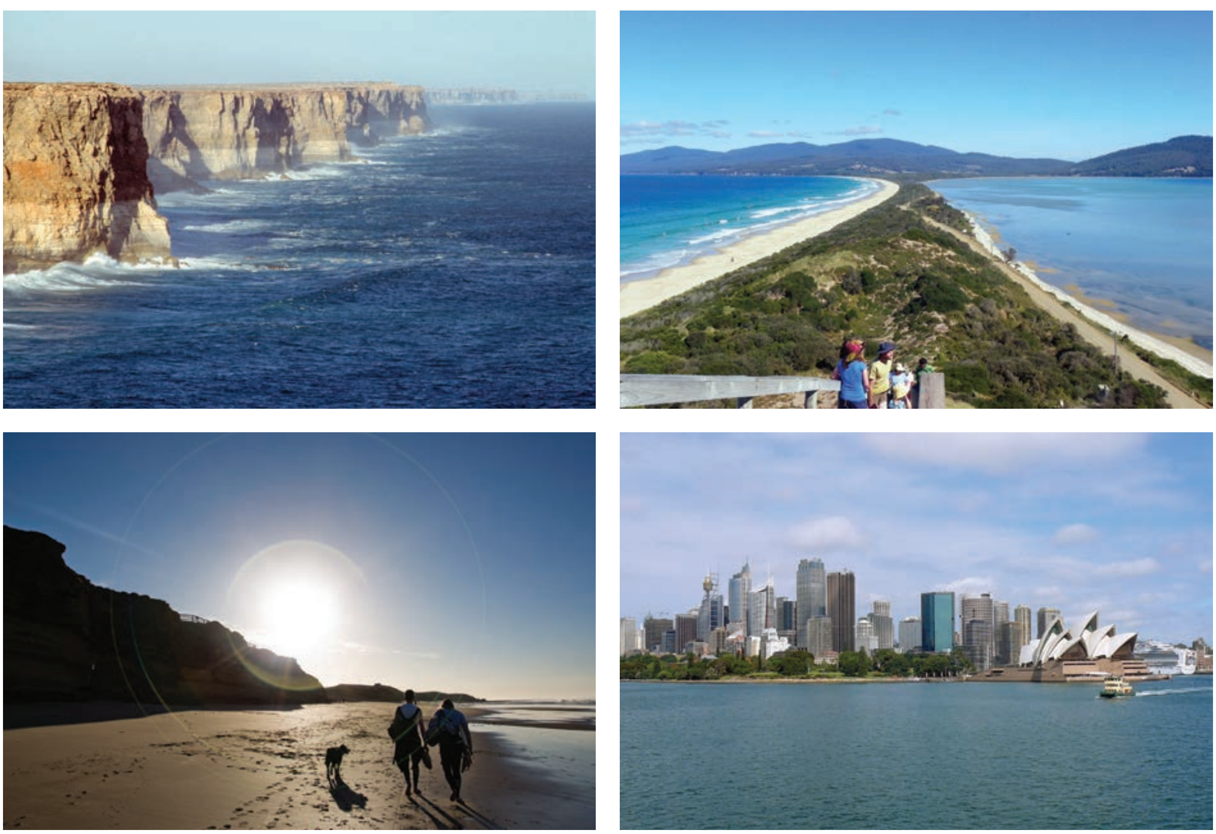

Figure 11: Australia has a diverse coastline with many remote areas and others that are integral to many aspects of Australian life (Source: CSIRO – Willem van Aken, Leise Coulter, James Porteous)

Figure 12: The oceans affect Australian weather and climate on a grand scale, from the tropic North to icy South (Sources: NASA, CSIRO – Robert Kerton, Glen Walker)

6. Oceans and climate

Australia's climate and weather is influenced profoundly by regional and global processes driven substantially by the oceans. Exchange of heat and moisture between ocean and atmosphere drive key climate features that, in turn, affect directly the weather and climate over Australia's terrestrial environments, including rainfall, temperature, and the frequency and intensity of extreme weather events (Chapter 5).

Improving medium to long-term forecasts of weather and climate for Australia and our region hinges on our ability to capture ocean–climate interactions in Australia's Earth system, climate and weather models. The ocean is a major player in the global carbon cycle and provides a key buffer to the greenhouse effect of humanity's additions of carbon dioxide to the atmosphere. This benefit comes at a cost, however, because absorbing extra carbon dioxide is leading to acidification of the oceans (Chapter 17). Equipping Australia to respond to these climate challenges and improving our ability to forecast weather and climate depends on ocean research at national scale.

7. Resource allocation

The intensity and diversity of ocean uses is growing rapidly. Different interests often have competing demands for access, resources and approvals to operate across the marine estate. Many of our land-based activities also affect the oceans (Chapters 11, 13). Managing these multiple demands and impacts on the marine estate increasingly requires sophisticated tools to quantify the trade-offs between alternative uses (Chapter 15).

Demand for such integrated, multiple-use management strategy evaluations is projected to be a key future challenge for marine science (Chapter 16) and Australia as an established leader in that field.

Marine research is important in responding to these challenges and so a National Marine Science Plan for future research in each of those areas has been developed.

Note: All Chapter references are for *Oceans: Science and Solutions for Australia*. CSIRO.

Activity 1 – Glossary

Creating a glossary. Use the table to define any science words that are related to this article.

Word	**Definition**
Marine estate	
Coastal estuaries	
Lagoons	
Intertidal areas	
Abyssal plains	
Energy resources	
Mineral resources	
Biological productivity	
Weather	
Climate	
Blue economy	
Marine operations	
Non-living resources	

Activity 1 – Glossary

Creating a glossary. Use the table to define any science words that are related to this article.

Word	Definition
Sub-seabed	
Natural gas	
Energy security	
Renewable wave energy	
Renewable tidal energy	
Fossil fuels	
Biodiversity	
Ecologically safe	
Extreme weather	
Carbon cycle	
Greenhouse effect	
Acidification (of the oceans)	

Activity 2 – Summarising

Summarise the information in Article 2 by responding to the following questions:

1. Briefly describe Australia's marine estate and summarise its importance.

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2. In the space below, create a table to summarise the seven challenges with headings that can include informative images, descriptions, examples, research and/or goals for the future.

3. List the types of data, and where possible the equipment required, to gather information about our oceans so that we can meet these seven challenges.

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Activity 3 – Questioning Toolkit

We have provided a series of discussion questions in the form of a questioning toolkit.

Choose some or all of the questions, or ask some of your own.

Further reading on questioning toolkits:

- McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. Questions ▪ How can research optimise our understanding of each of the seven challenges? ▪ How are governments coordinating the research across the seven challenges?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. Question ▪ Which organisations will be responsible for the research across the seven challenges?	

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the what-ifs? They are useful when we want to test our hunches. Question ▪ If you were to grant funds for research into one of these areas, which would you help develop, that is, which do you think should have priority?	
Provocative questions Questions to challenge convention. Question ▪ Do areas of society benefit equally across all seven challenges?	

Ocean Science Now And The Future

The oceans around Australia provide both protection and resources in abundance, and influence almost all aspects of Australians' lives either directly or indirectly.

Our jurisdiction of enormous areas of those oceans comes with responsibilities to both use the ocean resources and protect the marine environments from damage from such uses. Those responsibilities depend heavily on research. The future of that research will benefit from rapidly advancing research technologies (Chapters 16, 18) but will need to integrate across conventionally separate marine science disciplines and include social and economic disciplines to provide truly integrated support for the stewardship of our marine estate.

Current technology

Taking observations to gain a meaningful understanding of the ocean is not easy and there are particular challenges in the Australian context. Australia's mainland coastline (including Tasmania) is around 36,000km long, with an additional 24,000km-plus of island coastlines. Our maritime domain spans ecological regimens from the Antarctic to the tropics and from shallow coastal zones to abyssal waters over 4,000m deep. The oceans are complex: water masses are three dimensional, heterogeneous and constantly moving. Understanding ocean states and processes requires collecting data at a range of spatial and temporal scales, as well as careful interpretation.

The number of ocean variables that are of interest to scientists and that can be observed is large. The most common of these are physical parameters, such as water temperature and salinity, with records at some locations extending back to the 19th century.

Other variables include optical parameters (colour, clarity), biological, chemical (pH, alkalinity), dissolved gases (CO_2, oxygen), nutrients and measurement of ocean currents. The levels of fluorescence in a water sample can be used to estimate the abundance of phytoplankton in that water sample because phytoplankton contain the fluorescent chemical chlorophyll.

Ocean observing also can include observations of marine plants and animals via acoustic devices, sampling with nets and dredges, imaging with camera systems and mapping of the ocean floor using acoustic sonar systems. These observations inform us about the past and present state of the oceans while contributing to models used to forecast future ocean conditions (Chapter 12).

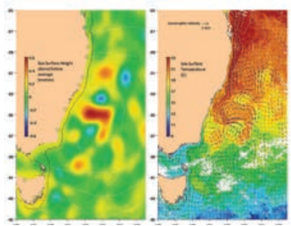
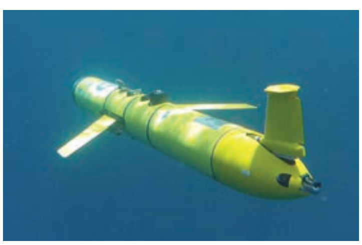
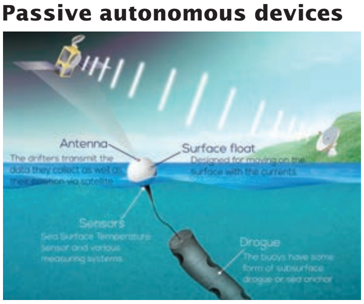
Table 1: Conventional tools for observations

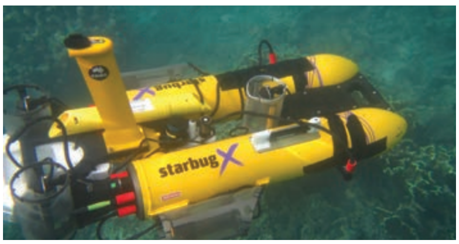
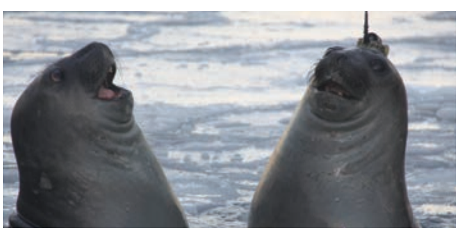
Ships A conductivity, temperature and depth instrument being deployed from a research vessel. (Source: Stewart Wilde, CSIRO). 	Sea surface temperature and salinity are measured continuously from modern research vessels with electronic instrumentation fitted to in line water-collection systems. Further variables, such as dissolved gasses and nutrients, can be measured by collecting water samples from the depths for analysis in the laboratory.
Scientific moorings This mooring package was placed to measure water temperature and currents near an ice sheet, improving our understanding of the influence of warm ocean currents on melting ice sheets (Source: Steve Rintoul, CSIRO). 	Arrays of instrumentation can be installed on ocean moorings at any depth to collect data autonomously for periods spanning several years. Moorings with surface floats can send data back to researchers in real time by radio or satellite communications while those without surface floats can store data internally until they are recovered by ships. There are several mooring arrays around Australia across the continental shelf and into the deep ocean.

Emerging tools for observations

The cost of sending people to sea in boats to collect data or install instruments is expensive, and limits the amount of data that can be collected by such conventional approaches. Technology has been developed increasingly to tackle this challenge. The future of scalable and sustainable ocean science lies in system autonomy and remote sensing.

Table 2: Emerging observation tools

Remote sensing 	A growing array of satellite-based sensors since the 1970s has added considerably to ocean observations. The range of variables that can be measured from satellites currently includes ocean surface temperature, ocean currents, ocean height and sea level, surface plankton, ocean colour, wave and wind regimens, and salinity.
Autonomous sensing A glider moves by changing its buoyancy and adjusting its centre of mass, thereby gliding up and down through the water in a zigzag fashion. It is programmed to follow a specific path guided by GPS, and can transmit data via satellite when it reaches the surface (Source: CSIRO). 	Autonomous sensing platforms aim to retain the benefits of high-quality, direct measurements by researchers without the need for staff to travel to the measurement site. This is achieved through the use of robotic vehicles that can operate on their own and do not require close continuous supervision by researchers. Unmanned vehicles also can transit to remote or otherwise inaccessible locations (such as under ice shelves), remain on location for extended periods and operate in hazardous areas, delivering new datasets that are otherwise difficult or impossible to obtain.
Passive autonomous devices 	The simplest autonomous systems are drifters. These devices originated from the 'message in a bottle' concept that yielded basic information on the average velocity of ocean currents derived from knowing its release point and the time and location of its eventual recovery. Modern drifters now include electronic sensors that can measure the environment (e.g. temperature and salinity) and regularly send this information along with their locations back to a central data centre via satellite.
Autonomous surface vessels (ASVs) 	ASVs can support a suite of ocean science instruments collecting data about the ocean surface, with some water column information also being collected using acoustic sensors. Some ASVs use solar, wind or wave energy for their long-term operation.

Autonomous underwater vehicles The Starbug X is a small autonomous underwater vehicle (AUV) developed by the CSIRO to collect data from the shallow sea floor. Its primary function is to take photos of the seabed and coral reef areas to enable scientists to evaluate the health of Australia's coastal waters. (Source: CSIRO). 	Autonomous underwater vehicles, equivalent to unmanned mini submarines, can be used to collect data in areas where it is difficult to sample otherwise, or make extended subsurface observations. Data from beneath sea ice, ice sheets and glaciers, for example, are key to understanding ocean-ice dynamics, but are difficult to collect using traditional methods. These vehicles also are starting to take the place of human divers to collect data in shallow water. AUVs are typically battery-powered and can carry a payload of sensors that measure temperature, salinity and depth, record acoustic data, biological variables and map the sea floor or undersides of ice sheets. AUVs come in all shapes and sizes and increasingly are becoming standard tools for collection of large spatial and temporal ocean datasets.
Animal-borne instruments Elephant seal fitted with a micro-sensor measuring ocean conductivity, temperature and depth. The data can be transmitted to researchers via satellite when seals surface to breath. (Source: Clive R. McMahon, Integrated Marine Observing System, Satellite Animal Tracking, Sydney Institute of Marine Science). 	Continued miniaturisation of sensors and data telemetry systems have made it viable to build self-contained data acquisition systems small enough to be mounted on animals such as whales and seals, but also on smaller animals including birds and fish. These applications bring value particularly in remote and difficult environments such as sea ice zones. The resulting datasets are useful particularly when studying an animal's behaviour and their interactions with the environment, but this technique can also act as a means to collect environmental data from a region without the need to place researchers in the field.

Future of observations – robotics and real-time data

A revolution in ocean observations seems imminent. Satellite observations are delivered at higher resolution in both time and space, now returning ocean surface measurements on spatial scales of metres rather than tens of kilometres, and on timescales of minutes rather than hours. New variables are being measured from space, including sea surface salinity and more diverse optical properties of the oceans.

Biological observations also are more sophisticated, enabling studies of biology, life history, movement, interaction and population structures of marine species in greater detail than was possible just a few years ago. Genetic methods are predicted to become indispensable in determining how closely related are fish stocks from different regions, for understanding organisms' responses to climate change, and for improving aquaculture production. New 'close-kin' methods developed by the CSIRO, for example, use 'genetic fingerprinting' to estimate abundances of marine fished species, as well as species of conservation interest.

Table 3: New technologies

Miniaturisation	The Environmental Sample Processor developed by the Monterey Bay Aquarium Research Institute is able to perform molecular analyses remotely from a mooring, or as a drifting instrument, to describe the bacterial communities found in the oceans. Future versions will be incorporated into autonomous underwater vehicles (AUVs) to increase the range over which analysis can be performed. Miniaturisation will enable the measurement of nutrients, biodiversity and other variables.
Measuring biological diversity	Measuring biodiversity across the vastness of our oceans remains a major challenge. Recently developed genomics methods that enable description of complex microbial communities based on DNA extracted from small samples have become the most affordable approach to assess biological diversity from large numbers of samples.
Satellites – more data, better processing	The recent launches of new-generation satellites with optical sensors capable of 500m or finer resolution and other sensor technology advances are going to improve the spatial and temporal coverage of satellite observations of the ocean significantly. These, in turn, will lead to better modelling and prediction accuracies.
Acoustics and optical observations technologies	Acoustic and optical sensors are ideal for sampling the behaviour, composition, biomass and distribution of marine organisms (millimetres to metres in length) at spatial scales of centimetres to kilometres and timescales of seconds to years. These observations are important to help build better ecosystem and fisheries models for sustainable management of our marine resources.
Concurrent data, big data	The above advances will make observations on the physics, the chemistry and all levels of the biology of the oceans affordable at a significantly higher spatial and temporal resolution. Linking these different observations will increase their value exponentially, leading to high-resolution coupled oceanic observations. Concurrent observations will allow us to see the effects of the physical ocean on ocean chemistry, assess the influence of chemistry on microbiology and primary productivity, and link ecosystem processes to fish stocks and entire ecosystems.

Conclusion

Technology innovation is key to Australian marine researchers filling the large gaps in our knowledge of our marine estate. Ocean observations historically have been slow, labour intensive, time-consuming, very expensive and sparse. New technologies developed over just the last few decades can now provide orders of magnitude more observations of more detail, at finer resolution, with greater cover and greater frequency than we could have imagined 50 years ago.

Automated observing devices in the oceans, satellite-based sensors, continuously recording instruments on ships and advanced chemical and genetic methods are, or have the potential to be, providing streams of data that document our marine estate in increasing detail.

Activity 1 – Glossary

Creating a glossary. Use the table to define any science words that are related to this article.

Word	Definition
Jurisdiction	
Ecological regimens	
Heterogeneous	
Spatial scales	
Temporal scales	
Ocean variables	
pH	
Alkalinity	
Sonar	
Dissolved gases	
Arrays of instrumentation	
Ocean moorings	
Autonomous	
AUV	
Sensors	
Data telemetry systems	
Real-time data	
Genetic fingerprinting	

Activity 2 – Summarising

Summarise the information in Article 3 by responding to the following questions:

1. What features of the oceans makes data collection so difficult?

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2. Suggest and justify which research tool you might use to collect data on the following:

Collecting data on	**Research tool used**	**Justification**
Marine animals' behaviour		
Temperature under an ice sheet		
Surface water salinity		

3. Make a list of as many different variables that are measured in the ocean that you can find in the article. How could they be grouped?

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4. What is the general trend over time in the change in data collection from early conventional methods, through emerging technologies to new technologies?

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Activity 3 – Questioning Toolkit

We have provided a series of discussion questions in Appendix D in the form of a questioning toolkit. Choose some or all of the questions, or ask some of your own.

Further reading on questioning toolkits:

- McKenzie, Jamie (2000) Beyond Technology, FNO Press, Bellingham, Washington, USA. www.fno.org/nov97/toolkit.html

Type of question	Your ideas and opinions
Essential questions These are the most important and central questions. They probe the deepest issues that confront us and can be difficult to answer. Questions ▪ What kinds of tools do we use to study the ocean, how accurate are they, and how accurate do they need to be? ▪ Why do we need to study so many different ocean variables?	
Subsidiary questions These questions help us to manage our information by finding the most relevant details. Questions ▪ What skills do marine scientists need to carry out their jobs? ▪ Where is all the data stored and how is it shared once it is collected? ▪ Will the data collected be able to help us meet the seven challenges reported in Article 2?	

Type of question	Your ideas and opinions
Hypothetical questions Questions designed to explore the possibilities, the what-ifs? They are useful when we want to test our hunches. Question ▪ What if we didn't have satellites to relate data from one place to the next; how would data collection be compromised?	
Provocative questions Questions to challenge convention. Question ▪ What kind of impact does some of the data collection methods and equipment have on the oceans and the organisms that live within them?	

Bringing It All Together

1. Go back to the mind-map you completed before you read these articles. Add in some of the new knowledge you have gained about our marine estate.

How has your thinking changed from when you completed the mind-map?

2. What else would you like to learn about the oceans?

Write a couple of questions related to what you would still like to know about our oceans.

About The Learning Matrix

What is the oceans learning matrix?

A learning matrix is a flexible classroom tool designed to meet the needs of a variety of different learning styles across different levels of capabilities. Students learn in many different ways; some are suited to hands-on activities, others are strong visual learners, some enjoy intellectually challenging independent hands-off activities, while others need more guidance. The matrix provides a smorgasbord of science learning activities from which teachers and/or students can choose.

Can I use the matrix for one or two lessons, or for a whole unit of study?

Either! The matrix is designed to be time flexible as well educationally flexible. Choose to complete one activity, or as many as you like.

Is there room for student negotiation?

Yes! Students can be given a copy of the matrix and choose their own activities, or design their own activities in consultation with their classroom teacher.

What do the column headings mean?

Developing	Extending
Designed to enhance student comprehension of information by including research (other peoples' knowledge and ideas) into their activities.	Gives the student the opportunity to apply or transfer their learning into a unique format where they have to create using their own design or evaluate using their own criteria.

What do the row headings mean?

First-hand investigations	Hands-on activities that follow scientific method. Includes experiments and surveys. Great for kinesthetic and logical learners, as well as budding scientists.
Engineering and making	Hands-on building, troubleshooting and reviewing a design of their own. Includes making robots or circuits or structure by using Lego or wires or recycled materials.
Ethical thinking	Students learn to recognise and explore ethical concepts. They examine reasons supporting ethical decisions, consider consequences of these decisions, and reflect on ethical actions. Students examine values, rights, responsibilities and points of view.
ICT	Students use searches to locate, access and generate digital data and information. Students generate ideas, plans and processes, and communicate these via computers. They select and use hardware, manage data, understand social and ethical protocols, and understand the impacts of ICT.
Personal and social capabilities	Students recognise emotions, personal qualities and achievements in themselves and diverse perspectives and relationships with and between others. They learn self management through working independently and learning how to express emotions appropriately. Students work corroboratively, make decisions, negotiate, resolve conflict and develop leadership skills.
Creative and critical thinking	Models the inquiry process. Students question, identify, clarify, organise and process information. They generate ideas, possibilities and actions, connect ideas, consider alternatives and seek solutions. Students also reflect on thinking (metacognition) and processes, apply logic and reasoning, draw conclusions, and evaluate procedures. Knowledge is transferred into new contexts.
Time travel	Here students consider scientific and technological development as a linear process by travelling back in time or creatively into the future.

Oceans Learning Matrix		
	Developing	**Extending**
First-hand investigations	Measure the seabed by modelling the use of sonar technology. See Linked Activity 1. Related to Chapter 4: Geology beneath our oceans by Joanna M Parr and Andrew Ross. **OR** If you live near the ocean, collect a sample of water and conduct a series of observations to test it for the presence of living things, pH, salinity, dissolved gases, and temperature. Record your findings in a data table and compare your results with the rest of the class. Related to Chapter 14: Tools and technologies for ocean observation by Mark Underwood and Andreas Marouchos.	Design, conduct and write up your own investigation to examine a research question of your choice based on finding out more about our oceans. The following questions can be used or altered if you do not have your own question. 1. What is the effect of the angle of solar radiation on the surface temperature of water? 2. What is the effect of radiation wind speed (or chill factor) on the surface temperature of water? 3. Which water conditions create biofilms? 4. Which method is best to clean up an oil spill? 5. Which method of desalination is most: cost effective/faster/greener? Related to Chapter 14: Tools and technologies for ocean observation by Mark Underwood and Andreas Marouchos.
Engineering and making	Compare a range of ocean research tools before building a static or working model of one of them. Record all your ideas and research in a log book. Related to Chapter 14: Tools and technologies for ocean observation by Mark Underwood and Andreas Marouchos.	Design and/or build a model underwater research vessel of the future. Make drawings of your creation and label all the technological advances and identify what each part of the vehicle can do. Related to Chapter 18: Future technologies by Bernadette Sloyan, Pascal Craw, Edward King, Craig Neill, Rudy Kloser and Levente Bodrossy.
Ethical thinking	What is integrated management of our oceans? Is it fair, is it a compromise, or is it a fair compromise? Choose, research and present a case of integrated management stating whether you believe all parties make an equal compromise. Related to Chapter 15: Managing multiple uses of our oceans by Beth Fulton, Tony Smith, Keith Sainsbury and Marcus Haward.	Consider multiple ethical and legal issues that are part of the responsibilities of governing our marine estate. See Linked Activity 2. Related to Chapter 7: Governance of Australian seas and oceans by Ian Cresswell and Marcus Haward.

Oceans Learning Matrix		
	Developing	Extending
ICT	Use Google maps to explore the ocean floor. Choose something of interest to you and write an interactive lesson for your peers that teaches them about the geography of our marine environment. Related to Chapter 4: Geology beneath our oceans by Joanna M Parr and Andrew Ross.	Explore eReefs and use it to investigate a single variable related to our oceans. For example, from the home page click on the eReef visualisation portal and use it to measure water temperature from Cairns out into the Coral Sea, about 150km, using the transect tool (top left of the screen – box with a line). Prepare a presentation to the class that describes and explains the variable you investigated and how you used the eReef to do this to locate the data. http://portal.ereefs.info/ Related to Chapter 11: Coastal development by Andrew DL Steven, Simon Apte, L Richard Little and Mat Vanderklift
Personal and social capabilities	Make a video, take a photo, design a campaign, start a blog, or create any other innovation that is in line with the work presented by National Geographic's 'New wave warriors' to help reduce damage to, and preserve our oceans. bit.ly/Newwavewarriors Related to Chapter 13: Ocean pollution – risks, costs, and consequences by Britta Denise Hardesty, Paula Sobral, Simon Barry and Chris Wilcox.	From *Undertow: Stories From The Land's End*: "Our relationship with the ocean is a very immediate, physical one – we swim, sail, fish, surf, pollute – we suffer storm damage to properties built within the ocean's reach. We know the sea is warming and choose to do little about it, unable to imagine that something so vast could be irreparably damaged. The oceans existed long before we did. "For [non-Indigenous] Australians, the longer we spend bedding down in Australia, the more the sea becomes other things for us – still a source of unease (sharks, crocodiles, foreigners in small boats) but also a kind of defining national identity." Visit this website – bit.ly/Landsend – and contribute a story of your own about our relationship with our marine estate. Related to Chapter 6: The oceans and our lives by Sean Pascoe, Toni Cannard, Natalie Stoeckl, Ian Cresswell, Samantha Paredes and Amar Doshi.

ELABORATE

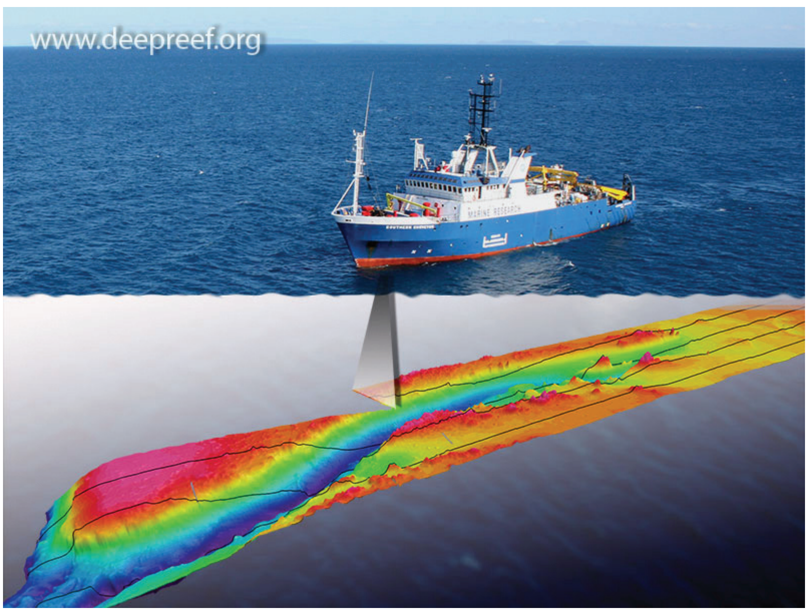
Oceans Learning Matrix		
	Developing	Extending
Creative and critical thinking	The Australian Maritime Safety Authority has run a slogan and poster campaign with the message: "Stow it, don't throw it." This is part of a campaign highlighting government restrictions on discharge of waste into the oceans. Create your own slogan to put on a poster or a sticker, which promotes a positive approach to any issue related to our oceans. See Page 130 of the CSIRO's Ocean book.	Choose one of the seven challenges outlined in Article 2 and think about the kind of research you could carry out to find new knowledge that helps meet a sub-section of that challenge. Why is this research important to you? Who could fund this research? Once you have decided on an appropriate research project, write a grant for your research using the template provided. See Linked Activity 3. Related to Chapter 1: Introduction by Bruce Mapstone.

The chapters referred to are from *Oceans: Science and Solutions for Australia*, Edited by Bruce Mapstone

Linked Activity 1

Mapping the ocean floor

Google has published 3D maps of the ocean floor. Scientists have managed to create these maps of mountains, volcanoes and ridges by using a form of technology known as sonar. Ships with equipment to send and receive sonar signals are needed. These ships cross the oceans and send sonar signals down to the ocean floor as they go. They time how long it takes for the signal to return. The longer it takes the signal to return, the further away the ocean floor is. Alternately, the quicker the signal returns, the closer the ocean floor is.



Maps of the seafloor are made by measuring the time taken for sound pulses to travel from the ship's hull to the seafloor and back. This image shows the RV *Southern Surveyor* from the Marine National Facility, CSIRO, using EM300 multibeam to survey palaeochannels on the Great Barrier Reef shelf (Source: R Beaman, James Cook University).

You will need:
- An empty shoe box or equivalent with a lid
- Plasticine
- Recycled materials
- Knitting needle
- Ruler
- Pen

What to do:

1. Remove the lid from the box and create an ocean landscape across the bottom using the recycled material and the plasticine. Build in a variety of terrains such as volcanoes, ridges and gentle slopes.
2. Put the lid back on the box so that the topography you have just created cannot be seen.
3. Rule a line from one end of the box lid to the other and label one end 'start'.
4. Punch a hole 1cm from the start of the line you have just drawn that is large enough to fit the knitting needle through. Continue to make holes every cm along the line.
5. Give your finished 'ocean floor in a shoe box' to a partner and have them place the knitting needle in each hole until it touches the bottom of the 'ocean'. They can measure how far the knitting needle went in and then minus that figure from the overall depth of the box. Record the depth of the 'ocean' in the results table below.
6. Graph the data you have collected to visually show the topography of the ocean floor.
7. Label any features of the landscape you can identify.
8. When you have finished graphing the topography of the model ocean floor, take the lid off the box and compare your graph with the actual shape of the landscape inside the box.

Results:

The depth of the box is ______________

Distance from the start of the line (cm)	Depth of the model 'ocean' (mm)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Graph:

In the space below graph your results to show the topography of the ocean floor inside the box.

ELABORATE

Discussion questions.

1. Which features of the landscape were you able to recognise from the graph alone (before taking the lid off the shoe box)?

2. How similar was the shape of your graph to the shape of the landscape inside the box?

3. How is this activity like the real-life mapping of the ocean landscape?

4. How is this activity different to the real-life mapping of the ocean landscape?

5. Identify any problems you had during this activity and how you overcame them.

6. What did you learn during this activity?

Linked Activity 2

Governance ethics and policy

Examine the image provided of Australia's Maritime Jurisdiction and use this information, as well as any information from Oceans Chapter 7, in your class discussion of the four scenarios below.

Scenario 1 – Mining fossil fuels

Australia shares maritime boundaries with six neighbours: Indonesia, East Timor, Papua New Guinea, Solomon Islands, France (Kerguelen Islands and New Caledonia) and New Zealand. Also adjacent to Australian waters lie international waters sometimes called the High Seas. Non-living resources of the seabed and subsoil in the High Seas, beyond any nation's jurisdiction, are considered 'the common heritage of mankind'. Extract from Chapter 8, Page 78

Class discussion questions

Imagine one of Australia's maritime neighbours is interested in mining oil and natural gas just beyond the Australian exclusive economic zone. Use the map provided, and gather any other information you need in order to respond to these questions. Discuss your ideas with the rest of the class.

1. Should Australia be concerned in any way with fossil fuel mining projects that are proposed or being undertaken just outside the Australian exclusive economic zone by a marine neighbour? Think broadly, such as in terms of economic and environmental advantages or drawbacks for both countries involved.
2. Should Australia negotiate involvement with any fossil fuel mining projects it is aware of by its marine neighbours? If so, what might they propose their involvement be?
3. How do you anticipate any neighbouring government will respond to what you suggested on behalf of the Australian government in question 2 above?
4. How could any disagreement related to fossil fuel mining projects in this area between the two governments be resolved?
5. Why might international policies between countries be so important on the high seas? Should international polices relate to the idea that the non-living resources of the seabed are 'the common heritage of mankind'?

Scenario 2 – Southern Bluefin tuna fishing

Southern bluefin tuna (SBT) is one of Australia's most valuable tuna fisheries, with current exports of $150 million per annum of SBT caught live off South Australia and 'grown out' to market size in sea cages. The fishery is subject to international management by the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) under the Convention for the Conservation of Southern Bluefin Tuna (1994). Australia and Japan are the two largest harvesters of SBT, followed by the Republic of Korea, Taiwan, New Zealand, Indonesia and South Africa. Regional management of SBT has been challenging, but early disputes over stock status have given way to greater confidence in stock assessments and a robust management procedure, leading to recovering stocks.
(Extract from Oceans: Science and Solutions for Australia*, Chapter 8, Page 80)*

Class discussion questions

Gather any information you need, and then take time to think about your response to these questions before sharing your ideas with the rest of the class.

1. How do you think the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) might best:
   a. Allocate the quantity of tuna fishing per country per annum?
   b. Monitor each country's fishing practices to ensure they are within the designated amount?
   c. Deal with countries that are over-fishing?
2. Australia has lodged a formal complaint with the CCSBT alleging one of the other harvesters of SBT is under-reporting their annual catch of SBT. What should be a fair process carried out by the CCSBT to respond to this allegation?
3. A 'flag of convenience' ship is a business practice whereby a merchant ship is registered in one country, but is owned by another country. How should the CCSBT respond to any catch found on these ships? Should flag of convenience ships be legal?
4. Should ships that are not CCSBT members be allowed to catch SBT? Why or why not?

Scenario 3 – Native title

Claims to sea country under native title legislation have been the basis of several High Court cases since native title was recognised in Australian law in 1992. The Court has recognised co-existence of native title with other existing marine rights (shipping, fishing, etc.), but has not supported exclusive native title to offshore marine areas.
(Extract from Oceans: Science and Solutions for Australia*, Chapter 8, page 84)*

Class discussion questions

Gather any information you need, and then take time to think about your response to these questions before sharing your ideas with the rest of the class.

1. When it first became law, why do you think native title excluded Australia's seas and oceans? Was this a fair exclusion? Why or why not?

2. The Blue Mud Bay case in 2008 confirmed exclusive Aboriginal rights over intertidal areas under existing land rights legislation that applies only to the Northern Territory. This legislation means that fishing licenses issued by the NT government are illegal. It's the Aboriginal Land Council that is entitled to grant these licenses.

a. How might commercial fisheries have responded to this legislation?

b. Was this a fair decision?

c. Do you think there could be an economic consequence of this legislation? Or any other consequences?

d. Should other states follow with similar legislation?

Linked Activity 3

OCEANS GRANT APPLICATION

1. Project title

____

2. Name of applicant (s)

____

3. Brief summary of the situation or problem related to our oceans that is to be addressed:

____

____

____

____

4. Purposes (objectives) of the oceans research project:

____

____

____

____

5. What research do you intend to do, and how do you plan to accomplish it?

____

____

____

____

6. Explain how the expected results will address the problem and/or enhance current research and resources.

____

____

____

____

7. Explain how the expected results will be made available to the CSIRO/Australia.

____

____

____

Estimated budget and costs:

a. Personnel costs (include both time taken and any money you personally need to spend)

____

____

b. Travel (include any places you need to visit and the actual kilometres)

____

____

c. Supplies and equipment (list the items you require and their estimated costs)

____

____

d. Contractual (will you need to contract out any work – such as writing programs, gathering data? List these and their estimated price)

____

____

e. Other costs (itemise)

____

____

f. Total project costs

____

____

8. Budget justification and/or explanation:

____

____

____

9. Timeline. When you expect to start and finish the project?

____

____

____

Section 1 – Creating your own oceans quiz

a) Ask each student to call out a word related to the activities you have carried out and what you have learnt during this unit on oceans. Record these words on the board.

b) Each student must pick six words from the board and write a definition for each.

c) Students then pick four more words from the board and write a paragraph describing them. They should highlight their chosen words in the paragraph.

Section 2 – Oceans individual unit review

What about you?	**Drawing**
Describe your favourite activity during this unit of study.	Create an image that summarised this unit of work for you.
Learning summary	**Your philosophy**
Write four dot points of things that you learnt about oceans.	Describe your overall thoughts about our marine state after completing this unit. Has this unit of work changed your thinking about how we use our oceans? Are you more interested in learning about oceans?
More questions?	**Metacognition**
Write two questions that you still have about oceans or anything else related to this unit of study.	Which activities did you find helped you learn the easiest? Why?

Further resources

Books

- *Oceans: Science and Solutions for Australia*, edited by Bruce Mapstone, CSIRO, 2017

Videos

- Archived videos of approximate one minute duration related to events on and around our shores
  www.abc.net.au/arts/girtbysea/
- Surf life saving video on surviving rip currents
  www.youtube.com/watch?v=ernDqqkfHCw
- A video about Google Earth 5: The Ocean
  www.youtube.com/watch?v=6ATw1f_qcEg

Articles

- An article on the science and legislation of rising sea levels and coastal erosion
  http://theconversation.com/scrapping-sea-level-protection-puts-australian-homes-at-risk-21271
- Blue Mud Bay High Court decision (regarding fishing legislation) explained
  https://www.creativespirits.info/aboriginalculture/land/blue-mud-bay-high-court-decision#ixzz4nd7LPMvM

Organisations

- CSIRO Oceans and Atmosphere
  www.csiro.au/en/Research/OandA
- Geoscience Australia
  www.ga.gov.au/scientific-topics/marine
- Australia's National Marine Science Committee – Marine science driving the development of Australia's blue economy
  www.marinescience.net.au
- International Ocean Discovery Program – Exploring the Earth under the Sea
  www.iodp.org
- eReefs – A collection of images, metadata and articles. It is a world-first in delivering vital information about the entire Great Barrier Reef from catchment to ocean
  ereefs.org.au/ereefs
- Australian government's Bureau of Meteorology
  www.bom.gov.au/marinewaterquality/
- National Geographic's New Wave Warriors
  www.natgeotv.com/int/new-wave-warriors
- ABC Radio National's stories about the sea
  www.abc.net.au/radionational/programs/360/undertow3a-stories-from-the-land27s-edge/5246012

NOTES

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OCEANS

Australia has the third largest marine estate in the world, extending from the tropics to Antarctica and including vast areas of the Indian, Pacific and Southern Oceans. We have a good reputation for management of our marine estate, but there is still much to understand about how our actions affect the oceans, including through climate change, fishing, resource extraction, shipping, and recreation and tourism.

Our oceans are tremendous resources, culturally, socially and economically, and are repositories for incredible biodiversity. Oceans provide food and energy, and influence weather and climate across the country. Indigenous Australians have had cultural and livelihood relationships with our oceans for thousands of years. Most Australians live within an hour's drive of the coast and the seaside is a valued recreational destination, as it is for increasing numbers of international tourists. Australia's oceans affect our every activity and managing them well is vital to our nation.

Oceans: Science and Solutions for Australia summarises decades of scientific research by CSIRO and other agencies to describe what we know about our oceans, how research contributes to their use and management, and how new technologies are changing marine research. It provides engaging and accessible reading for all those interested in Australia's magnificent marine estate.

CSIRO