Coral Reefs and Climate Change

Workbook

Field, Classroom and Lab Activities

First published 2009 by CoralWatch, The University of Queensland, Brisbane.
www.coralwatch.org
email info@coralwatch.org

This workbook may be cited as:
Coral Reefs and Climate Change Workbook
Craig Reid, Justin Marshall, Dave Logan and Diana Kleine
CoralWatch, The University of Queensland, Brisbane 2009

This workbook accompanies the book:
Reid et al. (2009) Coral Reefs and Climate Change: The Guide for Education and Awareness.
CoralWatch, the University of Queensland, Brisbane. ISBN: 9780646523606 (pbk.)

Acknowledgements

The authors would like to thank the following people and organisations who have contributed to the production of the workbook, activity CD and coral reef education package. Without the passion and inspiration of these people, none of this would have been possible.

Support
Paul Greenfield, AO, Vice-Chancellor and President,
The University of Queensland
John Hay, Vice-Chancellor and President (former),
The University of Queensland
Marine Teachers Association of Queensland
Project AWARE Foundation
Sustainable Tourism Cooperative Research Centre
Australian Coral Reef Society
Heron Island Research Station
Heron Island Resort (P&O, Voyagers)
Great Barrier Reef Marine Park Authority
National Oceanographic and Atmospheric Administration

Reviewers / editors
Ali Hudon, The Pier Aquarium, USA
Kelly Goodingham and Sheree Bell
Marine Teachers Association of Queensland
Ulrike Siebeck, UQ

Contributing writers
Kelly Goodingham, Marine Teachers Association of Queensland
Chris Roelfsema, UQ
Ian Tibbetts, UQ
Paul Bird, CSIRO
Sandra Zicus
Kylie McPherson

Proof reading
Cassie Bryant

Photography and illustrations
Acknowledged per image

CD development
Conor Champ

Contributors to the CoralWatch program
Anke Kluter, Brad Cox, Cassie Bryant, Craig Reid, Danny Osorio
Dave Logan, Diana Kleine, Kylie McPherson, Kylie Greig,
Ove Hoegh-Guldberg, Paul Bird, Sandra Zicus, Tony Isaacson,
Ulrike Siebeck and many volunteers.

Preface

This workbook accompanies and complements 'Coral Reefs and Climate Change: The Guide for Education and Awareness'.

It contains practical ideas, solutions and teaching ideas and we hope it will give you the tools to help in a global effort to preserve reefs for our children. This is a 'growing organism' and we encourage you to send us further ideas for classes, exercises in environmental awareness and reef guardianship. We will add these to future editions of this CD.

Coral reefs have a fragile beauty. Intimately linked to our vast oceans, they cover less than one percent of the Earth's surface yet contain over twenty five percent of all the marine creatures of the seas. They are a reminder of the dynamic complexity that exists within all ecosystems and stand as a testament for our growing need to understand how we are causing dramatic, and in some cases irreversible, change to our planet. The primary aim of this CD and book, is to galvanise action to minimise damage and restore life on reefs.

Integrated within this package is the CoralWatch Coral Health Chart. By using the chart and uploading the data you are actively contributing to a global data base on coral reefs. From this data bank, decisions on the conservation of the reefs can be made based on science.

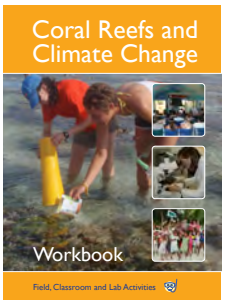
We recognise that not everybody will have the opportunity to see and appreciate reefs first hand. That is why we have designed this workbook to incorporate a number of activities that can be conducted within a classroom situation or even from your own home. The virtual tools and access to some of the latest research on our current understanding of coral reefs are available on this CD.

At the same time, we hope to empower you to think and act upon global climate change, humanity's greatest challenge, and by doing so, prevent the future tragedy of losing our beautiful reefs and the lives they sustain.

This CD has already been contributed to by many committed and keen biologists, teachers, students, photographers and environmentalists. In particular we would like to thank MTAQ, Heron Island Research Station, Sustainable Tourism CRC and Project AWARE Foundation.

Justin Marshall, Craig Reid, Diana Kleine and Dave Logan

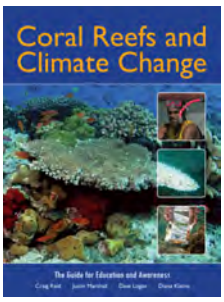
Dave Logan



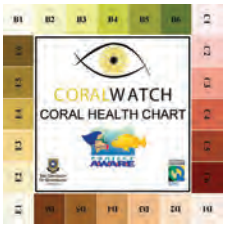
How to use this workbook

This workbook contains activities that allow you to explore what is happening on coral reefs and why, discover positive solutions and the steps we need to take immediately to safeguard reef systems worldwide. We must urgently combat climate change and stabilise our carbon dioxide emissions.

The individual, classroom, lab and field activities are designed for high school and early tertiary level students, and anyone interested in exploring coral reefs, climate change and sustainable living in more detail. Some activities make use of the Coral Health Chart supplied. Additional virtual tools provide an opportunity to learn more about coral bleaching and active monitoring. They can be used to prepare for a field trip or as a valuable alternative to a field trip. Away from the reef you can engage in activities in the classroom and your local environment and access recommended DVDs, books, articles and websites.



Each section of the workbook relates to the chapters in the education guide, Coral Reefs and Climate Change, however, you can use it as a standalone workbook. A printed version can also be supplied on request.



Each activity has a clear structure

Aim A detailed description of the aims and actions within the topic.

Background Additonal information that will assist with the activities.

Tools A list of what you need to perform the activity.

Field/Lab/Classroom Activities
Instructions on how to perform the hands-on tasks, performed individually or in a group.

Questions A series of questions that challenge your knowledge.

Research Projects or questions that outline further ways to investigate the topic.

References A list of relevant sections in the 'Coral Reefs and Climate Change' book and other sources such as websites and articles.

We invite you to send us your ideas for activities, classes and projects. These will be added to the workbook and we will continue to distribute the CD as an ever-growing resource for everyone. Thank you for your support and participation!

Extra educational materials are supplied on the Activity CD
These include CoralWatch and Project AWARE monitoring kits, instructional video, datasheets, spreadsheets and further education materials such as articles, conceptual models, reef life ID charts, coral photographs and a virtual reef poster.

Contents

Ocean Environment

Field, Classroom and Lab Activities

Contents

Biogeography

The aim of this study is to identify factors influencing the distribution of marine habitats and to develop a food web that demonstrates the flow of nutrients between reefs and nearby systems. You will compare maps showing the global distribution of mangroves, coral and seagrass diversity and explore current research programs to better understand the issues involved in determining and managing biodiversity and areas of essential habitat.

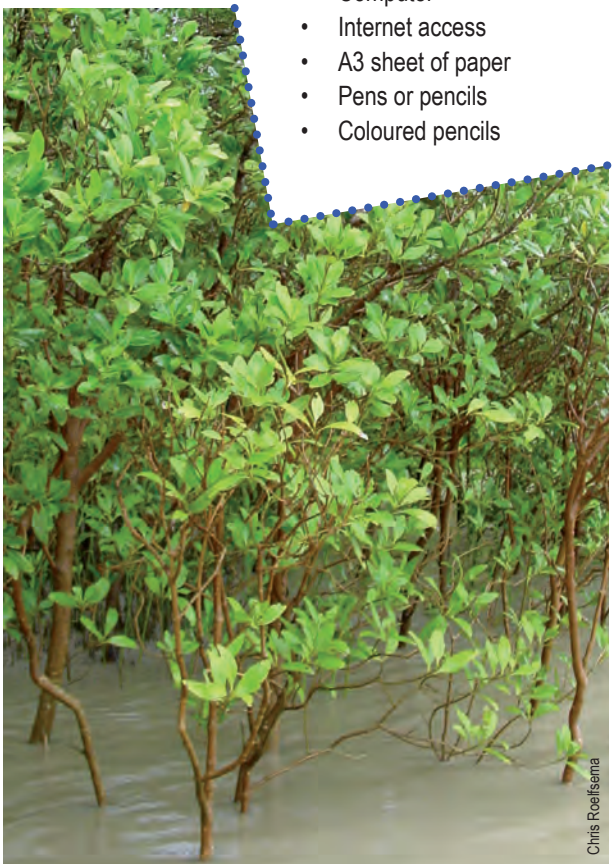
Time Three hours

Tools

- Computer
- Internet access
- A3 sheet of paper
- Pens or pencils
- Coloured pencils

Seagrass meadow.

Coral reef.



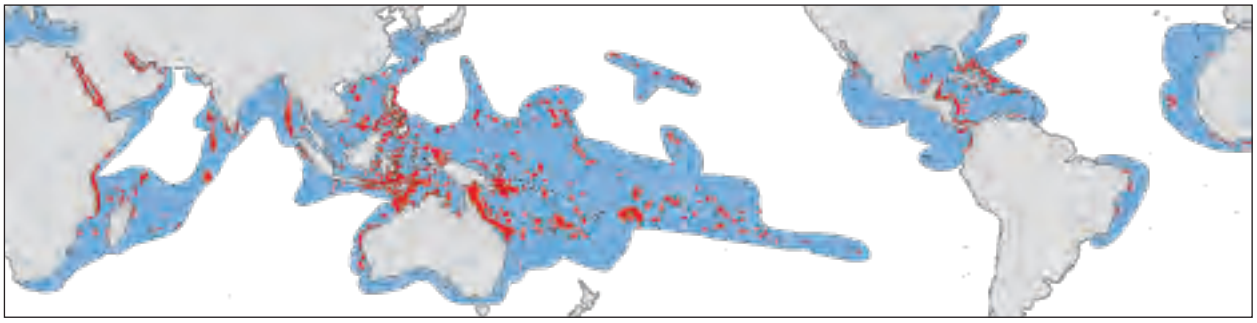
Mangrove.

Background

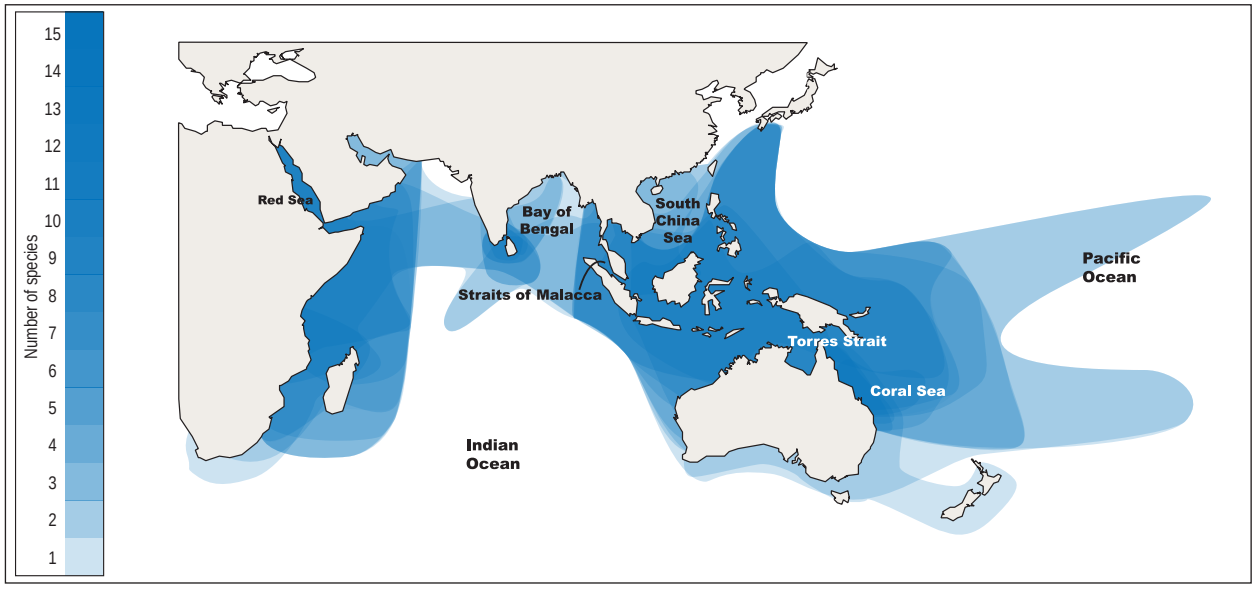
There are places on our planet where life just seems to explode. At the equator, the currents of the northern and southern hemispheres diverge, moving back towards the temperate and polar seas. They form a long thin ribbon of life, as a constant stream of nutrients is brought towards the surface to be bathed in the tropical sun.

On reefs and adjacent mangrove and seagrass beds you can find more species than you would in tropical rainforests. These productive areas form essential habitats supporting complex food webs from the smallest phytoplankton to some of the world's largest marine predators.

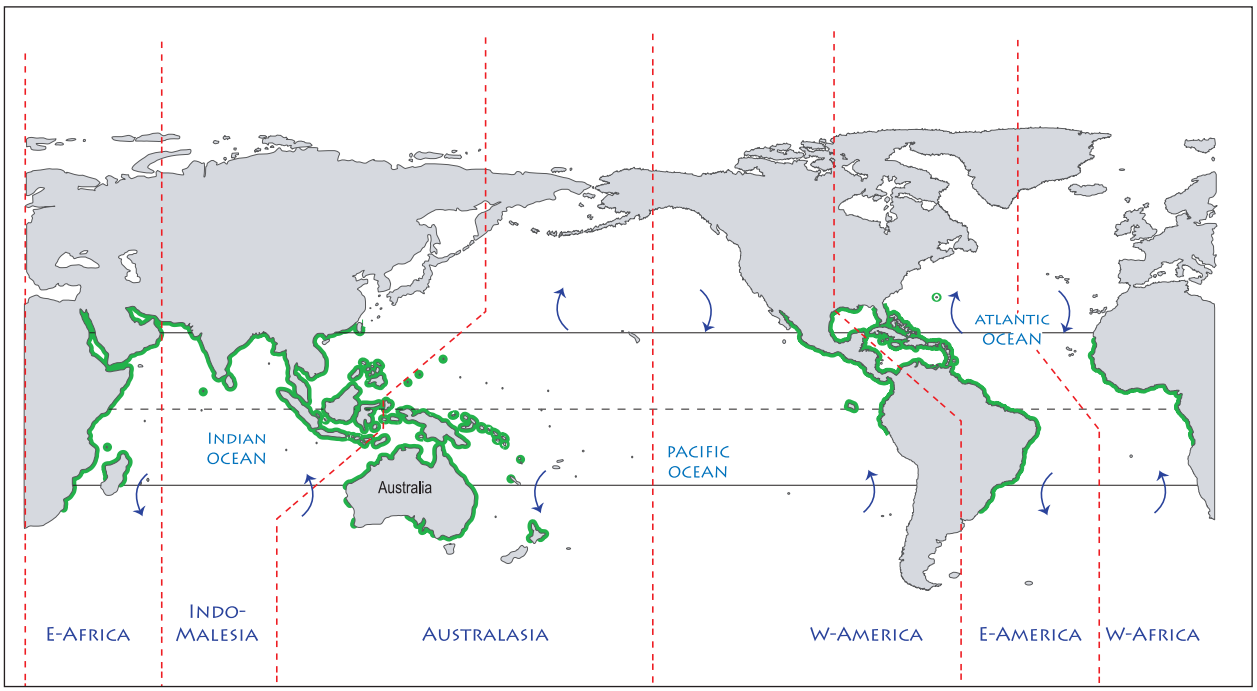
Maintaining and conserving these biological hotspots ensures that the greatest number of species survive into the long term future. Constant monitoring from scientists and volunteers helps to determine how these important areas are changing over time and assists researchers, managers and users to make informed decisions on the best ways to protect them and our future.



Coral distribution. source Veron 2000



Seagrass distribution. source Waycott et al 2004



Mangrove distribution. source Duke 1996

Classroom activity

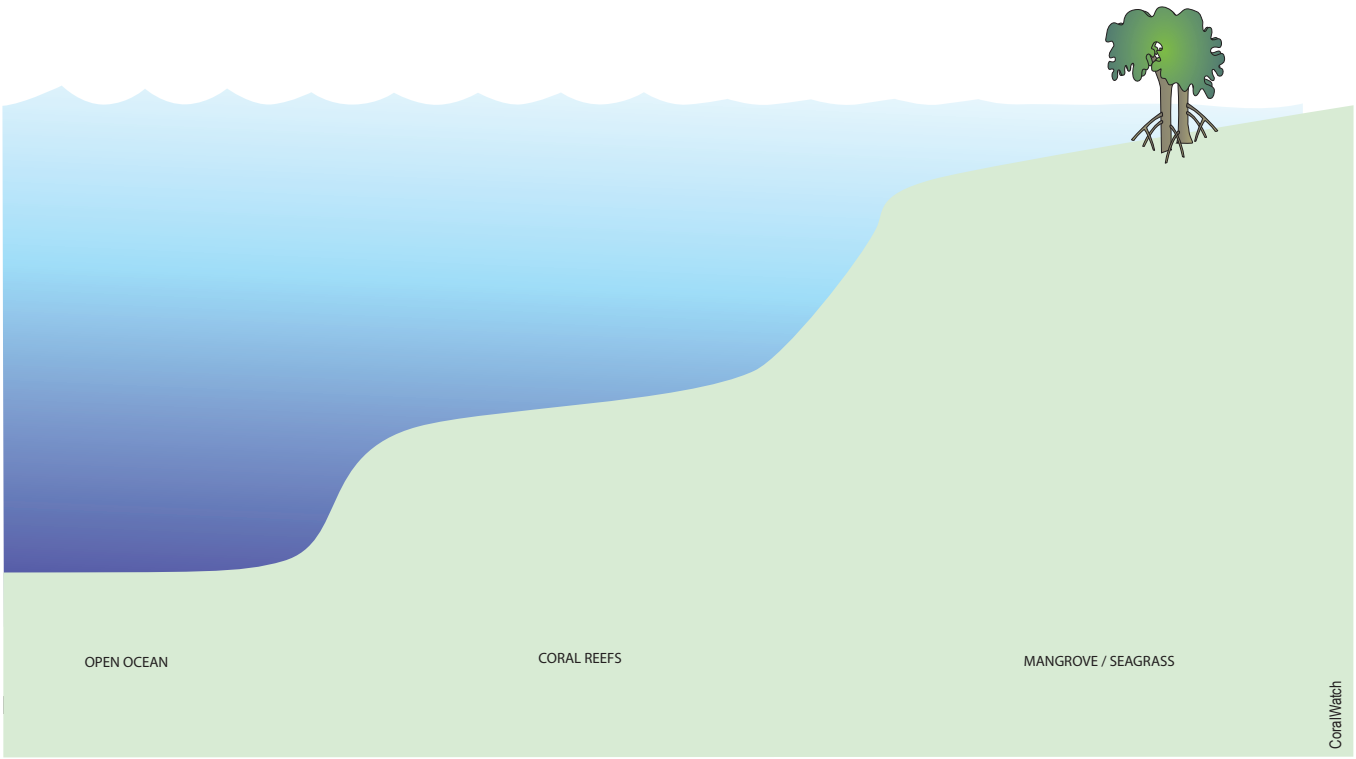
1. Research the three monitoring programs:
   a. CoralWatch
   b. Mangrove Watch
   c. Seagrass Watch
2. Draw up three columns on a page and answer the following:
   a. what is the program trying to achieve (e.g. quantify amounts of habitat, assess condition or impacts of disturbance)?
   b. what methods do they use to monitor the environment (e.g. transects, satellite images)?
   c. what kind of people are doing the monitoring (e.g. students, scientists, tourists)?
   d. how long have they been monitoring?
3. Find the closest site near you containing data and answer the following:
   a. what is the name of the site?
   b. what does the data collected tell you about that site?
   c. describe how that site has changed over time.
4. Create a five minute presentation on the benefits and challenges of your chosen monitoring program. Use some of the real data they provide in your report to give reasons for your answers.
5. List five other environmental 'Watch' programs that are monitoring important habitats. You can search for these online.

CORALWATCH	Seagrass-Watch	MangroveWatch

Teacher Hint
If you are short for time, split the group into three, each researching a separate monitoring program.

Classroom activity

1. List all the organisms you have found or have heard of associated with coastal marine ecosystems and enter them into the 'reef ecosystem table' as either a producer or consumer.
2. For the consumers, list the order these fall into; 1st, 2nd, 3rd or 4th. First-order consumers eat producers, second-order consumers eat first-order consumers and so on.
3. Draw a food web including these organisms in the space provided or on blank pages.
4. Using coloured pencils, show which direction energy and nutrients are flowing between organisms as well as into and out of the system.



Field activity

During this activity you will estimate the amount of plant material being eaten by select grazers on the reef.

1. Choose an herbivorous fish, such as a parrotfish or rabbitfish, or a crab to observe (it is easy to find crabs feeding on top of coral colonies on a reef flat at low tide if you stand still and it is not too windy).
2. Wait until the animal is no longer disturbed by your presence and tally the number of bites or claw scrapes it takes in the space of one minute.
3. Repeat this three more times to calculate average bites per minute.
4. Assuming it eats at the same rate for the whole day, calculate the total number of bites the organism would take in 12 hours.

Ecosystem table

		Consumer (tick the appropriate box)			
Common name	Producer	1st order	2nd order	3rd order	4th order

Questions

1. Identify and name the main areas of land and ocean on the map that have high and moderate diversity of:
   a. corals
   b. mangroves
   c. seagrass
2. What correlation (if any) exists between these three ecosystems?
3. Describe the reasons why we see shifts in diversity of corals, mangroves and seagrasses the further we move north and south from the equator.
4. Describe how you could monitor or quantify these changes?
5. How could scientists and conservation managers use monitoring data and information to help protect areas of high diversity?
6. Coral bleaching is one of the most visible indicators of climate change. Using the food web, nutrient cycles and energy flows that you have drawn, explain how a coral bleaching event affects this reef ecosystem.
7. What are the implications of removing the 4th order consumers?
8. Why are herbivores so important to the reef?
9. Discuss the reasons why coral reefs are so sensitive to land based pollution.

Research projects

1. How do land use patterns affect the ecologies of these three ecosystems?
2. What are the potential effects on seagrasses and mangrove ecosystems if the coral reefs become heavily degraded as a result of climate change?
3. What is the relationship between the diversity of these ecosystems and pelagic fish population densities?
4. How will changes in the three ecosystems impact the people living?
5. Explain why seagrass beds and mangroves act as nurseries for young reef fish.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane (See Productive Seas page 56 and Connectivity page 118)
Duke N (2006) Australia's Mangroves. The University of Queensland, Brisbane
Waycott et al. (2004) A Guide to Tropical Seagrasses of the Indo-West Pacific. James Cook University, Townsville
Veron JEN (2000) Corals of the World. Australian Institute of Marine Science and CRR QLD Pty Ltd, Townsville
Allen GR and Steene R (1994) Indo-Pacific Coral Reef Field Guide. Tropical Reef Research, Singapore
Gosliner TM, Behrens DW and Williams GC (1996) Coral Reef Animals of the Indo-Pacific. Sea Challengers, Monterey CA

CoralWatch; www.coralwatch.org
Mangrove Watch; www.marine.uq.edu.au/marbot/
Seagrass Watch; www.seagrasswatch.org

Monitoring Coral Reefs
using Remote Sensing and GIS

This activity has two aims:

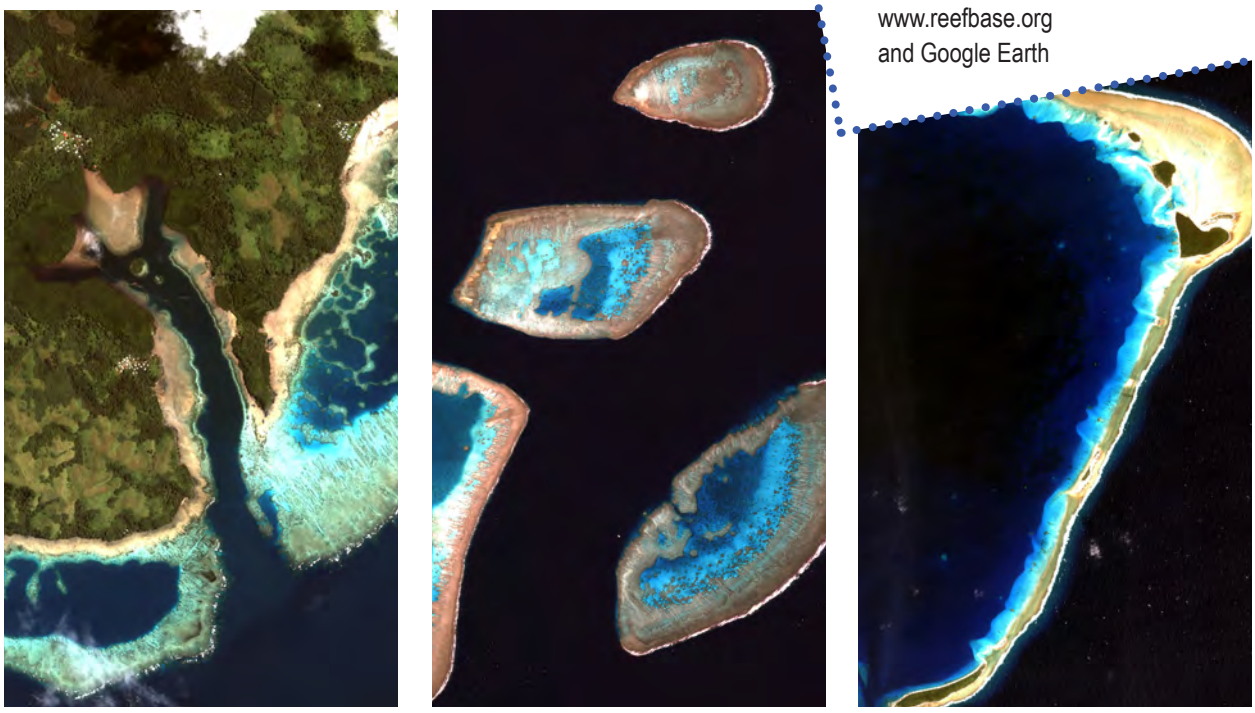
1. Develop an understanding and appreciation of the different types of reefs that occur globally and determine their status.
2. Develop an understanding of the internet tools that use geographical information systems (GIS) and remote sensing imagery to conduct spatial analysis in coral reef environments.

You will first select examples of each of the three reef types: fringing, barrier and atoll reefs, after which you will determine their status *(Figure 1)*.

Time One hour

Tools

- Access to internet www.reefbase.org and Google Earth



(Figure 1) Examples of a fringing reef in Fiji, barrier reef in Australia and atoll reef in Marshall Islands. All images are high spatial resolution satellite imagery. Source: Centre for Remote Sensing and Spatial Information Science at University of Queensland.

Background

To better understand this activity it is important to read Zones Across the Reef (pages 94-97) in the guide, Coral Reefs and Climate Change. This chapter presents the four major reef types: barrier, fringing, platform and atoll reefs, including examples of each. It further explains reef origins based on geomorphologic processes and changes in sea level.

Coral reefs are located along the coastlines of many nations and are known to be the most biologically productive and diverse ecosystems in the world. Reefs are threatened by a variety of impacts including coral bleaching, coral diseases, sea level rise, coastal development, overfishing, destructive fishing, inland pollution and erosion, and marine pollution. Impacts influence the 'normal' functions of marine habitats and the organisms occupying them, and the surrounding people whose livelihoods depend on healthy reefs. Monitoring and management programs are developed and implemented to better protect the coral reef resources and their biodiversity. Spatial data of biophysical properties (e.g. sea surface temperature, coral reef habitat), often represented by maps, form an integral part of these programs.

As coral reefs are known to cover a large spatial extent, at various depths, varying water clarity and often in remote areas, they are a challenging environment to manage. Satellite or airborne sensors are able to capture

imagery of these coral reefs at various temporal (e.g. 1 day, 5 days, 16 days) and spatial scales and are therefore a unique tool used to derive biophysical spatial data that can be used in monitoring programs. The spatial scale has two components: the extent of the area captured by an image (e.g. one reef or several reefs within one image), and the size of the pixels that make up the image and determine the visible detail (e.g. pixel size 2.4m x 2.4m, the size of a small boat lot (Figure 2a), or 25m x 25m, the size of a parking lot). Examples of these programs are the Millennium Coral Reef Habitat Mapping program (Figure 2b), which created maps of coral reefs worldwide showing the geomorphic zones, and NOAA's Coral Reef Watch program, which provide global daily information to predict coral bleaching on coral reefs, or individual reef-based mapping programs (Figure 2c). Water depth, clarity and roughness, however, determine how well biophysical properties can be derived from remote sensing imagery.

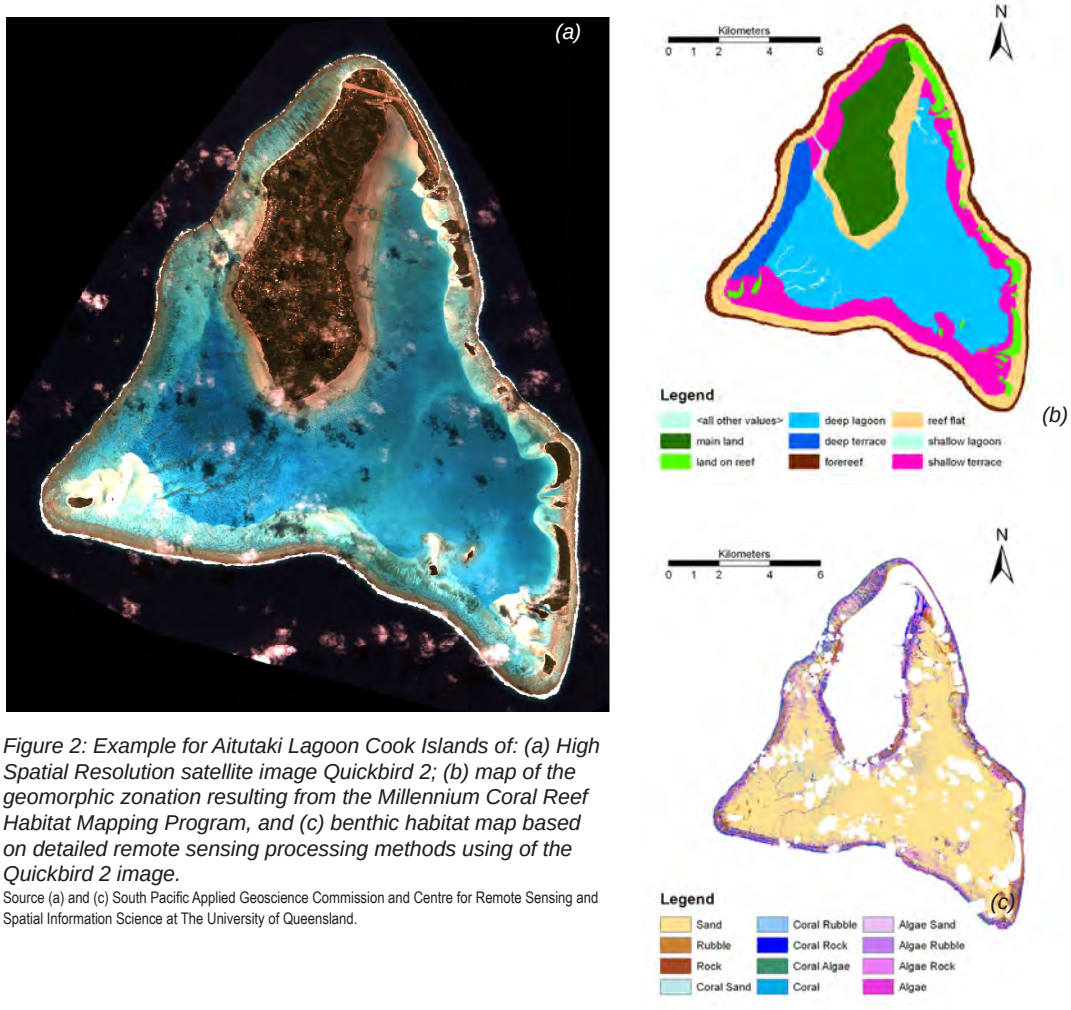


Figure 2: Example for Aitutaki Lagoon Cook Islands of: (a) High Spatial Resolution satellite image Quickbird 2; (b) map of the geomorphic zonation resulting from the Millennium Coral Reef Habitat Mapping Program, and (c) benthic habitat map based on detailed remote sensing processing methods using of the Quickbird 2 image.

Source (a) and (c) South Pacific Applied Geoscience Commission and Centre for Remote Sensing and Spatial Information Science at The University of Queensland.

The strength of spatial data sets derived from satellite imagery is that they have known locations in reference to a coordinate system (e.g. latitude and longitude). As a result, information gathered in the field for which the position is determined with a Global Positioning System (GPS) can be used compared with other spatial data sets. For instance, through reef flat walking, snorkelling or diving, photos or information on the coral cover or from the coral health chart, that have a known GPS position, can be used to create and assess thematic maps of benthic cover (Roelfsema et al 2009) or coral health (Leiper et al 2009). To compare, analyse and/or create maps of spatial data (e.g. map of location of marine parks on top of a habitat map), a Geographic Information Systems (GIS) is used. Examples of GIS are, Google Oceans®, Google Earth®, Microsoft Virtual Earth® and Reef Base GIS (Figure 2). Reef Base host a GIS (http://reefgis.reefbase.org) which specifically provides a spatial information portal of coral reef environments for interested people of the community, scientists and/or managers. The website provides the opportunity to determine what reef types are present in a country and what its threats are.

Classroom activity

Teacher Hint
Explore the Reef Base GIS web site, Google Earth and Marine Remote Sensing Toolkit website before the class room activity.

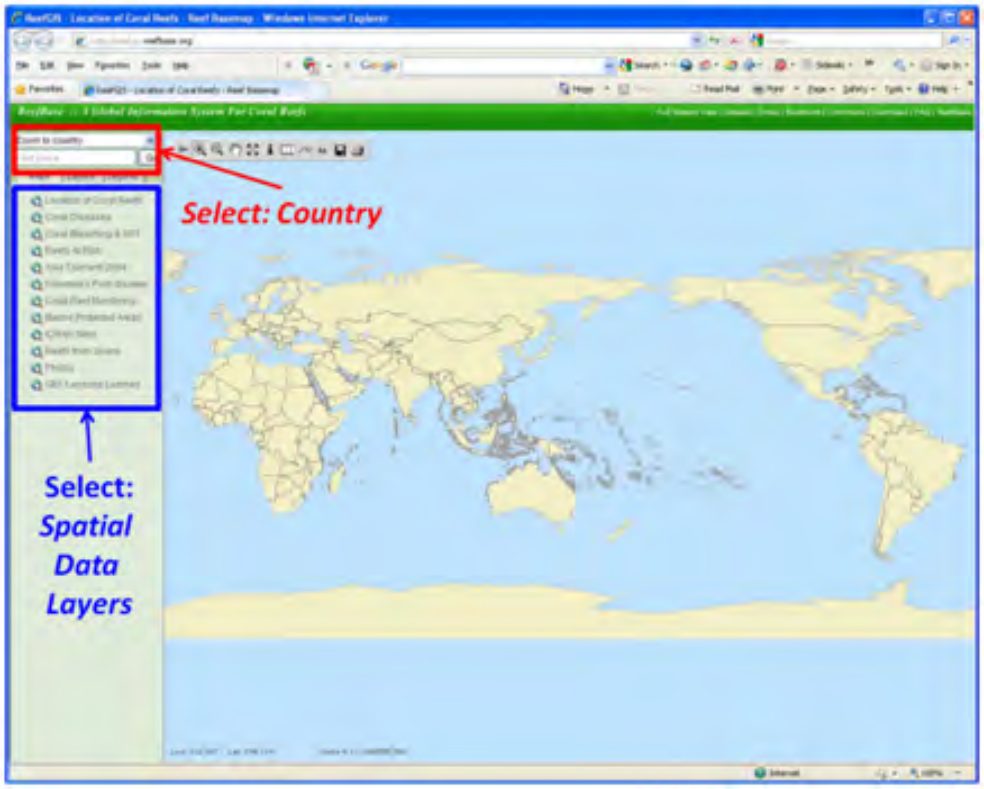


Figure 3: Screenshot of the Reef Base Geographical Information System Website which provides a user interface to assess, question and analyse geographic information related to the reefs of the world by selecting a spatial data layer and a region of interest.

Use http://reefgis.reefbase.org to:

1. Recall where coral reefs are in the world by describing the main regions (e.g. Red Sea).
2. Identify which regions in the world were affected by a severe coral bleaching event during the period January to December 2002 by selecting the spatial data layer: Coral bleaching and SST and then select the dates and refresh the map.
3. Identify the regions which had the largest occurrence of coral disease in the period January to December 2002 by selecting the spatial data layer: Coral diseases, and then select the dates and refresh the map.
4. Locate in South East Asia which countries are mostly threatened in 2002 by: coastal development, overfishing, destructive fishing, or marine pollution by selecting the country and then select the spatial data layer: Reefs at Risk, and refresh the map.
5. Determine areas in South East Asia that are commonly monitored by Reef Check's volunteer monitoring program by selecting the country or zoom into South East Asia and then select the spatial data layer: Coral Reef Monitoring, and refresh the map.
6. For South East Asian countries find out which one's have: atoll reefs, fringing reefs or barrier reefs by selecting the country or zoom into South East Asia and then select the spatial data layer: Location of Coral Reefs, then select the reef and geomorphic type and refresh the map.

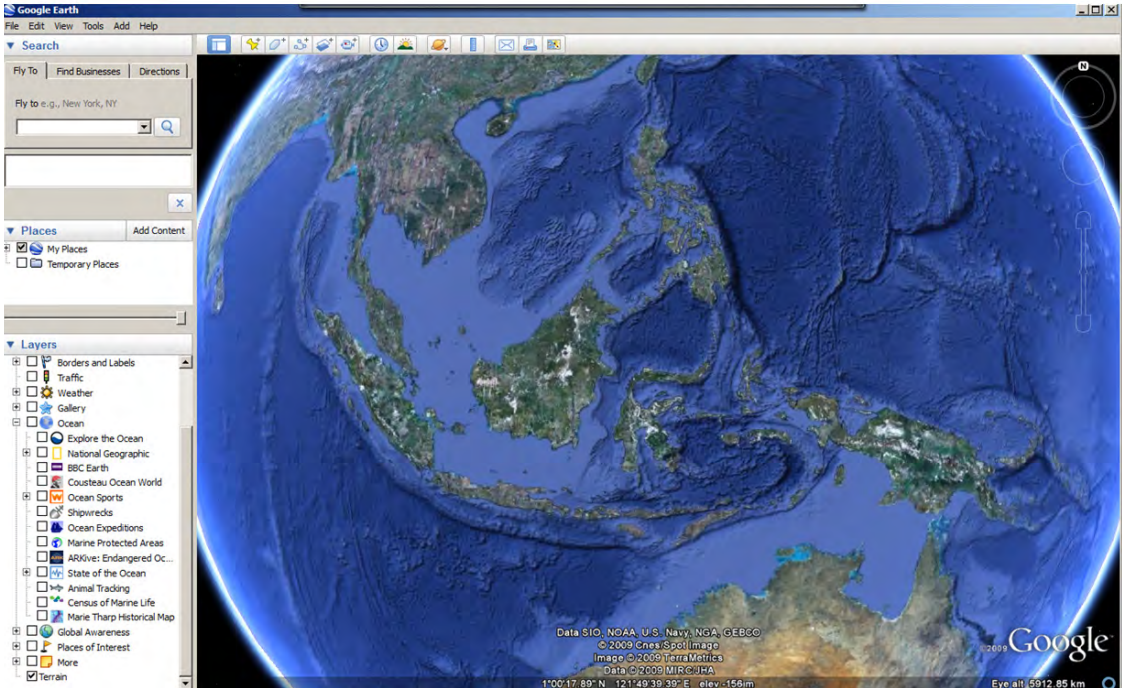


Figure 4: Screen shot of Google Earth zoomed in on the Coral Reef Triangle. Source www.earth.google.com

Use Google Earth *(Figure 4)* **to***:*

7. View the satellite imagery of an atoll reef, fringing reef or barrier reef, previously found in Reef Base GIS (task 6) and then describe the location of the reef types in relation to the country by zooming into the area of interest using Google Earth tools and determine the neighbouring countries.
8. For the atoll reef, fringing reef or barrier reef of tasks 6 and 7, describe what you expect are the impacts using a visual assessment of the imagery in location to adjacent countries and oceans. Again, zoom into the area of interest and assess the land adjacent to the reefs on number. Determine the population density by assessing the number of cities or villages or the run of turbid water.

Use Marine Remote Sensing Toolkit *(Figure 5 and 6)* **to:**

Figure 5: Screenshot of Remote Sensing Toolkit, that provides options for managers and scientists planning to use Remote Sensing to map and monitor parameters in terrestrial, marine and atmospheric environments (www.gpem.uq.edu.au/CRSSIS-rstoolkit). Source www.gpem.uq.edu.au/crssis-rstoolkit

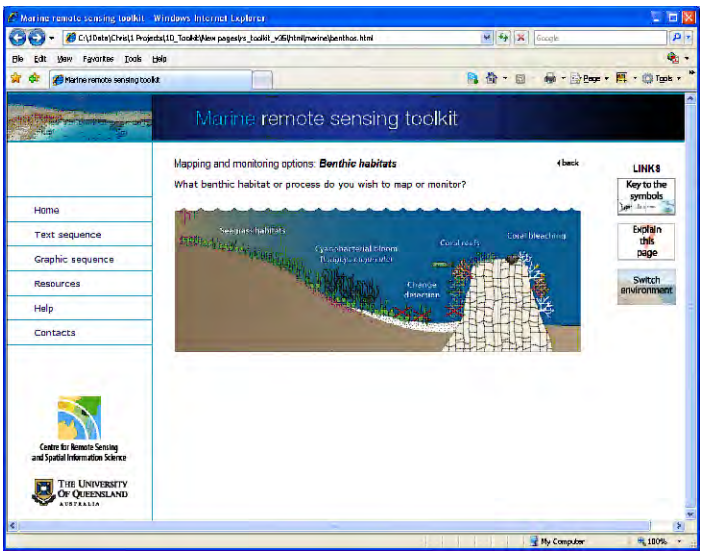


Figure 6: Screenshot of Marine Toolkit where a selection can be made which benthic habitat variable needs to be assessed, such as coral bleaching.

Source www.gpem.uq.edu.au/crssis-rstoolkit

9. Determine what type of remote sensing sensor can be used to derive a map of severe coral bleaching in clear shallow water and maps that predict coral bleaching *(Figure 5)*. Then, go to the marine toolkit user interface and find the suitable monitoring option for a specific environmental variable and use the graphics to determine your remote sensing sensor.
10. Determine what environmental factors influence the capacity of remote sensing to map coral reefs. Read the relevant sections in the marine remote sensing toolkit and interpret the figures.

Questions

1. Explain why management programs need spatial data.
2. Determine the major threats to a reef close to you or of interest to you.
3. Using the images in this activity, describe the difference between a fringing reef, barrier reef and atoll reef.
4. Describe the difference between a satellite or airborne image and a thematic map.
5. Explain the difference between geomorphic zone map and a benthic community map.

Research

1. What reef types will be most influenced by activities on land and why?
2. Use the Marine Remote Sensing Toolkit (www.gpem.uq.edu.au/crssis-rstoolkit) to determine what type of sensor can be used to map a benthic community map in shallow clear water.
3. Discuss the environmental factors that will influence the quality of maps showing benthic habitat in coral reef environments that can be derived from remote sensing imagery.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Patterns of Distribution page 86 and Zones across the Reef page 94)

Leiper IA, Siebeck UE, Marshall NJ & Phinn SR (2009) Coral health monitoring: linking coral colour and remote sensing techniques. Canadian Journal of Remote Sensing, 35, 276-286 (supplied on CD)

Roelfsema CM and Phinn SR (2009) A Manual for Conducting Georeferenced Photo Transects Surveys to Assess the Benthos of Coral Reef and Seagrass Habitats, version 3.0. Centre for Remote Sensing and Spatial Information Science, The University of Queensland, Brisbane, Australia (supplied on CD)

Bryant D, Burke L, McManus J and Spalding M (1998) Reefs at Risk: a map-based indicator of threats to the world's coral reefs. World Resources Institute, Washington, D.C.

Google Ocean; www.earth.google.com/ocean

ReefBase; www.reefbase.org

NASA Earth Observatory; www.earthobservatory.nasa.gov

National Oceanic and Atmospheric Administration (NOAA); www.noaa.gov

UQ Centre for Remote Sensing and Spatial Information Science; www.gpem.uq.edu.au/CRSSIS/

Marine Remote Sensing Toolkit; www.gpem.uq.edu.au/crssis-rstoolkit

Millennium Coral Reef Habitat Mapping Program; http://imars.usf.edu/corals/

REMOTE SENSING Handbook for Tropical Coastal Management; www.unesco.org/csi/pub/source/rs.htm

Ocean in Motion

The aim of this activity is to explore how currents affect a coral reef at a local level.
You will experiment in the field measuring current flows at different tides, along with water and wind conditions, to gain a better understanding of how currents behave and can influence marine life.

Time

One day (including low, mid and high tide)

Tools

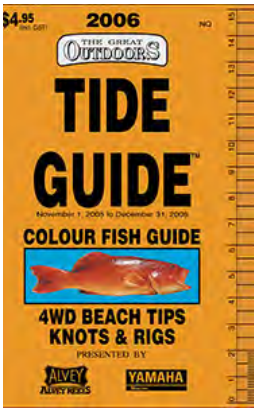
- GPS (optional)
- Compass
- Measuring tape
- Oranges
- Stop watch
- Sample jars
- The Beaufort Scale
- Water quality testing kit
- Silver chloride/potassium cromate dropper test for salinity
- Thermometer
- Tide charts
- Graph paper

© Mark A. Johnson

Background

Tides, wind and coastal topography determine the direction and speed of local currents, which affect water temperature, salinity, nutrients and oxygen levels in an area. You can easily see and measure these changes in flows and determine how they affect you and other species. Predicting water flows is useful for determining whether conditions are good for a snorkel or perhaps better suited for a reef walk. For the plants and organisms that live within the intertidal zone of our shores, the changing nature of water flowing around them presents immense challenges and opportunities in the continuous struggle to survive. The fish move with the ebb and flow of the tide, while other organisms, restricted in their movement, employ a series of strategies to cope with an environment always in motion.

Large ocean currents are determined by the same factors as local currents, as well as the rotation of the planet, differences in salinity and sea surface temperatures and weather patterns around the globe.



You can look up local tides in the newspaper, on the web, in tide table booklets or software.

Field activity

1. During this activity, measurements will be taken at a low tide, mid tide and high tide at one location. Which order these are done in will depend on the tide times on the day of the investigation. All measurements need to be recorded in the 'Current and tide comparison table'.
2. Stand on the shore of a coastal zone, draw a line in the sand and fix your position using a GPS, if available.
3. Measure the speed of the current:
   a. throw three oranges into the water at the same time and start a stopwatch
   b. walk down the shore, parallel to the water, until you have reached a distance of 20m (or similar)
   c. record the time it takes for each orange to reach you and use these results to calculate the speed of the current
4. Use the compass to find the direction of the current.
5. Use the Beaufort Scale to find the strength of the wind.
6. Use the thermometer to measure the air temperature on shore.
7. Use the thermometer to measure the water temperature at the shoreline.
8. Collect a sample of seawater in a bucket, or something similar.
9. Using a Hach Test Kit (or similar brand) test for the following factors:
   a. pH
   b. dissolved oxygen
   c. phosphorous
   d. nitrogen
10. Test for salinity levels using the silver chloride/potassium cromate dropper test (or similar).
11. Draw a sketch of the area you are studying and draw the current direction during low and high tide.

Teacher Hint
Laminate the Beaufort Scale to take in the field

Direction of currents map

Current and tide comparison table

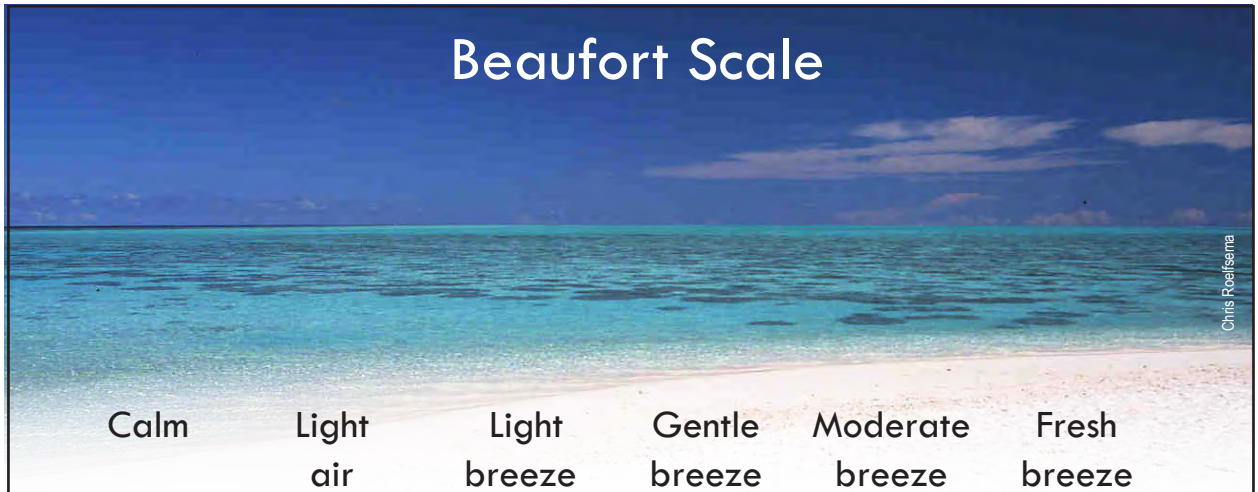
Observer(s):

Location: Date:

Weather conditions: windy / calm / cloudy / sunny

Abiotic factor	Low tide Time: Tide Height: Direction:	Mid tide Time: Tide Height: Direction:	High tide Time: Tide Height: Direction:
Current speed s=d/t	1. 2. 3. Average:	1. 2. 3. Average:	1. 2. 3. Average:
Air temperature			
Water temperature			
Wind speed (Beaufort Scale) and direction			
pH			
Dissolved oxygen (mg/L)			
Phosphorous (mg/L)			

Beaufort Scale



0	1	2	3	4	5
Calm	**Light air**	**Light breeze**	**Gentle breeze**	**Moderate breeze**	**Fresh breeze**
1 knot Sea like a mirror.	1-3 knots Ripples with the appearance of scales, no foam crest.	4-6 knots Small wavelets. Crests do not break.	7-10 knots Large wavelets. Crests begin to break. Scattered horses.	11-16 knots Small waves becoming longer. Fairly frequent white horses.	17-21 knots Moderate waves. Many white horses. Some spray.

6	7	8	9	10	11	12
Strong breeze	**Near gale**	**Gale**	**Strong gale**	**Storm**	**Violent storm**	**Hurricane**
22-27 knots Large waves. Extensive white foam crests. Spray.	28-33 knots Sea heaps up. White foam begins to be blown in streaks.	34-40 knots Moderate high waves. Crests begin to break.	41-47 knots High waves. Dense streaks of foam. Crests begin to roll over. Spray may affect visibility.	48-55 knots Very high seas. Tumbling sea. Surface mostly white. Visibility affected.	56-63 knots Exception-ally high waves. Small and medium vessels sometimes lost to view.	>64 knots Air filled with foam and spray. Sea completely white. Visibility very seriously affected.

Classroom activity

1. During this activity you will create graphs to show how the physical parameters you have measured change over time. Use different symbols or colours for each different parameter and ensure you label them accurately.
2. Use graph paper or a spreadsheet to plot:
   a. current speed versus time
   b. nutrients: dissolved oxygen, phosphorous and nitrogen levels, in milligrams per litre (mg/L) versus time
   c. temperature versus time
   d. pH versus time
3. Compare the graphs and look for trends or patterns in the data.

Questions

1. What relationship can be seen between the currents and water temperature?
2. Explain the variations that exist in the data between current speed and the nutrient concentrations.
3. What causes the fluctuations in the dissolved oxygen and pH over the duration of the tide?
4. What conclusions can be drawn about the ocean currents on a local level and the distribution of the nutrients on the reef?
5. Why do scientists use this set of analyses to assist them in determining the health of a coral reef?
6. What other data would be required to gain a better understanding of the health of a coral reef?
7. How can fishermen use these data to their advantage?
8. Predict which direction the tide will be flowing at the same site at 12:00pm in 1 day, 2 days and 10 days time.
9. Provide the time(s) and height(s) of high tide on March 1st and October 1st this year.

Research

1. Propose how you would undertake the same process on a regional basis and why this would be important.
2. What advantages are there in linking this information with satellite data of land use patterns?
3. How are currents tracked on a global scale?

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Rhythm and Flow page 44, Breath of Wind page 48 and Current Connections page 52)

Current Publishing (2006) Life on an Ocean Planet. Current Publishing Corp., California

CSIRO Marine and Atmospheric Research; www.cmar.csiro.au

Coastal Vegetation

The aim of this activity is for you to map the different types of vegetation present on an island / coastal area and determine the reasons for their distribution. You will walk through a coastal area recording plant species, height, location from shore and soil conditions to gain an appreciation of how their distribution is influenced by the ocean, wind and other species.

Time

Two hours

Tools

- GPS or measuring tape
- Coral cay plant charts
- Soil pH kit
- Pad of paper
- Pencil
- Plant identification guide

Pandanus on Heron Island.

Background

Plants growing along coastlines are adapted to a salty, windy and often nutrient-poor environment. Some arrive on islands and beaches as buoyant saltwater-resistant seed pods, while others are deposited in the droppings of birds or blown to an area by the wind. The *Casuarina equisetifolia,* or she-oak, have bacteria in root nodules that convert nitrogen in the air to compounds that allow them to thrive in nutrient-poor beach sand. Low growing grasses and rounded bushes survive here as they are not as easily blown over in high winds.
Many coastal plants have small or wax covered leaves to reduce water loss in salty environments. Some species can only grow after a succession of other plants have stabilised sand dunes and have formed a barrier to wind and spray. Birds attracted to the area will rain fertiliser down upon the ground (and heads of unwary visitors) as they feed and build nests, providing added nutrients to support a greater diversity of coastal plant life.

Field activity

1. Draw a diagram of the coastal area that you are surveying and use a GPS (if available) to plot your location.
2. Decide on a direction in which you will walk to conduct the survey (usually away from the shoreline using existing tracks if possible).
3. Approximately every 10m (this can be altered depending on your coastal area), stop and make the following observations of the area around you and record them in the 'Vegetation study results' table:
   a. distance travelled
   b. the dominant plant species
   c. average plant height
   d. height of the ground above sea level
   e. a symbol for each plant species you identify
4. When you notice a change in vegetation type or dominant species, stop and measure:
   a. soil pH
   b. colour of soil (e.g. white, sandy, grey, black, etc.)
5. Use these observations to plot the vegetation densities in the area on the map. Use the key symbols from your table to show the different plants in the area.

Teacher Hint
Laminate 'Plant species of a coral cay' to take in the field.

Vegetation study map

N

Plant species of a coral cay

***Pandanus* sp. (Screw Pine, Walking Palm)**

This tree has long keeled leaves with prickly margins. It is defined by its prominent root system and produces a fruit that ripens to a yellow colour.

***Sonneratia* (Apple Mangroves)**

Sonneratia leaves are rounded and leathery with berries that have a star shaped base and white flowers. The pneumatophores have a thick cone shape and use ultrafiltration to exclude salt.

***Albutilon asiaticum* (Chinese lantern bush)**

This shrub has heart shaped leaves with yellow to orange flowers that resemble a hibiscus.

***Scaevola sericea* (Cardwell cabbage)**

A shrub with shiny obovate leaves with white fan-shaped flowers.

Plant species of a coral cay

***Casuarina equisetifolia* (She-oak)**

This tree has grey bark with fine strand-like leaves and nodular seed pods.

***Sophora tometosa* (Silverbush)**

A shrub with fine hairy leaves and yellow flowers.

***Pisonia grandis* (Pisonia)**

This large tree has soft wooded trunks with large oval shaped leaves; the fruits are sticky. Pisonia are a dominant species that can be found on most coral cays.

***Argusia argentea* (Octopus bush)**

A shrub with dense leaves that are silvery and hairy; produces small white flowers. This is a foundation plant for coral cays, the seeds are extremely hardy and salt water resistant.

Vegetation study results table

Observer(s):

Location: Date:

Weather conditions: windy / calm / cloudy / sunny

DISTANCE (m)	PLANT SPECIES ID	PLANT HEIGHT (m)	HEIGHT ABOVE SEA LEVEL (m)	SOIL pH	COLOUR OF SOIL	KEY SYMBOL

Questions

1. List the abiotic factors that affect the plant distribution and growth.
2. What relationship exists between the changes in the shape and height of the vegetation and each abiotic condition?
3. How does soil pH affect the diversity of plant life in the area?
4. How is the vegetation in a windy area different from that in more sheltered areas of coastline? Discuss the factors that might cause these differences.
5. Why is bird poo important?
6. List three mechanisms of seed transport to islands.

Research projects

1. How do birds contribute to the nutrient cycles of the vegetation?
2. Compare the vegetation types found on a coral cay with those of a continental island. What are the fundamental differences in the processes of establishing the vegetation on these islands?
3. What are the major conservation issues for plants on coral cays? How could this effect bird population numbers on these islands?

References

Duke N (2006) Australia's Mangroves. The University of Queensland, Brisbane

Cribb AB and Cribb JW (1985) Plant Life of the Great Barrier Reef and Adjacent Shores. University of Queensland Press, St. Lucia

Moroney D, Bourke S and Hanson S (1994) Caring for the Coast: Coastal Activities for Primary Schools. City of Henley and Grange, Henley Beach, SA

Bird Life

The aim of this activity is to identify the variety of bird species on an island or coastal area and to establish population distribution and dynamics. You will identify and estimate numbers of birds in a coastal area and relate this to the type and amount of local vegetation, position of nests and human presence. You will gain a greater understanding of factors that influence coastal bird behaviour and abundance and how this may affect local and remote ecosystems.

Time

Approximately two hours

Tools

- Map or chart of the area
- Field guide
- GPS
- Results table
- Pencil or pen
- Binoculars
- Digital camera

Background

Many birds rely on the ocean for food, nesting materials and suitable breeding and nesting habitats of coral cays, coastal cliffs and sheltered beaches. You can tell a lot about a bird by looking at its body features, behaviour and where it lives. Birds will often nest in trees for protection if they live alongside ground dwelling foxes, pigs or snakes, while ground nesting is common for birds living on offshore islands, away from predators or human influence. Long legs and long beaks may indicate wading birds that enjoy plucking worms and crustaceans from the beach and reef at low tide. Webbed-feet are a giveaway for all seabirds that feed almost exclusively on small baitfish, jellies and squid. Disturbance to coastal habitat that disrupts bird populations can have ongoing effects in local and global food webs.

Some birds are only temporary visitors to an area, including those that have migrated over thousands of kilometres of the ocean surface to the areas where the seas are the most productive or warm enough to ensure the survival of their young. Migratory species of birds, mammals and some fish that can regulate their temperatures regardless of the temperature of the surrounding environment are known as endothermic. These animals move through the isotherms following the currents and the seasons.

Field activity

1. Draw a diagram of the coastal area that you are surveying and use a GPS (if available) to plot your location.
2. Decide on a direction in which you will walk to conduct the survey (usually away from the shoreline).
3. Approximately every 10m (this can be altered depending on your coastal area) stop and make the following observations of the area around you and record them in the 'Bird life observations' table:
   a. percentage groundcover (e.g. plants and shrubs, etc)
   b. ground substrate (e.g. sand, coral, dirt, etc)
   c. level of human disturbance (low, medium or high)
   d. species and number of birds on the ground
   e. number of ground nests
   f. species and number of birds in the trees and air
   g. number of nests in surrounding trees
4. Use these observations to plot bird population densities in the area on the map.

Teacher Hint
Laminate 'Common coastal bird species' to take in the field.

Island / coastal birdlife map

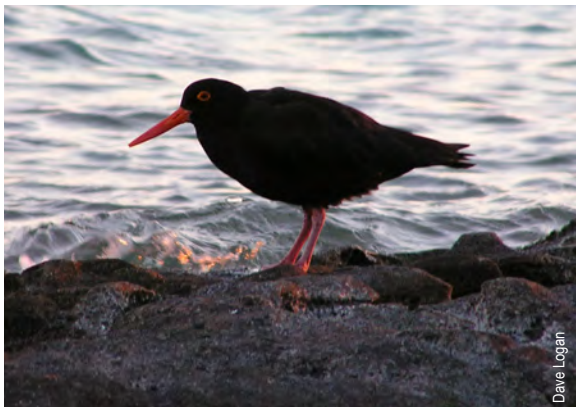
N

Common coastal bird species

Waders
Ruddy turnstones, Spoonbills, Sand pipers, Wimbrels, Egrets

Egretta sacra (Eastern Reef Egret)

Arenaria interpres (Ruddy Turnstone)



Haematopus fuliginosus (Sooty Oyster Catcher)

Island birds
Finches, Silvereyes, Kingfishers, Doves, Rails, Crows

Gallirallus philippensis (Buff Banded Rail)

Zosterops lateralis (Silvereye)

Todiramphus sanctus (Sacred Kingfisher)

Common coastal bird species

Soaring birds

Frigates, Petrals, Albatros', Boobies, Shearwaters

Sula leucogaster (Brown Boobies)

Phoebastria immutabilis (Laysan Albatross)

Terns

Crested, Noddy

Thalasseus bengalensis (Crested Tern)

Anous minutus
Black Noddy or White Capped Noddy

Gulls Silver, Large

Chroicocephalus novaehollandiae (Silver Gull)

Raptors Kites, Falcons, Sea Eagles

Haliaeetus leucogaster (White Bellied Sea Eagle)

Bird life observations

Observer(s): Location:

Date: Time: Weather conditions: windy / calm / cloudy / sunny

Distance (m)	Vegetation	Bird identification	Number of mutton bird holes	Number of nesting birds	Height range of the nests in the canopy	Number of ground birds	Human activity low/medium/high

Questions

1. List the biotic and abiotic factors that determine the dynamics of the bird population.
2. Describe the relationship between the bird populations and human activity.
3. Is there a correlation between tree height and the number of nesting birds present? What are the reasons for this?
4. Where are the greatest population densities found and what might be the contributing factors?
5. Explain how we could establish a relationship between the productivity of the reef and the total bird population.
6. Which of the bird species that you have recorded are likely to be temporary visitors to the area?
7. Describe the physical and behavioural differences you expect to see when comparing waders and raptors.
8. Estimate the total number of birds on the island or coastal area based on your study and evaluate the reliability of the results collected in this particular way.

Research projects

1. How could climate change impact the dynamics of the breeding bird populations on reef ecosystems?
2. What are the impacts of commercial fishing upon sea bird populations?
3. Investigate how far the migratory birds have travelled and where they have stopped along the way.
4. Identify conservation agreements or management plans that exist for migratory birds and their habitats in the countries they are travelling from.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane (See Ocean temperature page 42 and Productive seas page 56)

Simpson K, Trusler P and Day N (1996) Field guide to the birds of Australia (Ed. 5). Viking, Penguin Books Australia.

Cayley NW and Chisholm AH (1996) What bird is that?: a guide to the birds of Australia (Ed. 4). Angus and Robertson, Australia

Bird DM (2004) The Bird Almanac: a guide to essential facts and figures of the world's birds (Ed. 2). Firefly Books, Ontario.

Congdon, BC, Seabirds, In: The Great Barrier Reef : biology, environment and management, eds Hutchings PA, Kingsford M, Hoegh-Guldberg O, Society ACRS (2008b) CSIRO Publishing, Collingwood, Vic

Congdon, BC, Erwin, CA, Peck, DR, Baker, GB, Double, MC, O'Neill, P (2007) Vulnerability of seabirds on the Great Barrier Reef to climate change, In: Climate change and the Great Barrier Reef: a vulnerability assessment, eds JE Johnson & PA Marshall, Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Townsville, Australia, p. 427-463 (Available online)

International Wader Study Group; www.waderstudygroup.org

Coral Reefs

Field, Classroom and Lab Activities

Chris Roelfsema

Contents

Reef Profile

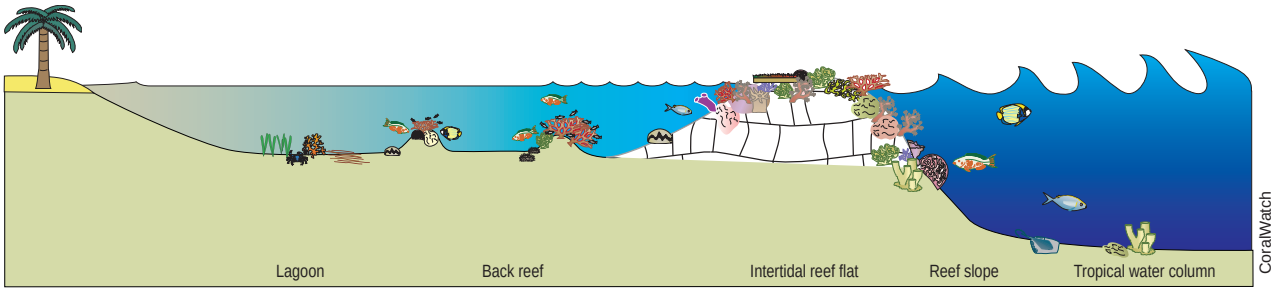
The aim of this activity is to investigate the relationship between the reef profile and location of organisms and substrate types. You will experiment on the reef flat, measuring the changing depth, different coral types and whether the bottom is covered in sand, live coral, rubble or algae as you travel from the shore to the reef crest. Appropriate footwear and sun protection are required and please pretend that every living thing you see is a puppy – you wouldn't stand on a defenceless little puppy would you?

Time

Two hours

Tools

- CoralWatch chart
- Two measurement staffs with 10cm segments along their lengths
- 20m of string with markings
- Spirit level to be attached to the string
- Waterproof slate with pencil



Reef zonation

Background

As you walk or snorkel across a reef, you will encounter a number of different zones which differ in their position, depth, light availability, dominant substrate, wave action, salinity and tidal range. Each area contains animals and plants that have adapted to the particular conditions and micro-habitats that form there. Sometimes you can tell which zone a reef organism may come from just by looking at its shape or morphology.

Working from the ocean inwards, reefs typically consist of an outer reef slope, a reef crest, a lagoon and a reef flat lying adjacent to land (if there is any around). Large colonies of all coral types are found on the reef slope while delicate branching corals can survive in lagoons where they are protected from high energy wave action. The reef crest is a terrace of cemented rubble and coral fragments exposed at low tide and constantly subject to high energy waves and strong currents. It is typically covered with scattered blocks of coral rock and fragments of coral head wrenched from the outer reef margins during storms. Any living corals tend to have 'short and stubby' (digitate) or encrusting growth forms in order to survive and produce copious amounts of mucus to preserve them through hours of exposure at low tide. Rubble is cemented together with coralline algae into a solid raised ridge which stops seawater flowing out of the lagoon and reef flat.

The reef crest and slope are frequently dissected by perpendicular channels or 'spur and groove' formations created by the constant high energy ebb and flow of water on and off the reef flat. Reef flats can range in width from a few metres to several kilometres and can be subdivided into beach, beachrock, gutter, inner and outer reef flat with patches of live coral separated by narrow, sandy-bottomed channels. Corals tend to grow upwards to the low tide level and then expand outwards, forming micro atolls.

Field activity

1. Decide on a suitable location in which you will walk to conduct the survey (avoiding large areas of live coral and using sandy tracks if possible).
2. Position a staff upright on the edge of the water with one of end of a 20m string attached at its base (the length of string can be altered depending on your reef).
3. From the shoreline, walk out 20m, hold the second staff upright and pull the string tight, raising and lowering it along the staff until it is level (when the bubble is in the centre of the window on the spirit level).
4. Stop and make the following observations of the area around you and record them in the 'Reef profile data' table:
   a. distance travelled
   b. height of string on the staff
   c. dominant coral type nearby (branching, boulder, plate or soft)
   d. substrate (sand, coral rubble, algae, live coral)
5. Leave the staff furthest from shore in place and carry the other staff from its current position out towards the reef crest, making sure the string is once again level before making your height measurements.
6. Repeat this procedure until you have reached the edge of the reef.
7. Use these observations to plot the reef profile in the area provided.

Teacher Hint
Laminate 'Coral growth forms' to take in the field.

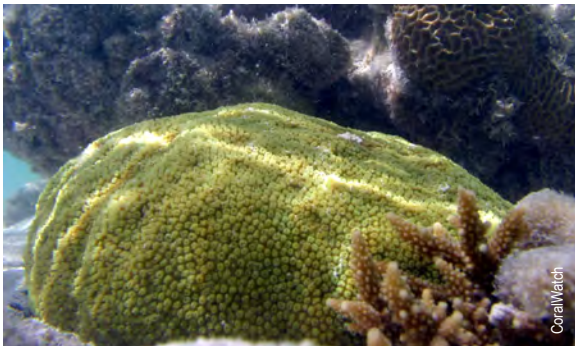
Reef profile drawing

Distance (m)

Coral growth forms

Massive boulder

Platygyra sp.



Porites sp.

Plate

Acropora sp.

Acropora sp.

Branching

Acropora sp.

Acropora sp.

Foliaceous

Turbinaria sp.

Pavona sp.

Coral growth forms

Free living

Fungiidae sp.

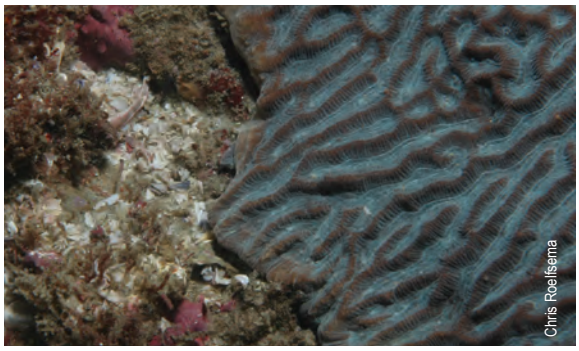
Fungiidae sp.

Digitate

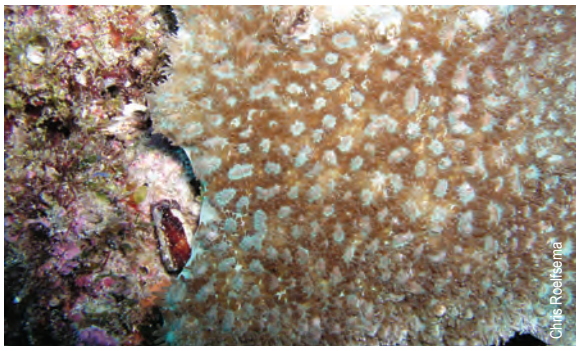
Pocillopora sp.

Stylophora sp.

Encrusting



Goniastrea sp.



Hydnophora sp.

Soft

Lobophytum sp.

Sarcophyton sp.

Reef profile data table

Observer(s):

Location: Date:

Weather conditions: windy / calm / cloudy / sunny

Distance (m)	Height difference	Coral type (Br, S, Bo, Pl)	Substrate (sand, coral, rubble, algae, live coral)

Questions

1. State which part of the reef flat was deepest and why this may be so.
2. Are there dominant coral types present on any part of the reef flat?
3. How does this relate to the abiotic conditions of the region surveyed?
4. Explain why there are clearly defined channels present on the reef flat.
5. What limits the growth of corals on the reef flat?
6. Describe the relationship between the physical features of reef zones and the animals you observe in each.

Research projects

1. Describe, with the aid of a diagram, the consequence of blasting a channel through a reef crest, in terms of water levels and flow and the effects this has on substrate and organisms on the reef flat.
2. Evaluate whether a relationship exists between coral colour, depth and coral type.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Coral growth page 92 and Zones across the reef page 94)

Hutchings PA, Kingsford M, Hoegh-Guldberg O, Australian Coral Reef Society (2008) The Great Barrier Reef: Biology, Environment and Management. CSIRO Publishing

Moffat B, (2009) Marine Science for Australian Students. Wet Paper Publications, Brisbane

UQ Centre for Remote Sensing and Spatial Information Science; www.gpem.uq.edu.au/CRSSIS/

Algae

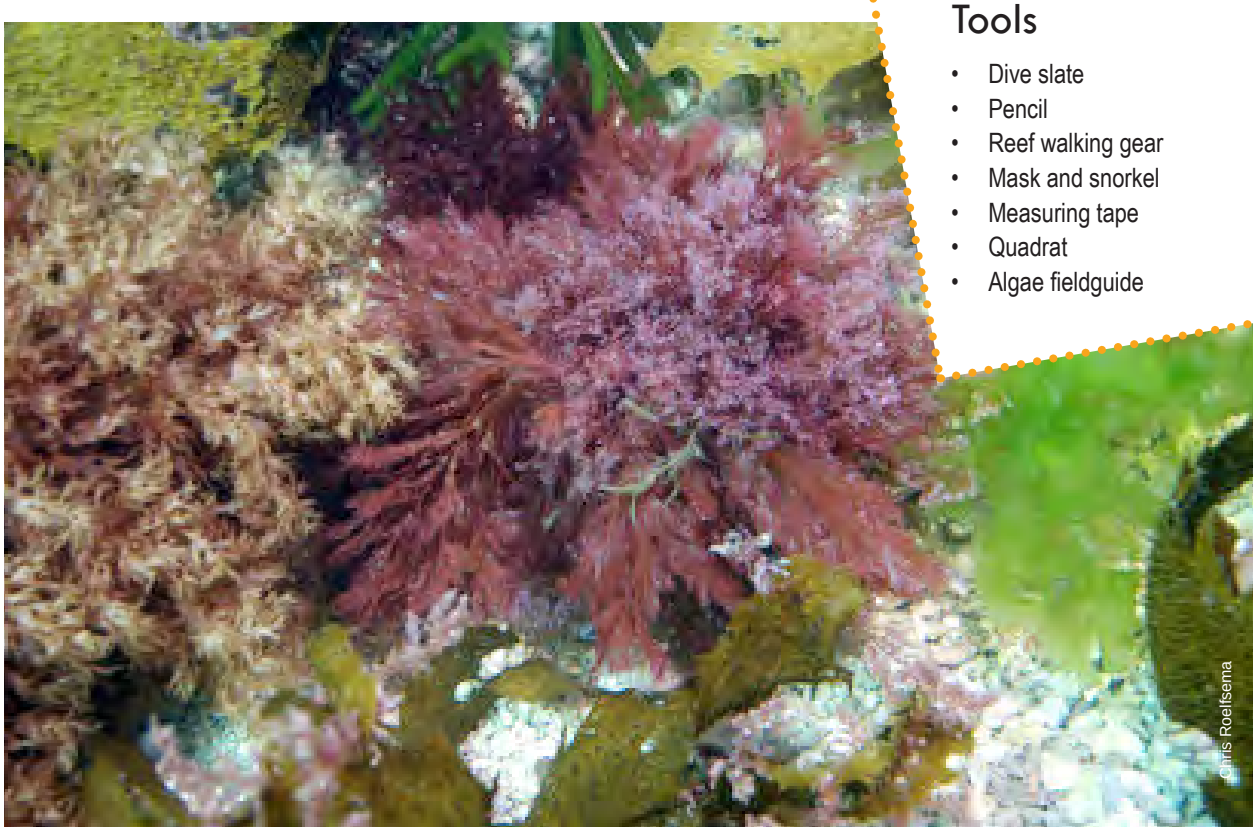
The aim of this activity is to investigate algal distribution in an area of the reef. You will experiment in the field recording the types and amount of algae and substrate in different reef zones. Exploring the relationship between algal cover, substrate and other species will improve your understanding of species' adaptations and processes maintaining a diversity of algae in equilibrium on healthy reefs.

Time

Three hours (reef walking at low tide or snorkelling at high tide)

Tools

- Dive slate
- Pencil
- Reef walking gear
- Mask and snorkel
- Measuring tape
- Quadrat
- Algae fieldguide



Background

Algae (also termed seaweeds) are mostly aquatic plants which contain chlorophyll, lack defined leaves, roots and stems and typically reproduce via spores. They are grouped by characteristic pigments or colours and, on reefs, range in size from single-cells to some species 3-4m in length. They grow in various forms either as turf, crustose (crust-forming), upright macro algae or as single-cells living in sediments in the water column or in close association (symbiosis) with other organisms.

The bright-green chlorophyll pigment is not masked by additional colours in green algae. Some common reef species include eye-catching tufts of green hair scattered about the reef termed 'turtle weed' and the 'sailor's eyeball', *Ventricaria venticosa*, a giant single-celled algae growing under coral boulders. Common brown algae on reefs include *Sargassum*, the leafy fronds for which the Sargasso Sea is named and *Turbinaria,* a bunch of rigid spiky branchlets often found on reef flats and lagoons. Bright red *Hypnea,* growing at depth, or *Gracillaria,* found in the shaded branches of coral, are easily identified red algae, as are the pink, crust-forming coralline algae, prevalent on reef crests where upright algae are swept away by crashing waves. However, many red algae often do not appear to be red. Primitive blue green algae (*Cyanobacteria*) are often the first to colonise open space on a reef as a fine hairy mat. Their additional pigments lend a blue tinge to some species, but many also appear red, brown or black. *Cyanobacteria*, dinoflagellates and other phytoplankton can rapidly multiply in the right conditions to create potentially toxic 'red tides', some so dense that early explorers mistook wind-streaked surface blooms of *Trichodesmius erythraeum*, 'sawdust of the sea', as unchartered reefs.

Field activity

Teacher Hint
Laminate 'Common groups of algae' to take in the field.

This is a small group activity which should be conducted on the reef flat at low tide.

1. Transfer the 'algae mapping results table' onto a dive slate.
2. Select an area of the reef flat where you suspect algae to be present.
3. Decide upon the distance at which your group will be conducting your survey.
4. Measure out the required distance.
5. Place the quadrat at your chosen distance ensuring that you minimize the disturbance of the surrounding environment.
6. Record the following information: distance, substrate (sand, coral rubble, dead coral, live coral), reef zone, % algal cover, algae shape and algae colour. Repeat this at each chosen distance.
7. When you get back to shore transfer your data to the results sheet.
8. Collate the results for the entire reef flat by sharing the data between groups on the 'group algae mapping table'.

Algae mapping results table

Observer(s):

Location: Date: Time:

Weather conditions: windy / calm / cloudy / sunny

	Substrate (tick appropriate box)				Reef zone (tick appropriate box)					
Distance (m)	Sand	Coral rubble	Dead coral	Live coral	Inner reef	Mid reef	Algal ridge	% Algal cover	Shape sketch	Colour

Common groups of algae

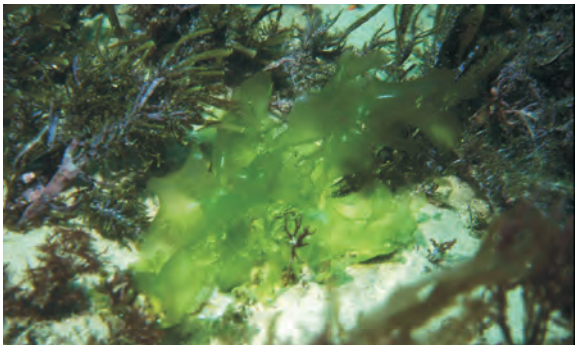
Green algae

Caulerpa, Chlorodesmis, Dictyosphaeria, Halimeda, Ostreobium, Udotea, Ulva, Ventricaria

Chlorodesmius

Halimeda

Caulerpa



Ulva

Brown algae

Dictyota, Chnoospora, Colpomonia, Hincksia, Hormophysa, Hydroclathrus, Lobophora, Padina, Sargassum, Sphacelaira, Turbinaria

Sargassum

Padina

Dilophus

Lobophora

photos Chris Roelfsema

Common groups of algae

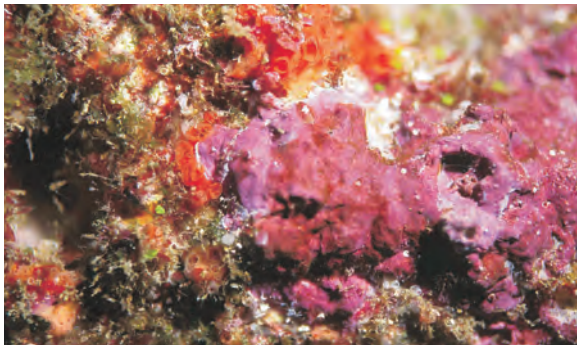
Red algae

Amphiroa, Asparagopsis, Corallophila, Eucheuma, Galaxaura, Hypnea, Jania, Laurencia, Melanamansia, Peyssonnelia, Porolithon, Polysiphonia

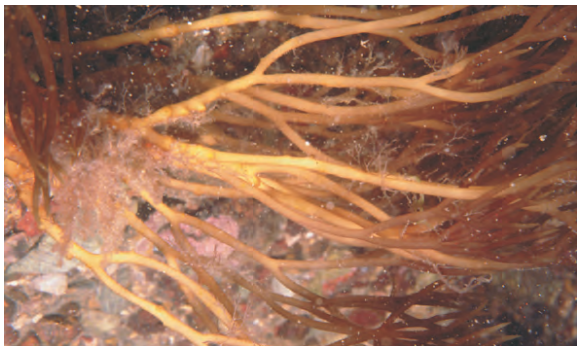
Asparagopsis

Haliptylon

Hypnea



Coralline algae



Sarconema

Gracilaria

Blue green algae

Trichodesmium, Lyngbya, Symploca

Lyngbya (Mermaids hair or fireweed)

Trichodesmius erythraeum (Sea sawdust)

photos Chris Roelfsema

Group algae mapping table

Observer(s):

Location: Date: Time:

Weather conditions: windy / calm / cloudy / sunny

	Substrate (tick appropriate box)				Reef zone (tick appropriate box)				
Distance (m)	Sand	Coral rubble	Dead coral	Live coral	Inner reef	Mid reef	Algal ridge	Algae ID	% Algal cover

Questions

1. What are the different colours of algae present?
2. What was the dominant type of algae?
3. Can you associate different types of algae with the different types of substrate?
4. What are the factors that determine this relationship?
5. Was there any evidence of coralline algae on the reef flat? Why is this type of algae important?
6. On which section of the reef flat was this dominant?
7. Are there any organisms that can be associated with the algae?
8. What are the functions of algae on the reef?
9. Algae grow at a much faster rate than corals. Why then is the reef not dominated by algae?
10. Why would scientists be interested in mapping algal cover on a reef?

Research projects

1. Propose how we could study the effects of a population shift from a coral reef community to an algal-dominated community.
2. Conduct a detailed quadrant survey on an area that is coral dominated, as well as an area that is algal dominated. Compare and discuss your results.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Colourful Algae page 114)

Hutchings PA, Kingsford M, Hoegh-Guldberg O, Australian Coral Reef Society (2008) The Great Barrier Reef: Biology, Environment and Management. CSIRO Publishing

Cribb AB (1996) Seaweeds of Queensland, A Naturalist Guide. The Queensland Naturalist Club, Brisbane

Census of Coral Reef Ecosystems (CReefs); www.creefs.org

Fish on the Reef

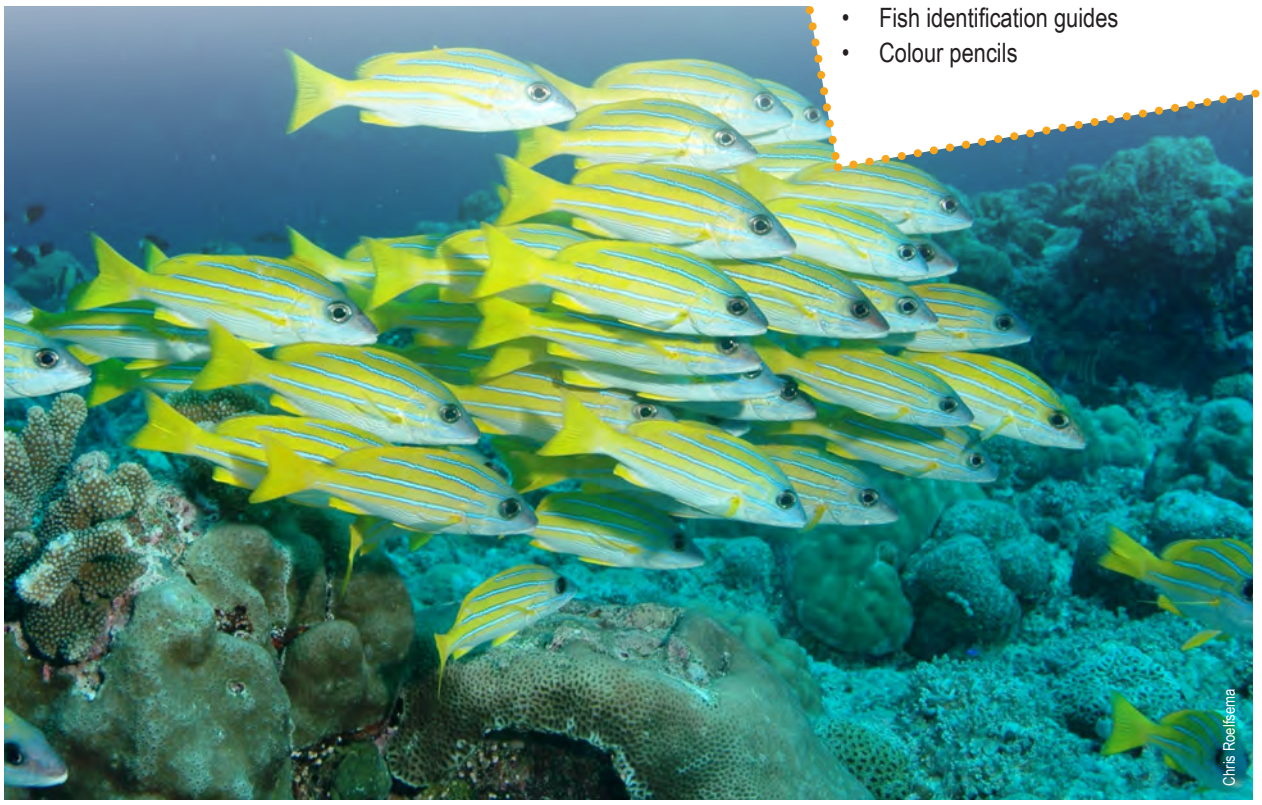
The aim of this activity is to test your powers of observation. When you go snorkelling or diving, see how many fish you can identify. You will record the patterns of colour and markings of as many fish species as you can remember to gain an appreciation and begin identification of the incredible diversity of species and colours of fish on reefs.

Time

One to two hours

Tools

- Snorkelling gear
- Fish charts
- Fish identification guides
- Colour pencils



School of yellow striped snappers, Lutjanus kasmira

Background

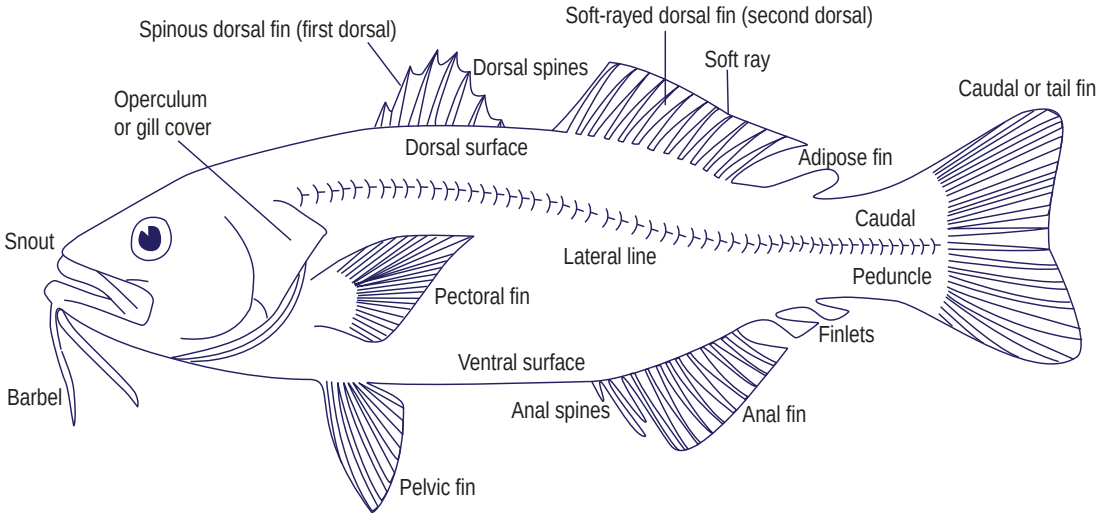
Fish are the most dynamic and colourful features of the clear, low nutrient waters of a healthy coral reef environment. It is here that fish reach their maximum diversity of many hundreds of species per hectare, ranging in size from the smallest of fish, a goby whose adults are 15mm long, to the huge whale shark, which is more than a billion times heavier. Fish use their amazing array of colours to communicate: attract a mate, hide from predators, lure in prey or warn others of their aggressive tendencies or toxic disposition.

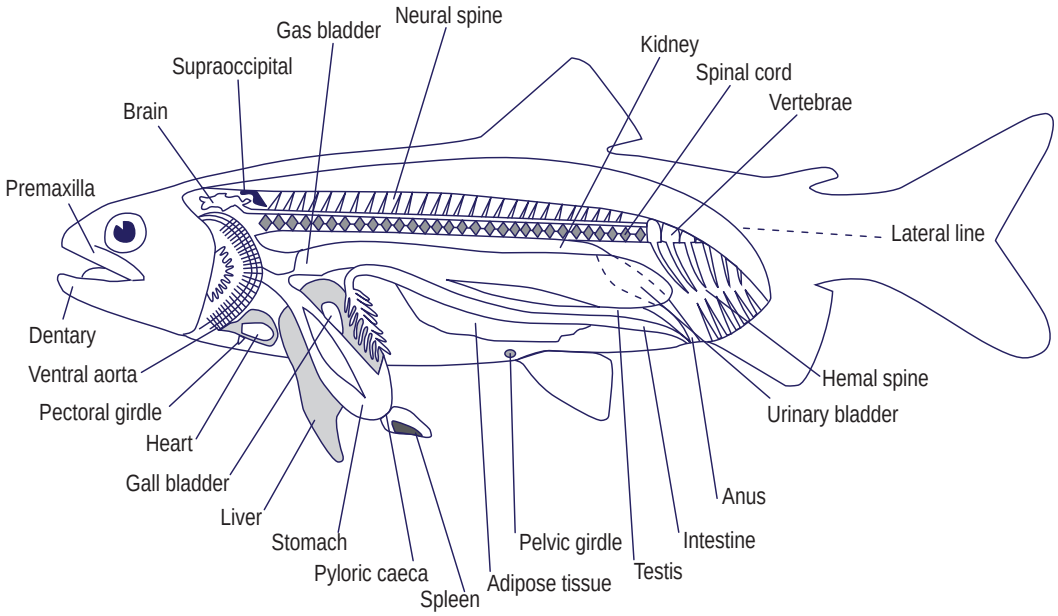
Grazing fish substantially modify the biomass and community structure of algae on coral reefs by intensive feeding. Fish herbivores, such as parrotfish (*Scarinae*), rabbitfish (*Siganidae*), surgeonfish (*Acanthuridae*), damselfish (*Pomacentridae*) and blennies (*Blenniidae*) are thought to be so important in shaping coral reef community structure that they have been referred to as a keystone group in coral reefs. Other species feed on plankton or gouge out individual coral polyps or take great chunks of the coral in each bite. At the other end of food webs are the fish-eaters such as sharks, moray eels and groupers. These animals pick off sick and injured fish, and keep the reef residents fit and healthy. Because of the risk of predation, small fish stay close to shelter and always find a nook or cranny when threatened by a larger organism. The response of small fish to larger objects can easily be observed by the snorkeller as small fish that teem up in the water column feeding on plankton sink gracefully down to the reef as the swimmer approaches. These hiding holes in the complex structure of a healthy reef are vital shelter and are another aspect of coral reefs that support high diversity of life.

Field activity

1. Go snorkelling and look for as many fish as you can.
2. Draw the basic shape of the fish on a waterproof slate and make notes about colour, size and specific features.
3. Take note of where they occur - near a particular coral type, on the sand, in the water column, etc.
4. Estimate the approximate numbers of fish of each species you observed (e.g. 1, 2-10, 50+).
5. Use field guides and your field notes when you are back on shore and write down the scientific and common name of each species you have identified.

Teacher Hint
Laminate 'Common groups of reef fish' to take in the field.





Source: Cailliet G, Love M, Ebeling A (1986) Fishes: A field and laboratory manual on their structure, identification and natural history. Waveland Press

Common groups of reef fish

Disk-shaped/colourful Butterflyfish, Angelfish, Spadefish

Pygoplites diacanthus (Regal Angelfish)

*Chaetodon mertensii (*Merten's Butterflyfish)

Ovals Butterflyfish, Angelfish, Spadefish

Acanthurus nigricans (Goldrim Surgeonfish)

Chromis flavapicis (Yellowtipped Damselfish)

Sloping heads/Tapered bodies Snappers, Coral Breams, Emperors

Lethrinus miniatus (Redthroat or trumpet Emperor)

Lutjanus russellii (Russell's Snapper)

Silvery Jacks, Barracudas, Tunas, Needlefish, Mullets, Flagtails, Grunters

Sphyraena jello (Pickhandle Barracuda)

Haemulon sciurus (Bluestriped Grunt)

Common groups of reef fish

Slender schools/Colourful Fusiliers, Anthias

Caesio Teres (Blue and Yellow Fusilier)

Pseudanthias dispar (Peach Fairy Basslet)

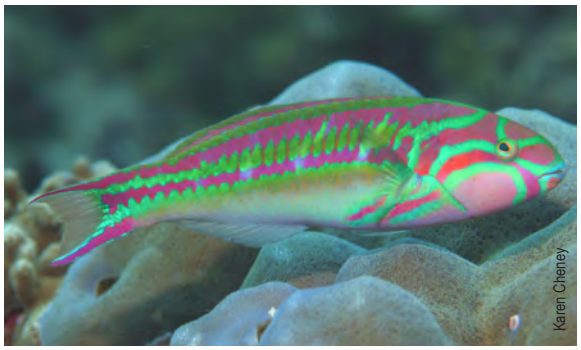
Heavy Bodies, large lips Groupers, Soapfish, Hawkfish, Sweetlips

Plectorhinchus lineatus (Diagonal Banded Sweetlip)

Parupeneus crassilabris (Thicklipped Goatfish)

Swim with pectoral fins Parrotfish, Wrasses

Scarus ghobban (Blue Barred Parrotfish)



Thalassoma quinquevittatum (Fivestripe Wrasse)

Reddish/Big Eyes Soldierfish, Squirrelfish, Bigeyes

Myripristis kuntee (Blackbar Soldierfish)

Priacanthus hamrur (Moontail Bigeye)

Common groups of reef fish

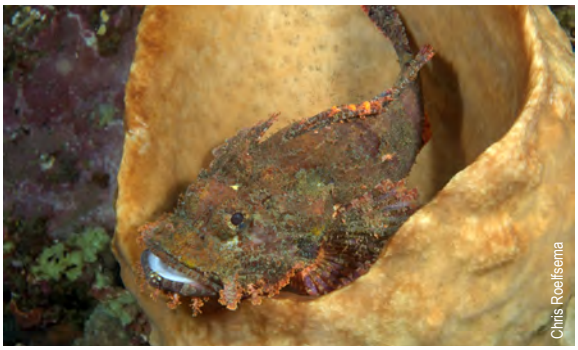
Elongate sand and bottom dwellers Dartfish, Lizardfish, Jawfish, Dragonets

Synodus variegatus (Reef Lizardfish)

Nemateleotris magnifica (Fire Dartfish)

Odd shaped bottom dwellers Frogfish, Batfish, Gurnards, Scorpionfish, Stonefish, Flounders

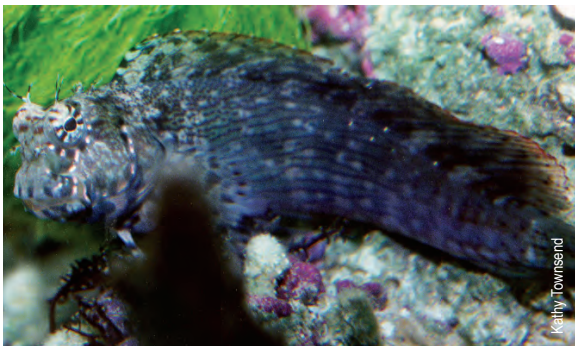
Pterois volitans (Common Lionfish)



Scorpaenopsis venosa (Raggy Scorpionfish)

Small, elongate bottom dwellers Gobies, Blennies

Ecsenius fourmanoiri (Fourmanoir's Blenny)



Salarias fasciatus (Jewelled Blenny)

Odd shaped swimmers Boxfish, Goatfish, Trumpetfish, Sweepers, Puffers, Molas, Filefish, Remoras

Aulostomus chinensis (Trumpetfish)

Ostracion meleagris (Spotted Boxfish)

Common groups of reef fish

Eels Morays, Snake Eels, Conger eels, Garden Eels

Rhinomuraena quaesita (Ribbon Moray)

Gymnothorax fimbriatus (Darkspotted Moray)

Pipefish and Seahorses Ghost Pipefish, Seahorse, Pipefish

Hippocampus bargibanti (Pygmy Seahorse)

Doryrhamphus pessuliferus (Orange-banded Pipefish)

Sharks, Rays Wobbegongs, Bamboo Sharks, Cat Sharks, Whale Sharks, Zebra Sharks, Hammerhead Sharks, Guitarfish, Coffin Rays, Stingrays, Eagle Rays, Cownose Rays, Manta Rays

*Manta birostris (*Manta Ray)

*Triaenodon obesus (*White Tip Reef Shark)

Pastinachus sephen (Cowtail Stingray)

Orectolobus maculatus (Spotted Wobbegong)

photos Chris Roelfsema

Names of observed fish table

Observer(s):

Location: Date:

Weather conditions: windy / calm / cloudy / sunny

Scientific name	Common name	Number

Questions

1. What relationship, if any, exists between the colour of fish and the coral type they are found near?
2. Discuss the possible patterns of fish distribution you found on the reef.
3. How do the tides influence fish behaviour?
4. Compare the differences in reef fish activity you notice during the day.
5. How does this relate to the abiotic factors?

Research projects

1. What is the number of fish that can be supported by a single coral on a reef flat?
2. Using the guides, is there a correlation between the fish guilds and their position on the reef?
3. How does a fish's shape influence its function within the reef ecosystem?

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Fish sections pages 98-105)

Allen GR and Steene R (1994) Indo-Pacific Coral Reef Field Guide. Tropical Reef Research, Singapore

Allen et al. (2003) Reef Fish Identification - Tropical Pacific

Gosliner TM, Behrens DW and Williams GC (1996) Coral Reef Animals of the Indo-Pacific Monterey, California: Sea Challengers

Australian Museum; www.austmus.gov.au/fishes/identify/index.cfm

FishBase: A Global Information System on Fishes; www.fishbase.org

Colourful Invertebrates

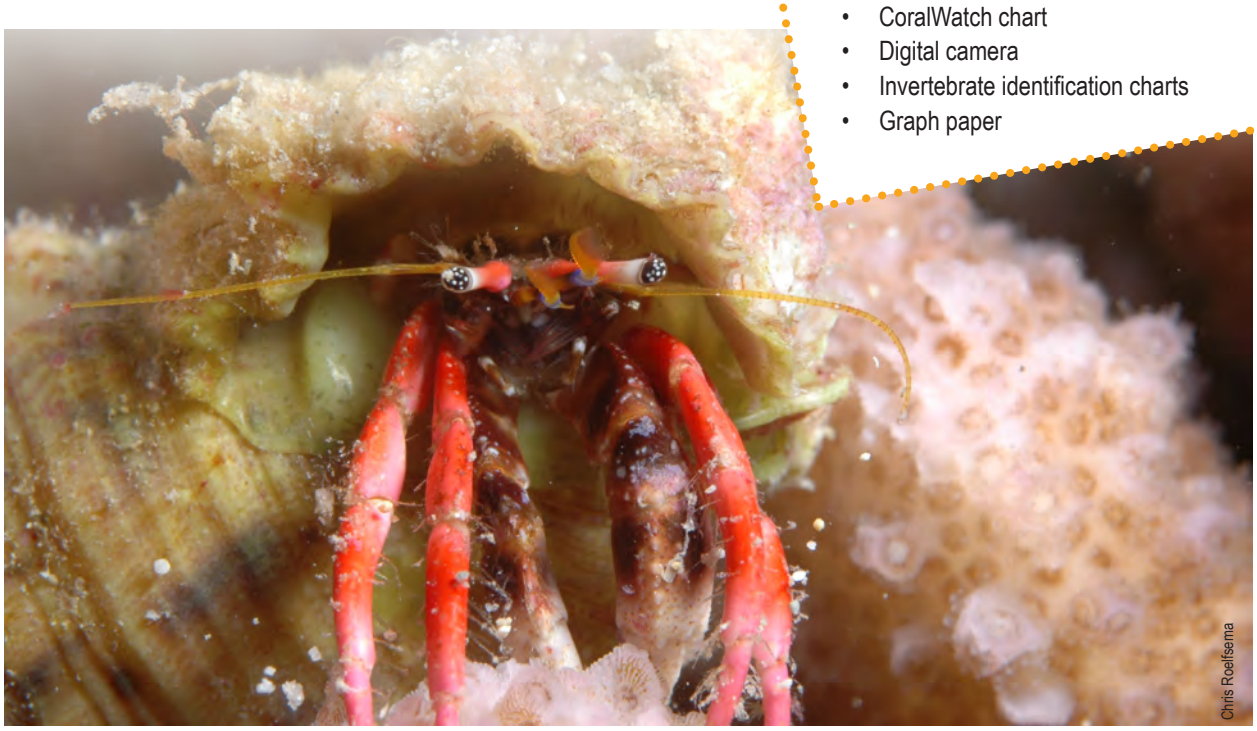
The aim of this activity is to identify invertebrate organisms and to investigate whether a correlation exists between invertebrate colour and the colour of the coral reef substrate. You will experiment in the field observing invertebrate types and their associated habitats, identify characteristic features of different invertebrate groups and create a dichotomous key for classification purposes.

Time

Three hours in the field, two hours in the classroom

Tools

- Reef shoes and snorkeling gear
- Dive slate and pencil
- Tape measure
- CoralWatch chart
- Digital camera
- Invertebrate identification charts
- Graph paper



Hermitcrab.

Background

Every time you look at the colourful reefs you are seeing invertebrates. Aside from corals, reef invertebrates include sea squirts, copepods, toxic nudibranchs, crown-of-thorns sea stars, cleaner shrimp, grazing crabs, parasitic worms and goose barnacles, to name just a few. They make up the web of life that sustains coral reefs. These invertebrates are eating each other, cleaning sand, digging burrows, eroding coral, grazing algae, providing protein, removing parasites, building shells, mating, competing for space and resources and filling every niche with incredible life forms uniquely evolved and adapted to the reef environment. Their amazing range of colours are a way that reef creatures communicate, sometimes using bright or contrasting colours to announce they are aggressive or toxic, while others have colours that keep them hidden in their environment.

Classification of so many species can be difficult. Colours can sometimes help, but can also confuse classification as they can differ between adult and young, male or female or from one moment to the next, in a single species. Invertebrates are separated into major groups, or phyla, based on characteristic features that all members of the group possess, such as jointed appendages of arthropods and possession of a shell in molluscs. However, some molluscs evolved to have small internal shells, or no shells at all, to adapt to their environment. For this reason, a combination of features is used, helped by genetic analysis, to classify each organism correctly. A dichotomous key is a simple tool that can be a used to identify unknown organisms based on mostly observable characteristic features. Dichotomous means ‘divided in two parts’ and the key is made up of a series of choices that leads a person to the correct identity of an unknown thing or organism.

Field activity

This activity should be conducted on the reef flat at low tide.

1. Conduct a line transect from the shore line to the reef crest.
2. At each point of the transect record the following data using the 'invertebrates results table':
   a. substrate and its colour
   b. reef zone
   c. coral type, using the CoralWatch chart
   d. coral colour
   e. invertebrates present
   f. invertebrate colour
   g. patterns on the invertebrate (stripes, spots, alternating colour schemes)
3. Take a digital photograph for referencing the invertebrate's identification back on shore.

Teacher Hint
Laminate 'Common groups of inverts' to take in the field.

Common groups of invertebrates

Porifera and ascideans Sponges, Seasquirts, Salps

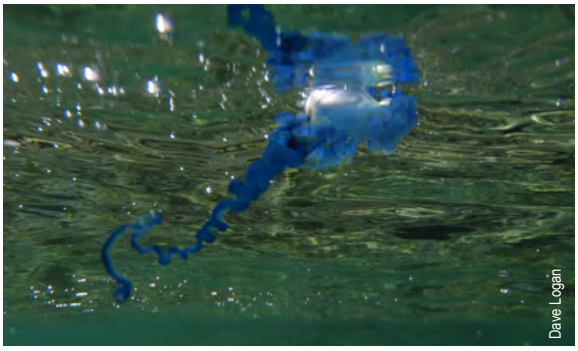
Polycarpa aurata (Sea squirt)

Nephtheis fascicularis (Blue lollipop tunicate)

Clavelina huntsmani (Lightbulb tunicate)

Didemnum vexillum (Ascidean)

Cnidarians Jellies, Hydroids, Corals, Anemones



Physalia utriculus (Blue bottle)

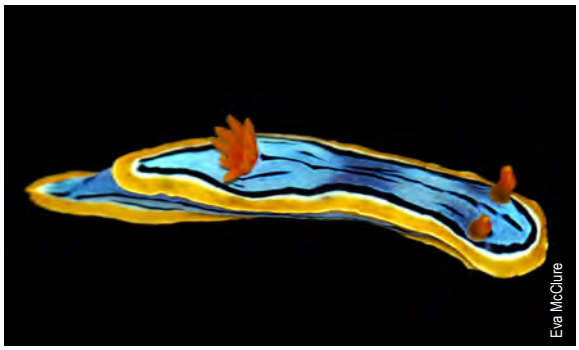
Stomolophus meleagris (Cannonball jellyfish)

Heteractis magnifica (Magnificent anemone)

Corals

Common groups of invertebrates

Mollucs Chitons, Clams, Mussels, Oysters, Snails, Slugs, Nudibranch, Octopus, Squid, Cuttlefish



Chromodoris elisabethina (Nudibranch)

Tridacna gigas (Giant clam)

Acanthopleura granulata (Fuzzy chiton)

Cypraea tigris (Tiger cowrie)

Crustaceans Copepods, Crabs, Shrimp, Lobster, Mantis shrimp, Amphpods, Isopods, Mysids, Barnacles

Odontodactylus scyllarus (Peacock mantis shrimp)

Lysmata amboinensis (Cleaner shrimp)

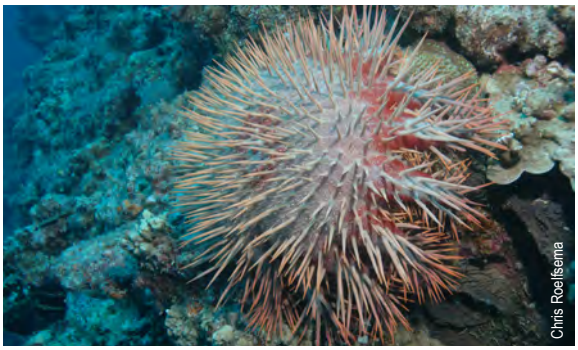
Panulirus interruptus (Spiny lobster)

Carcinus maenas (Green crab)

Common groups of invertebrates

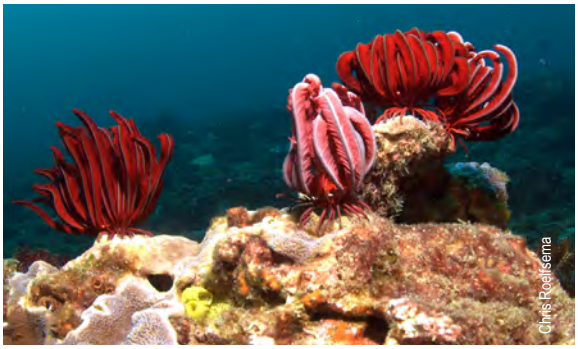
Echinoderms Sea stars, Cucumbers, Urchins

Stichopus chloronotus (Black sea cucumber)



*Acanthaster planci (*Crown-of-thorns sea star)

*Nardoa novacaledoniae (*Common sea star)



*Lamprometra palmata (*Feather star)

Worms Bristleworms, Nematodes, Flatworms, Lace animals

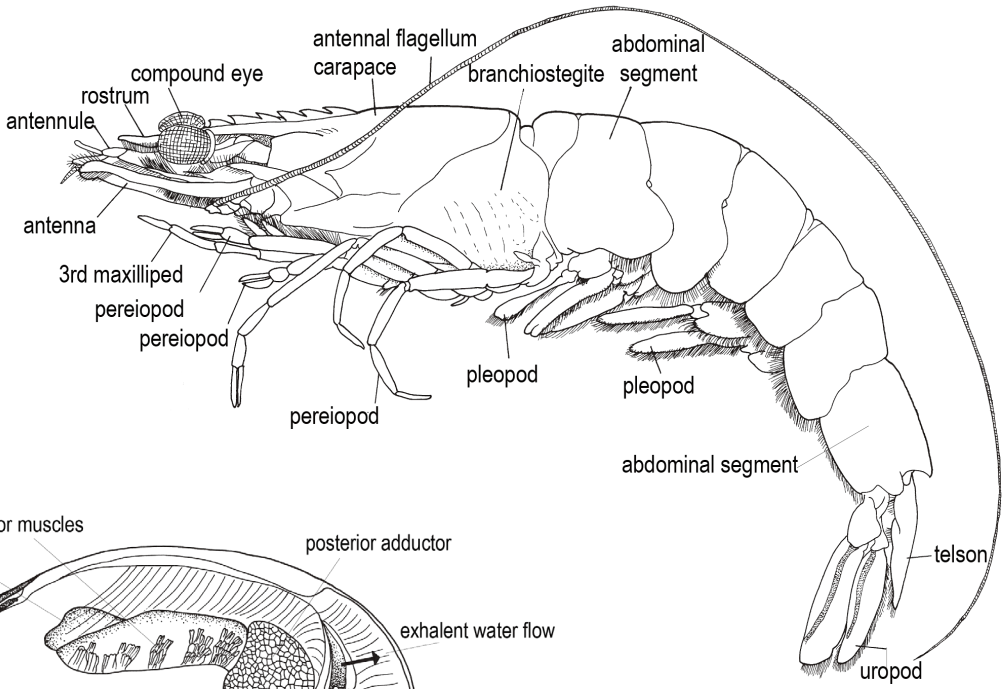
Spirobranchus spinosus (Christmas tree worm)

Phidolopora labiata (Lacy bryzoan)

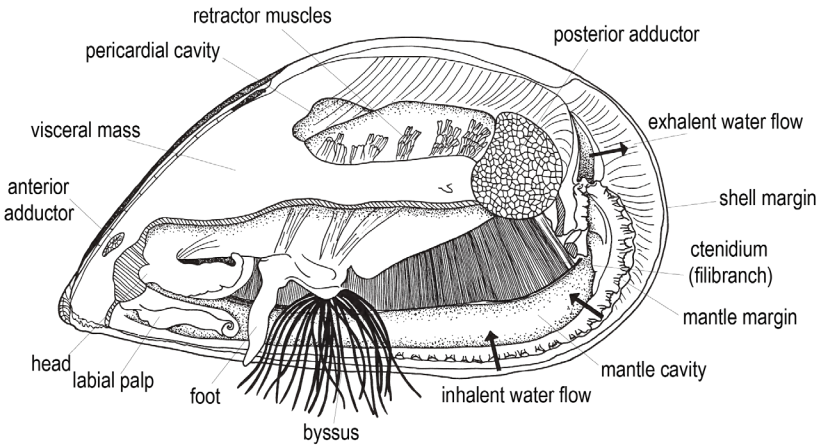
*Eupolymnia crassicornis (*Spaghetti worms)

Thysanozoon nigropapillosum (Yellowspot flatworm)

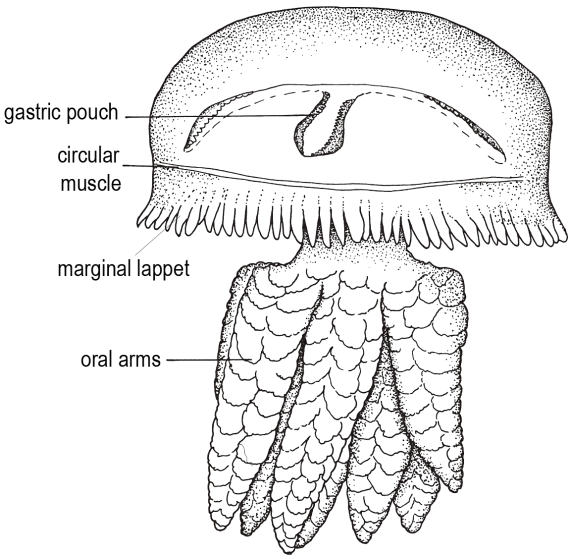
Anatomical drawings



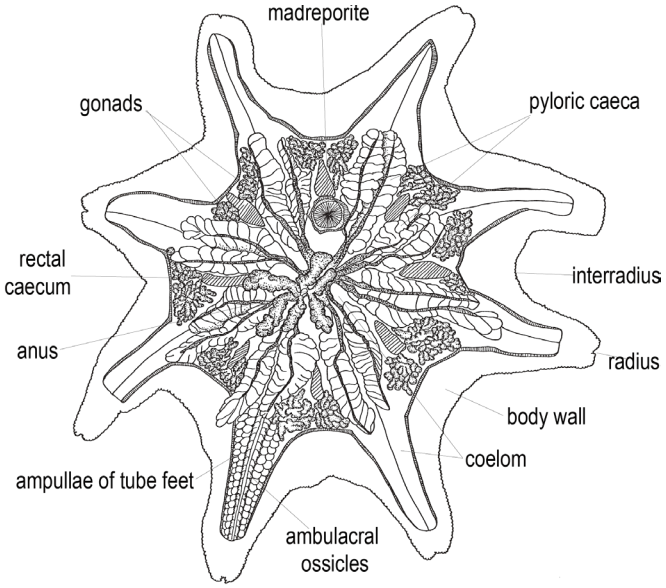
Prawn anatomy, external structure.



Mussel anatomy, external structure.



Jellyfish anatomy, external structure.



Sea star anatomy, external structure.

Source: Anderson DT (1996) Atlas of invertebrate anatomy. New South Wales University Press Ltd

Invertebrates results table

Observer(s):

Location: Date:

Weather conditions: windy / calm / cloudy / sunny

Substrate (tick appropriate box)					Reef zone (tick appropriate box)			Invertebrate data		
Sand	Coral rubble	Dead coral	Live coral	Substrate colour	Inner reef	Mid reef	Reef crest	Identification	Colour	Patterns

Classroom activity

1. During this activity you will identify invertebrates you have observed and create graphs to show relationships between invertebrates, their location on the reef and coral colours nearby. Using your digital photos and invertebrate identification charts or books, identify the invertebrates you found on the reef including their phylum, class, scientific and common name where available.
2. Discuss in a group how you plan to quantify invertebrate colours (i.e. solid and patterned; red, green and blue; pale or dark). Use graph paper or a spreadsheet to plot:
   a. invertebrate abundance versus reef zones
   b. invertebrate richness versus reef zones
   c. coral colour scores versus invertebrate colour
3. Compare the graphs and look for trends or patterns in the data.
4. Write down the features that are characteristic for each major invertebrate phylum.
5. Use these features to make a dichotomous key. The first branch has already been provided as an example. Create your key by asking questions relating to these features.

Invertebrate phylum features

Phylum **Cnidaria**

Features
-
-

Phylum **Porifera**

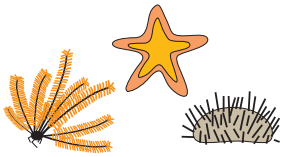
Features
-
-

Phylum **Annelida**

Features
-
-

Phylum **Chordata**

Features
-
-

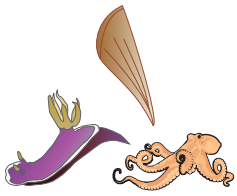


Phylum **Echinodermata**

Features
-
-

Phylum **Arthropoda**

Features
-
-



Phylum **Mollusca**

Features
-
-

Phylum **Bryozoa**

Features
-
-

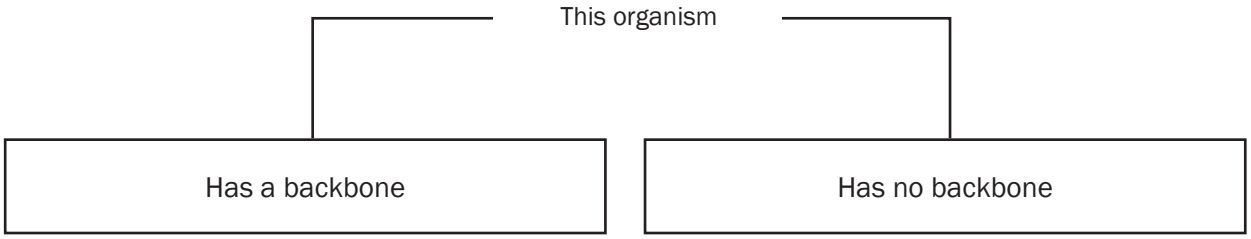
Dichotomous key

Does this organism

2a Have an external skeleton it sheds and replaces as it grows? (go to ...)

2b Have a shell, internal skeleton or no skeleton? (go to ...)

or draw your dichotomous key as a tree



Teacher Hint

You can provide specific species, one in each phyla or several in one phylum, with images to get things started.

Questions

1. What trends or patterns in invertebrate distribution in reefs zones did you find?
2. Suggest the factors that might determine the patterns of distribution.
3. What is the function of invertebrates on the reef?
4. Looking at the graphs you have constructed for this section, is there any correlation between invertebrate colour and coral colour?
5. What sorts of colour patterns were apparent on some of the animals?
6. Does any relationship exist between these colour patterns and the substrate?
7. How would the invertebrates use colour to their advantage?
8. Why are colours not the best features to use to identify species?
9. What are some of the difficulties in constructing a dichotomous key?

Research projects

1. If you were conducting a survey of the entire reef area, what species would you select as indicators to determine the population numbers of invertebrates on the reef? Justify your reasoning.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See A Crowd of Invertebrates pages 106-113)

Allen GR and Steene R (1994) Indo-Pacific Coral Reef Field Guide. Tropical Reef Research, Singapore

Gosliner TM, Behrens DW and Williams GC (1996) Coral Reef Animals of the Indo-Pacific Monterey, California: Sea Challengers

Census of Coral Reef Ecosystems (CReefs); www.creefs.org

Australian Museum; www.austmus.gov.au

Reef Education GBRMPA; www.reefed.edu.au

Acting on Coral Bleaching

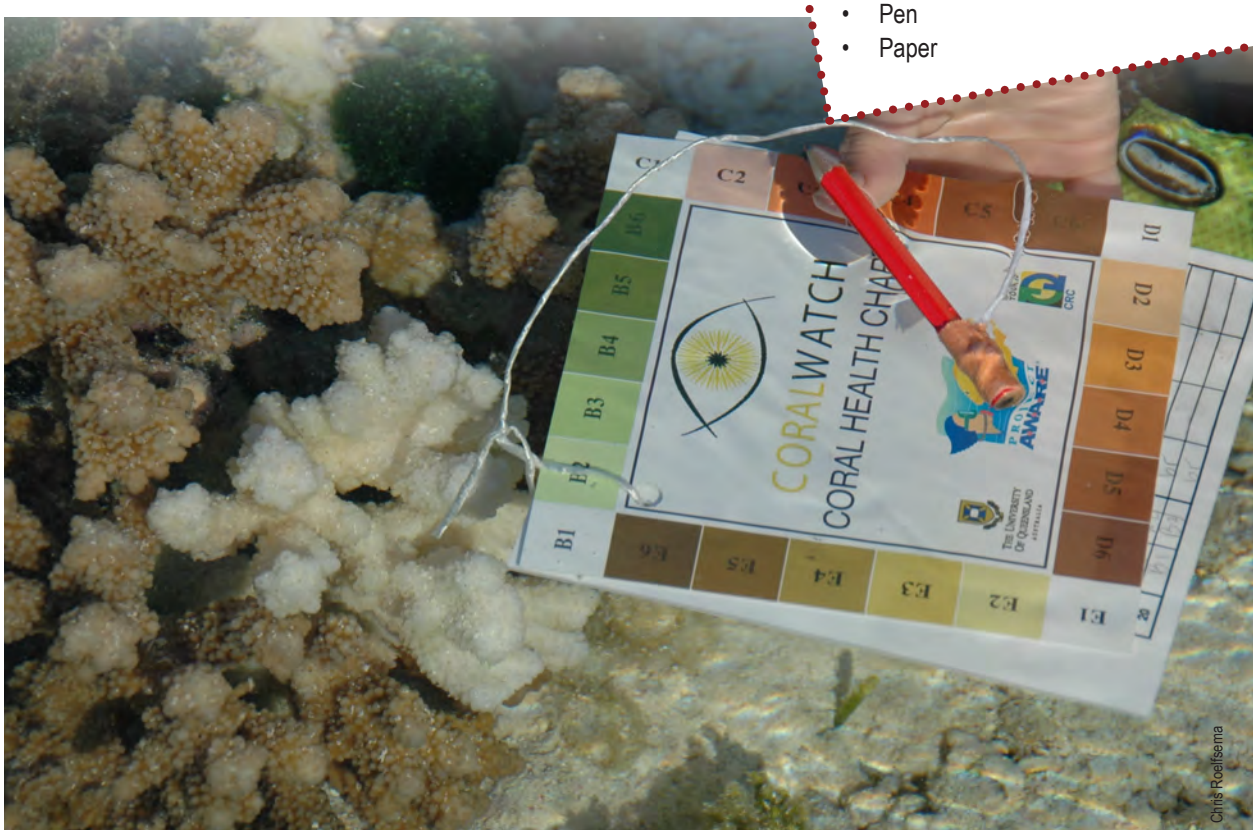
The aim of this activity is to explore how coral reefs are being impacted by climate change and envision practical ways to create a future containing healthy reefs. Using virtual tools and online data, you will identify coral bleaching trends and present your findings and possible solutions in a letter to a political leader or newspaper editor.

Time

Three hours

Tools

- Virtual reef
- Pen
- Paper



Chris Roelfsema

Coral bleaching

Coral bleaching occurs when corals change colour, generally from dark brown to a lighter shade of brown or white. The colour change is generally caused by a loss of symbionts from the coral's tissue, but can also be associated with a decrease in the concentration of photosynthetic pigments within the symbionts. Coral bleaching is a reaction to stress and can be caused by a variety of environmental factors including:

- elevated or decreased water temperatures
- changes in water salinity
- increased solar irradiance (both visible and ultraviolet)
- elevated exposure to chemical contaminants

It is important to understand that there are two distinctly different types of bleaching: localised and mass bleaching. Localised bleaching occurs over small geographical regions and can be caused by any of the above factors. Mass bleaching occurs over large geographical regions and is caused by increased water temperature over extended periods of time, together with increased levels of ultraviolet light. Sea temperatures are predicted to continue to rise and thus mass bleaching is expected to occur more frequently, and with greater intensity. This could lead to the death of large areas of coral reefs worldwide within a few decades.

Monitoring coral bleaching

Little is known about trends of coral bleaching on a global scale. Current attempts to monitor bleaching often involve costly satellite-born technologies, require sampling of live tissue and are restricted to the few reefs that are regularly visited by scientists. There are many questions that need to be answered in order to build a greater understanding of our reefs. This is where you can help.

By collecting bleaching data using the Coral Health Chart you will be providing valuable data to researchers. With your support it will be possible to monitor coral bleaching throughout the year, not just during bleaching events, and also across the world rather than at selected locations. Your data will help researchers answer questions related to issues such as patterns of bleaching and recovery.

Bleaching is closely linked to coral health. However, it is important to remember there are several other factors that affect the overall health of a coral reef, such as:

- Physical damage caused by storms or human impact
- Coral diseases, e.g., black band and white spot
- Over-fishing, e.g., reduced numbers of herbivorous fish provide the opportunity for algae to flourish, which can smother and kill corals
- Increased nutrient levels can also enhance algal growth
- Increased sedimentation can also smother corals
- Levels of coral diversity and reef connectivity

For people to effectively manage and reduce threats to reefs, they require community understanding and support and strong political leadership. You can help bring this about by advocating for positive change through a written letter.

Bleached coral

CoralWatch volunteer

Source: ReefBase: http://www.reefbase.org with the data from UNEP-WCMC, Institute for Marine Remote Sensing, Institute de Recherche pour le developpement, NASA and ReefBase

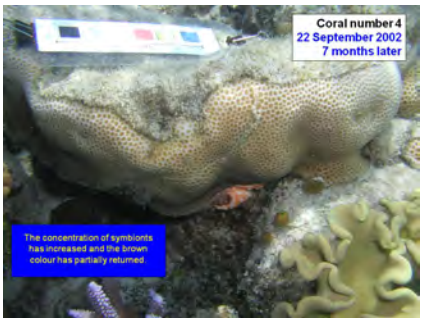
Classroom activity 1

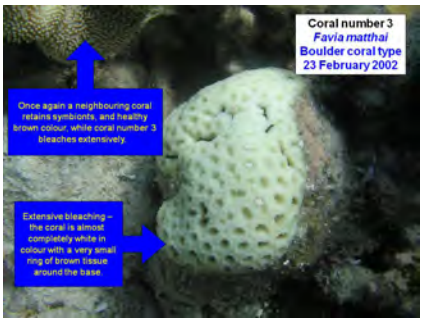
In this activity you will investigate the consequences and frequency of coral bleaching and determine if these events seem to be increasing.

1. Using the CoralWatch *Virtual Reef*, review the power point slides/ flash presentation on the process and progression of bleached corals in the field. Take note of:
   a. how many recover
   b. how long recovery can take
   c. how many died as a result of bleaching
2. Log on to Reefbase and open the coral bleaching data set (global database –> threats -> bleaching).
3. Download the data for the world, or a region of your choice, and look at bleaching event data for the last 15 years.
4. For each year, record:
   a. how many events have been reported in total
   b. how many are severe
   c. how many are moderate
   d. how many are low
   e. coral death reported – yes or no
5. Generate a graph to show trends in bleaching data.
6. Compare this to the trends cited in the references you have access to.

Questions

1. Was there enough available data for you to come up with good conclusions?
2. Who else would you ask for current data?
3. How could you collect your own data?
4. Does the data indicate how many corals were affected in each event?
5. Does the data show recovery from bleaching?
6. What is the current state of coral reefs on a global scale?
7. List the six actions being taken by management authorities in addressing the issues of climate change?
   a. Rank these in order of what you believe will be most effective to the least effective.



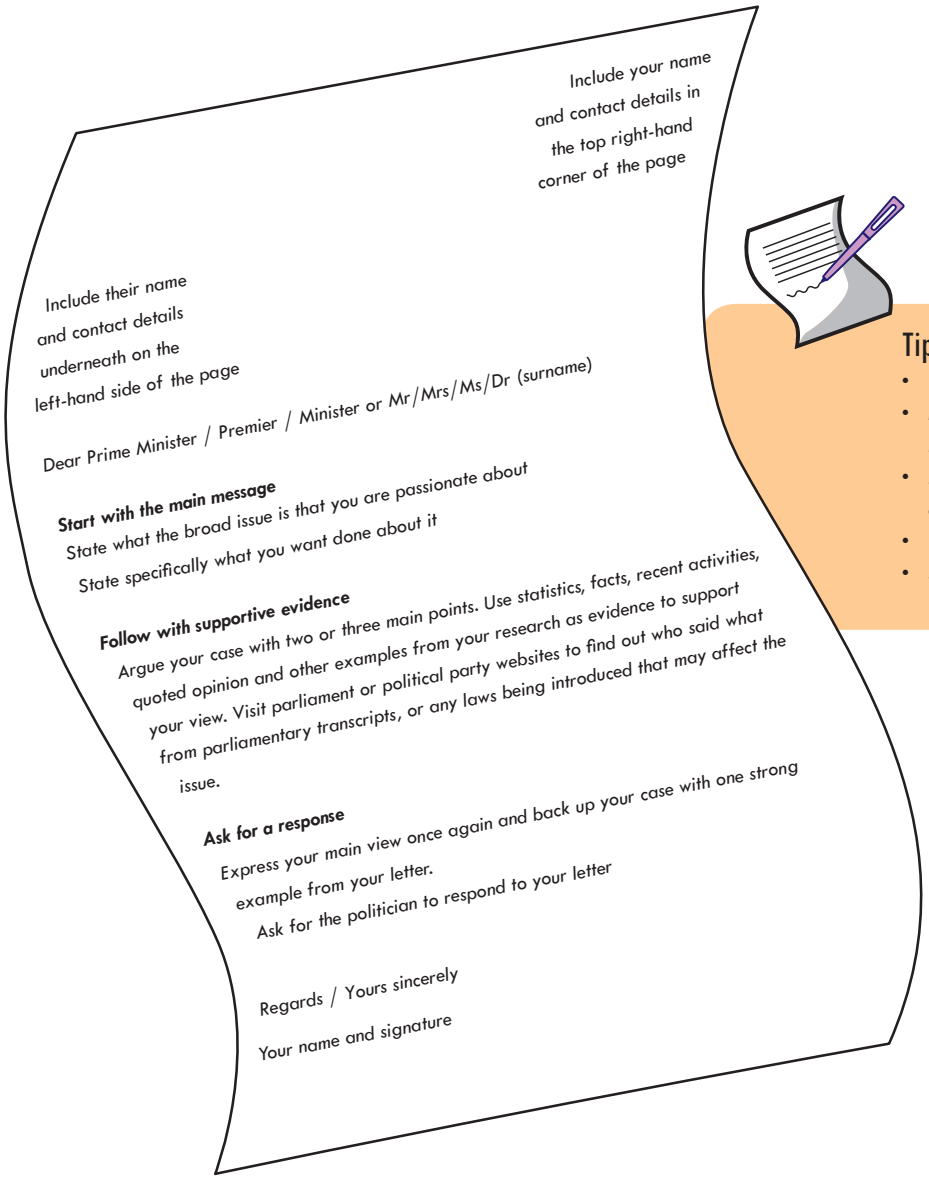


CoralWatch virtual reef.

CoralWatch activity in the classroom to prepare for a field trip.

Classroom activity 2

1. In this activity you will write two letters regarding a reef related issue and suggested solutions. Address your first letter to a suitable person in power. Your second letter will be in response to a letter written by someone else, imagining you are in a position of power.
2. Write a letter persuading a person in power to act on an identified threat. Choose an issue or reef threat that you already know a little bit about.
3. Identify your audience (minister of environment, fisheries manager, prime minister, newspaper editor, etc.).
4. Research their role, correct title and address.
5. Include in your letter:
   a. main idea – problem and solution - what do you want the person to do?
   b. reason
   c. evidence to back it up
6. Format and finish the letter appropriately.
7. Swap letters with another and write a response to their letter, pretending you are the person the letter is addressed to (you may have to research their position and possibly their opinion on the subject first – look for other projects or ideas they support).
8. Decide whether you actually want to send the letter you have written (only you can make that choice).



Tips for writing the letter

- *Use formal language*
- *Express your point of view with phrases like 'I feel' and 'I want to see'*
- *Don't expect a reply if you are rude, abusive or offensive*
- *Handwrite your letter*
- *Send your letter in the mail*

Australian Coral Reef Society Inc.

A society promoting scientific study of Australian Coral Reefs

Address: ACRS Memberships
c/- Centre for Marine Studies
The University of Queensland
St Lucia QLD 4072
Tel: (07) 3365 1397
Fax: (07) 3365 4522
Email: Justin.marshall@uq.edu.au

9th September 2009

The Honourable Mr Peter Garrett
Minister for the Environment, Heritage and the Arts
Parliament House
Canberra
ACT

Dear Minister Garrett

Australian Coral Reef Society Comment on recent oil spills in the vicinity of Australian coral reefs and coastline.

Australia is a world leader in the call for the conservation of coral reefs and demonstrates role model management of The Great Barrier Reef (GBR). The GBR is one of the largest protected areas in the world, and was protected in its first instance when faced with the potentially high environmental risks of oil and gas exploration. With worldwide reef systems 40% destroyed or degraded to unrecognizable, Australia must continue as a world leader in protecting our less degraded reef systems and coastlines from threats such as this.

Despite the high standard of Health Safety and Environment policies promoted in the oil and gas industry, 2009 has witnessed two recent oil spills of significant threat to the marine environment.

The first in March when the Pacific Adventurer lost containers of ammonium nitrate and 270 tones of fuel oil offshore of Cape Moreton where as detailed by the Australian Marine Safety Authority (AMSA) :*"The oil impacted significant portions of the south-east Queensland coast, in particular the eastern and northern beaches and headlands of Moreton Island (a National Park), the eastern beaches of Bribie Island (north of Brisbane), the beaches and foreshores of the Sunshine Coast (north of Brisbane) and small areas of the Brisbane River."*
(AMSA:www.amsa.gov.au/Marine_Environment_Protection/Major_Oil_Spills_in_Australia/Pacific_Adventurer/index.asp)

The second spill started on the 21st of August 2009, when a leak developed in an oil well of the Montara oil field in the Timor Sea, close to world significant biodiversity hotspots (http://www.environment.gov.au/coasts/mpa/ashmore/index.html): Cartier Reef (a National Marine Reserve), 150km from the Ashmore complex a National Nature

President: Prof Justin Marshall; Tel: 07 3365 1397; Fax: 07 3365 4522 Email: justin.marshall@uq.edu.au
Hon Secretary: Dr. Ulrike Siebeck; Tel: 07 3365 4070; Fax: 07 3365 4522 Email: u.siebeck@uq.edu.au
Hon Treasurer: Dr Anna Scott; Tel: 02 6648 3923; Fax: 02 6651 6580 Email: ascott@nmsc.edu.au

Reserve; and 250km from the Kimberley coast. This is currently releasing a conservatively estimated 3000 barrels of oil or approximately 470,000 litres a day of sweet light crude, gas (including the greenhouse gas methane) and is expected not to be stopped for at least 7 weeks. In the first three days it was reported that at least 10,000 litres of dispersant, which is also toxic to the environment, where used to contain the resulting slick. These estimates are based on the information available to the public and it is also of concern that there has not been more transparency in this process. One of the learning experiences from the Pacific Adventurer disaster was that the scale of the spill was underestimated and the more rapid action commensurate with the scale of the spill was delayed.

Records show that the Montara oil field spill follows six major oil spills in Western Australia since 1975 and given the well recognized fragility of the coast and offshore reefs in this region, this history of accidents is of concern. Even more alarming is the fact that both chemicals and a new drill rig have had to be shipped from great distance to deal with the current event. This clearly foreseeable delay in treatment, demonstrates that exploitation of natural resources for short term gain is placed above our natural heritage in federal and state government priorities. (www.amsa.gov.au/Marine_Environment_Protection/Major_Oil_Spills_in_Australia/).

Coral reefs are currently declining worldwide as a result of human interaction and climate change. The remote reefs of Northern Australia will not escape the resultant threats of coral bleaching, ocean acidification and over fishing (http://royalsociety.org/page.asp ?id=3093). Added to this, the potential compounding threats of pollution from oil and gas operations must be taken more seriously than they currently are. An ever increasing suite of pressures and impacts will undermine reef resilience to the point where they will not recover (www.australiancoralreefsociety.org/ and http://www.coralcoe.org.au/).

It should be the clear duty of all nations to pass on the environment to subsequent generations in a responsible fashion. It is a responsibility of stakeholders, engaging in activities with the potential to impact the environment, to be able to contain and minimize impacts. The ways in which this will be done, should be clearly documented for the public and it is a Federal Government responsibility to ensure this sort of insurance against disaster both occurs and is taken seriously.

The Australian Coral Reef Society would therefore like to call upon the state and federal government agencies, oil and gas industry and general public, to exercise extreme caution in the ongoing developments which, although intrinsically linked to Australia's economy, should not put the Australian environment at great risk.

We call for tighter approval processes for developments on the doorstep of internationally significant wonders such as The Great Barrier Reef World Heritage Area, Cartier Island Marine Reserve, the Ashmore Reef National Nature Reserve, Hibernia Reef, Scott Reef, Rowley Shoals and the Kimberley and Pilbara coastlines. This process should include the review of major projects by independent scientific bodies and greater transparency in environmental assessments.

The Australian Coral Reef Society: 1) supports calls for an inquiry into the recent events in the Timor Sea, including the adequacy of Australia's oil spill response to major offshore oil spills; and 2) calls for increased investment and effort into understanding and protecting our coastal and offshore coral reefs in both North Eastern and North Western Australia. These ecosystems hold a wealth of biodiversity which is increasingly scarce worldwide.

Of particular concern to The Australian Coral Reef Society is that the recently green-lighted Gorgon Project in WA is Australia's largest energy resource project. Firstly, the required safety measures to deal with the spills and leaks that will occur here do not seem sufficiently advanced. Secondly, we now know that a future with 450ppm CO_2 is a future most likely containing coral reef degradation on a massive scale. We refer you in particular to Figure 5.2 in the recent "Great Barrier Reef Outlook Report 2009 In Brief", from The Great Barrier Reef Marine Park Authority and to the findings of this report. We urge the federal and state government to accelerate measures that will bring us well under this currently aimed for threshold by moving away from large scale CO_2 releasing energy projects.

The Australian Coral Reef Society would value a reply to these concerns and an outline of the new actions to be implemented in the future to prevent oil spills on or near our coastlines.

Yours sincerely

Professor Justin Marshall
President of The Australian Coral Reef Society

The Australian Coral Reef Society (ACRS) is the peak professional body representing coral reef scientists in Australia. It is the oldest coral reef organisation in the world, and its membership includes many of the world's leading experts in coral reef sciences. Since its key role in establishing the Great Barrier Reef Marine Park in 1975, the ACRS has maintained a tradition of highly regarded, science-based contributions to issues relating to Australian coral reefs. As scientists with extensive knowledge of coral reefs and the health of reef organisms, members of the Society have become increasingly concerned about the fate of these precious ecosystems in the face of current and future pressures. Australian coral reefs are critically important to Australia economically and culturally and the ACRS believes we have an international responsibility to lead the way.

Questions

1. Why is a hand written letter more effective than e-mail?
2. What is the use of a petition?
3. How would you write differently to a newspaper editor as opposed to a politician?
4. What do the vested interests stand to gain by denying climate change?
5. Evaluate the current state of international negotiations to reduce carbon emissions?
6. Why can't coral reefs adapt with the changes in sea surface temperature?
7. Will we see coral reefs migrating further south?
8. How will these scenarios impact the marine organisms that depend upon the reef ecosystem?
9. What are the social and economic implications of the degradation of coral reefs?
10. Why are coral reefs such a good indicator of the changes to other ecosystems on a global scale?

Research projects

1. How is 'uncertainty' used in the debate on climate change?
2. Why is there such a rift between the advice provided by scientists and the impetus for governments to react?
3. Are we overreacting to climate change?
4. What are the vested interests involved with the disagreement of climate change?
5. What are Australia's and the United States' arguments for not signing the Kyoto protocol?
6. Are the following justifications reasonable? Explain your answer for each.

   a. that the scientific findings on climate change are uncertain, and we cannot act on uncertainty

   b. that an individual cannot make a difference in addressing the climate change issue

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Coral Bleaching page 128, Community Input page 198 and Changing Perspectives page 206)

CoralWatch; www.coralwatch.org
CRC Reef Research Centre; www.reef.crc.org.au
Project AWARE Foundation; www.projectaware.org
Actnow; www.actnow.com.au
11th International Coral Reef Symposium (ICRS); www.nova.edu/ncri/11icrs
ARC Centre of Excellence for Coral Reef Studies; www.coralcoe.org.au
Australian Coral Reef Society (ACRS); www.australiancoralreefsociety.org
Australian Institute of Marine Science (AIMS); www.aims.gov.au
Great Barrier Reef Marine Park Authority (GBRMPA); www.gbrmpa.gov.au
International Energy Agency (IEA); www.iea.org
Garnaut Review Web Site; www.garnautreview.org.au

Climate Change

Field, Classroom and Lab Activities

Dave Logan

Contents

Climate Change Basics

The aim of this activity is to develop your understanding of the basic processes underlying climate change and determine how people are contributing to climate change through their everyday behaviour. You will identify key greenhouse gases, their sources and their effect on Earth's energy balance and use a carbon calculator to determine the amount of carbon emissions your lifestyle and the people around you directly and indirectly generate.

Time

Three hours

Tools

- Internet access
- Paper and coloured pens / pencils

Background

Greenhouse gases are a tiny fraction of the total composition of the atmosphere that forms a thermal blanket around the earth. Without them the global average temperature would be 30°C cooler than the current average temperature of 15°C. These naturally occurring gases are released into the atmosphere by biogeochemical processes such as the decomposition of organic matter, plant and animal respiration and volcanism. The three main gases are water (H_2O) at less than 1%, carbon dioxide (CO_2) 0.035% and methane (CH_4) at just 0.00018% of the total atmosphere.

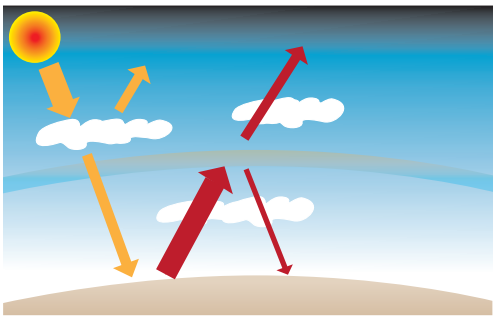
These gases act just like a garden greenhouse. Short wavelength light energy from the sun is absorbed by the components of the climate system (air, water, soil, ice and forests). The excess energy that is absorbed is reradiated back out into the atmosphere and space as long wavelength heat energy. This energy flow keeps the temperature of the Earth's surface in balance. Greenhouse gases prevent a proportion of the reradiated surface heat energy from escaping the Earth's atmosphere and passing out into space. The higher the concentration of greenhouse gases in the atmosphere the greater the amount of surface heat energy is trapped close to the Earth's surface, causing our atmosphere to warm-up.

The various greenhouse gases released into the atmosphere (collectively known as carbon emissions) are the result of activities and processes that support our lifestyle. Individually they form the basis of a carbon footprint. We each contribute to carbon emissions directly from the use of fossil fuels to power and heat our homes, fill up our cars or when we travel and indirectly through energy that is "embedded" in activities we participate in and the items we buy.

Global change depends on each of us reducing our contribution to climate change. To do this we need to first workout just what those contributions are. There are many websites that provide a way of measuring your carbon emissions using a carbon calculator. You can also estimate using averages provided by trusted sources, or you can make a more detailed measurement of your own consumption of fuel, electricity, food and other natural resources and generation of waste.

Classroom Activity 1

Draw a similar model as shown and explain in your own words the processes taking place.

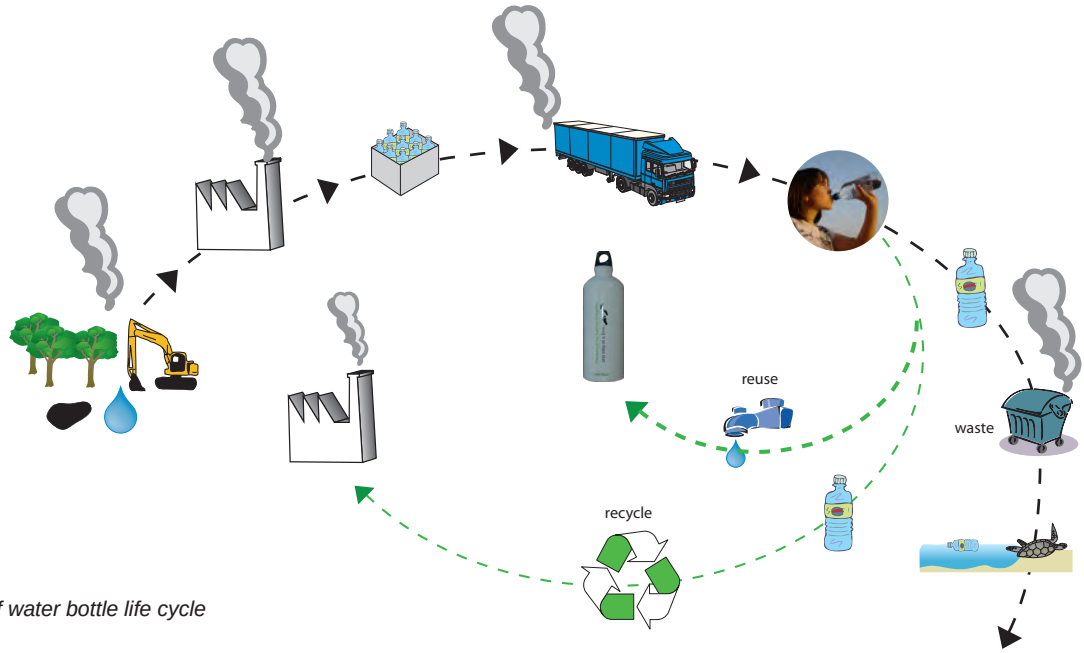


CoralWatch

Classroom Activity 2

Using the lifecycle of the water bottle as an example, draw and label the lifecycle of an everyday item in your life (e.g. your mobile phone, pen, shoe, can of drink).

1. Draw or paste an image of the item in the middle of your page.
2. Draw labels to each component (e.g. for a biro pen; plastic lid, ink, plastic casing, metal nib).
3. Now draw and label the process that has created that item from extraction of raw materials ► processing ► manufacture ► packaging ► distribution ► sale ► use ► disposal / recycling.
4. For each step, also draw or list the sources of greenhouse gas emissions (these could include direct emissions from vehicles and manufacturing machines, use of electricity from a powerplant, clearing of land and burning of trees and wood, etc).



Example of water bottle life cycle

CoralWatch

Classroom Activity 3

1. Make a list of 10 activities you enjoy doing every day.
2. Next to each, identify if you believe it releases none, few or lots of carbon emissions.

Hint: If you don't know the answer to this, it helps to think about the bigger picture. For each item on the list, think about how it was manufactured, what are the raw materials needed to make it, what is the energy used in the process.

3. Write one way you could reduce the emissions from the activity.

Reducing daily emissions		
Activities I enjoy doing every day	Carbon emissions (none, few, lots)	Way I could reduce emissions

Before Class

Find out the following facts:

- How far is it from your home to school?
- What type of fuel does your car use?
- What do you use to heat water at home? (gas, electricity, solar)
- How much electricity did you use on your last electricity bill? Over what amount of time?

Carbon Calculator

1. Complete a carbon calculator online to determine your carbon emissions.
2. Compare this to the rest of your group and find the average carbon footprint of your group.

Questions

1. What is the greenhouse effect?
2. What are the main greenhouses gases that are found in our atmosphere?
3. What are the sources of those gases?
4. How is climate change different from the greenhouse effect?
5. Using examples describe the differences between natural and anthropogenic forcings.
6. Explain how recycling helps to reduce greenhouse gas emissions.
7. List at least three things you could do while shopping to help reduce greenhouse gas emissions.

Research projects

1. Evaluate the factors that limit the implementation of clean coal technology today.
2. Outline the case for the development of new zero emissions technologies.
3. What industry would be the largest source of GHGs in your area? List five actions that you could participate in that could reduce these emissions.
4. Methane is a GHG that has a greenhouse effect 24 times more powerful than carbon dioxide. Investigate the main sources of methane production and how climate change may be increasing the rate of release of methane into our atmosphere.
5. What are methane clathrates and how have they been implicated in climate change in the past?
6. Why is the stability of clathrates so important?
7. Investigate whether nuclear power is the solution to climate change.
8. What is carbon trading and how does it work?
9. Debate the argument: “Australia only produces 1.5% of the total greenhouse gas emission on a global basis and cannot justify the economics of mitigating for climate change.”
10. Evaluate the role of renewable energy into the future.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Climate Change sections pages 152-158)

Gore A (2006) An Inconvenient Truth. Bloomsbury Publishing, London

Intergovernmental Panel on Climate Change (IPCC); www.ipcc.ch

CO2CRC Cooperative Research Centre for Greenhouse Gas Technologies;

http://www.ga.gov.au/oceans

United Nations Framework Convention on Climate Change; www.unfccc.int

RealClimate; www.realclimate.org

Global Carbon Project (GCP); www.globalcarbonproject.org

The Pew Center on Global Climate Change; www.pewclimate.org

The Australia Institute; www.teachingclimatechange.com.au

1degree; www.1degree.com.au

Act on CO2; actonco2.direct.gov.uk/actonco2/home.html

Australian Government; Department of Climate Change, www.climatechange.gov.au/en/community/carbon-footprint.aspx

Climate Crisis; www.climatecrisis.net/takeaction/carboncalculator/

Tracking Change

The aim of this activity is to develop a better understanding of local and regional weather events in relation to the global climate system. You will investigate and display the global El Niño and La Niña cycles and the associated trends and predictions of temperature, rainfall and extreme weather events in your local region.

Time

Two hours

Tools

- Internet access
- Pens
- Paper

Extreme weather events can devastate local populations, landslide in Taiwan 2009.

Background

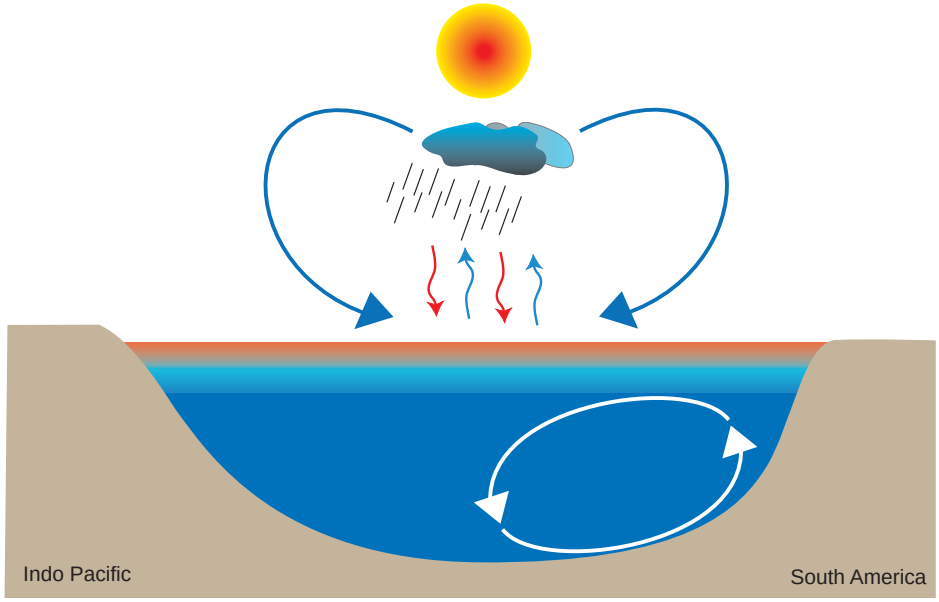
The term "El Niño", which means little boy and refers to the Christ child, was originally applied to a weak warm ocean current that ran southwards along the coast of Peru, usually occurring near Christmas. It has only recently become associated with much more extensive ocean temperature increases that extend over the Pacific basin, causing changes to global climate patterns. The atmospheric component tied to "El Niño" is termed the "Southern Oscillation". Scientists often call this phenomenon, where the atmosphere and ocean collaborate together, ENSO (El Niño-Southern Oscillation).

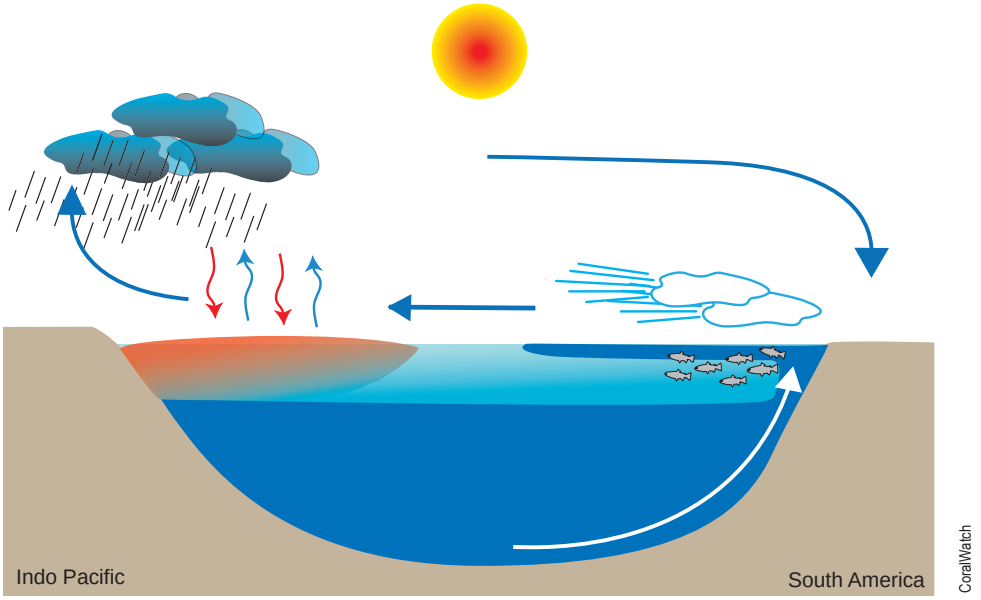
ENSO is a natural phenomenon and there is good evidence from cores of coral and glacial caption ice in the Andes that it has been going on for millennia. The ocean and atmospheric conditions in the tropical Pacific are seldom average, but instead fluctuate somewhat irregularly between El Niño events and the opposite "La Niña" phase, consisting of a basin-wide cooling of the tropical Pacific, with a period of about 3-6 years. The most intense phase of each event usually lasts about a year.

On a global scale, ENSO has a profound impact on humanity and society and is associated with droughts and increased fire risk in Australia, floods and severe coastal storms in California, heat waves on the European continent and other changes that have severely disrupted agriculture, fisheries, health, and the environment. One of the potential consequences of climate change, if temperatures move above 3ºC, will be the establishment of a permanent El Niño pattern.

Classroom activity

1. Label the models given and explain, in your own words, the processes involved.



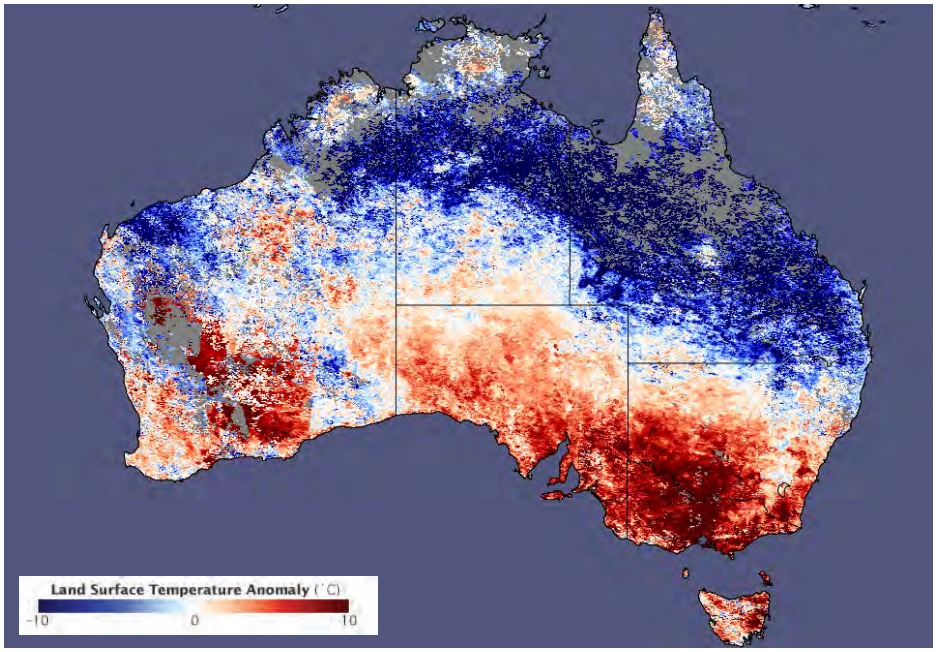


Classroom activities

1. Use the web and other references to search for:
   a. the yearly or seasonal averages of rainfall and temperature in your region for this year and last year
   b. frequency of extreme weather events such as storms or droughts which may have caused flooding or fires for the same period
   c. any long term averages in rainfall or temperature available (e.g. a 10 year average)
   d. the phase of ENSO cycle existing now and last year

2. Create a webpage or poster (max 400 words) using the information you have found including:
   a. explanation of ENSO
   b. predictions for your region (include some relevant data to support these predictions)
   c. actions which could prepare for expected changes
   d. summarise an extreme weather event from your region
   e. what people should do in the case of extreme weather events

The two sides of El Niño. During 2008, south east Queensland experienced one of its longest dry spells ever recorded The following summer, 66% of Queensland was flooded.



Wet in the north and dry in the south. Climate changes will not impact all areas evenly.

Source: NASA map, based on MODIS land surface temperature data.

Questions

1. What is the difference between weather and climate?
2. What are El Niño and La Niña?
3. Discuss the weather patterns associated with these two weather events on a global scale.
4. What are the associated changes in weather patterns that occur in your region during an El Niño event?
5. What are some of the extreme weather events that have occurred in the past 10 years?
6. How will climate change impact upon rainfall in your region?
7. How will it affect the temperature?
8. What are the costs and benefits of these changes?

Research projects

1. Discuss, using data, whether a possible link exists between El Niño and the increased frequency of coral bleaching events.
2. What are the possible consequences for your region if permanent El Niño weather were to develop?
3. Discuss what strategies you would put in place to cope with these changes.
4. Can we confidently link the increased frequency and intensity of these events to climate change?

   Note: you must argue the science in this question and not accept opinion.
5. Investigate how the Indian Ocean Dipole influences the climate of the southern hemisphere.
6. What is the meridional overturning and how does it influence the climate of the northern hemisphere?

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See El Nino page 62 and Tracking Change page 166)

Bureau of Meteorology; www.bom.gov.au/climate/enso/
NOAA's El Niño Page; www.elnino.noaa.gov
The University of Queensland; www.uq.edu.au
Climate Shifts; www.climateshifts.org

Ocean Acidification and Carbon Cycle

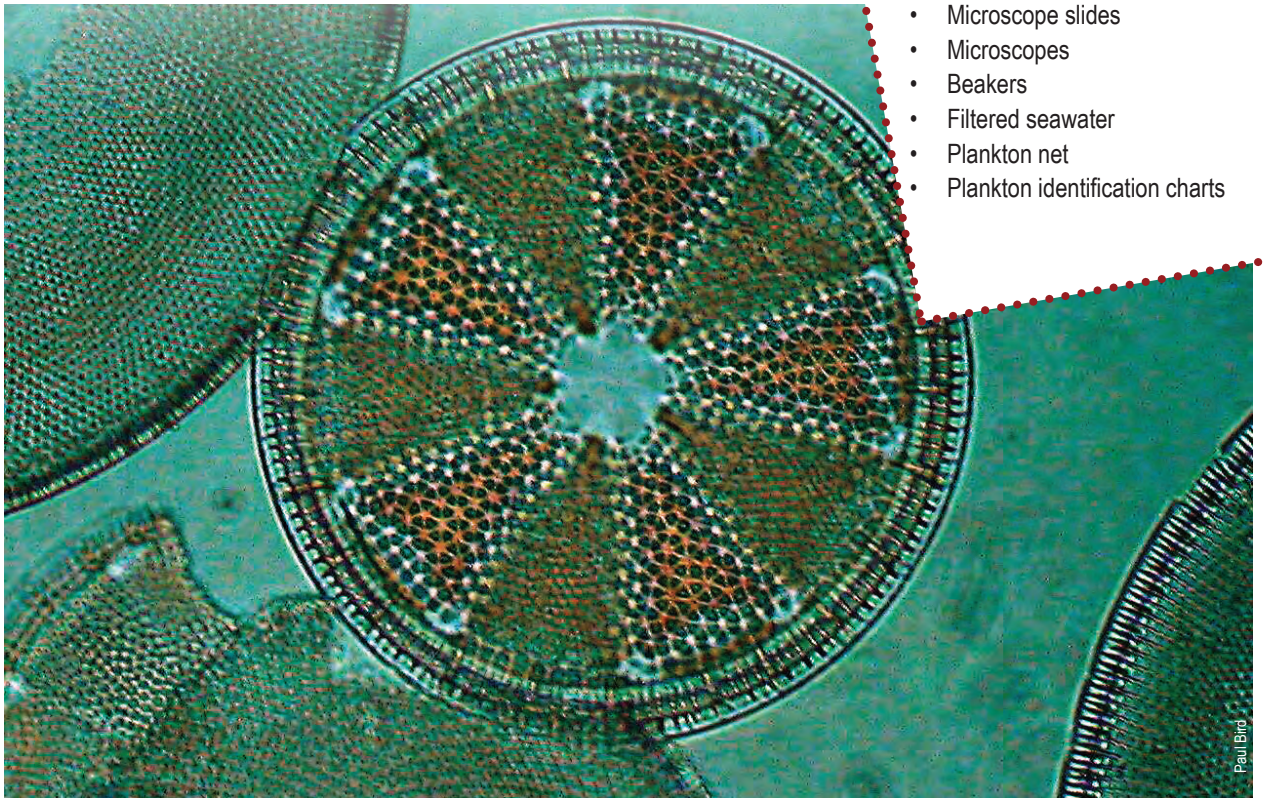
The aim of this activity is to investigate the impacts of ocean acidification and expand your understanding of the ocean's role in the carbon cycle. You will collect and identify plankton from sediments, algae and the water column and explore chemical changes that occur in an elevated CO_2 environment.

Time

Three hours (one hour field, two hours lab)

Tools

- Sample jars with lids
- Pipettes
- Microscope slides
- Microscopes
- Beakers
- Filtered seawater
- Plankton net
- Plankton identification charts



Diatom Actinoptychus sp.

Background

One of the most important elements for all life on earth is carbon. It provides the framework and structure upon which every living thing on our planet is built, from the largest whale to the simplest single celled plankton in our oceans.

As gaseous carbon dioxide (CO_2) from the atmosphere comes in contact with the ocean's surface, it dissolves. A proportion of this reacts with seawater, forming carbonic acid (H_2CO_3) while the remainder exists as a dissolved gas and is used by marine organisms such as phytoplankton and other marine plants for photosynthesis.

The amount of CO_2 that will dissolve in the ocean is determined by Henry's Law and provides the basis for a simplified equation that describes the marine carbonate system.

$$CO_2\,(g) + H_2O \leftrightarrow H_2CO_3 \leftrightarrow [H^+] + HCO^{3-} \leftrightarrow 2[H^+] + CO_3^{2-}$$

The carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate (HCO^{3-}), and carbonate (CO_3^{2-}) represent the total dissolved inorganic carbon present in our oceans. All three forms are vital for the biological processes occurring in the ocean. It is the carbonate ions (CO_3^{2-}) that act as the buffer by their reactions with the hydrogen ions that prevent any large changes in pH from occurring in our oceans.

Many marine plants and animals concentrate calcium ions within their tissues to produce solid calcium carbonate, in the forms of aragonite and calcite, for their shells and skeletons. The beautiful calcified skeletons of plankton such as diatoms and forams can be easily viewed through a microscope. When these marine organisms die, their skeletons and the organic material in the tissues fall through the ocean as marine snow, taking the carbon dioxide that is fixed within their organic structures with them. Below ~4000m, high acidity causes these remains to dissolve back into the ocean waters. Through upwellings, the carbonate ions are cycled back to the surface to be used again for the building blocks of life. At certain depths the ocean is saturated with ions. These saturation horizon depths vary with the conditions of the ocean and are ultimately tied to the concentration of carbon dioxide in our atmosphere.

Field activity

During this activity you will collect plankton and microscopic organisms from three different parts of a reef or coastal environment.

1. Find an area on the reef flat, beach or sand flat that has discoloured sediments covered in seawater.
2. Collect a sample of the sediments with some seawater and seal the jar.
3. Leave some room at the top to shake the contents.
4. Find a living common algae that you can identify from the reef flat, beach or sand flat.
5. Extract a sample of the algae and seal this in a jar.
6. Using a plankton net, trawl through the water for 10 minutes and seal the collected plankton in a jar.

Lab activity

1. Looking at the sediment sample you collected in the field:
   a. shake the jar and allow the sediments to settle, then tip off the sea water into a plastic beaker
   b. wash the sediments with filtered seawater and repeat this process twice
   c. using a pipette, extract a small amount of the seawater and place onto the microscope slide and view under the microscope
2. Looking at the algae sample you collected in the field:
   a. add filtered sea water to the algae, seal it and gently shake
   b. tip the water into a plastic beaker and repeat this process twice
   c. using a pipette, extract a small amount of the seawater, place on a microscope slide and view it under a microscope
3. Looking in the water column sample you collected in the field:
   a. wash the plankton net with filtered seawater to improve extraction of microorganisms
   b. tip the jar into a clean plastic beaker
   c. using a pipette, extract a small amount of the seawater, place on a microscope slide and view it under a microscope
4. Use books, websites and plankton charts to assist you in identifying what you have found and note the abundance of plankton.
   Draw and identify two dominant plankton from each section, using identification charts.
5. Take two equal sub samples of plankton-filled seawater from each substrate type. Add 10ml of filtered seawater to one sub sample, add 10ml of soda water, vinegar or another dilute acid in the other. Leave the samples to sit for half an hour. Now use the pipette to prepare a slide of normal plankton and acidified plankton. (This is an extreme case of acidification that does not reflect current realities).
6. Collect two samples of calcareous algae, place one in dilute acid and the other in filtered seawater overnight. Observe any visible changes in the two samples.

Plankton drawings – Sediment

Plankton drawings – Algae

Plankton drawings – Water column

Questions

1. Where were the plankton most abundant and why?
2. What functions does plankton perform in reef and other marine environments?
3. Suggest how we could gain a better understanding of the fluctuations of population numbers of plankton throughout the day.
4. How would the concentration of nutrients (nitrogen and phosphorous) affect plankton populations?
5. What role does plankton play in the carbon cycle?
6. What is aragonite and how is this important for marine organisms?
7. What is ocean acidification and what are the potential effects on primary productivity in the ocean?
8. What are the expected changes in ocean chemistry, particularly in the southern ocean and how is this related to the increased partial pressures of carbon dioxide?
9. How could changes in ocean temperature magnify the effects of ocean acidification on marine ecosystems?

Research projects

1. What is Redfield's ratio and how does this relate to the growth of marine plants?
2. What is the relationship between the concentration of phytoplankton and the global surface currents?
3. How does phytoplankton make clouds?
4. What is the response by plankton to increased nutrient inputs from land based activities?
5. Is it possible that we may see an explosion in planktonic life forms due to 'carbon fertilization'?
6. What is the potential of using nutrients to enhance the uptake and sequestration of carbon dioxide within the marine environment?
7. If we change the bottom chemistry of the oceans through increased carbon dioxide concentrations, how will this impact the surface waters?
8. Investigate the reasons why scientists are so concerned about ocean acidification.
9. How could changes in ocean temperature magnify the effects of ocean acidification on marine ecosystems?

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See A Basic Ocean page 34, Productive Seas page 56, Ocean Acidification page 68 and Coral Growth page 92)

Veron JEN et al. (2009) The coral reef crisis: The critical importance of <350 ppm CO_2. Marine Pollution Bulletin 58:1428–1436. (supplied on CD)

Acid Test (movie) Natural Resources Defense Council; www.nrdc.org/oceans/acidification/

A Sea Change (movie); www.aseachange.net/

European Project on Ocean Acidification; www.epoca-project.eu

Ocean Acidification Network; www.ocean-acidification.net

Climate Shifts; www.climateshifts.org

Global Outlook

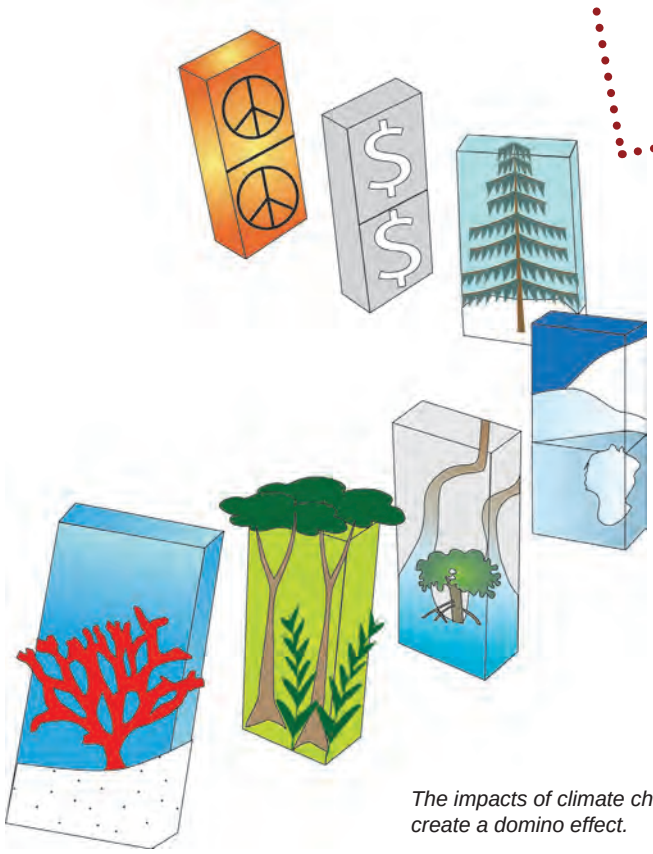
The aim of this activity is to explore the costs and benefits of climate change in different ecosystems across the world. You will investigate and create a poster presentation on the changes that will occur in human communities and natural systems if global temperatures increase above two degrees Celsius.

Time

Three hours (classroom)

Tools

- Computer
- Pen
- Paper



CoralWatch

The impacts of climate change will create a domino effect.

Background

The consensus that is derived from the data is that, if we wish to avoid the harsher effects of climate change, the average global temperature increase must remain below 2°C, with CO_2 emissions remaining at a 450ppm CO_2 equivalent. The long term projections by the IPCC suggest we are already dancing on this critical edge.

It is suggested that beyond 2°C the ecological fabric begins to tear, causing shifts in species range and transforming entire landscapes over time. Impediments such as farms, roads and cities lie directly in the path of the most favourable migration routes. This is why we see the projected increase in the rate of extinction occurring with the increases in global temperatures into the future. Redistribution of rainfall will impact natural and agricultural systems. The temperatures for the germination of some plants will be surpassed, with the extension in the ranges of pest and weed species contributing to a decrease in land productivity of staple cereal crops.

Vector borne diseases such as malaria, dengue and yellow fever will breach their equatorial confines as the range of their mosquito carriers is expanded with the increases in temperature. These alone will place a substantial additional burden on health systems, even in developed countries such as Australia. The further we move away from this threshold, the greater the magnification of the health effects. Malnutrition, diarrhoea, and

mortalities due to heat waves and flooding become part of an expanding array of health issues that must be addressed as terrestrial and marine ecosystems tend towards carbon sources rather than sinks, accelerating changes.

Every country, regardless of their geographic location and economic status, will be affected by climate change to some degree. Developing countries will be the most vulnerable but developed nations will also be overwhelmed. America watched, first in fascination, then in horror, as one of its states descended into chaos and anarchy when Hurricane Katrina caused the death of 1800 people as 80% of New Orleans was submerged in flood waters.

The science informs us that to avoid the dangerous impacts of climate change, CO_2 levels should be no greater than 450ppm, a situation expected to arrive in the next six years. The economists, while conceding that this is the case, point to the economic realities, which show why it is not achievable in the near term, resulting in setting a limit of 550ppm CO_2. Beyond this is unknown territory. The International Energy Agency has suggested that on current trends we are moving to an emissions scenario where 1000ppm by the end of this century is a very real possibility. Inherent within all these conclusions is a level of risk.

The two strategies available to us are mitigation (taking steps to reduce our carbon emissions) and adaptation (coping with those effects that cannot be avoided). It will be the level of engagement on local and international scales that will determine the risks of the adverse affects of climate change. While each nation will have its own individual approach, tailored to their social and economic circumstances, it will only be through an international agreement on the accepted levels of carbon dioxide in the atmosphere that the scope of response by each nation state will be determined.

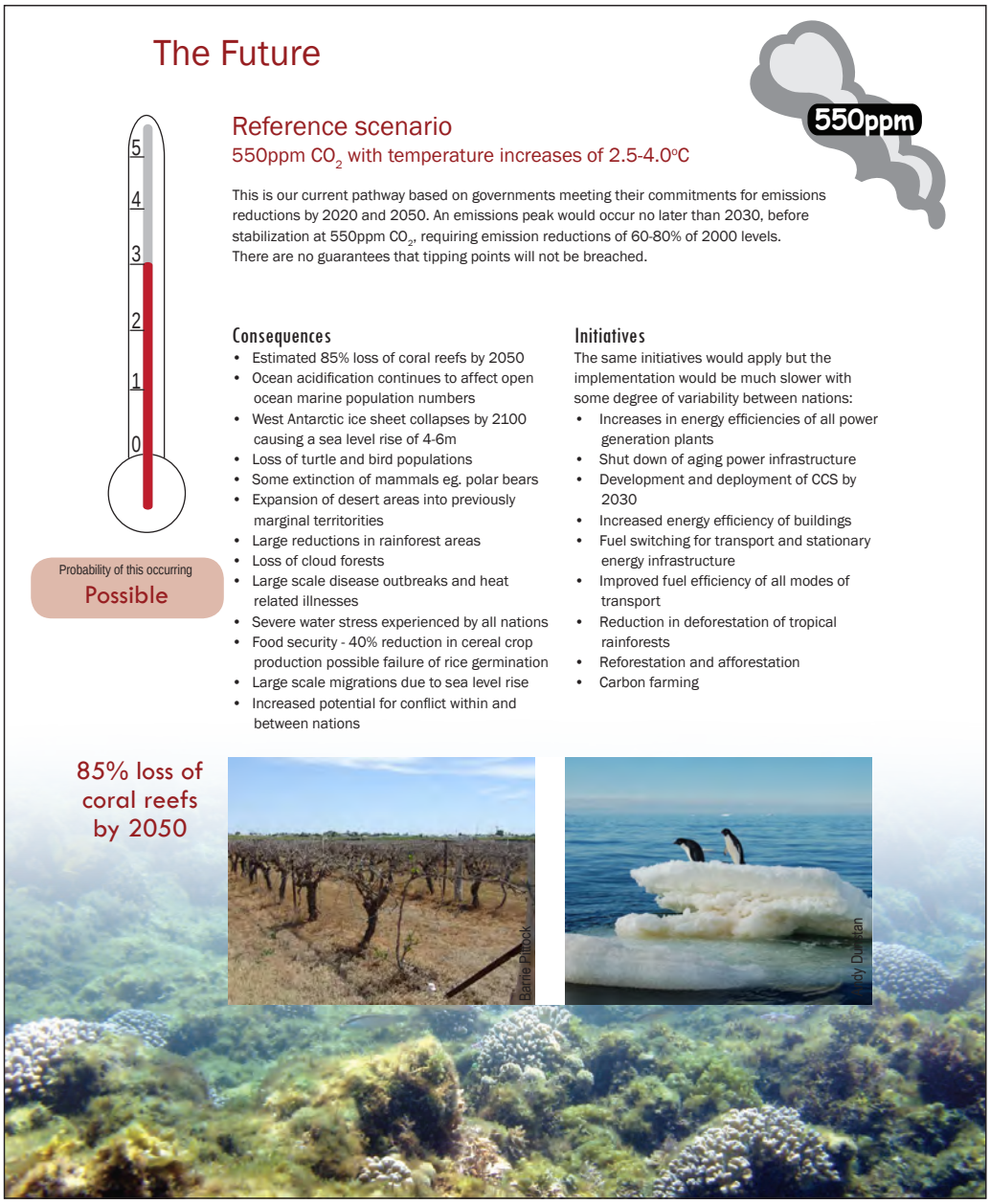
To achieve a level of stabilisation for carbon emissions at 450ppm will require nothing short of an energy revolution. Following a global agreement, all countries would need to reduce their 2000 level carbon emissions by 80-90% by 2050, with emissions peaking no later than 2015. The sheer scale of the challenge that would confront all nations makes meeting this target unlikely in the short to medium term.

To keep our reefs intact, 350ppm is suggested as the target level for a safe climate, which we have already surpassed.

Over 16,000 plant and animal species are now threatened worldwide with extinction. Polar bears, green tree frogs, corals and planktonic pteropods are under threat right now.

Classroom activity

1. During this activity you will research and create a poster on the effects a 2°C temperature increase will have on a chosen biome.
2. In a group of three choose one of the following biomes:
   Tundra
   Polar region
   Rainforest
   Deserts
   Temperate forests
   Grass and rangelands
   Marine ecosystems
   Freshwater ecosystems
3. Research the following question: What are the costs and benefits of a 2°C rise in temperature to the biome, the people who use it and the economy it helps to support?
4. Create a poster to display along side other biomes on the planet that other groups will research.
5. As a class, discuss each biome briefly and the kinds of costs and benefits climate change means.



Questions

1. State the biome you investigated and how you would be personally affected by the changes predicted there from a 2°C global temperature rise.
2. What is the relationship between developed and developing countries and the geography of the biomes?
3. List some ways of improving the resilience of biomes and the communities that they support.
4. Which regions are most likely to benefit from climate change and why?
5. Describe what tipping points are.
6. What are the factors that influence any ecosystem surpassing these points?
7. Explain ways that temperature increase magnifies and exacerbates the existing pressures within an ecosystem.
8. What are some tipping points that may be triggered within your biome?
9. How are changes within an ecosystem linked to the overall stability of an economy?
10. Discuss some of the key changes within our society that will ensure that we stay below the 550ppm CO_2 limit.

Research projects

1. Investigate the issues of food and water security.
2. Using a diagram and labels, draw what an 'energy revolution' would look like.
3. What are the social and ecological impacts resulting from the loss of one of these biomes?
4. What are the security implications of climate change?
5. How would you manage some of the situations given in the example of the future?

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Breaking Points page 148 and Safer Targets page 150)
Veron JEN (2008) A Reef in Time. Harvard University Press, London
Gore A (2006) An Inconvenient Truth. Bloomsbury Publishing, London

FishBase: A Global Information System on Fishes; www.fishbase.org
Intergovernmental Panel on Climate Change; www.ipcc.ch
United Nations Environment Programme; www.unep.org/,
Global environment outlook; www.unep.org/geo/

Adaptation

The aim of this activity is to envision how you and our communities can cope with the impacts of rapid climate change. You will create a story, from now until the year 2050, of events that have occurred that helped your community adapt to expected change.

Time

One hour

Tools

- Your imagination
- Coloured pencils
- Blank paper

Some places are more prepared for climate change than others, Lady Elliot Island, QLD, Australia.

Background

Adaptation is the process by which we as individuals and a society will increase our chance of survival in response to an altered environment. It is how people, and governments, cope with the effects of rapid climate change on both regional and local scales.

The global efforts to reduce our carbon emissions will, in all probability, still commit us to a minimum 2-3°C increase in average global temperature by 2100, leaving us no choice but to adapt. Extinctions of plant and animal species will occur, permanently altering our landscapes as deserts expand, glaciers melt and sea levels rise. A growing population of 6.8 billion people rely on these natural ecosystems to survive. The developing countries near the equator, whose incomes depend on climate-sensitive industries such as agriculture, fishing and tourism, have increased risk of disease, extreme heat and drought conditions. Given that the impacts of climate change will be unevenly distributed, specific agreements must be in place to share skills and resources across the world.

Every region will have different needs. Those living in urban coastal areas will learn to address sea-level rise, while farming regions deal with water supplies under threat due to the increased intensity and frequency of drought conditions. All adaptation measures will cost money and limits will be placed on the amounts of where,

when and how it can actually be spent. The potential for civil unrest may trigger some of the largest human migrations in history as many people become unintended environmental refugees.

The most likely trigger that will drive the large-scale changes necessary, in both mitigating our carbon emissions and the adaptation measures needed to cope, is the clear and present dangers of very real and increasingly life-threatening disruptions to our daily lives. The vast array of options and measures that are available to us now will steadily diminish with each passing year as we move towards the verge of dangerous climate change.
The legacy that the leaders of today leave behind through their decisions will be judged by those left to cope with the consequences.

Classroom activity

1. During this activity you will create a story board based on events occurring now and into the future, finishing with a headline from your local newspaper in the year 2050 that reads 'Town Saved from Climate Change threats'.
2. Imagine the events that have taken place in the world and your town for this to happen (you can imagine it as a person growing up in your neighbourhood, or as if you are a political leader).
3. Record the big events on a story board with a picture, one sentence caption and the year they take place.
4. You should include in your story:
   a. the main challenges that would face your region from rapid climate change (use the list provided as a starting point and also think up your own)
   b. large changes that have occurred to the environment, the economy and to society
   c. local and global events or ideas that might have motivated people to make big adjustments in their lives
5. When creating your story, think about the following:
   a. how people could be convinced that human-induced climate change is happening
   b. how a target for atmospheric carbon levels was reached
   c. if there are any people that are likely to migrate to or away from your area
   d. there will be an extra 3 billion people on the planet
   e. where you get your food from
   f. how energy is generated
   g. what new inventions and structures may exist

Teacher Hint
Laminate 'Adaptation measures' for use in the classroom.

Worksheet

Below are the just some of the choices that our political leaders and planners will have to confront, now and into the near future. While each category has been presented as a separate set of circumstances and the possible actions that will need to be taken into the future, it is important to remember that these situations can interact and in some cases, magnify one another. The decisions become more perilous and involve a heightening of a nation's moral, ethical and economic challenges as the impacts of climate change, coupled with other factors, begin to be felt.

Adaptation measures

Pushing against the sea

Preparing for increasing sea level and storm surges

- Planning laws and increased insurance premiums restrict coastal developments and the purchase of low lying real estate
- New building standards incorporate enhanced structural support, raised decking and water tolerant foundations or moveable dwellings
- New and high value settlements and productive land protected behind extended sea walls and dyke systems or roads are replaced by canals
- Low energy desalination plants replacing freshwater sources now contaminated by salt water
- Evacuation, relocation and assistance for low lying countries such as the Maldives and Tuvalu


Gary Braasch


Andrew Watkinson

Not a drop to drink

Preparing for drought and water shortages

- Water restrictions and higher water costs applied to all urban areas
- All industrial processes, except food production, switch to secondary water
- Desalinated seawater, recycled treated sewage water and storm water increasingly added to current drinking water supplies
- Selective abandonment of regions under severe water stress that can no longer be sustained with migrations of people towards water sources and main cities to reduce transport costs

Food on the table **Preparing for shifts in productive land**

- Improved weather forecasting services allow for shifts in planting times
- Banning inefficient irrigation practices, enforcing best farming practices and using native drought, disease and heat tolerant crop strains to improve yields
- Diversification of farm incomes through the integration of agro-forestry that support native species, reduce erosion and provide additional economic benefits through carbon capture
- Relocation of agricultural activity into more productive areas or reductions in exports and a movement towards self-sustainability


Chris Roelfsema

Adaptation measures

How's your health?

Preparing for diseases and heat stress

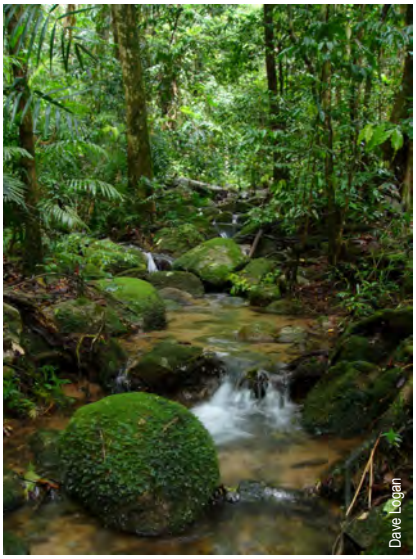
- Improvement in sanitation, education and the availability of clean, fresh drinking water for developing countries
- Increased monitoring and international cooperation to reduce the spread of tropical and novel infectious disease outbreaks
- Green-scaping cities and lifestyle changes to reduce the heat island effect and deaths due to heat stress
- Emergency response plans to deal with large scale climate induced disasters and evacuation

Infrastructure **Preparing for fossil fuel shortages and stress on infrastructure**

- Create smart power grids that switch on demand between a number of sources of energy (coal fire, nuclear, biomass, wind, wave, solar)
- Increase in resilience of road, rail and power infrastructure to prolonged temperature extremes with increased monitoring for degradation
- Deconstruction, removal and recycling of infrastructure such as power, water, sewer and communication networks for those areas that are deemed non-recoverable from the effects of climate change

Life in the corridor **Preparing for migrating species**

- Quantifying the value of forests as 'carbon reserves', assisting developing countries to reduce tropical deforestation and support for afforestation projects to reduce rates of desertification
- Establishment of large scale terrestrial and marine peace parks and wildlife corridors to enable the shift of organisms across habitat fragments and political boundaries
- Fire shelters and evacuation corridors for communities at risk from increasingly frequent wild fires



Storyboard

2010: Climate change basics and sustainability included in all schools.

Town Saved From Threats of Climate Change

Questions

1. Why do we need to adapt to climate change?
2. Predict what the most likely adaptation challenges are as a result of climate change for your community, state and country in the medium and long term.
3. Why is it important that we plan adaptation strategies?
4. Discuss what the key priorities for adapting to climate change should be, ranking these in order from highest to lowest. Justify the reasoning behind your decisions for the priorities.
5. Find out who is developing a climate change adaptation plan or project in your region and provide a summary of these activities.
6. What are the impediments that are presented to us for adapting to climate change?
7. What is mal-adaptation?
8. Discuss the risks of mal-adaptation to climate change.
9. Evaluate the potential difficulties that face political leaders in the decisions on adaptation measures.
10. How are the millennium development goals important in adapting to climate change?

Research projects

1. Are zoos and seed banks an adequate way of protecting species against climate threats?
2. Can we confidently link ecological change with social and economic consequences? Discuss, giving examples.
3. Using the Royal Society report on Geo-Engineering, assess some of the potential consequences of moving down this path.
4. Should our focus on adaptation be on simply addressing the local threats?
5. Evaluate the consequences of choosing not to adapt.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Path to Success page 186 and Changing the Globe page 222)

Millenium Development goals; www.un.org/millenniumgoals/
Intergovernmental Panel on Climate Change (IPCC); www.ipcc.ch
Shifting Baselines; www.shiftingbaselines.org
Global Change Institute; www.gci.uq.edu.au
Global Environment Facility; www.gefweb.org
Local Governments for Sustainability (ICLEI); www.iclei.org
Sustainability Street Institute; www.sustainabilitystreet.org.au
Department of Climate Change - Australian Government; www.climatechange.gov.au
Global Carbon Capture and Storage Institute (GCCSI); www.ret.gov.au
COP15 United Nations Climate Change Conference Copenhagen 2009; http://en.cop15.dk/frontpage
The Royal Society http://royalsociety.org/

Power of Us

Field, Classroom and Lab Activities

Chris Roelfsema

Contents

CoralWatch

The aim of this activity is to monitor the health of corals using the Coral Health Chart. During a reef walk, snorkel or dive you will match the colour and type of randomly selected corals to the categories on the chart, record this with water temperature and site details and plot the results. Please report real data to **www.coralwatch.org**

Time

Two hours field and two hours classroom

Teacher Hint
If you don't have access directly to the reef you can use the virtual transect.

Tools

- Coral Health Chart
- Slate
- Pencil
- Viewing tube
- Mask and snorkel
- Computer
- Internet

Branching coral

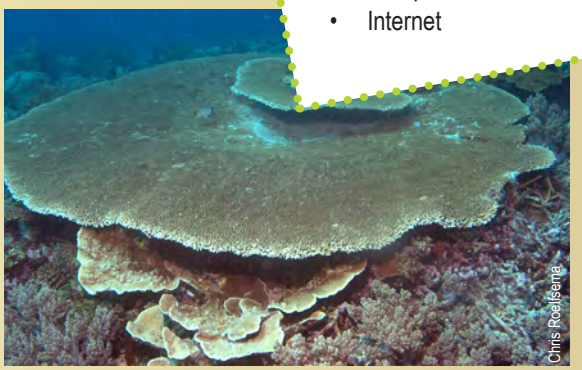


Plate coral

Boulder coral

Soft coral

Background

Classifying corals at the species level is very difficult, so easily identified groups are often used when recording data about coral cover or general coral health. For this purpose, coral types are described simply by the basic growth forms or shapes of coral colonies.

The Coral Health Chart uses four coral types to classify corals. Branching refers to any branching coral such as *Acropora* species. Boulder refers to any massive or rounded corals such as some *Platygyra* and *Porites* species. Plate refers to any coral that forms a plate-like formation such as tabular *Acropora* species, and the soft category refers to corals lacking a hard skeleton, such as the *Xenia* species.

Due to the dynamic nature of coral morphology, these categories are not strict, as there are many forms that do not fit into one of these categories. Our aim is to keep the chart and survey as simple as possible, so if you're experiencing difficulties when classifying your corals, please simply choose the closest coral type.

The Coral Health Chart

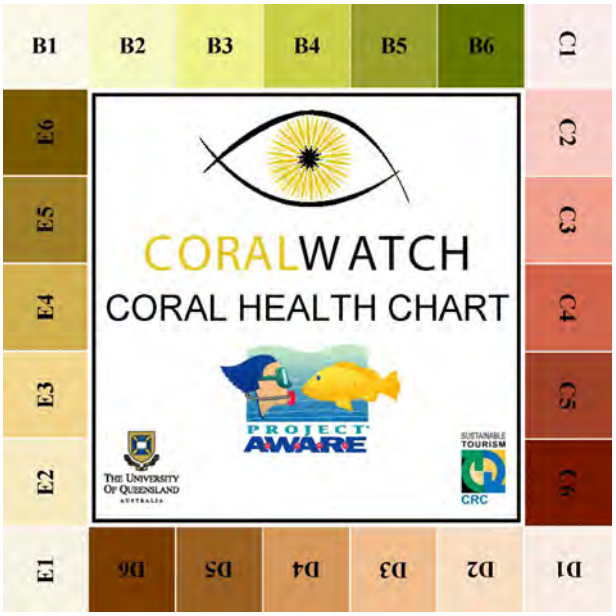
The colour charts are based on the actual colours of bleached and healthy corals. Each colour square corresponds to a concentration of symbionts contained in the coral tissue. The concentration of symbionts is directly linked to the health of the coral.

In the field, all you need to do is match the colour of the coral with one of the colours on the Coral Health Chart. You then record the lightest and darkest colour score for each coral on the data sheet provided. The lightest and darkest colours are recorded to allow for the natural colour variation within a coral. The averaged value is used during the spreadsheet and website analyses.

Waterproof data slates can be created by simply copying the data sheet onto a piece of hard white plastic. Pre-printed waterproof slates can also be purchased through CoralWatch by emailing info@coralwatch.org.
You can scratch up smooth plastic surfaces to make a better surface to write on.

If the chart is used below five metres you need to use a source of illumination, like an underwater torch, to shine on both the chart and the coral. This is to counteract the changing spectral properties of water with increased depth.

The Activity CD contains two Microsoft Excel spreadsheets that provide a range of data collection and analysis options.



Coral Health Chart

Healthy coral

Bleached coral

- The Reef Fingerprint© spreadsheet is designed to be used with randomly collected data. This spreadsheet provides a graphical and numerical summary of your data, showing information such as average coral colour scores, the percentage of different coral types and the overall colour of the reef. Detailed instructions can be found on the first page of the spreadsheet.

- The Reef Transect© spreadsheet is designed for data collected using belt or line transects, and requires additional information such as water temperature and depth. This spreadsheet therefore provides a more comprehensive analysis, i.e., information about the relationship between coral colour and water depth. Once again, detailed instructions can be found on the first page of the spreadsheet.

Once you have collected your data please remember to forward it to CoralWatch.

You can enter your data directly onto the website www.coralwatch.org or email your spreadsheet to info@coralwatch.org and we'll upload your data for you. The website also produces graphs for different reefs across the world – don't forget to check out your reef!

How to use the Coral Health Chart

Measuring coral colours on Heron Island reef flat, QLD, Australia.

Record lightest and darkest colours scores for each coral colony.

1. **Be an AWARE diver.** Be sure to secure equipment, be properly weighted and move slowly through the water in a neutrally buoyant state. Dive carefully to avoid any reef contact as reefs are extremely fragile to even the slightest touch.

2. **If snorkelling or walking alongside the coral (reef walking)**, ensure all movements avoid any contact with live coral.

3. **Select a coral.** The chart may be used with branching, boulder, plate or soft coral. It may not be used with blue/purple corals or fire coral as these do not vary during bleaching events.

   Survey methods include (depending on experience and location):
   a. random survey - select corals randomly, such as every second fin kick.
   b. quadrant or transect survey - select your corals by marking a square area or following a transect line. Make sure your markings have no affect on marine life in the area. Then assess corals within the quadrant or along the transect line.
   c. easily identified corals - select corals that are easy to identify and return to on each dive.

4. **Look down at the coral and select the overall lightest area, avoiding the tips of branching corals.**
   Due to colour loss at depth, use a torch/flashlight at depths below 5 metres/15 feet. For some corals it will be difficult to match the colour exactly. Simply pick the closest colour, paying particular attention to brightness.

5. **Hold the Chart next to the lightest area and rotate it until you find the closest colour match.**

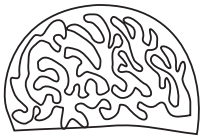
6. **Record the matching colour code and coral type on the data sheet.**

7. **Repeat steps 2 to 5 for the overall darkest area of the coral.**

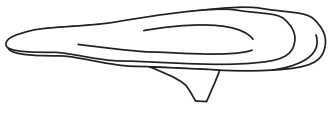
8. **Submit your data at www.projectaware.org or www.coralwatch.org.**

Coral types

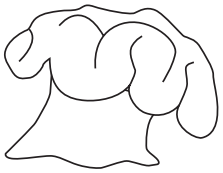
Br=Branching



Bo=Boulder



Pl=Plate



So=Soft

www.coralwatch.org

Field activity

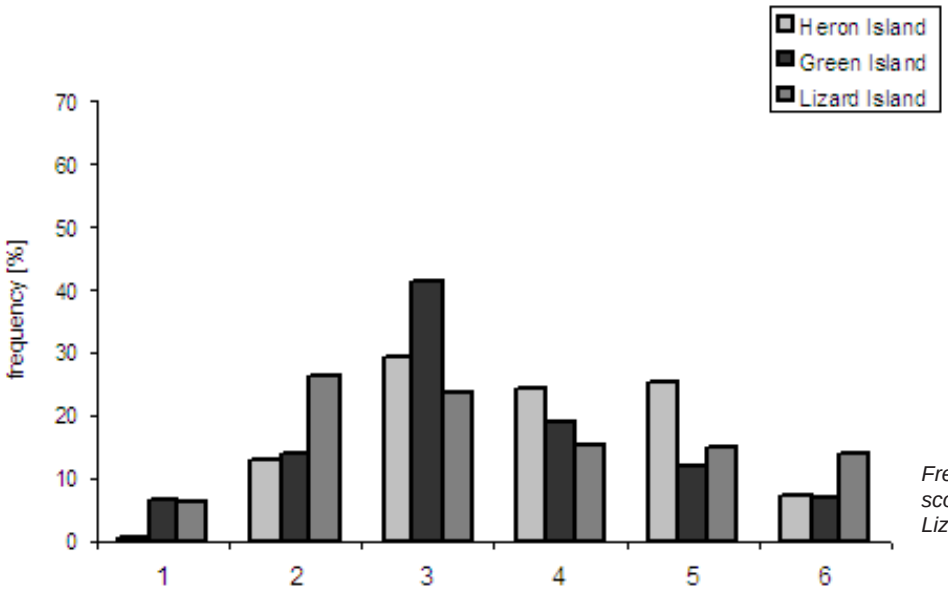
During this activity you will spend time with each type of coral and observe what is taking place on, in and around the colonies as well as measuring coral health in the area. Ensure you wear appropriate safety equipment (sun protection, enclosed shoes or booties).

1. Select an area of reef suitable for a reef walk or snorkel.
2. Locate a colony of coral, observe it for about five minutes and record:
   a. what type it is (branching, boulder, soft or plate)
   b. lightest and darkest coral colour scores for the colony
   c. a sketch of the colony
   d. a list of any other marine organism that you observe on, in and around the coral
3. Repeat this with colonies of the three other coral types (or as many types as you can find).
4. Following the instructions on the Coral Health Chart, measure the health of at least 20 coral colonies in your reef area and record the data on the datasheet or slate. You can visit several areas to compare coral health between different zones on your reef.

Coral types	
Branching	Boulder
Plate	Soft

Classroom activity

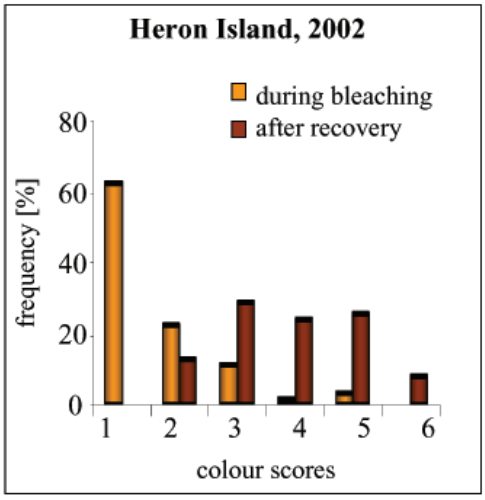
1. Enter your data into a spreadsheet supplied on your Activity CD or straight into the online database at www.coralwatch.org.
2. Take note of the graph showing coral colour score frequencies and compare it to the coral colour scores obtained by researchers on three healthy reefs during July 2002.

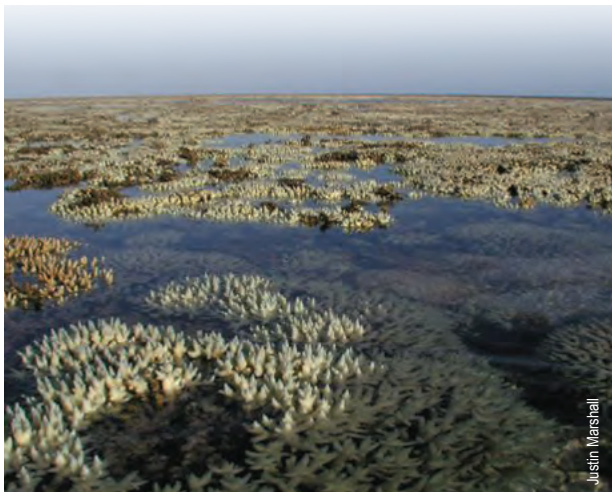


Frequency of coral colour scores at Heron, Green and Lizard Island during July 2002.

3. Use the online database and compare the data you collected to:
   a. past data on your reef
   b. a nearby reef
   c. a reef in another country

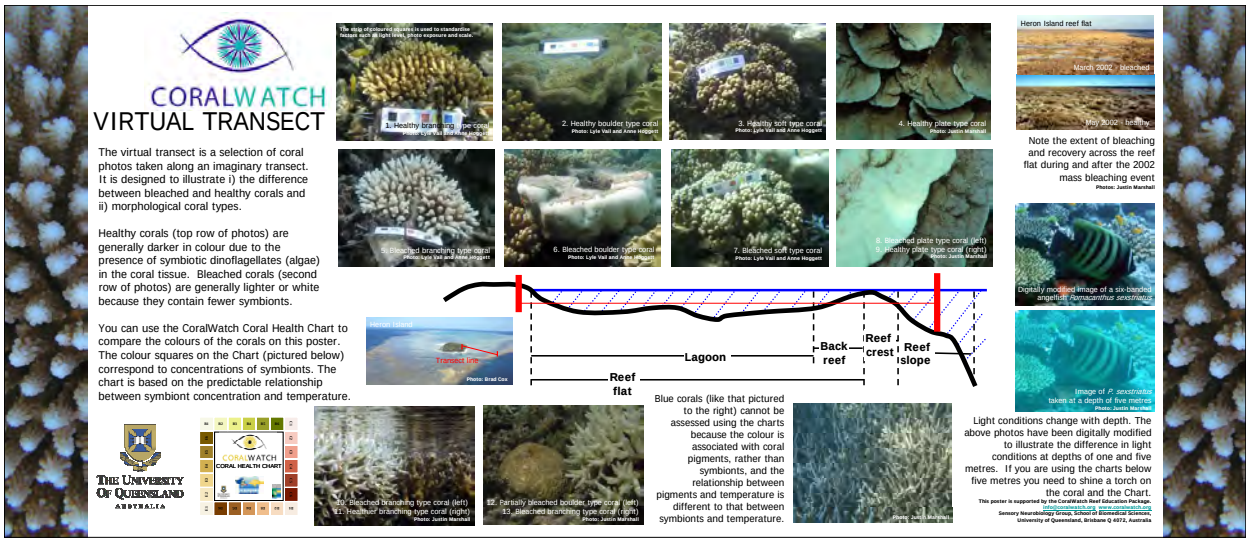
   For each, take note of the date, time, weather conditions and water temperature and whether the graphs appear similar or different from yours. Note, you may have to download the raw data for this.
4. A healthy reef would be expected to have a majority of corals with scores over 3, a few corals with scores of 2 and a very small number of corals with a colour score of 1. A reef experiencing a bleaching event has coral colour scores typically below 3. Rate the health of each of the reefs you have data for.





Classroom activity

1. In this activity you will use the Coral Health Chart to determine the health of a virtual reef.
2. Following the instructions on the back of chart, match the colours of printed coral photographs or the virtual transect poster (supplied on the Activity CD) with the colour scores on the Coral Health Chart.
   Note: that these colours will change depending on the printer used and may not represent the original colour of corals at the time photos were taken.
3. Record your scores on a data sheet.
4. Compare and explain any differences you find between the average colours of:
   a. bleached coral versus healthy coral
   b. corals observed in full sunshine versus shade
   c. corals observed through sunglasses verses no sunglasses
   d. corals on a computer screen versus printed copy



CORALWATCH

DATA SHEET

Group name: _____ Your name:_____

Email address: _____

Participation field: dive centre / scientist / environmental / school or university / tourist

Country of reef: _____ Reef name: _____

GPS if possible: _____ _____ Sea temperature:_____^{o}C

Date of survey: _____/_____/_____ Time collected: (ie.14:00 or 2pm) _____
Day Month Year

Weather: sunny / cloudy / raining Your activity: reef walking / snorkelling / diving

Coral Number	Colour Code L=Lightest D=Darkest		Coral Type Br=Branching Pl=Plate Bo=Boulder So=Soft			
example	*L: D2*	*D: E5*	*Br*	*Bo*	*Pl*	*So*
1	L:	D:	Br	Bo	Pl	So
2	L:	D:	Br	Bo	Pl	So
3	L:	D:	Br	Bo	Pl	So
4	L:	D:	Br	Bo	Pl	So
5	L:	D:	Br	Bo	Pl	So
6	L:	D:	Br	Bo	Pl	So
7	L:	D:	Br	Bo	Pl	So
8	L:	D:	Br	Bo	Pl	So
9	L:	D:	Br	Bo	Pl	So
10	L:	D:	Br	Bo	Pl	So
11	L:	D:	Br	Bo	Pl	So
12	L:	D:	Br	Bo	Pl	So
13	L:	D:	Br	Bo	Pl	So
14	L:	D:	Br	Bo	Pl	So
15	L:	D:	Br	Bo	Pl	So
16	L:	D:	Br	Bo	Pl	So
17	L:	D:	Br	Bo	Pl	So
18	L:	D:	Br	Bo	Pl	So
19	L:	D:	Br	Bo	Pl	So
20	L:	D:	Br	Bo	Pl	So

Any other relevant information, e.g. average diving depth, species of coral, pollution, long term weather such as drought, flood, heat-wave.

Any comments or enquiries.

Please use one of the following options to enter your data:
i) directly onto the CoralWatch website (www.coralwatch.org)
ii) by fax: +61 7 3365 4522 to the attention of Dave Logan
iii) by post: Dave Logan, Sensory Neurobiology Group (formerly known as VTHRC), SBMS, University of Queensland, Brisbane Queensland 4072 Australia.
Thank you very much for participating! Check our website for survey results and global bleaching trends.

Questions

1. State which coral type in your survey:

   a. was the most abundant b. was the least abundant

2. Describe how the growth form of a colony could help a coral survive against physical damage and other organisms competing for space and food.

3. What was the average colour score for each coral type?

Coral Type	Colour Score
Branching	
Boulder	
Plate	
Soft	

4. Which colour score had the highest frequency?

5. Natural variation in coral colour occurs as a result of environmental conditions. For example, elevated temperature and intense rainfall can reduce a coral's symbiont concentration, thereby affecting its colour. Check what the weather conditions were like at your location before you arrived. State any unusual weather patterns experienced at your location recently and what impact you think they had on the reef.

6. Based on the above table, which of the coral types appears to be more resilient to coral bleaching? Why do you think this is the case?

7. What is the importance of collecting baseline data on coral colours before a bleaching event takes place?

8. How would you rate the general health of the reef at this point, based on the data you have collected and analysed together with your general observations? Explain your reasoning.

9. How could your data help researchers get a more accurate picture of coral bleaching and reef health?

10. List some other features of reefs you could measure to determine their health.

Research projects

1. Explain, with the aid of a diagram, the possible effects of bleaching on the future growth rate of the reef.

2. Assume that sea surface temperatures and coral bleaching will increase in frequency and intensity over the next 50 years. What are the likely long term impacts on the marine life of the coral reefs?

3. Investigate the benefits and limitations of data collected by untrained volunteer observers.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness CoralWatch, The University of Queensland, Brisbane. (See Coral Bleaching page 128 and Changing Perspectives page 206)

Siebeck UE, Marshall NJ, Klüter A, Hoegh-Guldberg O (2006) Monitoring coral bleaching using a colour reference card. Coral Reefs 25:453-460 (supplied on CD)

Veron JEN (2000) Corals of the World. Australian Institute of Marine Science, Townsville

CoralWatch, www.coralwatch.org

Project Aware Foundation; www.projectaware.org

Reef Check - Saving Reefs Worldwide; www.reefcheck.org

Reef Check Australia; www.reefcheckaustralia.org

The University of Queensland, Australia; www.uq.edu.au

Reef Management

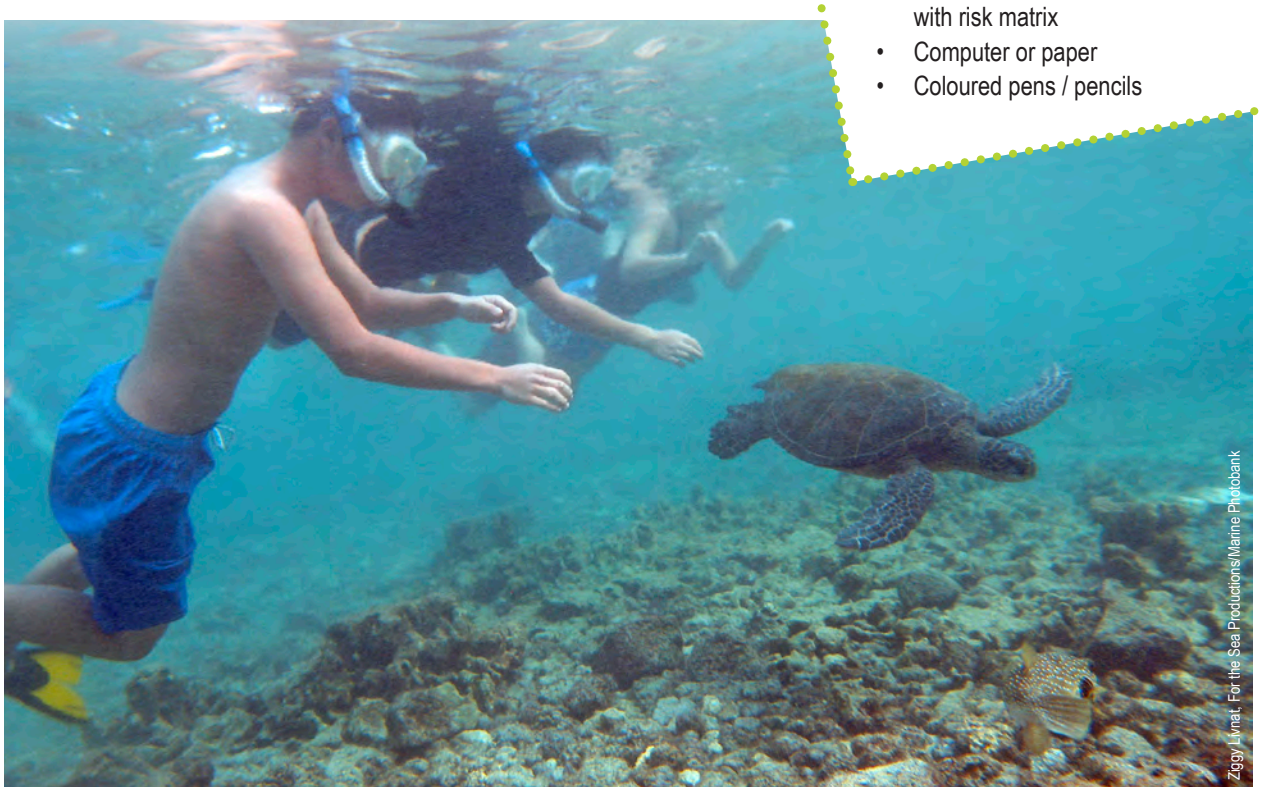
The aim of this activity is to develop and present a code of practice for visiting the reef and discuss the practical implications of its implementation. Imagining yourself as a reef manager, you will create a brochure or presentation including a short promotion of your reef, main activities for visitors and best code of practice you should follow in order to protect yourself, others and the reef environment.

Time

Four hours

Tools

- Risk assessment worksheet with risk matrix
- Computer or paper
- Coloured pens / pencils



Snorkeling tourists attempt to touch a protected green sea turtle.

Background

The millions of people visiting and working on reefs can benefit or degrade reefs, depending on how they behave. Reefs need effective management to remain resilient to existing and predicted disturbance. Reef managers and business operators on reefs are responsible for developing, communicating and enforcing best practices for reef visitors.

It makes sense to follow advice that will keep us safe and to look after the things we value. Look out for strong currents before swimming, wear a helmet when riding your bike, don't text while driving, don't feed the birds, apply immediate pressure to a bleeding wound. These are tested ideas (some enforced by law and some not) recommended to protect people, assets and the environment. When several ideas are written around a theme, such as tourism, they form a code of practice, or best practice.

Many reefs are only visited temporarily by tourists or researchers. Ecotourism is a way of protecting environments when travelling to them. Ecotoursim follows specific codes of practice to conserve the environment and improve the well-being of local people in natural areas through responsible travel. These practices should minimise impact, build environmental and cultural awareness and respect, provide positive experiences for both visitors and hosts, provide financial benefits and employment for local people and raise sensitivity to the host country's political, environmental, and social climate.

Classroom activity 1

In this activity you will develop a risk assessment for specific reef related activities in the field and in the lab. Complete the risk assessment worksheet provided, or one your school / group already own.

1. List at least eight activities you would do during a field trip to a reef.
2. Identify the main hazard involved with each (any situation that poses a level of threat to life, health, property or the environment).
3. Calculate the risk involved using the risk assessment matrix.
4. List the specific control measures you could use to bring each risk to acceptable levels.
   These can include:
   a. getting rid of the hazard or risk (e.g. the activity should not be done)
   b. replace with something less harmful (e.g. an alternate activity or method)
   c. separate people from the harm (e.g. keep a distance or restrict access)
   d. change behaviour or the physical environment, (eg re-designing equipment, change locations or timing, add warning signs)
   e. apply administrative arrangements (e.g. limit entry or time spent in a hazardous area, ensure immediate access to first aid kit)
   f. use personal protective equipment (e.g. foot protection or sun smart gear)

Risk assesment matrix

Consequence / Likelihood	One minor injury **Negligible**	One severe injury or multiple minor injuries **Marginal**	One death or multiple severe injuries **Critical**	Multiple deaths **Catastrophic**
Certain	High	High	Extreme	Extreme
Likely	Moderate	High	High	Extreme
Possible	Low	Moderate	High	Extreme
Unlikely	Low	Low	Moderate	Extreme
Rare	Low	Low	Moderate	High

Risk assesment table

Fieldwork activity	Hazards	Risks	Control measures to bring risk to acceptable levels
Snorkelling	Drowning	Moderate	Boat support
Collecting samples			
Reef walking			
Lab work			

Day tourism to the outer reef from Cairns, QLD, Australia.

Classroom activity 2

1. During this activity you will develop a brochure or power point presentation of best practices for reef visitors.
2. Identify the main activities reef visitors are likely to be involved in.
3. For each activity list 3-5 things people should do to keep themselves and the reef safe. Remember to think about how reefs may change throughout a year (e.g. some areas may need to be avoided during breeding seasons or evacuated during cyclones).
4. In your project you should also include:
   a. a brief description of the reef (location, size, access, accommodation)
   b. points of interest and importance (special wildlife or events, why this reef is important)
   c. local threats to the reef
   d. current protection status (is it a marine park, who owns or looks after it?)
   e. who is responsible for enforcing these practices and penalties that apply
5. Think carefully about the length, order and layout of your project to best communicate the code of practice you have developed. Devise a communication strategy of where you would provide details of the code of practice to reef visitors.

Field activity

1. For several or all of the activities you and your group are involved in, you will observe reef visitors (usually your classmates) and make a note of how a code of conduct was followed (or not) for each activity.
   a. pay attention to how the code of practice was communicated
   b. think about the consequences, for visitors and the reef, of following the code

Questions

1. What were the most typical things you saw, or expect would happen, in breach of the code of practice on reefs?
2. List some difficulties involved in establishing a code of practice for people visiting the reef.
3. Describe how you determined what was most important to include in the code?
4. What are some other methods you could use to choose what sort of activities should be included in a code of practice?
5. How can you minimise the following:
    a. anchor damage
    b. diving
    c. dynamite fishing
    d. coral bleaching
6. How would you enforce any regulations you put in place?
7. Who is currently responsible for this on the Great Barrier Reef? In the Maldives? On your local reefs?
8. What are some other methods you would use, as well as a code of practice, to minimise threats to reefs?

Research projects

1. Present a case study on a local natural area that is currently being protected through best practice.
2. Investigate two ecotourism accreditation programs available and how tourism operations benefit from having accreditation.
3. How much money should reef visitors have to pay towards conservation and management (if any), each time they visit? Justify your answer.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Importance of Coral Reefs page 82 and State of the Reefs page 122)

GBRMPA (Best Environmental Practices); www.gbrmpa.gov.au
World Tourism Organisation; www.unwto.org
Ecotourism Australia; www.ecotourism.org.au
Project AWARE; www.projectaware.org
Reef Resilience; www.reefresilience.org/Toolkit_Coral/C1_Intro.html

Zoning Plans

The aim of this activity is to transfer what you have learned from the reef environment and examples of marine zoning plans to assist you in developing a zoning plan for a local ecosystem. You will present your plans in a stakeholder discussion group and need to justify your decisions based on science and negotiation.

Time

Four hours (two hours field, two hours classroom)

Tools

- Your observations / research on the reef or a local ecosystem, including: human uses, animal and plant populations, seasonal changes
- Coloured pencils
- Current management / zoning plan of the reef or area you are studying
- Butcher paper
- Coloured markers
- GPS
- Map of local ecosystem (or materials to sketch one)
- Existing management plans for that area

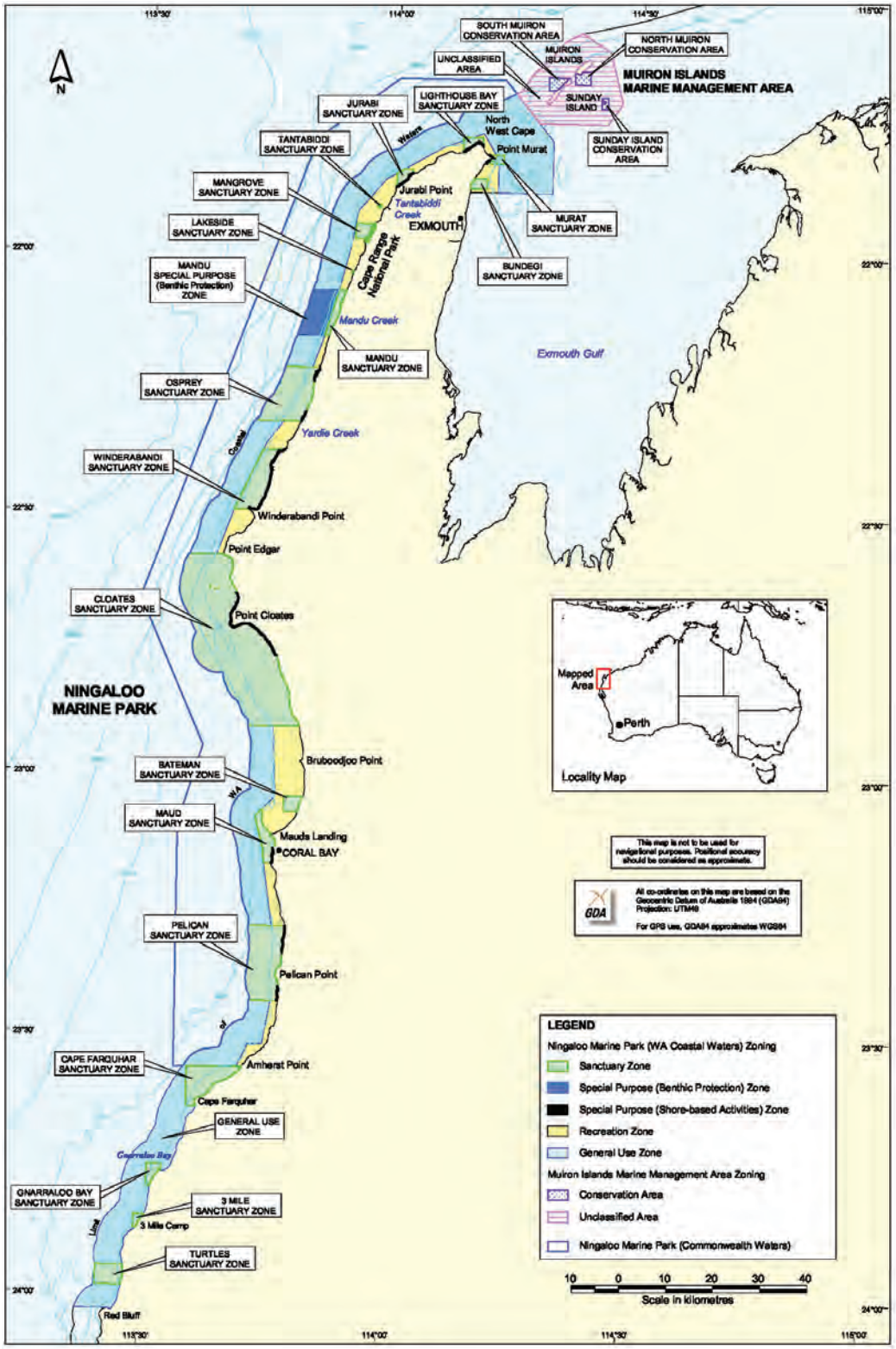
Background

Environmental zoning plans are developed through negotiation to satisfy user needs and lifestyle choices while protecting important landscapes, habitats and species. They are created from a mixture of scientific investigation and political negotiation, governed by economic rationale as well as cultural and social expectations.

The Great Barrier Reef (GBR) Marine Park is a multiple-use area covering 344,000km^2 of one of the natural wonders of the world. Zoning plans define where activities such as tourism and recreation, research, commercial activities and fishing can occur or be modified to both protect the environment and support vital social and economic needs and benefits. Zoning in the GBR was developed following extensive research and community consultation, and revised in 2004 with a dramatic increase in green, or 'no-take', zones from 5% to 33% of the park. The plan was developed using complex computer models to determine representative areas of connected habitat to conserve and to assign multi-use areas.

Classroom activity

1. Use an online search engine to find a Marine Protected Area with an existing zoning plan. The Great Barrier Reef and Ningaloo Reef provide two Australian examples.
2. List the zones that are represented in this area.
3. For each, list the activities which are allowed.
4. Share the various zones you have found with the rest of your group and select the ones you will use in a zoning plan for your local area.



Zoning map Ningaloo Reef, WA, Australia.

Source: Western Australia Dept of Environment and Conservation

Field activity

1. As a group, select a suitable accessible area of river, lake, forest or bushland, reef, beach or any other habitat to create a zoning plan for. You could even make it an urban environment, such as a local park or school grounds.
2. Visit the area, taking note of different zones or habitats within it (e.g. river, estuary, forest, clearing). You may want to use a GPS to mark important areas if you have access to GIS software.
3. Make a copy or draw a map of the area and mark on it different habitat types and landmarks.
4. Mark on any known important historical or cultural features or areas set aside for special activities.
5. Include any known significant or vulnerable species or habitats.

Classroom activity

1. As a group, discuss the importance of this area to local wildlife, as well as people, and come up with a short list of conservation goals, be it preservation, improvement, expansion or development of existing areas. You may consider how this system interacts with others nearby and the possibility of wildlife corridors that link different areas.
2. List the existing or potential users of the area. Designate someone to write each one on a separate small piece of paper. Once the list is completed, place all users into a hat or box.
3. Individuals should randomly select a user from the pile. Pretend you are that user and consider:
   a. how you and people you represent would like to use the area
   b. your needs and expectations
   c. plans for the future
   d. power within the community
4. Devise two main outcomes you would like from a zoning plan. Write the user group you belong to and your desired outcomes in large clear writing on a piece of paper.
5. On a blank map, mark at least one area of significance to you (as that particular user) and designate a suitable zone for that area.
6. Write two instructions for that particular zone (e.g. limited crabbing in the Conservation Park (Yellow) Zone by restricting the number traps to four per person).
7. Create a rough plan of other zones with which you will negotiate with the rest of the group. Include multi-use, no-take, scientific and preservation zones (or ones you have decided on from the previous activity).
8. In groups made of the different users, negotiate a new zoning plan for the area.
   a. take turns presenting your two main outcomes you want to see
   b. now mark down your significant zone on a group map (each user should use a different colour for this part). It is ok if some overlap (these may become multi-use) but if they are conflicting activities you may have to negotiate
   c. write the name of each user group on the map and display your final zoning plan on the wall to compare with others
9. Make a sign to protect wildlife in your area.

Teacher Hint
Students can work together in user groups.

Sign to protect dugongs in Moreton Bay, QLD, Australia.

Questions

1. State the main things you considered when choosing your outcomes.
2. List any considerations other users had that you did not.
3. What are some challenges you faced in the negotiation?
4. Did you come to an agreed zoning plan? Identify why or why not (e.g. two users had opposite needs, one person dominated discussions, etc.)?
5. What infrastructure (buildings, pathways, signs, etc.) would you put in place to aid in promoting correct use of zones?
6. List five benefits of the zoning plan and for whom they occur.
7. Which groups (fishers, tourist operators, reef visitors, etc.) does your final plan disadvantage and why?
8. What challenges exist for natural resource managers in establishing and maintaining the zoning plan for your region?
9. Who do World Heritage Areas belong to and who is responsible for managing them?

Research projects

1. Formulate an argument for or against the following statement: An area where no one is allowed to visit is worth less than a place you are allowed to go. (Think about values other than just money.)
2. Create a timeline and document the process that took place in establishing an existing zoning plan of your choice.
3. Devise a strategy that allows tuna fishers in the Coral Triangle to sustainably supply fish to a growing world population.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness, CoralWatch, The University of Queensland, Brisbane. (See State of the Reefs page 122 and Collaborative Effort page 214)

Coral Triangle Initiative; www.cti-secretariat.net

Great Barrier Reef Marine Park Authority (GBRMPA); www.gbrmpa.gov.au

WA Department of Environment and Conseration; www.dec.wa.gov.au/marine/marine-conservation/approved-management-plans.html

Pushing Past Our Complacency

The aim of this activity is to explore effective ways of delivering key messages about climate change. You will create a 30 second televison advertisement with a script, voice over, images and sound to connect with a chosen audience and convey your opinions and beliefs, backed with data, on the threats climate change poses to reefs, our environment and ourselves.

Time

Four hours (one hour field, three hours classroom)

Tools

- Script writing worksheet
- Computer
- Sound recorder, digital camera or video camera
- Garage band, powerpoint or similar media software (if available)

Think differently, live differently

Background

In western societies we seem to have lost touch with what is natural. The sum total of many of our experiences with the environment is often limited to the popular wildlife documentaries we watch on television. We shelter from the elements, with nature, even in its diminished form, seen as an inconvenience, something that needs to be placed at the margins of where we live and replaced with gardens and lawns that require a minimum amount of maintenance. To move past complacency in the face of climate change we need a wake-up call that reconnects us with the environment and the immediate realities of our changing world.

Our desensitisation towards the natural world leads us to the misconception that climate change is solely based on changes in our local weather patterns, when in fact, the greatest impact is on the ecosystems which support and sustain us. This disconnection is reinforced by the fact that greenhouse gases cannot be seen, touched or tasted. Many look at the issue of climate change and see the problem as just too big, happening on timescales that span beyond our own lifetimes. The projections which look at the years 2030, 2050 and 2100 are hard to comprehend for a global society that lives within the land of the instant. For the majority of people, it is easier to accept, or at least expect their governments to solve the problem rather than believing that an individual can make a difference. Governments, on the other hand, have delayed action simply due to lack of empirical data and the unpalatability that some of the solutions will have on their respective economies.

When this is coupled with the embedded belief that engineers and scientists will find the solutions to prevent the harsher elements of climate change from occurring, we sit, we wait and we watch the news on the latest findings of its effects.

Classroom activity 1

During this activity you will create a 'wake-up call', in the form of an advertisement, focused on what you feel is important for others to know about our environment and climate change.

1. Choose one key message you would like to share as your wake-up call.
   a. think of what has shaped your views and make a locally relevant example (if you are undecided, perhaps it is an advertisement on how to get informed)
2. Select an audience you would like to speak to (be creative, it could be your younger brother or sister, a bike club, students in another country, unemployed people, celebrities, the super wealthy).
3. Write a script with suggested images to accompany the words. Think of images you will be able to create or photos you could take in your local area.
4. Practice speaking it out loud with another person.
5. Trim what you've written so it can be read out loud in a specific number of seconds. You will only have time to speak between 90-100 words, so make them all count.
6. Look on the Activity CD to see if there are any models or photos that you can use.

What is your key message (one sentence):

What is a slogan for your message (a few words):

Who is your target audience:

Script: Write five sentences using language relevant to your audience. Begin with your most meaningful statement. Make sure it is something you truly believe and it is something the audience will care about. Include specific facts and end with a memorable concluding remark.

Tips: Saying more in fewer words is the key to holding people's attention.
Add photographs or illustrations to reinforce your words.

Field activity

1. During this activity you will capture extra images (and sounds if possible) from your local environment that will best convey your key message in your advertisement.

Classroom activity 2

1. Use garage band, powerpoint or similar software to create an electronic advertisement, or act one out in real life.

Script writing worksheet

Transfer your script to the words columns to time your advertisement and write notes on when you will use the other materials in your production.

Quotes, Sound, Video, Stills, Graphics	Words			Time
				1 sec
				2
				3
				4
				5
				6
				7
				8
				9
				10
				11
				12
				13
				14
				15
				16
				17
				18
				19
				20
				21
				22
				23
				24
				25
				26
				27
				28
				29
				30

Questions

1. List some events that have shaped your thinking on climate change. They could include natural events, visits to places, conversations, shows, books, movies, etc.
2. During what kind of show or event would you run your advertisement? Justify your answer.
3. How could the time of the day or year affect the impact of your advertisement?
4. What is it about your advertisement that makes it stand out?
5. What is the main outcome you wish from your advertisement?
6. What are some other outlets for your message?
7. Explain in your own words the role of advertising and mass media in the climate change debate.
8. Identify some companies or groups who you believe would likely use your advertisement campaign or a similar one.

Research projects

1. Using examples from websites, reports and fact sheets, describe the key message your government is sending out about climate change.
2. Define 'greenwashing' and explain how it reduces our ability to address climate change and other issues.
3. Write a case study on an advertising campaign that has had a significant change on society.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland. (See You are the market page 194 and Community input page 198)

BBC news; www.news.bbc.co.uk
Australian Conservation Foundation (ACF); www.acfonline.org.au
We Can Solve It; www.wecansolveit.org
World Wildlife Fund; www.worldwildlife.org
The Nature Conservancy; www.nature.org

Future Guardian

The aim of this activity is to design, and hopefully implement, a change in your school or organisation that will benefit reefs. You will select a specific service, facility or activity (or develop a new one) in the school community that you believe could be made more sustainable. By doing this you can gain an appreciation of how change takes place and is influenced by people and the system it occurs in.

Time

Three hours

Tools

- Blank Paper
- Coloured pens / pencils
- Internet access

Chris Roelfsema

Background

Schools can do a lot to ensure that your future and that of the reef is a good one, through what you learn and also how you behave. A good idea can come from anyone in the community, including you. Sustainable projects for schools should include staff, students and parents in decision-making, whole school participation in activities, partnerships with other groups in the area, inclusion of sustainable ideas in different subjects (maths, history, english, etc.) along with school resources and grounds management that reduces the school's ecological footprint. They should also be measured and require monitoring to see if the project is successful in changing things for the better and celebration of school's achievements, so a party or festival or two will be necessary.

Schools and students are often key multipliers of change, with messages spreading through whole communities. Successful projects that help the reef could include activities that increase environmental awareness and stewardship in all school units, learning about local surroundings and their relationship with reefs (and other ecosystems) as well as different community members and groups, setting examples and working with other schools in catchment care and monitoring of water, waste, energy and biodiversity. Some examples of on-ground projects may include cleaning up local hotspots, revegetation, permaculture gardens, initiating a plastic-free community program or work with Landcare / Coastcare groups and natural resource management bodies to implement long-term programs. Community members could be invited to participate via newsletters, brochures, fetes and fun days, presentations and documentaries or direct visits with farm, home or business owners or government representatives in your area.

Classroom activity

1. In this activity you will design a project plan including:
   a. a specific project goal (e.g. reduce the amount of light spilling from the school onto a beach where turtles are nesting, or increase the number of people riding their bikes to school to reduce carbon emissions)
   b. the steps you would take (in a logical order) of creating change
2. In small groups formulate a single goal that is SMART:
   - Specific: Clear to anyone that has a basic knowledge of the project
   - Measurable: Know if the goal is obtainable and when it will occur
   - Agreed Upon: Agreement with all the stakeholders what the goals should be
   - Realistic: Within the availability of resources, knowledge and time
   - Time Based: Enough time to achieve the goal, but not too much to lose motivation
3. Put your project goal in the middle of a blank sheet of paper and write down all the ways you can think of to make this happen (think really outside the box). This is where you can get creative, use colours and pictures to show your ideas.
4. Separate your ideas into the categories outlined in the Factors of Change table and next to each one write down who is responsible for making it happen. (Draw your own table similar to the one below).
5. Now complete your project plan, including a time line and list of resources you will need to make it happen.

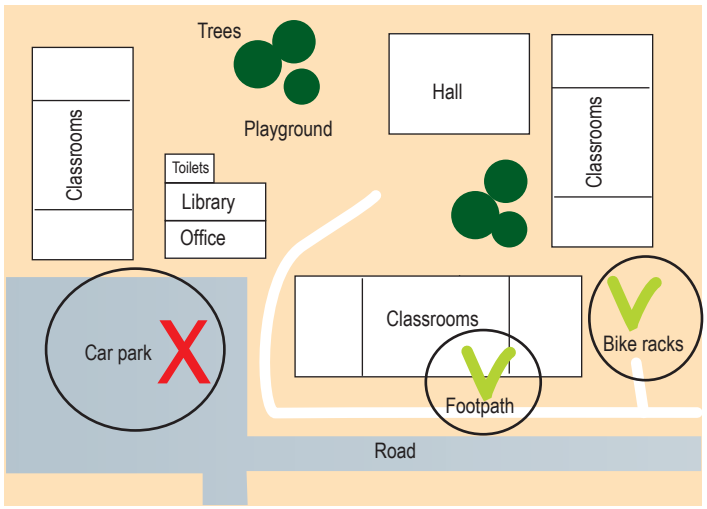
Factors of change

Infrastructure (things that could be built or developed such as buildings, tools, software, manuals) • Solar panels • Website with student stories of how they are reducing energy at home • Signs on light switches saying 'turn me off'	**Regulations** (things that can be enforced such as laws, rules, codes of conduct) • New rule in student handbook about computers being turned off • Fines for leaving lights on
Incentives (things that encourage people to be involved such as prizes, gifts, rewarding experiences) • A prize for the best photo in a photo competition • The chance to spend a day cleaning a local beach, not in the classroom	**Education** (things that people should know about to raise their awareness on the issue sent via e-mail, brochure, website, word of mouth, sky writing etc.) • How do I buy a solar panel? • How is overconsumption of energy impacting the reef

ACTION	WHO	DUE DATE	RESOURCES
Infrastructure			
Regulations			
Incentives			
Education			

Field activity

1. In this activity you will research and audit one aspect of your school, work or home environment. You can choose from the following list or come up with one of your own:
   - Transport
   - Biodiversity
   - Electricity
   - Food
   - Waste
   - Water
   - Curriculum
   - Administration
2. Draw or copy a map of your chosen area, as if you are looking from above (e.g. a room, building, grounds, parking lot or whole complex).



3. On the map, mark down significant objects, doorways, roads etc.
4. Draw circles around areas significant to the aspect you are auditing (e.g. Transport – circle bus stops, car parks, roads, walkways, bike racks etc.).
5. Draw ticks to indicate which of these areas are more sustainable (e.g. bike racks get a large tick as bikes produce no pollution, bus stops a small tick as they reduce emissions)
6. Draw crosses to indicate which of these are less sustainable (e.g. car parks and roads as they produce more emissions).
7. The sustainability of each aspect depends on how it is being used or managed by people. How many people are choosing an activity with less environmental impact or emissions. Decide how you will measure the sustainability of the aspect you are auditing (e.g. number of bikes at school in a day, ask for a show of hands who has driven in today versus taking the bus). Auditing tools are available online to provide ideas or existing worksheets.
8. Take photos as well as specific measurements. You can do a single measurement or repeated measurements over a few days or longer time frame.
9. Interview members of the school community for their opinions on how sustainable your school / workplace is with respect to the aspect you are auditing.
10. Share your findings in your school newsletter.

Questions

1. Write one change that has occurred, involving more than one person, that you have helped make happen. (e.g. your family got a new dog or car, your sports team has decided to wear more sun protection, your band has decided to take on a new member).
2. What sustainable activities are taking place in your school community that are helping the reefs?
3. How would you document and report your project? Be creative.
4. How would you involve the whole school community?
5. List three methods you would use to communicate the message.
6. How would you know your project has been successful?
7. Who do you think would be interested in giving your project money or assistance (think about local business, government agencies)?
8. What change would this cause outside of the school grounds?
9. Who is responsible for making change occur?
10. List five things you can do to reduce your environmental impacts:
    a. at home
    b. at school
    c. at the shops

Research projects

1. Investigate what sustainable projects other schools are doing nearby.
2. Outline the requirements and benefits of becoming a reef guardian school.
3. What are the social costs of climate change?
4. Comment on if it is fair that developed countries impose emission targets on developing nations.

References

Reid et al. (2009) Coral Reefs and Climate Change: The guide for education and awareness. CoralWatch, The University of Queensland, Brisbane. (See Daily Life page 122 and Bridging the Gap page 214)

AUSMEPA; www.ausmepa.org.au
Australian sustainable schools iniative; www.environment.gov.au/education/aussi
Coral Reef Alliance; www.coral.org
Sustainable schools UK; www.teachernet.gov.uk/sustainableschools/
Reef guardian program; www.reefed.edu.au
The WWF Climate Change Team; www.worldwildlife.org
Scientists in Schools; www.scientistsinschools.edu.au
Australian Marine Conservation Society; www.amcs.org.au

Act Now

for our future

Coral Reefs and Climate Change Workbook

The teaching ideas in this workbook will give you the tools in the field, lab and classroom to help in a global effort to preserve reefs and raise awareness of our changing climate. The individual and group activities can be performed using resources provided on the activity CD including a CoralWatch instructional video, monitoring kits, articles, Reef Life ID charts and a virtual reef poster.

Ocean Environment
How does the ocean support life?
What keeps ecosystems connected?
How do we monitor oceans?

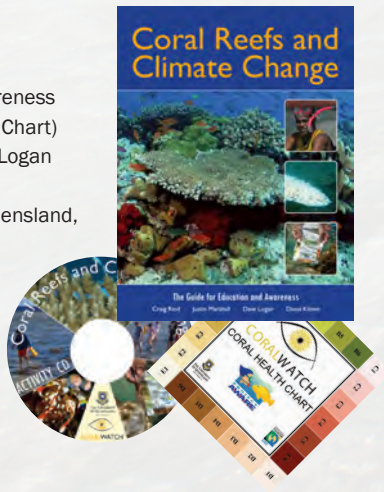
Coral Reefs
What makes a healthy reef?
Why are coral reefs so important?
How can we improve their resilience?

Climate Change
How is our climate changing?
What are the consequences?
How will we adapt?

The Power of Us
What actions can you take?
How do we address global problems?
How can we protect our local areas?

This workbook accompanies:

Coral Reefs and Climate Change
The Guide for Education and Awareness
(incl. Activity CD and Coral Health Chart)
Craig Reid, Justin Marshall, Dave Logan and Diana Kleine
CoralWatch, The University of Queensland, Brisbane, 2009, PB, 256 pages



This book is available from:
CoralWatch, The University of Queensland, Brisbane, QLD, Australia

www.coralwatch.org

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CORALWATCH

PROJECT AWARE
www.projectaware.org