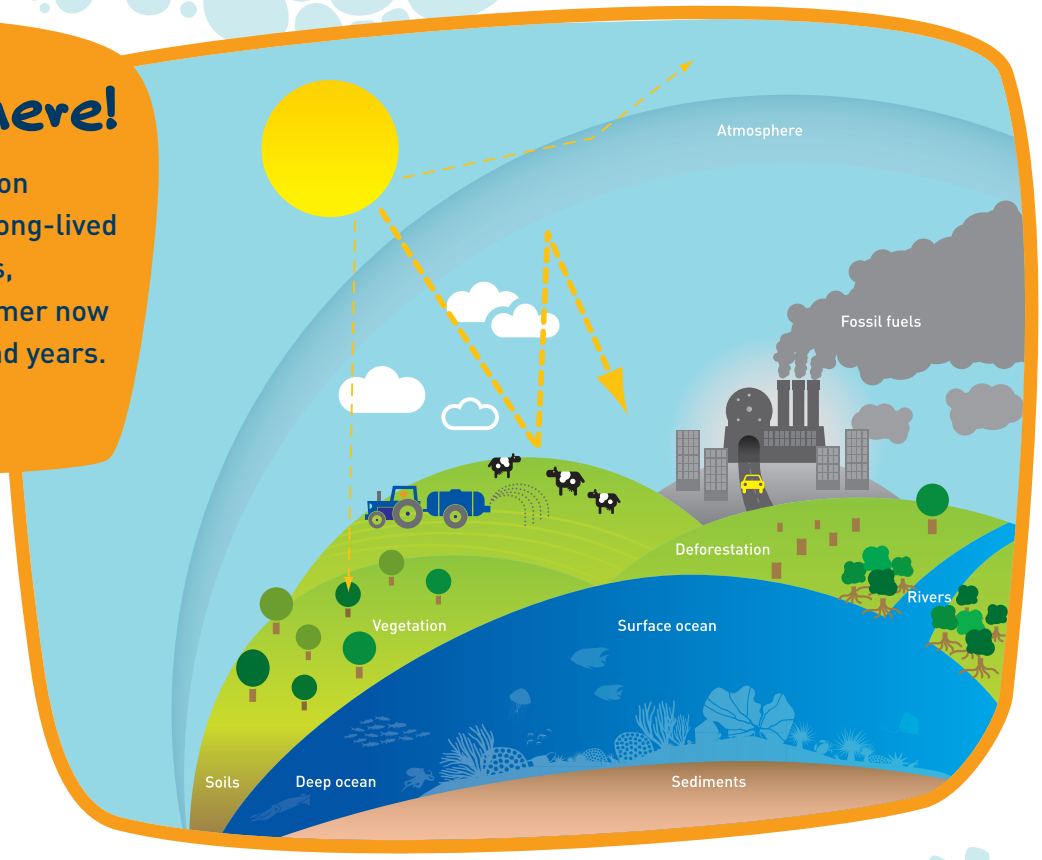
What is climate change?

Climate change and the Reef

It's getting hot in here!

The Earth's climate is warming. Based on information collected from tree rings, long-lived corals, and bubbles trapped in ice cores, scientists can tell that the world is warmer now than it has been in more than a thousand years. This trend is called climate change.



The greenhouse effect...

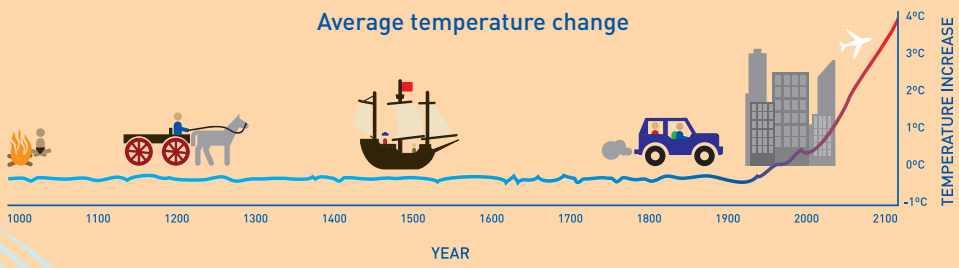
Our planet is naturally warmed by a phenomenon called the greenhouse effect. Water vapour, carbon dioxide, methane and other greenhouse gases have been present in the Earth's atmosphere for millions of years. Gases in the atmosphere act like a blanket around the Earth, trapping heat from the sun and keeping our planet warm.

We're driving climate change

We rely on the greenhouse effect to keep the Earth at a temperature suitable to sustain life. However, human activities like burning fossil fuels such as coal, gas and oil and clearing forests are causing greenhouse gas concentrations to rise above natural levels. As the blanket of gases surrounding the planet thickens, more and more heat from the sun is trapped within the atmosphere, slowly heating up the Earth and seas.

Our planet is continuing to warm. The past decade was the warmest on record and the amount of carbon dioxide in the atmosphere is higher now than at any time in the last 420 000 years.

While dramatic changes in global climate have occurred before in the Earth's history, human activities are causing our climate to change faster than ever before – and this will mean big changes for us.



What makes carbon dioxide?

- Burning living things like trees makes carbon dioxide.
- Burning fossil fuels like coal, petrol or natural gas (this is how we create most of our electricity) releases carbon that has been stored underground for many millions of years.
- Humans and other animals make carbon dioxide when breathing out.
- Plants use up carbon dioxide so cutting down forests means more carbon dioxide ends up in the atmosphere.

Climate change is happening now and it's time for us all to take action.

Feeling the heat

We are already seeing changes caused by climate change. Glaciers are melting, severe storms and droughts are more frequent, and plants and animals are being forced from their habitat.

- The average temperature of the Earth's surface has risen by 0.6˚C over the last 100 years and small changes in average temperature mean big changes in weather.
- The number of category four and five cyclones has nearly doubled in the last 30 years.
- At least 279 species of plants and animals are moving closer to the poles in response to our warming climate.
- The flow of ice from melting glaciers in Greenland has more than doubled over the past decade.

Climate vs weather

Climate change is causing changes to weather conditions worldwide.
But what's the difference between weather and climate?

Weather: short-term changes in the atmosphere (like rain, snow, sun or thunder and lightning).

Climate: the average weather in a location over a long period of time (a place that doesn't get much rain over many years would have a dry climate).

Australian Government
Great Barrier Reef Marine Park Authority

REEF Beat 1

Coral bleaching

Climate change and the Reef

Corals under threat

Corals are the building blocks of coral reefs. Without corals, the reefs we know today would not exist.

Corals are very sensitive animals. They live in clear, warm waters and survive best in stable conditions. Temperature increases of just a couple of degrees can cause corals to become stressed and bleach. If ocean waters stay too warm for too long, bleached coral may die. Warmer waters caused by climate change are threatening the future of corals and coral reefs.

Life's a bleach!

Without their zooxanthellae, bleached corals begin to starve. If temperatures return to normal quickly enough, the corals can recover but if temperatures remain high for six to 12 weeks, the corals may die.

Imagine the reef with no colour

Coral bleaching is a stress response

The brown colour of this healthy coral is due to microscopic algae called zooxanthellae (pronounced zoo-zan-thel-ee) that live within its tissue. Corals have a special relationship with the algae (called a symbiotic relationship). The coral gets up to 90 per cent of its food from the algae and the algae gets a safe place to live. Zooxanthellae give corals their rich colours.

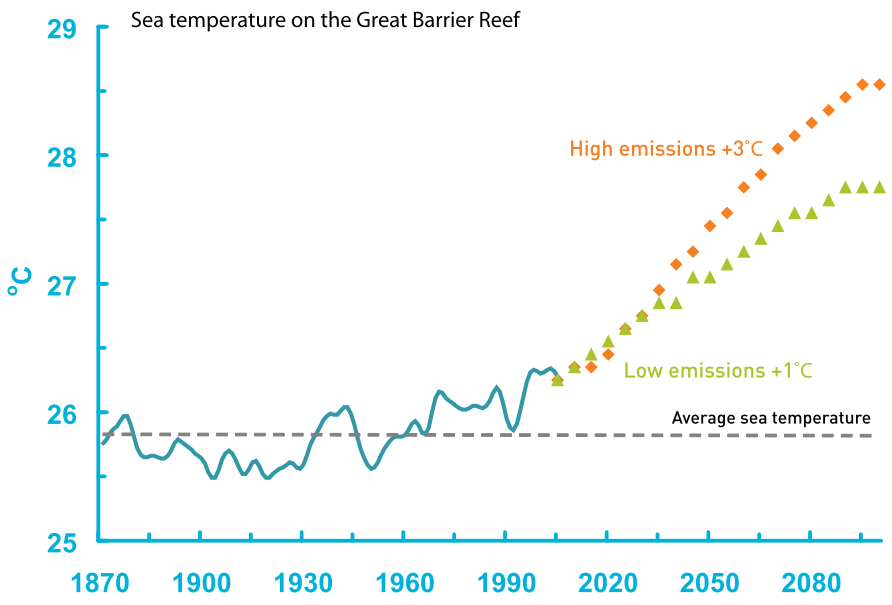
When corals are stressed, their zooxanthellae move out. When the algae leave, corals loose their colour. This is called coral bleaching.

When the going gets tough...the algae get going!

Bleaching has affected the Great Barrier Reef

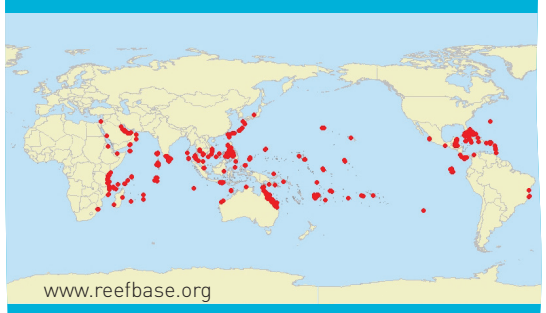
In the last 30 years, the Great Barrier Reef has experienced unprecedented rates of bleaching. Until 1979, mass coral bleaching had only been documented three times around the world. In the last few decades, the Great Barrier Reef has experienced mass coral bleaching eight times.

Scientists predict that mass coral bleaching will happen every summer if temperatures continue to rise. Damaged reefs can take decades to recover.



Corals in hot water...

Sizzling summer temperatures are bad news for corals and things are only getting worse. As our oceans warm, coral bleaching is becoming more frequent.



Global map of extreme coral bleaching since 1990

Can corals adapt?

Although corals have lived for more than 18 million years and survived previous changes in climate, scientists believe current changes are happening too quickly for corals to keep up.

What will the future be?

Over the last 100 years, the water temperature of the Great Barrier Reef has increased by 0.4 C. By 2050, temperatures could increase as much as 1.2 C. Historically, similar changes would have taken thousands of years.

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REEF Beat 2

Climate change

impacts on the Great Barrier Reef

Climate change and the Reef

The real sea change

Climate change is one of the greatest threats to coral reefs worldwide. More than 30 per cent of coral reefs throughout the world have already been affected and scientists fear that 60 per cent of reefs may lose many corals by 2030 due to increased coral bleaching.

The Great Barrier Reef is one of the largest and healthiest reef systems in the world and can cope with stress better than most reefs, but it is not immune to climate change.

Impacts on coral reefs – the ecosystem effect

Already, coral bleaching and other signs of coral stress are evident. But climate change affects more than corals. Seabirds, marine mammals, turtles, plankton, invertebrates, marine plants, fish and habitats such as wetlands and islands are also under threat. Because plants, animals and habitats are integrally connected, the impacts of climate change will have far reaching impacts on every part of the coral reef ecosystem.

Rising sea level

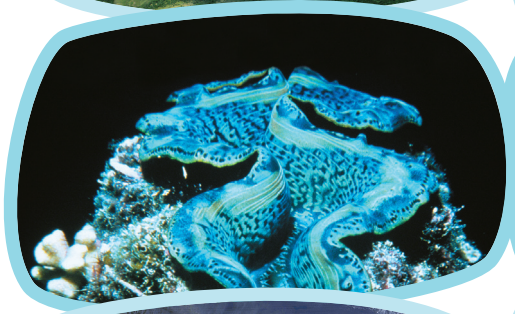
Increased sea levels elevate the risk of coastal flooding from storm surges and intensify coastal erosion. Rising seawater can flood important bird and turtle nesting sites, wetland areas, mangroves and coastal towns.

Changing ocean circulation

Ocean currents transport oxygen, nutrients and an array of marine life. These ocean conveyor belts connect reefs to each other and connect the coastline to the Great Barrier Reef. Changes in ocean circulation impact food webs and influence the productivity of the ecosystem.

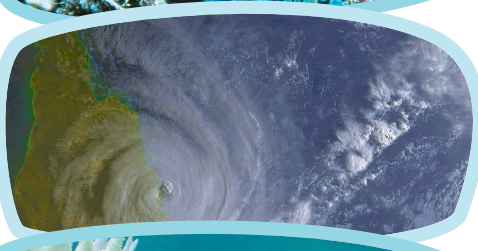
Altering rainfall, drought and run-off patterns

Rain patterns are changing. Some places are drier while others receive more rain. Intense rain leads to increased erosion and floodwaters that carry sediments, nutrients and pesticides to the Reef impacting on the plants and animals that live there.



Ocean acidification

Higher levels of carbon dioxide in the atmosphere are absorbed by the oceans, affecting the chemistry of the ocean and making it more acidic. This reduces the growth rate and strength of corals and affects the limestone foundations of the Reef.



Increasing frequency of intense storms

More intense storms will magnify physical impacts on coastal areas, mangroves, seagrass beds, shallow reef habitats, islands and coral cays in the Great Barrier Reef.

Increasing sea temperature

Increases in sea temperature result in more frequent mass coral bleaching and a decrease in the overall growth of the Reef. Temperature increase will impact other marine animals such as fish, turtles and seabirds.

Degrees of change

If carbon dioxide levels continue to rise, the Great Barrier Reef could look very different. It will be up to us to determine what reefs of the future will be like.

Increase in temperature:
> +3 degrees

CO_2 (ppm):
> 500

Increase in temperature:
+ 2 degrees

CO_2 (ppm):
450-500

Increase in temperature:
+ 1 degree

CO_2 (ppm):
375

ppm: parts per million

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REEF Beat 3

Ocean acidification

Climate change and the Reef

A hidden menace

Increasing levels of carbon dioxide in the atmosphere are changing the chemistry of the Earth's oceans and threatening marine life. Every time we start a car or turn on the lights, about one-third of the carbon dioxide we emit ends up in the ocean. When carbon dioxide is mixed with water it creates carbonic acid.

carbon dioxide (CO_2)
+ water (H_2O)
= carbonic acid (H_2CO_3)

Acidity is measured on the pH scale. The lower the pH, the more acidic the substance. Excess carbon dioxide in the atmosphere causes more carbonic acid to form in the ocean, making it more acidic and reducing the pH. This process is known as ocean acidification.

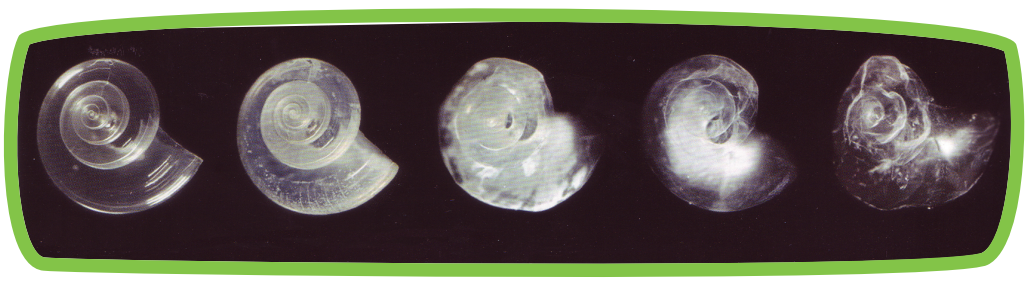
pH	Examples of solutions and their respective pH
0	Battery Acid
1	Hydrochloric Acid
2	Lemon Juice, Vinegar
3	Orange Juice, Soda
4	Tomato Juice
5	Black Coffee, Acid Rain
6	Urine, Saliva
7	"Pure" Water
8	Sea Water

Corrosive impacts on marine life

The new chemical composition of our oceans is expected to harm a wide range of ocean life, particularly creatures with shells.

More acidic water decreases the ability of ocean creatures to form their skeletons. Increased acidity reduces carbonate – the mineral used to form the shells and skeletons of many shellfish and corals. The effect is similar to osteoporosis, slowing growth and making shells weaker. In theory, pH levels could drop enough that shells will literally dissolve.

This process will not only harm some of our favourite seafood, such as lobster and mussels, but will also hurt some species of smaller marine organisms – such as pteropods and coccolithophores. Which form a vital part of the food web. If these smaller organisms are lost, the larger animals that feed on them could suffer, as well.



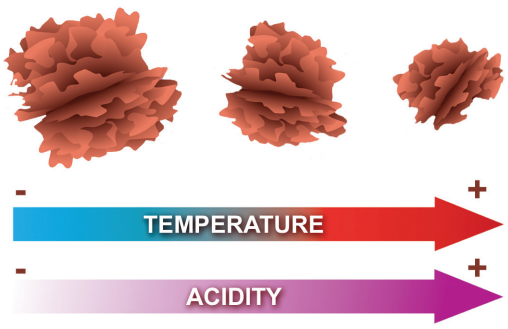
Disappearing coral reefs

Delicate corals may face an even greater risk than shellfish because they require very high levels of calcium carbonate to build their skeletons.

More acidic water slows reef-building, which lowers the resilience of corals and could lead to the erosion and eventual extinction of coral reefs.

Coral growth on the Great Barrier Reef has declined by 14 per cent since 1990 – a year scientists believe may have been a 'tipping point' for coral growth. This sudden decline in coral growth is unparalleled in the last 400 years.

Coral reefs serve as the home for many other forms of ocean life. Their disappearance would be akin to rainforests being wiped out worldwide. Such losses would reverberate throughout the marine environment and have profound effects upon humans as well.



Coral growth is decreasing as our oceans become warmer and more acidic.

Reaching the limits

Our oceans are becoming more acidic than they have been in hundreds of thousands of years. The change is happening fast and it will take fast action to slow or stop it. Over the last 250 years, oceans have absorbed 530 billion tonnes of carbon dioxide, triggering an unprecedented rise in ocean acidity.

Before people started burning coal and oil, ocean pH had been relatively stable for the previous 20 million years. But scientists predict that if carbon emissions continue at their current rate, ocean acidity will reach levels not encountered for hundreds of millions of years.

A slow recovery

The current increase in ocean acidity is happening a hundred times faster than any change over the last many millions of years. By the end of this century, if carbon emissions are not stabilised, ocean acidity could be three times what it was before human industrialisation. It would require thousands of years for the oceans to re-establish chemical conditions that even partially resemble those found today. Hundreds of thousands to millions of year would be required for coral reefs to return, based on the past record of natural coral-reef extinction events.

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corals living

history books of the seas

Climate change and the Reef

Unlocking climate secrets from corals

Long-lived corals growing on the Great Barrier Reef are used to help construct global climate records. Core samples from corals up to 400 years old, are helping scientists understand what Earth's climate was like in the past.

Hard core science

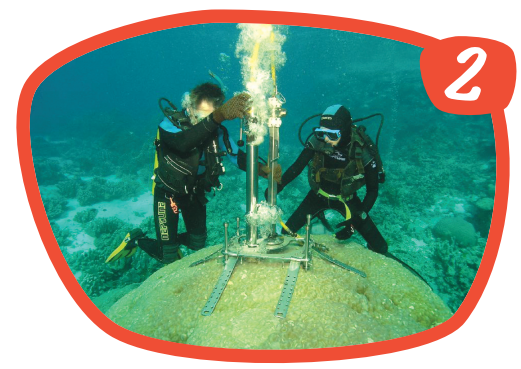
Step 1 First scientists SCUBA dive to locate the oldest corals. Massive Porites corals, like this one on the Great Barrier Reef, can live to be several hundred years old.

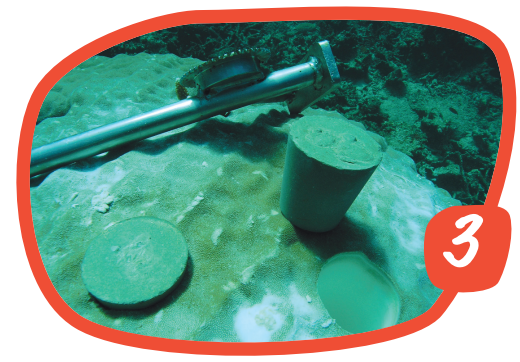
Step 2 Specialised underwater drilling equipment is used to collect coral core samples. Scientists from the Australian Institute of Marine Science have collected core samples from more than 328 colonies of massive coral from 69 reefs on the Great Barrier Reef. Together, these core samples provide information on how life on the Reef has changed over the past 400 years.

Step 3 Once the core samples have been drilled and removed, protective plugs are inserted into the coral to prevent it from becoming susceptible to disease.

Step 4 The core samples are transported back to the laboratory.

Step 5 The cores are then sliced into thin strips and analysed under x-ray or UV light to reveal annual bands.





Photos: E. Matson, AIMS

Coral vision - corals can help us see the past but can they predict the future?

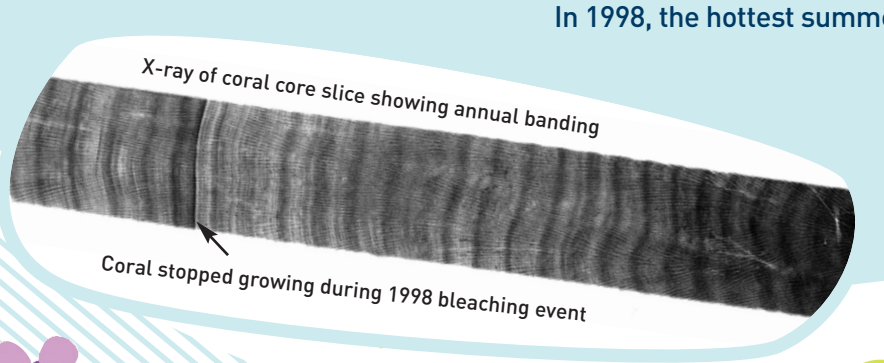
Massive corals found throughout Australia's tropical waters act like living libraries with information about oceanic conditions of the past recorded within their skeletons. Core samples of coral skeletons contain information about past temperatures, water quality, rainfall, ocean acidity and coral growth.

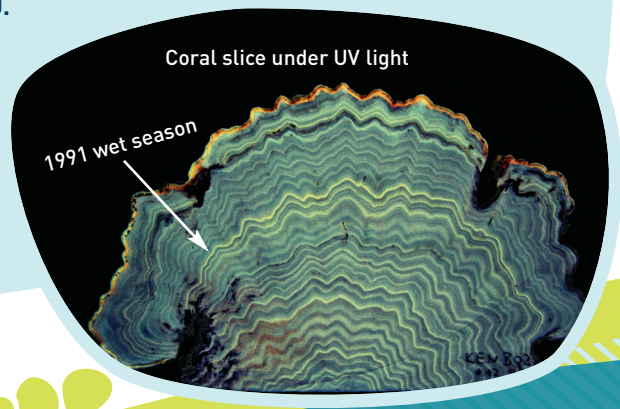
Scientists examine thinly sliced core samples under X-ray and UV light to unlock clues about past conditions on the Reef.

Corals have yearly growth bands, like tree rings which scientists can use to track changes in the coral's environment and growth. For example, yearly wet seasons appear on this coral slice as light bands. The big 1991 wet season appears as a thick, bright band indicating higher than average rainfall.

Data from coral cores has shown that coral growth on the Reef has decreased by 14 per cent since 1990. In 1998, the hottest summer on record, this coral actually stopped growing and many corals on the Great Barrier Reef bleached and died.

Coral cores have shown us that water temperatures have warmed, rainfall has become more variable, coral growth has declined, and human land use has increased the sediment carried out to the Reef. Will these patterns continue into the future? The answer will be up to us.





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REEF Beat 5

Something fishy going on here

Climate change and the Reef

Fish fry

More than 1500 species of fish live on the Great Barrier Reef. They have many important roles like tending gardens of algae, cleaning, and sculpting the Reef. Without fish, the Reef would look very different. Climate change is already having a range of impacts on fish populations.

Butterflies go hungry

Butterfly fish are coral-eaters and depend on corals for their main source of food. When coral reefs bleach, butterfly fish go hungry and populations of coral-eating fish shrink dramatically.

Shark nurseries under threat

Blacktip shark pups frolic in the safety of warm, shallow, nursery waters nestled amongst the roots of coastal mangroves. Here they learn to hunt and have a plentiful source of food until they are old enough to live in deeper water. With climate change, though, this habitat is under threat. Rising sea levels could flood mangrove areas, leaving the shark pups without a nursery.

Many more homeless fish

Many reef fish make their home in the intricate structures created by living corals. These beautiful coral apartments provide protection from predators. Climate change could turn luxury coral apartments into slums leaving fish vulnerable to predators.

Baby fish lost in space

When damselfish breed, their eggs are swept out to sea and the baby fish must swim back to the reef to find a home. Baby fish are carried at the mercy of currents, the conveyor belts of the ocean. Climate change is changing how these ocean transport systems work and could mean that baby fish are swept far from their reef home.

Fish populations grow & shrink with climate fluctuations

Fish numbers can increase or decrease due to changes in the climate. This is similar to what happens to other animals – for example, warm wet weather increases mosquito numbers. Scientists have found that damselfish populations increase when ocean currents carry warmer water to the Reef. This could mean that fish populations across the Reef will boom and bust at the same time due to changes in climate.

Nemo won't be coming home

Nemo, the lovable clownfish, may be unable to find his way home as the acidity of the world's oceans increases due to carbon dioxide emissions. Clownfish are swept away from their home reef into the open ocean as tiny babies and use their acute sense of smell to find their way back again. When sea water becomes more acidic, fish are unable to smell their way home. If we don't cut back emissions, scientists fear that fish could completely lose their sense of smell in about 150 years.

...and if he does he may find his home is not so 'homey'

Like corals, anemones can also loose their symbiotic algae and bleach. No one knows for sure yet, but bleached anemones may not make suitable homes for clownfish. If climate change continues, Nemo could be one of countless fish left without a home.

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REEF Beat 6

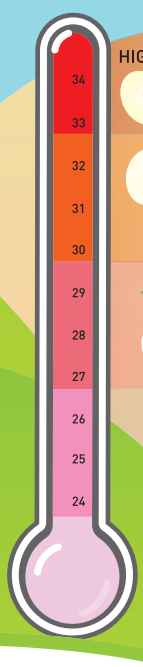
Sea turtles

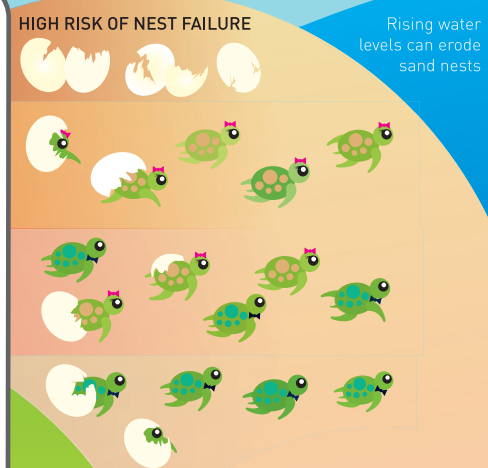
Climate change and the Reef

Climate change
a cold blooded killer

Because the marine environment is relatively stable, many marine animals have not adapted to cope with even small changes to their habitat. Like fish and most reptiles, sea turtles are 'cold blooded' ectotherms. This means their body temperature changes with the temperature of their environment.

If sea temperatures become too warm or too cold, ectotherms, like sea turtles, can't survive. Climate change is turning up the heat for already threatened sea turtles and putting future generations of turtle toddlers at risk.





Gender bender

Sea turtles lay their eggs in nests they dig on sandy beaches. The temperature of the nest determines the gender (male or female) of the hatchlings. As nest temperature increases, more female hatchlings are born leading to an unbalanced population. If temperatures get too high, the fragile eggs won't hatch at all.

Australia's treasured turtles

Six of the world's seven species of sea turtles occur in the Great Barrier Reef Marine Park. These are the loggerhead, green, hawksbill, flatback, leatherback and olive ridley turtles.

Eastern Australian beaches support the only significant **loggerhead turtle** breeding stock in the south Pacific.

The world's largest aggregation of nesting **green turtles** occurs at Raine Island, in the far northern Great Barrier Reef.

One of the world's largest **hawksbill turtle** nesting populations occurs in the northern Great Barrier Reef, primarily at Milman Island.

Flatback turtles are endemic to Australia and not known to venture off the Australian continental shelf.

With so many sea turtles at risk from climate change, maintaining the health of Australia's oceans is more important than ever.

Why are all turtle species on the Great Barrier Reef threatened?

All sea turtles are listed as vulnerable or endangered and their biggest threat is humans.

Threats include:

- Climate change
- Coastal development and loss of habitat
- Hunting and collecting
- Fishing activities
- Declining water quality
- Boat strikes
- Pollution and marine debris
- Marine dredging and construction
- Feral animals destroying nests and eating eggs
- Disease

Climate change is having a devastating impact on sea turtles. Experts believe that unless drastic measures are taken to reduce climate change impacts, most northern Great Barrier Reef green turtle rookeries will produce only female hatchlings by 2070 and populations will be unable to reproduce within 60 years. Other likely impacts of climate change include decreased seagrass food supplies and reduced nesting habitat due to sea level rise and coastal erosion.

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REEF Beat 7

Seabirds are feeling the heat

Climate change and the Reef

Seabirds and their chicks are under threat from climate change

We all know 'birds of a feather flock together', but climate change is causing major problems for the 1.5 million seabirds that live on the Great Barrier Reef.

Seabirds nest on islands and sand cays and feed themselves and their chicks on fish found nearby.

As climate change warms coastal waters, ish move further away trying to find cooler water and seabirds have difficulty finding food.

Sometimes seabirds can't find enough fish to feed their chicks and in cases of extreme weather, none of the chicks survive.

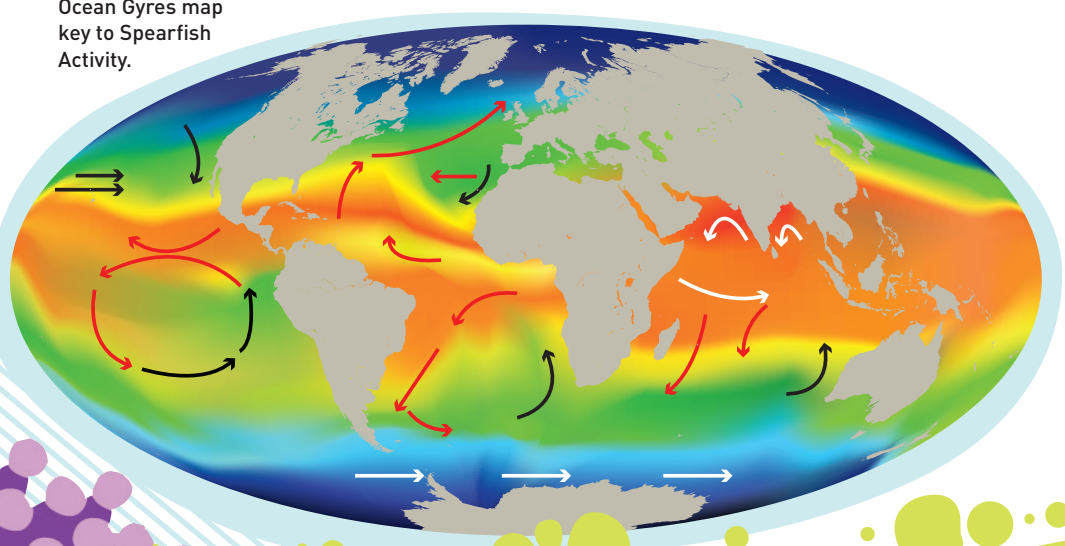
Many seabirds nest on islands in burrows, in tussock grass or in low shrubs and trees. Sea level rise is expected to threaten seabird nesting habitat.

Signs of decline

Climate change is already threatening seabird populations and has been blamed for dramatic declines in seabird populations on the Great Barrier Reef with tens of thousands of seabirds failing to breed due to food shortages caused by warming waters.

- Populations of great and lesser frigatebirds declined by six to seven per cent each year between 1992 and 2004. These populations have not yet recovered.
- On Raine Island, in the northern Great Barrier Reef, populations of at least 10 of the 14 breeding seabird species have been falling. Numbers of common noddies have fallen by 96 per cent, sooty terns by 84 per cent, bridled terns by 69 per cent, and red-footed boobies by 68 per cent. The cause of the declines is attributed to depletion of marine food stocks linked to changing climate.
- On the Swain Reefs, near Rockhampton, the number of brown booby nests has dropped from 350 in 1975 to less than 30 since 2000.
- On Heron Island off the coast of Gladstone, the black noddy population had been rising since early last century, but the number of active nests fell from about 70 000 to 30 000 between 1996 and 2000 with mass death of adults and chicks in 1998, an extremely warm year.
- In 2002, another year of abnormally high sea surface temperatures, almost none of the huge numbers of wedge-tailed shearwaters that normally nest annually on Heron Island succeeded in raising young.
- Off Heron Island in 2003, a 1°C increase in sea surface temperature reduced feeding frequency by shearwaters from one night in two to one night in five.
- In 2006, a similar rise in water temperature resulted in the number of daily meals fed to the chicks of black noddies falling from three meals a day to half a meal each day.

Ocean Gyres map key to Spearfish Activity.



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REEF Beat 8

A resilient reef
is a healthy reef

Climate change and the Reef

A resilient reef

A healthy Reef is important to the communities and industries that depend on it. Climate change poses a major health hazard for the Great Barrier Reef.

Much like a healthy person is better able to cope with an illness, a healthy reef will be better able to cope with the impacts of climate change. The Great Barrier Reef Marine Park Authority is working hard to keep the Reef healthy. In Queensland, caring for the Great Barrier Reef is a community effort. To ensure our Reef stays healthy in the face of climate change, everyone can help take the pressure off.

Putting the pressure on	Taking the pressure off	What you can do?
Overfishing and illegal hunting	**Traditional Owners protect Sea Country** – Traditional Owners are working to manage marine resources sustainably and maintain the cultural connections to the Reef they've established over thousands of years. **Getting in the zone** – Marine Park zoning specifies what types of activities (like boating and fishing) can be conducted in various parts of the park. This helps to protect important habitats and animals. In green zones, some fish populations have increased by 30 per cent.	When fishing, check your zoning map and follow fishing rules. Taking only as many fish as you need is a good way to make sure there are some left to replenish the population.
Declining water quality	 **Farmers growing concern** – Many farmers and graziers in the Great Barrier Reef region have adopted ground-breaking sustainable farming practises to improve the quality of water entering the Reef.	Keep drains clean and free of chemicals. Washing your car on the lawn and using less chemicals around the house helps reduce the pollutants carried from our drains to the Reef.
Rubbish and marine pollution	**Kids saving the Reef** – Over 150 Reef Guardian schools are working to save the Reef. Reef Guardians are recycling, reducing school rubbish, taking litter free lunches and cleaning up their school and local waterways. 	Using reusable bags instead of plastic, backyard composting, and buying bulk products with less packaging are all ways of reducing the amount of rubbish you make. Picking up other people's litter helps set a good example and protect marine animals.
More people on the Reef	**Tourism operators are the eyes and ears on the Reef** – Operators provide invaluable information on reef health, coral bleaching and invasive species. They also report illegal activities and help visitors respect and protect the Marine Park. Special tourism permits ensure that there aren't too many people on one part of the Reef at any one time.	When visiting the Reef, stay clear of coral to prevent damage. 
Coastal development	**Caring councils** – Reef Guardian Councils manage urban run-off and facilitate vital community partnerships that help protect the Reef. Councils are working with marine managers to reduce the impacts of coastal development. 	Saving energy around your home and planting a garden of native plants helps reduce your environmental footprint.

We can all do our bit to help protect our Great Barrier Reef!

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REEF Beat 9

What you can do...

Climate change and the Reef

The slippery slope to slime

If climate change continues at the current rate, the Great Barrier Reef will change irreversibly. Scientists predict that under a worst case scenario, reefs could become dominated by slimy algae instead of hard corals. If this happens, many reef creatures will disappear.

We must do everything we can to avoid further changes to the climate. We must act now to solve this problem. Small changes to our daily routines can add up to big differences for the climate and for the Reef.

Make a calculated effort

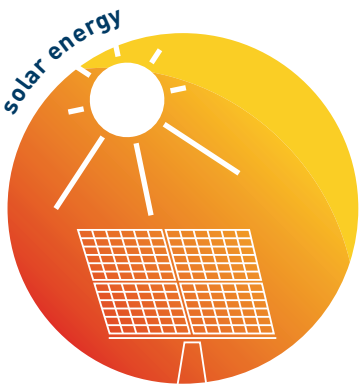
If you want to find out just how much carbon dioxide you are creating, try using a carbon calculator.

Here are some good ones:

www.earthday.net/footprint/index.html

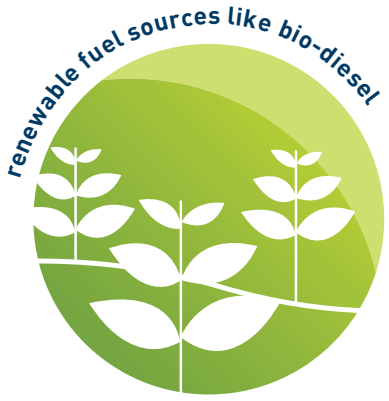
http://www.powerhousemuseum.com/education/ecologic/bigfoot/bigfoot2007/

http://www.climatesmart.qld.gov.au/get_informed/carbon_calculator



Alternative forms of energy

One way to help slow climate change is for us to produce less carbon dioxide. We can all take simple steps to reduce the amount of carbon dioxide we produce. There are also lots of alternative forms of energy we can use that make less carbon dioxide.



What is carbon offsetting?

We can't stop creating greenhouse gases altogether so some companies have started carbon offsetting as a way to offset the environmental costs of polluting.

Here's how it works:

1. You pay the companies based on how much you pollute.
2. They invest your money in activities that reduce greenhouse gases. For example, carbon offsetting companies might plant trees or protect forests which absorb carbon dioxide or they might buy energy from wind farms or solar plants and use this 'clean' energy in place of energy that creates greenhouse gases.
3. The idea is that our activities do not increase the overall amount of carbon dioxide in the atmosphere because we pay money to offset our pollution.

It's easy being green!

The Great Barrier Reef is closer than you think. What we do at home and at school can affect the Reef. By reducing our carbon footprint we can all do our bit to help protect the Great Barrier Reef – no matter where we live.

Here are some ideas on how to reduce your climate footprint:

- Set air conditioners and heaters at the right temperature – 25°C for summer, 18°C for winter
- Switch off lights and appliances when you're not using them – save energy with fluorescent lights
- Have shorter showers and install solar hot water systems
- Buy 'green' renewable energy from your energy provider
- Dry clothes on a clothesline, not in the dryer
- Plant native trees – they use up carbon dioxide as they grow and native plants need less water
- Drive less – car pool, use public transport, walk or cycle
- Reduce, re-use and recycle – keeping things you already have reduces the energy needed to make new things
- Heat and cool houses naturally using windows, fans and insulation
- Buy locally made products or grow your own food – this reduces energy used in transport
- Try backyard composting – organic waste produces fewer greenhouse emissions when it breaks down in a backyard compost compared to a landfill
- Donate things – don't send them to landfill
- Spread the word to others

Australian Government
Great Barrier Reef Marine Park Authority

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