Spatial patterns and dimensions:

Location - *extends from the northern tip of Queensland south to just north of Bundaberg.*

Altitude - *has an average depth of water of 35m in the Great Barrier Reef lagoon.*

Latitude - *12°S - 25°S*

Size - *Area = 344 000 km^2*
- *Length = 2300 km*
- *Width = 60 - 250 km*

GBR - Optimal conditions for coral growth

- Depth of water - 2m above to 40m below sea level
- Fairly warm water temps - 20°C - 34°C, higher temps cause coral bleaching
- Clear water - turbidity (sediment) blocks sunlight and can smother coral
- Constant high salinity - corals die if salinity fluctuates
- High oxygen levels - wave actions and currents provide oxygen
- Low nutrient levels - nutrients stimulate algae and Crown of Thorns Starfish (COTS)

GBR - Dynamics of weather and climate

Temperature

The optimal water temperature for coral growth and limestone formation is 26 - 27°C

Coral reefs are found in the low latitudes or more specifically in the tropics as the temperature in these areas is ideal for optimal coral growth.

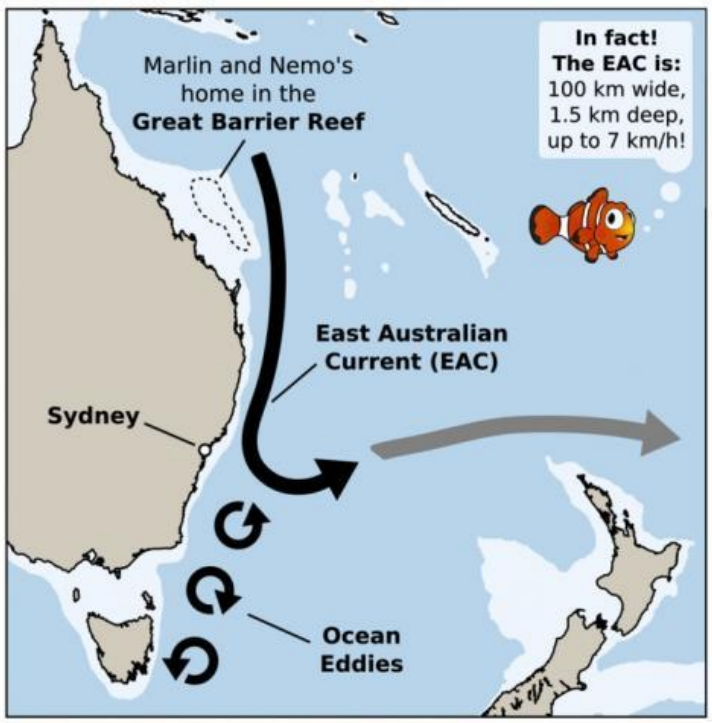
Water currents

- Waves and tidal currents are responsible for transportation and deposition of sediments, flora and fauna and nutrients.
- Currents are important for transporting coral spawning (ecological succession).
- There are two currents which affect the GBR:
    - The Trade Wind Drift Current (TWDC)
    - The East Australian Current (EAC)

Trade Wind Drift Current (TWDC)

For about nine months of the year, the south easterly trade winds make the water flow in a northerly direction.

East Australian Current (EAC)



EAC - pushes warm water down to the south
- warmer waters down south allows corals to grow

Geomorphic and Hydrologic Processes (Lithosphere and Hydrosphere)

Corals produce solid limestone (dead skeletal remains of corals).

Corals can be broken down by:

- Wave action
- Parrot fish
- Chemical reaction - carbonic acid

Weathered coral is transported - coral cays

Sediment from land is washed onto Fringing reefs increasing turbidity. When combined with agrichemicals (phosphates, nitrogen) can be devastating to reef.

Also, link to currents discussed in dynamics of weather and climate.

Formation of a coral cay:

Hydrosphere
Waves breakdown limestone - 2
Water currents move coral sand - 4

Lithosphere
Limestone becomes coral sand - 3
Sand becomes a more complex soil - 6

Atmosphere
Wind carries seeds to sand islands - 5

Biosphere
Polyps work to create limestone - 1
Birds carry seeds to sand islands - 5
Animals and plants grow larger in population - 7

Biogeographical Processes (Biosphere)

GBR = Very high biodiversity

- More than 330 species of coral in GBR
    - Living coral - Polyps
- Within polyps is a symbiotic algae - Zooxanthellae
- Zooxanthellae produces sugar and oxygen through photosynthesis
- Zooxanthellae gives corals their brilliant colours

When sea temps rise due to climate change the Zooxanthellae are expelled by the polyps, this removes the corals colour, known as coral bleaching, and will usually lead to the death of that coral.

Ecological Succession

- The progressive change in the species composition of an ecosystem

Coral spawning

- During one night between late spring and early summer over 140 coral species spawn. This coincides with a full moon.
- Spawning is sexual reproduction which increases the biodiversity (genetic diversity) of the GBR; making it more resilient.

Impacts due to Natural Stress

The GBR is impacted by natural stresses of cyclones/tropical storms and Crown of Thorns Starfish (COTS).

The GBR historically has a high resilience to these stresses, although recently due to the culmination of a range of human impacts the reef is less able to cope.

Cyclones

Negative impacts:

- Rip apart softer corals
- Chip and break harder corals
- Increased rainfall leads to high run-off from adjoining coast
    - Increased agrichemicals - Eutrophication (algal blooms)
      - Nutrient cycles
    - Increased sediment - Turbidity blocks sunlight
      - Energy flows
- Increased rainfall lowers salinity

Positive impacts:

- Can lower temps, reducing risk of coral bleaching
- Increase biodiversity - reduces dominant species of coral
- Cyclones are localised, only affecting a relatively small area of the GBR

Eamples:

- Cyclone Debbie - 2017 - Category 5
- Cyclone Yassi - 2011 - Category 5

Crown of Thorns Starfish (COTS)

The Crown of Thorns Starfish (COTS) is a relative of the sea urchin with four to five centimetre long, poisonous spines covering its body.

COTS feed nocturnally on fast growing corals and usually is part of the natural ecology of a reef. However, when COTS outbreaks occur, the coral is consumed faster than it can grow and the density of the outbreak can block out sunlight, also killing the corals.

In 1979-1991, the GBR suffered a COTS outbreak but only 17% of the reef was affected. The latest outbreaks peaked between 2001-2004 and currently in 2018.

Currently there are three major theories that could explain the cause of COTS outbreaks:

- Natural phenomenon - natural fluctuations in the environment
- Removal of predators - the overfishing of the Giant Titan Snail
- Land use / runoff impacts - nutrients washed into the ocean due to agriculture

Due to the limited control measures, management of COTS is focused on injecting them with bile salts or vinegar and controlling the runoff of nutrients from local land use.

Negative Human Impacts

- Climate change
- Agriculture / land clearing
- Overfishing
- Tourism
- Mining and shipping

Impact of Climate Change

Summer sea temps rises of just 2-3°C for a week or two, or 1-2°C for a month or two are enough to kill sensitive corals.

The upper temperature limits for corals varies between 28°C for coral living in cooler waters and 31°C for warmer water corals.

Other impacts of climate change on coral reefs include:

- Gradual acidification of the ocean
- Gradual sea-level rises
- Increased intensity of tropical cyclones
- More extreme rainfall events

Coral Bleaching

Coral bleaching occurs when coral Polyps expel Zooxanthellae. This occurs when sea temps rise and the Polyps recognise that the Zooxanthellae has become poisonous.

1500km out of 2300km has been bleached along the GBR.

In 2016, the Northern section of the reef was most affected; however in 2017, the middle section suffered the worst of the bleaching.

Other bleaching events of significance have occured in 1998, 2002 and 2016/17.

The GBR's resilience to coral bleaching is also affected by runoff and cyclones.

Ocean Acidification

CO_2 absorbed into ocean creates carbonic acids. These carbonic acids weaken shells and prevent the creation of limestone structures, making corals less resilient to storms.

Agriculture & Land Clearing

A study by the GBR Marine Park Authority (GBRMPA) estimated that 15 million tonnes of sediment and 77,000 tonnes of nitrogen and 11,000 tonnes of phosphorus are dumped into the coastal waters of Queensland annually.

This is approximately 4 times the total load estimate before European settlement.

Increased algal growth inhibits the growth of coral skeletons by more than 50%. Corals are overgrown by algae, making them more susceptible to damage by storms and tourists.

Water quality and land based runoff

- The reef receives runoff from 35 major catchments, draining 425,000 square kilometres of coastal Queensland
- More than 80% of GBR catchments support some form of agriculture
- The most extensive land use is cattle grazing and banana and sugar cane plantations
- Increased sedimentation and nutrients can cause higher algal growth as they feed off the abundance of nutrients, ultimately blocking sunlight and smothering the corals and eventually killing them
- Increased nutrient runoff can also lead to an outbreak in COTS due to the abundance of food energy in the waters. This leads to more corals being killed quicker and at a rate that they are unable to recover from

Mining and shipping

- Queensland is home to natural resources such as coal, uranium and liquid natural gas (LNG). These minerals are shipped to countries such as China and India. For large ships to get to ports such as Gladstone Harbour, the harbour must be made deeper and wider. This process is done through sand dredging. The sand and soil that is removed (spoils) must then be dumped out to sea. This can increase the turbidity of the water. (Changes to management in 2015 led to spoils being now dumped on land)

- Heavy metals which lay dormant on the ocean/harbour floor (from previous heavy industry) are stirred up and enter the food chain (bioaccumulation).

- It is estimated that port developments will increase the number ships travelling through the GBR to 10,000 ships per year. Increased shipping also increases the risk of tankers running aground on coral, spilling oil onto the reef. Increasing also the risk of hitting sea animals - dugongs, whales

Tourism

The utility value of the GBR refers to its usefulness and potential usefulness. Tourism at the GBR has provided the Queensland economy $5.4 billion annually through its range of tourism activities. As well as this, the GBR tourism industry also supports 67,000 jobs, again benefiting the economy.

Tourism can also bring about negative impacts for the reef. These are brought about by activities such as snorkelling, tours, scuba diving, cruises, recreational fishing, helicopter tours, whale-watching boats, and glass-bottom boats. These activities lead to the weakening of coral structures, mainly from walking, dropped anchors and pollution. Corals can also be damaged by sunscreen and run-off sweat from tourists.

The tourism industry in the GBR is managed through zoning and very strict guidelines with reference to exactly where and when certain activities can take place. Because 80% of all tourism occurs within only 7% of the GBR, and all tourism businesses follow strict guidelines, the impacts of tourism on the reef is manageable.

Oxybenzone can be found in many sunscreens, and can be harmful to sensitive corals even when very diluted. The oxybenzone blocks ultraviolet rays from the sun causing deformities in baby coral from a damage in their DNA. The effect is forcing the corals to encase themselves in their own skeleton, leading to eventual death.

Overfishing

Although commercial fishing in the past has had a significant impact on fish stocks in the GBR, those impacts have now been limited due to current management (zoning) and education. However, the reef still remains threatened by illegal fishing.

Impacts of overfishing:

- Decrease in biodiversity - usually only a certain species is overfished (higher trophic level species) - Giant Grouper and Humphead Wrasse
- Interrupts breeding cycles, decreasing fish populations as more and more juvenile fish are captured
- Overfishing of the Giant Tritan is believed to have helped outbreaks of COTS (only natural predator)

Traditional and Contemporary Management Practices

Traditional - Indigenous owners

Contemporary - Strategies used today

Evaluation can be based on:

- Biodiversity
- Intergenerational equity - equity between present and future generations
- Intragenerational equity - equity between people of the same generation and includes consideration of resource distribution
- Precautionary principle - strategy to cope with possible ecological risks where scientific understanding is incomplete

Traditional Management

- Follows the philosophy of stewardship (custodians of the land)
- Combination of conservation and utilisation
    - Eg. Hunting and agriculture
- Ecologically sustainable management

Sustainable management strategies practiced by Indigenous Australians include:

- Seasonal hunting
    - Allows for breeding cycles to be maintained
- Restriction / Taboo on certain species (keystone species)
- Sustainable hunting methods
    - Using spears or line fishing
- Totems
    - Families assigned an animal / species to protect

Evaluation of traditional management:
Biodiversity has been maintained over many thousands of years, thus resulting in intergenerational equity. As such, traditional management has proven to be effective and sustainable.

Contemporary Management

GBR management strategies:

- Zoning
- Reef Protection Plans
- Anchoring and mooring
- Climate Change Management

The GBR is managed by the Great Barrier Reef Marine Park Authority (GBRMPA). They advise the government on management and protection, at both federal and state level.

The GBR is also managed by UNESCO (world heritage organisation) who report on quality of the GBR but has no direct power.

The challenge of managing the GBR is balancing the utility values of the reef (tourism, mining and shipping, agriculture) with the intrinsic values (heritage, indigenous peoples).

Zoning

Zoning is the planned division of the reef into areas that are most protected to least protected. In each zone, various activities are allowed and prohibited.

In the light blue (general use) zone, almost all activities are allowed, with fishing and tourism requiring a permit. In the green (Marine National Park) zone, most activities are prohibited except for traditional use, research and tourism require a permit.

The benefit of zoning means that the balance between utility and intrinsic values can be managed. High protected zones are crucial as they allow the reef to flourish without disturbance.

Zoning addresses the human impacts of:

- Tourism
- Commercial fishing
- Mining and shipping

Evaluation of zoning

Successes:

- Recent changes (2004) has increased green zones from 4.5% to over 33%.
- Green zones have higher biodiversity than other zones

Benefits of zoning:

- Better protection of biodiversity
- Helps ensure:
    - Contained existence of unique animals / plants
    - GBR reliant industries remain
    - Recreational, cultural, educational and scientific values kept
    - Future generations
- Coral trout in green zones are 50% more abundant
- On average, green zones have larger and more fish
    - Strengthens ecosystem resilience and biodiversity

Limitations:

- GBR is a very large area - difficult to police
- Tourists may not speak or read english
- Attitudes toward the natural environment may change through cultures
- Fauna is unaware of zoning boundaries
- Currents can flow through any zone (pollution)

Reef 2050 Long Term Sustainability Plan

The reef plan is Australia's long-term plan for sustainable development to protect the Outstanding Universal Value of the reef. The key principal for the plan is to develop reef resilience in the face of a changing climate. The Queensland government have planned to invest approximately $2 billion over the next decade.

Input for the plan was provided by scientists, communities, traditional owners, industry and NGOs.

Where zoning focuses on activities undertaken on the reef, the Reef 2050 Plan focuses more on improving water from:

- Agricultural runoff
- Dredging

And managing the increase in shipping.

Improving water quality
The biggest source of pollutants entering the inner reef is from agricultural runoff.

The plan sets out ambitious targets for reducing sediment, nitrogen and fertiliser loads by 2025:

Targets	**Strategies**	**Outcomes so far**
● Reducing pollutants in land-based runoff ● Reduce nitrogen loads by 80% by 2025	Working with farmers to achieve best practice management involving the efficient use of fertilisers and pesticides	● Pesticide load reduced by 28% ● Nitrogen loads reduced by 10%
● Reduce sediment loads by 20%	Improving wetland areas and riparian (river bank) vegetation	● Sediment load reduced by 11%

Managing coastal land use - ports and shipping
30% of Australia's GDP comes from seaborne trade, with the total value of the GBR trade aquaiting to $40 billing. In addition to banning dredged material being dumped in the GBR, new and current legislation ensures new development is only in existing ports. Therefore, no new ports will be built. However, the expansion of existing ports will still cause significant damage through dredging - causing turbidity and mixing heavy metals from previous heavy industry.

Shipping safely through reef waters
Roughly 27 ships pass through the GBR daily, with around 10,000 ships passing through per year.

Anchoring and Mooring

Anchors can cause damage to corals and dredge up seagrass. To combat this, the GBRMPA have installed public moorings. Moorings are concrete blocks with a chain that has a buoy attached to it.

The negative impacts of mooring are that the concrete block is destructive to the environment initially, however its destruction is limited to this one area. It is also hard to police and it limits fishers to only certain spots.

Managing Climate Change

- Paris Climate Agreement

What is it?

- 2015 agreement to limit global warming to 2°C
- Developed countries will provide support to developing countries ($100 billion per year)
- Each country will decide how they will reduce their emissions

Will is save the GBR? (limitations)

- Trump
- Australia are supporting new coal mine - Adarni in QLD
- Although Australia has signed up, they have not decided how they will achieve the goals

Positives / Accomplishments	**Negatives / Challenges**
● Pesticides reduced by 28% ● Dissolved inorganic nitrogen reduced by 16% ● Sediment load reduced by 11% ● On-land dumping of dredged material	● Co_2 emissions have not been reduced ● Major oil, coal, gas developments ● Dredging for ports

As such, management of the GBR has been relatively successful in the reduction of agricultural impacts and shipping impacts, however not successful in climate change induced effects and challenges.