GEOGRAPHY BULLETIN

OCEANS 2
Australia's Great Southern Reef

The Geography Teachers Association of NSW & ACT Inc.

Volume 53 No4 2021

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GEOGRAPHY BULLETIN

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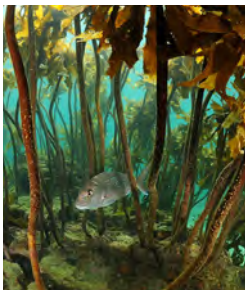

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The Geography Bulletin is a quarterly journal of The Geography Teachers' Association of NSW & ACT Inc. The 'Bulletin' embraces those natural and human phenomena which fashion the character of the Earth's surface. In addition to this it sees Geography as incorporating 'issues' which confront the discipline and its students. The Geography Bulletin is designed to serve teachers and students of Geography. The journal has a specific role in providing material to help meet the requirements of the Geography syllabuses. As an evolving journal the Geography Bulletin attempts to satisfy the requirements of a broad readership and in so doing improve its service to teachers. Those individuals wishing to contribute to the publication are directed to the 'Advice to contributors' at the back of this issue.

GEOGRAPHY BULLETIN

Volume 53, No 4, 2021
EDITOR: Lorraine Chaffer

EDITORIAL

EDITORIAL

Welcome to Edition 53, Volume 4, 2021. This edition is the partner volume to Edition 53, Volume 3 Oceans 1. Oceans 2 is a fully developed resource on the Great Southern Reef (GSR), a largely unknown environment around the Australian coast larger than the Great Barrier Reef (GBR)

Target Curriculum

The resource is targeted as a case study for *Stage 6 Ecosystems at Risk*. It can also be used for *Stage 5 Environmental Change and Management*. This Bulletin version of the GSR Case Study contains the content and direct links to video and other resources. This document can be provided to your students in PDF or print format. The Geography Bulletin material is supported by a Google Site as a digital version containing the case study content with videos and resources embedded PLUS fieldwork ideas, including a virtual fieldwork activity.

Background

I have been working on this resource throughout 2021 having used kelp forests as an illustrative example over many years of teaching Ecosystems at Risk. (I fell in love with sea otters and their role as a keystone species in kelp forest ecosystems in North America)

During my writing of the Sydney Harbour Case Study for *Stage 5 Environmental Change and Management* in 2017 I had the opportunity to visit the *Sydney Institute of Marine Science* (SIMS) and learn about Operation Crayweed. I continue to follow the work of SIMS scientists and have been inspired by the work of Adriana Verges from UNSW.

The seed was sewn for a resource about kelp forest ecosystems.

Since that visit the Great Southern Reef has gained a discrete identity. This case study is an alternative to the GBR. There is a wealth of supporting teaching material and added advantage of fieldwork opportunities on any section of rocky coast in NSW.

In April 2021 I attended an education workshop at the *Manly Seaweed Forests Festival* by Stefan Andrews who created the *Great Southern Reef website.* Resources from that website are embedded throughout this case study.

Geography perspective

This resource was written to provide a geographic perspective to a wealth of scientific material and to meet NESA syllabus requirements.

A big thank you

I want to thank the scientific community for their support and generosity in allowing the use their resources and photographs and answering my queries and requests along the journey to complete this resource.

Enjoy

Lorraine Chaffer

Lorraine Chaffer,

AUSTRALIA'S GREAT SOUTHERN REEF

'The Great Southern Reef is an extensive and valuable ecosystem … that not very many people know about.'

Australian Academy of Science

"The Great Southern Reef is a fantastic example of how the natural world can thrive when we leave it alone. However, more must be done, because right now the Reef faces extreme threats'

Dr. Sylvia Earle, Founder, Mission Blue

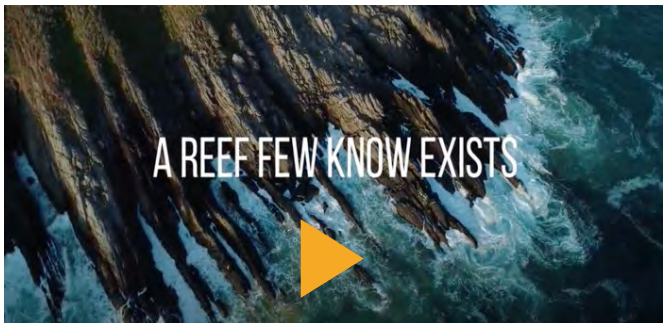
Lorraine Chaffer, Education consultant

Image source: Ocean Imaging / Great Southern Reef

WHAT IS IT? WHERE IS IT? WHY IS IT UNIQUE? WHY SHOULD I KNOW ABOUT IT?

Video 1

Introducing Australia's Great Southern Reef https://www.youtube.com/watch?v=clWCpejKrEc



Video 2

Story of the Great Southern Reef, Australias underwater forests – https://www.youtube.com/watch?v=LMgXuG_xu5g

ECOSYSTEMS AT RISK

A case study of an ecosystems at risk to illustrate its unique characteristics including:

- Spatial patterns and dimensions
- Biophysical interactions
- The nature and rate of change which affects ecosystem functioning (integrated throughout)
- Human impacts (both positive and negative)
- Traditional and contemporary management practices

Giant Australian Cuttlefish. Source: Ocean imaging: Great Southern Reef

The Weedy Seadragon, unique to the GSR. Source: Ocean imaging Great Southern Reef

OPENING CREDITS

This resource has been created to provide a Geographical perspective on Australia's Great Southern Reef using the following resources PLUS the references and links at the end of this document.

1. Great Southern Reef website – https://greatsouthernreef.com
2. Teachers of the Great Southern Reef Facebook Group* – https://www.facebook.com/greatsouthernreef/
   * Stefan Andrews is the creator of both the website and Facebook Group. Stefan is a marine biologist, videographer and marine educator.
3. Australian Academy of Science. Who's heard of the Great Southern Reef? – https://www.science.org.au/curious/earth-environment/whos-heard-great-southern-reef
4. The 'Great Southern Reef': social, ecological and economic value of Australia's neglected kelp forests. Scott Bennett, Thomas Wernberg, Sean D. Connell, Alistair J. Hobday, Craig R. Johnson and Elvira S. Poloczanska. CSIRO. Marine and Freshwater Research – https://www.publish.csiro.au/mf/Fulltext/MF15232
5. Kelp Forest Restoration in Australia. Layton, C., Coleman, M., Marzinelli, E., Steinberg, P., Swearer, S., Vergés, A., Wernberg, T. and Johnson, C., 2021. Frontiers in Marine Science – https://www.frontiersin.org/articles/10.3389/fmars.2020.00074/full
6. Reef Life Survey – https://reeflifesurvey.com
7. Sydney Institute of Marine Science (SIMS): Operation Crayweed. Restoring Sydney's Underwater Forests – http://www.operationcrayweed.com
8. BBC Travel Australia's forgotten other 'Great Reef' – https://www.bbc.com/travel/article/20200922-australias-forgotten-other-great-reef
9. National Geographic. Great Southern Reef – https://fieldnotes.nationalgeographic.org/expedition/greatsouthernreef
10. Stefan Andrews (Ocean Imaging), John Turnbull (#MarineExplorer), Cayne Layton, Haig Gilchrist, Sydney Institute of marine Science, (SIMS) and @ saltywings on Instagram for photographs used in the resource

GREAT SOUTHERN REEF

USING THIS RESOURCE

Visit the Great Southern Reef website for information and teaching resources https://greatsouthernreef.com

Join the Great Southern Reef Facebook Group for teachers to keep up to date with new information and events https://www.facebook.com/greatsouthernreef

Visit the GTANSW & ACT GREAT SOUTHERN REEF Google Site – https://sites.google.com/view/gtanswactgreatsouthernreef

The Google site is a digital version of the contents of this article with videos and documents embedded and important resources hyperlinked. The site also includes fieldwork and virtual fieldwork options. Some content from the article has been reduced and additional resources embedded

Use the media reports to develop teaching and learning activities.

For Stage 5 there is a comparative study on the GTA Website with this edition.

GREAT SOUTHERN REEF: A KELP FOREST ECOSYSTEM

SPATIAL PATTERNS AND DIMENSIONS

Until recently temperate rocky reef ecosystems in Australia lacked a comprehensive identity. This has stifled public and political attention and a failure to recognise the ecological, economic, and socio / cultural value of the reefs in the wider community.

The **Great Southern Reef** name has been adapted by the scientific community to redress this identity issue and in doing so improve knowledge, understanding, interest in and appreciation of the reefs, and increase research funding for scientific knowledge and conservation purposes.

Figure 1: The Great Southern Reef extends along the southern coastline of Australia.

Source: https://www.science.org.au/curious/earth-environment/whos-heard-great-southern-reef

The **Great Southern Reef** (GSR) is an ecologically connected system of **temperate rocky reefs** on the southern coast of Australia. Figure 1. The common feature connecting multiple rocky reefs into one large ecosystem is kelp growing in kelp beds (shorter species) or kelp forests (taller canopy forming kelps).

Spatially the Great Southern Reef:

- is a temperate marine ecosystem in Australia's 'coastal zone'
- extends for 8,000 km around the Australian coastline from northern New South Wales (28.58° S) to Kalbarri in Western Australia (27.78° S)
- covers 71 000 km2 (area) of the nearshore continental shelf
- extends to depths of 30 metres below sea level but may reach 60 metres asl.
- is sub-tidal (below sea level)

Like the Great Barrier Reef, the GSR comprises hundreds of individual reefs with significant ecological, social, and economic value.

> *"Even though it's not a physical rock connecting them, they are still sharing that ecological connectivity."*
>
> Sahira Bel, ecologist

Source: https://particle.scitech.org.au/earth/kelp-forests-of-western-australia/

Australia's kelp-dominated rocky reefs are largely managed independently by the states of NSW, Victoria, Tasmania, South Australia, and Western Australia because they are found in the 'coastal zone' which extends up to 5.5 km from shore.

Sections of the GSR such as Giant Kelp forests communities are protected under Commonwealth legislation.

THE GREAT SOUTHERN REEF ECOSYSTEM

THE BIOPHYSICAL ENVIRONMENT

- **Rocky outcrops and boulders** are the main substrate (surface) for the GSR, interspersed with areas of marine sediment on the seafloor.
- The GSR ecosystem comprises extensive seaweed/kelp, sponge, seagrass, and other **biogenic habitats** such as those shown in **Figure 2**. These habitats support high levels of biodiversity that includes marine crustaceans such as crabs and lobsters; molluscs such as squids and snails, echinoderms such as starfish, sea urchins and fish.
- The nature of the substrate, water temperature, light, ocean currents and wave action determine the diversity of habitats at different locations on the reef. **Figure 3** shows how wave action alone can influence habitats in a small area.
- **Kelp** is the dominant habitat forming species on the Great Southern Reef. The kelp, a macroalgae, attaches itself to rocky outcrops and boulders where it creates a complex 3D living habitat much like a terrestrial forest. The main kelp species is "Golden Kelp" (Ecklonia radiata), sometimes called Common Kelp. This foundation species forms a forest canopy and provides the primary biomass and habitat for hundreds of other species. Other species such as Giant Kelp and Crayweed coexist with Golden Kelp. Kelp forests have been likened to a *'hipster beard'* on the chin of the Australian coastline.
- Other **habitat forming species** contribute to the complexity of the GSR, occupying niches less suited to kelp or found beneath the canopy of the kelp forest. For example, and sponges grow on deep rocky surfaces where there is less sunlight.

Learn more about seaweed/kelp, seagrasses, and sponges in **Fact Sheet on pages 60–61.**

INTERCONNECTED HABITATS AND ECOSYSTEMS

Reef habitats are connected through ecological processes such as food chains, energy flows and nutrient cycles. Kelp produce food through photosynthesis and feed primary consumers such as fish and zooplankton across multiple habitats.

Sponges filter food and nutrients from the water, keeping the water clear for kelp.

Giant Australian Cuttlefish gather in kelp forests to breed while sharks and other marine mammals hunt in the corridors created by kelp plants.

Connectivity is an essential component of **ecosystem functioning** on rocky reefs and includes important connections to adjacent ecosystems such as seagrasses. 'Edge effects' benefit biodiversity across connected ecosystems and enhance their resilience. **Figure 4** is an example of a connection between kelp and adjacent seagrasses that helps fish biodiversity.

BIODIVERSITY HOTSPOT

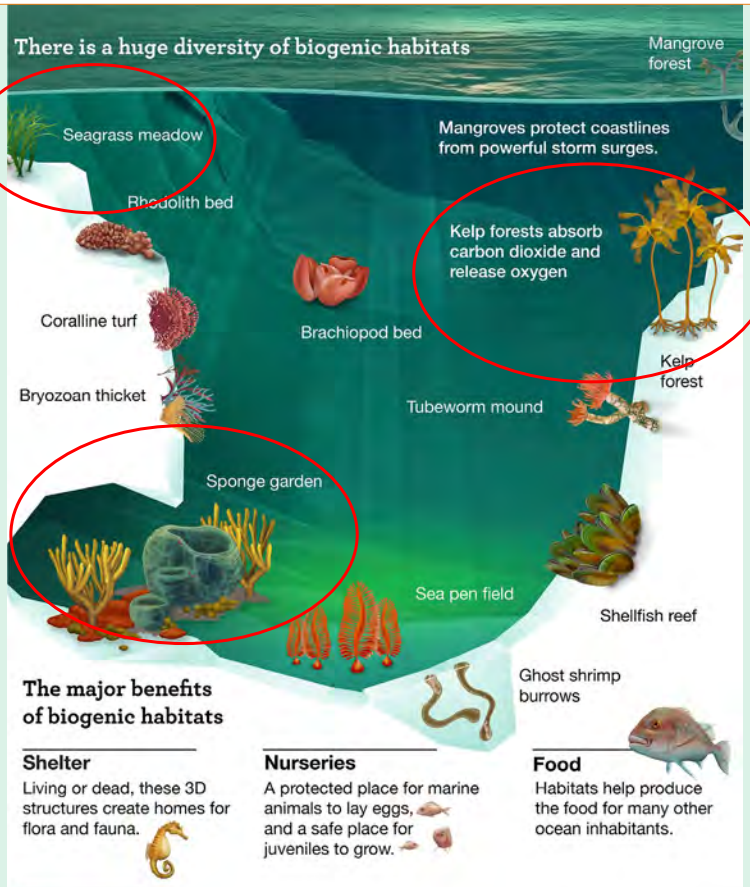
The GSR is a **global biodiversity hotspot** with species such as the Weedy Seadragon found nowhere else in the world and more seaweed species than any other location. The GSR had more **endemic** species than the Great barrier Reef.

> *'The GSR is a global hotspot for marine biodiversity and endemic species, hosts the highest diversity of seaweeds on Earth (>1000 species) and is one of the most productive ecosystems on Earth. GSR kelp forests produce 65 tonnes of biomass per hectare per year'.*
>
> Source: https://marinesocioecology.org/great-southern-reef-webinar-uncovering-the-value-of-australias-gsr/

Golden Kelp on the Great Southern Reef. Source: Shutterstock

Sponge garden on the Great Southern Reef
Source: Ocean Imaging | Great Southern Reef

Figure 2: Biogenic habitats on rocky reefs

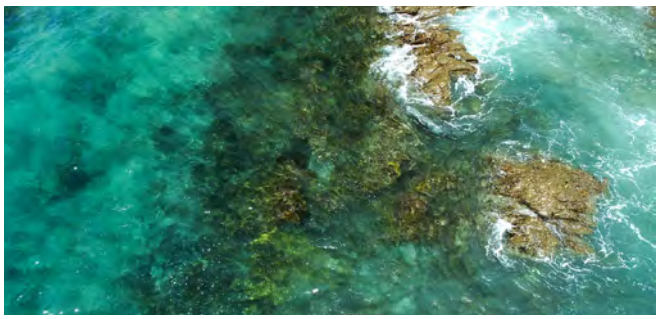


The habitats created by living organisms are called biogenic – 'bio' means life and 'genic' means formed by. **Biogenic** habitats are made of living things (such as kelp) or form from the activities of plants, animals, or other organisms (like the burrows that a crab makes). In a biogenic community one type of organism provides the structure for many other organisms to live.

Diagram source: Science Learning Hub – Pokapū Akoranga Pūtaiao, University of Waikato, https://www.sciencelearn.org.nz/images/4599-biogenic-engineers-and-architects

Figure 3: Influence of wave exposure on habitats within rocky reef ecosystems

Source: Science Learning Hub – Pokapū Akoranga Pūtaiao, University of Waikato, www.sciencelearn.org.nz and https://www.sciencelearn.org.nz/images/4599-biogenic-engineers-and-architects



Rocky outcrops are the foundation of the GSR. Source: Ocean Imaging | Great Southern Reef

Figure 4: Ecosystem connectivity

'Along temperate coastlines, seagrass meadows and kelp forests are critical nursery habitats for fish'. Source: Olson, A. M., Hessing-Lewis, M., Haggarty, D., and Juanes, F. (2019). Nearshore seascape connectivity enhances seagrass meadow nursery function. – https://doi.org/10.1002/eap.1897

Starfish. Source: Ocean Imaging | Great Southern Reef

STATUS OF GLOBAL KELP FORESTS

Kelp forests are found along 25% of the world's coastlines in cold, nutrient-rich water. These ecosystems have some of the highest rates of primary production anywhere on Earth. There is extensive diversity of kelp species.

Figure 5 shows the distribution of major kelp forests. Kelp forests support high levels of biodiversity and provide valuable habitat, and environmental services for ecosystems and coastal communities.

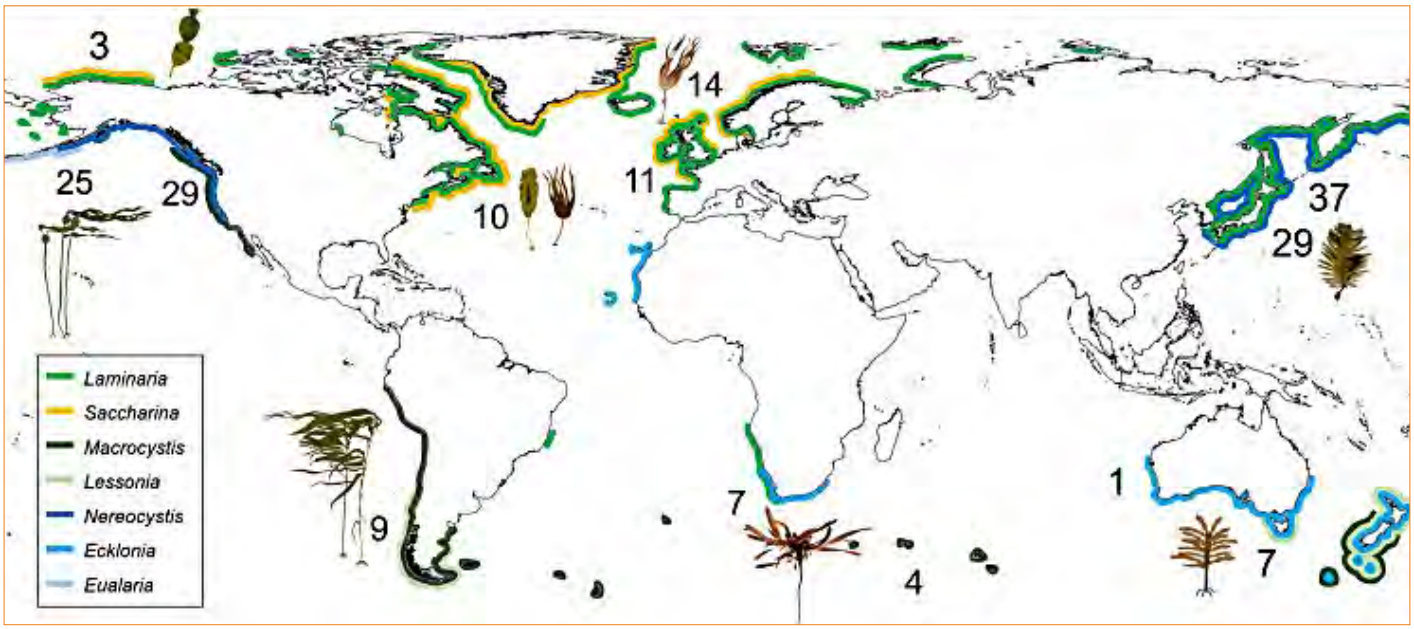
Temperate kelp forests are declining at a global scale despite showing historically high levels of resilience to natural stresses over time. One study 'Global patterns of kelp forest change over the past half-century' (https://www.pnas.org/content/113/48/13785) found that 38% of kelp forests have declined in the past 50 years. In California, giant kelp forests have been replaced by urchin barrens and in Australia, kelp forests of the Great Southern Reef have also been lost. Overharvesting, pollution, sedimentation, invasive species, marine heatwaves and the tropicalisation of species due to climate change are among the stressors impacting on kelp forest ecosystems.

Management Actions

Actions are being taken to halt or reverse this decline and restore kelp forest ecosystems. The removal of invasive species, the creation of marine protected areas, reforestation and 'future proofing' are among strategies being implemented or trialled globally. Region specific responses based on stressors at a local scale have been the principal approach. Operation Crayweed in NSW is an example of a local response. At a global scale, action on climate change is critical to the future of kelp forests.

The 'invisibility' of rocky reefs such as the Great Southern Reef in Australia has restricted research and management efforts. With increasing global attention, the economic, social, and ecological value of the reefs is being recognised.

Figure 5: Global distribution of kelp species



From: Status and Trends for the World's Kelp Forests. Rightslink licence 5131200204971. Thomas Wernberg, Kira Krumhansl, Karen Filbee-Dexter, Morten F. Pedersen,– https://doi.org/10.1016/B978-0-12-805052-1.00003-6

BIOPHYSICAL INTERACTIONS AND ECOSYSTEM FUNCTIONING

Atmosphere
- Temperature
- Sunlight
- Wind
- Storms
- Carbon cycle
- Climate change

Hydrosphere
- Cool water
- Salt water
- Clear water
- Nutrients
- Waves
- Ocean currents

Lithosphere
- Continental Shelf
- Rocky substrate
- Sediment
- Tectonic stability
- Geomorphic processes

Biosphere
- Biogenic habitats
- Macroalgae/kelp forests
- Food webs
- Energy flows
- Nutrient cycles

Photo John Turnbull #marineexplorer

The unique characteristics of the Great Southern Reef Kelp Forest ecosystem result from biophysical interactions between **abiotic** and **biotic** components of the natural environment. The lithosphere, atmosphere and hydrosphere create the conditions required for kelp to grow.

Kelp are the foundational species (primary biomass) of the ecosystem and critical to its functioning (food webs, energy flows and nutrient cycles). It is the high **primary productivity** of kelp that supports high levels of biodiversity and creates habitats.

Limiting conditions for kelp

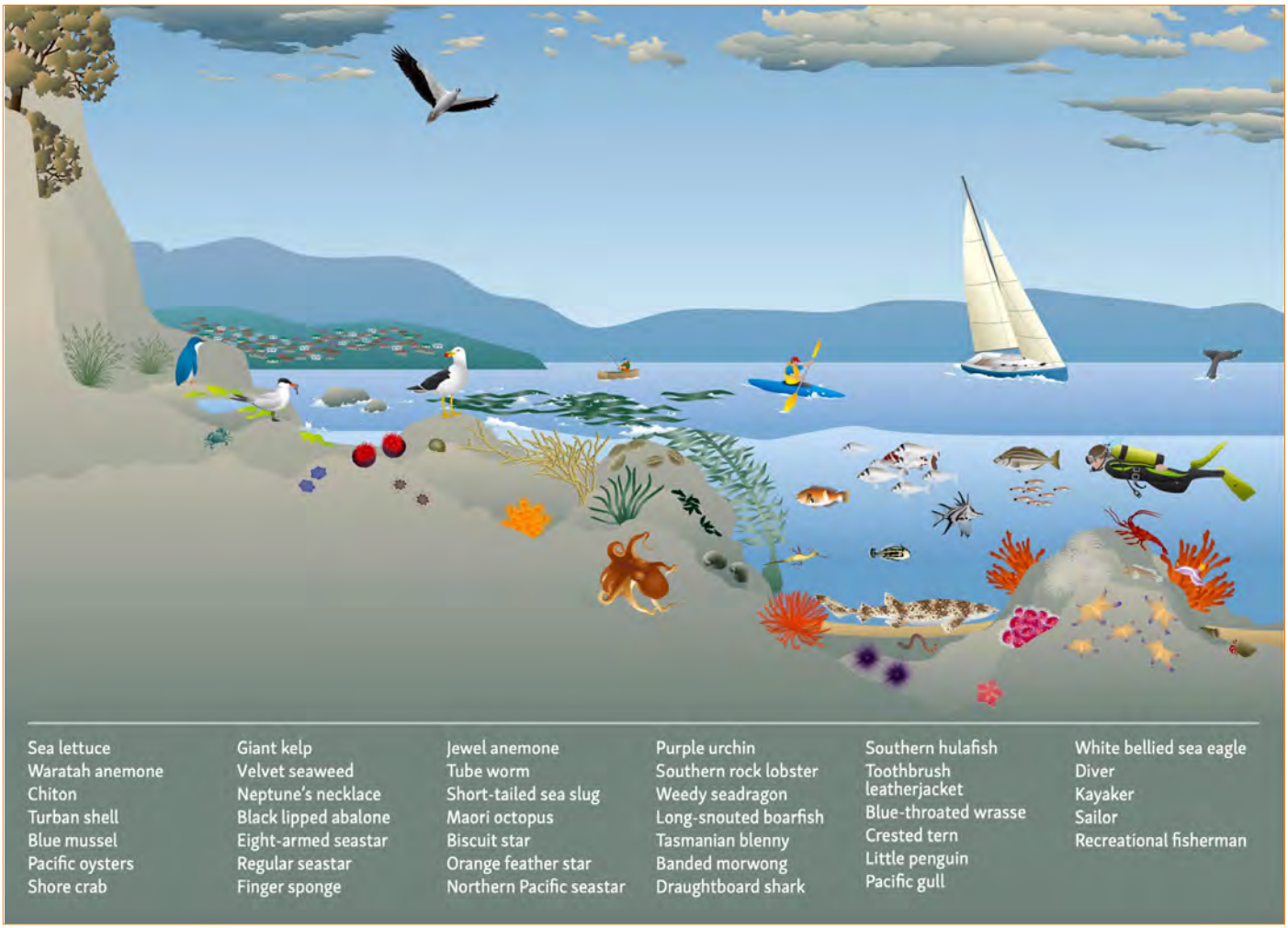
- Rocky substrate as the essential solid foundation for kelp to establish
- Sunlight for photosynthesis to produce primary biomass
- Low turbidity to maximise sunlight penetration
- Cool water less than 20 °C is best (Maximum 26 °C)
- Normal seawater levels for pH (8.1 which means it is alkaline) and salinity (35,000 ppm compared to freshwater at less than 1,000 ppm).
- Nutrient rich water for high primary productivity Seasonal upwelling events provide essential nutrients
- Low to moderate wave energy although some species can survive on high energy coasts.

These biophysical conditions are found on subtidal rocky reefs in Australia's temperate latitudes where kelp species are adapted to varying conditions within these limits.

Golden Kelp (Ecklonia radiata), the dominant species on the GSR, thrives in the subtidal zone to depths of approximately 30m and forms dense 'forests' in the most sheltered locations, however it is also known to grow to depths of 50 metres in Eastern Tasmania. Giant Kelp mostly grows on reefs exposed to moderate wave action in depths of eight metres and below and Bull Kelp is found in very high wave exposed locations such as Tasmania's west coast.

Golden Kelp. Source: Ocean Imaging | Great Southern Reef https://www.facebook.com/greatsouthernreef/

Figure 6: Diagram of a rocky reef in southern Tasmania, supporting a diversity of habitats such as kelp and sponges, and multiple species of organisms across a small area.



Use the INTERACTIVE DIAGRAM to identify species here: https://www.derwentestuary.org.au/rocky-reefs-kelp-beds-and-inter-tidal-zone/

THE LITHOSOPHERE

A stable coast

At the continental scale, The Great Southern Reef is located on the landward edge of Australia's continental shelf where coastal landforms extend below sea level in **a mosaic of rocky reefs and soft sediments.**

Marine ecosystems such as the GSR have developed into complex systems with high levels of **biodiversity** and **endemism** over very long periods of time. This can be explained by:

- Australia's tectonic stability due to its location within the Indo-Australia plate
- low sediment loads from coastal rivers due to the dry climate
- a lack of continental glaciation to cause isostatic movement

'… thousands of kilometres of the present rocky coast of eastern and southwestern Australia largely retain the outline created more than 30 Ma.'

Source: http://press-files.anu.edu.au/downloads/press/p194981/pdf/chapter-6.pdf

Geomorphic processes

The rocky outcrops and boulders that form the Great Southern Reef are a result of the weathering and erosion of the continent. They may be extensions of rock platforms, remnants of coastal cliffs and headlands or isolated rocky outliers.

Weathering and ***erosion*** continuously shape the GSR, changing the availability of rock surfaces for kelp colonisation and forming crevices, channels and overhangs that support a diversity of non-kelp species. Loose substrate *deposited* on the seabed between the rocky outcrops, adds complexity to the ecosystem and the biodiversity it supports.

Lithosphere – hydrosphere interactions

Coastal geology (rock type and structure) and exposure to wave energy influence the physical features of rocky reefs. Fast eroding granite produces uneven surfaces and crevices that become habitat for a diversity of species such as eels and octopus while sandstone reefs have more smooth surfaces on which kelp attaches and overhangs where sponges will thrive.

The coastal sandstone around Sydney is exposed to moderate wave energy with cliff retreating at a rate of around 1 mm/year.

Along the Great Australian bight, soft limestone is exposed to very high wave energy and average cliff retreat rate of around 25 mm/year. The rate of retreat influences current and future characteristics of the Great Southern Reef.

Lithosphere – biosphere interactions

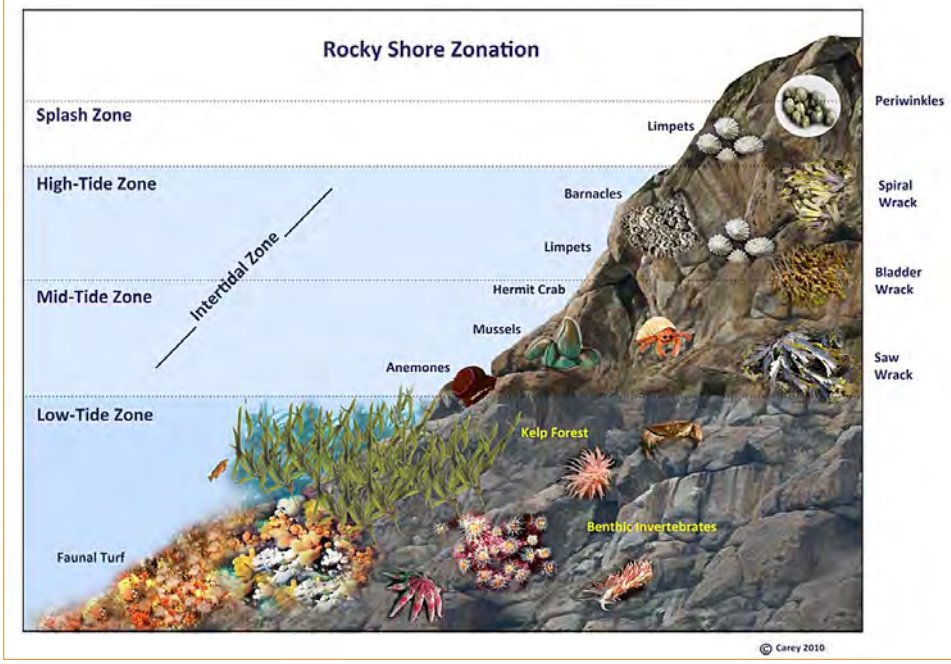
Variations in the seafloor and water depth contribute to the high level of species diversity. **Figure 7** shows **zonation of species** on a rocky surface.

Marine organisms are adapted to conditions in the water column from sea level to sea floor. Kelp forests grow in the subtidal zone where biophysical conditions create a stable environment for organisms with fewer natural stresses than in the tidal zone. For example, there are no strong fluctuations in temperature, water pressure and sunlight; organisms do not dry out and they extract essential nutrients such as nitrogen and phosphorous from the water. As a result, kelp grows quickly within the **photic zone** here, can grow to great lengths, and produce high primary biomass. As the water gets deeper and the light fades kelp gives way to faunal turfs such as sponges, soft corals and sea fans.

Great Australian Bight, WA.
Source: Shutterstock.

Cabbage Tree Bay, NSW Northern beaches
Source: https://www.northernbeaches.nsw.gov.au/things-to-do/recreation-area/cabbage-tree-bay-aquatic-reserve

Figure 7: Rocky shore zonation



Tidal zones

Mostly shelled organisms and wrack

Wrack is organic material washed onto beaches and rocks by tides and waves. It breaks down and is recycled back into the marine ecosystem.

Subtidal zone

Mostly soft bodied organisms and algae

Other species will grow on soft sediment between rocky outcrops shown in Figure 1

Image source: https://gcs.instructure.com/courses/37951/assignments/115556

THE HYDROSPHERE

The Great Southern reef is a marine environment influenced by

- hydrological conditions such as water temperature, depth, and clarity.
- hydrological processes including waves, tides, ocean currents and upwelling and extreme events such as marine heatwaves and floods.

Limiting conditions for kelp forests include cool, clear, shallow, nutrient rich water with the average pH and salinity levels of seawater. (Revisit details in 'Limiting conditions').

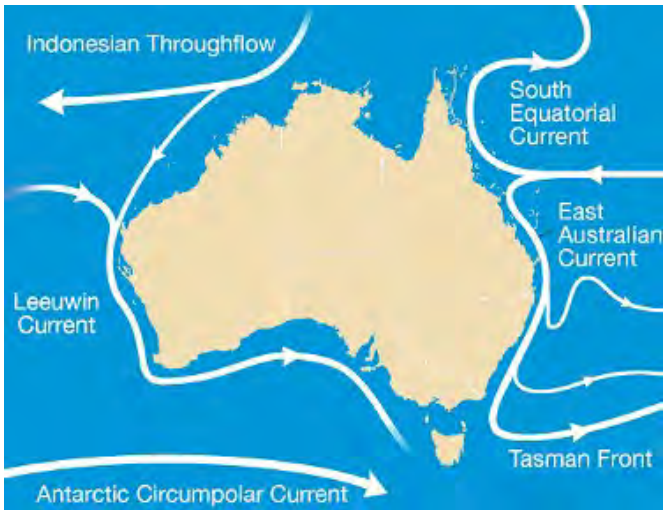
Two **Australian Ocean Currents**, the *East Coast Current* (EAC) and *Leeuwin Current* on the west and southern coasts impact the spatial distribution and functioning of GSR kelp forest ecosystems. These currents add several degrees of temperature to coastal waters.

Ocean currents also cause **upwelling**, a process that brings cold nutrient rich water to the surface, effectively fertilising surface waters and contributing to high primary productivity. **Figures 8 and 9**

WATCH this short trailer for Australia's Ocean Odyssey as an introduction to the EAC – https://www.youtube.com/watch?v=ulNOSK2YE7Q

Learn more about these important ocean currents on the Bureau of Meteorology website.

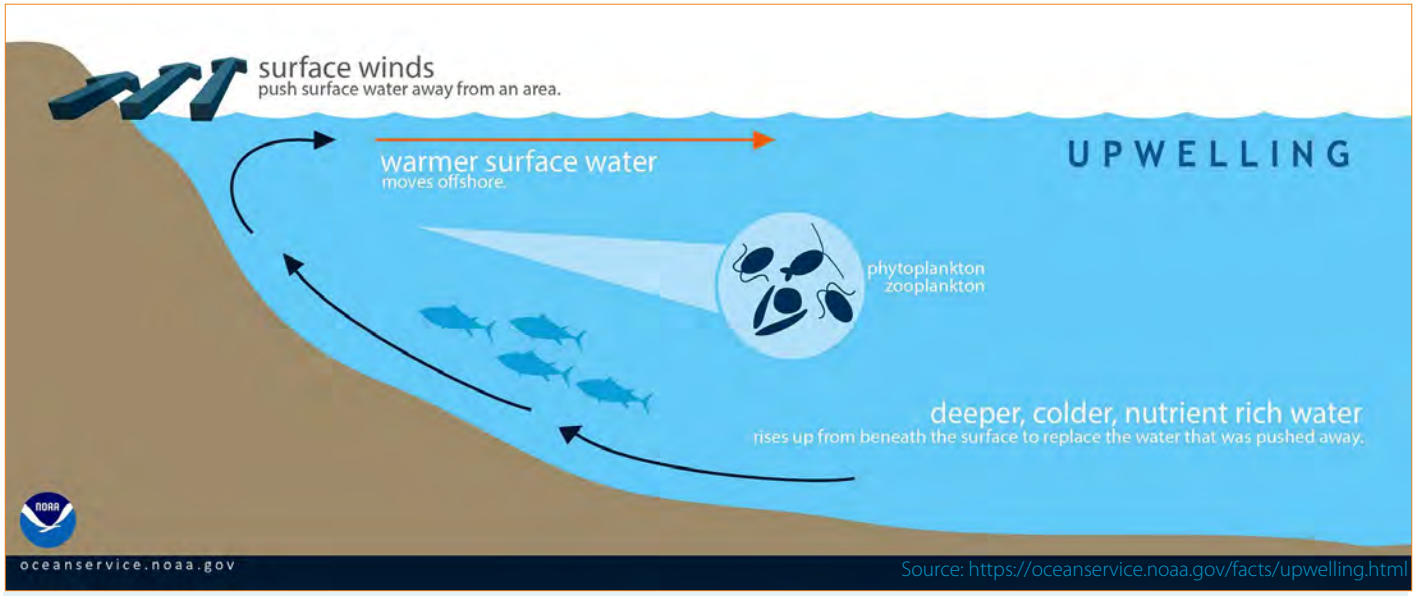
Figure 8: Australia's major ocean currents



Source http://www.bom.gov.au/oceanography/forecasts/forecast-help.shtml

Figure 9: Upwelling brings cold nutrient rich waters to coastal ecosystems

Displaced surface waters are replaced by cold, nutrient-rich water that "wells up" from below. Conditions are optimal for upwelling when winds blow along the shore.



Source: https://oceanservice.noaa.gov/facts/upwelling.html

WATCH these video clips to better understand upwelling:

Upwelling – real life visual from the Oregon Coast – https://www.youtube.com/watch?v=60_y6-CiUMA

What is upwelling (animation 50 secs) – https://www.youtube.com/watch?v=bp5UBuVD9e0

Hydrosphere and biosphere interactions

The hydrosphere is the determining factor for the spatial distribution of kelp and other species on rocky reefs. For example:

- The zoning of species on rocky coasts occurs due to changes in sunlight and water temperature through the water column. **Figure 7**
- Kelp reproduction requires the dispersal of spores in water.
- Different ocean conditions such as waves suit different consumer organisms. **Figure 3**
- A diversity of kelp and algae species thrive in different oceanic conditions. Giant Kelp grows in Tasmania's deeper colder waters while Sea Lettuce, a green algae, grows in shallow water on most rocky reefs.

Ocean warming

Warm currents are nutrient poor and if their influence increases or decreases there are implications for kelp productivity. The **tropicalisation** of species into temperate kelp forests has been associated with strengthening of the EAC. This has consequences for biodiversity as herbivorous tropical species feed on kelp and compete with for habitat and food.

The impact of warming

The ABC media report *'Hungry tropical fish, sea urchins marching south as kelp forests disappear'* identified the following impacts:

- Tropical fish numbers are increasing in usually temperate waters
- Migrating fish and sea urchins are eating kelp, leading to a decline in kelp forests
- over 1000 square kilometres of kelp forests have been lost in WA and sea urchins on the eastern coast are even cleaning up the turf algae that replaces kelp.

Resilience to natural stresses in the hydrosphere

High energy waves

Low to medium **wave energy** suits most kelps although some, such as Bull Kelp, can thrive on high wave energy coasts. Water movement circulates nutrients and oxygenates the water.

Storms created by weather events such as East Coast Lows and intense cold fronts, produce high energy waves that damage kelp during the duration of a weather event. This is evidenced by large amounts of **wrack** on the seashore after storms.

The natural resilience of kelp helps them to recover by recolonising exposed surfaces where kelp has been ripped off the surface and through high primary productivity as new blades grow. Kelp produces large amounts of spore for dispersal and fertilisation in the water. Kelp fertilisation to colonisation takes about six months. When kelp returns a new **primary succession** of organisms begins at the previously deforested site.

Floods

Flooding result in large amounts of sediment entering coastal waters where it increases turbidity and may smother smaller habitat species like seaweeds and sponge gardens through sedimentation. **Turbidity** impacts on ecosystem functioning by interrupting solar energy transmission through the water column where it plays an essential role in primary biomass productivity.

Flood waters also increase nutrient loads which can cause eutrophication. Once clarity returns however, normal functioning will resume, and the impacts will be short term unless successive flood events impede recovery.

The plume of sediment entering the ocean after floods on the central Coast of NSW in March 2021. Credits: Central Coast Aero Club and Andy Smith Photography.

Wrack on a beach and floating in the water after large seas in June 2021
Photo credit: L Chaffer

THE ATMOSPHERE

Conditions in the atmosphere such as **weather** and **climate** influence the abiotic features of the Great Southern Reef. Air temperatures influence the critical water temperature kelp requires for optimum growth (around 20 degrees C) and contribute to marine heatwaves that cause kelp forests loss. Atmospheric change is increasing stresses on the kelp forest ecosystems on the Great Southern Reef and globally. The ocean absorbs most of the excess heat from greenhouse gas emissions, leading to rising ocean temperatures.

Essential role in ecosystem functioning

In addition to determining the abiotic conditions in which kelp thrives, the atmosphere plays an essential role in ecosystem functioning through nutrient cycling and energy flows. Without sunlight, kelp would not grow. Kelp absorbs carbon dioxide and releases oxygen, playing a critical role in climate stabilisation.

- **Sunlight** is essential for **photosynthesis** by which kelp uses solar energy to produce food (primary biomass). Kelp maximises access to sunlight through adaptations such as gas chambers, 'floaties', and wide spreading blades. Kelp is the **primary biomass** and the foundation trophic level of the GSR ecosystem. See the Fact Sheet
- **Weather and climate** influence water temperature and therefore the spatial distribution of kelp forests within Australia's **temperate** climate zone. Global wind circulations (trade winds) drive the ocean currents that determine water temperatures along the GSR.

Atmosphere, hydrosphere, and biosphere interactions

- **Biochemical cycles** essential to ecosystem functioning are the carbon cycle, oxygen cycle and water cycle. Kelp absorbs carbon dioxide and releases oxygen. Kelp ecosystems are identified as 'carbon sinks' permanently removing carbon from the atmosphere and sequestering it into the deep sea or coastal sediments. It is estimated that 11% of global macroalgae is permanently sequestered in the ocean with about 90% of that in the deep sea.
- **Oxygenation**. Waves, currents and kelp oxygenate ocean water. Oxygen is used by consumer organisms at higher trophic levels.
- **Acidification** occurs when carbon dioxide in the atmosphere dissolves into the ocean, lowering the pH and making it more acidic, a process accelerated by warming waters. This affects shelled organisms
- **Upwelling**, a natural process bringing cold, nutrient-rich water to the surface, is caused by wind and earth's rotation. Coastal upwelling supports some of the world's most fertile ecosystems. **Figure 9**.
- **Natural stresses** impacting the hydrosphere such as high energy waves and floods are linked to atmospheric weather conditions.
- **La Nina and El Nino events** alter normal trade winds and subsequent ocean current conditions including the EAC, Leeuwin Current and upwelling currents.

Atmosphere – Hydrosphere – Biosphere interactions

Quotes from 'Marine heatwaves threaten the future of underwater forests'

- In 2011, strong La Niña conditions increased the southward flow of the Leeuwin Current, which pushed warm water from the tropics into cooler temperate latitudes.
- At the same time, winds were calmer than normal resulting in unusually high transfer of heat from the air into the upper layers of the ocean. The outcome was an unprecedented marine heatwave which affected more than 2,000 km of the west Australian coastline from north of Ningaloo Reef to Cape Leeuwin on the southwestern corner of the continent. Water temperatures soared past anything recorded for at least 140 years.
- Many of the species found along the coastline of southwestern Australia have evolved to live in cooler temperate waters. When peak summer sea temperatures soar, as they did in early 2011, many species overheat and become physiologically stressed or even die.
- One forest-forming seaweed was eradicated from over 100 km of coastline in just a few months as a result of the marine heat wave.

Source: The Conversation – selected statements. https://theconversation.com/marine-heatwaves-threaten-the-future-of-underwater-forests-37154

WATCH: How climate change is impacting Australia's Kelp Forests – https://www.youtube.com/watch?v=1jQH6ZG11zU

Source: Great Southern Reef

Climate change: Atmosphere and biosphere interactions

Anthropogenic climate change is placing increased stress on the Great Southern Reef and has caused significant kelp forest losses. Changes to kelp forest ecosystems attributed to a warming atmosphere include:

- **tropicalisation** and migration of herbivorous species of fish and urchins
- **kelp bleaching** reduces the ability of algae to photosynthesise and reproduce and makes them more susceptible to grazing by fish and other marine herbivores
- **marine heatwaves** bring temperatures that exceed the threshold for kelp to grow
- **ocean acidification** impacts organisms with shells or skeletons made from Calcium Carbonate e.g., lobsters. Shells dissolve in acidic water and organisms' ability to produce Calcium Carbonate structures is reduced. This can mean smaller creatures with thinner shells, slower growth and reproduction rates and repercussions for food chains and food webs.

BIOSPHERE AND ECOSYSTEM FUNCTIONING

'Kelp forests are the biological engine of the southern reef, producing as much as 65 tonnes of biomass per hectare per year, more than 16 times the yield from Australia's most fertile wheat fields.'

'This biological powerhouse provides both a habitat and a rich food source in our coastal ecosystems, critical for the energy and nutrient cycles supporting the rich marine life of the reef and the wider ocean beyond shelf waters.'

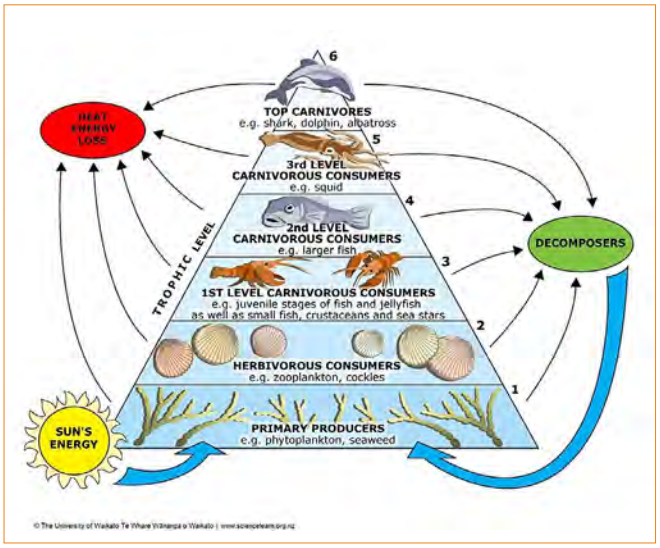
Source: https://theconversation.com/australias-other-reef-is-worth-more-than-10-billion-a-year-but-have-you-heard-of-it-45600

Food chains, food webs and energy flows

Kelp and microalgae (phytoplankton) are the **primary producers** of the Great Southern Reef. They are the primary biomass that captures the suns energy and creates food through photosynthesis. Organisms such as fish and urchins feed directly on kelp, others such as abalone, graze on *drift seaweed* (dislodged kelp or blades caught in cracks and crevices) and detritus or like sponges, organisms filter food floating in the water.

Consumers transfer energy through the trophic levels of the ecosystem. **Figures 10 and 11**

Figure 10: Trophic levels and energy transfer through a kelp forest ecosystem



Science Learning Hub – Pokapū Akoranga Pūtaiao, University of Waikato, Source: https://www.sciencelearn.org.nz/images/144-marine-trophic-pyramid

Kelps are **keystone species** and a **foundation species** because:

- without kelp the GSR ecosystem would not exist – when the kelp is lost the ecosystem collapses
- kelp creates 3D habitats for a large diversity of marine organisms.
- the physical structure of the reef and the biochemical properties of the seawater (oxygen, carbon dioxide, nutrients) that support life are largely determined by kelp.

The foundation species of the Great Southern Reef is the brown macroalgae known as Golden Kelp. Other large macroalgae include Crayweed, Giant Kelp and Bull Kelp growing on a reef.

WATCH this short video to learn more about Golden Kelp https://youtu.be/6gdeNgqGs5o

Recorded observations of Golden Kelp
Source: Atlas of Living Australia

Crayweed at centre are juveniles and adult plants on the right.
Image source: John Turnbull

The **high primary productivity** of kelp forests supports high levels of biodiversity across all trophic levels. Kelp also modifies the environment to create conditions that favour biodiversity. For example, kelp

- slows water movement providing a sheltered habitat on the sea floor
- shades the seabed for species needing low light
- creates an under-storey below the canopy
- provides habitat for mobile and sessile animals across all levels of the forest including within the holdfast.

Slowing water movement also catches drifting larvae making it easier for species such and rock lobster to reproduce and maintain their populations.

Great Southern Reef

The rocky reefs of the Great Southern Reef are home to some of the world's most pristine waters and diverse marine life.

Many of the species found on the Great Southern Reef make use of both the temperate rocky reef habitat itself as well as the adjoining inter-reef habitats such as the deeper water sponge gardens as well as shallow water seagrass meadows.

This week we are exploring the Great Southern Reef's vast networks of shallow water seagrass meadows.

Seagrasses differ to seaweeds as they are plants (unlike seaweeds which are algae). This means they have a root system, stems and leaves, and produce flowers and seeds. Like seaweeds, seagrasses are highly productive ecosystems and provide shelter and food to an incredibly diverse community of animals

GSR species visit many inter-reef habitats Source: Great Southern Reef Facebook Group for teachers . Posted Aug 30, 2021 – https://www.facebook.com/greatsouthernreef/

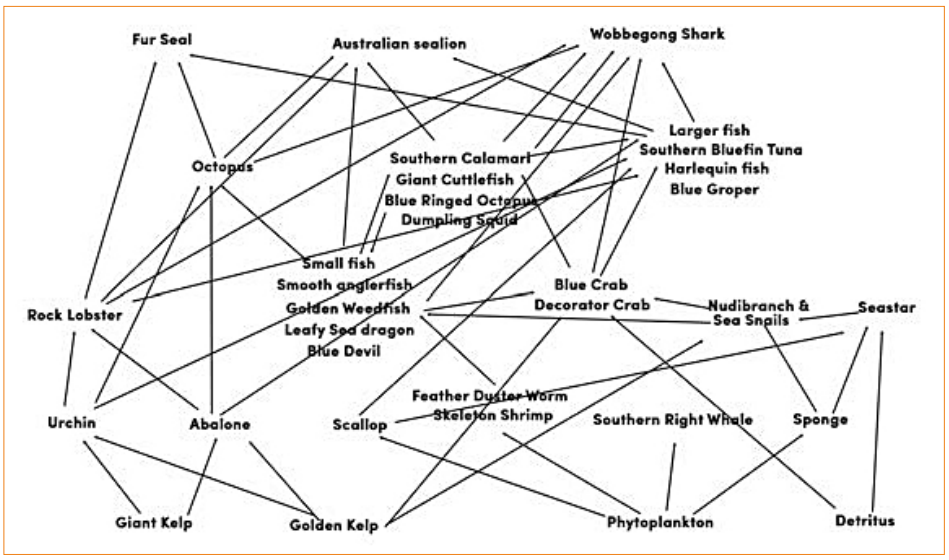
The GSR is a designated **global biodiversity hotspot** with species found nowhere else in the world and more **endemic species** than the Great barrier Reef. Of the three groups of algae (brown, green, and red) the Great Southern Reef has the greatest diversity of red algae in the world, more than 800 species with over 75% found nowhere else.

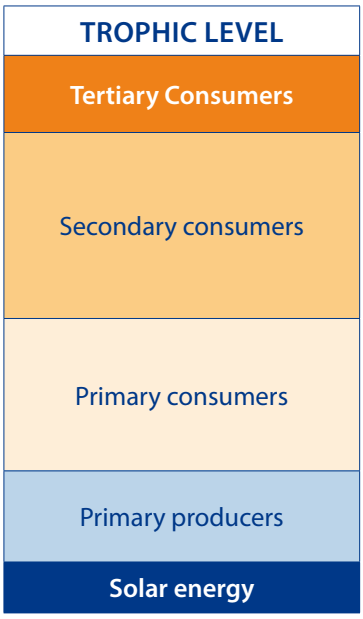
EXAMINE the biodiversity on the Great Southern Reef on the website https://greatsouthernreef.com/marine-life

COMPLETE a food chain and food web activity using the totem cards provided in the Great Southern Reef website. **Figure 12**

Figure 11: Kelp Forest food web

Note: Some species are on multiple trophic levels. For example, an omnivorous fish that eats seaweed and other fish is both a primary and secondary consumer.





Source: Great Southern Reef

Figure 12: Food chain / Food web activity

Totem Card Activity (Download totem cards **HERE**)

- Create a food web using the totem cards.
  1. Move around the room and find other on a similar trophic level. What do your species have in common?
  2. Move around the room and form a food chain by finding predator or prey species of your totem.
  3. Record the food chains of other groups and link them together to make a food web.
  4. Use your food web to predict the consequences if there were too many urchins, and not enough predators of urchins.
- Complete further research on species using this **worksheet** and the **marine life section of this website**

Source: Great Southern Reef Resources https://greatsouthernreef.com/resources

Nutrient cycling

Kelp plays an integral role in **nutrient cycles** including the carbon, oxygen, nitrogen and phosphorus cycles. They absorb carbon dioxide and release oxygen. The oxygen rich water supports consumer organisms that feed on the kelp and phytoplankton. Kelps absorb nutrients such as Nitrogen and Phosphorus directly from the water and transfer these nutrients to other consumer organisms through the food web. Nutrients and detritus from decomposed kelp support other consumer species such as sponges that feed by filtering water.

Beach wrack found on beaches adjacent to the Great Southern Reef consists of decomposing kelp and kelp forest organisms such as sponges and crustaceans that have been washed ashore. The decomposition of organic material recycles essential nutrients for both coastal and marine ecosystems. When it returns to the ocean decomposed wrack become another source of food in the kelp forest ecosystem. Many birds and terrestrial species also utilise wrack. For example, in South Australia, 40 species of birds use beach wrack for nesting, shelter and /or food.

Dynamic Equilibrium

There is a fine balance between producer and consumer organisms in the kelp forest ecosystem and unique and specialised relationships between organisms. This balance is easily upset by changes that cause as loss of species or reduced populations. Natural events such as storms and floods or human modifications such as pollution, sedimentation, overharvesting, introduced species and anthropogenic climate change. Kelp forests become **barrens** or are replaced by **algal turfs** cause imbalances.

'Research published today into the state of kelp forests around the world shows they are being degraded into flat seascapes carpeted by short, unwanted turf-algae – and the Western Australian coastline is one of the worst-affected areas.'

"Most worryingly, these critical transitions can be very difficult to halt or reverse because climate change is pushing more and more kelp forests over the tipping point for collapse."

Source: The rise of turfs—flattening of global kelp forests. University of Western Australia. 2018 – https://phys.org/news/2018-01-turfsflattening-global-kelp-forests.html

Kelp is a stationary species that cannot move to avoid a stress event. Once kelp is decimated or lost, reforestation is difficult without sufficient adult population. When a **tipping point** is passed kelp forests and the species they support will not recover naturally. Examples of kelp forest losses on the Great Southern Reef include Crayweed forests in Sydney, Giant kelp forests in Tasmania and Golden Kelp in Western Australia.

See Illustrative Examples

A Pygmy leatherjacket clings onto a stalked ascidian (sea squirt)
Source: Great Southern Reef Resources https://greatsouthernreef.com/resources

Spotted Handfish

The unique Spotted Handfish in Tasmania was impacted by the overfishing of scallops, the invasion of North Pacific Seastar and loss of the ascidians the fish need for reproduction. This story illustrates how **disequilibrium** has consequences for species.

WATCH: Spotted Handfish – https://www.youtube.com/watch?v=mWXpbmgDbE8

Endangered & Invasive Species – Teacher Guide **HERE**

Great Southern Reef
26 August at 21:21 ·

Many herbivorous fish that live on the Great Southern Reef such as the silver drummer (Kyphosus sydneyanus) feed on brown algae such as the golden kelp.

Mild herbivory on kelp forests is normal for a healthy kelp forest. But in recent years tropical herbivorous fish have moved further south into the Great Southern Reef on both the East and West coast.

A similar fish species, the grey drummer (Kyphosus bigibbus) is a tropical herbivore and usually feeds on tropical algae such as Sargassum and Turbinaria. With climate change increasing warming southern waters and increasing the range of tropical species, kelp forests have get a double whammy of stress.

"First you have the acute temperature stress then, at the same time, the warming temperatures bring in all of these tropical fish that like to eat seaweeds," explained Dr Thomas Wernberg.

Tropicalisation of species changes the dynamic equilibrium. Source: Great Southern Reef Facebook Group for teachers . Posted Aug 27, 2021 – https://www.facebook.com/greatsouthernreef/

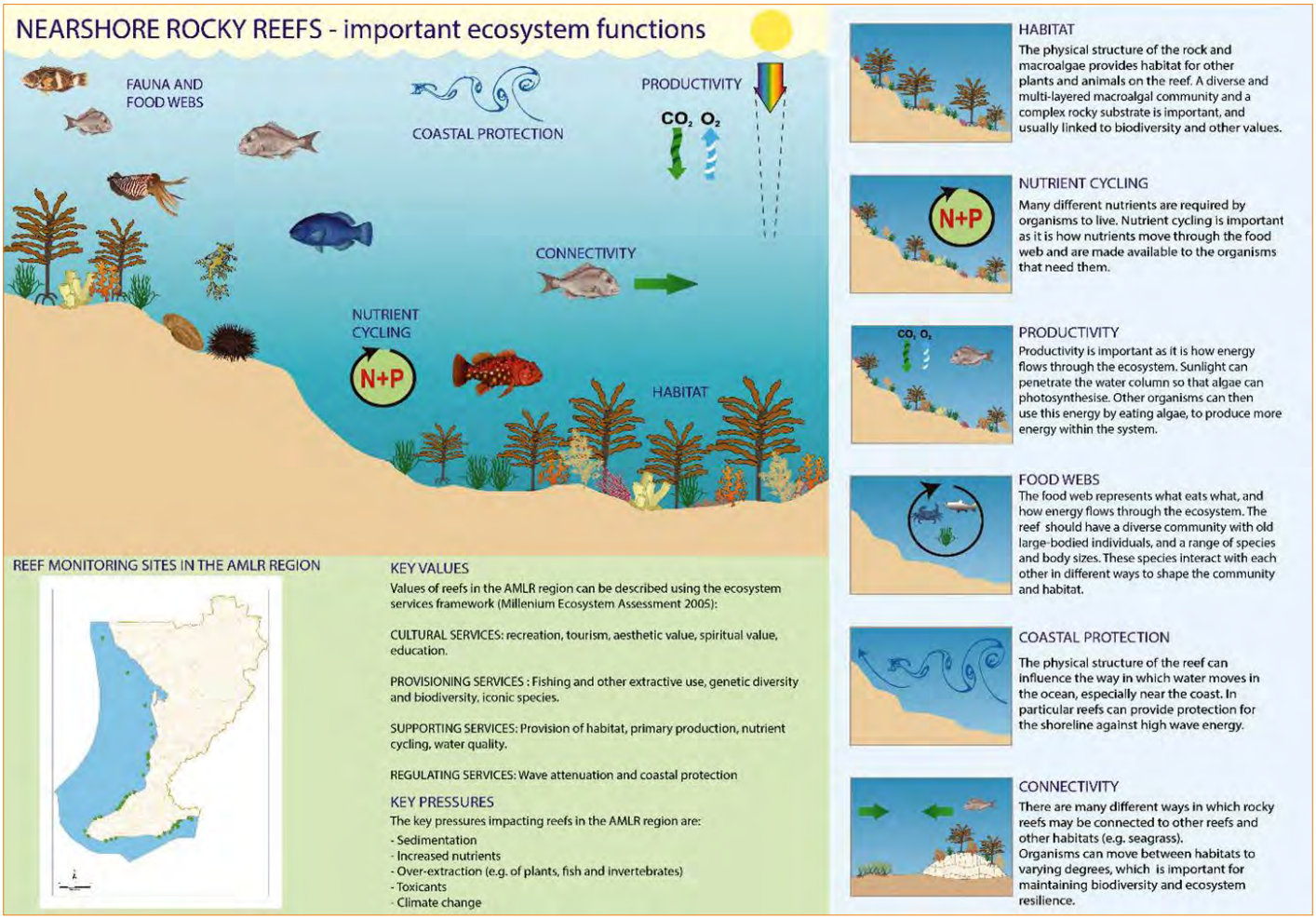
Spotted Handfish and egg mass on ceramic ASH
Photo credit Alex Horrmann and IMAS.

CONCLUSION: KELP FOREST ECOSYSTEM FUNCTIONING

Figure 13 summarises the ecosystem processes and functions of kelp forest ecosystems on the Great Southern Reef in South Australia and is representative of the functioning of kelp forest ecosystems across the entire reef.

See 'IMPORTANCE OF MANAGEMENT AND PROTECTION' on page 29 for more about the values of the GSR kelp forest ecosystem.

Figure 13: Conceptual model – Nearshore Rocky Reefs



Source: Imgraben, S., Peters, K. and Brock, D. (2019). Conceptual models of nearshore reefs in the Adelaide and Mount Lofty Ranges region. DEW Technical note DEW-TER-2018-10, Government of South Australia, Department for Environment and Water, Adelaide - https://data.environment.sa.gov.au/Coast-and-Marine/Ecosystems/Pages/home.aspx

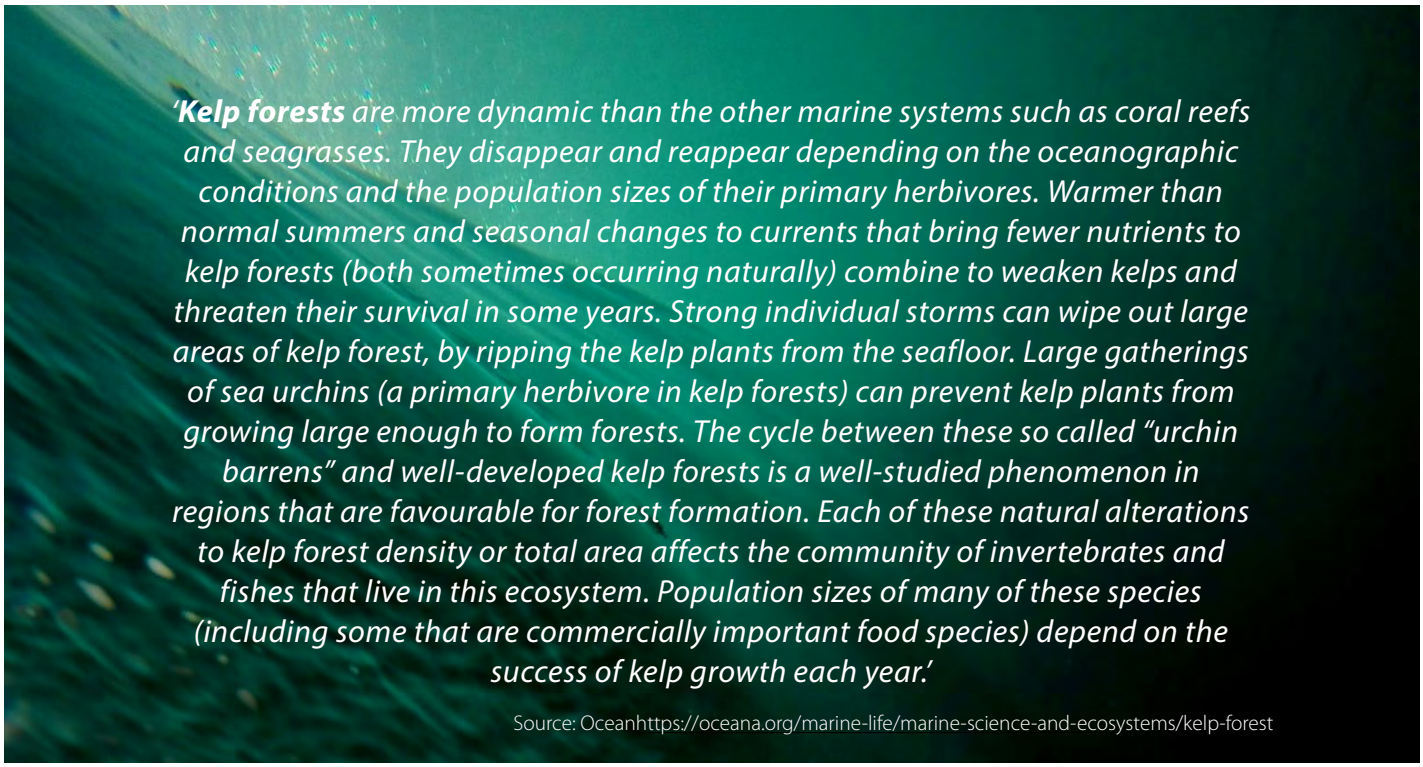
Ecosystem functioning concepts for the Great Southern Reef

upwelling	biodiversity hotspot	oxygenation	turbidity
urchin barren	carbon sink	primary productivity	detritus
dynamic equilibrium	herbivory	trophic level	zonation
temperate	substrate	rocky reef	macroalgae
continental shelf	subtidal	marine heatwave	wrack
keystone species	microalgae	endemism	acidification
algal turf	habitat	biogenic habitat	tropicalisation

KEY: Atmosphere Lithosphere Biosphere Hydrosphere

VULNERABILITY AND RESILIENCE

Marine ecosystems such as the Great Southern Reef continuously adjust to stresses caused by changes to their environment. This balancing act is known as **dynamic equilibrium**.



*'**Kelp forests** are more dynamic than the other marine systems such as coral reefs and seagrasses. They disappear and reappear depending on the oceanographic conditions and the population sizes of their primary herbivores. Warmer than normal summers and seasonal changes to currents that bring fewer nutrients to kelp forests (both sometimes occurring naturally) combine to weaken kelps and threaten their survival in some years. Strong individual storms can wipe out large areas of kelp forest, by ripping the kelp plants from the seafloor. Large gatherings of sea urchins (a primary herbivore in kelp forests) can prevent kelp plants from growing large enough to form forests. The cycle between these so called "urchin barrens" and well-developed kelp forests is a well-studied phenomenon in regions that are favourable for forest formation. Each of these natural alterations to kelp forest density or total area affects the community of invertebrates and fishes that live in this ecosystem. Population sizes of many of these species (including some that are commercially important food species) depend on the success of kelp growth each year.'*

Source: Oceanhttps://oceana.org/marine-life/marine-science-and-ecosystems/kelp-forest

RESILIENCE

The ability to adapt to a changing environment is called **resilience**. Kelp forests on the GSR display a high level of natural resilience within the biosphere. For example:

- flexible stipes allow kelp to bend and adjust to changes in wave energy caused by variations in weather conditions.
- high spore production allows for fast propagation and re-establishment on rock surfaces deforested by storm waves.
- rapid growth rates under optimal conditions speed recovery from change
- storage of nutrients enables species to survive periods of poorer water quality and low nutrients such as during floods or ocean warming events.
- natural predators keep herbivore populations in check
- high primary productivity supports complex food webs and connections between organisms. More complex food webs are more resilient to loss of organisms.

There is a low level of resilience to changes in the atmosphere and hydrosphere such as temperature and water quality.

VULNERABILITY

Kelp forests are extremely **vulnerable** to natural and human induced stresses. Kelp is the ***keystone species*** and principal ***primary producer*** for the Great Southern Reef kelp forest ecosystem**.** The loss or decimation of kelp can cause a ***trophic cascade*** of change that can result in a kelp forest ecosystem replaced by an urchin barren or algal turf.

Factors causing vulnerability include biodiversity, extent, location, and linkages. Figure

Biodiversity. Complex ecosystems with high levels of biodiversity have greater resilience. If one species is lost or suffers reduced population, the ecosystem can still function… unless it is the primary producer of the ecosystem.

Extent. Extent refers to dimensions including area, shape and continuity. Large, compact and continuous ecosystems are less vulnerable than smaller, fragmented and / or elongated areas where edge effects have greater impact.

Location. The location of an ecosystem determines the vulnerability to natural and human stresses including climate variability, extreme weather events, urban development, resource exploitation and pollution.

Marine ecosystems at all latitudes are vulnerable to global warming and marine heatwaves, although some locations, including the GSR, are experiencing a greater magnitude and rate of change.

Linkages. Connections within and between ecosystems are essential to ecosystem functioning. When linkages are broken or altered the dynamic equilibrium is disturbed. All ecosystems are linked to the atmosphere and hydrosphere and are increasingly vulnerable to changes in these systems.

Climate change and increasing vulnerability

'Due to their low capacity to relocate and high sensitivity to warming, kelp forests are projected to experience higher frequency of mass mortality events as the exposure to extreme temperature rises (very high confidence). Moreover, changes in ocean currents have facilitated the entry of tropical herbivorous fish into temperate kelp forests decreasing their distribution and abundance (medium confidence). More evidence from model projections in the 21st century supports this observed range contraction of kelp forests at the warm end of their distributional margins and expansion at the poleward end with the rate being faster for high emission scenarios (high confidence).'

IPPCC Report 2021 P499

The frequency and intensity of extreme weather events is predicted to increase. The events that will increase the vulnerability of the Great Southern Reef include:

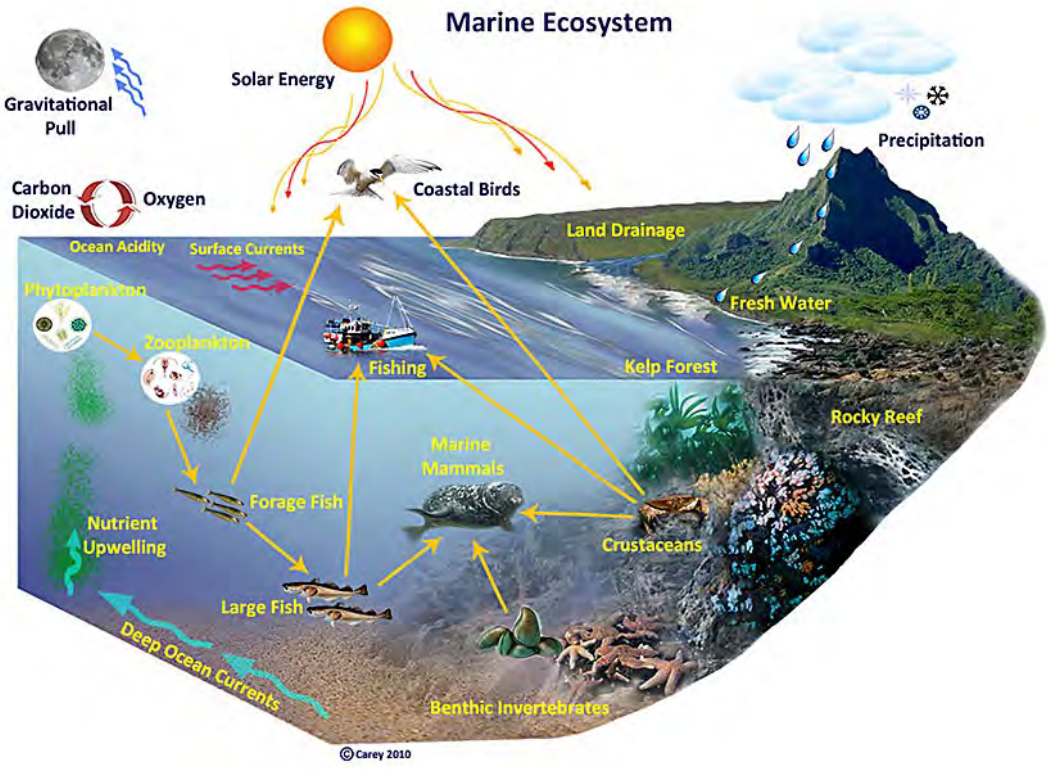
- longer, more intensity and more frequent heatwaves
- more intense and frequent extreme rainfall events and flooding
- higher sea levels

Management: Building resilience

Management is aimed at reducing vulnerability and maintaining or building resilience by:

- protecting vulnerable species and habitats to maintain biodiversity
- conserving and protecting current kelp forests and restoring lost forests
- maintaining populations of native species or removing threatening species
- managing stresses at specific locations by controlling human activities such as fishing

At a global scale, action on climate change is essential to minimising future kelp losses



Source: https://www.flickr.com/photos/xbordercurrents/5228770307

VULNERABILITY: GREAT SOUTHERN REEF

BIODIVERSITY

The Great Southern Reef has high levels of ***genetic***, ***species*** and ***ecosystem*** (habitat) diversity that reduce its vulnerability to stress. For example: in Western Australia, ***genetic resilience*** is attributed to Golden Kelp that was not decimated by a marine heatwave in 2010 –11. This find gives hope to kelp forest restoration efforts. Illustrative example – Green Gravel.

Golden Kelp has proven more resilient than Crayweed and Giant Kelp to changing environmental conditions and has survived in places where other species have been lost. See Illustrative examples – Super Kelp and Operation Crayweed

The Great Southern reef has a large ***diversity of interconnected habitats*** such as kelp, sponges, and seagrasses. Organisms move between habitats for food, breeding and shelter.

NOTE: Kelp habitat, the foundation of the GSR, is the most vulnerable to change.

EXTENT

The Great Southern Reef has a large latitudinal extent and covers 8000 km of coastline. However, it is comprised of many ***discontinuous smaller reefs*** with rocky outcrops often separated by large distances. These reefs occupy a ***narrow band of subtidal continental shelf*** where kelp grows to depths that light can penetrate. These environmental constraints make kelp forest ecosystems particularly vulnerable to changes in hydrologic and atmospheric conditions.

NOTE: There is little potential for kelp forests to extend seaward or coastward in the short term because of the limiting environmental conditions kelp requires. Over a longer timeframe however, adaptation, invasion and succession into different environments is possible if the rate of environmental change is slow.

LOCATION

Sections of the Great Southern Reef are adjacent to large populations and some of the fastest urban growth regions in Australia. All southern capital cities are coastal and put stresses on the GSR through pollution, harvesting resources, fishing, and recreation. See Illustrative Example- Operation Crayweed. Agricultural catchments increase the vulnerability of the GSR to pollutants and sedimentation.

Fortunately, large areas of the coast bordering the Great Southern Reef are protected in National and State Parks and reserves. These areas are often remote so much of the GSR in these locations is in good condition.

NOTE: No location along the GSR however can escape global warming and marine heatwaves. Increased herbivory and the disappearance of kelp is happening all along the GSR as a result of ocean warming. Sections of the GSR, such as eastern Tasmania are experiencing a greater magnitude and rate of warming.

LINKAGES

Kelp forest food web connections are easily broken by changes to biotic and abiotic conditions. Increased runoff from urban and agricultural landuse delivers sediment and pollutants that reduce kelp productivity. Declining populations of species due to overharvesting causes explosions in herbivore populations that overgraze kelp. Kelp loss has repercussions for food webs and biodiversity.

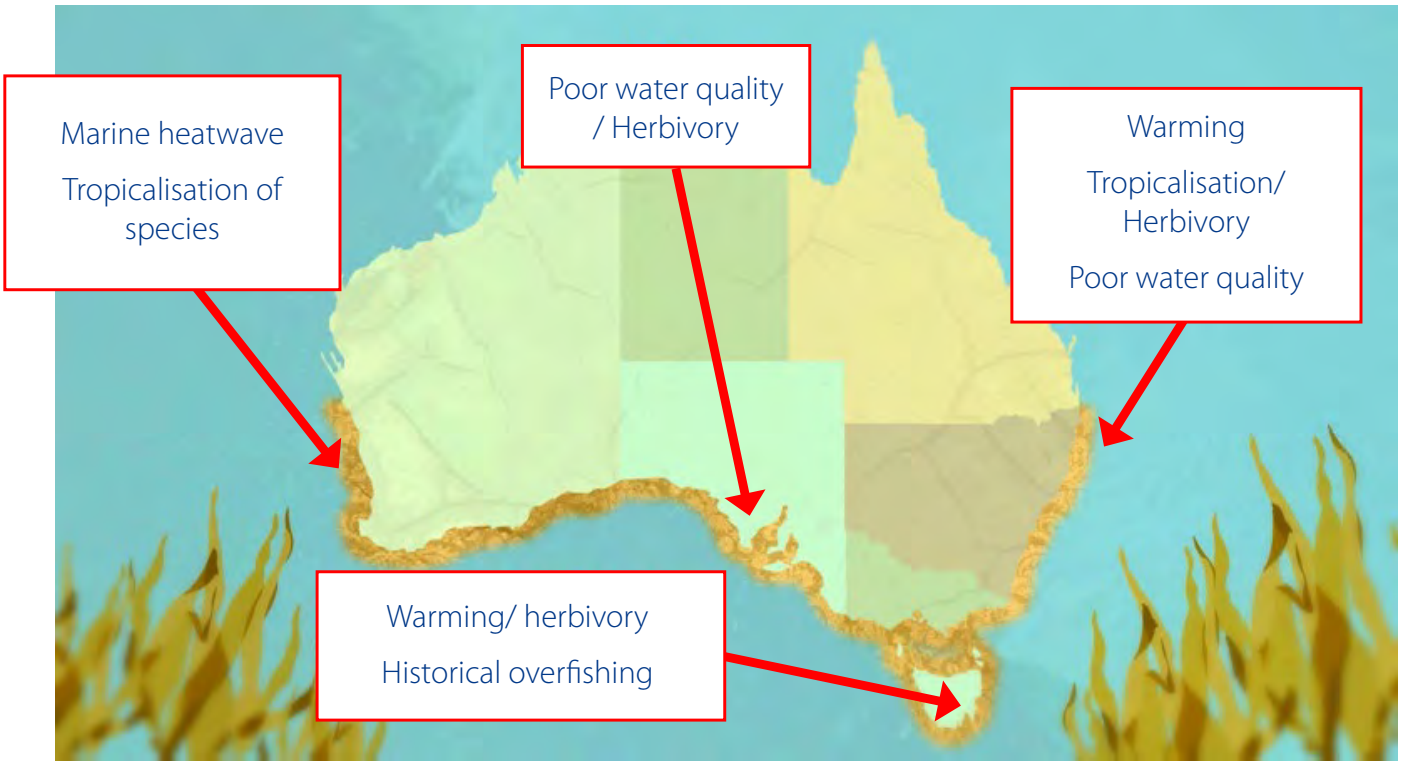
The Great Southern Reef is ecologically linked to adjacent ecosystems such as seagrasses, rock platforms and beaches and the deeper ocean. Changes to adjacent ecosystems and/or a loss of species has repercussions for kelp forests. For example, without coastal mangroves and seagrasses, kelp forests face increasing coastal sediment loads and turbidity and reduced biodiversity.

HUMAN IMPACTS AND ECOSYSTEM FUNCTIONING

Human impacts on kelp forests globally are well documented. Pollution / poor water quality, overfishing / overharvesting, sedimentation, invasive species /herbivory, changes to ocean circulations / currents and climate change have been identified as key causes of change. All can be linked to human activities from a local, regional and global scales.

On the Great Southern Reef, the main cause(s) of change differ by geographical location. See **Figure 14**.

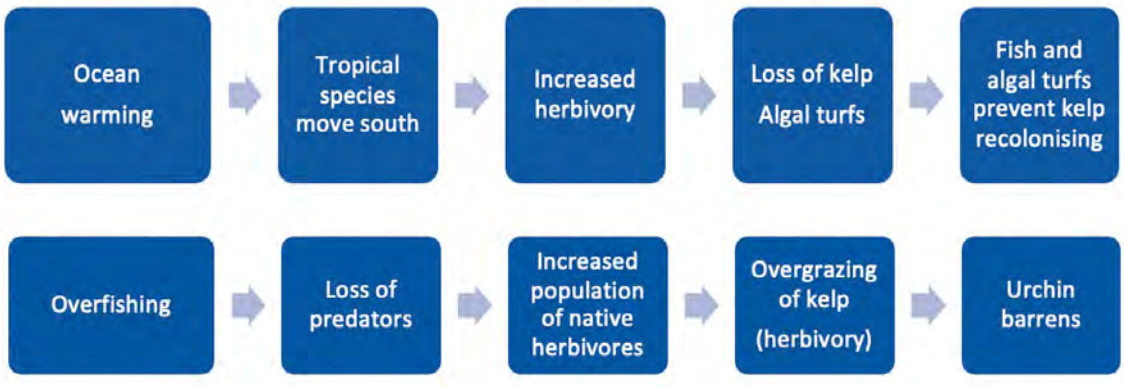
Figure 14: Causes of change to Great Southern Reef kelp forests.



Base map: Great Southern Reef https://greatsouthernreef.com
Adapted from GTANSW & ACT 2021 Annual Conference Presentation. *'Operation Crayweed. Engaging local communities and restoring underwater forests'* https://vimeo.com/560465469

The most significant impacts of change have been the loss and degradation of kelp forests, tropicalisation of species, the 'homogenisation' of kelp forest ecosystems, the replacement of kelp forests by algal turfs and urchin barrens and a loss of marine biodiversity. These impacts have economic, environmental and social consequences for the Great Southern Reef ecosystem and the communities that depend on it.

Some consequences of change



Climate Change and tipping points

Climate change projections and predicted impacts suggest that the kelp forests of the GSR will survive because they are resilient and adaptable, however they face permanent change in spatial distribution, characteristics and functioning.

Frequent impacts over a period of time have been shown to reduce ecosystem resilience and ability to recover. Further change associated with a warming climate e.g., an increase in storms and warming oceans, will increase the stresses on kelp forests and for some this will be the ***tipping point*** beyond which they will not recover. **Figure 15**

Measuring change

Historical data provides a baseline against which current and future change can be mapped. A 50-year global analysis by scientists showed a large variation in the magnitude and direction of change by species and geographic distribution with kelp losses in some regions and gains in others. There was evidence of decline in 38% of the kelp forests studied and an increase in the abundance of kelp in 25% of regions illustrating the influence of regional factors. Kelp Forests in the SE and SW Australia were in the declining category.

Longitudinal scientific studies of kelp forests in northern NSW (2002 – 2012*) and Western Australia (2001 – 2015*) by universities and research organisations are two studies showing that the causes and impacts of change on the Great Southern Reef vary geographically.

Organisations such as the Reef Life Survey Foundation are helping to fill knowledge gaps and provide access to quality, scientifically acquired data to record and monitor change, and to inform or evaluate management.

WATCH how quality data is obtained in the field:

1. Reef Life Survey makes the underwater visible
   https://www.youtube.com/watch?v=grq8dflbm8Q
2. Monitoring trends in marine life through citizen science
   https://www.youtube.com/watch?v=3I4V9iRKCBE

READ these reports to examine changes to kelp forests globally and in Australia:

Global patterns of kelp forest change over the past half-century
https://www.pnas.org/content/pnas/early/2016/11/09/1606102113.full.pdf?sid=b5c75459-7507-4cf9-93a8-1388e349a056

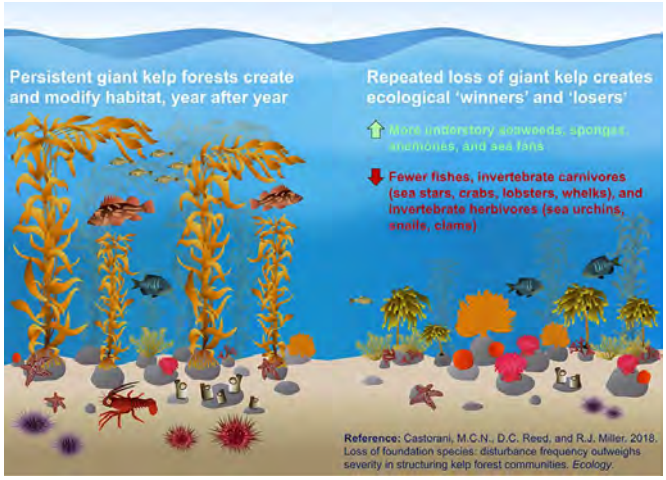
Underwater Health Check shows forests are declining around the world
https://theconversation.com/underwater-health-check-shows-kelp-forests-are-declining-around-the-world-68569

Tropical invaders, heat waves and pollution take toll on Australia's kelp forests
https://www.abc.net.au/news/science/2016-11-15/tropical-fish,-heat-waves,-pollution-threat-to-australias-kelp/8023634?nw=0

Multiple threats

Kelp forest ecosystems face multiple threats to their functioning with one change usually identified as a key driver or stressor. Frequent change over a period of time can reduce an ecosystems resilience and ability to recover as can increased stressors from natural events, human activities and climate change. **Figure 15**.

Figure 15: Impacts of frequent change on kelp forest biodiversity



LEFT: Increasing frequency of ocean storms alters kelp forest ecosystems
Source: https://www.nsf.gov/news/mmg/media/images/7_Kelp%20infographic%20(Max%20Castorani%202018-07-22).jpg

A. IMPACTS FROM TERRESTRIAL AND MARINE BASED ACTIVITIES

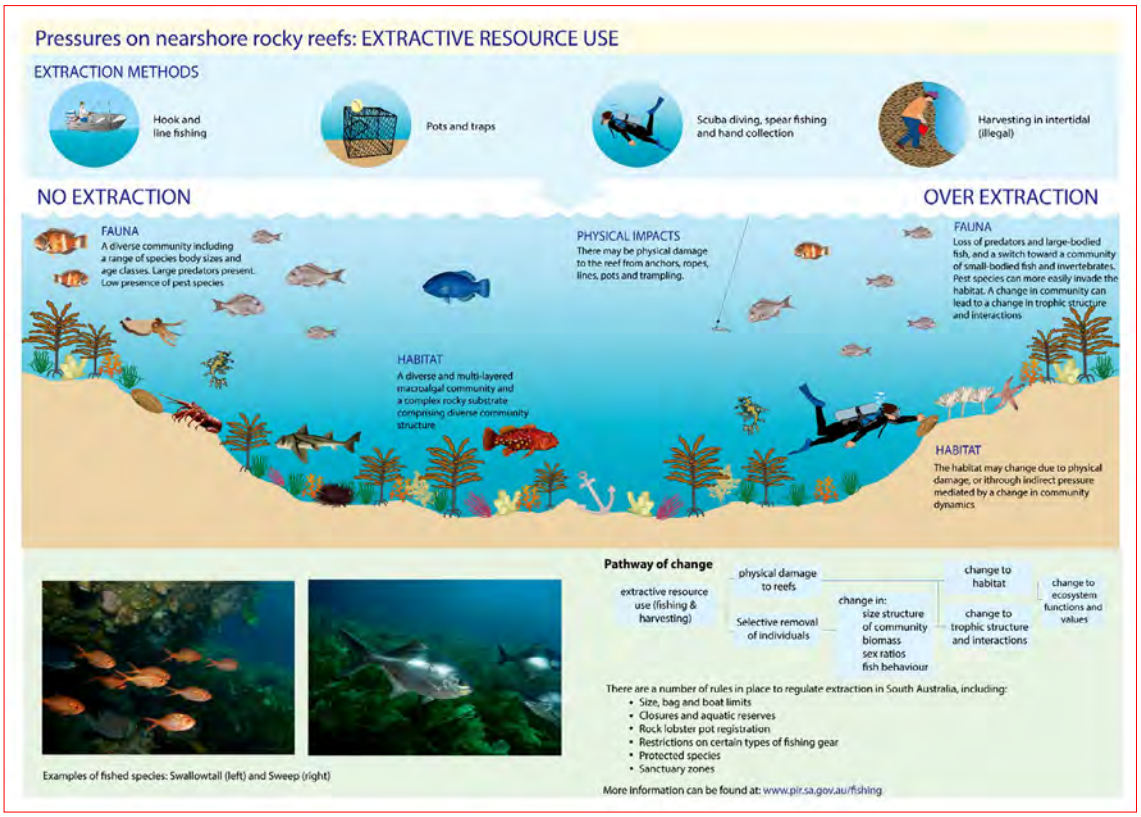
* Many of these impacts are detailed under the headings *Biophysical Interactions* AND *Vulnerability and Resilience*. Some examples are referred to in the *Illustrative Examples*.

HUMAN ACTIVITY	IMPACT ON ECOSYSTEM FUNCTIONING
Extracting resources / Commercial fishing See Figure 16	Loss of secondary and tertiary consumers / increased herbivory Example: Overhunting crayfish in Tasmania remove a natural predator of urchins and caused imbalance in the food web*
Pollution / Nutrients and chemicals See Figure 17	Eutrophication / algal blooms increase turbidity, fish kills Example: Sewage discharged into the ocean in Sydney in the 1970's caused the loss of Crayweed forests that could not tolerate the increased nutrient load*
Coastal development **Agriculture / urban / industrial / erosion / runoff** See Figure 18	Sedimentation – increased turbidity and reduced sunlight penetration / loss of baby kelp – smothering and reduced photosynthesis. Example: Coastal development and agriculture on Spencer Gulf in South Australia reduced water quality and increased turbidity that caused a shift from kelp to algal turf.
Tourism / boating / scuba diving	Damage / loss of species or primary biomass Example: Damage to seagrasses caused by boats anchoring in Cabbage Tree Bay Marine Reserve (Manly) led to calls in early 2021 to prohibit anchoring and extend the reserve.
Invasive species / marine pests	Competition / herbivory Example: Southward migration of fishes on the WA coast south of Kalbarri after the marine heatwave killed the kelp forests prevented the re-establishment of kelp.

Conceptual models

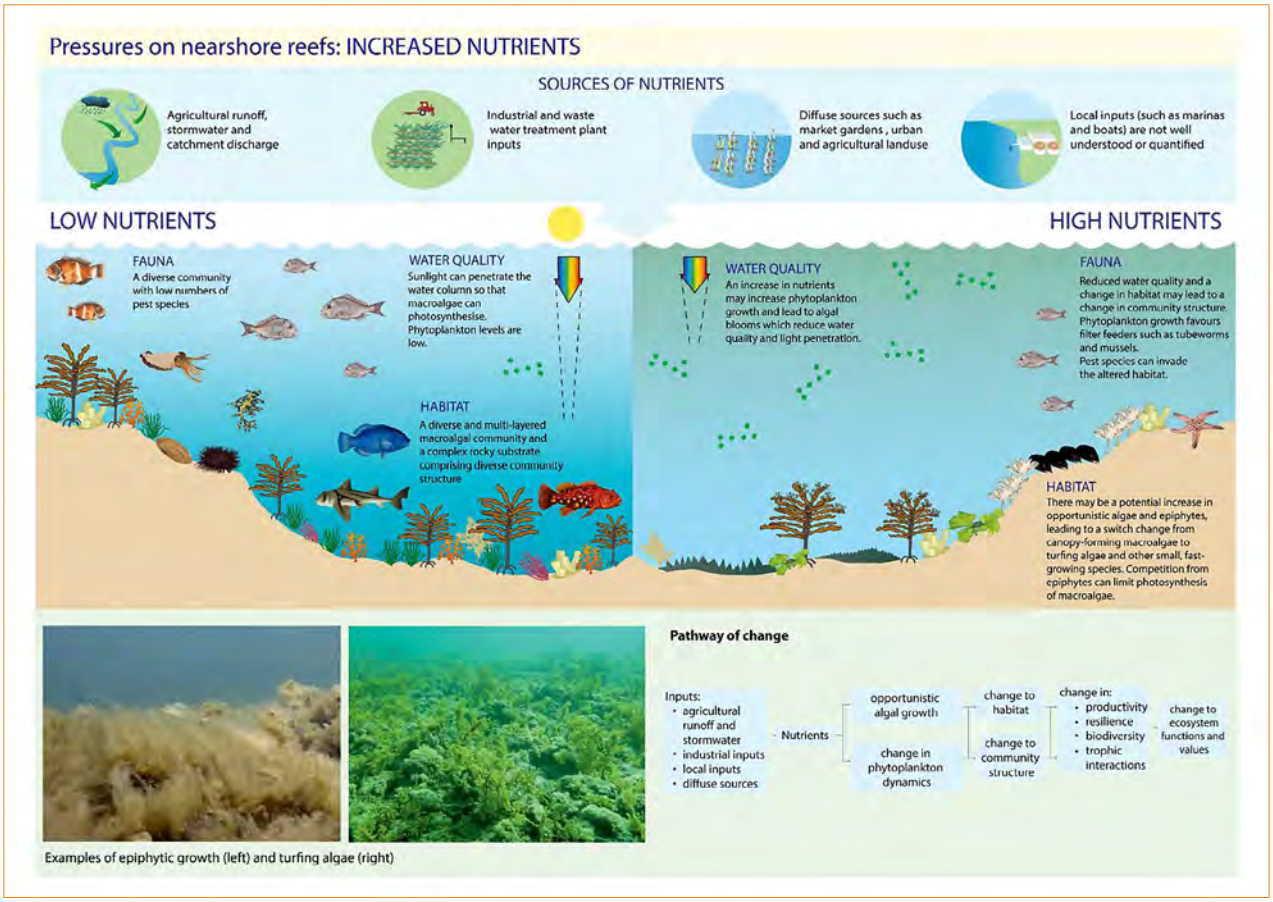
The following conceptual models were created for the South Australian Department for Environment and Water (2019) to summarise key threats and impacts on subtidal reefs. The three pressures illustrated are common to rocky reefs across the Great Southern Reef and useful for analysing the impacts of human activities.

Figure 16: Extractive Resource Use



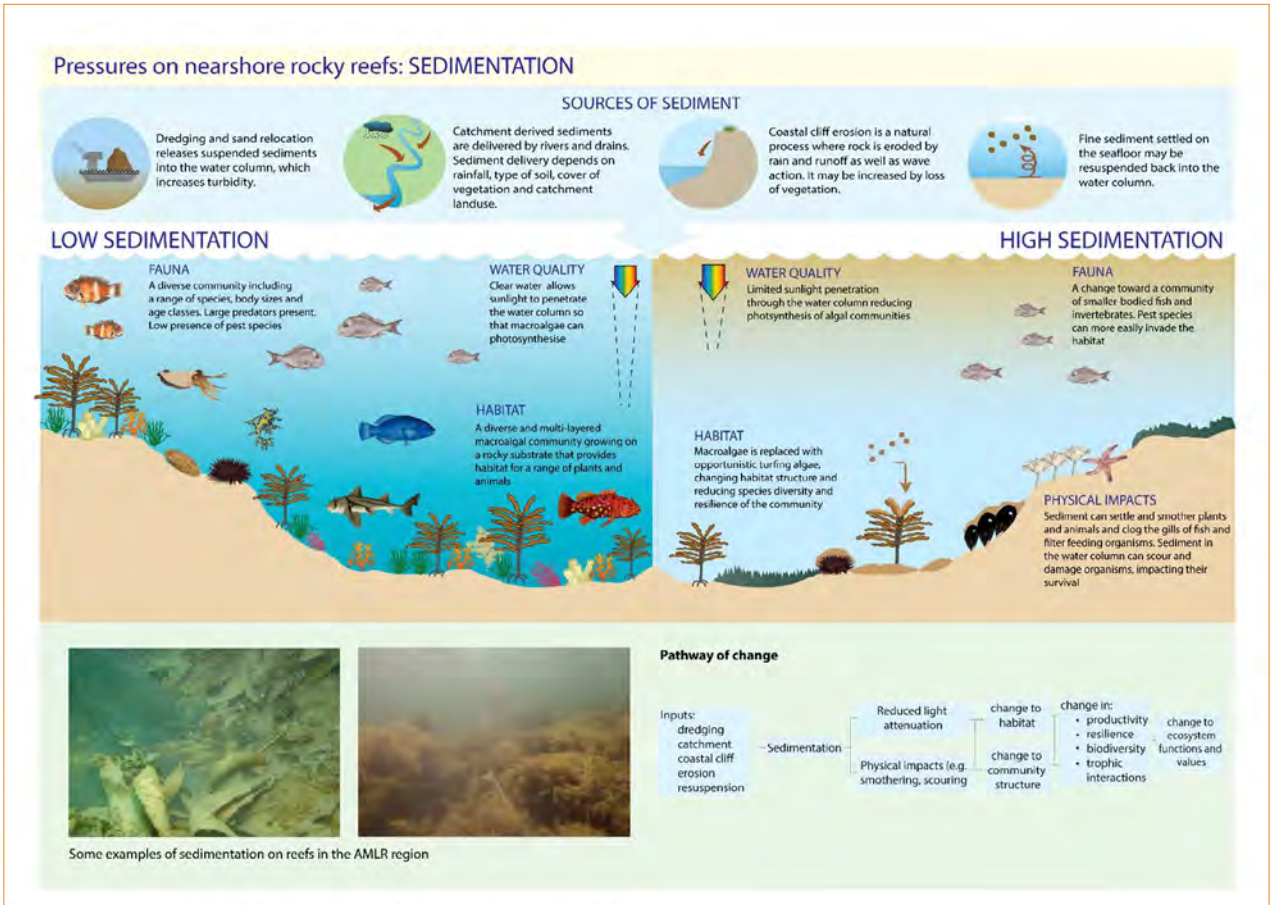
Conceptual models of nearshore reefs in the Adelaide and Mount Lofty Ranges region Department for Environment and Water 2019 https://data.environment.sa.gov.au/Content/Publications/AMLR%20Conceptual%20models-Technical-NOTE.pdf

Figure 17: Increased nutrients



Examples of epiphytic growth (left) and turfing algae (right)

Figure 18: Sedimentation



Some examples of sedimentation on reefs in the AMLR region

B. IMPACTS LINKED TO CLIMATE CHANGE

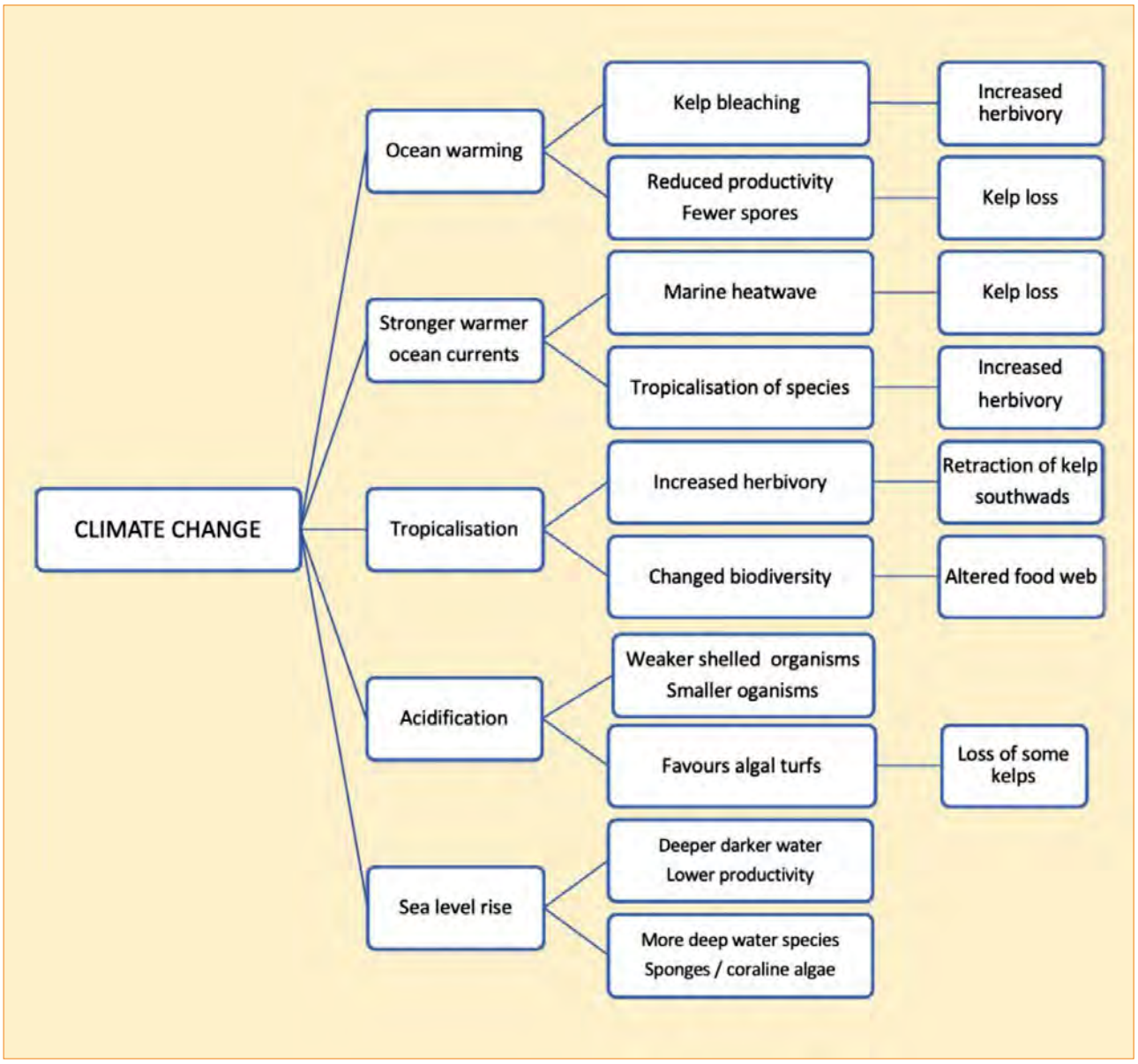
Carbon emissions from human activities are causing ocean warming, acidification and oxygen loss with some evidence of changes in nutrient cycling and primary production. The warming ocean is affecting marine organisms at multiple trophic levels, impacting fisheries with implications for food production and human communities.

'The loss of kelp forests is followed by the colonisation of turfs, which contributes to the reduction in habitat complexity, carbon storage and diversity (high confidence). Kelp ecosystems are expected to continue to decline in temperate regions driven by ocean warming and intensification of extreme climate events.'

Source: IPCC: Special Report on The Ocean and Cryosphere in a Changing Climate Ch5 https://www.ipcc.ch/srocc/chapter/chapter-5/

Figure 19 refers to many of the impacts of climate change on Kelp Forests referred to under previous headings and in the Illustrative Examples that follow.

Figure 19: Real and potential consequences of climate change for GSR kelp forests



Source: L chaffer

The Harlequin Fish is an iconic species in South Australia

The Adelaide and Mount Lofty Ranges Natural Resources Management Region:

- is ≈ 50% terrestrial and 50% marine
- supports iconic species and species of conservation concern such as the Harlequin Fish and Blue Groper
- provides critical habitat important for the lifecycles of commercially and recreationally fished and non-fished species
- is close to the large population area of greater Adelaide

See Conceptual models on pages 25 and 26

Harlequin Fish: Iconic GSR species on in South Australia
Source: Ocean Imaging | Great Southern Reef.

References

Tropical invaders, heat waves and pollution take toll on Australia's kelp forests https://www.abc.net.au/news/science/2016-11-15/tropical-fish,-heat-waves,-pollution-threat-to-australias-kelp/8023634?nw=0

Cool water fish floundering as tropical fish invade temperate reefs https://newsroom.unsw.edu.au/news/science-tech/cool-water-fish-floundering-tropical-fish-invade-temperate-reefs

Bleaching is a serious threat to the kelp forests of Australia's Great Southern Reef https://www.science.org.au/curious/earth-environment/kelp-needs-our-help

Call to protect reserve Apr 15, 2021 | Lifestyle, Manly ward https://www.northernbeachesadvocate.com.au/2021/04/15/call-to-protect-reserve/

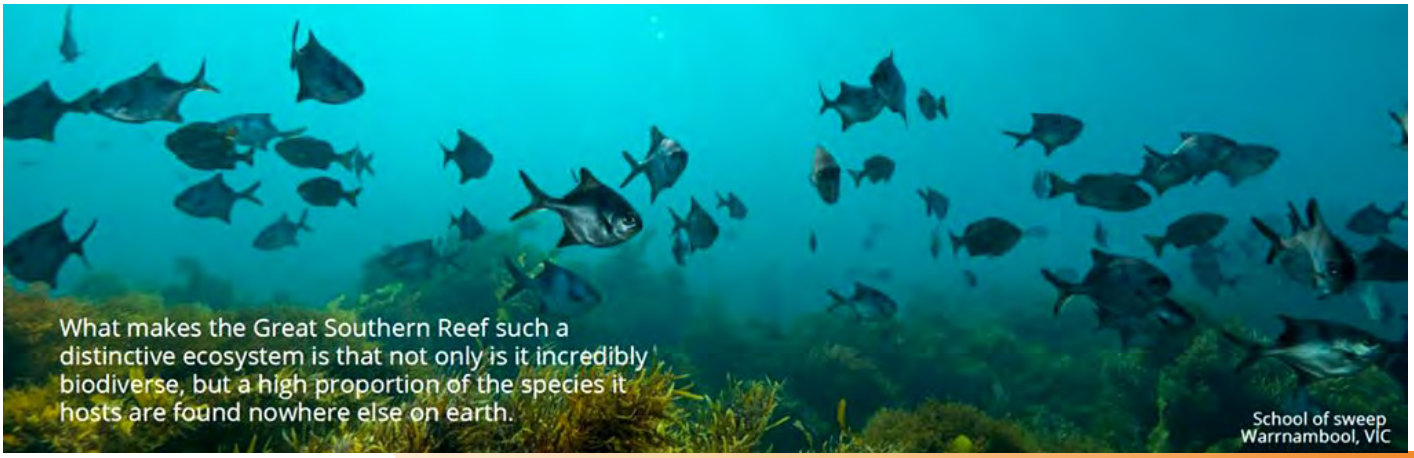
Status and Trends for the World's Kelp Forests. Thomas Wernberg, Kira Krumhansl, Karen Filbee-Dexter, Morten F. Pedersen, https://doi.org/10.1016/B978-0-12-805052-1.00003-6

Global patterns of kelp forest change over the past half-century https://www.pnas.org/content/113/48/13785 Source: The Conversation – selected statements.https://theconversation.com/marine-heatwaves-threaten-the-future-of-underwater-forests-37154

How Climate change is impacting Australia's Kelp Forests https://www.youtube.com/watch?v=1jQH6ZG11zU

Extreme Marine Heatwaves Alter Kelp Forest Community Near Its Equatorward Distribution Limit https://www.frontiersin.org/articles/10.3389/fmars.2019.00499/full

SPECIAL REPORT: GLOBAL WARMING OF 1.5 ºC CH 03. Impacts of 1.5ºC global warming on natural and human systems https://www.ipcc.ch/sr15/chapter/chapter-3/



MANAGEMENT AND PROTECTION

A. IMPORTANCE OF MANAGEMENT AND PROTECTION

Values of the Great Southern Reef

"Some people might not be interested in seaweed. But they may be interested in fishing, or their beachfront property not getting washed away, or making sure that their coastal waters are clean. All of those things are intimately tied to kelp forests."

Cayne Layton. Source: https://www.greenbiz.com/article/can-forests-worlds-oceans-contribute-alleviating-climate-crisis

"Kelp is SO much more than slimy beach debris. It's the habitat building, carbon storing and tooth-paste thickening, algae-extraordinaire responsible for maintaining and regulating cool, rocky shores across the globe."

Source: https://www.themarinediaries.com/tmd-blog/help-whats-kelp

HERITAGE VALUES

i. Aboriginal heritage

'Aboriginal cultural heritage includes tangible and intangible values, such as Song Lines, Dreaming stories and ceremonies passed from generation to generation, as well as physical objects and places'. (Heritage NSW)

Aboriginal people have been sustainably using and managing Sea Country and its resources for tens of thousands of years, in some places since before rising sea levels created the current GSR marine environment. Aboriginal people do not separate land from sea and many ***Song Lines*** cross from land to nearshore to deep coastal waters. **Figure 20**

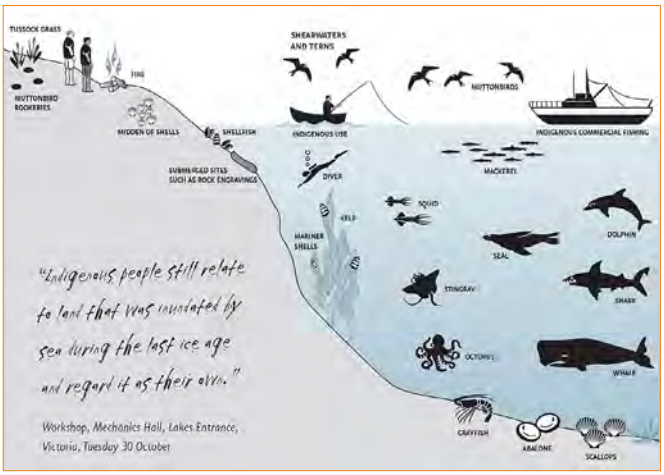
Evidence of Aboriginal use of marine resources across the GSR region include ***middens*** and ***fish traps*** such as those at Arrawarra in northern New South Wales and Whyalla in South Australia. These sites were used to provision food, cultural and spiritual activities. Other heritage artefacts including items made from kelp and shells.

Marine plants and animals have a special spiritual place in stories passed through generations and that value is also demonstrated through the social system of ***totems*** that carry with them a responsibility for the management and protection of species.

" Indigenous Australians have lived off the sea's abundant resources for tens of thousands of years. Tidal fish traps and productive coasts would act as camping grounds where knowledge was shared through storytelling, including the sustainable fishing and preparation of local fish, shellfish and crustaceans. Jasan Billny, a representative of the Barngarla people in South Australia explains, "Part of our connection to land and sea is that every flora and fauna has a story to it, so you treat it with respect." He continues, "This connection to our country is why these resources have survived for so long."

Source: https://greatsouthernreef.com/about

Figure 20: Indigenous use of oceans & marine resources



Source: Sea Country: An Indigenous perspective https://www.environment.gov.au/system/files/resources/271c0bfc-34a2-4c6c-9b02-01204ebc0f43/files/indigenous.pdf

Source: Great Southern Reef https://www.youtube.com/watch?v=LKO_YNPizvE

WATCH: Indigenous connection to the GSR

Bunna Larwie is a Mirning elder and Whale songman (totem) on the Great Australian Bight whose ancestors cared for country for 3000 generations.

In Mirning language "Goonminyerra" means "to keep protecting that place". It describes a gratitude to Country and everything that lives on it.

Source: Great Southern Reef Lesson 1 Teacher Guide

READ: Coast of Dreams: Aboriginal Connection with the sea in and around Whyalla (SA) to learn more about the past use of the GSR


SINGING TO THE SHARKS RITUAL

Where: Point Lowly.

When: Summer.

All three tribal groups – Barngarla, Andyamanthanha and Kokatha agreed that Point Lowly was a place where people used to sing to the sharks. At Weeroona Bay, the men gathered at the rocks while the women danced on the beach. The men sang to the sharks. The sharks gathered schools of fish and drove them towards the beach. The men then entered the water and collected fish. The last person in Whyalla who was able to sing to the sharks passed away in the late 1960s.

Explainer:
In general terms, fish are not drifters, they swim with a reason. They have a well-developed

Source:https://www.whyalla.com/sites/whyalla/media/images/cuttlefest-2020/coast-of-dreams-for-website.pdf

ii. *European Heritage*

Australia has a long non – indigenous maritime history. The 8000 km coastline of the Great Southern Reef with its extensive rocky outcrops and headlands experiences some of the most treacherous seas in the world, particularly during storm events. There are over 1,000 known shipwrecks in Tasmanian waters where jagged cliffs and submerged rocky reefs posed huge risks in the days of sailing ships. The wrecks include the Sydney Cove, the eighth oldest known shipwreck in Australia. These vessels form part of Australia's Maritime Heritage and are protected under government legislation.

iii. *Natural heritage*

All of the habitats and species of the Great Southern Reef make up a significant component of the Australian Marine Estate. It is important for intergenerational equity that this natural heritage is protected for future generations.

UTILITY VALUES

i. *Economic services*

It's estimated that the Great Southern Reef contributes more than $10 billion a year to the Australian economy. Some major economic contributions from ***fisheries*** and ***tourism*** per year include:

- rock lobster fisheries ≈ $375 million pa
- abalone fisheries ≈ $134 million pa
- direct tourism activities ≈ $10 billion pa
- total tourism (reef and adjacent coastal areas) ≈ $40 pa

WATCH: Australia's Southern Rock Lobster (Crayfish) fishery https://www.youtube.com/watch?v=uz2zP2j1Dp8

Source: Great Southern Reef

Many ***regional coastal communities*** along the Great Southern Reef rely on ***tourism*** to provide employment and generate income. On Phillip Island in Victoria, Tasmania's west coast, and Kangaroo Island in South Australia, the reef contributes ≈15% to total economic activity.

The protection of the marine estate is essential to maintain and grow that value.

WATCH: Cuttlefest Annual Event in Whyalla
Source: https://www.whyalla.com/cuttlefest

Each year thousands of tourists visit marine parks to enjoy unique natural environments and species. The ***Giant Australian Cuttlefish aggregation*** in South Australia attracts tourists from around the world, who come to snorkel or SCUBA dive at this unique breeding site. In 2020 tourists visiting during the aggregation period contributed over $17 million to the city's economy (ABC News).

See Illustrative Example on Marine Protected Areas

ii. Environmental Services

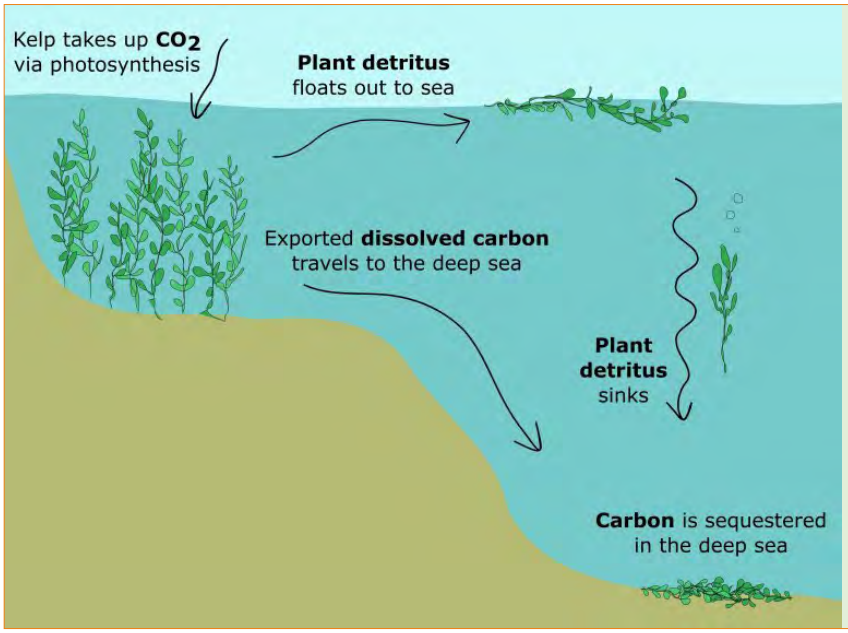
The Great Southern Reef kelp forests perform important **environmental functions** that include:

- helping to ***prevent coastal erosion*** (by absorbing and deflecting wave energy)
- acting as a ***'biofilter'*** trapping sediments and absorbing nutrients
- providing ***habitats*** for courtship, mating, egg laying and juvenile fish (nurseries)
- supporting a huge ***diversity of species*** in all tropic levels in complex food webs

One of most important features of productive ocean ecosystems such as kelp forests is their role absorbing Carbon Dioxide and producing Oxygen. Kelp and other seaweeds (macroalgae); microalgae (phytoplankton); and marine plants (seagrass) absorb CO2 during photosynthesis to grow biomass. They produce oxygen as a byproduct of photosynthesis, oxygenating the ocean for consumer organisms.

When marine algae die, carbon locked in its tissues is transported to the deep ocean where it remains, potentially forever. This is known as 'carbon sequestration' and is why kelp forests are referred to as 'carbon sinks', and the carbon they hold is known as 'Blue Carbon'. It is estimated at that at a global scale, seaweeds are thought to sequester nearly 200 million tonnes of CO2 every year. **Figure 21**

Figure 21: Sequestration of carbon into the deep sea



Most of the carbon sequestered by macroalgae is sent to the deep sea in the form of dissolved carbon or plant detritus which easily floats out to sea thanks to its gas-filled bladders.

Source: How kelp naturally combats climate change https://sitn.hms.harvard.edu/flash/2019/how-kelp-naturally-combats-global-climate-change/

LISTEN to a PODCAST from the Manly Seaweed Forest Festival Podcast: Episode 2
https://www.seaweedforestsfestival.com/podcasts/

Professor Tim Flannery speaks about the value of seaweeds as carbon pumps

Also in this podcast, the impact of climate change

iii. Cultural Services

'Due to its sheer scale and close proximity to almost 70% of the Australian population, the reef forms an integral part of Australian culture and society'

Cultural services are the non-material benefits people gain from an environment such as recreational use, aesthetic appreciation, spiritual enrichment, sense of place, health and well- being. Bells Beach in Victoria has a reputation developed through surf culture and folklore as an internationally renowned surfing icon. As well as hosting the longest running annual international surfing contest, Bells Beach's surfing history is commemorated in its status as a Surfing Recreation Reserve.

'National Surfing Reserve status recognises surfing as a sport that is part of the social and economic fabric of many coastal communities across the Great Southern Reef and beyond'.

MAINTENANCE OF GENETIC DIVERSITY

WATCH: Bells Beach – how a world first became a model for conservation https://www.youtube.com/watch?v=sn66TPpDChI

Source: Ocean Imaging | Great Southern Reef

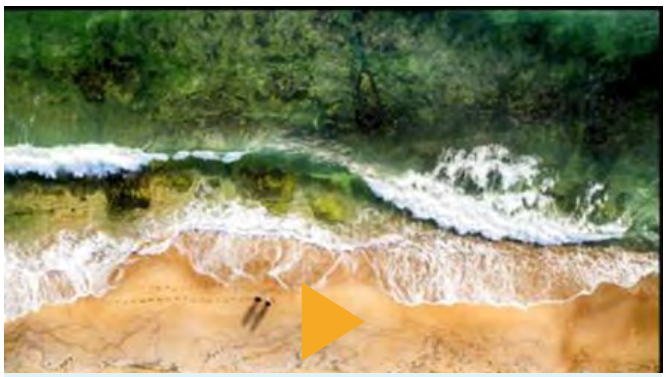
Genetic diversity is an important contributor to the resilience of kelp and other kelp forest organisms. The Great Southern Reef is rich in biodiversity with one of the highest rates of endemism in the world with an estimated 10,000 species not yet identified. The reef supports a greater diversity of marine life (especially flora and invertebrate fauna) than the GBR leading scientists referring to it as Australia's Unique South

Biological diversity is a bank of genetic material made up of the individual genes of each species. Over long periods of time species have adapted to change through a process of ***natural selection*** in which the best characteristics for survival are maintained and passed to future generations.

The ***genetic database*** in Great Southern Reef is a potential safety net for adapting to future change, in particular Climate Change. Scientists are already experimenting with the selection of species they believe to be more resilient to climate change for the restoration of lost kelp forests across the Great Southern Reef. The science is new, and the research and restoration trials are dependent on the maintenance of genetic diversity.

See Illustrative examples

There is growing interest in kelp and other seaweeds (macroalgae) and microalgae (phytoplankton) for the chemical compounds and nutrients they contain for food and health applications. This has implications for using selected genetic material in ***seaweed aquaculture*** with the potential to produce food and nutritional supplements while benefiting the environment through carbon sequestration. A loss of genetic diversity will hinder this potential by limiting the available genetic database.



WATCH: BBC Report – The miraculous power of the humble seaweed https://www.bbc.com/reel/video/p09bqf8t/the-miraculous-power-of-the-humble-seaweed?fbclid=IwAR1Lwhvpni-vkJ4fZAI91m5eANDVgSiTXGAu1Y3_sQ2OPJKwRGhNuvZQLDw

INTRINSIC VALUE

The Great Southern Reef ecosystems have a right to exist irrespective of other values.

This value links very closely to spiritual values and our sense of belonging to the natural world that comes from appreciating nature.

NEED FOR UNIMPEDED NATURAL CHANGE

Many scientists believe it is important that evolutionary processes that have created the Great Southern Reef continue to function. With well protected areas where this can happen, the causes of future change can be determined as being human induced or evolutionary. This will assist with future management and also bring new genetic diversity. The challenge is in creating large marine parks or zones in existing parks designated as 'scientific use only'.

Conclusion

Learn more about the values of the Great Southern Reef and the need to manage and protect

Using the following webinar panel discussion and the media reports provided as references.

WATCH: Great Southern Reef Webinar: Uncovering the value of Australia's GSR https://marinesocioecology.org/great-southern-reef-webinar-uncovering-the-value-of-australias-gsr/

References

Review of Coast and Marine Ecosystems in Temperate Australia Demonstrates a Wealth of Ecosystem Services https://www.frontiersin.org/articles/10.3389/fmars.2020.00453/full

Australia's forgotten other 'Great Reef' https://www.bbc.com/travel/article/20200922-australias-forgotten-other-great-reef

The remarkable power of Australian kelp https://www.bbc.com/future/article/20210406-how-kelp-can-help-solve-climate-change

All eyes on Whyalla's spectacular cuttlefish aggregation, as numbers may have come in lower than hoped https://www.abc.net.au/news/2021-07-10/whyalla-cuttlefish-numbers-aggregation-fishing-ban-kingfish-farm/100281726

Substantial role of macroalgae in marine carbon sequestration https://www.nature.com/articles/ngeo2790

Biodiversity photographs and information https://greatsouthernreef.com/marine-life

B. MANAGEMENT

1. TRADITIONAL AND CONTEMPORARY ABORIGINAL MANAGEMENT

Over thousands of years Aboriginal people have developed and used sustainable management practices on the Great Southern Reef. Resources were taken to satisfy needs and maintain biodiversity and ecosystem functioning. Two examples of traditional cultural practices focused on sustainability are ***totems*** and ***resource*** use based on seasonal calendars.

Totems

Totems are about responsible stewardship.

'Each clan/family is responsible for the stewardship of their totem: the flora and fauna of their area and the stewardship of the sacred sites attached to their area. This stewardship includes the sustainable management of the resources and the spiritual management and ceremonies needed to ensure adequate resources for each season'.

https://australianstogether.org.au/discover/indigenous-culture/aboriginal-spirituality/

WATCH: Aboriginal responsibility of caring for country and the Great Southern Reef https://www.youtube.com/watch?v=Q5dnkzvNW0s

The Wadandi (Saltwater) People from the Noongar nation, in the SW corner of Australia have a continuous cultural, physical and spiritual relationship with the land and sea. Zac Webb, a Wadandi custodian explains the concept of totems.

Seasonal calendars

The sustainable use of resources was illustrated by:

- moving campsites to take advantage of seasonal abundance
- using every part of a plant or animal to avoid waste and conserve living resources
- forbidding harvesting at different times of the year

The seasonal calendar of the Kaurna people of the Adelaide region shows the traditional migration between the coast and inland plains in different seasons. During Wirltuti (Spring) Kaurna headed to the coast where blue crabs, garfish, shellfish and crustaceans were harvested, and fish caught. **Figure 22**

Figure 22: Kaurna Calendar

Image: Indigenous Weather Knowledge http://www.bom.gov.au/iwk/calendars/kaurna.shtml

Traditional knowledge and contemporary management

The involvement of Aboriginal people in the contemporary management of marine ecosystems is increasing. This includes management within state and commonwealth Marine Protected Areas and with organisations and agencies such as Parks and Wildlife.

Two examples of the integration of traditional and contemporary management for the Great Southern Reef within NSW coastal waters are the Gamay Indigenous Rangers at Botany Bay in Sydney and Gumbaynggirr (Garby) people at Arrawarra in Northern NSW.

Gamay Indigenous Rangers: Botany Bay

Shell middens and rock art are evidence of traditional cultural use of marine resources in Botany Bay and surrounding coastal waters by the Gamay people where country extends from the bay to several kilometres out to sea.

The Gamay Rangers are the first urban rangers in the national Indigenous Ranger Program. The rangers work with research scientists and the NSW Parks and Wildlife Service to protect the marine ecosystem of Botany Bay by integrating Traditional Ecological Knowledge (TEK) and contemporary management practices.

Activities of the Gamay Rangers have included:

- Working with Sydney Institute of Marine Science (SIMS) scientists on preparation of kelp for restoration at Kurnell for ***Operation Crayweed***
- assisting University of New South Wales (UNSW) researchers track the effects of invasive sea urchins.

Everyday ranger activities relate to:

- patrolling marine waters
- marine mammal awareness and protection (particularly whales)
- cultural and environmental awareness for vessel operators and visitors.

The Gamay Rangers were featured in a LANDLINE program in 2020. This program highlights the dual benefits for the Aboriginal Rangers and NPWS employees.

WATCH: Gamay Rangers: Indigenous rangers share unique knowledge of Botany Bay https://www.abc.net.au/landline/gamay-rangers:-indigenous-rangers-share-unique/12811904

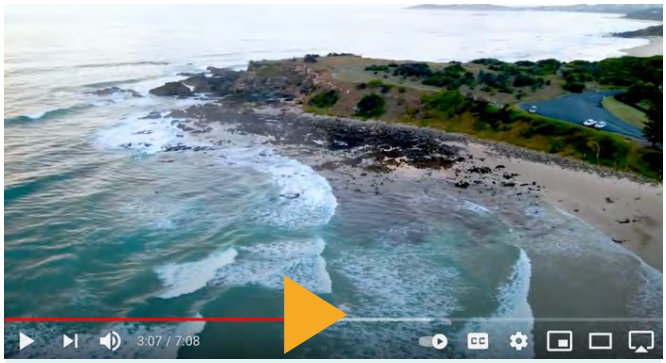
Cultural resource use and management: Arrawarra

For thousands of years, Garby Elders, from the ***Gumbaynggir Natio***n, relied on the marine resources at Arrawarra Headland, on the mid-north coast of New South Wales. Evidence of traditional use by the Garby people include large ***stone fish traps*** and a ***midden*** adjacent to Arrawarra Creek. Traditionally, the stone fish traps were an effective means of capturing fresh fish. The trapping of fish, as well as hand collection, spearing and line fishing have been, and continue to be, an integral part of the Garby Elders' way of life.

The Arrawarra Headland rock platform is located within the Solitary Islands Marine Park. A ***Special Purpose Zone*** was declared by the NSW Marine Parks Authority in 2002 to provide for traditional use (harvesting marine resources), monitoring and scientific research. The Special Purpose Zone extends 200m offshore and encompasses subtidal GSR habitats.

WATCH: 360 Aboriginal Storytelling: Arrawarra Fish Traps 3.38 https://vimeo.com/232286117

A ***Conservation Plan*** allows traditional harvesting under strict guidelines and with a requirement for research and monitoring. The plan involves collaboration between Yarrawarra Aboriginal Corporation and Garby Elders, Marine Parks Authority, the National Marine Science Centre and University of New England. The aim of the plan is to manage the cultural and environmental values of the site sustainably. **Figure 23**



WATCH: Arrawarra Headland, surfing, fish traps and Solitary Islands Marine Park.7.08 https://www.youtube.com/watch?v=ralx7f7yAuU&t=312s

Images are screen captures from these two short video presentations. L Chaffer

Learn more about the Garby People and their cultural practices from Fact Sheets downloadable here http://www.arrawarraculture.com.au/fact_sheets/index.html

Figure 23: Arrawarra Conservation Plan

Extract from Arrawarra Conservation Plan

3.2 Plants and animals to be taken from the Arrawarra Headland special purpose zone can only be taken in accordance with bag and size limits. Methods of capture are limited to fish traps (including traditional woven baskets and string nets), hand spears, hand collecting and handlining. Garby Elders will ensure that threatened species or communities are not harmed or affected by resource use. Garby Elders will ensure the rock platform is free of fish carcasses following collection, capture and cleaning of all catches. The sale of any plant or animal taken from the Arrawarra Headland special purpose zone is prohibited.

3.3 Monitoring of Indigenous resource use on Arrawarra Headland. Monitoring of resource use is an important component of the management of the Arrawarra Headland special purpose zone. The objectives of the monitoring program are to: identify resources that will be harvested; develop suitable assessment and monitoring strategies to assess short and long term effects of harvesting on populations; provide training for local Indigenous people to carry-out effective, quantitative, long-term monitoring; and to conduct regular, long-term monitoring of harvested taxa to ensure sustainability.

Source: http://www.arrawarraculture.com.au/images/arrawarra_conservation_plan.pdf

2. CONTEMPORARY MANAGEMENT

INFLUENCES ON MANAGEMENT

Ocean Imaging | Great Southern Reef – https://mission-blue.org/2019/12/the-great-southern-reef-of-australia-honored-as-new-hope-spot/

Identity of the Great Southern Reef

Despite bordering 78% of coastal electorates and 50% of all rural and regional electorates in Australia, the now Great Southern Reef was the perfect example of '***out of sight, out of mind***'.

A lack of knowledge has hindered investment in research and protection. Compared to tropical marine ecosystems in Australia, temperate marine ecosystems have only received a small portion of research funding. For example, between 2015 and 2021 funding from the Australian Research Council for temperate reef research was just 21% of coral reef funding (AU$6.5 vs AU$29.6 million) despite temperate ecosystems having higher economic value and the majority of Australia's commercial fisheries.

The identity ***Great Southern Reef*** was first used in an academic paper written by a group of concerned scientists in 2016 to give an identity to the interconnected rocky reef ecosystems. This occurred at a time when the degradation and loss of kelp forests ecosystems was becoming more common in Australia and overseas. Research scientists saw a growing need to raise awareness and develop strategies for its protection and management.

The GSR identity has been adopted by the scientific community in Australia and increasingly overseas. It was named a ***Mission Blue Hope Spot*** in 2019 in recognition of the values of the reef and to promote the need for increased protection.

"People protect what they love, and they love what they understand. We want to help everyone recognise the GSR's importance, and to wholeheartedly understand what a special place we have here."

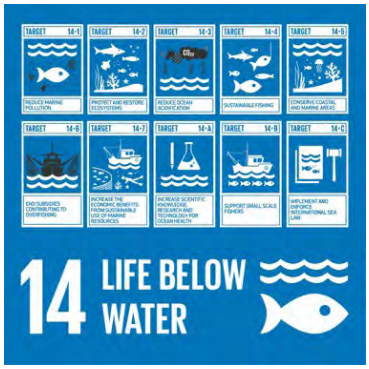
Sahira Bell, https://mission-blue.org/2019/12/the-great-southern-reef-of-australia-honored-as-new-hope-spot/

It remains to be seen if increased government funding for research and management follows.

International Agreements and Targets

At a global scale large IGO's, NGO's and research organisations promote environmental protection and management and the conservation of species, habitats and ecosystems. Examples include the IUCN, Mission Blue, Marine Conservation Institute (Blue Parks initiative), and the United Nations Environment Program (UNEP). International agreements aim to galvanise countries to act. Three recent actions link directly to the future of the GSR.

Paris Agreement – is an international treaty on climate change, adopted in 2015 to tackle climate change and its negative impacts. Government leaders became signatories to the agreement to set long-term goals to guide their nations to net-zero emissions. Leaders will meet again in 2021 at Glasgow to consolidate their commitments.



The UN Sustainable Development Goals – a collection of 17 interlinked global goals designed to be a "blueprint to achieve a better and more sustainable future for all" agreed to by world leaders. The SDGs were set up in 2015 by the United Nations General Assembly and are intended to be achieved by the year 2030. Goal 14 is Life Under Water. Goal 13 is Action to combat climate change and its impacts.

UN Decade of Ecosystem Restoration focuses attention taking action to protect and restore degraded ecosystems

International action has the potential to make a difference to the future of the Great Southern Reef.

3. MANAGEMENT STRATEGIES

Management for the GSR can be categorised by the intent of the strategy. These include:

- Protection and Regulation
- Restoration
- Community action / Citizen Science
- Education

PROTECTION AND REGULATION

a. Legislation – State / Federal

Protection for the natural and cultural values of the Great Southern Reef is provided by state and Commonwealth legislation. Laws incorporate requirements for management plans and the regulations needed to enact and enforce the protections granted.

Examples of legislation relevant to protecting the GSR in NSW include:

- ***Environment Protection and Biodiversity Conservation Act 1999*** (Cwlth)- to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places of national environmental significance. This legislation was used to list the Giant Kelp Forests of Southeast Tasmania as an endangered ecological community in 2012.
- ***The Fisheries Management Act 1994*** (NSW) applies to all coastal waters under NSW jurisdiction. The legislation requires management plans and regulatory controls for all fisheries. Permits, catch limits, seasonal restrictions and species or habitat protection are some of the regulations included under the act.
- The ***Fisheries Management Act 1991*** defines the Australian Fishing Zone (AFZ) and sets out responsibilities for ecologically sustainable development. The ***Environment Protection and Biodiversity Conservation Act 1999*** requires an assessment of all Commonwealth-managed fisheries before permission is given to export catch.
- ***Marine Estate Management Legislation 2015*** (NSW) 2015 controls the establishment of Marine Parks for conserving biological diversity, ecosystem functioning in the marine estate, and its' management and use.
- ***Underwater Cultural Heritage Act*** (2018) (UCHA), effective from July 2019. A federal law to protect underwater cultural heritage in Commonwealth waters.
- The ***NSW Heritage Act 1977 (***within State waters of NSW)

Example: Legislation, sustainable fisheries and the Great Southern Reef

The Southern Bluefin Tuna Fishery is managed by Australian Fisheries Management Authority, under the Fisheries Management Act 1991. To manage the catch of Southern Bluefin Tuna off the Australian east coast, AFMA uses zones. These are reviewed weekly and set in relation to sea surface temperature and currents.

Southern Bluefin Tuna are an important apex predator in the Great Southern Reef ecosystem and one of the top predators in the marine food chain. Young fish travel south in the Leeuwin Current along the reef and congregate in The Bight during summer to feed.

"Southern Bluefin Tuna gain about 80-90% of their annual growth as they feed for four months along the Great Southern Reef. This reefy system is vital to the nourishment and success of the species."

Kirsten Rough, Tuna Researcher & Fisher, Port Lincoln,SA. Great Southern Reef at https://greatsouthernreef.com/southern-bluefin-tuna

WATCH: Story of Southern Bluefin Tuna.

In the 1960s and 70s, the southern bluefin tuna was highly overfished and were a high-volume low value fishery. Kirsten Rough explains how research and strict regulations helped make fishery sustainable with a low volume yet high value output. https://www.youtube.com/watch?v=v2a88TWhCyY

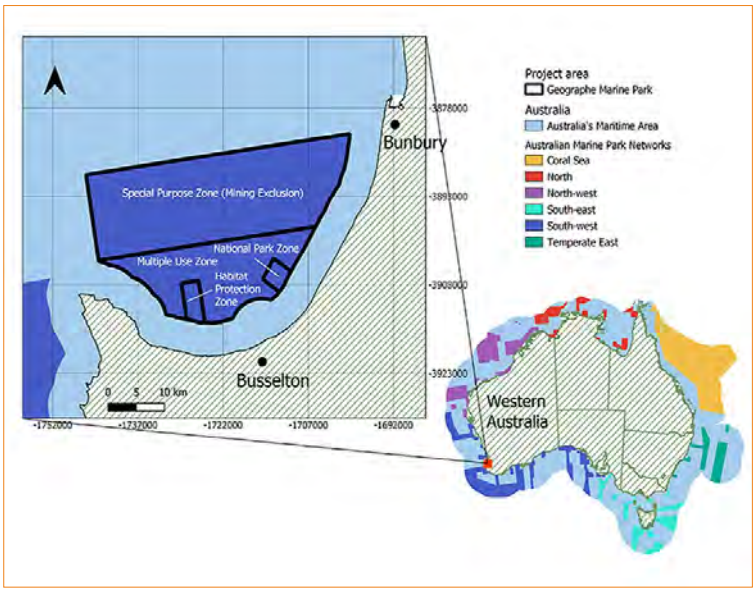
b. Marine Protected Areas (MPAS)

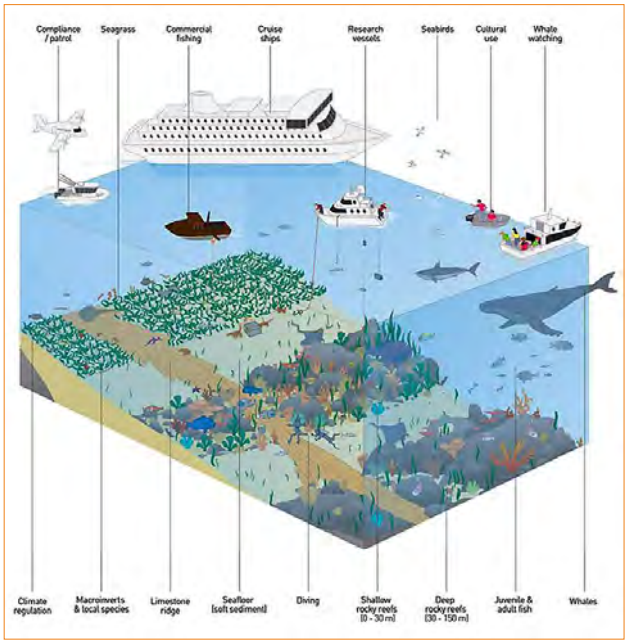
Marine protected areas are a system of parks and reserves established by governments to protect and manage large marine environments.

See Illustrative Example 4

Two of the main tools used successfully in marine parks on the Great Southern Reef are **zoning** and allowing ***multiple uses***. Figure 3 illustrates the multiple uses that need to be managed by zoning in the Geographe Marine Park (WA).

Figure 24: Geographe Marine Park





Source: https://eea.environment.gov.au/accounts/ocean-accounts/geographe-marine-park

RESTORATION /FUTURE PROOFING

Restoration programs are used where kelp forests have been degraded or lost. Three significant programs on the Great Southern Reef involve using different methods to restores lost kelp forests.
See Illustrative Examples 1– 3

There is discussion in the scientific community about the need to go beyond restoring what was there before (Restore or Revive) and looking to improving the species (Reinforce) or even introducing or creating a new species (Replace or Redefine) such as those resilient to warmer temperatures.

The idea of ***future proofing*** sections of kelp forest on the Great Southern Reef at greatest threat from climate change is an option that raises bioethical issues around using genetic engineering to save species and ecosystems. **See Illustrative Example 3**

Effective restoration is based on scientific research, data collection and monitoring. Organisations working at a range of scales are conducting research on kelp forests and other reef habitats and species including Australia universities and research facilities such as SIMS in Sydney..

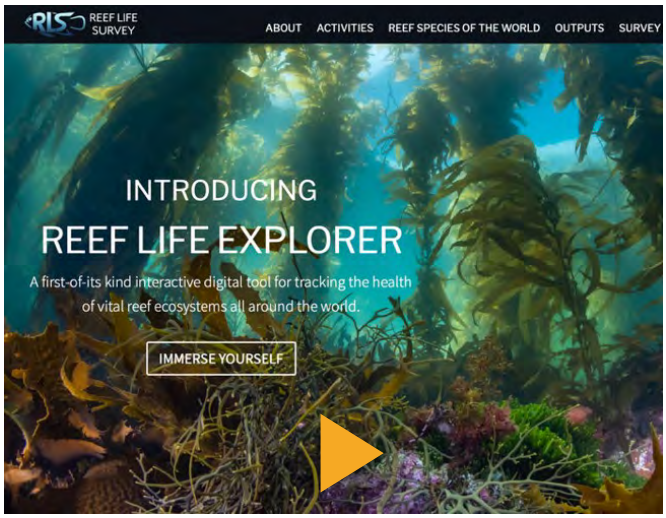
VOLUNTERISM / CITIZEN SCIENCE

Many management activities at a local scale depend on the work of ***volunteers*** concerned about local environmental issues. Often these are research trials such as Operation Crayweed conducted at 11 locations along the Sydney Coastline. **See Illustrative Example 1**

Citizen Science activities provide opportunities for community members to collect valuable data through surveys and Apps. Kelp Tracker is an App being used in Tasmania to locate remnant areas of Giant Kelp to create a database of locations for potential restoration.

See Illustrative Example 3

Reef Life Survey (RLS) is a large team of citizen scientist SCUBA divers using the same methods to record the abundance of all species on rocky and coral reef around the world, including the Great Southern Reef. The aim is to makes the underwater world visible – to scientists, governments, managers, artists and anyone interested. The data is made visually accessible through Reef Life Explorer the interactive website for RLS.



Reef Life Survey team at work Source: https://www.youtube.com/watch?v=grq8dflbm8Q

EDUCATION

Education is an essential component in the protection of the Great Southern Reef and is particularly important to making kelp forests visible and developing appreciation of the values they hold. Raising awareness through community events, school programs, social media, documentaries and recognition such being a Mission Blue Hope Spot are increasing knowledge, understanding and care.

See Illustrative Example 1.

HARVESTING PEST SPECIES

To restore the ecological balance created by invasive species such as sea urchins a viable option is to commercially harvest species. The benefits of harvesting sea urchins include:

- mitigating the spread and restore degraded kelp forests.
- protecting the biodiversity that other fishermen rely on, particularly abalone.

Tasmania has successfully expanded the commercial fishing of Long Spined Sea Urchins into a large-scale operation with 400 tonnes now harvested each year.

In NSW, native urchins are decimating kelp forests along the south coast where the dynamic equilibrium of the ecosystem has been altered by overfishing of consumer species and climate change. Scientists are calling on the NSW government to change fishing regulations and incentivise the expansion of commercial urchin harvesting. The move is supported by the local traditional owners who were being involved in consultation meetings in 2021.

A Sea urchin harvesting operates out of Pambula on the far south coast to take advantage of the exploding population.

READ

South Coast Sea Urchins
https://www.southcoastseaurchins.com.au/about

WATCH the harvesting of sea urchins on the NSW far south coast for their roe.

South Coast Sea Urchins
https://www.youtube.com/watch?v=lCdl6YKioO4&t=20s

READ

Sea urchin harvest could limit spread of 'barrens'
https://www.naroomanewsonline.com.au/story/5173459/sea-urchin-harvest-could-limit-spread-of-barrens/

Purple sea urchins Source: Shutterstock

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Heritage NSW https://www.heritage.nsw.gov.au/about-our-heritage/maritime/

The great southern reef of Australia honoured as new Hope Spot https://mission-blue.org/2019/12/the-great-southern-reef-of-australia-honored-as-new-hope-spot/

New ocean Hope Spots, vetted by IUCN and Mission Blue, to ignite global support for ocean protection https://www.iucn.org/news/secretariat/201609/new-ocean-hope-spots-vetted-iucn-and-mission-blue-ignite-global-support-ocean-protection

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Paris Climate Agreement in Australia https://www.industry.gov.au/policies-and-initiatives/australias-climate-change-strategies/international-climate-change-commitments

ILLUSTRATIVE EXAMPLE 1: RESTORE

SYDNEY'S TEMPERATE KELP FORESTS OPERATION CRAYWEED

Vast underwater forests have gone missing from the Sydney coastline, with repercussions for local fish, abalone, crayfish, and coastal marine biodiversity.

Sydney Institute Marine Science

Healthy re-generated crayweed forests at low tide
Source: Patagonia Once lost Now returned Photo Justin Gilligan.

Location and spatial patterns

Crayweed (*Phyllospora Comosa*) is a species of brown macroalgae growing up to 2.5 metres in length in dense underwater beds, also referred to as forests, to depths of 5 –18 metres.

The crayweed found on the temperate rocky reefs from Port Macquarie to Tasmania are a part of Australia's Great Southern Reef.

Characteristics

Crayweed ecosystems support high levels of biodiversity including fish and invertebrates such as abalone and crayfish. As well as providing food and habitat, crayweed provides detritus (decaying plant matter) to adjacent ecosystems and soft sediment habitats such as seagrasses. Crayweed supports a unique biodiversity not found in places dominated by other seaweed species. For example, crayweed supports 7–10 times more abalone than other seaweed species in the region and has a diversity of microbes on its surface, not found on other seaweed species.

Forest lost

The once abundant crayweed on Sydney's rocky reefs began disappearing in the 1980s but went unnoticed and unreported until 2008 by which time the loss, attributed to sewage pollution, extended for 70 km along the Sydney coastline.

'The local disappearance of crayweed from the most urbanised stretch of coastline on the Australian continent was linked to the high volumes of poorly treated sewage that used to flow onto Sydney's shores before the construction of deep ocean outfalls in the 1990s. These outfalls and improvements in wastewater treatment practises have vastly increased water quality around Sydney since the 1980s, but despite this, crayweed has failed to recover'.

Source: http://www.operationcrayweed.com

OPERATION CRAYWEED

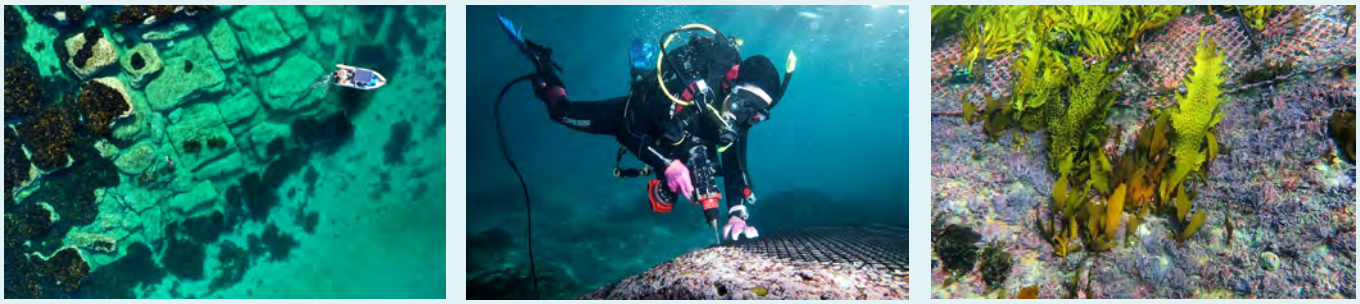
The aims of Operation Crayweed are **RESTORATION** and **SUSTAINABILITY**. This means restoring crayweed to bare surfaces where healthy forests once grew to a level when reproduction and growth are self-sustaining. Restoration began in 2011 as the signature project of the Sydney Institute of Marine Science (SIMS).

The method developed by scientists involves transplanting healthy, fertile adults from places north and south of Sydney where populations are plentiful, by attaching them to rocks on biodegradable mesh frames. Volunteers play an important role in Operation Crayweed restoration projects at many sites and, in 2021, the Gamay Indigenous Rangers worked with scientists at Kurnell.

ILLUSTRATIVE EXAMPLE 1: RESTORE

WATCH the following short videos to learn more about the restoration process:

- The Operation Crayweed Story at https://vimeo.com/228955452
- Marine Explorer Operation Crayweed https://vimeo.com/186118316
- Sixty Second Docs https://www.facebook.com/60SecDocs/videos/1629220030612813



Aerial and submarine photographs showing restoration in action (left & centre), 'Craybies' are evidence of successful recruitment, at Kurnell, 2021 (right)
Photos: Operation Crayweed Facebook Group, diver and craybies John Turnbul; Aerial view Haig Gilchrist

The desired outcome – to produce ***'craybies'*** in the transplanted patches that would then attach themselves to the rocky reef surfaces to form new, self-sustaining populations that would expand to cover the bare rocky reef over time. Once the Crayweed habitat is re-established biodiversity would return.

Funding – was provided by government and non-government organisations, businesses, and individuals. These include the NSW Department of Primary Industries, the Australian Research Council, the John T Reid Foundation, the Evolution & Ecology Research Centre of UNSW Sydney and the Sim-Lutton and Breen Initiatives. Restoration at Newport in March 2021 for example, was funded by Patagonia and the site at Freshwater, originally planted in 2016 was extended in 2020 with the support of local government through the Warringah Communities Environment grant. A full list of supporters is on the Operation Crayweed website **here**.

Locations

Transplanting has taken place at eleven locations along 70 km of the Sydney coastline including Cabbage Tree Bay, Freshwater, Kurnell, Long Bay and Little Bay, North and South Bondi, Coogee and Newport.

Evaluation

The success of Operation Crayweed has been evaluated using visual observations, scientific monitoring, and a criteria-based tool created by the Society for Ecological Restoration. Video productions, websites and academic articles illustrate the success of Operation Crayweed in kelp forest restoration at all sites on the Sydney coastline.

The transplanted crayweed in the first trials (2011) and subsequent plantings have had survival rates of around 70%, much the same as those in natural populations and surprisingly, higher reproduction and birth rates.

The 'babies' of transplanted, fertile adults had firmly attached to rock up to hundreds of metres from originally restored patches and had themselves become reproductive.

> *'… as of 2019, transplanted crayweed has reproduced in six locations such that multiple generations are now identifiable, often hundreds of meters from the original restored patches. These restored crayweed forests have become self-sustaining without the need for additional cost or maintenance, which is a rare result in marine restoration. This relatively small-scale intervention has translated into a large-scale impact/benefit, with crayweed populations continuing to expand and colonize substantial areas and beginning to function as natural forests.'*
>
> Source: Kelp Forest Restoration in Australia https://www.frontiersin.org/articles/10.3389/fmars.2020.00074/full

In a study published in 2020, *Kelp Forest Restoration in Australia*, Operation Crayweed was judged the most successful marine restoration project in Australia to date, however the conclusion was also drawn that a longer time frame was needed to see if full restoration across all trophic levels is achieved.

The Society for Ecological Restoration (SER) assessment tool known as the '5-star recovery system' was applied to Operation Crayweed to evaluate its success. The system uses a set of criteria to assess key ecosystem attributes using indicators for kelp forest restoration such as transplant survival, growth rates, genetic diversity, and recruitment. Juvenile recruitment was identified one of the best indicators of successful restoration to build kelp forest resilience.

ILLUSTRATIVE EXAMPLE 1: RESTORE

'For Operation Crayweed, the mean attribute score was 3.7, indicating that restoration of crayweed forests at the local of the initial loss is well under way, with high levels of recruitment and good progress toward development of associated communities and ecosystem functions that are on a self-sustaining trajectory.'

Source: Kelp Forest Restoration in Australia https://www.frontiersin.org/articles/10.3389/fmars.2020.00074/full

Challenges moving forward

1. **Workload and cost** – initially, about 5 days is required at each site for site marking and preparation, securing mesh mats for crayweed attachment, collection of crayweed and transplanting. Estimated costs include:
   - $US 6,850 per site for a 4-person team, boat and tow-vehicle, SCUBA tank fills, equipment and consumables.
   - $US18,500 p.a. for project management and monitoring at multiple sites

   Source: Kelp Forest Restoration in Australia https://www.frontiersin.org/articles/10.3389/fmars.2020.00074/full

2. **Project scale** – restoration projects have been completed at a small to medium local scale with high levels of success. Scalability of kelp forest restoration to the seascape-scale at which crayweed losses have occurred remains a challenge.

Education and emotional engagement: Bringing community on the journey

Educating the public about the value of kelp forests has become an important component of Operation Crayweed and the work of scientists involved in kelp restoration Australia wide. Volunteers have played an important role in replanting crayweed across sites in Sydney, but the challenge since the project began has been to make the public more aware of these important ecosystems and to care about their future.

In the words of marine ecologist and Associate Professor at UNSW Adriana Verges, *'education does not make people care'* and you need to emotionally engage people to get them to care. In 2019 Adriana won UNSW Sydney's Emerging Thought Leader prize for her ability to merge science, the arts and powerful storytelling to make issues visible and inspire the community to respond to environmental crises.

"Art can be a particularly effective way to communicate science because it engages with people at an emotional level."

Source: Adriana Verges https://www.secondnature.org.au/bringing_back_our_underwater_forests_q_a_with_adriana_verg_s

Several successful initiatives aimed at engaging the public emotionally in Operation Crayweed include:

1. *Operation Crayweed Artwork Installation*, Bondi 2016 (At Sculptures by the Sea)

This project involved an environmental installation, participation activities and a performance developed to engage the community with the 'invisible' underwater restoration site at Bondi. Scientists and artists ran workshops with school children who created and paraded wearable sculptures of marine creatures that would return to the restored crayweed forests in the future. A local school band performed 'We All Live in The Yellow Crayweed' and a community swimming group performed a synchronised swim at the replanting site.

Right: Bondi public artwork installation and event. One of three viewscopes above the site; Student parade and public performance. Source: https://turpincrawfordstudio.com.au/work/operation-crayweed-art-work-site

2. *Primary School restoration site visits.*

Visit the Operation Crayweed Facebook page to learn more about how local schools such as Clovelly and Woollahra Public Schools are engaging with kelp forest learning and restoration – https://www.facebook.com/OperationCrayweed

3. *Manly Seaweed Forests Festival 2021* was a mix of science, art and food with panel discussions and workshops with scientists and leading thinkers and an art installation, 'Seaweed Arboretum'. Learn more about this successful community engagement festival and listen to the podcast series about Operation Crayweed and The Great Southern Reef at https://www.seaweedforestsfestival.com/podcasts/

For more details visit the Operation Crayweed website at http://www.operationcrayweed.com and follow Operation Crayweed on Facebook.

Panel Discussion about Climate Change at the Manly Seaweed Forests Festival 2021. Source Manly Seaweed Forests Festival Website at https://www.seaweedforestsfestival.com/resources/

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Bringing back our underwater forests: Q&A with Adriana Vergés – https://www.secondnature.org.au/bringing_back_our_underwater_forests_q_a_with_adriana_verg_s

Project under way to bring rock lobsters and abalone back to Kurnell waters – https://www.theleader.com.au/story/6853567/ocean-habitat-returns/?fbclid=IwAR1LusUFXHB5ivPTy_QVNwjQi3vaoibMukJNzXaZCyBu4l1ALby1pzCCusg

Manly Seaweed Forests Festival – https://www.seaweedforestsfestival.com

Seaweed Forest Festival podcasts https://www.seaweedforestsfestival.com/podcasts/

Operation Crayweed Facebook page – https://www.facebook.com/OperationCrayweed

Turpin Crawford Studio: Operation Crayweed Art-Work Site https://turpincrawfordstudio.com.au/work/operation-crayweed-art-work-site & https://vimeo.com/299624551

Reforesting the Ocean from Reasons to be cheerful – https://reasonstobecheerful.world/reforesting-the-ocean/?fbclid=IwAR3zly7-5jSpnWvSIe0jqIhTxPwnzNbo1TFEJIJjXKQk5yKaMPcyornYaLo

Australia's Ocean Odyssey https://iview.abc.net.au/show/australia-s-ocean-odyssey-a-journey-down-the-east-australian-current

Once lost Now returned – https://www.patagonia.com.au/blogs/roaring-journals/operation-crayweed-once-lost-now-returned?fbclid=IwAR1z42cdtYegF603HB2TAexdQ1V9MA1rXk4nGDWa1B_oScnzY-OY-ov9fhw&utm_source=facebook&utm_medium=social&utm_campaign=w20_brand_enviro_eco_awareness

360 Degree image – https://www.facebook.com/OperationCrayweed/photos/2634251320036252

Operation Crayweed Balgowlah North PS – https://www.youtube.com/watch?v=WmM_VT9iOes

ILLUSTRATIVE EXAMPLE 2: RESTORE

WESTERN AUSTRALIA'S KELP FORESTS GREEN GRAVEL PROJECT

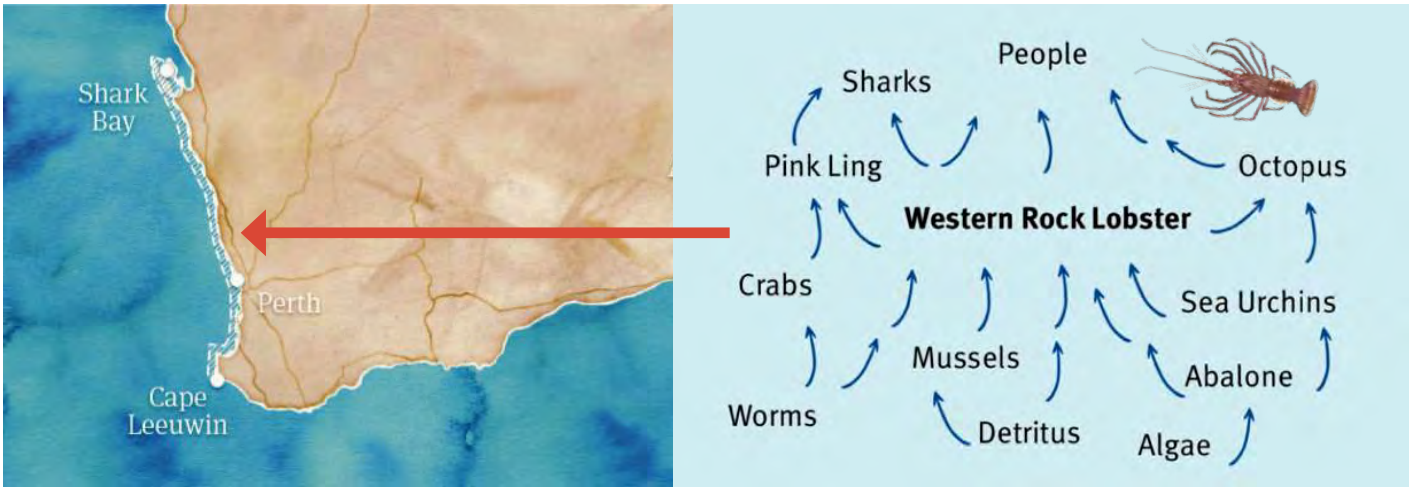
'Let's green the blue front yard'

Professor Thomas Wernberg, University of Western Australia

Golden Kelp. Source: Ocean Imaging | Great Southern

The Great Southern Reef extends along the Western Australian Coastline from Kalbarri to the South Australian Border. **Golden Kelp** (Ecklonia radiata) is the foundation species supporting a high diversity of temperate fish and invertebrates including economically important Western Rock Lobster and abalone. An example of biodiversity can be seen in **Figure 1**

Figure 1: Kelp Forest ecosystem in Western Australia



Left: Rock lobster habitat. Centre: Golden kelp. Right: Rock lobster food web.
Sources: Marine Stewardship Council: Rock Lobster Fishery Fact Sheet; Shutterstock photo.
https://www.msc.org/docs/default-source/aus-files/education/rock-lobster-fishery-factsheet.pdf

Warming seas

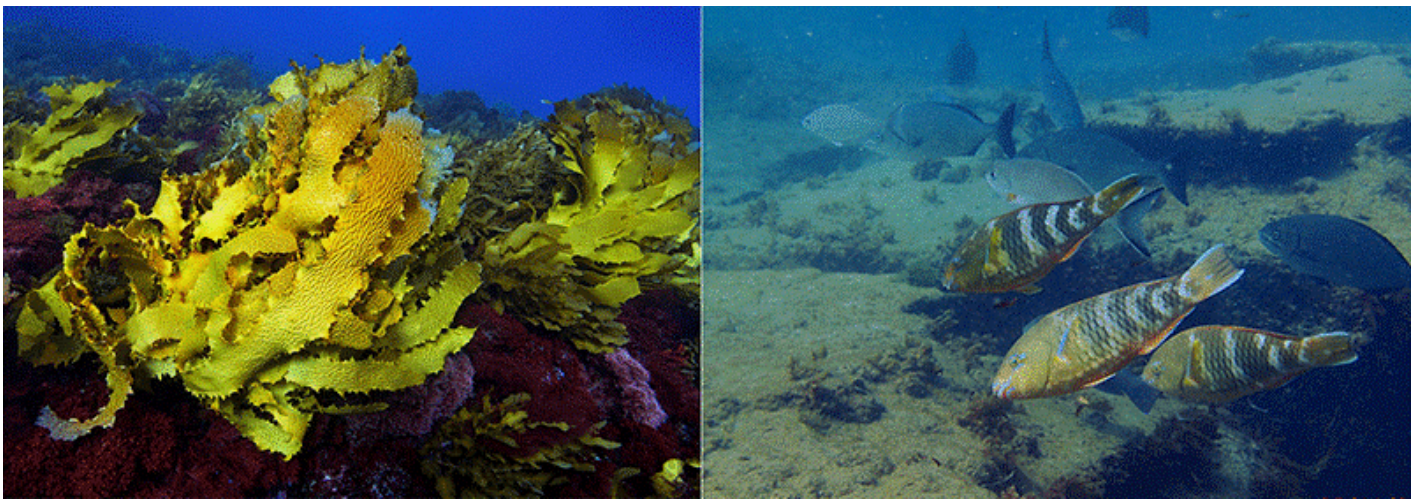
Since the 1970's the WA coast south of Kalbarri has experienced steadily increasing ocean temperatures, tropicalisation of species and kelp forest loss.

Impacts of this warming include:

- **Kelp bleaching**, a whitening caused by a loss of the pigments essential for photosynthesis that can cause the death of seaweed.
- **Increased herbivory** due to the migration southwards of kelp-eating fish and urchins.

Coastline south of Kalbarri showing coastal rocky reefs adjacent to Kalbarri National Park. Source:

ILLUSTRATIVE EXAMPLE 2: RESTORE



Before and after the 2011 heatwave which saw the virtual extinction of some of Western Australia's vast temperate kelp forest ecosystems. Grazing tropical and sub-tropical fishes which use their teeth to scrape the reef substrate leave little chance for new kelp to re-establish and there has been no sign of recovery 5 years after the heatwave event. Image: J.Costa . Source: Australian Institute of Marine Science https://www.aims.gov.au/docs/media/latest-news/-/asset_publisher/EnA5gMcJvXjd/content/scientists-document-the-extinction-of-wa-s-great-southern-reef-kelp-forests

Extreme Marine Heatwave

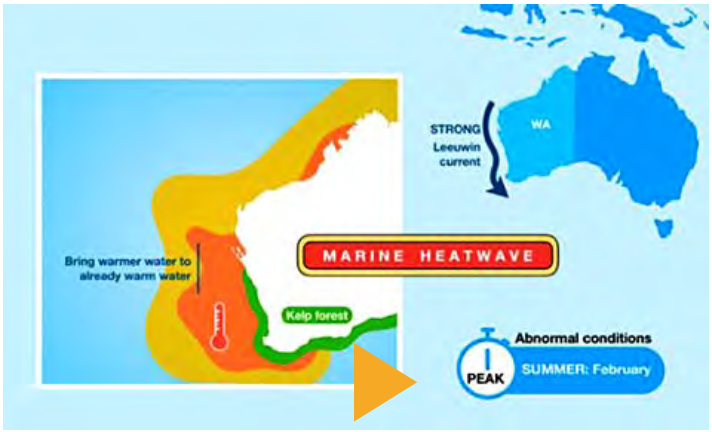
In 2010, kelp forests covered over 70 per cent of shallow rocky reefs along 2000 km of the Western Australian coast. Approximately100 km of kelp south of Kalbarri disappeared completely and has not recovered since a devastating **marine heatwave** in the summer of 2010 – 2011. Above-average ocean temperatures continued through 2012 and 2013. Further south kelp was reduced to 50% of its 2010 population. Using baseline data from a 20-year study along the WA coastline, scientists estimated that 963 km^2 of kelp forest was lost. The heatwave was one of the most extreme ever experienced in the world with ocean temperatures increasing 2°C – 6°C above long-term maximums.

Two global circulations changed simultaneously to cause this heatwave:

- The **La Niña** cycle in 2011 was one of the strongest on record bringing higher than average water temperatures
- The **Leeuwin Current** extended south bringing warmer water and tropical species

WATCH: How Climate change is impacting Australia's Kelp Forests – https://www.youtube.com/watch?v=1jQH6ZG11zU

Cape Leeuwin surrounded by Leeuwin Naturaliste National Park, and protected as a sanctuary zone in Ngari Capes marine Park.Source: https://parks.dpaw.wa.gov.au/park/ngari-capes



Great Southern Reef Student Educational Resource Lesson 3 Booklet Page 4

Tipping point

This event was a tipping point after years of warming. There was little to no kelp left to propagate and recolonise bare surfaces when waters cooled again. If seeding did happen, the rate of grazing by tropical species was too fast for kelp to establish. An increase of 400% in the biomass of scraping and grazing fishes has been documented. Tropical fish prevent the re-establishment of kelp forests across several degrees of latitude to this day. The inability of kelp to re-establish changed the ecological structure of the reef to a flatter **algal turf** ecosystem in a very short period of time.

ILLUSTRATIVE EXAMPLE 2: RESTORE

"Instead of kelp forests we now have turf reefs – mats of algae that change the whole habitat structure of the reef. It's like going from a skyscraper to a flat field."

Karen Filbee-Dexter, University of Western Australia – Kelp parachutes: green gravel reforestation projects showing promise
https://www.aquaculturealliance.org/advocate/kelp-parachutes-green-gravel-reforestation-projects-showing-promise/

GREEN GRAVEL PROJECT

A team of scientists have been studying kelp forests in Western Australia for 20 years, monitoring kelp losses, collecting site data, and looking for solutions to conserve remaining ecosystems and potentially restore lost forests. Recent discoveries of remnant kelp that survived the heatwave deeper off the coast have provided some hope.

In the past, restoration of underwater species has relied on scuba divers, physically attaching adult kelp to mats on rocky surfaces, as occurred with **Operation Crayweed** in NSW (See Illustrative Example 1). This method is considered *'inefficient, expensive, and potentially dangerous.'* It is also small-scale and difficult to expand to a landscape wide program.

Green Gravel

Funding from the Australian Research Council in 2020 provided an opportunity to complete further trials at UWA using *Green Gravel* – small rocks seeded with resilient strains of kelp. This innovative project is a potential solution for safer, large-scale restoration and replenishment of damaged kelp forests. The *Green Gravel Action Group* of scientists has 15 global projects in different stages of progress and has attracted a lot of international interest.

Some features of *Green Gravel* restoration include:

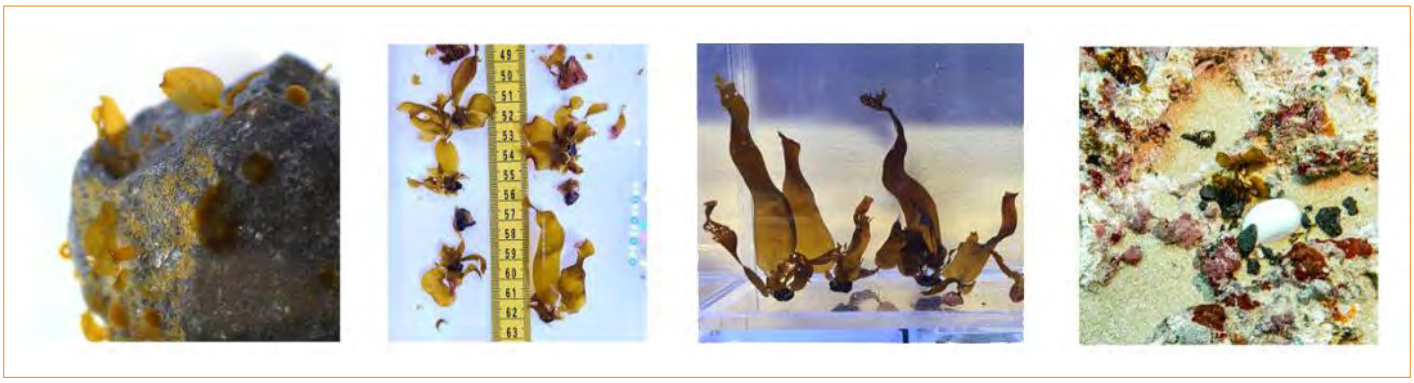
- The kelp and rock are sourced locally and attached in a lab (Figure 2)
- Green gravel (the kelp and their rock anchors) can be scattered from a boat
- Once settled on the seabed, the kelp can quickly grow into adults and over time colonise surrounding areas.

The method has the potential to:

- quickly restore reefs between heatwave events
- use kelp strains more resilient to warming to 'future proof' reefs
- upscale to much larger areas than possible in other restoration projects.

Research has shown that using this method, local kelp species in Western Australia can grow to lengths of 1–1.5 metres, create habitats and function like other kelps.

Figure 2: Green gravel in the lab and on the seafloor (right)



Source: Green Gravel Action Group https://www.greengravel.org

One anticipated advantage of this method is that it will be **scaleable** – and could involve **community** in reef restoration. It is thought that commercial kelp farmers could grow 'green gravel' for scientists working on conservation projects as well as citizens and local authorities to spread on local reefs. Scaling could build **resilience** to future warming events.

Planned outcome

'Healthy kelp forests that are resilient to future stress maintaining the valuable ecological services and habitats that the forests naturally provide'.

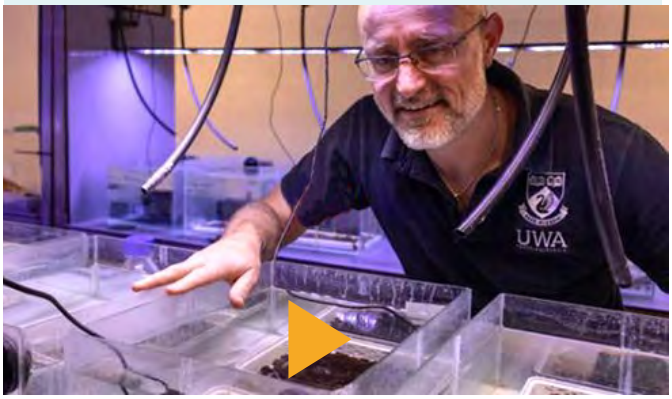
Source: https://www.greengravel.org/about

ILLUSTRATIVE EXAMPLE 2: RESTORE

Figure 3: From algal turf to healthy kelp beds

Source: Green Gravel Action Group https://www.greengravel.org

WATCH: Professor Thomas Wernberg explain the 'green gravel' project. 2 min 51. .Source: University of Western Australia. – https://www.youtube.com/watch?v=UN6mrcok91Y&t=71s



WATCH: 'Blue is the New Green' Webinar. Thomas Wernberg Q & A (From 7 -18 min). Source: University of Western Australia – https://alumni.uwa.edu.au/blue-is-the-new-green

Skills Activities

Figure 4

a. State the latitude of Kalbarri

b. State the direction of Kalbarri from Perth

c. What word describes ecosystems north of Kalbarri represented by the red arrow?

d. Identify three features of the marine ecosystem north of Kalbarri.

e. Describe three features of the ecosystem at 34 degrees South.

f. Explain what happened to the marine ecosystem from Kalbarri to Perth between 2006 and 2015.

g. What is meant by the term 'Kelp Contraction zone' in the diagram

h. Why was Kalbarri the northernmost limit of temperate Kelp forests.

i. Explain the cause of the change. Using geographical language from the illustration.

Figure 5

a. What area of kelp was lost at 28°S and 32°S

b. Over how many km was there a loss of kelp?

c. At what latitude was 50% of kelp lost?

Figure 6

a. Explain images a. and b.

b. In what year did seaweed turf overtake kelp as the main ecosystem?

c. Describe kelp forest loss between 2010 and 2013 using data from the graph.

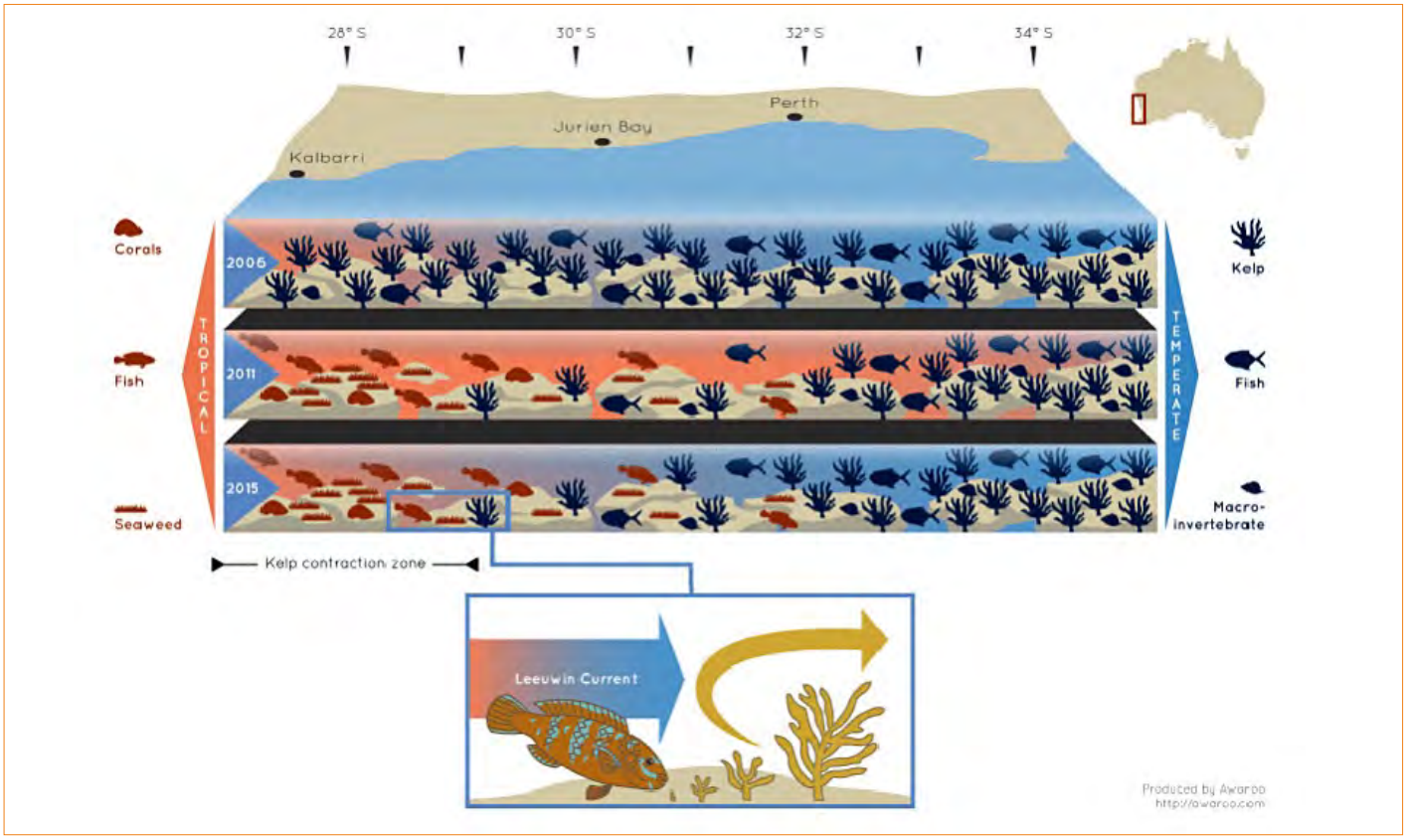
d. Calculate the ration of kelp to seaweed turf in 2001 and mid 2012.

e. Calculate the rate of change in seaweed turf between the end of 2010 and the end of 2015.

SKILLS: VISUALISING THE NATURE AND RATE OF CHANGE

Figure 4: Ecosystem change

Relative changes on temperate reefs in Western Australia over 10 years.



Source: Ecos – https://ecos.csiro.au/kelp-forests-hot-water/

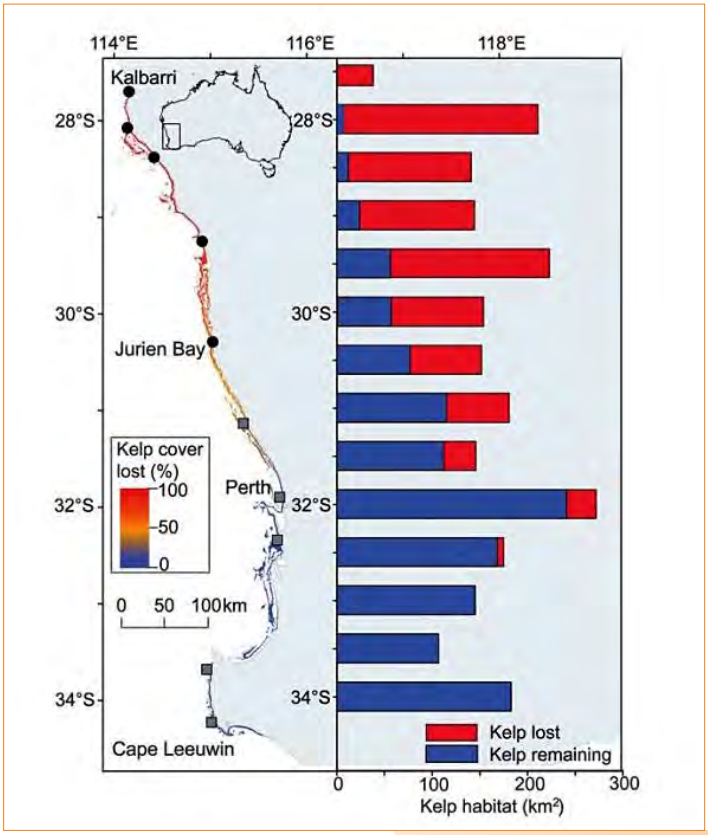


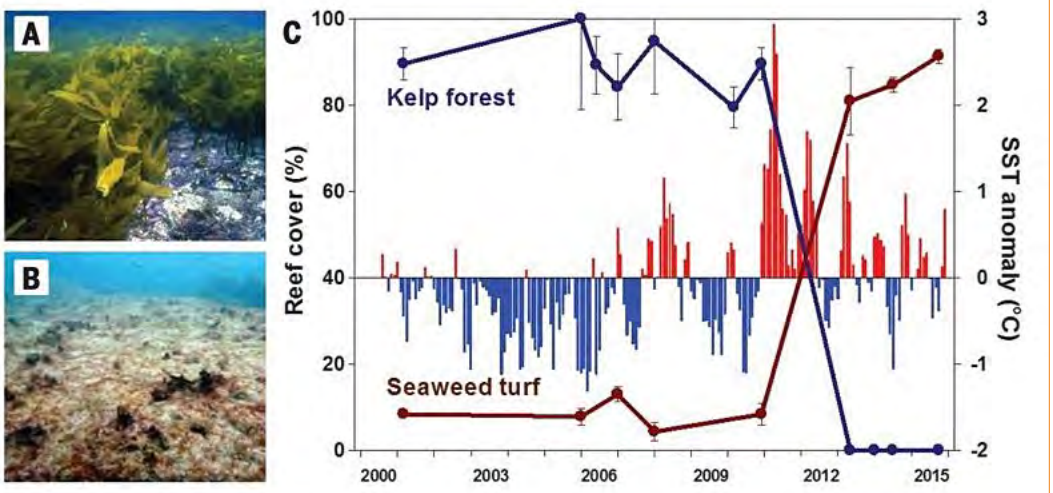
Figure 5: Climate-driven regime shift of a temperate marine ecosystem

The extent of kelp forests from 0 to 30 m depth before 2011 is shown with a colour scale indicating the proportion lost by 2013. On the left side of the map, grey squares (southwest region) and black circles mark locations where reefs were surveyed by scuba divers to establish proportional kelp loss.

Source: *Climate-driven regime shift of a temperate marine ecosystem.* The American Association for the Advancement of Science – http://science.sciencemag.org/content/353/6295/169

ILLUSTRATIVE EXAMPLE 2: RESTORE

Figure 6: Regime shift from Kelp forest to Seaweed turf after 2011



Climate-driven regime shift of a temperate marine ecosystem. The American Association for the Advancement of Science – http://science.sciencemag.org/content/353/6295/169
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TASMANIA'S GIANT KELP FORESTS

One of the last remaining patches of giant kelp forest on the NE Tasmanian coast
Photo: Cayne Layton Quote: Zoe Kean for ABC Science

The largest and the most colourful Weedy Sea Dragon are found in Tasmania.

Source: Behind the News – https://www.youtube.com/watch?v=BJU64Vm0T-U

Interesting facts

⚓The giant kelp forests along Tasmania's East coast were once so dense they featured as obstacles on shipping maps.

🌿Giant kelp forests are the most productive ecosystems on Earth in terms of total amount of **carbon fixed** per square meter per year.

Source: Great Southern Reef website – https://greatsouthernreef.com/giant-kelp

SUPER KELP

Giant kelp (*Macrocystis pyrifera*)

- Giant kelp is a large brown alga growing on rocky reefs in water depths of 8 metres or more. The fronds grow vertically toward the surface, in the cold temperate waters of southeast Australia where mean sea surface temperature range between 5 °C and 20 °C with moderate wave exposure.
- The largest areas of Giant Kelp in Australia are in Tasmania, South Australia, and Victoria.
- In the past Giant Kelp was harvested as a natural resource in Tasmania.

The Giant Kelp Forest Ecosystem

Giant Kelp

- are identified by long string-like stalks with multiple leafy blades and gas filled flotation bladders that allow the kelp to reach the surface where they to form **a floating canopy.**
- **have very high primary productivity** under ideal conditions of cool, nutrient rich water. The kelp can:
  - grow over **35 metres long**
  - grow up to **half a metre each day**
- do not store Nitrogen well so rely on **nutrients** taken directly from ocean water.
- is the **foundation species** forming 3D forest habitats extending beneath a closed or semi closed canopy to the sea floor.
- provide **habitat** for mobile and stationary organisms including fish, molluscs (sea snails), bryozoans (lace corals), polychaetes (worms), crustaceans (crabs, isopods, amphipods), echinoderms (sea urchins, sea stars) and sponges.
- slows water movement and catches the drifting spores and larvae of a variety of species, helping them to settle on the seabed to grow e.g., rock lobster and kelp.

ILLUSTRATIVE EXAMPLE 3: FUTURE PROOF?

Giant kelp forest loss

Tasmania's Giant Kelp Forests have been in slow decline since the 1940's. In the last 15 years however, research has revealed that 95 % of giant kelp forests on the east coast of Tasmania have disappeared. These forests are now listed by the Australian Government as the first **endangered marine community** in Australia.

"Sixty years ago, Tasmania's coastline was cushioned by a velvety forest of kelp so dense it would ensnare local fishers as they headed out in their boats."

Cayne Layton, Institute for Marine and Antarctic Studies, UTAS
Source:https://www.yesmagazine.org/environment/2020/07/01/climate-carbon-oceans-kelp

In Tasmania we have seen a rapid and catastrophic loss of the kelp forests that dominated the State's eastern and south-eastern coastlines until very recently.

Professor Craig Johnson, IMAS. Source: https://www.imas.utas.edu.au/news/news-items/first-global-study-of-kelp-forest-change-gives-mixed-news-on-key-marine-ecosystem

The decline of giant kelp forests in eastern Tasmania is associated with increased influence of warm and nutrient-poor East Australian Current water.

Where Giant Kelp is lost it is replaced by the naturally occurring Golden Kelp (Ecklonia Radiata) or common kelp. Common kelp can tolerate warmer, nutrient poor water and is better able to store Nitrogen so can survive without a continuous supply of nutrient-rich water. The composition of the rocky reef community is almost completely changed with large, three-dimensional giant kelp ecosystems replaced by this shorter, stubbier species.

'It's like comparing heathland to a forest of 30-metre trees: the verticality of giant kelp, and the space it takes up, creates a home for a huge range of organisms.

Source: https://www.smh.com.au/environment/climate-change/inside-the-battle-to-save-tasmania-s-giant-kelp-forests-20210506-p57pls.html

Causes and impacts

The three contributing causes of giant kelp forest loss are:

a. The **East Australian Current** (EAC) current flowing up to 350 km further south and displacing cool nutrient rich water with warm nutrient poor water. Ocean temperatures have increased by an average of 2.5°C since the 1940's. This is the main cause of Giant Kelp loss.

'When water temperatures increase the kelp becomes impaired and becomes susceptible to disease and breaks down.'

https://greatsouthernreef.com/giant-kelp

'In December of 2015 the temperatures along here were about 14.5° C. Within two weeks – it's hard to believe – it jumped to over 17 degrees'

'In the ocean that's a massive change. It was a shock to the system'.

'By April there was nothing left. Nothing. Not a single strand of kelp was left.'

Mick Baron, Eaglehawk Dive Centre . Source: https://thenewdaily.com.au/life/science/environment/2020/02/09/tasmania-ocean-hotspots-giant-kelp/

For **heat maps** and **graphs** on ocean temperatures see 'The Dead Sea' from The Guardian. – https://www.theguardian.com/environment/ng-interactive/2020/feb/24/the-dead-sea-tasmanias-underwater-forests-disappearing-in-our-lifetime.

b. **Invasive species** have increased since the first long-spined sea urchin was detected in 1978. In the 15 years prior to 2016 scientists found an increase in urchin numbers in rocky reef habitats of ≈ 50% (= 200,000 additional urchins a year). Species of kingfish, snapper, and octopus from NSW now live in Tasmanian coastal waters while once populous rocky reef species numbers have fallen. Up to 40 invasive species have been identified including a Port Jackson Shark, changing the biodiversity, and functioning of the kelp forests. Sea urchins are having a significant impact on Golden Kelp and creating urchin barrens.

'Longspine urchins are common along the east coast of mainland Australia, but the cold waters in Tasmania have always hindered their extension southwards. As climate change has warmed the waters in Tasmania, the urchins have taken up residence in Tasmania, extending their range southwards by 640 kilometres over the past 40 years. They prevent young kelp from becoming established and create "urchin barrens" where they eat every living thing down to the rock.'

https://www.uw360.asia/tasmania-and-its-vanishing-forests/

Australian Museum specimen of the Long-spined Sea Urchin, Diadema savignyi. Image: Stuart Humphrey.

Source: https://australian.museum/learn/animals/sea-stars/invertebrates-collection-long-spined-sea-urchin/

ILLUSTRATIVE EXAMPLE 3: FUTURE PROOF?

c. **Overfishing** of the Southern Rock Lobsters (crayfish) has disrupted the natural food chain by removing the natural predators of sea urchins. The abalone industry has been forced to reduce its catch by about 40% since 2016 due to the impact of higher temperatures and over-fishing. The food web disruption has endangered many species.
   - **See** the Red Handfish Story under Dynamic Equilibrium.
   - For management to conserve the Critically Endangered Red Handfish **visit** https://www.nespmarine.edu.au/project/project-a10-conservation-handfish-and-their-habitat

WATCH this animation to identify the causes of giant kelp forest loss.

Forests of the Sea animation – https://www.youtube.com/watch?v=UhM6QKGZd_s. Tasmanian Giant Kelp Forests, the changing distribution of species due to warming water and changes to the EAC.

Can Super Kelp rescue Tasmania's Giant Kelp forests?

The project

A joint **research project** between the University of Tasmania's Institute of Marine and Antarctic Studies (IMAS) and the Climate Foundation to develop super kelp for the potential restoration of Tasmania's giant kelp forests. The project is based on the idea that thermally tolerant kelp is bred in a lab and replanted into the ocean to rehabilitate areas where kelp was lost. Over time restored kelp patches would become self-sustaining and spread to more areas.

The Process

Samples from the remnant 5% of giant kelp forests are collected from the ocean. These are tested in a lab to find genetic groups of kelp that are resilient to warmer water temperatures with the aim of breeding 'super kelp'. Field trials follow using plates attached to the sea floor and more recently with spores embedded in twine, wound around ropes attached to the sea floor. The spores develop into 'saplings' that will release their own spores to drift in water currents and establish new mini-forests nearby.

Super cell cultures in the lab at IMAS, Salamanca. Photo: Cayne Layton

'The real tipping point will be if they can self-expand.'

The vision is to:

- create self-expanding and self-sustaining seed patches
- 'future-proof' restored kelp by using heat tolerant varieties
- 'scale-up' to restore large areas of lost kelp forest
- involve community, including local indigenous peoples, in restoration activities
- apply successful techniques to commercial aquaculture and as a 'carbon capture' strategy to address climate change

WATCH this introductory video about the giant kelp forest restoration project. https://www.youtube.com/watch?v=vOQ3hd0dzX8

Restoring Australia's Giant Kelp forests (3.46 m) https://www.youtube.com/watch?v=vOQ3hd0dzX8. Source: Great Southern Reef YouTube

ILLUSTRATIVE EXAMPLE 3: FUTURE PROOF?

WATCH this webinar by Dr Cayne Layton from UTAS for a full explanation of the issues facing the Great Southern Reef and full details about the giant kelp restoration project.

Webinar (59 min): The feasibility and future of restoring Tasmania's disappearing giant kelp forests – Dr Cayne Layton
Source: https://youtu.be/JKPV6Dn5efw

Progress

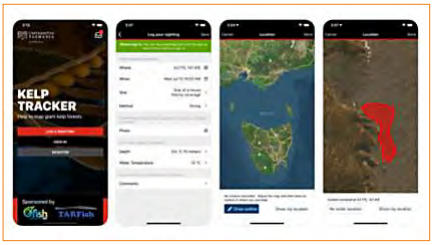
Six project sites are monitored regularly, and progress is promising. For example, in 2020 it was reported that:

- five best performing families of Super Kelp and two crosses (mixed families) were installed at Storm Bay using more than 45 m of kelp-seeded twine installed at three restoration sites.
- giant kelp planted in Storm Bay continue to grow healthily without bleaching and fouling (being overgrown by animals or other algae). Over 100 juvenile giant kelp are growing with an average of about 25 cm and largest individuals over 65 cm.

For details, project updates and photographs visit the IMAS UTAS site here – https://www.imas.utas.edu.au/research/ecology-and-biodiversity/projects/projects/assessing-the-potential-for-restoration-and-permaculture-of-tasmanias-giant-kelp-forests

Kelp Tracker – Citizen Science

Scientists have called on community members, particularly recreational fishers, to record sightings of Giant Kelp using a smartphone Kelp Tracker App. Sightings are verified by scientists and mapped identify potential sources of genetic material and restoration sites. In early 2020 over 100 sightings from 22 fishers had been recorded.



Read more HERE – https://ozfish.org.au/projects/giant-kelp-restoration-project-tasmania/

Source: Ozfish

Sharing knowledge and restoring Sea Country

The site at Trumpeter Bay, off Bruny Island, is being restored in partnership with the **Weetapoona Aboriginal Corporation** after the community approached the university and explained they had extensive knowledge of the site and had seen the giant kelp decline. The collaboration recognises the value of kelp forests culturally and as a food source and has the potential to expand and contribute to the upscaling of the project.

Future proofing

Successfully restoring giant kelp forest ecosystems to Tasmania requires a shift in thinking:

- FROM replacing / restoring what was there with kelp that has the same traits as the original forest species
- TO restoring forests with kelp possessing traits that allow it to thrive in new and future environmental conditions.

This is being called *'future proofing'.*

Challenges

Funding

Compared to the money invested in projects for the Great Barrier Reef and mainland national parks, projects to restore kelp forests remain underfunded.

Sea Urchins

Currently a commercial urchin harvesting project is one avenue used to address the large populations of urchins that decimate kelp and hinder kelp restoration.

Education

People will fight for what they love. The challenge is to increase education about the value giant kelp forests and the entire Great Southern Reef and provide opportunities to be involved in projects.

'Warming waters can have various different influences on the native organisms that live there. Some species move towards the poles or into the deep, where waters are cooler; some already exist in such a narrow window of biological tolerance that their numbers dwindle. Warmer waters can also change the timing of an organism's life cycle as well as impacting their growth. Tasmania has seen many of these influences on its marine ecosystems'.

Source" https://www.uw360.asia/tasmania-and-its-vanishing-forests/

ILLUSTRATIVE EXAMPLE 3: FUTURE PROOF?

Restoring Lobster and Sea Urchin Equilibrium

The presence of sea urchins in Tasmania is a result of warming waters along the East Coast and a range extension of the species from mainland Australia (tropicalisation). The urchins overgraze kelp and create urchin barrens. This has negative impacts on kelp beds and reef dependent species such as abalone, rock lobster and fish. Large rock lobsters are one of the few predators of long-spined sea urchin, but numbers have declined due to overfishing.

There are TWO solutions:

- increasing predator numbers (rock lobsters)
- reducing sea urchins

Two programs are being used to build lobster stocks:

- the East Coast Stock Rebuilding Strategy that limits harvesting via bag limits, seasons and catch triggers.
- the East Coast Rock Lobster Translocation Program transferring lobsters from the southern waters.

Incentives have been provided to successfully increase the harvesting of urchins to over 400,000 tonnes annually.

WATCH

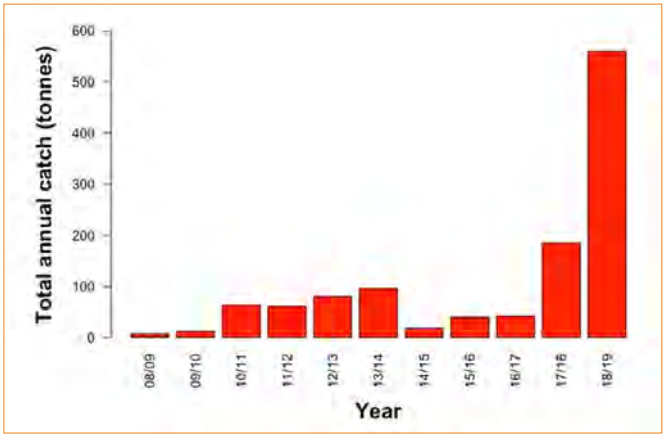
Who's been eating all the kelp (Animated explanation) https://www.youtube.com/watch?v=FF_4URQ1MrI\

Invasive Sea Urchin population growth off Tasmania's East Coast (1.50 min) https://www.youtube.com/watch?v=SSHwDY4Uuvs&t=106s

LISTEN

Tasmanian Country Hour Recording (6 min) https://www.abc.net.au/radio/programs/tas-country-hour/sea-urchins/12340542

Annual Catch of Longspined Sea Urchins



Source: https://www.imas.utas.edu.au/__data/assets/pdf_file/0006/1337604/Centro_assessment_FINAL-004.pdf

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Marine biodiversity hub – https://www.nespmarine.edu.au

Public call to find giant kelp in Tasmania – https://thewest.com.au/news/environment/public-call-to-find-giant-kelp-in-tasmania-ng-s-1982877

Listing of Giant Kelp Marine Forests of South East Australia PDF – http://www.environment.gov.au/biodiversity/threatened/communities/pubs/107-listing-advice.pdf

Tasmanian Government DPIPWE Rock Lobster Strategy http://dpipwe.tas.gov.au/sea-fishing-aquaculture/sustainable-fisheries-management/ fisheries-management-starategies/east-coast-rock-lobster-stock-rebuilding-strategy

MARINE PROTECTED AREAS PROTECTING THE GREAT SOUTHERN REEF

A Marine Protected Area (MPA) is a section of sea and associated seabed established by law for the protection and maintenance of biological diversity and natural and cultural resources. Different names are used to describe marine protected areas including marine parks, marine reserves, marine conservation reserves, marine nature reserves and marine sanctuaries. Marine sanctuaries offer the highest level of protection as 'no take' areas.

A network of state and Australian Marine Protected Areas enacted by legislation protects the Great Southern Reef. Legislation is also used to protect threatened and endangered species and biological communities of the Great Southern Reef such as the Commonwealth listing in 2012 of the Giant Kelp Marine Forests of Southeast Australia as Endangered.

State protections

Australian states are responsible for managing the '*coastal zone*' that extends 5.5 km from the coastline. The Great Southern Reef falls mainly into that zone putting it under is the jurisdiction of NSW, Victoria, South Australia, Western Australia, and Tasmania.

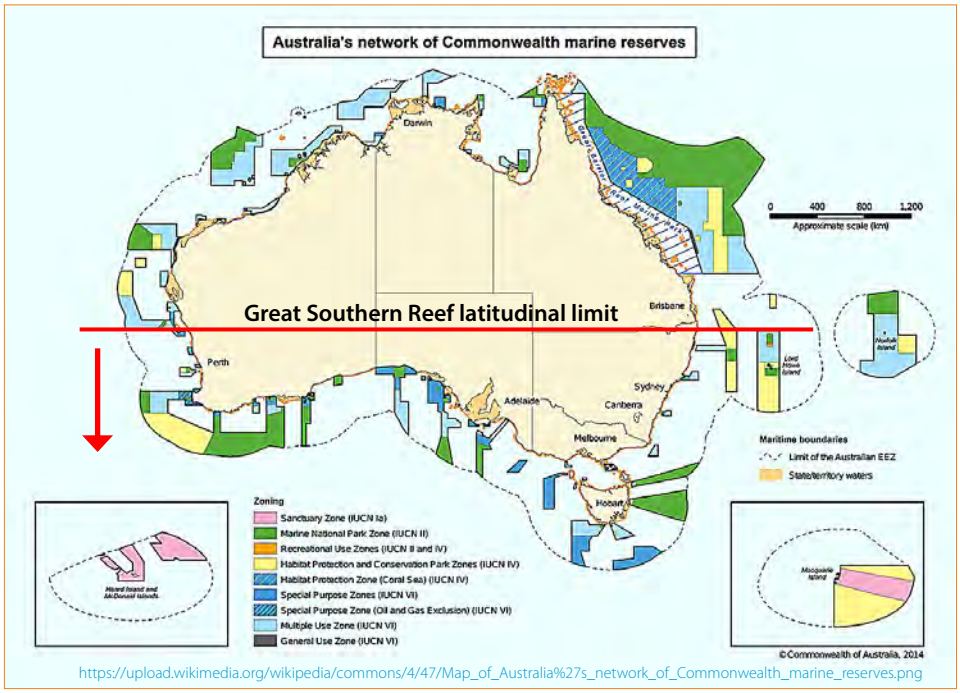
Each state has a network of carefully managed marine areas and system of zoning that reflects the value of different habitats and species and the threats or stresses they face.

In NSW for example, the system of marine protected areas includes 12 aquatic reserves, 6 multiple use marine parks and NSW National parks and nature reserves that include marine habitats. The Department of Primary Industries controls the the day-to-day management of these parks and reserves.

Commonwealth protections

The Australian Government has responsibility for ocean waters from the coastal zone to the edge of the Australian Economic Zone. They also have responsibility for the protection of threatened and endangered species and communities. A network of 60 Australian Marine Reserves protects habitats and marine life while providing for multiple uses such as tourism and fishing. Zoning is used in marine parks to show where different activities are permitted. **Figure 1**

Figure 1: Australia's network of Commonwealth Marine Reserves



https://upload.wikimedia.org/wikipedia/commons/4/47/Map_of_Australia%27s_network_of_Commonwealth_marine_reserves.png

Source: http://www.environment.gov.au/system/files/pages/709fa30c-d649-4d66-8dfb-b831d1f9ec16/files/national-map.pdf

ILLUSTRATIVE EXAMPLE 4: PROTECT

THE VALUE OF MARINE PROTECTED AREAS

'Scientific studies have confirmed that well-regulated, well-enforced marine protected areas (MPAs) can provide significant ecological benefits, increase resilience to natural and anthropogenic disturbances, and allow for ecosystem recovery. For example, fully and highly protected MPAs can allow depleted fish populations to recover, serve as refuges for endangered species, and increase resilience to climate change.'

Source: https://marine-conservation.org/ocean-advocacy/

Marine Protected Areas are regarded by scientists as critical tools for safeguarding biodiversity, habitats, and ecosystem processes and maintaining or restoring the health of ocean ecosystems. The ecological, social, and economic benefits of MPAs are embedded in the ***UN Sustainable Development Goals*** directly through Goal 14: Life below water and are a recognised strategy for marine ecosystems in the ***UN Decade of Ecosystem Restoration.***

A. Environmental values of MPAs

i. ***Safeguarding biodiversity.***
Global scientific studies show that compared to unprotected ecosystems, Marine Protected Areas
   - increase biodiversity by an average 21%
   - increase the size of fishes and other marine organisms by 28%.
   - have, on average, 450% more biomass
   - help protect threatened, endangered or unique marine life

ii. ***Ecological benefits*** extend to adjacent unprotected ecosystems through the movement of species from an MPA thus improving biodiversity and ecological balance.

iii. ***Protecting large predators,*** such as sharks, essential to healthy food webs and stable ecosystem functioning. Large predators keep populations at lower trophic levels in balance and can assist ecosystems to recover from environmental challenges such invasive species.

The journal Nature reported in Volume 506, 2014, that *'large, highly protected, isolated, well-enforced and long-standing marine reserves have 14 times as much shark biomass, twice as many large fish and five times as much fish biomass as do unprotected areas.'*

B. Economic and social values of MPAs

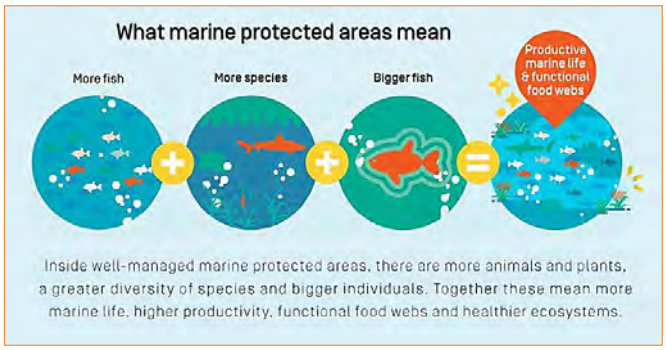
i. ***Supporting local economies*** through activities such as tourism and fishing by maintaining the biodiversity on which they depend.

ii. ***Increasing the resilience of coastal communities*** to cope with change, including extreme weather events such as storms and long-term change such as ocean warming.

iii. ***Educating citizens*** about ecosystem functioning and the need for effective management and protection.

iv. ***Undertaking scientific research***

v. ***Appreciating*** the role of nature in human wellbeing and ***creating hope*** for future generations facing an uncertain environmental future



Source: https://saveourseasmagazine.com/marine-protected-area/

Effectiveness

'MPA effectiveness, in ecological terms, is commonly measured by comparing values of ecological or biological measures (e.g., sizes of organisms, density and biomass of fish assemblages, species richness, live cover of benthic organisms) in MPAs and adjacent unprotected areas and/or before and after an MPA is established.'

Source: https://www.frontiersin.org/articles/10.3389/fmars.2018.00223/full

A number of academic studies make the point that legislation, protection, time protected, stakeholder consultation and enforcement are also important influences on the success / effectiveness of a marine protected area. These can be used as criteria when evaluating the effectiveness of MPAs as a management strategy for the Great Southern Reef.

For information and a map of NSW Marine Protected Areas visit the NSW Department of Primary industries https://www.dpi.nsw.gov.au/fishing/habitat/protecting-habitats/mpa

ILLUSTRATIVE EXAMPLE 4: PROTECT

GREAT SOUTHERN REEF MARINE PROTECTED AREAS

VICTORIA: PARKS AND SANCTUARIES

Victoria's coastal waters form part of the Great Southern Reef. The state's Marine National Parks and Marine Sanctuaries cover approximately 63,000 hectares or 5.3% of Victoria's marine waters and protect a range of significant species and important habitats, maritime artefacts and evidence of past Indigenous occupation and use. Victoria's parks system aims to protect viable representative samples of the State's natural marine environments.

1. Wilsons Promontory Marine National Park (2002)

Wilsons Promontory Marine National Park's is Victoria's largest protected area. It's record for *'management and exceptional marine biodiversity, research and conservation'* has been recognised internationally with a ***Global Ocean Refuge Platinum Award***. The award is issued by the Marine Conservation Institute as a part of its Blue Parks initiative that seeks to *'celebrate effective MPAs and incentivise governments, managers, communities and leaders to achieve effective conservation.'* **Figure 2** shows why the park received this international award. The Park is managed by Parks Victoria with 30 plus partner organisations and volunteers.

Read more about Blue Parks here https://marine-conservation.org/blueparks/

WATCH the following videos showing the diversity of life on the Great Southern Reef within Wilsons Promontory Marine NP and the Award Parks Victoria received. https://www.youtube.com/watch?v=Ql01RfhEuQI&t=6s

Recent baited camera and towed video capture https://www.youtube.com/watch?v=v5uSguSDCEI

Figure 2: Blue Park Platinum Award for marine conservation

Wilsons Promontory Marine National Park protects a rich mixing zone of warmer eastern Australian waters and the colder waters of Bass strait to the west. This blending drives high biodiversity and supports many creatures across the park's sheltered bays, subtidal rocky reefs, kelp forests, and intertidal habitats. The coastline features beautiful sandy beaches, granite mountains and cliffs. The deep waters of Wilsons Promontory Marine National Park feature colourful sponge gardens, corals, and abundant fishes. Its diversity of sessile invertebrate communities is comparable to that of the Great Barrier Reef.

Wilsons Promontory Marine National Park is a refuge for great white sharks, humpback and southern right whales, and fur seals. It is considered a significant area for great white shark population recovery in Australia. Twenty-five shore and seabird species of conservation concern have also been sighted in Wilsons Promontory Marine National Park.

Wilsons Promontory Marine National Park was established in November 2002, and it is the largest marine protected area in Australia's Victoria state. The Park is one part of the state system of 13 Marine National Parks and 11 Marine Sanctuaries. These marine protected areas are managed by Parks Victoria's South Gippsland District management team in partnership with the Environment and Science Division as part of the strategic statewide MPA program. Parks Victoria also works closely with the Victorian Fisheries Authority in undertaking compliance activities, particularly in regard to surveillance for illegal fishing in no-take areas of Wilsons Promontory Marine National Park.

2. Jawbone Marine Sanctuary (2002)

The Jawbone Marine Sanctuary is considered significant in the Victoria's state-wide system of marine Protected Areas because it represents significant ecosystems in Port Phillip Bay (Boonwurrung Country) and plays an important role in scientific research.

Extensive reefs formed by a wide band of basalt and boulders up to 30 m wide, occupy half of the sanctuary (15 ha). The reef is covered by shorter turfing algae, coralline algae and Ulva (Sea Lettuce) as well as sponges, and temperate hard corals – all adapted to environmental extremes and high wave energy.

The coastline surrounding the sanctuary is highly urbanised, and the catchment has significant cropping and grazing. The marine environment faces stresses similar to other locations on the Great Southern Reef near large urban concentrations.

WATCH this video explaining the interconnections between species in the sanctuary and the importance of protection to maintaining the natural balance of species.

Protecting Jawbone Marine Sanctuary
https://www.youtube.com/watch?v=s5tdNddr3Oc&t=225s

Source: Jawbone Marine Sanctuary Care Group Facebook

SOUTH AUSTRALIA: PROTECT A UNIQUE SPECIES

Protecting the Giant Australian Cuttlefish

The Upper Spencer Gulf Marine Park is known as a breeding area for the Giant Australian Cuttlefish, a species endemic to southern Australia, found only the Great Southern Reef. The population that aggregates in the Northern Spencer Gulf is a unique sub species in need of special protection to ensure sustainability.

Each winter tens of thousands of the cuttlefish aggregate to spawn on an 8 –10 km stretch of rocky reef where they lay their eggs within and underneath the rocks. The spawning event is a significant tourist attraction and cuttlefish harvesting is an important activity for commercial and recreational fishers in South Australia.

Protection measures

There are measures within the Marine Park to ensure the sustainability of the species

- Exclusion Zone – a Cephalopod (squid, cuttlefish and octopus) fishing closure between Whyalla and the Point Lowly lighthouse.
- Cuttlefish Coast Sanctuary Zone – fully protected, to protect the cuttlefish and the whole food web and ecosystem it relies on to survive.
- Fishing limits outside exclusion zones – personal bag and boat limits

Giant Cuttlefish with an Eastern Blue Groper in it's mouth.
Image: Elaine de Jager, Wikimedia Commons

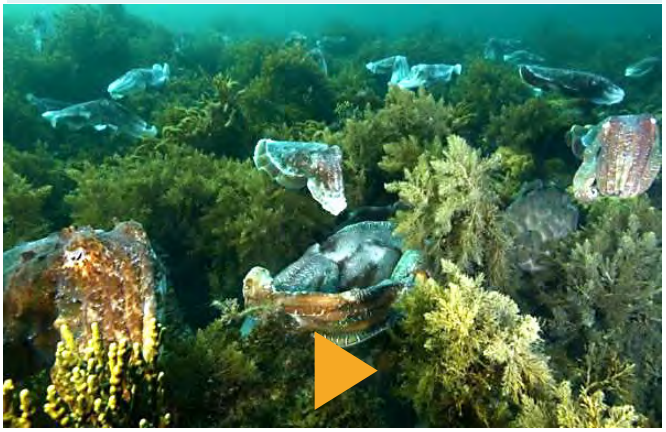
Flexible zoning

The Marine Park Management Plan also allows for additional protections and/or temporary restrictions to protect a species. In response to fluctuating populations the entire Northern Spencer Gulf was temporarily closed to fishing in 2013 and a temporary extension around Point Lowly was added for the period of the 2021 spawning event.

In recent years cuttlefish populations have rebounded. In 2020, the temporary ban of fishing cuttlefish from the entire northern Spencer Gulf was lifted.

ILLUSTRATIVE EXAMPLE 4: PROTECT

WATCH: All about South Australia's Cuttlefish Aggregation https://www.youtube.com/watch?v=6gav27Nwfgc



Source: Great Southern Reef https://greatsouthernreef.com/cuttlefish

Take a **VIRTUAL TOUR** with South Australia National Parks and Wildlife. https://roundme.com/tour/576169/view/1869429/

Learn more

The protection of the Giant Australian Cuttlefish on the Great Southern reef website here. https://greatsouthernreef.com/cuttlefish

SA National Parks and Wildlife Service: Upper Spencer Gulf Marine Park https://www.parks.sa.gov.au/parks/upper-spencer-gulf-marine-park

WATCH: Giant cuttlefish spawning aggregation from Ocean Imaging https://www.youtube.com/watch?v=o2Fnx9bxn_M

OTHER EXAMPLES included in the Google Site – Stage 6: Great Southern Reef.

- Solitary Islands Marine Parks and Cabbage Tree Bay Aquatic Reserve (NSW)
- Ngari Capes Marine Park in WA

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Marine Parks and Sanctuaries Victoria https://www.marineandcoasts.vic.gov.au/marine/marine-national-parks-and-sanctuaries

SA National Parks and Wildlife Service: Upper Spencer Gulf Marine Park https://www.parks.sa.gov.au/parks/upper-spencer-gulf-marine-park

Marine Parks SA Interactive map https://www.marineparks.sa.gov.au/find-a-park

Great Southern Reef https://greatsouthernreef.com/cuttlefish

Giant Australian Cuttlefish 2020 Survey Results. https://www.youtube.com/watch?v=0kFNm_ojoL0

Explaining the science behind Giant Australian Cuttlefish https://www.youtube.com/watch?v=y-odZJ2PvGI

Protection zone extended for cuttlefish season https://www.whyallanewsonline.com.au/story/7249425/protection-zone-extended-for-cuttlefish-season/?cs=1550

Increased protection for Giant Australian Cuttlefish https://www.premier.sa.gov.au/news/media-releases/news/increased-protection-for-giant-australian-cuttlefish

Fishing limits for cuttlefish https://www.pir.sa.gov.au/fishing/fishing_limits/cuttlefish

SEAWEED and KELP, SEAGRASSES and SPONGES

Australasian snapper under a kelp forest canopy Source: iStock

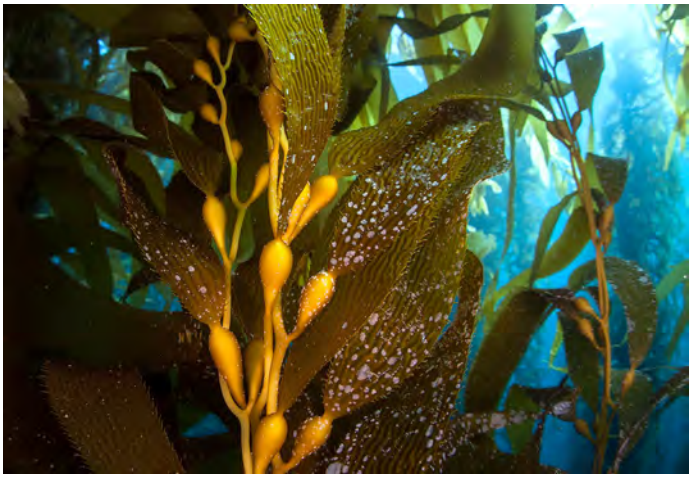
Seaweeds, kelp, seagrasses, and sponges are habitat forming species

A **seaweed** is a macroscopic (visible) form of red, brown, or green **algae**. Green algae can be seen on intertidal rock platforms and in rockpools. Red algae grow closer to the sea floor where there is less light. Brown algae are the largest macroalgae and commonly known as kelp. Seaweeds and kelp come in many shapes and sizes. They play an important role in marine ecosystems as a source of food and habitat for marine animals.

Kelp is **brown macroalgae** found on rocky coasts in temperate and subpolar regions with cool, nutrient rich water and ample light for photosynthesis. Pigments and chlorophyll in the kelp tissue create the brown colour. Accumulations of kelp transform rocky outcrops into complex 3D kelp forests with clearly recognisable layers such as canopy, understorey, and forest floor.

Recognisable features of kelp include:

- *holdfast* attaches kelp to a rocky surface
- *stipe* (like a stem)
- *air bladder* – a gas-filled pod, on the blades or between the blades and stipe assists flotation.
- *blades* (like leaves)



Kelp blades and air bladders. Source: Shutterstock

Adaptations

Kelp is uniquely adapted to life below the surface.

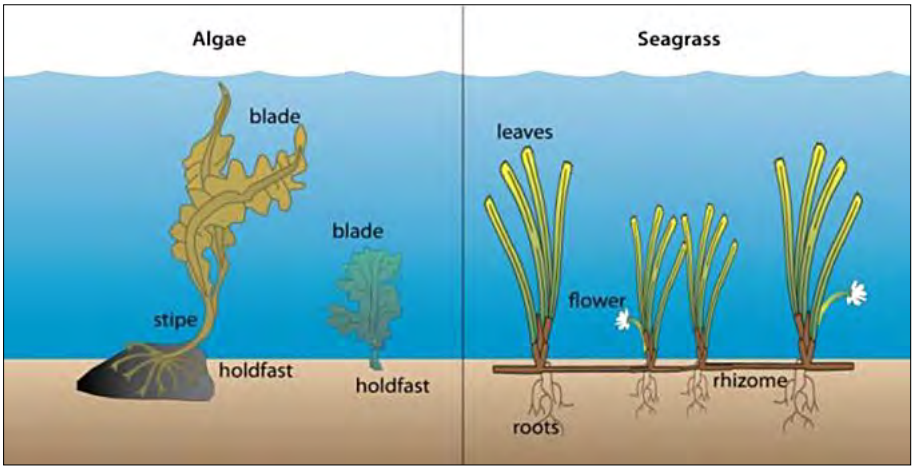
- The holdfast acts as an anchor, helping the kelp **withstand the ebb and flow of daily tides**
- A flexible stipe allows kelp to **sway and bend in moving coastal waters**
- Balloon shaped pneumatocysts (gas bladders) filled with waste gases keep the **kelp fronds upright, floating** and holding blades near the surface to **maximise light absorption.**

FACT SHEET

Kelp are ALGAE: Sponges are ANIMALS: Seagrasses are PLANTS. All play a role in kelp forest ecosystem functioning

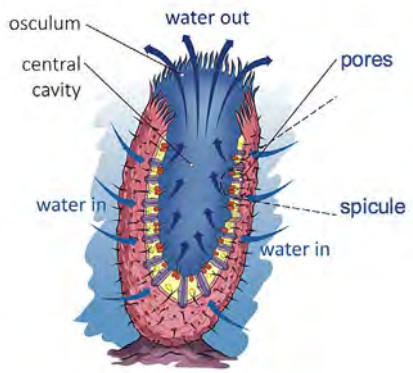
KELP (MACROALGAE)	SPONGES (ANIMAL)	SEAGRASSES (PLANT)
Holdfast, blades, and a stipe	Silica or Calcium carbonate rods	Roots, stems, leaves and flowers
Produce food by photosynthesis and absorb nutrients from water Holdfast does not absorb nutrients	Filter food and oxygen from water pumped through pores and channels No photosynthesis	Produce food by photosynthesis Nutrients are absorbed by the roots and transferred through veins
Reproduce via spores and buds	Reproduce via sperm and eggs	Reproduce by seed or rhizome

Seagrasses are commonly found in shallower water adjacent to Kelp forests. **Sponge gardens** can be found in shaded rock crevices and on the floor of kelp forests.



Smithsonian https://ocean.si.edu/ocean-life/plants-algae/seagrass-and-seagrass-beds

'Algae or "seaweeds" (left) differ from seagrasses (right) in several ways. Algae on the seafloor have a holdfast and transport nutrients through the body by diffusion, while seagrasses are flowering vascular plants with roots and an internal transport system.'



Sponges are colonial animals with hard, multi-pointed rods (spicules) permanently attached to substrate. Sponges consume organic particles, plankton and oxygen from water pumped through pores and channels – this water also removes wastes. They produce larvae that colonise new areas or reproduce from broken fragments (buds). Sponge gardens can grow in shaded locations and provide habitat for a diversity of marine creatures.

Connected habitats and ecosystems

Rocky reef habitats are connected through ecological processes such as food chains, energy flows and nutrient cycles. **Kelp** produces food through photosynthesis and directly and indirectly feeds primary consumers such as zooplankton across multiple habitats. **Sponges** filter food and nutrients from the water, keeping the water clear for kelp to photosynthesise. Kelp and seagrass ecosystems are connected and mutually beneficial in supporting marine biodiversity.

Learn more about Kelp https://www.youtube.com/watch?v=GcbU4bfkDA4

Swim through kelp and seaweed here https://www.youtube.com/watch?v=Ps5gq1wCzXY

Watch sponges pumping water here https://www.youtube.com/watch?v=pTZ211cljX8

ABOVE: Sponge Garden. Ocean Imaging. Great Southern Reef

LEFT:Blue World: Sponges pumping water – https://www.youtube.com/watch?v=pTZ211cljX8

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GTA NSW & ACT is providing ONE TIME access to selected presentations recorded at the 2021 GTA Annual Conference to schools unable to attend due to factors unique to 2020–2021. Some recordings, particularly workshop sessions are condensed versions of the live events.

DETAILS

- Presentations in the package focus on the following Professional Teaching Standards
  - Standard 2: Know the content and how to teach it; and Standard 6. Undertake Professional Learning
  - classroom practice
  - deep learning about environmental processes, change and management
  - integrating geospatial technologies
  - identifying careers that draw on Geography
- Access is continuous until 30 October 2021 (Week 4, Term 4)
- Accessible at any time via a weblink with a passcode – not downloadable
- PPTs and support materials for each presentation as provided at the conference

HOW TO USE THE PACKAGE

- **Whole faculty /department/ team** viewing at team or staff meetings/ professional development days
- **Individual** viewing and discussion at team or faculty level
- For workshop sessions, stop and complete the activities as if you were at a conference.
- Elective PL Hours – reflection using the identified Teaching Standards https://etams.nesa.nsw.edu.au/help/how-to-log-teacher-identified-pd-index/

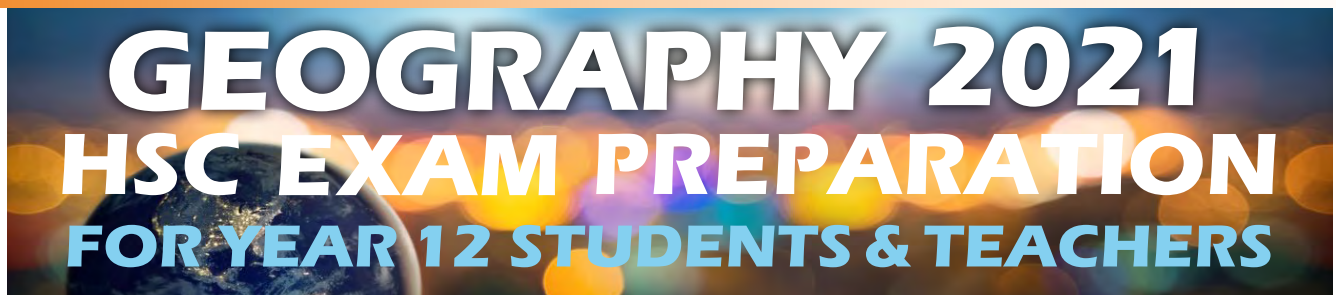
COST

- **Member schools – $330 per school** (inc. GST)
- **Non-member schools – $440 per school** (inc. GST)

Registration until 14 August 2021 to allow adequate time to make use of the materials in the package.

ORDER & PAY HERE

ACCESS THE INFORMATION FLYER OUTLINING THE PACKAGE CONTENT



GTA NSW & ACT has traditionally organised revision lectures for HSC Geography students and their teachers. In 2021 schools will be offered a repeat of the Digital Package produced in 2020 (minor revisions made) with a 2021 Supplement of new and updated materials.

The package consists of pre-recorded videos and support materials. Teachers can use the materials with their HSC classes, irrespective of the number of enrolled students.

- Recommended for tutorial and in class revision / teacher led revision.
- Transfer key ideas from illustrative examples and case studies to your own studies*
- Not to be used for private tutoring purposes.
- Streamed directly from Vimeo and not downloadable.
- Support materials downloadable from a Google Drive Folder.

CONTENTS:

MAIN PACKAGE	2021 SUPPLEMENT
Ecosystems at Risk – EAR Part 1 & Part 2 using illustrative examples. Lorraine Chaffer	EAR: Know your case studies – through the lens of a study of the Great Barrier Reef. Matt Carroll
	HSC Question Drop EAR / EAR Matt Carroll
People and Economic Activity with a focus on Global Tourism. Dr Grant Kleeman	PEA: Investigating an Economic Enterprise – through the lens of a study of Tamburlaine winery Matt Carroll
People and Economic Activity – General syllabus overview and advice. Lorraine Chaffer	Economic Activity Update: Global Tourism in the age of COVID-19 Dr Grant Kleeman
Urban Places Karen Bowden	Section III – Hitting the band descriptors Alexandria Warnock
HSC Geographic Tools and Skills Sharon McLean	Effective use of fieldwork. Making your fieldwork count. Grace Larobina
	Know your fieldwork tools and skills cards Lorraine Chaffer
Student workbooks for: – EAR, PEA, Urban Places – Skills and tools.	Checklist: On the road to the Trail HSC Extended response templates Catherine Donnelly

ACCESS:

The package will be available from Friday 11 June until Tuesday 2 November – the day of the HSC Geography Exam. The teacher(s) who completes the registration will be provided with the download details once payment has been received.

NOTE: ACCESS INFORMATION IS NOT TO BE SHARED WITH STUDENTS.

COST:

Main Package plus 2021 Supplement –

- **$250** plus GST – **Members** (school or personal)
- **$350** plus GST – **Non-members**

2021 Supplement ONLY –

- **$60** plus GST – **Member schools**
- **$120** plus GST – **Non-members**

NOTE: the supplement is for those schools who were able to download the 2020 package to their school network for students to access independently; this feature is not offered in 2021.

BENEFIT:

Although created for students in Year 12, teachers new to teaching Stage 6 and currently teaching Year 11 could benefit from a good overview of the Year 12 topics and the advice from presenters covered in this package.

ORDER AND PAY HERE

ADVICE TO CONTRIBUTORS

Geography Bulletin guidelines

1. *Objective:* The Geography Bulletin is the quarterly journal of The Geography Teachers' Association of NSW & ACT Inc. The role of the Geography Bulletin is to disseminate up-to-date geographical information and to widen access to new geographic teaching ideas, methods and content. Articles of interest to teachers and students of geography in both secondary and tertiary institutions are invited, and contributions of factually correct, informed analyses, and case studies suitable for use in secondary schools are particularly welcomed.
2. *Content:* Articles, not normally exceeding 5000 words, should be submitted to the GTA NSW & ACT Office by email gta.admin@ptc.nsw.edu.au

   Submissions can also be sent directly to the editors: Lorraine Chaffer (lchaffer@tpg.com.au)

   Articles are welcomed from tertiary and secondary teachers, students, business and government representatives. Articles may also be solicited from time to time. Articles submitted will be evaluated according to their ability to meet the objectives outlined above.
3. *Format:* Digital submission in Word format.

- Tables should be on separate pages, one per page, and figures should be clearly drawn, one per page, in black on opaque coloured background, suitable for reproduction.
- Photographs should be in high resolution digital format. An indication should be given in the text of approximate location of tables, figures and photographs.
- Every illustration needs a caption.
- Photographs, tables and illustrations sourced from the internet must acknowledge the source and have a URL link to the original context.

Note: Please try to limit the number of images per page to facilitate ease of reproduction by teachers.

Diagrams created using templates should be saved as an image for ease of incorporation into the bulletin.

All assessment or skills tasks should have an introduction explaining links to syllabus content and outcomes. A Marking Guideline for this type of article is encouraged.

4. *Title:* The title should be short, yet clear and descriptive. The author's name should appear in full, together with a full title of position held and location of employment.
5. *Covering Letter:* As email with submitted articles. If the manuscript has been submitted to another journal, this should be stated clearly.
6. *Photo of Contributor:* Contributors may enclose a passport-type photograph and a brief biographical statement as part of their article.
7. *References:* References should follow the conventional author-date format:

   Abbott, B. K. (1980) *The Historical and Geographical Development of Muswellbrook* Newcastle: Hunter Valley Press.

   Harrison, T. L. (1973a) *Railway to Jugiong* Adelaide: The Rosebud Press. ***(2nd Ed.)***

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All suitable manuscripts submitted to the Geography Bulletin are subject to the process of review. The authors and contributors alone are responsible for the opinions expressed in their articles and while reasonable checks are made to ensure the accuracy of all statements, neither the editor nor the Geography Teachers' Association of NSW & ACT Inc accepts responsibility for statements or opinions expressed herein.

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