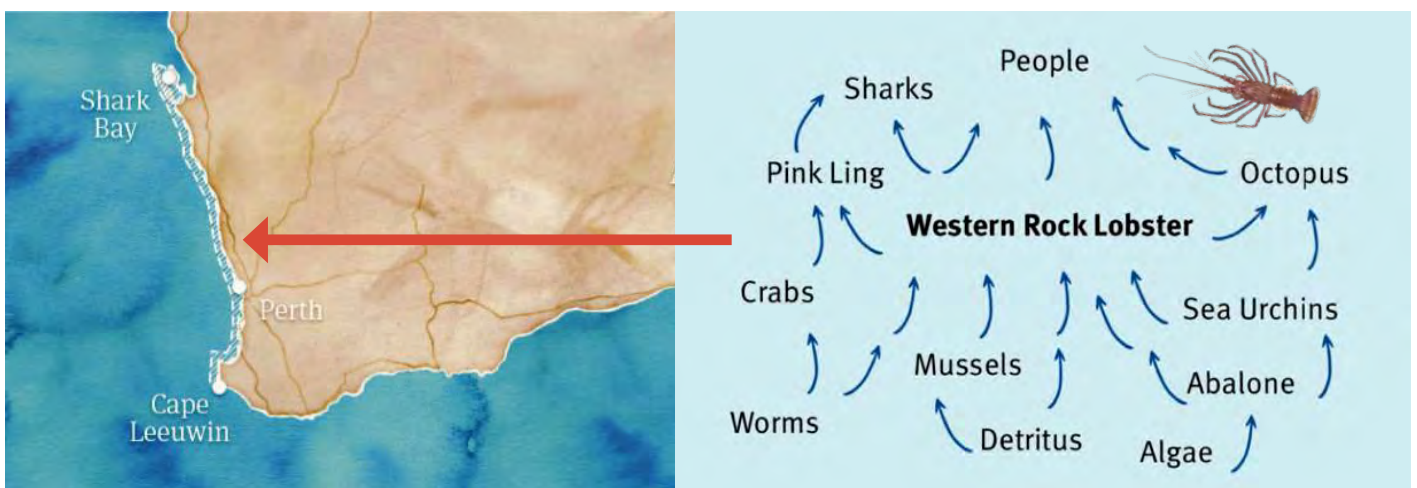


ILLUSTRATIVE EXAMPLE 2: RESTORE



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. Approximately 100 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 km² 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:

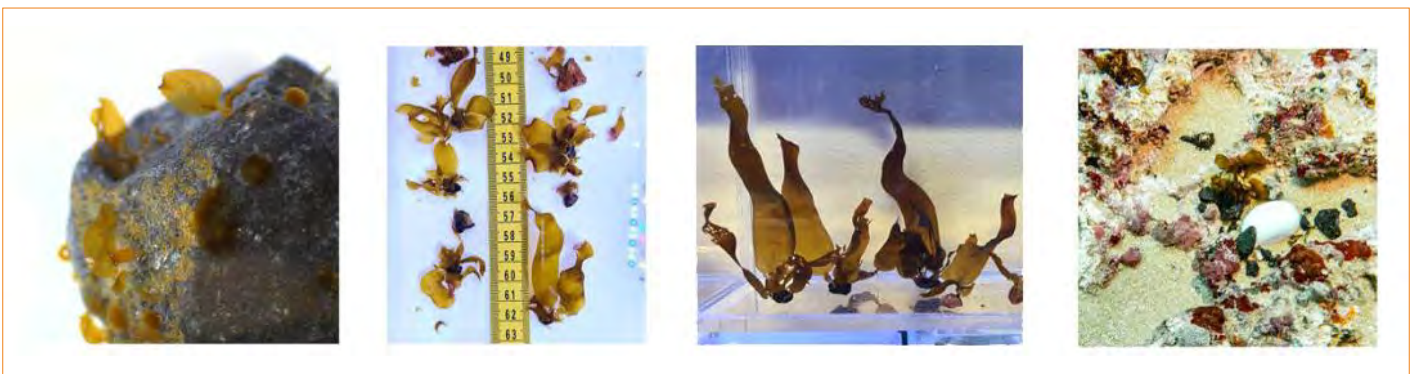
- The kelp and rock are sourced locally and attached in a lab (Figure 2)
- Green gravel (the kelp and their rock anchors) can be scattered from a boat
- Once settled on the seabed, the kelp can quickly grow into adults and over time colonise surrounding areas.

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>

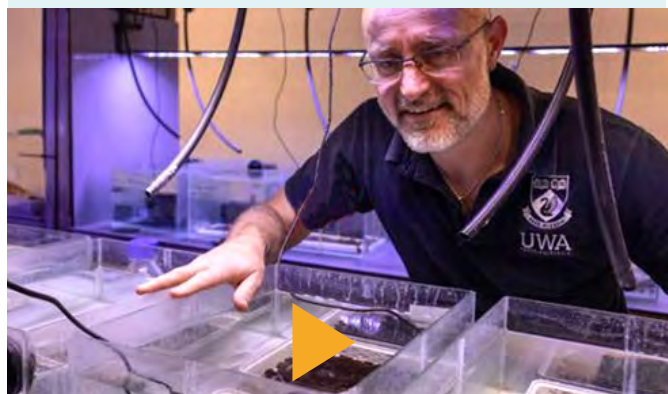
ILLUSTRATIVE EXAMPLE 2: RESTORE

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

- State the latitude of Kalbarri
- State the direction of Kalbarri from Perth
- What word describes ecosystems north of Kalbarri represented by the red arrow?
- Identify three features of the marine ecosystem north of Kalbarri.
- Describe three features of the ecosystem at 34 degrees South.
- Explain what happened to the marine ecosystem from Kalbarri to Perth between 2006 and 2015.
- What is meant by the term 'Kelp Contraction zone' in the diagram
- Why was Kalbarri the northernmost limit of temperate Kelp forests.
- Explain the cause of the change. Using geographical language from the illustration.

Figure 5

- What area of kelp was lost at 28°S and 32°S
- Over how many km was there a loss of kelp?
- At what latitude was 50% of kelp lost?

Figure 6

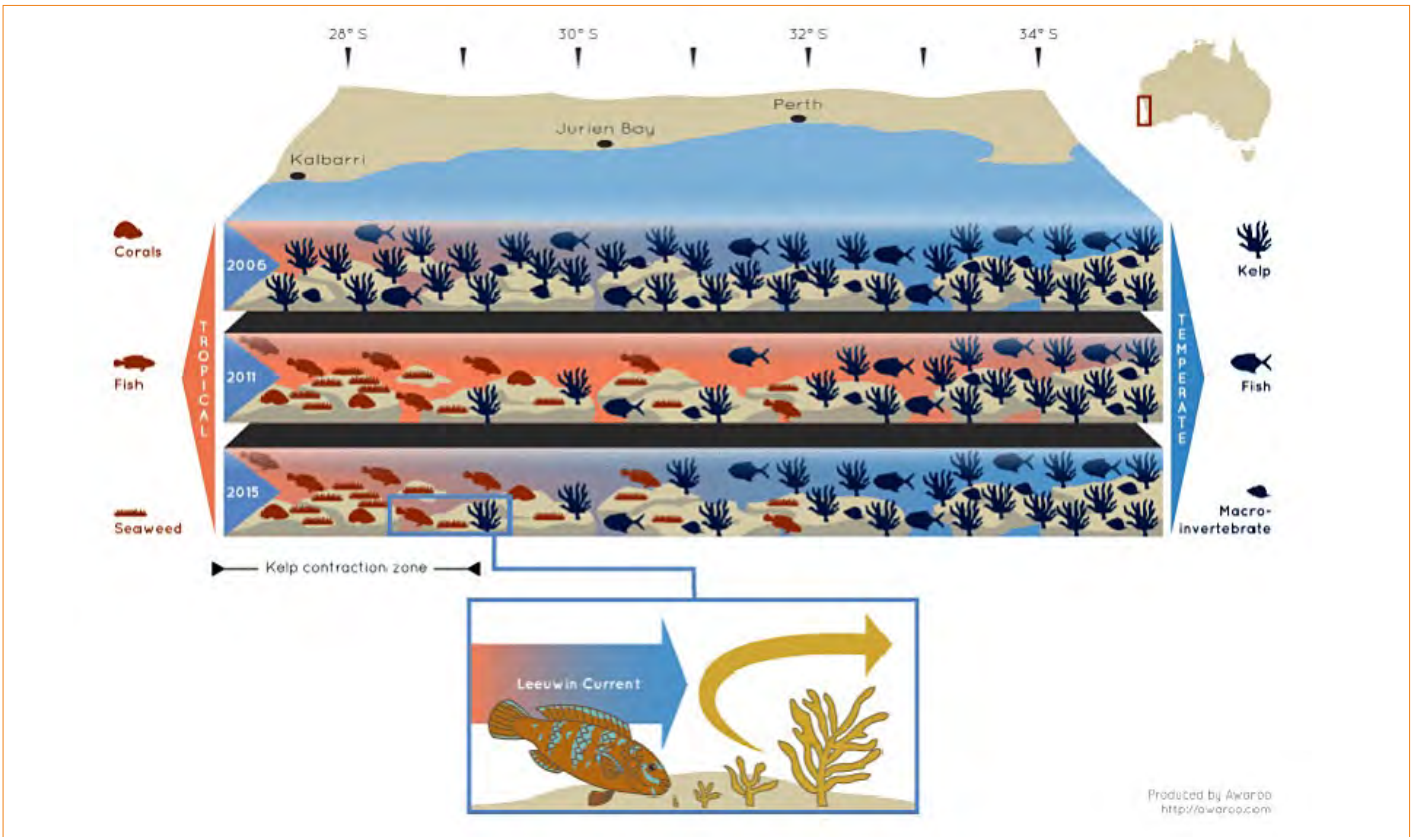
- Explain images a. and b.
- In what year did seaweed turf overtake kelp as the main ecosystem?
- Describe kelp forest loss between 2010 and 2013 using data from the graph.
- Calculate the ration of kelp to seaweed turf in 2001 and mid 2012.
- Calculate the rate of change in seaweed turf between the end of 2010 and the end of 2015.

ILLUSTRATIVE EXAMPLE 2: RESTORE

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/>
 Information © Copyright CSIRO Australia, 'Western Australian kelp forests in hot water' first published July 15th, 2016. Infographic by Awaroo – <http://awaroo.com/en/>

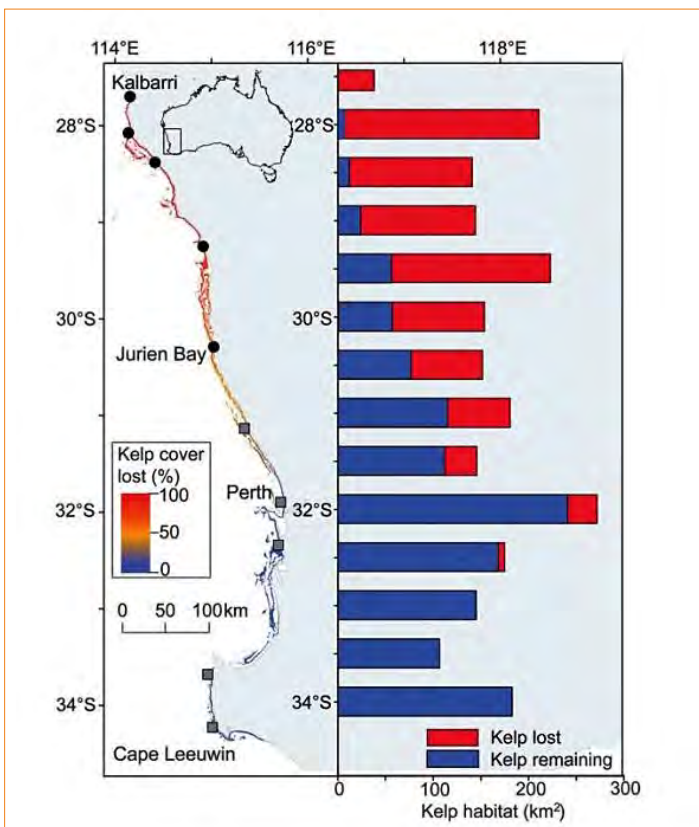


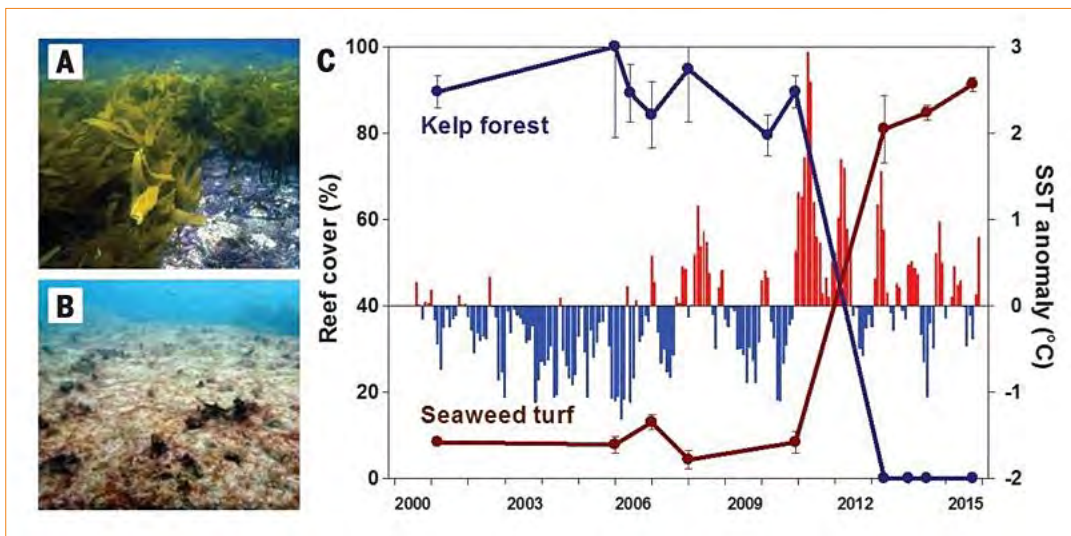
Figure 5: Climate-driven regime shift of a temperate marine ecosystem

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>
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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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References

- Forests of the sea in Western Australia slashed by marine heatwave ABC Science – <https://www.abc.net.au/news/science/2016-07-08/kelp-forests-of-the-sea-in-wa-slashed-by-marine-heatwave/7577934>
- Underwater understory: the south-west forest you've never heard of (Scitech.org) – <https://particle.scitech.org.au/earth/kelp-forests-of-western-australia/>
- Western Australian kelp forests in hot water – <https://ecos.csiro.au/kelp-forests-hot-water/>
- Marine heatwaves threaten the future of underwater forests – <https://theconversation.com/marine-heatwaves-threaten-the-future-of-underwater-forests-37154>
- Marine Stewardship Council: Rock Lobster Fishery Fact Sheet – <https://www.msc.org/docs/default-source/aus-files/education/rock-lobster-fishery-factsheet.pdf>
- Help for kelp – <https://researchimpact.uwa.edu.au/research-impact-stories/help-for-kelp/>
- Super-warm seas wiped out an entire underwater forest, scientists report – <https://www.washingtonpost.com/news/energy-environment/wp/2016/07/07/super-warm-waters-wiped-out-an-entire-underwater-forest-in-australia-scientists-report/>
- Climate-driven regime shift of a temperate marine ecosystem – <http://science.sciencemag.org/content/353/6295/169>
- Facebook Great Southern Reef Facebook group – <https://www.facebook.com/watch/?v=263069682309755&ref=sharing>
- Great Southern Reef - Thomas Wernberg . Thomas Wernberg answers a few questions on the Great Southern Reef. – <https://www.youtube.com/watch?v=du3JARwNE9o>
- Restoring blue forests with Green Gravel– <https://www.greengravel.org/projects-and-organisations>
- Kelp parachutes: Green gravel reforestation projects showing promise – <https://www.aquaculturealliance.org/advocate/kelp-parachutes-green-gravel-reforestation-projects-showing-promise/>
- Scientists document the extinction of WA's Great Southern Reef kelp forests – 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
- 'Blue is the New Green' Webinar. University of Western Australia. – <https://alumni.uwa.edu.au/blue-is-the-new-green>