Level 3 Certificate/Extended Certificate
APPLIED SCIENCE

Unit 3 Science in the Modern World
January 2020

Pre-release Material

- This pre-release material should be opened and issued to learners on or after **1 November 2019**.
- **A clean copy of the pre-release material will be provided at the start of the examination.**

Information

This pre-release material is to be issued to learners for use during preparation for this examination. The pre-release material consists of four sources (**A–D**) on the subject of **coral bleaching**.

This material is being given to you in advance of this examination to enable you to study each source in preparation for questions based on the material in **Section A** of the examination.

A wider understanding of the topics and issues raised in the sources would be beneficial for the assessment. You are not required to understand any detailed scientific explanations beyond that outlined in **Sources A–D** and that in the Applied Science specification.

You may write notes on this copy of the pre-release material, but you will not be allowed to bring this copy, or any other notes you may have made, into the examination room. You will be provided with a clean copy of this pre-release material at the start of the examination.

It is suggested that a minimum of three hours detailed study is spent on this pre-release material.

Source A: Adapted article from *The Conversation* website, 7 April 2016

Great Barrier Reef disaster is the latest harbinger of a global mass extinction

April 7, 2016 11.16am BST

Author James Dyke Lecturer in Sustainability Science, University of Southampton

Large sections of the Great Barrier Reef, the Earth's largest living structure, are dying before our eyes. Sustained high sea temperatures have stressed the corals to the point where they expel the brightly coloured algae that live within their tissues. This process is aptly named bleaching as it removes all pigment and exposes the shocking white calcium skeleton of the reef structures.

The coral can survive in this state for up to a few weeks. Thereafter, if temperatures do not decrease then they will die.

The Great Barrier Reef has experienced bleaching events twice before. The first, in 1998, was bad enough, with 50% of the reef affected. 2002 was even worse with 60% of the reef bleached. Recent aerial surveys of the northern 1000 km of the reef evaluated 500 different sections – 95% were bleached.

The full impact that such bleaching is having will not be known until biologists directly observe the corals in the water. Estimates coming back from initial monitoring show that on some reefs more than half of the coral has already died.

Given the record-shattering temperatures over the past year, coral researchers were preparing themselves for another mass bleaching. But the scale of this event has left some researchers stunned. Or angry. Returning from five weeks investigating the reefs, Jodie Rummer, a biologist at the ARC Centre of Excellence for Coral Reef Studies said:

"I witnessed a sight underwater that no marine biologist, and no person with a love and appreciation for the natural world for that matter, wants to see".

Why corals need their colour

Coral polyps and their colourful zooxanthellae algae have a tightly coupled relationship, where each aids the other.

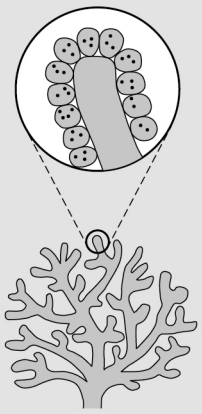
The algae are autotrophic photosynthesisers, which means they make their own food by using sunlight to split carbon dioxide molecules and form sugars. Coral polyps are much more complex heterotrophs – they use fine-meshed sieves to sweep up suspended organic matter from seawater.

CORAL BLEACHING

Have you ever wondered how a coral becomes bleached?

Healthy coral

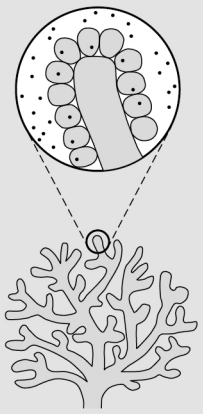
1 Coral and algae depend on each other to survive.



Corals have a symbiotic relationship with microscopic algae called zooxanthellae that live in their tissues. These algae are the coral's primary food source and give them their colour.

Stressed coral

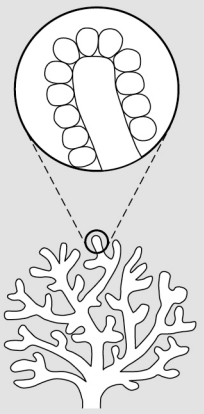
2 If stressed, algae leaves the coral



When the symbiotic relationship becomes stressed due to increased ocean temperature or air pollution, the algae leave the coral's tissue.

Bleached coral

3 Coral is left bleached and vulnerable



Without the algae, the coral loses its major source of food, turns white or very pale, and is more susceptible to disease.

What causes coral bleaching?

Change in ocean temperature

Increased ocean temperature caused by climate change is the leading cause of coral bleaching.

Runoff and pollution

Storm generated precipitation can rapidly dilute ocean water and runoff can carry pollutants – these can bleach near-shore corals.

Overexposure to sunlight

When the temperatures are high, high solar irradiance contributes to bleaching in shallow-water corals.

Extreme low tides

Exposure to the air during extreme low tides can cause bleaching in shallow corals.

For the algae, a coral reef represents the perfect place to live. There, they are safe and secure within a strong structure, near the surface and so able to receive large amounts of energy from the sun along with coral polyp waste, which helps promote photosynthesis. In fact photosynthesis is so productive that the algae produce more food than they can consume. This surplus is greedily gobbled up by the coral polyps. It's a win-win situation – what biologists call a mutualistic symbiosis.

However, just like any biological process there are environmental limits. Higher temperatures along with very bright sunshine can impact both coral polyps and their algae and their relationship breaks down, leading to the expulsion of the algae and bleached coral.

Bleaching can also be driven by pollution, particularly agricultural run-off and sedimentation from activities such as dredging. These two factors threaten the more southern portions of the Great Barrier Reef which at least so far have dodged some of the very worst bleaching as sea temperatures have been lower. The northern stretch of the reef is more remote and better protected from human impacts, but it has borne the brunt of extreme temperatures.

Our response...

Given that scientists have been warning about a significant bleaching episode for some time now, one may have hoped for a coordinated response to this predictable disaster. There have indeed been related developments.

While biologists were in the air and under the water scrambling to understand the severity of this latest bleaching event, the Queensland Government approved mining leases for the A$21.7 billion Carmichael coal mine and associated new rail line in the Galilee Basin. If all of this coal is extracted and burnt, some 4.6 billion tons of carbon dioxide will be released into the Earth's atmosphere.

Given climate change's obvious impact on the Great Barrier Reef, some scientists have pointed out the fundamental contradiction in a government stating that it is both committed to protecting the reef and developing these new coal mines.

As if adding insult to injury, the vast majority of the Galilee Basin coal will be shipped out of the deep water port of Abbot Point which is within the Great Barrier Reef UNESCO world heritage site. Those shipping the coal will be able to wave goodbye to the reef in more than one way as they transport it to power stations in India, China and Japan where it will be burnt and so contribute to further warming and further bleaching.

At times like this, it's hard not to anthropomorphise – to see the Great Barrier Reef and other coral reefs around the world turning white not due to bleaching, but in shock at our sustained attack on the natural world. The events unfolding off the coast of north eastern Australia are dramatic, but are also just the latest manifestation of the mass extinction event humans have initiated.

This not only drains the colour from the Earth's most magnificent aquatic ecosystems, but robs us of biological beauty across the world. We will all lead diminished lives because of it.

END OF SOURCE A

Source B: Adapted article from the *BBC News* website, 3 May 2018

Hawaii to ban certain sunscreens harmful to coral reefs

BBC News 3 May 2018

Hawaii has become the first US state to pass a bill banning the sale of any sunscreens that have chemicals known to harm coral reefs.

The bill bars the sale of sunscreens containing chemicals oxybenzone and octinoxate, which some scientists say contribute to coral bleaching. The chemicals are used in over 3 500 of the most popular sunscreen products.

The bill, which would take effect in 2021, now awaits the signature of Democratic Governor David Ige. Democratic Senator Mike Gabbard introduced the bill, which proposes to end the sale of any non-prescription sunscreens containing oxybenzone and octinoxate, state-wide. Mr Gabbard told the Honolulu Star Advertiser that if the governor signs the bill, it would become "a first-in-the-world law". "Hawaii is definitely on the cutting edge by banning these dangerous chemicals in sunscreens," Mr Gabbard said. "This will make a huge difference in protecting our coral reefs, marine life, and human health." The bill states that the chemicals kill developing coral, increase coral bleaching and cause "genetic damage to coral and other marine organisms".

What do scientists say?

Craig Downs, one of the co-authors of the main study showing the adverse effects of oxybenzone and octinoxate on reefs, told the Washington Post in 2015 that "any small effort to reduce oxybenzone pollution could mean that a coral reef survives a long, hot summer, or that a degraded area recovers".

The scholarly journal Nature noted that other reef scientists were unsure that banning sunscreens would have a big impact. "Banning sunscreen will not solve other problems: for example, temperature anomalies, overfishing, coral predators and the big issue of coastal runoffs that pollute and destroy reefs," Jorg Wiedenmann, head of the Coral Reef Laboratory at the University of Southampton in the UK told Nature. "But if you have places with a high load of tourists going in, it is not unreasonable to stay cautious and say, 'Yes, there may be additive effects.'"

Hawaii's waters see more than eight million tourists each year, and the visitor numbers have been increasing. Mr Downs' study, published in the Archives of Environmental Contamination and Toxicology journal, found that an estimated 12 000 metric tonnes of sunscreen end up washing into coral reefs.

The Star Advertiser reported that Bayer, the company that manufactures Coppertone sunscreen, said there are no similar ingredients available in the US with the same effectiveness as oxybenzone.

The Hawaii Medical Association told the newspaper that it disagreed with the bill due to a lack of peer-reviewed evidence suggesting that sunscreen caused coral bleaching, while plenty of evidence shows that sunscreen protects from skin cancer.

The governor has not indicated whether he will sign the bill.

"The world was watching. We delivered," wrote Senator Will Espero on Twitter, when the senate passed the bill.

END OF SOURCE B

Source C: Adapted article from *The Times* website, 7 December 2017

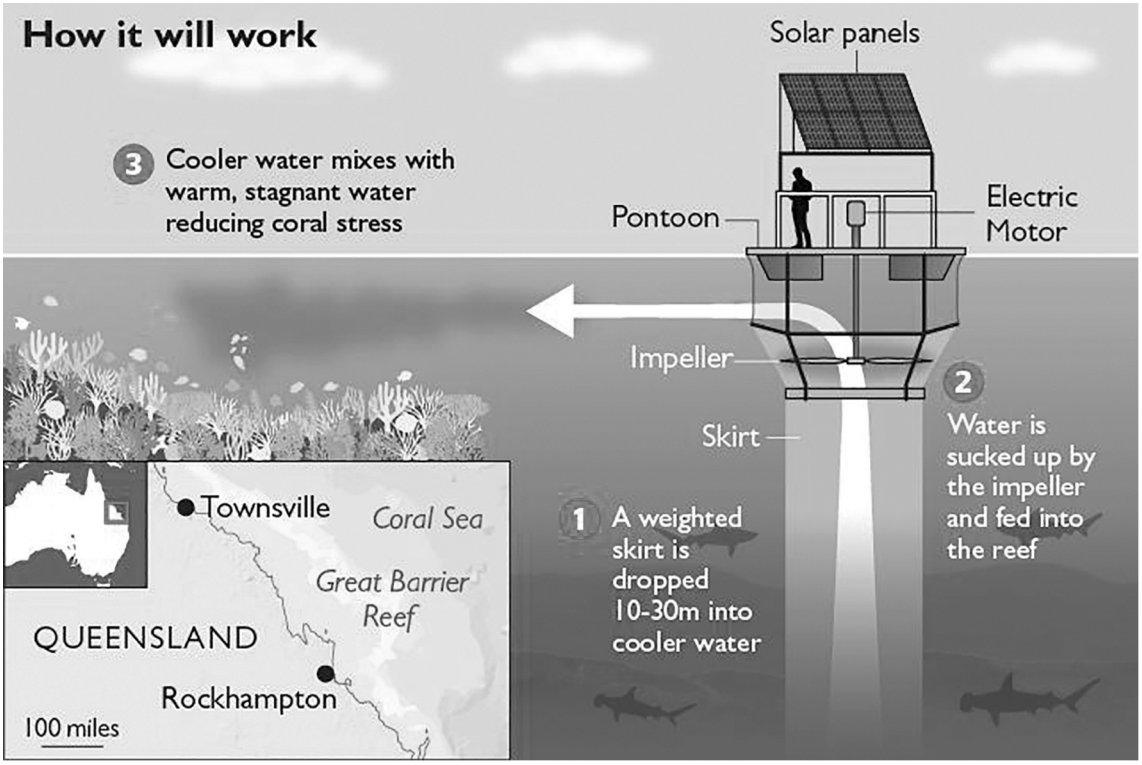
Giant cooling rotors aim to breathe new life into Great Barrier Reef

Bernard Lagan, Sydney
December 7 2017, 5:00pm, The Times

Huge rotating pumps will be installed in the Coral Sea in an attempt to save Australia's Great Barrier Reef from climate change by cooling it.

Eight of the solar-powered devices will be placed over a section of the reef near Cairns in Australia's far north.

It is hoped that they can ward off bleaching that has either damaged or killed coral on swathes of the 2 300 km long reef, the world's largest living thing.



The machines, mounted on pontoons, use large rotating pumps to draw cooler water from 30 metres below the surface and propel it over the coral to re-create cold currents around the reef that have been weakened by warming seas. The cooler currents reduce damage and help the reef to recover after warmer water has bleached the coral.

Four serious bleaching events over the past 20 years have affected more than half the reef.

Tropical coral reefs can tolerate only small temperature changes. Bleaching of the coral kills the algae that live inside it. The coral then becomes transparent. Its growth is stunted and it can die if temperatures do not drop back to normal levels.

“We’re hoping that turning on the fan when it’s really hot will help keep the corals more comfortable,” Sheriden Morris, head of the Reef and Rainforest Research Centre in Cairns, said.

She claimed that it was vital that measures were taken to save the reef now. The pumps will be placed over a square kilometre and the project will be expanded if it is a success. “This intervention will never save the whole of the Great Barrier Reef,” Ms Morris said. “But it will be important for some of our particularly valuable tourist sites, which [provide] 64 000 jobs.”

Last month teams of reef scientists began searching for so-called super corals that have survived the bleaching events of the past two summers.

Charlie Veron, the scientist who has discovered 20 per cent of the world’s coral species, said that researchers hoped to learn why some of them were more resilient to bleaching.

“It’s gut wrenching,” he told the Australian Broadcasting Corporation. “The predictions that scientists made well over a decade ago have all turned out to be spot on.”

END OF SOURCE C

Source D: Adapted article from *The Guardian* website, 1 October 2018

Back from the brink: the global effort to save coral from climate change

Underwater nurseries offer glimmer of hope for endangered ecosystems, encouraging growth of coral fragments on fibreglass structures anchored to the seabed

by Oliver Milman

Wed 26 Sep 2018 Last modified on Mon 1 Oct 2018

As an ocean early warning system, coral reefs have been sounding the alarm for years. They have been bleached white by marine heatwaves and killed off en masse by a combination of factors including pollution, overfishing, acidification and climate change.

But now scientists in Florida, and other tropical locations worldwide, are attempting to stop the rot by creating coral "nurseries" in which young populations can be raised in controlled conditions before being planted on denuded reefs. Off the southern tip of Florida, a sprawling marine farming operation has been established in which corals are painstakingly grown on anchored fibreglass trees and then planted on the barrier reef. "The idea is to do as much as we can now to give these coral populations a fighting chance," says Jessica Levy, programme manager at the Coral Restoration Foundation. "If you don't put back the material and diversity that has been lost, the populations are going to crash and become extinct. For reefs, you're looking at a global extinction of the ecosystem if things don't change quickly."

Florida has the world's third largest barrier reef, with nearly 1400 species of plants and animals and 500 species of fish, but the reef is vanishing fast. Research found that roughly half of the reef has disappeared over the past 250 years. Coverage of acropora, the primary genus of reef-building corals, has plummeted by 97%. "The reef is pretty barren right now," says Levy.

The maladies are numerous and stretch back decades. A burgeoning Floridian population and mass tourism have led to water pollution and direct damage to corals, while agriculture has sent torrents of nutrients flowing on to the reef. Although regulations have curbed some of these local risks, climate change remains a big threat. In 2014 a spike in water temperatures led the Florida corals to bleach – when a reef expels its symbiotic algae under heat stress, whitens and potentially dies. It happened again in 2015, as a prolonged global bleaching event gripped the planet's corals. Australia's Great Barrier Reef was cooked to the point that it reportedly smelled of death.

The world is on course for a temperature increase that will comfortably wipe out most of the coral ecosystems, a scenario that would strip away a crucial nursery and smorgasbord for countless marine species, diminish fisheries and remove a vital coastal buffer to storms that will intensify as the planet warms. "The outlook for the Florida reef is pretty grim,"

Turn over ►

says Kim Cobb, a coral expert at Georgia Institute of Technology. “The threats are overwhelming. Just as the reef is climbing out of decades of systemic problems it is under increasing threat from climate change.”

The Coral Restoration Foundation has increased the replanting of corals as the situation has deteriorated, and the foundation’s underwater trees are becoming sought-after items for stressed reefs around the world. Partnerships have formed to provide trees to places such as Jamaica and Colombia. A chartered fishing operation in Mexico is in talks to do the same. This month, it was announced that 100 corals had been successfully planted on the Great Barrier Reef, the world’s largest living structure, using the coral tree frames.

The operation came about after tropical fish collector Ken Nedimyer noticed a rare type of coral called *Acropora cervicornis* growing on his live rock farm in 2003. A loophole in endangered species laws meant the coral was his to keep, so he began cutting it up to grow new coral from the fragments. Nedimyer hoped to regrow enough coral to start patching up Florida’s reef. Initially, the fragments were mounted on sunken concentric blocks that mimicked reefs. But the real breakthrough came in 2011 with the development of fabricated trees on which dozens of pieces of coral can be dangled from the branches. Backed by funding from the federal government and concerned donors, the foundation now has around 700 trees arranged in seven nurseries along the reef system as far as Ernest Hemingway’s old haunt of Key West.

Retrieved fragments of wild coral are sliced into finger-sized pieces, sorted into genomic types and strung from the fibreglass and PVC trees, which are anchored to the seabed and buoyed with a float. Alongside the staghorn and elkhorn corals, swaying gently on lines in the currents, are boulder-covering corals that are mounted on nearby platforms. This environment lets the corals grow three times faster than normal. Even so, it takes up to nine months for them to reach the size of a small football, at which point they are taken to be attached to an appropriate reef using a special putty.

Diversity is key, says Levy. While some other projects are experimenting with heat-resistant corals that can cope with occasionally warming waters, the foundation hopes a range of coral candidates will produce survivors. “We don’t want to put all our eggs in the heat tolerance basket,” she says. The aim is for the corals to take root, connect and spawn with each other. So far in 2018 more than 18 000 corals have been planted on to reefs, double that achieved annually five years ago. Around 8 in 10 planted corals survive at least a year.

The largest of the nurseries, located three miles off the Key Largo coast, has around 500 trees, which look a bit like giant, antiquated TV aerials. Branching staghorn and elkhorn coral dangle from the trees just 10 ft underwater. A constellation of marine life, such as trumpetfish, hogfish and triggerfish, flit between the trees. A nearby reef site is dotted with replanted corals bearing the tags of the Coral Restoration Foundation, although the overall coral coverage is scant. The bleak scene is completed by stands of lifeless pillar coral, ravaged by a bacterial disease that swept through the Keys last summer. A nearby brain coral is split by jagged white lines, further evidence of disease. The origins of many coral diseases are vague but at least one major outbreak has been linked to human faecal waste:

the Keys only gained a fully functioning sewer system during the past decade. Recent research has found that these diseases will worsen as the oceans warm.

The scale of the foundation's task is "monumental", says Cobb. But the restoration work could help provide a lifeline for reefs, she says. "Corals made it through the impact that killed the dinosaurs," she says. "I believe some corals will limp through, the question is how much will be left. There is important work that holds real promise. There won't be just one solution but a whole basket of them, some of which we can only guess at."

Another form of reef renovation has been taking place in the Bahamas, where scientists have been collecting material from mass spawning events – when corals release plumes of sperm and eggs into the water en masse – to help produce more numerous, stronger offspring for replanting. "We've had pretty good results," says Joseph Pollock, coral strategy director for the Caribbean division of the Nature Conservancy. He worked on a recent spawning event off Cape Eleuthera that has resulted in more than one million coral larvae. "This in itself is not a solution, it's part of a suite of tools that can be used. If you're not working on stressors from climate change down to coastal pollution, you may as well not be doing this work."

Back in Florida, the Coral Restoration Foundation is training a new batch of interns, who will help in educational outreach efforts with the public. At the foundation's offices, fibreglass trees are being scrubbed clean and plans made to survey a nursery site as the skies clear from a tropical storm. The work, much like the morphing climate conditions ranged against it, seems endless. "I'm not ready to give up," says Levy. "No one wants these reefs to die on their watch, so I would rather do something than sit back and watch everything die."

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There are no sources printed on this page