1.3 STRESSES UPON STRESSES – WESTERN INDIAN OCEAN UNDER CLIMATE CHANGE VIDEO DURATION– 10:45

The world's oceans are entering an alarming period of change and uncertainty.

Human activities have increased the atmospheric concentrations of greenhouse gases, and raised the Earth's average surface temperature by almost one degree centigrade since the start of the Industrial Revolution. There is a high level of confidence that global warming will place additional pressure on ocean ecosystems through increased sea temperatures, rising sea levels and expanding oxygen minimum zones. The greenhouse gas carbon dioxide is also dissolving into the ocean and acidifying it.

These impacts of anthropogenic change on our oceans are not things that are going to happen in the distant future.

Marine ecosystems are feeling these impacts now. Global fisheries catches are already increasingly dominated by warm-water species as a result of fish migrating towards the poles in response to rising ocean temperatures. Coral reefs – the most diverse of marine ecosystems – are already experiencing mass bleaching events that are becoming both more intense and more frequent.

Although climate change is a global problem, its manifestation in various regions on the planet is often unique and shaped by local factors. Unfortunately, while reducing CO_2 emissions is a straightforward way to mitigate climate change, there are no simple solutions for adapting to climate change.

Developing adaptation options first of all requires scientific understanding of climate change at a global scale. But it also requires regional expertise, detailed knowledge about the area in question, and local understanding of social and environmental contexts.

This lecture was written by Dr Katya Popova and Dr Andrew Yool – ocean and climate modellers at the National Oceanography Centre in the UK.

In this lecture we will look at the key climate stressors of marine ecosystems, and put these into the context of the Western Indian Ocean.

Stressor 1: Rising Ocean Temperature

Ocean Temperature is one of the key stressors of marine ecosystems as it affects the rates of all biological processes. Rising temperatures brought on by climate change will negatively impact a range of marine organisms living close to their thermal tolerances. It is already changing species' geographical distribution ranges, which is likely to accelerate in the near future.

This animation shows a projection of sea surface temperature. It is focused on the Western Indian Ocean; however similar temperature increases are expected in all ocean regions.

The globe on the left keeps showing the temperature during the first decade of the century. The globe on the right shows its future projection to the end of the century under a high emissions climate scenario called RCP8.5. You can see the ocean getting progressively warmer, heating up by between 3 to 4 degrees by the year 2100.

However, it is important to recognise, that against the background of the steady rise in the annual mean temperature, the ocean is also experiencing extreme but short-term events such as marine heatwaves. These can have devastating impacts on ecosystems, causing abrupt ecological changes, followed by socioeconomic consequences.

For the Western Indian Ocean, one of the key concerns is the high sensitivity of coral ecosystems to short-term increases in temperature. As a result, the many organisms that use coral reefs as habitats are also under increased pressure. If high temperatures persist for prolonged periods of time, the corals experience bleaching, which weakens and eventually kills the coral. Such coral bleaching events are becoming more pronounced as the oceans warm and marine heatwaves increase in frequency, duration and intensity. Some species important for fisheries react to the heatwaves by changing their behaviour and moving to deeper, cooler waters further offshore.

Stressor 2: Ocean acidification

Much of the carbon dioxide produced by human activities that enters the atmosphere dissolves in the ocean. There, it alters seawater chemistry causing a phenomenon known as "ocean acidification". While the full impacts of ocean acidification are still uncertain, many organisms are undoubtedly vulnerable, particularly those with calcium carbonate shells or skeletons. For example, decreased ocean pH may affect corals, resulting in a slow-down in the building of carbonate reef structures, and less diverse reef communities.

Stressor 3: Declining Ocean productivity

The majority of life in the oceans is ultimately dependent on the production of organic matter by phytoplankton in sunlit surface waters. The magnitude of this primary production is broadly limited by the amount of nutrients brought to the surface by ocean mixing.

In a warmer world, this mixing is expected to reduce in intensity, with the result that less nutrients will reach the surface and primary production will be reduced. Changes in the total amount of production can have profound impacts up the entire food chain and affect the success of fisheries. Most climate models project a global decline in primary production with a high confidence.

However, what this global decline will mean regionally is less certain.

Many local features play an important role, and in the Western Indian Ocean, one of the key uncertainties is the future changes in the monsoonal winds which drive its productive seasonal upwelling systems.

Stressor 4. Deoxygenation

Ocean deoxygenation is the ongoing general decline in ocean oxygen concentrations. It is driven primarily by lower oxygen solubility under higher surface temperatures. And it manifests as the expansion of oxygen minimum zones across the world's oceans.

The Oxygen minimum zones are regions in which oxygen saturation in seawater is at its lowest. These zones occur at depths of between 200 and 1,500 m, and are most pronounced along the western coasts of continents, mostly in the tropics. Expansion of these zones, as well as the general decline of oxygen concentrations, will result in a major decline in the health of marine ecosystems, and lead to serious impacts on the economies dependent on them.

Unlike the Arabian Sea and the Bay of Bengal, the Western Indian Ocean does not currently include any of the major oxygen minimum zones. However, it already has low oxygen concentrations in many coastal systems, in particular around vicinity of the coast of Somalia.

Stressor 5. Changing ocean circulation

Ocean currents redistribute heat, nutrients and living organisms around the globe. Surface currents can move tropical heat to temperate zones, and upwelling currents can bring nutrients to the surface and drive ocean primary production.

Many fish and other marine species rely on ocean currents to transport their eggs and larvae from spawning grounds to the locations they will inhabit as adults. Changes to the speed or direction of currents may affect recruitment to commercial and artisanal fisheries and contribute to shifting geographical ranges of species distributions.

Ocean currents also have a strong impact on the positioning and behaviour of upwelling systems. Coastal upwelling regions – such as the Somali, North Kenya Banks or Agulhas Bank upwelling systems in the Western Indian Ocean – supply cold, nutrient-rich waters to their local ecosystems, fuelling rich ecosystems and marine fisheries. Consequently, ocean currents have shaped the socio-economics of adjacent communities for centuries, and any shifts may profoundly impact societies, especially those where artisanal fisheries are important.

Stressor 6. Sea level rise

As temperatures around the world have risen, the volume of the ocean itself has also increased. The increase in volume is driven by the thermal expansion of seawater and the contribution of freshwater from increased melting of ice on land, such as glaciers and the ice sheets of Greenland and Antarctica. As a consequence, the global sea level has risen by around 20 cm since the late 1800s.

The most obvious effect of sea level rise is coastal inundation and flooding of low-lying areas. However, increasing sea level can also salinify coastal freshwater supplies, as well as challenge important seagrass and mangrove ecosystems.

As sea levels continue to rise, these ecosystems will increasingly be pushed inland or even lost where coastal infrastructure or human communities prevent this. Such corals and mangroves provide protection from tidal and storm surges, so their loss has the potential for significantly increased property damage or even risk to lives.

Small scale fisheries are dominant in the Western Indian ocean. They tend to operate at a family or community level, have low levels of capitalisation, and make an important contribution to food security and livelihoods. Because they are often dependent on coastal ecosystems such as coral reefs and mangroves, both as a source of food and protection, these small-scale fisheries communities are among the most vulnerable to the impact of climate change-mediated sea level rise.

It is important to recognise that these stressors are not acting in isolation. Because they are all occurring at the same time, their combined impact can be much more significant than their individual effects.

Furthermore, in parallel there are many other mounting pressures on the marine environment, including loss of biodiversity, habitat destruction and pollution, including by growing quantities of plastic waste. These and many other damaging impacts of human activities are all compounded by climate change impacts. Climate change weakens the ability of the ocean to provide critical ecosystem services such as food provision, carbon storage, and oxygen generation.

Only urgent global political action that aims to drastically reduce carbon emissions can ensure

that the health of the world's oceans is preserved not only for future generations but for the **communities** that rely on it – and its **natural** wildlife – **today**.

In this lecture you have learned about the key climatic stressors of the ocean ecosystems and their manifestations in the Western Indian Ocean: rising temperature, ocean acidification, declining primary production, deoxygenation, changing ocean currents and sea level rise. We discussed other anthropogenic pressures on the marine environment and the need for urgent political action to reduce carbon emissions.