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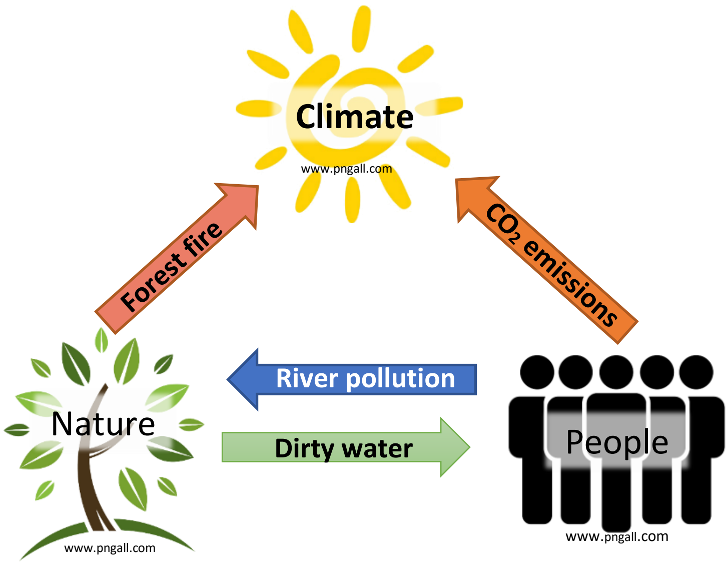
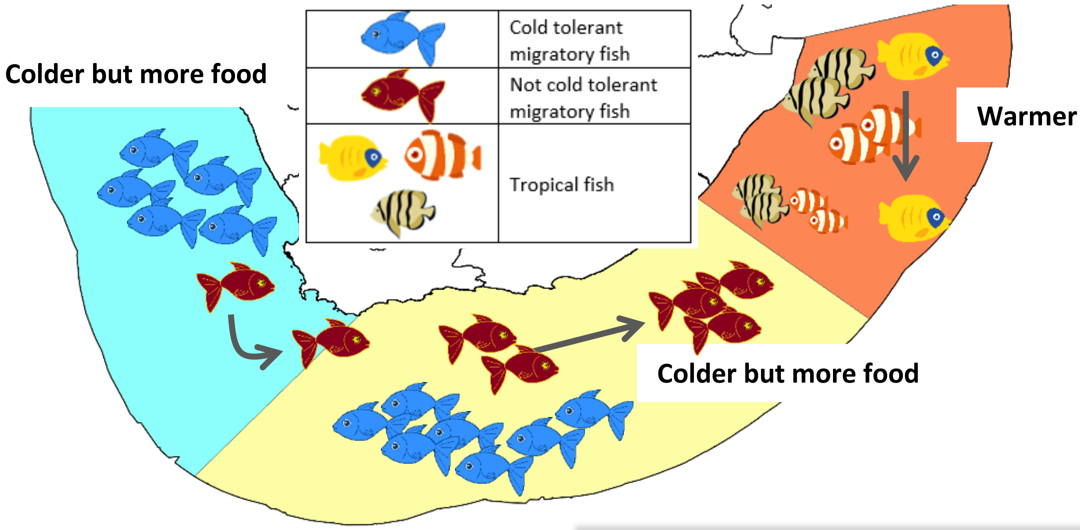
NRF National Research Foundation 20 1999-2019
SAEON South African Environmental Observation Network

Climate Change
From challenges to opportunities

Public Engagement





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Contents

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Foreword

Climate Change is a global environmental challenge confronting present and future generations. Global ambient temperatures are rising due to dramatically high greenhouse gas concentrations in the atmosphere. Those are largely resulting from socio-economic activities. Global atmospheric warming leads to changing weather patterns that have highly significant implications for ecosystems, society and the economy. Already climate zones in South Africa are shifting causing ecosystems and landscapes to change. The South African Environmental Observation Network (SAEON) is designed to generate information on why, how, and how much, ecosystems are changing over long periods. SAEON collates comprehensive long-term data from multiple ecosystems. In doing so, SAEON enables research on the unfolding impacts of Climate Change in South Africa and offers contributions to science communication and policies on Climate Change.

SAEON's long-standing education and outreach programme in environmental sciences enriches the scientific knowledge and critical thinking skills of beneficiaries. This booklet aims to increase public awareness of Climate Change by demystifying Climate Change using scientific evidence. We hope to inform South Africans of some of the Climate Change uncertainties, risks and opportunities they may be exposed to. Most importantly, readers will obtain insights on how they may mitigate and adapt to Climate Change-related challenges and opportunities.

1. Introduction:

By Caitlin Ransom (SAEON National Office)

Climate change is an important challenge facing all of us. To rise to this challenge, we need to understand climate change. We need to understand what caused climate change, and how it will affect us. Minimising the effects of climate change will help us adapt and cope with the changes.

Climate change refers to changes to the average weather patterns (temperature, rainfall, extreme weather events, amongst others) over a long period of time - typically decades or longer; although we may experience some of the changing patterns at shorter time scales (for example, noticing more severe floods over time). Global warming refers only to the increase in global surface temperatures (IPCC 2014b), and the warming of the lower atmosphere. Globally, the average surface temperature has increased (Figure 1), with temperature in South Africa increasing 1.5 times faster than the global average (DEA 2013).

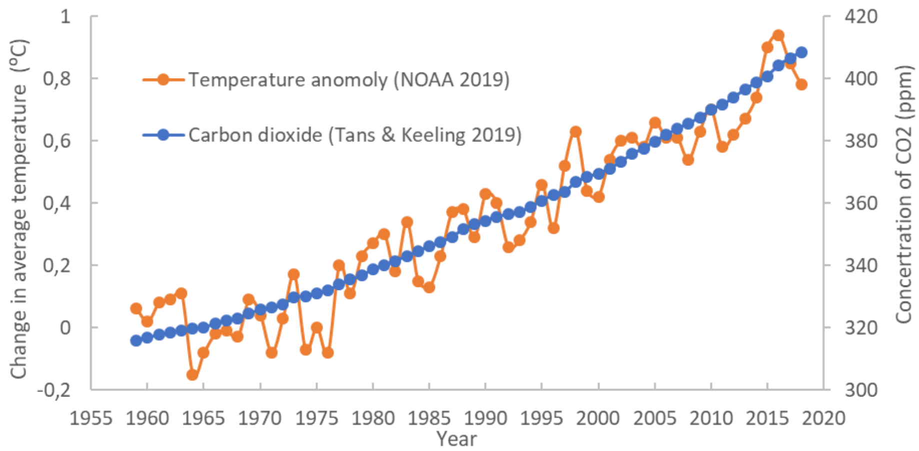
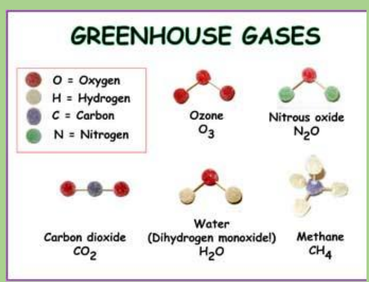


Figure 1.1: Global surface temperature anomalies and atmospheric concentrations of carbon dioxide (CO_2). Temperature anomalies show how the yearly temperature varied from the average between 1910 and 2000.

Human-driven increased greenhouse gases in the atmosphere (or the enhanced greenhouse effect), have helped drive this temperature increase (Figure 1.1). Greenhouse gases (such as Carbon Dioxide, Methane and Nitrous Oxide) let in light from the sun, but prevent some warmth from escaping into space (Figure 1.2). These gases act like a blanket around Earth, so that we experience warmer temperatures due to the trapped heat. These greenhouse gases are also what make Earth liveable, as without them Earth would be 33°C cooler than it is now (Scholes *et al.* 2015). Through the burning of fossil fuels (coal, oil and gas) and land-use change, people have released significant amounts of greenhouse gases into the atmosphere (IPCC 2014; Le Quéré *et al.* 2018), increasing the greenhouse effect and warming Earth. Effectively, human activities have enhanced the greenhouse effect.

In celebration of International Year of the Periodic Table. Here's the molecular structure of some key greenhouse gases.



Courtesy NASA/JPL-Caltech

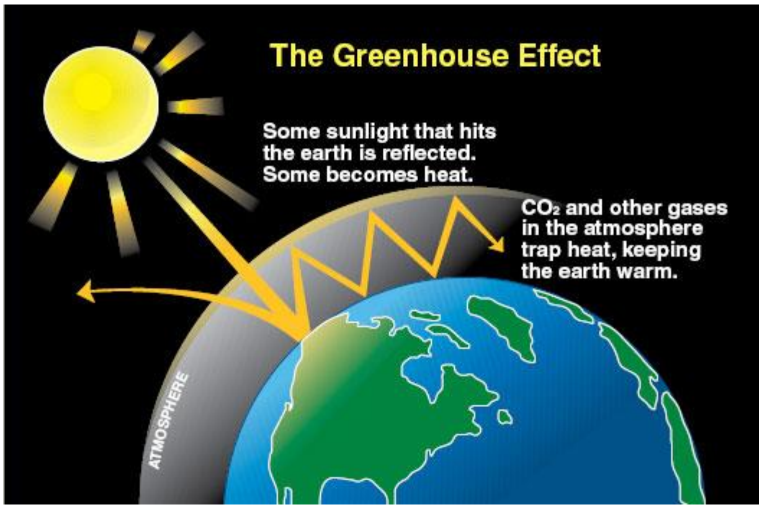


Figure 1.2: The greenhouse effect. *Image from https://blog.hotwhopper.com/2013_03_01_archive.html*

Like the rest of the world, South Africa has been and will be affected by climate change. Temperatures have increased faster than the global average, and the interior of the country (not by the coast) is expected to increase by as much as 5-8^{o}C by the end of the century (2100), if greenhouse gas emissions remain high (DEA 2013). The country is also likely to experience more intense storms, with floods and drought more likely (DEA 2013; Davis-Reddy and Vincent 2017). South Africa has been experiencing severe droughts in some areas in the last few years (although we have also seen severe droughts in the past), leading to water restrictions in many major cities, drops in dam levels and even borehole and natural springs drying up (DEA 2017). These droughts have severely impacted food and water security. Crop and livestock losses due to a lack of food and water have also increased food prices (DEA 2017). On the other hand, in April 2019, Kwa-Zulu Natal experienced damaging floods. Such extreme events are likely to become more common in the future, and we need to be prepared.

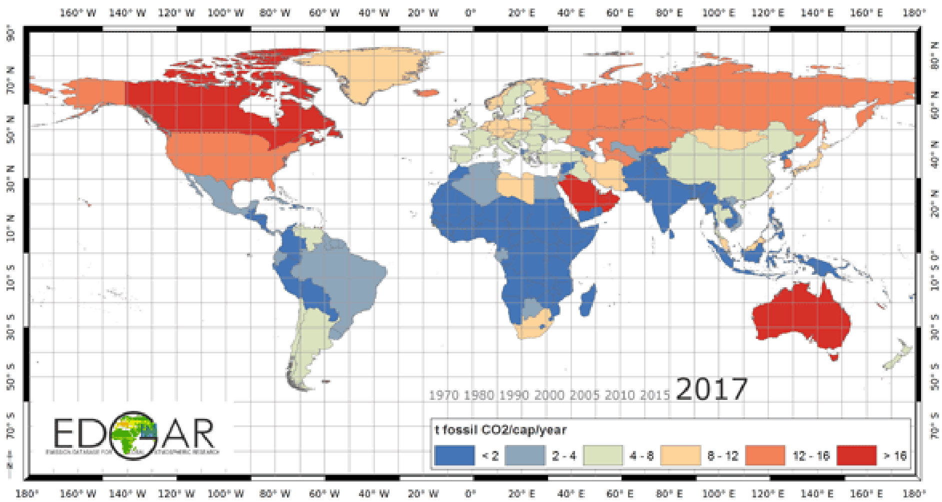


Figure 1.4: 2017 Carbon dioxide emissions per person per country (Muntean et al. 2018). South Africa appears represented by a peach colour, indicating that carbon dioxide emissions are relatively high. South Africa's emissions per person are 1.5 time the global average (Muntean et al. 2018).

Carbon dioxide is the primary greenhouse gas released by people (IPCC 2014). While carbon dioxide is not the strongest at trapping heat and warming up the atmosphere, the rapidly increasing amount of carbon dioxide and the fact that it stays in the atmosphere for thousands of years makes it one of the most important contributors to our changing climate. South Africa is the 14th largest emitter of carbon dioxide (Muntean *et al.* 2018). While we only contribute 1,26% to global carbon dioxide emissions, South Africa is still a significant producer of carbon dioxide per person (Figure 1.4). It is important to understand how much each of the different sectors contribute towards the country's overall carbon emissions (Figure 1.5). More than half of South Africa's carbon dioxide is emitted through the generation of electricity (Muntean *et al.* 2018), as we are still heavily reliant on coal-fired power stations. Coal is a fossil fuel and releases greenhouse gases when burnt. South Africa has, however, decreased its carbon dioxide emissions per person since 2014 (Muntean *et al.* 2018), and committed to reducing greenhouse gas emissions further by ratifying the Paris Agreement (DEA 2017).

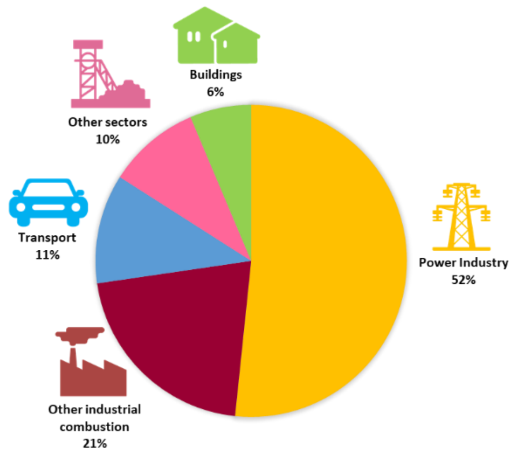


Figure 1.5: South Africa's 2017 carbon dioxide emissions per sector (Muntean et al. 2018). Power industry includes emissions from electricity generation. Other industrial combustion includes emissions from industrial manufacturing and making petrol and diesel. Transport includes emissions from car, buses, trains, ships and planes. Other sectors include emissions from industrial processes, agriculture and waste.

2. Busting some myths around climate change:

2.1. Scientists don't agree on climate change

The climate of Earth is definitely changing (IPCC 2014; IPCC 2018) and more than 97% of published papers in the field agree that humans are the cause of climate change (Cook *et al.* 2016).

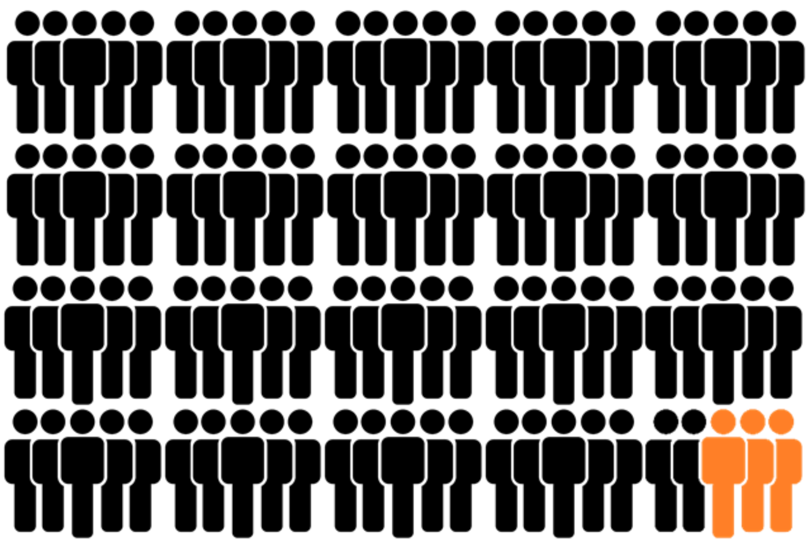


***Figure 2.1.1**: 97% of published papers agree that humans are causing climate change*
Image adapted from www.pngall.com

2.2. The climate has changed before. It's just a natural cycle

It is indeed well-established that climate has changed in the past, and that Earth has gone through cold (ice age) and warmer periods. Increases and decreases in greenhouse gases (mainly carbon dioxide) in the atmosphere were linked to changes in the climate, amongst other factors (Vitousek 1994). Scientists have determined how much carbon dioxide was in the atmosphere in the past by among others measuring air bubbles in the ice of Antarctica. Changes in atmospheric carbon dioxide over the past 420 000 years have been obtained from ice core data. During warm periods, carbon dioxide levels increased, while during the cold ice age periods, carbon dioxide levels were low (Vitousek 1994). While carbon dioxide levels have changed historically, they have remained between 180 ppm and 280 ppm (Figure 2.2.1). Today, carbon dioxide levels have rapidly increased well beyond the 'natural norm' (zero human interference), to above 400ppm, as a result of carbon intensive industrial development, pushing us into the unknown (IPCC 2014). Global temperatures are evidently rising faster than natural phenomena can explain (IPCC 2014), and there is global agreement on conclusive physical science theory that that explains how extraordinary high greenhouse gas concentrations in the atmosphere are the direct cause of global warming.

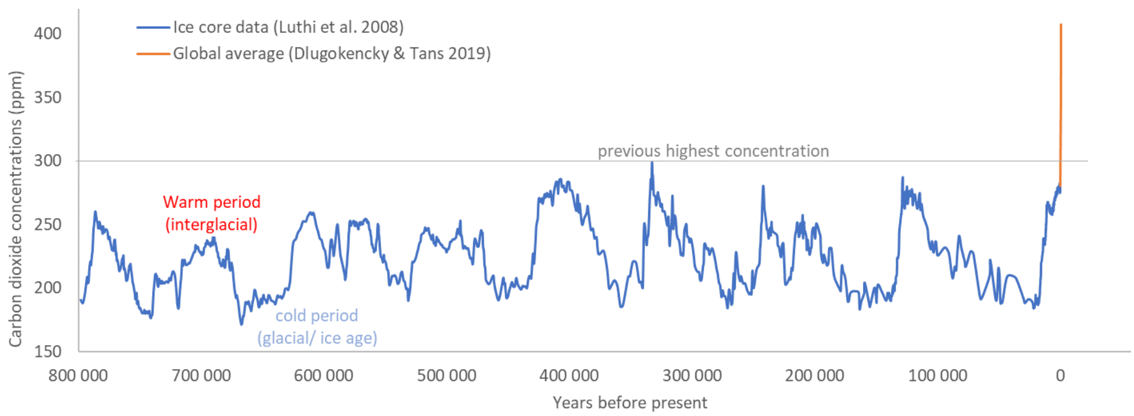


Figure 2.2.1 Atmospheric carbon dioxide concentrations based on ice core data for the past 80 000 years.

2.3. Animals and plants and adapt to the changes

Yes, it is widely observed how plants and animals are generally able to adapt to environmental changes. For example, instead of adapting to a warmer climate while staying in place, certain plants and animals may be also able to move to adapt to the changing climate. Species may migrate south wards or to a higher altitude (up a mountain) where conditions are cooler (Foden et al. 2008). However, scientists believe that many plants and animals will not be able to adapt (or evolve) quickly enough to their new climate (Quintero & Wiens 2013), this is because the environment is changing faster than the evolutionary process allows the species to adapt. Climate change is fast becoming a major cause of species extinction, and it is projected to severely impact biodiversity and ecosystem services in the future (Foden *et al.* 2008, IPBES 2019).

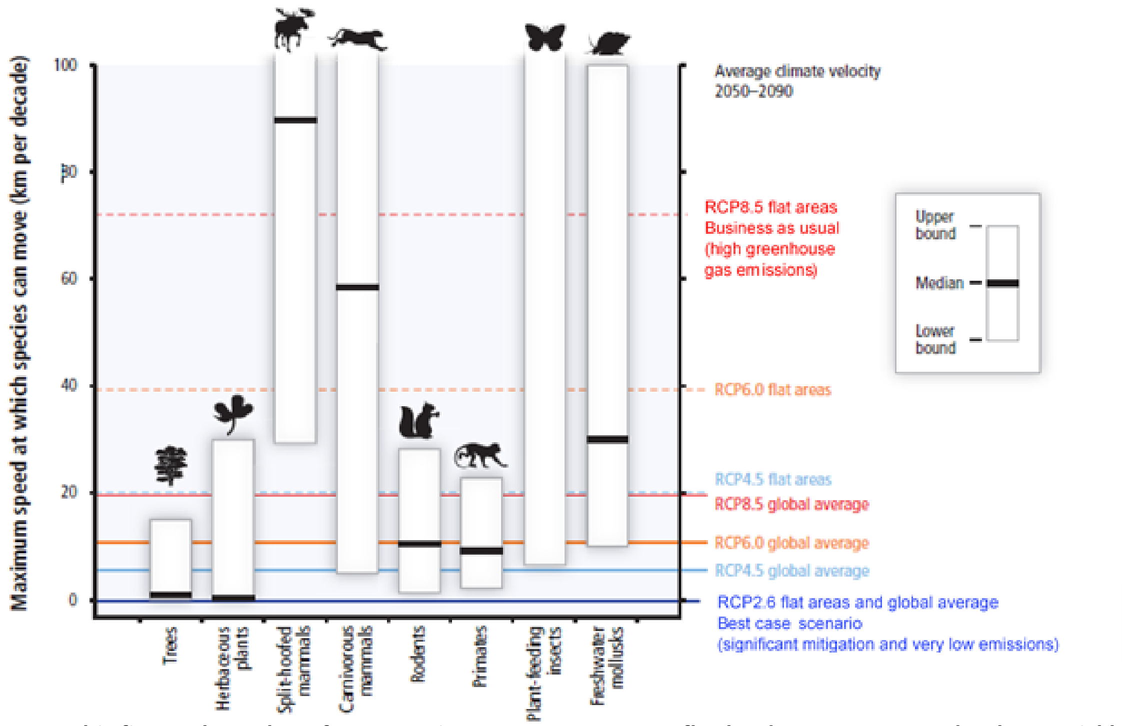


Figure 2.3.1: This figure shows how fast a species can move across a flat landscape, compared to how quickly temperatures are expected to change. The coloured horizontal lines represent the rate at which scientists think temperatures will change under different greenhouse gas emission scenarios. The red line (RCP8.5) represents a business as usual scenario with continued high greenhouse emissions. The orange (RCP6.0) and light blue (RCP4.5) lines represent scenarios of lower greenhouse gas emissions. The blue (RCP2.6) line represents the best case scenario, with a dramatic decrease in greenhouse gas emissions. Species with maximum speeds below each line are expected to be challenged in adapting to warming in the absence of human intervention (IPCC 2014b).

Some species are better able to move in response to a changing climate than others (Figure 2.3.1) but many plants, will not be able to move towards more favourable conditions very fast, because they cannot move by themselves. For plants to move they rely on their seeds being spread and growing big enough to produce its own seeds. This can be a very slow process as some trees can take 100's of years before they produce fruit and seeds. On the other hand split-hoofed animals (such as antelopes) move much faster than plants and other species to follow favourable temperatures. Some split-hoofed antelopes, such as the wildebeest of the Serengeti and Masai Mara, are famous for traveling huge distances search of water and seasonal lush nutritious grass to graze on. Highly mobile animals, such as larger bird species, have adapted to migrate according to the seasonal conditions and should thus be able to respond within limits to climate change.

It is important to consider how human impacts on the environment may increase the extinction risk of many species, including challenging their ability to move or shift in response to climate change. We have, of course, changed the landscape in many parts of South Africa, converting natural vegetation into settlements, fenced farms and roads, amongst other types of land use. In some of these areas, plants and animals cannot live or move through in their search for a new home. We have also introduced invasive species, which are already putting significant pressure on our indigenous species, challenging their ability to adapt to a changing climate (IPCC 2014b).

3. The climate, environment and people are all connected

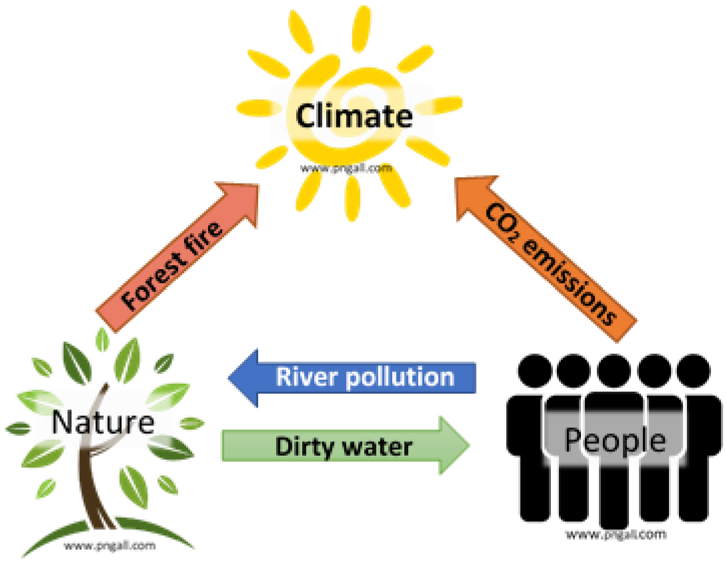


Figure 3.1: How the earth's systems interact with each other (adapted from Stone et al. 2013)

Table 3.1: Some examples of how drivers (the cause of an impact) can impact other parts of the earth's systems. For example, the rising carbon dioxide levels in the atmosphere have led to warmer temperature. The indirect impacts illustrate how this increase in temperature affects living things. Some plants may grow faster under the warmer conditions, while others may grow slower or even die out because the conditions are too hot. (adapted from Stone et al. 2013)

	Impacts	
Drivers	**Direct impacts**	**Indirect impacts**
Carbon dioxide (CO_2) emissions CO_2	Warming	Some crops and plants may grow faster and others may grow slower Shifts the timing of biological events (such as when a plant flowers)
	Carbon fertilisation of plants CO_2	All trees will grow faster Change in humidity
Pollution of rivers	Collapse of fisheries Affect drinking water	
Plague of crop pests	Less crops	

The environment, the climate and people are all interconnected. Using the figure (3.1) and table (3.1) below, consider how your actions can affect the climate and the environment. Also consider, and discuss how you may act to try and minimise your impacts.

4. Climate change and extreme weather events in South Africa

By Dr. Claire Davis-Reddy (SAEON uLwazi Node)

Research Background:

Extreme weather events that are likely to affect South Africa are floods, droughts, fires and large storms (see Box 1 for definitions). Of all natural disaster deaths, climate events cause as much as 67%. Based on data from the Centre for Research on the Epidemiology of Disasters' (CRED's) Emergency Events Database (EM-DAT), South Africa experienced 82 recorded weather-disasters (meteorological, hydrological, and climatological) over the last four decades (1980-2019). In 2014, extreme weather events cost the insurance industry over R1 billion in claims (Uys, 2014) and in 2016[1], the one single insurer reported more than R500 million in weather-related claims for that year.

The frequency, extent and severity of weather-related disasters have increased over the last several years (Field *et al.*, 2014; Seneviratne *et al.*, 2012) and insurers have observed a rising trend in economic losses. Climate change will increase the frequency and magnitude of extreme weather events (Seneviratne *et al.*, 2012). This means that in the exposure of South Africa's population to weather-related events, particularly floods, droughts, wildfires and storm surges is likely to increase into the 21st century.

This expected increase in events poses significant challenges for South Africa and as it could negatively impact infrastructure and transport, food security, water resources, health and tourism among others. Increasing population, poor land-use practices, and an increasing number of people living in risk adverse areas (e.g. informal settlements) in conjunction with an increase in extreme weather events are likely to aggravate the current levels of disaster risk.


[1] https://www.fanews.co.za/article/short-term-insurance/15/general/1217/insurers-face-a-toll-from-severe-weather-events/22045

Box 1: Terminology

- **Wildfires**: any uncontrolled and non-prescribed burning of plants in a natural setting
- **Storms**: tropical, extra-tropical and convective storm events
- **Floods**: riverine, flash and coastal flood events
- **Extreme temperature**: both cold waves and heat waves
- **Drought**: An extended period of unusually low precipitation that produces a shortage of water for people, animals and plants. Drought is different from most other hazards, in that it develops slowly, sometimes even over years, and affects large regions at a time.
- **Landslide**: moderate to rapid soil or rock movement including mudslides and debris flows

Data:

Information from the Emergency Events Database (EM-DAT) of the Office of Foreign Disaster Assistance/ Centre for Research on the Epidemiology of Disasters (OFDA/CRED) International Disaster Database (www.emdat.be) is used here (see Box 2). Data includes the type of disaster, the number of deaths, number of people left homeless, the number of people affected, and an estimate of the financial cost of the disaster.

Box 2: EM-DAT: The International Disaster Database (http://www.emdat.be)

EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from a range of sources, including UN agencies, nongovernmental organisations, insurance companies, research institutes and press agencies. Users can download data and create their own tables and figures by selecting from among the data sets. While this dataset has some limitations, it provides a good resource to provide a baseline estimate of the impact of weather-related disasters in South Africa. South Africa does, however, experience a broader diversity of small and everyday hazards than included in EM-DAT, which have resulted in significant economic losses. For example, the hail event on 28 November 2013 in Gauteng resulted in a loss to the insurance industry estimated at R 1.4 billion as a result of claims in the motor and property sectors.

Use the table and graphs below to answer the research questions. As you do so, try and connect this back to what you have learnt about climate change.

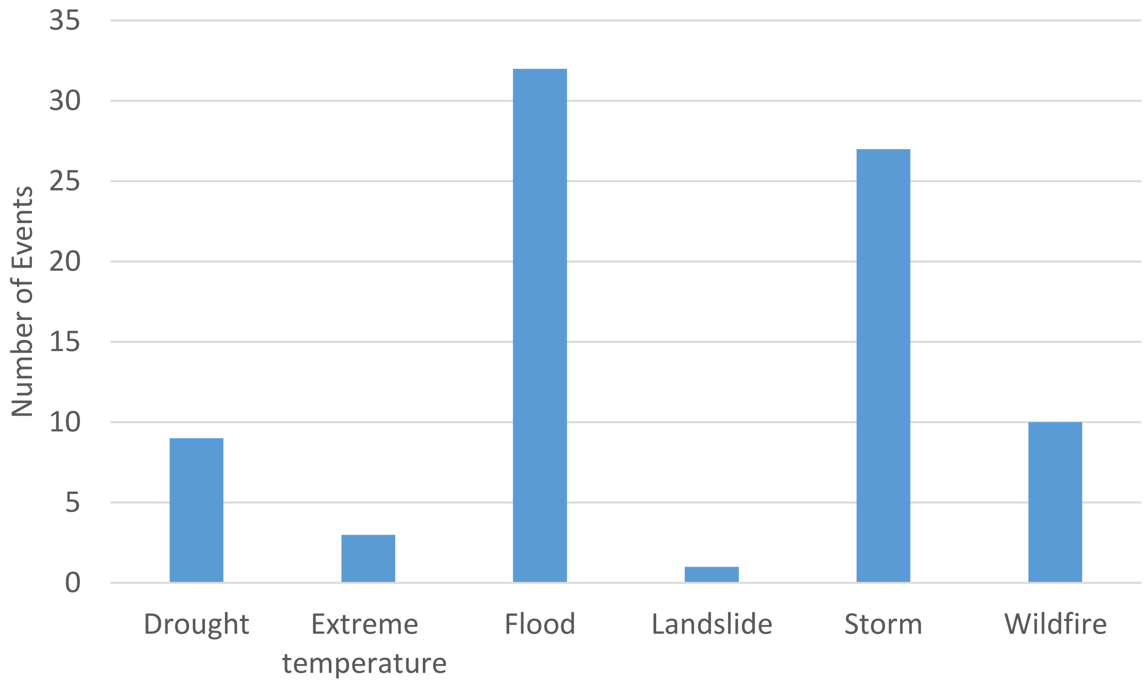


Figure 4.1: The number of weather disasters in South Africa between 1980 and 2014

- *What types of weather disasters in the area where you live should you be prepared for in future?*

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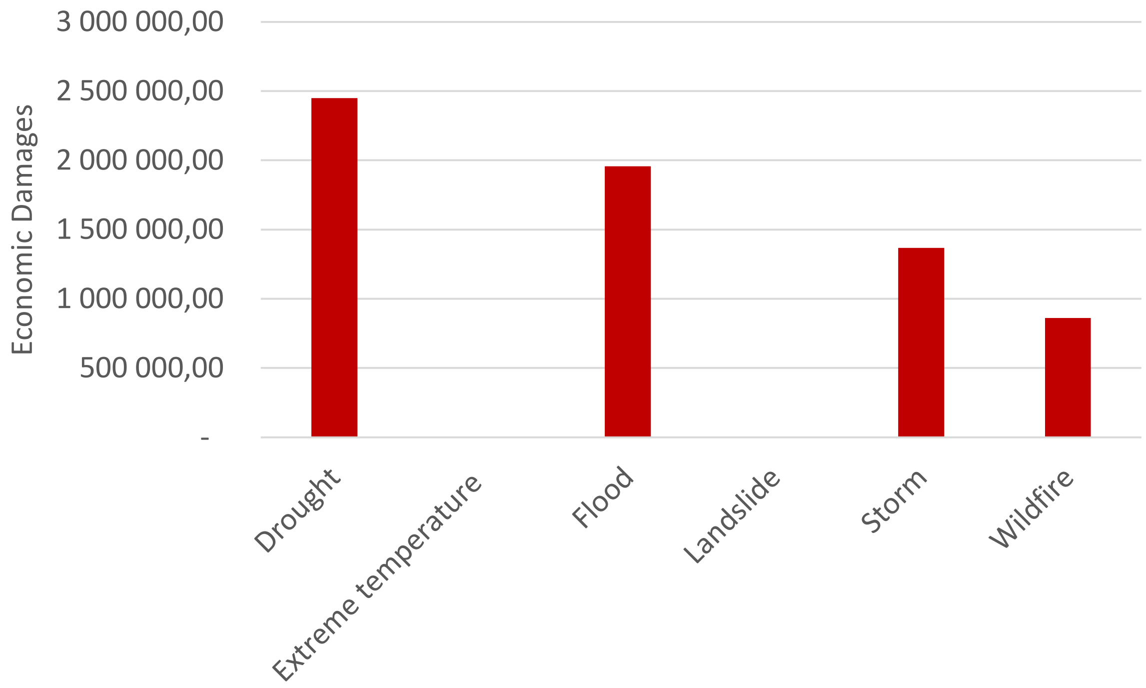

Figure 4.2: Summary of the cost of weather disasters in South Africa between 1980 and 2014

Table 4.1: The impact of the top 10 weather disasters in South Africa between 1980 and 2014

Disaster	Date	Total damage ('000 US$)
Drought	2017	1 200 000
Drought	1991	1 000 000
Flood	25-09-1987	765 305
Wildfire	30-08-2008	430 000
Wildfire	07-06-2017	420 000
Storm	20-03-1990	393 000
Storm	09-10-2017	320 000
Storm	07-06-2017	283 000
Drought	2015	250 000
Flood	01-01-2011	211 000

- *Can South Africans afford to deny climate change?*

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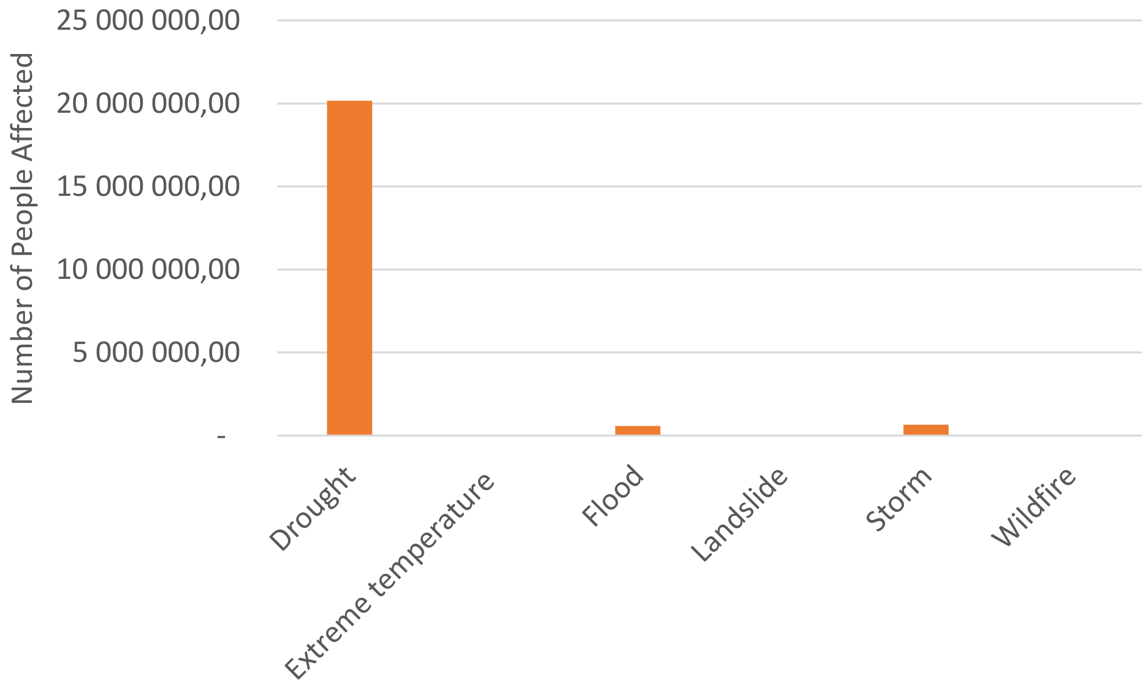

Figure 4.3: Summary of the number of people affected by weather disasters in South Africa between 1980 and 2014

- *Why do you suppose that drought has affected the most South Africans by far?*

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- *Consider what has been the impact of weather disasters in South Africa?*

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- *Have you, your family or community been affected by a weather event in the past? If yes, describe what happened and the effect it had on you, your family or community.*

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- *Imagine that you work in government in the National Disaster Management Centre (NDMC). What measures should be your priorities to reduce the impact from weather disasters?*

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- *Imagine that you are a scientist working in the field of climate change and disasters. What are the most important things to research next to help continue to answer these questions on the impact of a changing climate on weather disasters?*

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Source: Simon Bundy

5. Historic Rainfall Patterns in Southern Africa

By Tamryn Hamilton (SAEON, EFTEON) this work is based on Tamryn's MSc

Terminology

Semi-arid – dry environment (but not desert)

Arid specialist plants – plants which are well suited to survive dry environments.

Southern Africa is diverse landscape dominated by semi-arid environments along the interior and western regions. These regions are limited by water availability and are at risk of being heavily impacted by climate change. Myers *et al.* (2011) predicts that South Africa will become hotter and drier (Figure 1), with an expected increase in extreme rainfall events. To predict landscape responses to future climate change, we need to understand how the landscape responded to similar events in the past.

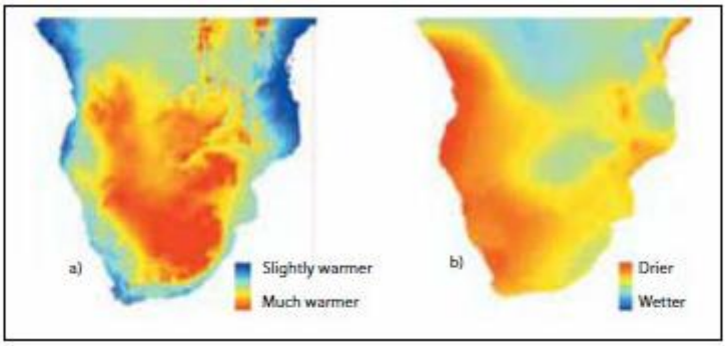


Figure 5.1: Predicted change in a) temperature and b) rainfall for southern Africa under high emissions scenario (Myers et al. 2011).

Using Isotopes to discover Past Climate

Dendrochronology is the science of tree ring counting and measurement to learn about the past climate, but in Southern Africa, our trees don't grow in quite the same way. Trees in semi-arid parts of Africa are arid specialists, but they still need some water to grow. When water resources are freely available, trees can grow continuous rings, meaning that one tree ring could represent more than one year - while during droughts, they may not grow any rings at all (Syampungani et al. 2010).

Plants take in carbon dioxide from the atmosphere and use this carbon to grow. The only problem is that when tiny openings (stomata) let the carbon dioxide in, the plant also loses water. Without water, the plant will wilt and eventually die. To solve this problem, plants close their stomata during dry conditions to prevent water loss. Amazingly plants are still able to grow by using carbon dioxide from within the leaf under these dry conditions. Using this process, and understanding how Baobab trees use water, we can estimate past rainfall.

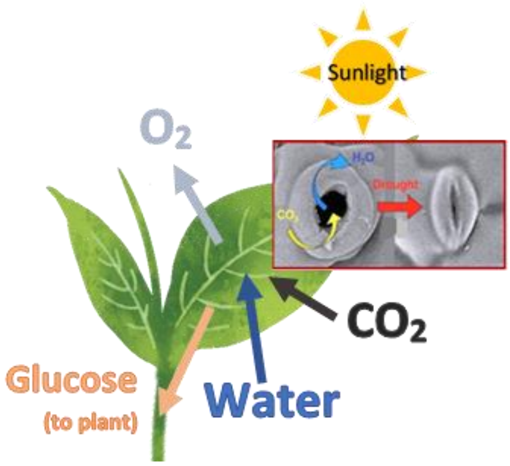
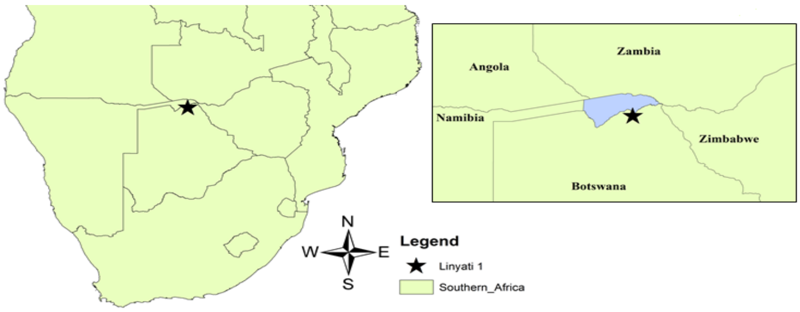


Figure 5.2: Photosynthesis at leaf level. Under water stressed conditions (such as droughts) many plants close their stomata to save water.

We used a tree core collected from a Baobab tree in Namibia to measure Carbon isotope levels and calculate past rainfall. The centre of the tree, where the rainfall record begins, dates back to 1375. The analysis of the Baobab core shows that the rainfall within Namibia varied in the past. As expected, there were periods in history where there was much more water available in the landscape, as well as periods when plants were very water stressed.



Photograph by Stephan Woodborne

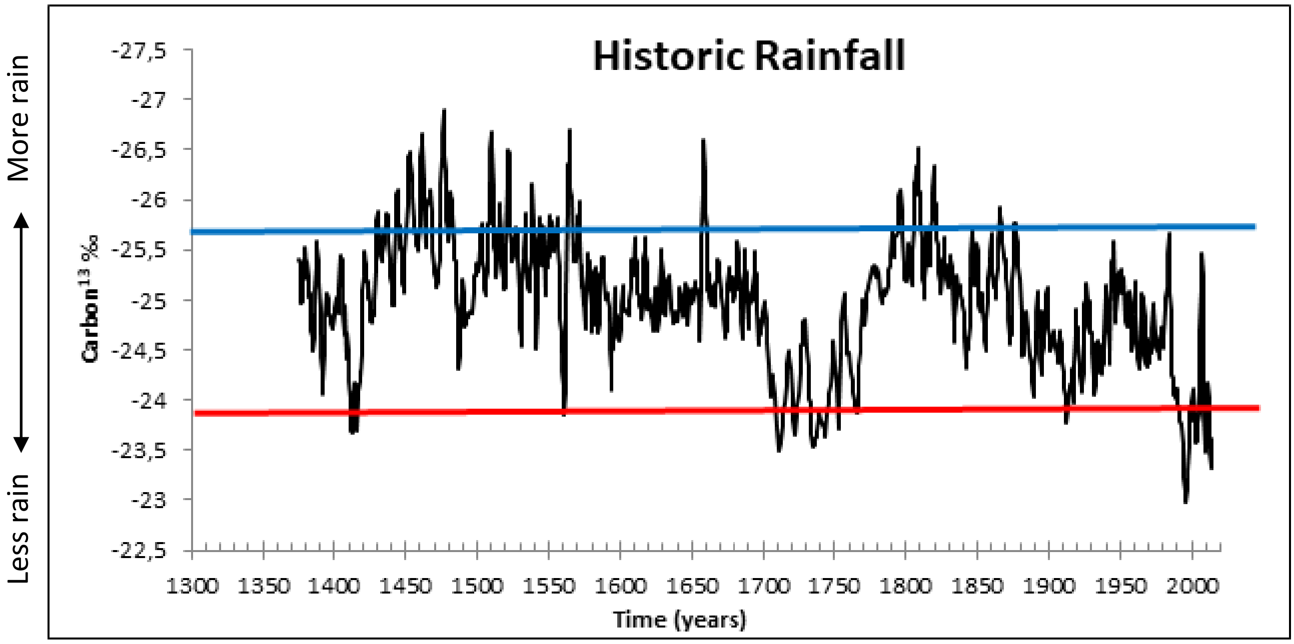


Figure 5.3 Historic rainfall record for Namibia from the Baobab tree. Extreme rainfall years were identified above the BLUE threshold line for extreme wet years and below the RED threshold line for extreme dry years.

How would you describe the recent (from 1970 onwards) rainfall in Namibia (Figure 5.3)?

____

Below is rainfall data for Cathedral Peak in the Drakensberg. Unlike the Namibian rainfall estimates from the Baobab tree (above), the amount of rain this area receives has actually been measured since 1949. Understanding what is happening at different locations can help scientist understand whether the increase in dry conditions is just occurring in the area of Namibia near the tree or if this pattern is seen across southern Africa.

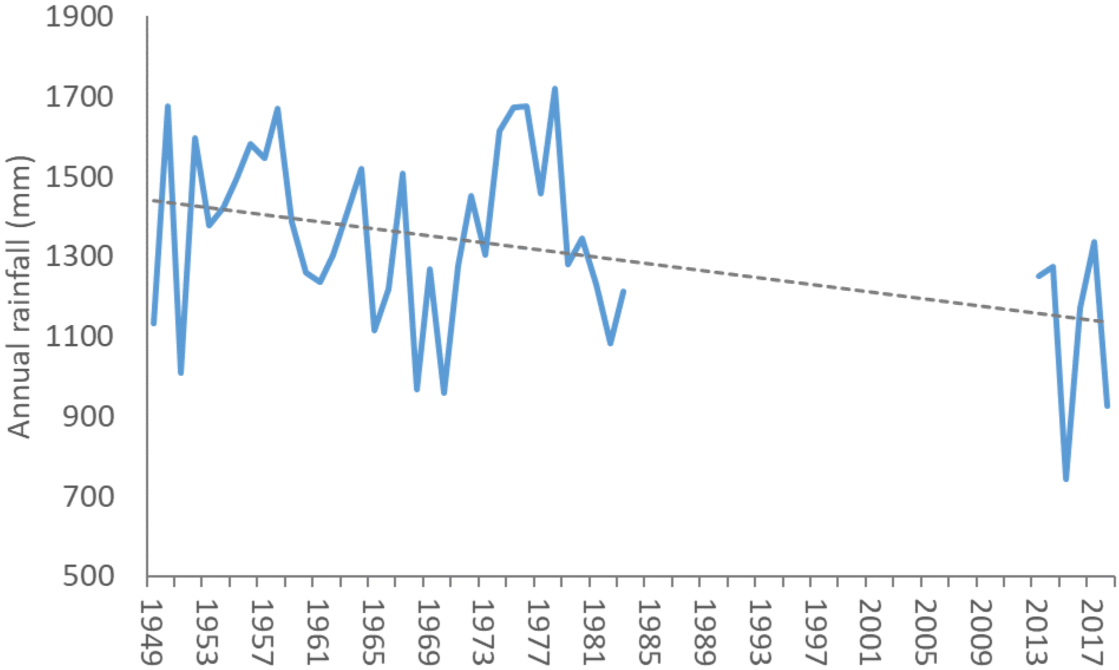


Figure 5.4 Long term rainfall record for Cathedral Peak in the Northern Drakensberg of Kwa-Zulu Natal between 1945 and 2018. There is 20 years of missing data between 1983 and 2013. The grey dotted line represents a linear trendline.

- *How would you describe the recent (from 1970 onwards) rainfall in Cathedral Peak (Figure 5.4)?*

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Both rainfall records, the historical data from Namibia and the more recent long term rainfall data from Cathedral Peak, show that southern Africa has gotten drier in over the last 50 years. Rainfall between years is variable (the graph is wiggly); with some wet years but overall both places have recently experienced less rain than the long term average. This is in line with how scientists predict rainfall will change in the future across southern Africa (Myers et al. 2011). These drier conditions will not only affect the amount of drinking water available, but also water quality, food security and even our health. The Cape Town and Beaufort West day zero scenarios (of taps running dry) may become more common across southern Africa in the future. We therefore need to manage our water carefully and save water to ensure we have enough water and food in the future. Can you link this to your own experiences?

6. Climate change is like forgetting to water your veggie patch

By Dr. Jasper Slingsby (SAEON Fynbos Node)

Climate change projections for the Western Cape of South Africa are for hotter and drier conditions (see Figure 5.1) (Myers *et al.* 2011; Altwegg *et al.* 2014; Davis-Reddy and Vincent 2017). This is bad news for plants in the region, which already have to survive the long, hot, dry summers. This exposure is not uniform though, and varies depending on growth form or plant age. For example, deep-rooted shrubs may access water throughout the year, while shallow-rooted herbs or grasses are only rooted in the surface soils, which dry out in summer. Even shrubs may be vulnerable when they are little seedlings, and haven't yet grown deep roots

A major feature of the Fynbos Biome, the dominant vegetation of the Western Cape, is that it is naturally fire-prone, typically burning and killing most adult plants every 10 to 30 years. In fact, a number of the species are considered to be fire-dependent, because they need fire to complete their life cycle by triggering key events like flowering, seed release or germination. This means that most species can only recruit new seedlings after a fire (what we term 'episodic recruitment'), rather than dropping seeds and recruiting new seedlings every year, as is common in most ecosystems throughout the world.

This episodic recruitment linked to fire is akin to putting all your eggs in one basket. In most ecosystems, seedling survival will vary from year to year, depending on the weather. In Fynbos, however, there is usually only one chance to 'get it right', and if the weather is not favourable, many seedlings and often entire localised populations of species may not survive.

Scientists at the SAEON Fynbos Node set out to test whether they could detect this effect using long-term data from the Cape of Good Hope Section of Table Mountain National Park over the years 1966 to 2008. Their approach was to look at changes in plant species numbers, and to relate these to changes in extreme summer weather that is likely to kill plants. Based on climate change projections (Altwegg *et al.* 2014) they predicted that periods of extreme summer weather have been becoming more intense, and that communities that burn and then experience particularly extreme summer weather in the first year after fire will have lost more species.

Methods

Repeat surveys of plant communities

A set of 54 plots, each 50 m^2 in size, were marked out in 1966, and all plants identified to species in 1966, 1996, 2010 and 2008. For each year, the number of species in each plot was counted.

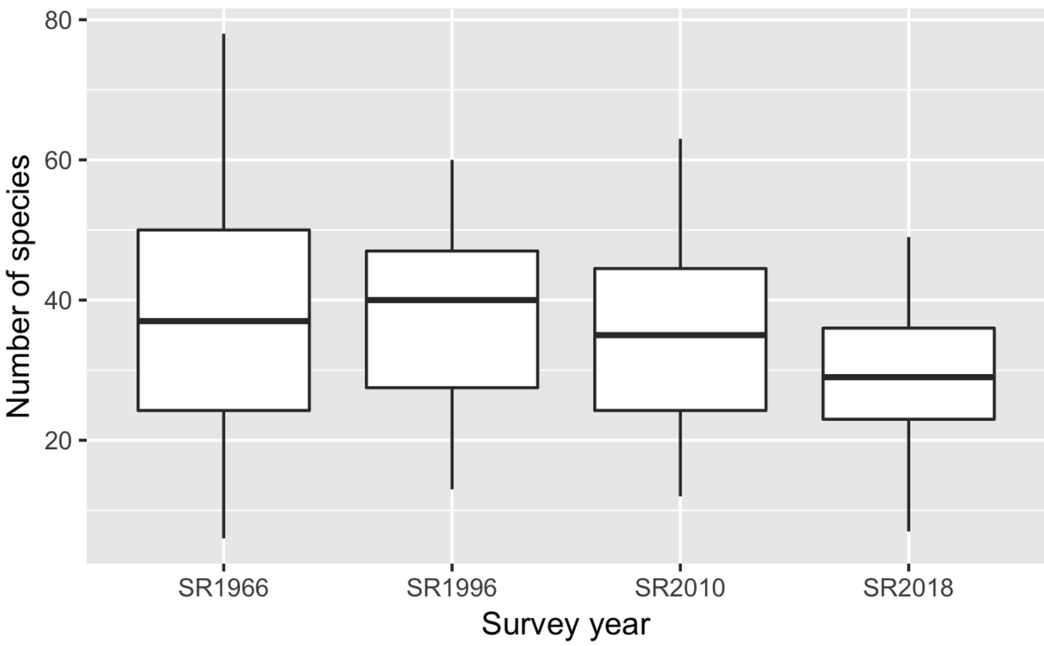


Figure 6.1 This is a boxplot of the species richness of all plots for each year. Each year is represented by a "box and whisker", showing the median (the mid-point of the data; indicated by the horizontal black stripe), interquartile range (the middle 50% of scores; shown by the white box) and whiskers (the upper and lower 25% of values; shown by the vertical black stripes).

- *Which year has the lowest number of species per site?*

____

- *Are there fewer species found in 2018 than in 1966?*

____

Weather data

To track changes in extreme summer weather, they used weather station records to look at changes in the duration of periods of consecutive hot and dry days. These are periods where no rain occurred, and the maximum temperatures stayed in the top 5% of hottest days on record for consecutive days. Think of these periods as similar to forgetting to water your veggie patch. If the weather is hot and dry for a few days, and you don't give your plants water, they are likely to wilt and die. The Western Cape has experienced more hot and dry days in a row recently than in 1963 (see graph below). This means that plants have to cope with not being watered for longer periods of time.

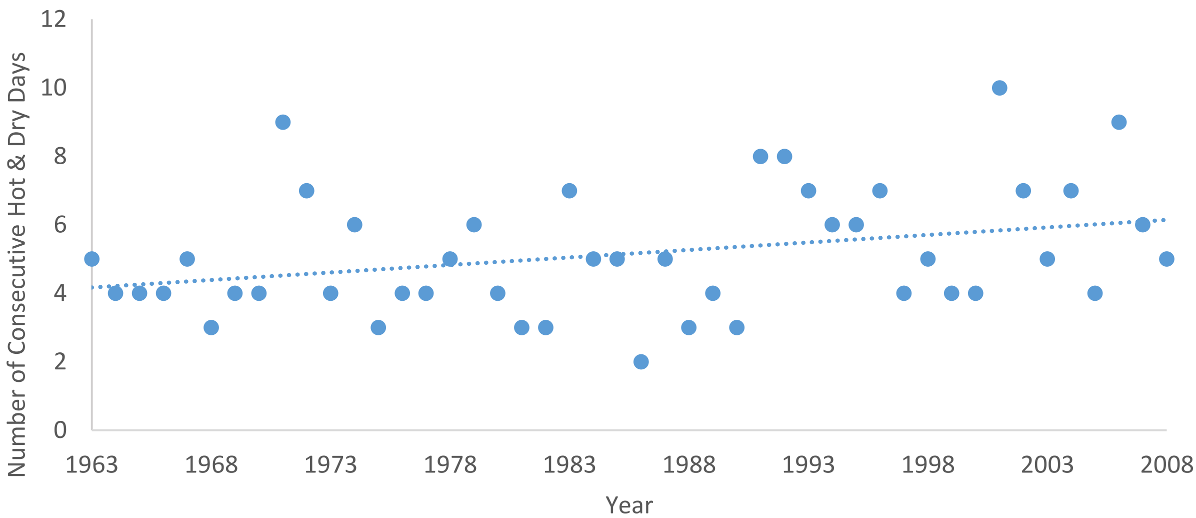


Figure 6.1: The number of consecutive hot and dry days, as measured at Cape Point, increased between 1963 and 2008.

Proviso: The exercise developed here is aimed at describing the pattern, but has not included testing them statistically. See Slingsby *et. al*. (2017) for further information.

7. Is climate change a threat to the world's 2nd largest antelope?

By Tamanna Patel (SAEON Grasslands-Forests-Wetlands Node)

Figure 7.1 Eland herd in Cathedral Peak, Drakensberg (Photo by Tamanna Patel)

Research background

Small changes in the world's temperature and humidity can have devastating effects on biodiversity, by modifying and threatening ecosystems (see, for example, IPBES 2019). Vegetation is heavily controlled by fire and other disturbances, such as grazing regimes. As global warming increases, these fires are likely to become more intense and extensive, and may result in significant ecosystem changes that would affect biodiversity through species loss or changes in species composition. In southern Africa, changes in the fire,grazing regimes and carbon fertilisation during the past century are thought to have increased woody plant density over large parts of the region. Over the next century, South Africa is expected to experience warmer and drier conditions due to climate change (Figure 5.1; Myers *et al.* 2011). This will not only affect the disturbance regimes (fire and grazing) but also the abundance and distribution of African herbivores. Changes to rainfall will alter the quality and quantity of forage and will therefore influence where and how many herbivores there are.

There are a number of antelope species found in the Drakensberg, and global change (climate change, land-use change and human impacts) is likely affecting their populations, although the extent to which these populations are negatively affected is largely unknown. Due to the difficulty of working in a mountainous landscape, limited research has been done on these species. Common Eland (*Taurotragus oryx)* is the largest and one of the most abundant antelope species in the Drakensberg. Eland feed on a wide range of grasses, forbs and browse, and use a wide range of vegetation types. The loss or alteration of terrestrial habitats by climate change is expected to impact the population by reducing population numbers and affecting their range and distribution. We therefore need to be able to assess whether individual populations are increasing, decreasing or remaining stable in order to derive the long-term projected trends of a population that will inform its conservation management.

Scientific question*:* Is the eland population in the Drakensberg increasing, decreasing or remaining stable, and could this be owing to global change? In your discussion, consider what other factors might contribute to these changes?

Data collection: Data was collected each year by Ezemvelo KZN Wildlife through game patrols and aerial surveys. Through this, a mammal database was created. It consists of long-term population data. It is important to assess a population's status using long-term data so that trends can be identified.

Graph

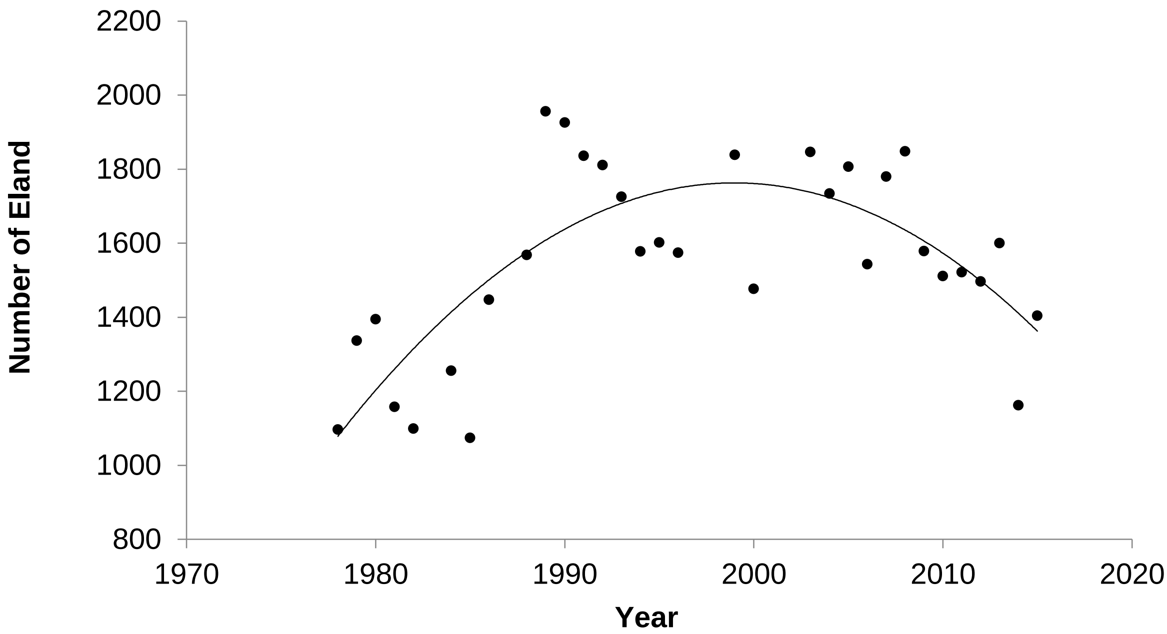


Figure 7.2: Changes in the Drakensberg's Eland population between 1980 and 2015

The Eland population increases steadily from 1980 to 2000, but it is clear that recently (since 2000) the Eland population has decreased. Researchers are now trying to understand why the population has decreased. Is climate change altering the vegetation (the Eland's food) and thus affecting Eland populations indirectly? What are the wider implications for conservation and agriculture in South Africa?

8. Rising Sea Levels

By Kogie Govender (SAEON National Office)

Global mean sea levels have been rising for centuries, but for a range of different reasons. Present sea level rise can be attributed to several factors, the first being as a result of the oceans warming, which results in the water expanding – called 'thermal expansion'. The second contributor to sea level rise is that the polar and glacier ice-caps in Greenland and Antarctica are melting, causing the water to enter the ocean, and thereby increase the volume of water. Finally, the melting of land based ice is also causing sea level change. The figure below graphically illustrates that the global sea level rise has been observed at an average rate of 3.2 millimetres per year from 1993 to currently.

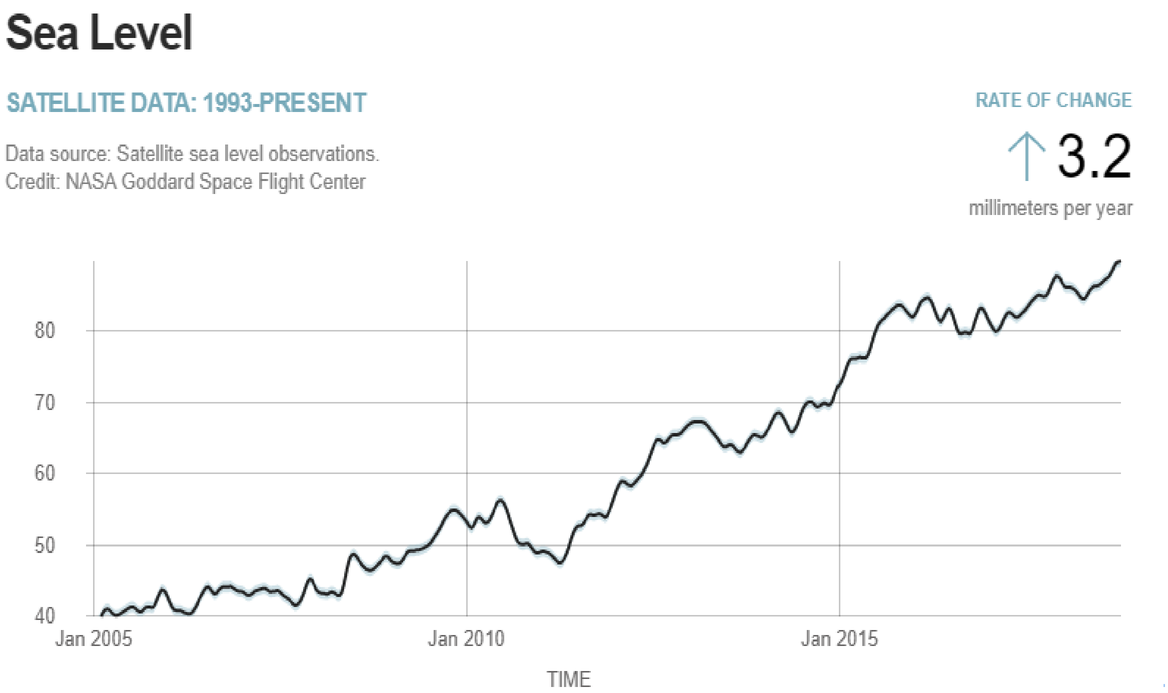


Figure 8.1: Rise in sea level since 2005

A glacier is a large mass of ice, formed when snow collects quicker than it melts. The melting of glaciers is measured using satellite and airborne instruments to see how the characteristics in the glacier are changing as it melts. Scientists from NASA have found a hole in the Thwaites Glacier in West of Antarctica in a study published in January 2019. The hole is so huge that the glacier would have lost an amount of 14 billion tons of ice in the last three years. The Thwaites Glacier melting rate currently accounts for 4% of the global sea level rise. The photo below reveals the huge cavity in Thwaites Glacier (Rasmussen 2019).

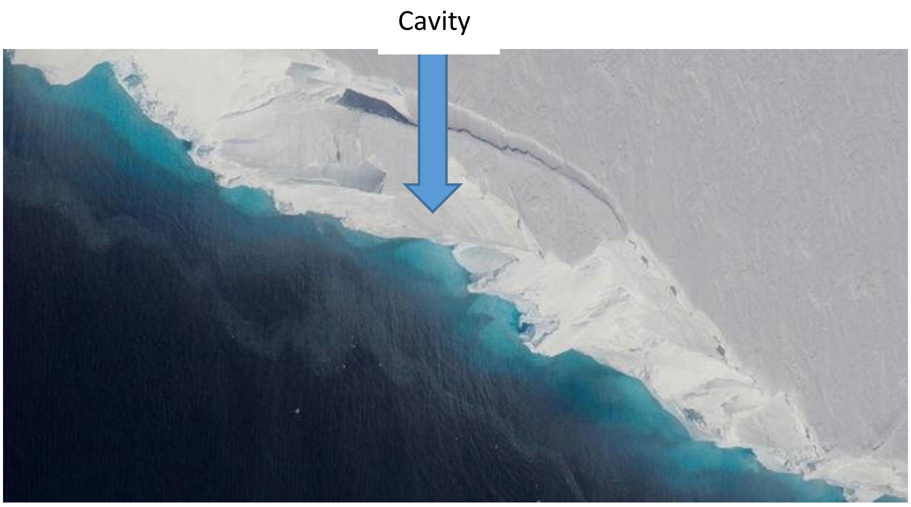


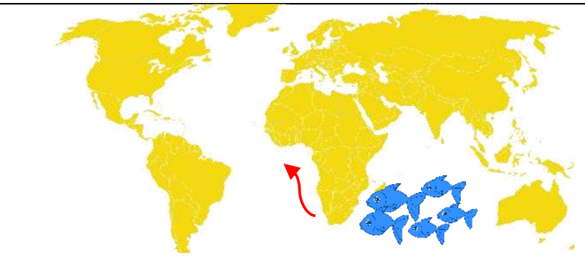
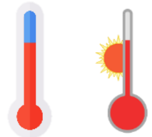
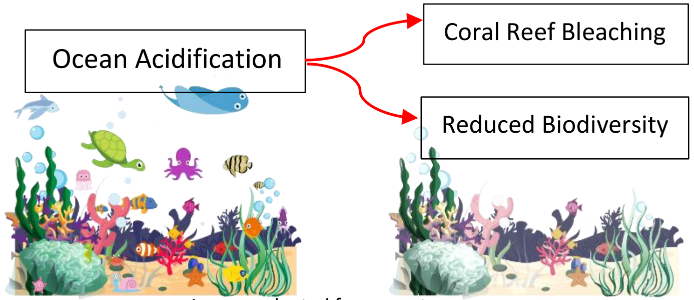
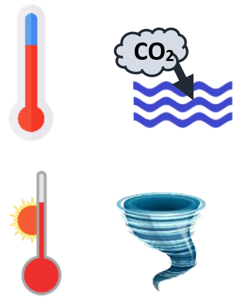
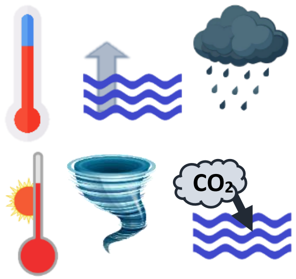
Figure 8.2: Thwaites Glacier. Credit: NASA/OIB/Jeremy Harbeck (climate.nasa.gov/news/2838)

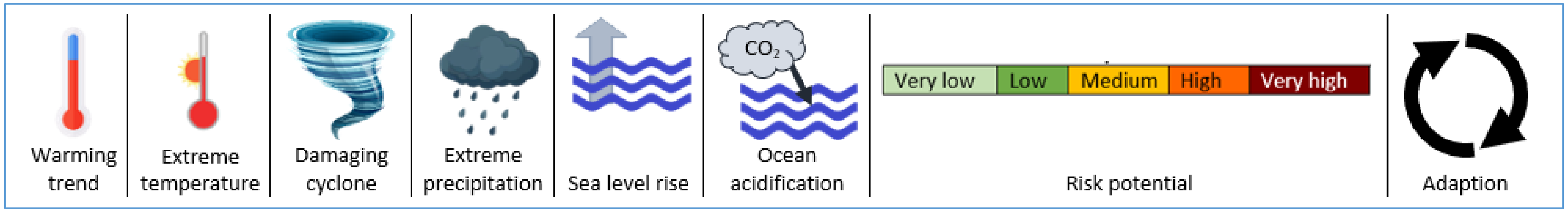
The photo of the Muir Glacier in Alaska shown below illustrates that the land-based glacier retreated and thinned from 1941 to 2004. Data from the National and Snow Ice Centre indicate that the front glacier moved back by approximately 11,2km, and reduced by approximately 8m.

Figure 8.3: Comparing the glacier loss in the Muir Glacier in Alaska between 1941 and 2004
Photo credits: Photographed by William O. Field on Aug. 13, 1941 (left) and by Bruce F. Molnia on Aug. 31, 2004 (right). From the Glacier Photograph Collection. Boulder, Colorado USA: National Snow and Ice Data Center/World Data Center for Glaciology

South Africa's sub-Antarctic island, Marion Island, found in the Southern Ocean and is approximately 1920km southeast of Cape Town. Historical data is indicating that parts of Marion Island that used to be covered with snow throughout the year a few decades ago is not covered anymore (Zietsman 2011).

Rising sea levels have an impact on people and biodiversity. In the next table (adapted from IPCC 2014), we look at the risk associated with sea level rise, and how we can adapt to these changes.

Key Risks	Adaptation issues and prospects	Climatic drivers	Time-frames	Risk and potential for adaptation
 Movement of fish and invertebrate's species causing decreases in fisheries catch.	• Fish and invertebrates change their movement to areas when the temperature is suitable for them, and they are most unlikely to adapt. • Fishing industries are having to relocate, and this already has an impact on coastal people and their livelihoods.		Present	
			Near term (2030–2040)	
			Long term (2080 – 2100)	
 Images adapted from: pngtree.com	• A decrease in the expansion of saleable shell fish and calcifiers • Stress from fishing and tourism should be restricted		Present	
			Near term (2030–2040)	
			Long term (2080 – 2100)	
Sea level rise  Images credit: pngtree.com	• Coastal flooding can lead to erosion that is more prominent in sandy beaches and loss of intertidal habitats in some instances (Fernandino *et al*. 2018).		Present	
			Near term (2030–2040)	
			Long term (2080 – 2100)	



9. Climate change and fish

By Dr. Nikki James and Kerry-Ann van der Walt (SAIAB)

Research background

Climate change that is linked to the build up of greenhouse gases and aerosols in the atmosphere has led to increases in the earth's surface temperatures over the last 50 years. As a result, the water in the world's rivers, estuaries and the sea is also heating up (Rouault *et al.* 2009).

Fish are more susceptible to changes in temperature than many land-based animals. Because their body temperature is the same as the water around them, fish cannot maintain a constant body temperature, and cannot survive in temperatures too far out of their preferred range. Consequently, of all of the physical stressors associated with climate change, temperature is considered to have the most impact on coastal fishes (fishes found in coastal areas). As water temperatures increase, the metabolism of the fish increases. They need more and more oxygen to fuel this high metabolism, and if not enough food is available, then all the fishes' energy goes into fuelling their high metabolism, with no energy left for growth and reproduction. As a consequence, worldwide, species are moving out of their normal ranges to find more favourable habitats elsewhere, as waters get warmer.

Scientists Nikki and Kerry-Ann wanted to know what the maximum water temperatures are that different species of fish found in Eastern Cape rock pools can tolerate before becoming stressed. They did this in order to understand how these fish might respond to warming waters. They chose to look at the juveniles of three fish species which are frequently found in rock pools - barred flagtail, strepie and blacktail. The barred flagtail is common in the rock pools of KwaZulu-Natal, and prefers warmer waters, whereas strepie and blacktail are more common in Cape rock pools, and prefer cooler waters. Nikki and Kerry-Ann predicted that the species which likes warm water (barred flagtail) would be able to tolerate higher temperatures than the two cooler water species.

Scientific data:

Use the table and figure below to answer the scientific question

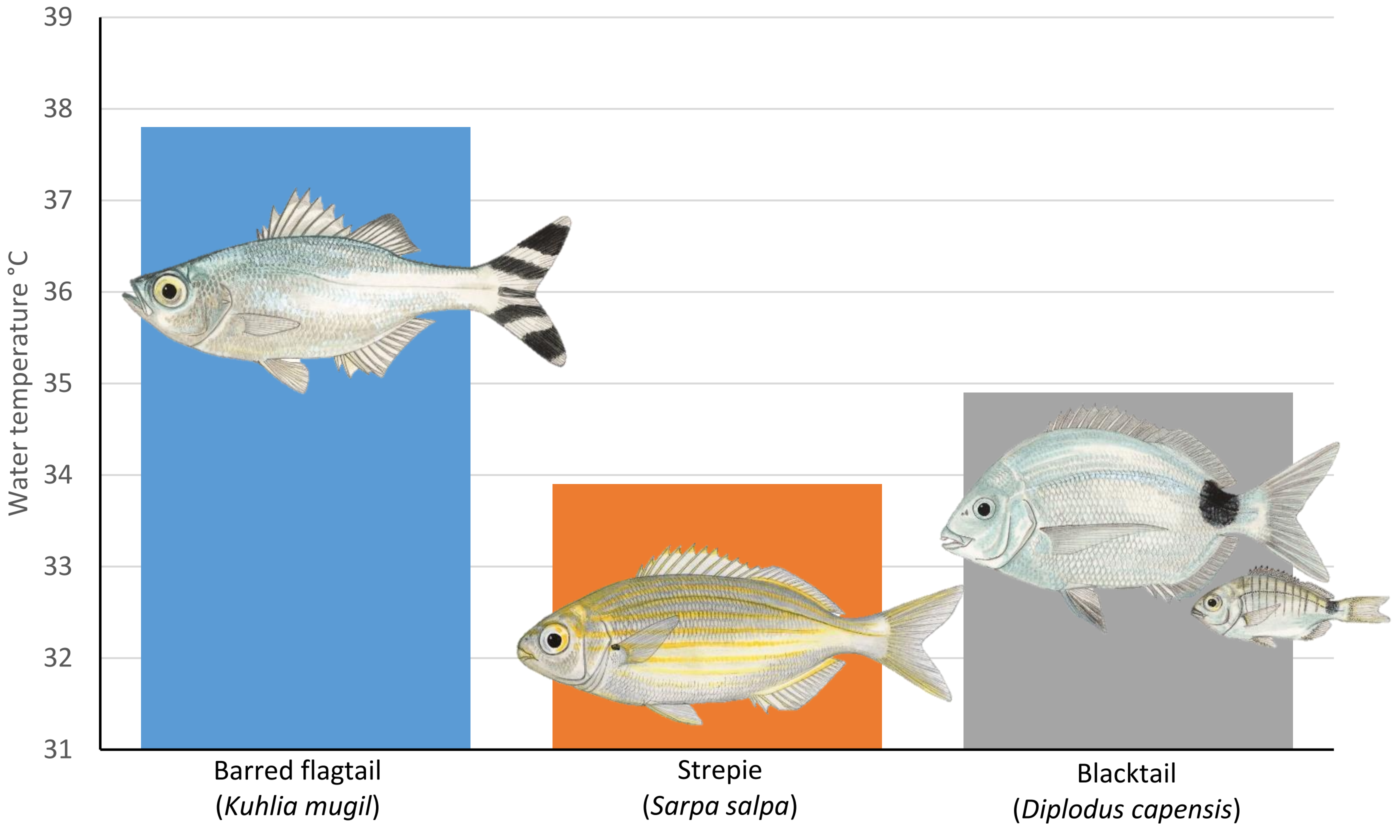


Figure 9.1: Maximum temperature tolerated by three rock pool fish species. Image Elaine Heemstra (SAIAB)

Scientific question: Do you agree with the scientists' prediction and why (not)?

10. How climate change will affect the fish along the South African Coastline?

By Caitlin Ransom (SAEON National Office)

As global temperatures increase, so do ocean temperatures (Figure 10.1). But something interesting is happening along the west and southern coast of South Africa, where it appears that the water is becoming colder (the blue areas). This decrease in water temperature is due to the intensification of upwelling. Upwelling is when winds push away the warm surface water (Figure 10.2). This leaves a gap on the surface, which is filled by the deeper, cool, nutrient rich water. These nutrients “fertilise” the surface water, which is why good fishing grounds are normally found where upwelling is common. Changes in the winds have led to the intensification of upwelling, and have contributed to a decrease in sea temperature in certain areas along our coast (Rouault *et al.* 2009). These changes to the water temperature will also affect the fish differently along our coast (Figure 10.3). The increased upwelling events along the west and southern coasts will bring cold nutrient rich water, meaning that there will be more food available so the numbers of cold tolerant fish may increase. For example, anchovy populations have moved eastward along the southern coast since 1986, following the cooler water (Watermeyer *et al.* 2016; Scholes *et al.* 2015). This will likely be an opportunity for the fishing industry, as there are more fish and invertebrates in the area to catch if the industry is able to adapt to these changes (IPCC 2014).

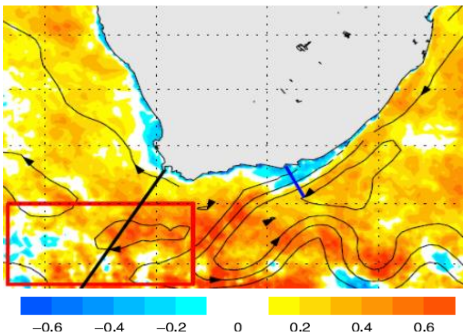


Figure 10.1: Change (°C/10 years) in sea surface temperature between 1985 and 2007 (Rouault et al. 2009).

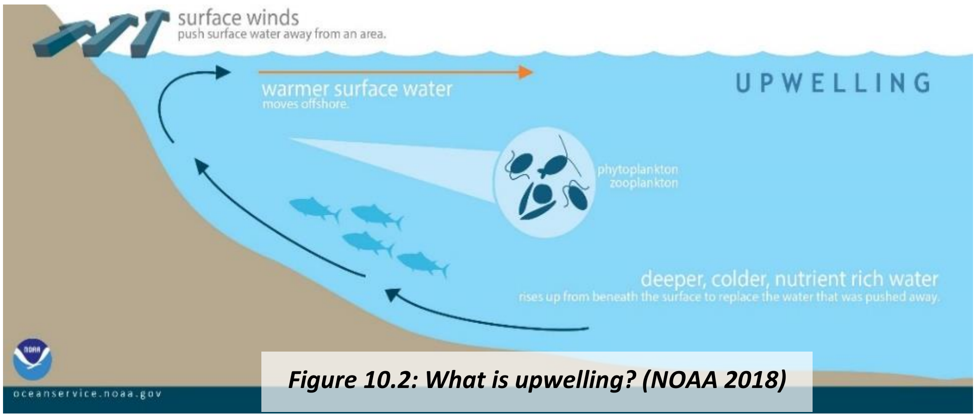


Figure 10.2: What is upwelling? (NOAA 2018)

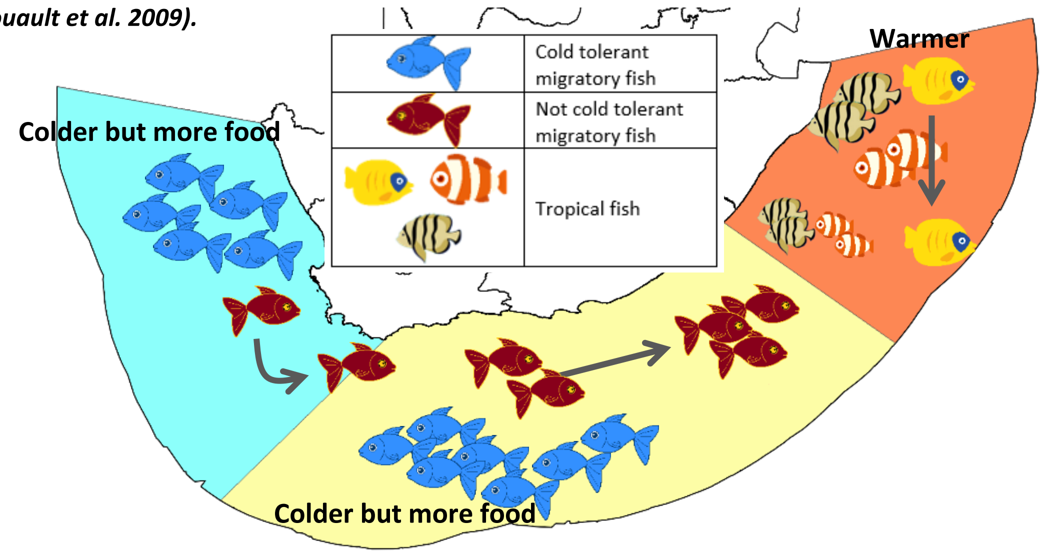


Figure 10.3: How will climate change affect fish species in the marine coastal zone? (information from James and Hermes 2011)

11. Climate Change and Coral Reefs

By Kogie Govender (SAEON National Office)

Coral reefs are an ecosystem that are home to a variety of life. The coral organisms are made up of many thousands of single animals called polyps, and have colour because of the algae that lives inside them. Algae is a plant-like organism that grows in water, and does not bear flowers or have a stem, roots or leaves. These coral animals develop the coral reefs that could be large reefs, shallow water reef or deep water reefs. Algae lives inside the cells of the coral organisms, and they make food from sunlight, which they provide to the coral organisms. The coral organism benefits from the algae, and the algae benefits from the corals - we call this relationship 'mutualism'. As the ocean warms, the algae cannot withstand the heat and leaves the corals. When the algae leave, the corals undergo a change in colour to white, and we say that the corals are bleached. If corals are bleached for a short period of time, then the corals are able to survive. If the coral bleaching takes place over long periods of time, the corals become diseased and suffer from starvation which can eventually lead to the death of corals (www. Climate.gov). As we've seen earlier in this book, climate change is one of the biggest factors that cause the air and the oceans to become warmer, causing more coral bleaching to take place (Scholes *et al.* 2015). Temperature is not the only factor influencing our coral reefs, Figure 11.1 below illustrates the different divers of changes to our coral reefs.

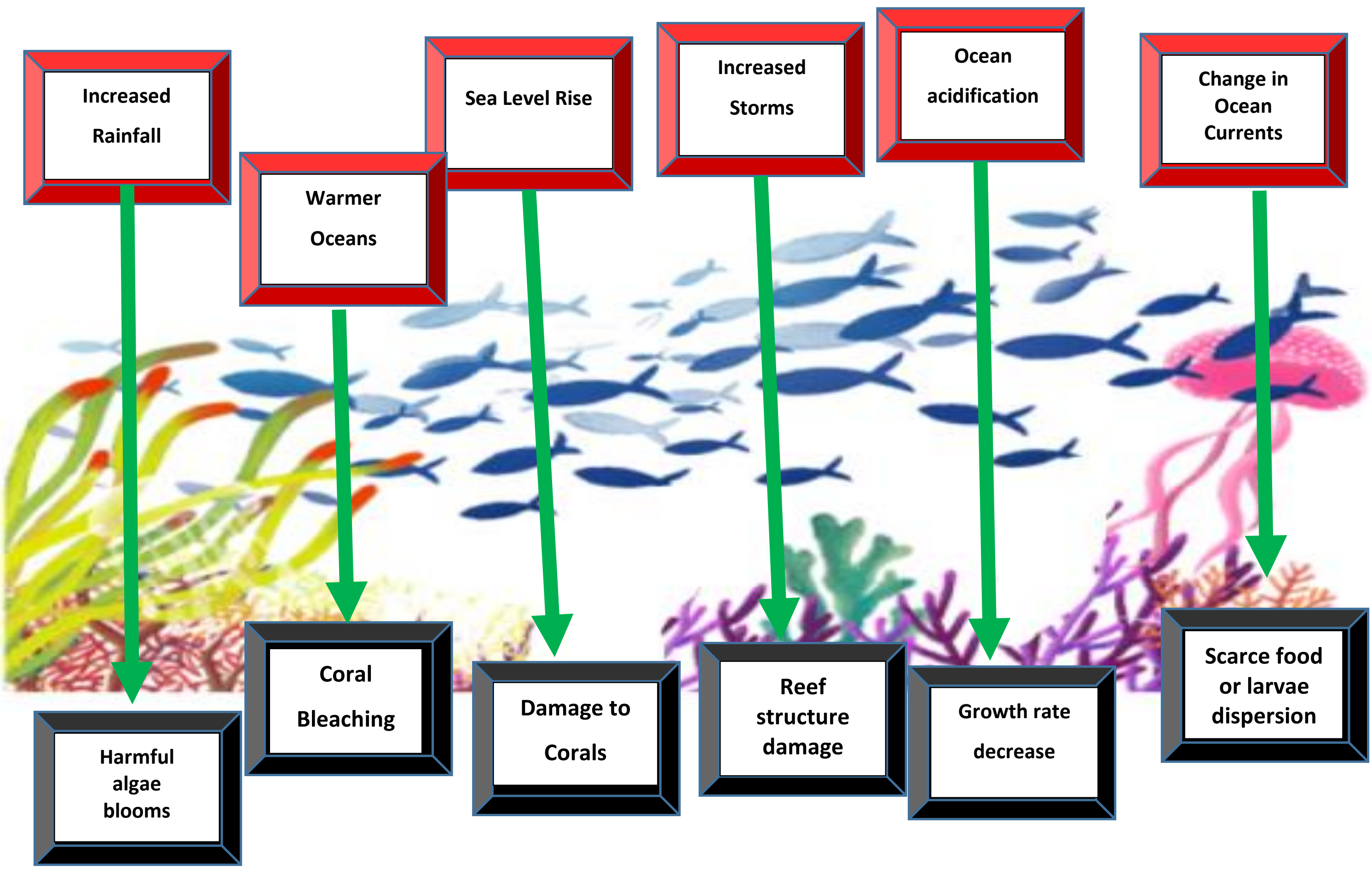


Figure 11.1: The diagram above illustrates how climate change affects coral reefs and was adapted from National Oceanic and Atmospheric Administration.(https://oceanservice.noaa.gov/facts/coralreef-climate.html).
Images adapted from www.pngtree.com.

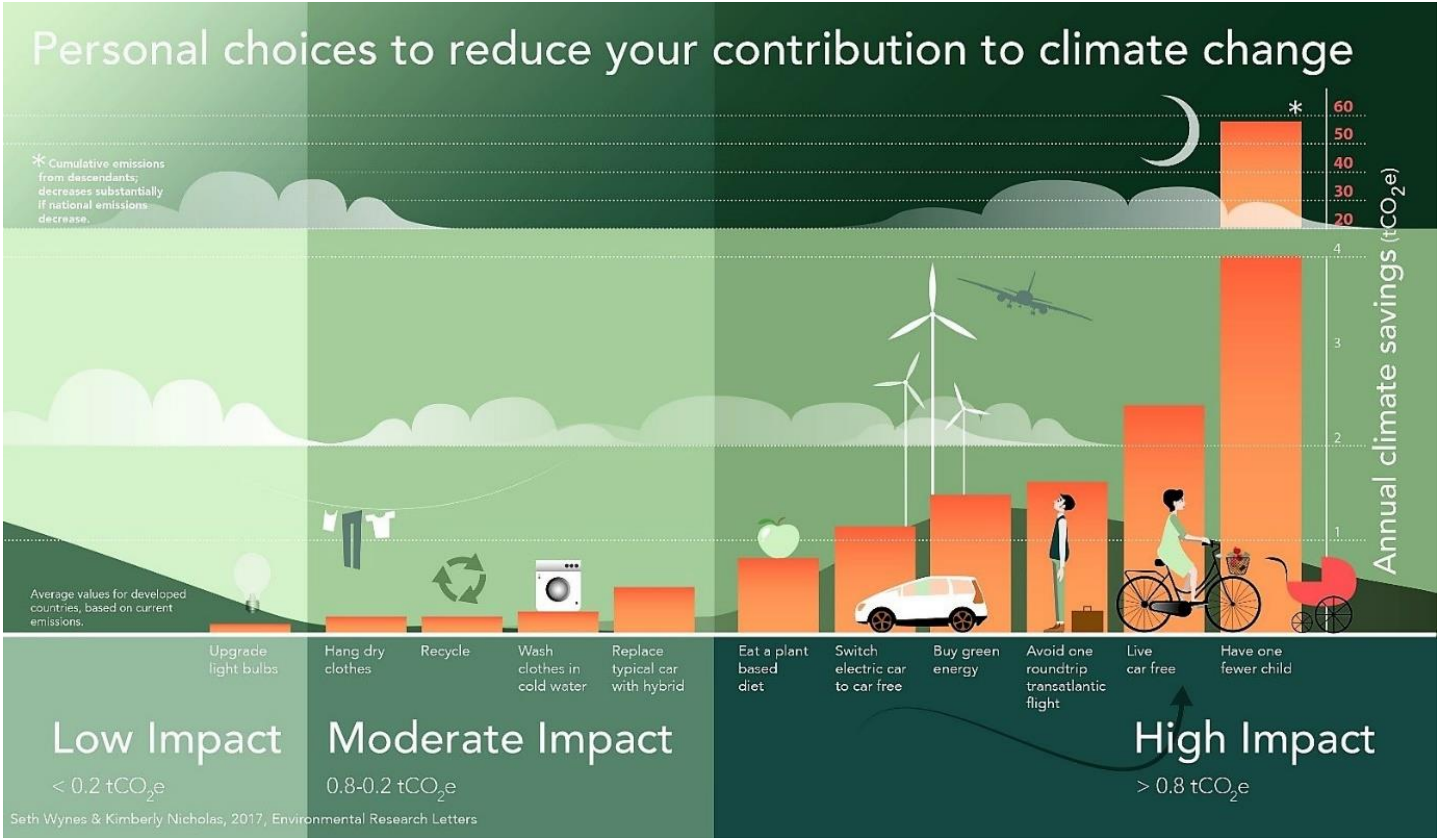
Coral reefs in South Africa are rare and rich in biodiversity, and are located on the eastern side of the African coast, in the Maputo land region of Kwa-Zulu Natal. The total coverage of corals is South Africa is about 42km^2(Porter and Shleyer, 2019).

Benefits of Corals Reefs in South Africa

- Revenue from tourism
- Ecosystem services (benefits to people from the natural environment)

The coral reefs in the northern Kwa-Zulu Natal region have not really been affected by coral bleaching due to climate change, as yet (Porter and Schleyer *et al.* 2017). The coral reefs are found at elevated latitudes, with currents from Mozambique and South East Madagascar. They are used to a lot of turbulence and would thus be resilient to increased storms. The corals in northern Kwa-Zulu Natal South Africa currently have not been affected by climate change however if the climatic drivers change then this could cause coral bleaching in the future.

12. How do your personal choices contribute to climate change? (Wynes & Nicholas 2017)



13. Here are a few ways in which you can play your part in decreasing your contribution to climate change:

Save electricity

Power generation is the biggest producer of carbon dioxide in SA.

http://www.pngall.com/?p=17911

- Change to energy efficient light blubs
- Turn off light and appliances (aircons, geysers, computers & TVs) when not in use
- Choose energy efficient appliances (geysers, fridges, washers)
- Install a solar geyser
- Insulate your house – save on heating and cooling
- Line dry your clothes
- Wash your clothes in cold water

Be water wise

We will experience more frequent droughts in the future and need to be prepared.

http://www.pngall.com/?p=17913

- Install water saving showerhead
- Take shorter showers
- Turn the tap off when brushing your teeth
- Choose water wise plants in your garden
- Install grey water irrigation systems
- Flush your toilet selectively
- Install rainwater tanks

Travel green

Transport is also a key contributor to carbon dioxide emissions

http://www.pngall.com/?p=17913

- Cycle or walk
- Use public transport (trains and busses)
- Share rides with others
- Drive more efficiently
    - Check tyres are properly inflated
    - Drive smoothly and slower
    - Consider a more fuel efficient/ electric/ hybrid car
- Fly less

Reduce your waste

Greenhouse gases are released during the making of many products.

http://www.pngall.com/?p=14997

- Recycle (know the recycling codes on packaging)
- Buy recycled products
- Reduce the amount of packaging – buy less
- Buy second hand products
- Compost your vegetable waste

Consider what food choices you make

Some processed and prepared products have a higher contribution to climate change than others.

https://commons.wikimedia.org/wiki/File:Vegetarian.png

- Buy products that are in season to reduce the impact from refrigeration
    - Buy local products because the less distance your food products have to travel the lower that carbon footprint
- Eat less and use your buying power to support meat that has been sustainably produced to ensure lower greenhouse gas emissions from livestock
- Don't waste food
- Grow your own food

Protect the environment

Terrestrial and marine ecosystems play an important role in regulating our climate

http://www.pngall.com/?p=11125

- Plants naturally remove carbon dioxide from the atmosphere. Currently about half of the human caused carbon dioxide emissions are removed from the atmosphere and stored in the oceans and plants. We therefore need to protect these important sinks of carbon dioxide.
- We need to remember that trees should not be planted indiscriminately, as that may disturb natural ecosystems. An intact ecosystem removes more carbon dioxide from the atmosphere than transformed ecosystems.

Local is lekker

Transporting goods long distances to consumers greatly increases that product's carbon footprint.

en.wikipedia.org/wiki/File:Flag_of_South_Africa_0

Choose locally made products (not just food!).

- The clothing industry is a significant source of carbon dioxide emissions. So consider buying clothing produced in South African next time as they haven't travelled as far.

14. Conclusion

Our climate is changing. In recent years South Africa has become hotter and drier and these trends are expected to continue in the future. These changes will affect the plants (the loss of species in the Western Cape), animals (from the eland in the Drakensberg to the fish in the sea) and even us. By understanding what challenges, we face from climate change, we can find the best ways to overcome them and create new opportunities.

We hope that through this booklet the we were able to communicate some of the scientific research around climate change in a way that allowed you to understand the facts to make informed decisions on how you, your family and your community can best deal with the challenges of climate change.

15. References

Altwegg, R., West, A., Gillson, L., Midgley, G.F. 2014. Impacts of climate change in the greater cape floristic region. *Fynbos: Ecology, Evolution, and Conservation of a Megadiverse Region*, eds Allsopp N, Colville JF, Verboom GA (Oxford Univ Press, Oxford), pp 299–320.

Cook, J., Oreskes, N., Doran, P.T., Anderegg, W.R., Verheggen, B., Maibach, E.W., Carlton, J.S., Lewandowsky, S., Skuce, A.G., Green, S.A. and Nuccitelli, D., 2016. Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters,* 11(4): 048002.

Davis-Reddy, C.L. and Vincent, K., 2017. *Climate Risk and Vulnerability: A Handbook for Southern Africa* (second edition). Council for Scientific and Industrial Research (CSIR): Pretoria, South Africa.

DEA (Department of Environmental Affairs), 2017. *South Africa's 2nd Annual Climate Change Report*. Pretoria: Department of Environmental Affairs

DEA (Department of Environmental Affairs). 2013. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa.* Summary for Policy-Makers. Pretoria, South Africa.

Dlugokencky, E. & Tans, P. 2019. Trends in Atmospheric Carbon Dioxide, Global. http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html [assessed 29/05/2019]

Fernandino, G., Elliff, C. I., & Silva, I. R. (2018). Ecosystem-based management of coastal zones in face of climate change impacts: Challenges and inequalities. *Journal of environmental management*, 215, 32-39.

Field, C.B., Barros, V.R., Mach, K., Mastrandrea, M., 2014. Climate change 2014: impacts, adaptation, and vulnerability. *Working Group II Contribution to the IPCC 5th Assessment Report-Technical Summary*. Cambridge University Press, UK.

Foden, W., Mace, G., Vié, J.-C., Angulo, A., Butchart, S., DeVantier, L., Dublin, H., Gutsche, A., Stuart, S. and Turak, E. 2008. Species susceptibility to climate change impacts. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland.

IPBES. 2019. *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES Secretariat, Bonn, Germany.

IPCC, 2014: *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland.

IPCC, 2018. *Global warming of 1.5°C*. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

IPCC. 2014b. *Climate Change 2014c:* Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

James, N. & Hermes, J. (eds). 2011. *Insights into impacts of climate change on the South African marine and coastal environment.* Pretoria: South African Environmental Observation Network (SAEON).

Le Quéré, C., Andrew, R.M., Friedlingstein, P., Sitch, S., Hauck, J., Pongratz, J., Pickers, P.A., Korsbakken, J.I., Peters, G.P., Canadell, J.G. and Arneth, A., 2018. Global carbon budget 2018. *Earth System Science Data* (Online), 10(4): 2141–2194

Lüthi, D., M. Le Floch, B. Bereiter, T. Blunier, J.-M. Barnola, U. Siegenthaler, D. Raynaud, J. Jouzel, H. Fischer, K. Kawamura, and T.F. Stocker. (2008). High-resolution carbon dioxide concentration record 650,000-800,000 years before present. *Nature*, 453:379-382.

Muntean, M., Guizzardi, D., Schaaf, E., Crippa, M., Solazzo, E., Olivier, J.G.J., Vignati, E. *Fossil CO2 emissions of all world countries - 2018 Report*, EUR 29433 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-97240-9, doi:10.2760/30158, JRC113738.

NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published May 2019, retrieved on May 28, 2019 from https://www.ncdc.noaa.gov/cag/

NOAA. 2018. What is upwelling? National Ocean Service website, https://oceanservice.noaa.gov/facts/upwelling.html, [accessed 2019/06/05]

Porter, S.N. and Schleyer, M.H., 2017. Long-term dynamics of a high-latitude coral reef community at Sodwana Bay, South Africa. *Coral Reefs*, 36(2), pp.369-382.

Porter, S.N. and Schleyer, M.H., 2019. Environmental Variation and How its Spatial Structure Influences the Cross-Shelf Distribution of High-Latitude Coral Communities in South Africa. *Diversity*, 11(4), p.57.

Quintero, I. and Wiens, J.J., 2013. Rates of projected climate change dramatically exceed past rates of climatic niche evolution among vertebrate species. *Ecology letters*, 16(8), pp.1095-1103.

Rasmussen, C. 2019. Huge cavity in Antarctic glacier signals rapid decay. NASA Global Climate Change. https://climate.nasa.gov/news/2838 [assessed 2019-05-29]

Rouault, M., Penven, P. and Pohl, B., 2009. Warming in the Agulhas Current system since the 1980's. *Geophysical Research Letters*, 36(12).

Scholes, B., Scholes, M. and Lucas, M. 2015. *Climate Change: Briefings from Southern Africa*. Wits University Press, Johannesburg, South Africa

Seneviratne, S., Nicholls, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., Luo, Y., Marengo, J., McInnes, K., Rahimi, M., 2012. Changes in climate extremes and their impacts on the natural physical environment: An overview of the IPCC SREX report. Presented at the *EGU General Assembly Conference Abstracts*, p. 12566.

Slingsby, J. A., Merow, C., et. al. (2017). Intensifying postfire weather and biological invasion drive species loss in a Mediterranean-type biodiversity hotspot. *Proceedings of the National Academy of Sciences*, 114(18), 4697-4702. https://www.pnas.org/content/114/18/4697.short

Stone, D., Auffhammer, M., Carey, M., Hansen, G., Huggel, C., Cramer, W., Lobell, D., Molau, U., Solow, A., Tibig, L. and Yohe, G., 2013. The challenge to detect and attribute effects of climate change on human and natural systems. *Climatic Change*, 121(2), pp.381-395.

Syampungani, S., Geledenhuys, C. and Chirwa, P., 2010, Age and growth rate determination using growth rings of selected miombo woodland species in charcoal and, slash and burn regrowth stands in Zambia, *Journal of Ecology and the Natural Environment*, 2(8), 167-174.

Tans, P. & Keeling, R. 2019. Trends in Atmospheric Carbon Dioxide, Mauna Loa, Hawaii. http://www.esrl.noaa.gov/gmd/ccgg/trends/index.html [assessed 29/05/2019]

Uys, D., 2014. Climate Change Risks Require Combined Effort.

Vitousek, P.M., 1994. Beyond global warming: ecology and global change. *Ecology*, 75(7):1861-1876.

Watermeyer, K.E., Hutchings, L., Jarre, A., Shannon, L.J. 2016. Patterns of Distribution and Spatial Indicators of Ecosystem Change Based on Key Species in the Southern Benguela. *PLOS ONE* 11(7): e0158734. https://doi.org/10.1371/journal.pone.0158734

Woodborne, S., Hall, G., Robertson, I., Patrut, A., Rouault, M., Loader, N.J. and Hofmeyer, M., 2015, A 1000-Year Carbon Isotope Rainfall Proxy Record from South African Baobab Trees (Adansonia digitata L.), *PLoS ONE*, 10(5), 1-18.

Wynes, S. and Kimberly A. N. 2017. “The Climate Mitigation Gap: Education and Government Recommendations Miss the Most Effective Individual Actions.” *Environmental Research Letters* 12(7). DOI: 10.1088/1748-9326/aa7541. Image credit: Catrin Jakobsson.

Zietsman, L. ed. 2011. *Observations of Environmental Change in South Africa*. Stellenbosch: Sun MeDIA,.