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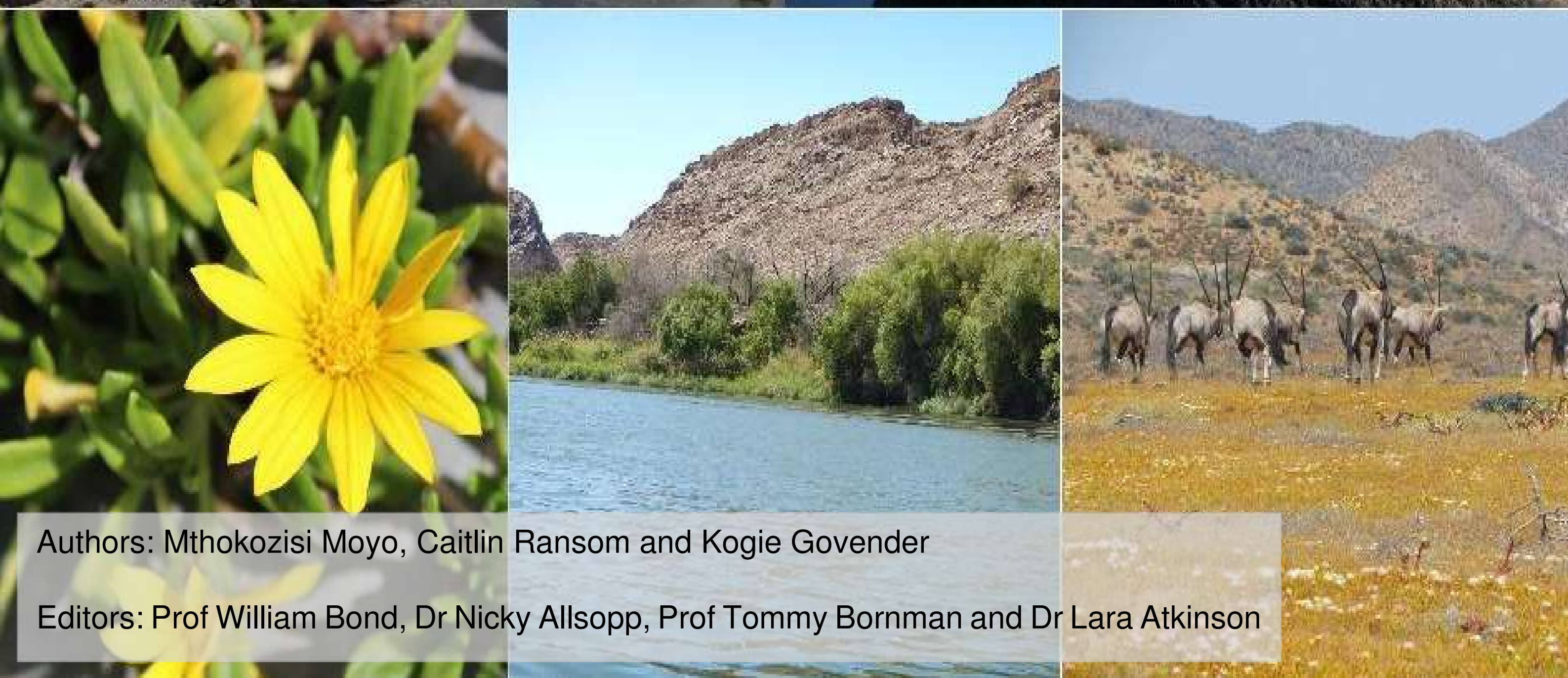
SAEON South African Environmental Observation Network

BIOMES OF SOUTH AFRICA TRAINING MANUAL



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Preamble

The South African Environmental Observation Network (SAEON) is a business unit of the National Research Foundation that undertakes long term ecological observations to understand the drivers of change in our environment. SAEON's environmental science education programme focuses on education and outreach programmes for educators and high school learners. The aim of this training manual is to make life science exciting and easy to understand when the classroom has limitations to teaching science. Through the use of this manual, learners will be remotely travelling through the different parts of our beautiful land, South Africa. As learners embark on this journey they will acquire immense knowledge of vegetation, climatic conditions, geography and biodiversity for each biome.

The biomes training manual was developed as an additional educator support material that contains a variety of activities that can be adapted and reproduced. The content in the biomes manual is based on the grade 10 Curriculum and Assessment Policy Statements (CAPS). The purpose of this manual is to ensure that the subject content knowledge on biomes is better understood as the learner activities promote inquiry based thinking. The activities are structured around the use of data to illustrate scientific phenomena. The world is being driven by data and there is a need for our learners to be able to use analytics to make informed decisions as we prepare for the 4th Industrial Revolution. Through engaging in the activities in this manual, learners will enhance their quantitative and critical thinking skills. This will help create interest and passion for life science and mathematics amongst learners.

Structure of the manual

For each biome, there is a short description of the biome followed by a case study. There are also several practical activities and discussion questions based on the case study and the biome in general. A summary assessment is found at the end of the book. Appendix C contains a memo to all activities found in the manual.

Objectives

At the end of this strand learners will be able to:

- Identify characteristics that define the nine terrestrial biomes of South Africa and the different aquatic ecosystems.
- Describe the effect of environmental changes in each biome and what makes them unique.
- Analyse data for the different biomes.
- Undertake summative assessment activities.

Recommended citation

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Table of Contents

1. Introduction

The planet has spheres or earth systems that play an important role in our ever-changing environment. Therefore, it is important to understand the connections between the different spheres. The Earth Systems are classified into four spheres which is lithosphere (land), hydrosphere (water), biosphere (living things), and atmosphere (air). These spheres interact with each other. If there is a disturbance in one, the other spheres are also affected. An example is deforestation. Trees are removed from the biosphere and this leads to increased carbon dioxide as there are no trees to absorb the carbon dioxide from the atmosphere. The soil is also not protected and there are increased chances of soil erosion (lithosphere) and the soil flows into the rivers (hydrosphere).

Spheres of the earth

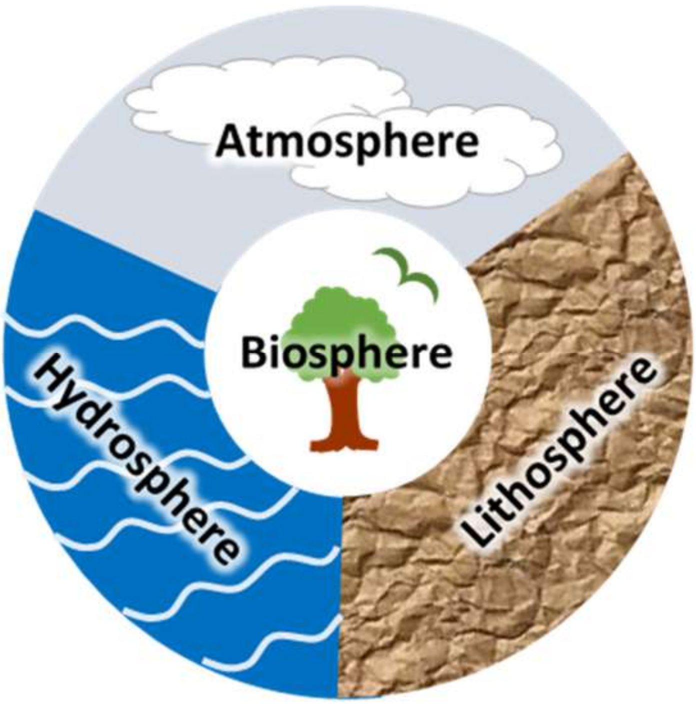

Figure 1.1: The spheres of the earth

Ecosystems are particular places that are formed when there are interactions between the Earth spheres. An ecosystem is a complex system that consists of living organisms in a particular area and how they interact with each other and the environment in which they are found.

Biomes are defined by the plants and animals that are found in that particular geographic area. Some factors that determine the plants and animals in a biome are temperature, soil, intensity of light and water. A biome is made up of different eco-systems which have climatic conditions that are almost the same.

Activity 1.1

1.1.1 Describe some biotic and abiotic factors that make up an environment.

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1.1.2 Describe other examples of where all the spheres are affected by one event?

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Biomes

The biosphere is divided into several biomes. There are two main biome categories: terrestrial and aquatic. Terrestrial biomes are typically characterised by the type of vegetation, but it is the climate (precipitation and temperature) and geography (longitude, latitude, altitude, distance from the ocean, and soil amongst other factors) that determines the kind of plants and animals and other organisms that are found there. The distribution of terrestrial biomes depends on these climatic and geographic factors. Aquatic biomes are classified based on the type of water they contain (primarily how salty it is and is the water flowing), which affects the plants and animals that are found there.

Biomes of South Africa

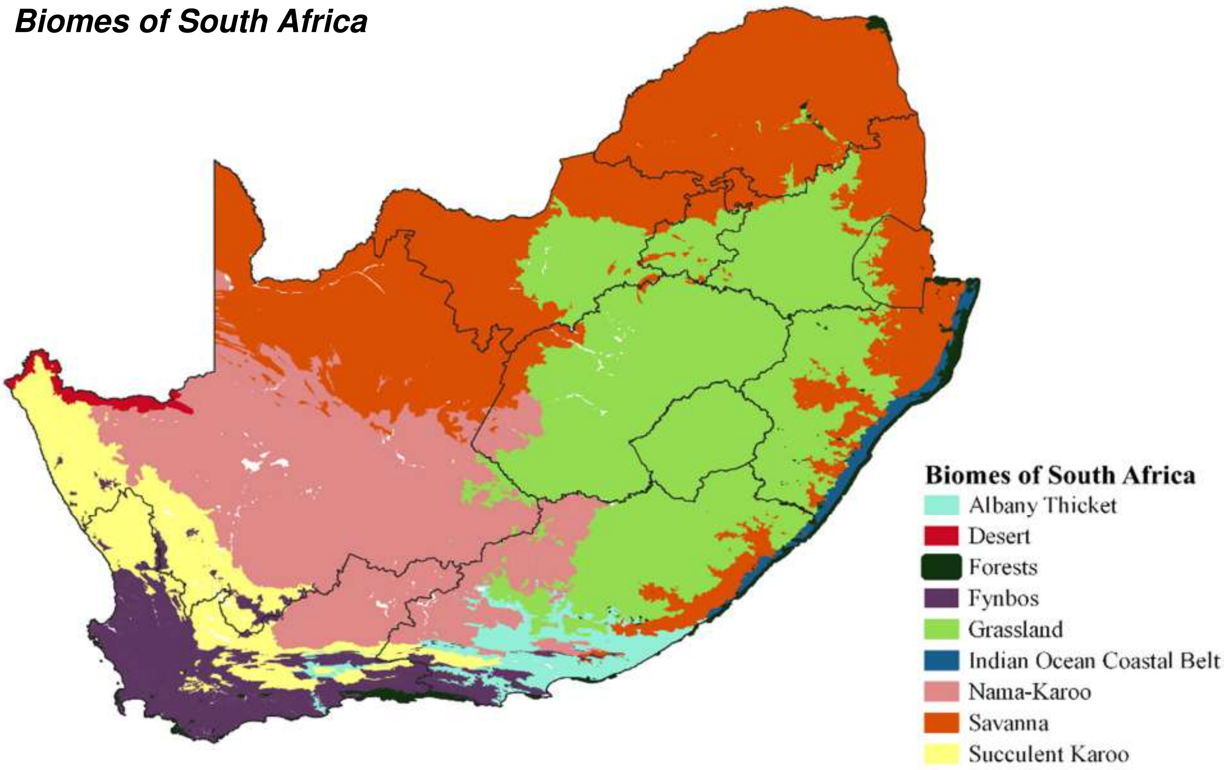

Figure 1.2: Terrestrial biomes of South Africa (SANBI 2012)

Bioregions

A bioregion is defined as “a composite spatial terrestrial unit defined on the basis of similar biotic and physical features and processes at the regional scale”. There are differences in the vegetation that is found within a particular biome. Not all the vegetation within a biome has the same species composition. There are local differences depending on the conditions in a particular area. South Africa has 35 bioregions (Figure 1.3) but only nine biomes (Figure 1.2).

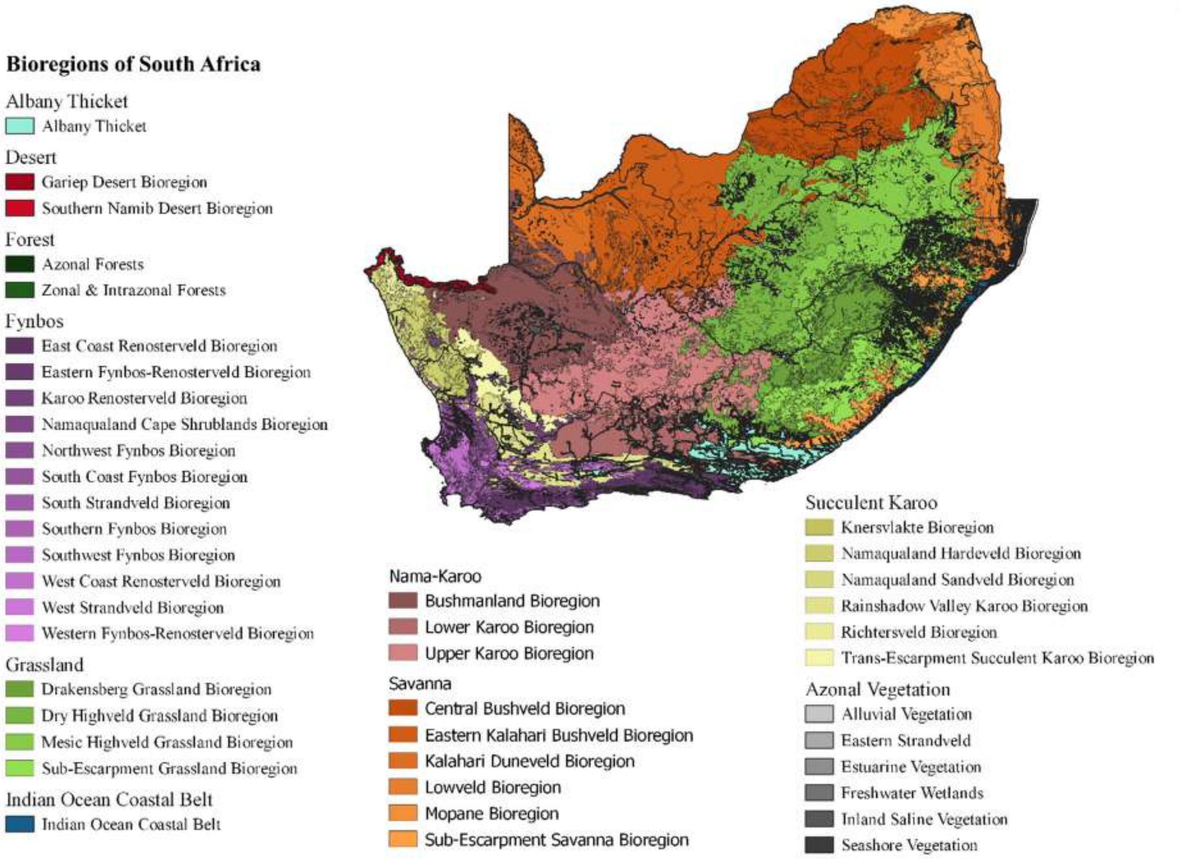

Figure 1.3: The Bioregions in South Africa (SANBI 2012)

1.1.3 Compare the difference between the biomes map and the bioregions map.

Bioregions can be further divided into smaller units that share similar species composition within the bioregion. These smaller units often have distinct climatic or soil differences within the bioregion. These are referred to as vegetation units. As the name suggests, these units can be defined by the type of vegetation that is found in that particular region.

Transition zones (ecotones)

Biomes do not have set boundaries. The change from one biome to the other can be abrupt, for example from a grassland to a forest, or rather gradual such as from grasslands to Karoo shrublands. The point where biomes change from one biome to another is called a transition zone or ecotone. There are also transition zones between bioregions and vegetation units. In these transition zones, the area is likely to have characteristics from both of the biomes (or bioregion or vegetation unit) that meet.

Activity 1.2

The aim of this activity is to identify the biomes that we have in South Africa. You are provided with pieces of the South African Map (page 73) which represent the biomes that we have. Give a brief description of each biome as you put the map together.

1.2.1 Identify the biome that shares borders with the most biomes.

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1.2.2 List the names of the biomes that share borders with the answer to 1.2.1.

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1.2.3 The land coverage of South Africa is approximately 1 219 912 km^2. Complete the table below

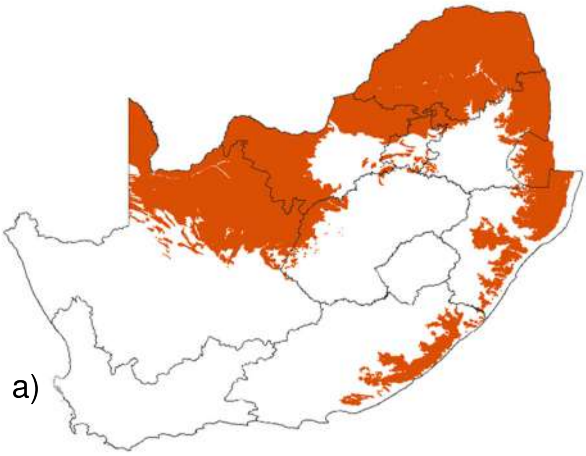
Biome	**Area (%)**	**Area (km^2)**	**Number of Bioregions**
Savanna	32.5		
Nama Karoo	19.5		
Indian Ocean Coastal Belt	1.1		
Grassland	27.9		
Fynbos	6.6		
Forest	0.3		
Desert	0.5		
Albany Thicket	2.2		
Succulent Karoo	6.5		
Other	2.3		

1.2.4 Use the information in the table above to draw a pie chart showing the area contribution of each biome in South Africa.

Terrestrial Biomes

2. Savanna Biome

a)



b)

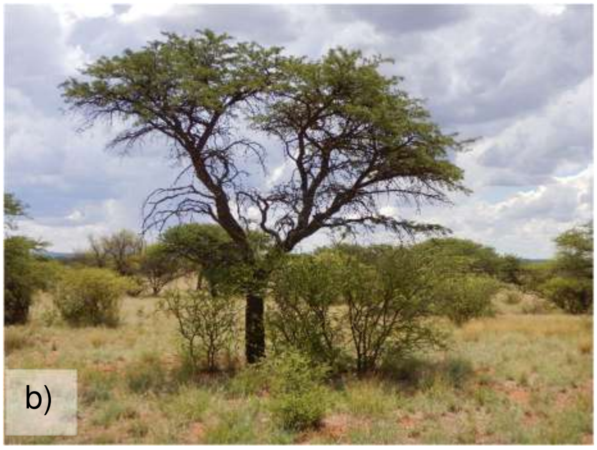


Figure 2: Savanna biome of South Africa
a) Distribution of biome (SANBI 2012) and b) savanna from Benfontein Nature Reserve Kimberley

The Savanna biome is the biggest biome in South Africa. It is dominant in the northern and eastern summer rainfall areas. Savannas are hot and experience rainfall during the summer. The winters are cold and frost may occur. This biome contains a mixture of grass and trees and it is sometimes referred to as the bushveld. Trees such as mopane, combretum and acacia are commonly found in this biome, but many other trees also occur including baobabs and marulas in some bioregions. It is also home to South Africa's Big 5. Fire and herbivory are important in maintaining the balance between grass and trees. If there are more grazers consuming most of the grass, there is less material that can burn and the chances of fire occurring are thus reduced. A lower fire frequency can lead to an increase in the woody vegetation. An increase in browsing by large herbivores (elephant, black rhino) can reduce the amount of woody vegetation and increase the amount of grass which generally leads to more fires and an increase in the grassy vegetation.

Acacia trees such as the Umbrella Thorn are characteristic of some savanna regions.
Photo: Richard/ CC BY-NC 4.0

A continuous layer of grass is a defining characteristic of savannas.

Bushwillows (Combretum species) are characteristic trees of some savanna regions. Photo: Christine Sydes/ CC BY-NC 4.0

Southern Ground-Hornbills are a charismatic savanna species. They are listed as vulnerable.

Marula trees are characteristic of some savanna regions. Photo: magdastlucia/ CC BY-NC 4.0

Savannas are home to the African Wild Dog, one of the worlds most endangered mammals.

Ecosystems

An ecosystem is a complex system that consists of living organisms in a particular area and how they interact with each other and the environment in which they are found. Energy flows through ecosystems and this is represented by food chains and food pyramids. Many food chains can be put together to construct a food web.

Case Study - Elephants as ecosystem engineers (Haynes 2012)

Organisms that create, modify and/or maintain habitats are known as ecosystem engineers. Their presence physically changes the environment in some way either directly or indirectly. Ecosystem engineering can alter the distribution and abundance of large numbers of plants and animals, and significantly modify biodiversity. Elephants are such ecosystem engineers. They change the landscape in various ways. Elephants dig wells in order to access subsurface water. This, in turn, benefits other animals as they will have access to that water as well. Elephants strip bark off trees, break branches and knock down trees. This leads to a loss in certain tree species. Other animals that rely on trees cannot feed on those trees. This, however. reduces the amount of woody vegetation which gives an opportunity for grass to grow. This creates a habitat for other animals that are not able to live in dense woodland, increasing the number of grazers in the area. This also increases the number of predators as it will now be easier to spot prey. Elephant dung provides nutrients to the soil. The dung also contains some undigested seed material which could lead to the germination of new plants.

Activity 2:

Food webs, Food chains and Ecosystems

2.1 Watch the following video on the reintroduction of wolves into the Yellowstone National Park in the United States of America.
www.youtube.com/watch?v=ysa5OBhXz-Q

Summary of the video: Reintroduction of wolves into Yellowstone (Boyce 2018):

Yellowstone National Park, in the USA, is not only the oldest national park in the world but home to one of the most significant ecological experiments. The reintroduction of wolves in Yellowstone is a classic example of trophic cascades. Trophic cascades are indirect interactions that can affect entire ecosystems. They are caused by changes to the top of the food chain that move through the lower trophic levels and eventually throughout the whole ecosystem.

By 1926 the Yellowstone National Park had got rid of all wolves through mass culling programmes. This loss of the apex predator (the wolf) led to a considerable increase in the elk populations. Within a few years without wolves, the elk were changing the vegetation and causing erosion which had knock-on effects on other animals. Elk are mixed feeders, meaning that they are both browsers and grazers. The elk's overgrazing was so severe that during the winter months many elk starved because there was not enough food

The introduction of wolves also affected elk behaviour; as elk began avoiding areas along rivers, where they would be an easy prey. The vegetation along the rivers began to regenerate, with the decrease in foraging pressure from elk, and trees once again grew tall along the rivers and the vegetation was able to recover. This vegetation stabilised the river banks preventing erosion and improving water quality. The availability of trees near the river meant there was an increase in beavers who build dams along the river creating habitats for other species such as otters, ducks and fish.

The reintroduction of wolves in Yellowstone National Park is a clear example of how the removal or addition of one species can have a knock on effect and influence an entire ecosystem. The wolves did not just affect the elk populations but had indirect effects on other animals, the vegetation and even the rivers.

2.1.2 Construct a food web from this ecosystem.

2.1.3 How did the introduction of wolves into the park affect the ecosystem of that park?

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2.2 Use the photographs below to create the following. (Images in Appendix B)

(primary producer)

(grazer)

(carnivore)

(grazer and browser)

(scavenger)

(primary producer)

2.2.1 A food chain.

2.3 A food web

2.2.3 Explain what could happen if the lions were removed from this ecosystem.

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2.2.4 Explain what could happen if elephants were added to this ecosystem?

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3. Grassland Biome

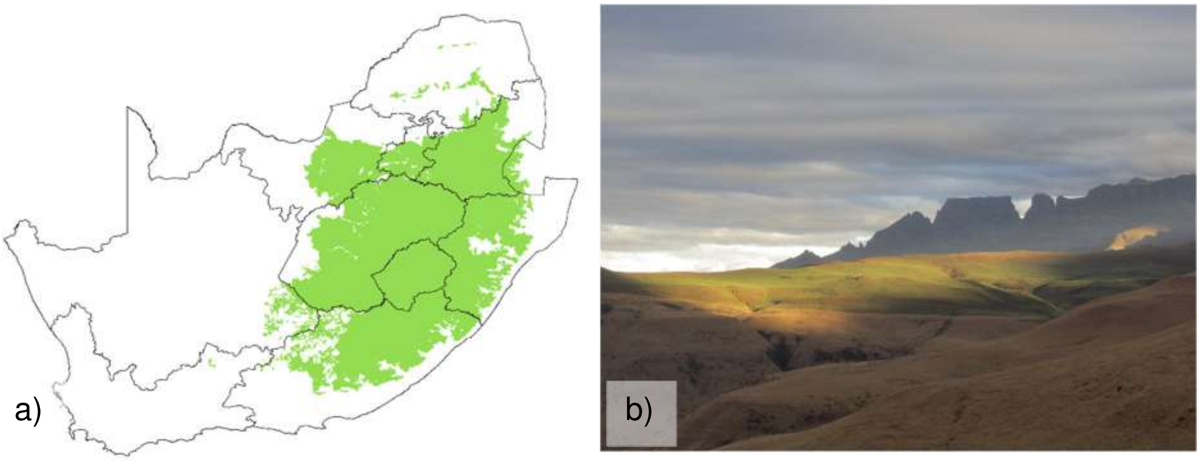

Figure 3: Grassland biome of South Africa
a) Distribution of biome (SANBI 2012) and b) grasslands at Cathedral Peak in the Drakensberg

Grasslands are dominated by herbaceous vegetation which include grasses and forbs. There are some shrubs that are found in grasslands but these are usually found close to hills and escarpments. Grasslands are found all over South Africa and they cover about 27.9% of the country. Not all grasslands are the same and according to Mucina and Rutherford (2006), they can be divided into 73 vegetation types which depend on where the grassland is located. They receive summer rainfall, but it ranges widely from 400mm to 2 000mm per year. In the drier grasslands the grass grows rapidly just after a rainfall event. Disturbances such as frost, fire and herbivory (grazing) are important factors in maintaining grasslands. Fire determines the structure, function and composition of the grassland biome in South Africa. It is used as a management tool as it burns all the old, dead grass found in the landscape. This allows for new grass to grow. It is also used to control bush encroachment, which is an increase in woody plants (shrubs and trees). If there was no fire in this biome, to control these woody plants, the biome would turn into a savanna or a forest. Fires are started naturally by lightning during storms but they are also started by humans.

Grazing is another important factor in grasslands supporting much of our livestock industry. Heavy grazing affects the composition of the plant species within an area since some herbivores prefer certain plant species over others. Grass species vary in their tolerance of grazing and fire. Lawn or stoloniferous grasses (e.g. *Cynodon dactylon*) grow horizontally and are therefore more tolerant of very heavy grazing. Several of these lawn grass types are used in our garden lawns and sporting fields.

Grasslands are dominated by different species of grass. Photo: Dave Richardson / CC BY-NC 4.0

Agapanthus add a distinct blue colour to the grasslands of the Drakensberg. Photo: Peter Warren / CC0 1.0

Herds of Black Wildebeest roam the grasslands of Golden Gate National Park. Photo: bukhal / CC BY-NC 4.0

Our national bird, the Blue Crane, is mostly found in natural grasslands. Photo: David Renoult / CC BY-NC 4.0

*Sungazers (*Smaug giganteus*) are dragon-like lizards that are endemic to the highveld grassland. Photo: Johnny Wilson / CC BY-NC 4.0*

Grasslands are home to a diverse array of wildflowers, adding vibrant colours to the landscape. Photo: Ryne Rutherford / CC BY-NC 4.0

3.1 Grasslands provide ecosystem services. Define ecosystem services.

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Grasslands, as do all vegetated systems, store carbon and have a direct impact on the carbon cycle and the carbon balance in the ecosystem. Grasslands are threatened and are subject to transformation from ploughing, urbanisation and mining. Most of the grassland biome is not formally protected. 30% of the Grassland Biome has already been transformed permanently with other parts fragmented or degraded.

Case Study – Enkangala Grasslands (WWF 2011; Carbutt 2011; Moyo 2015)

Volksrust, a small town in southern Mpumalanga is an important agricultural region and the main products are maize, soybean and grazing for cattle. The surrounding local area called the Mesic Highveld Grassland Bioregion is one of the critical conservation areas in South Africa.

This region has high plant biodiversity. There are many endemic plant species and several endemic birds and reptiles. Some of these populations are endangered. The Enkangala Grasslands are a remnant of formerly much more extensive Highveld

Grasslands which have been transformed and used for urban development, mining, industries and agriculture. Many mining rights and prospecting applications have been made in this area because of the coal reserves which underlie it. Mining has an impact on biodiversity and water resources.

The Wakkerstroom wetland is found in this region. This wetland supports up to 485 resident and migratory bird species, making the town of Wakkerstroom a major birding area. The peat wetland also acts as a major carbon sink. This region is also important as three major river systems arise here from the Thukela, Vaal and Usutu/Mhlatuze catchments. These catchments provide water for other parts of the country, agriculture, power stations and coal mines. There is an increase in the spread of alien invasive species of plants in that area with an impact on the water resources. Concerns for biodiversity and resource conservation have led to the establishment of the Enkangala Grasslands Project.

Activity 3.1

Use the case study above to assist you in answering the following questions

3.1.1 Why is the Wakkerstroom wetland important?

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3.1.2 What would happen if the grasslands in this region were to be transformed even more?

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Activity 3.2

3.2.1 Fill in the blank cells in table 3.1 below.

Table 3.1: The conservation status of grasslands in South Africa (Carbutt 2011)

Bioregion	Total Area (km^2)	Protected Area (%)	Protected Area (km^2)	Transformed Area (km^2)	Transformed Area (%)
Drakensberg Grassland	42177	5.9		8220	
Dry Highveld Grassland	117753	1.5			27.8
Mesic Highveld Grassland	125044		2001	51693	
Sub-escarpment Grassland	75615		1081	27547	
Grassland Biome (Total)		2.0	7212		33.3

3.2.2 Name the bioregion that is the most transformed.

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3.2.3 Identify which bioregion is least protected.

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Table 3.2: Land use responsible for the transformation of the grassland biome

Land use Type	Transformation (km^2)	Transformation (%)
Cultivation	97874	27.10
Forestry plantations	9932	2.80
Urban and industrial areas	5843	1.62
Mines and Quarries	933	0.26
Total	114582	31.78

Use the information provided in the table above to answer the questions below.

3.2.4 Identify which land use type is responsible for the most transformation in the Grassland Biome.

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3.2.5 Compare Table 3.1 and Table 3.2. and calculate what percentage is not accounted for.

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3.2.6 Describe other activities that could be responsible for transformation in the Grassland Biome which are not described in this table.

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3.2.7 Define the term endemic.

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4. Nama-Karoo Biome

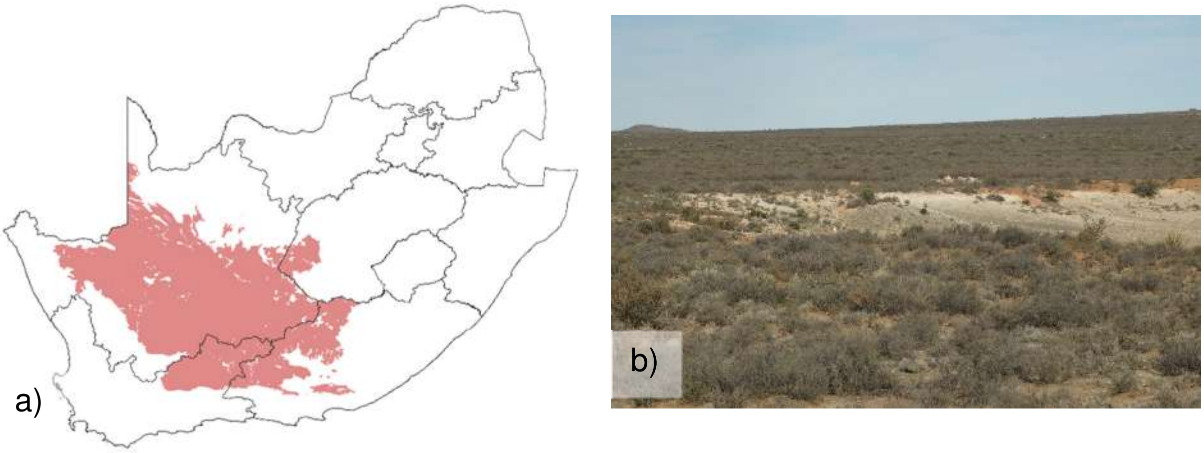

Figure 4: Nama-Karoo biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Nama-Karoo at Uintjiesleegte in mid-Karoo

The Nama-Karoo biome is the third largest biome in South Africa. It is found in the Northern, Eastern and Western Cape. It is arid and receives little rainfall. The average annual rainfall ranges from 70 mm in the north west to 500 mm in the east. The Nama-Karoo is characterised by small-leaved shrubs and grasses. The land is mainly used for stocking sheep for meat and wool.

The Nama-Karoo is dominated by dwarf shrubs. Photo: douglaseustonbrown / CC BY-NC 4.0

Taller trees can be found along drainage lines, including the invasive Mesquite. Photo: Tony Rebelo / CC BY-SA 4.0

Historically large herds of Springbok, South Africa's national animal, once roamed the Nama-Karoo region.

Case Study – Fracking in the Karoo (Todd et al 2016)

As South Africa develops, there is a rising demand for energy, and a need to explore alternative energy sources. Large shale gas deposits have been found in South Africa. This gas is accessed using the process of hydraulic fracturing commonly known as fracking. A mixture of chemicals, water and sand are injected into the shale rock to create fractures where the gas will flow out. Several biomes will be affected by fracking in South Africa with the Nama-Karoo being the most affected. Fracking will not only affect plant species but animals too. There are other potential impacts that could occur in areas where fracking is carried out. These are noise pollution, dust, soil erosion and invasion of alien plants. The water crisis from fracking will cause pressure on water resources. Firstly, over abstraction of water will deplete natural systems of water and reduce the amount of water for people and their livelihoods. Another factor is that contaminants will get into the ground water from the fracking process. The actual footprint of a fracking site in physical space is not that large relative to things like ploughing land for maize or surface coal mining.

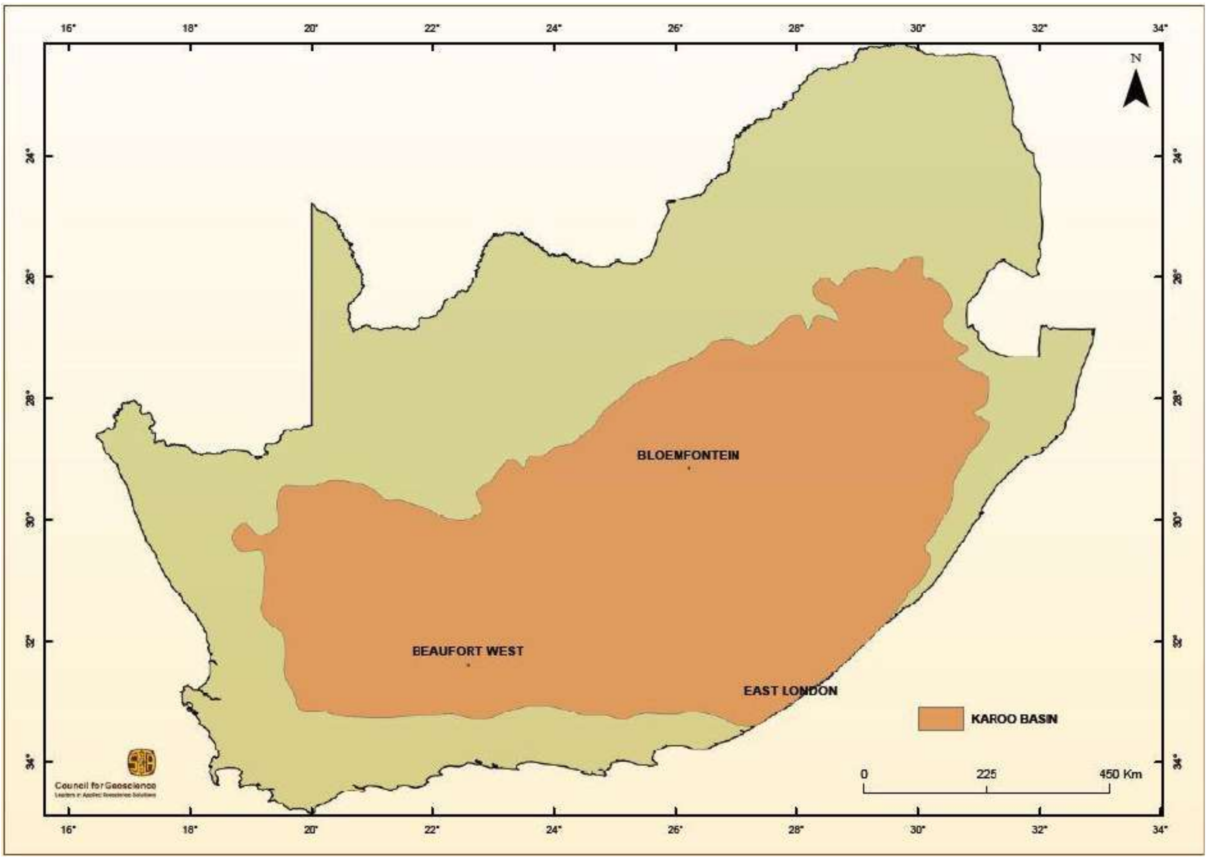

Figure 4a: The Karoo Basin where shale gas has been found. Image from the Department of Mineral Resources Website (http://www.dmr.gov.za/mineral-policy-promotion/shale-gas).

Table 4: Biomes that will potentially be affected by fracking in South Africa (Todd et al 2016)

Biome	**Total area of biome (km^2)**	**% of biome affected**	**Vegetation Types in the biome**	**% Vegetation types affected**
Thicket	41466	27	14	64
Forest	6723	3	12	17
Fynbos	120162	5	119	5
Grassland	460628	14	72	44
Nama-Karoo	335040	52	14	93
Savanna	513952	9	87	13
Succulent Karoo	114073	10	63	13
Azonal (Other)	38695	39	34	29

Activity 4.1

Use the case study above to assist you in answering the following questions

4.1.1 Name the current sources of energy in South Africa.

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4.1.2 Tabulate the advantages and the disadvantages of fracking?

Advantages	Disadvantages

4.1.3 Determine the area of the Nama-Karoo which will potentially be affected by fracking.

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4.1.4 Draw a bar graph to show the number of vegetation types that are affected by fracking in each biome.

5. Fynbos Biome

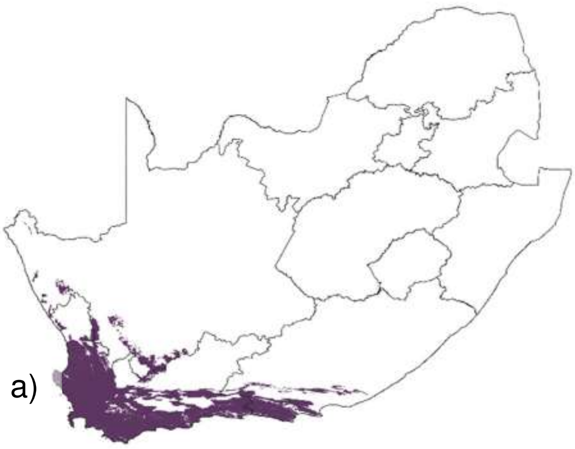

Figure 5: Fynbos biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Proteas are a key element of fynbos vegetation

The Fynbos biome is found in the south western parts of South Africa. This biome has a Mediterranean climate meaning that winters are cold and wet while summers are hot and dry. The Fynbos world's hottest biodiversity hotspot, meaning that there are more plant species per unit area in this region than anywhere else in the world. It has about 7 500 plant species. Proteas (such as our national flower the King Protea), Ericas (small-leaved shrubs) and Restios (also known as "cape reeds', which look a little like grasses, but are not) are typical of this area. Fire is very important in this biome and it usually occurs during the dry summer months. Many fynbos plants are 'born to burn' and only germinate after a fire as the heat from the fire, or chemicals in the smoke, stimulate germination. Serotiny is when plants store seed in insulated structures such as cones. Seeds are released when the structures open up in response to fire as the environmental trigger. Seeds then germinate in the open post-fire habitat, free of predators and plant competitors.

Proteas, such as our national flower the King Protea, are characteristic of the Fynbos. Photo: Felix Riegel / CC BY-NC 4.0

These colouful pincushion are also a type of protea. Photo: Robert Blackhall-Miles and Ben Ram / CC BY-NC 4.0

Restios are characteristic of the Fynbos. They also known as cape reeds and look like shrubby grasses. Photo: Tony Rebelo / CC BY-SA 4.0

Ericas are small leaved shrubs often with beautiful small flowers. They are characteristic of the Fynbos. Photo: Richard Adcock / CC BY-NC 4.0

The Orange-breasted Sunbird is endemic to the Fynbos. Photo: Anne Fröhlich / CC BY-ND 2.0

Cape Dwarf Chameleons are endemic to the Fynbos. Photo: Caitlin Ransom

Case Study – Adapted from Fire Management in the Fynbos (Van Wilgen 2013)

The Fynbos biome is an important biome globally. The vegetation in this biome is adapted to fire, as fire is one of the drivers in this ecosystem. The interval between fires is very important because it has an impact on the diversity of the area. Too frequent fires may eliminate species that are not able to resprout or take several years to produce seeds. Other species may go extinct if fires do not occur. One of the biggest threats to the fynbos biome is the invasion by alien species. Invasive plants such as the black wattle, port jackson wattle, rooikrans, hakea, eucalyptus and pine trees are also fire adapted.

Several animal species occur in fynbos, such as the Cape sugarbirds and grysbok, but little is known on how they escape fires.

Activity 5.1

Use the case study above to assist you in answering the following questions.

5.1.1 Why is fire an important driver in this biome?

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5.1.2 Explain some of the consequences of this increase in the number of fires.

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6. Succulent Karoo Biome

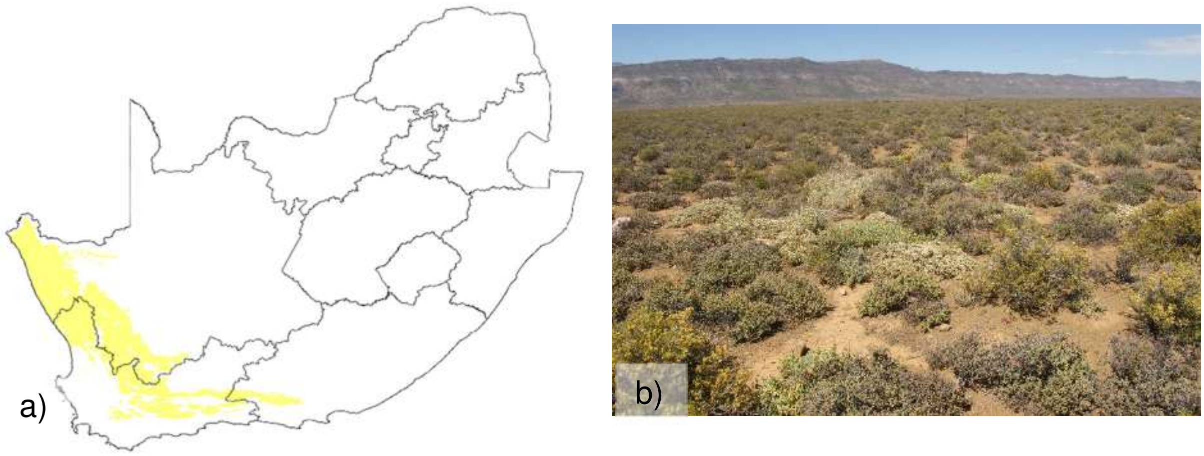


Figure 6: Succulent Karoo biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Bushmanland, farm Nooitgedacht, quiver tree

The Succulent Karoo is located along the West Coast of South Africa and in the northern parts of the Western Cape, extending into the Eastern Cape. This biome is a semi desert region and receives between 20 and 290 mm of rainfall per year in winter (Low & Rebelo 1996). Like the neighbouring Fynbos Biome, the Succulent Karoo is also a biodiversity hotspot that is known for the high number of endemic species. Dwarf succulent shrubs, with species such as vygies and stone plants, are characteristic of the Succulent Karoo. Following good winter rains, the ground will be carpeted with brightly coloured flowers.

Cone plants or toontjies are dwarf cousin succulents found in the Richtersveld region on the Succulent Karroo.
Photo: juddkirkel / CC BY-NC 4.0

The Succulent Karoo has relatively high reptile diversity. The Namaqualand tent tortoise is endemic to this region.
Photo: kevinjolliffe / CC BY-NC 4.0

Vygies produce brightly coloured flowers. Photo: Felix Riegel / CC BY-NC 4.0

Buddha's Temple (Crassula columnaris) are an example of the interesting succulents found in this region. Photo: Marinus de Jager / CC BY-NC 4.0

The Namaqualand daisy. These flowers create a brilliant orange carpet when it flowers in Namaqualand in early spring.
Photo: Tony Rebelo / CC BY-SA 4.0

Baby-bottoms are dwarf succulent that produces bright purple-pink flowers during the early winter months. Photo: Tony Rebelo / CC BY-SA 4.0

The Succulent Karoo, a biodiversity Hotspot

There are currently 36 biodiversity hotspots globally and South Africa is home to three: The Cape Floristic Region, Maputaland-Pondoland-Albany and the Succulent Karoo (Noss *et al.* 2015). Biodiversity hotspots have high levels of endemism (at least 1 500 species of plants need to be endemic, found nowhere else on earth) and are highly transformed (more than a 70% loss of natural vegetation). The Succulent Karoo is special amongst these biodiversity hotspots in that it is one of only two arid hotspots (the other is in the horn of Africa). The Succulent Karoo is home to the most species of succulents in the world (highest species richness), in addition to a high reptile and invertebrate diversity.

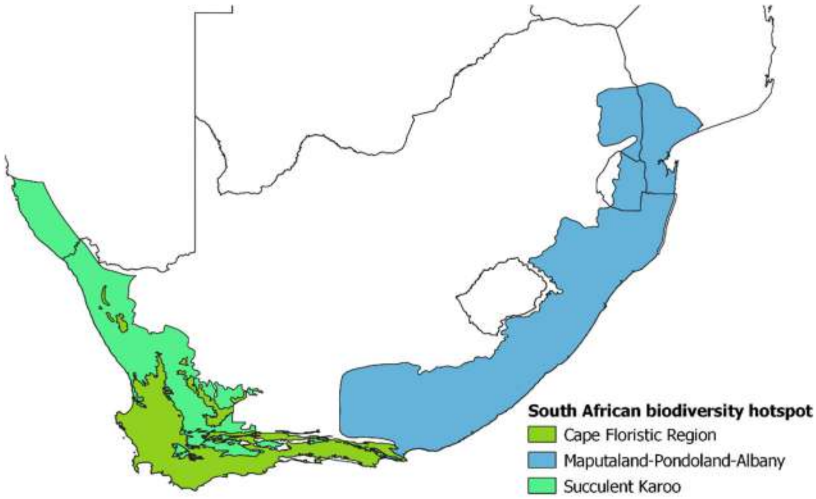


Figure 6c: South Africa's three biodiversity hotspots (Noss et al. 2015).

Biodiversity is the variety of life. Scientists studying biodiversity consider three key aspects: species richness, species evenness and species diversity. Species richness is the number of species. Species evenness refers to how uniformly abundant species are, is one species dominant with a few individuals of other species or are there a similar number of individuals of each species. Species diversity takes into account both species richness and evenness. Therefore, a population that has a high species richness with species uniformly abundant, will be more diverse than a population where a single species is dominant.

Activity 6.1

Use the case study above to assist you in answering the following questions.

6.1.1 Calculate what percentage of endemic species for each taxonomic group in table 6.1 below.

Table 6.1: South Africa's three biodiversity hotspots (Rundel and Cowling. 2013).

Taxonomic group	Species	Endemic species	Percent endemism
Plants	6356	2439	
Mammals	75	2	
Birds	226	1	
Reptiles	94	15	
Amphibians	21	1	
Freshwater Fishes	28	0	

6.1.2 Identify the taxonomic group with the highest levels of endemism in the Succulent Karoo.

____

6.2 Scientist were interested in comparing the plant diversity between the Succulent Karoo and the neighbouring Nama Karoo. Using data adapted from Cowling *et al.* (1998) in figure 6.3, to answer the following questions.

a) Succulent Karoo **b) Nama Karoo**

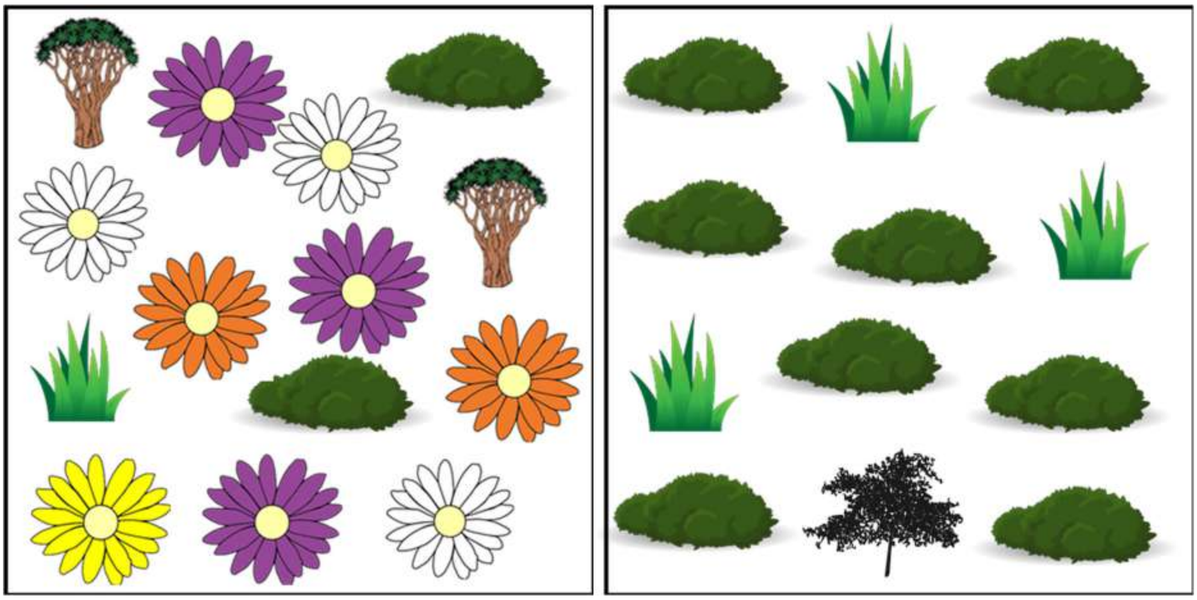


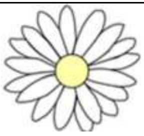
Figure 6d: Comparing the plant diversity in quadrate a) Succulent Karoo and in b) Nama Karoo (species numbers adapted from Cowling et al. 1998).

6.2.1 Calculate the plant species richness for each of the quadrates in figure 6d

a) Succulent Karoo: ______________________

b) Nama Karoo: ______________________

6.2.2 Calculate the percent contribution of each species to the plants sampled by each quadrate.

Species	Succulent Karoo	Nama Karoo
1 		
2 		
3 		
4 		
5 		
6 		
7 		
8 		

6.2.3 Which quadrate has the highest species evenness? Explain you answer.

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6.2.4 Identify the quadrate with the highest species diversity. Remember that species diversity takes into account both species richness and species evenness.

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7. Albany Thicket Biome

Figure 7: Albany Thicket biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Albany Thicket in Addo Elephant National Park

The Thicket Biome is similar to the forest biome in that it occurs in patches in the Eastern and Western Cape. Thickets occur in semi-arid areas where the rainfall is high enough to support thicket vegetation but not enough to turn the thicket into a forest. This biome is characterised by short trees or shrubs that form dense vegetation. Many plants have spines or thorns and many also have succulent stems or leaves. There are a lot of animals that are found in this biome including the elephant and the kudu.

Spekboom is a common species in this region. Photo Mthokozisi Moyo

Many succulent Euphorbia *species can be found in the Albany Thicket. Photo: capietours / CC BY-NC 4.0*

Much of Addo Elephant National Park falls within the Albany Thicket biome. Addo is famous it its elephants. Photo Mthokozisi Moyo

Case Study - Biocultural Diversity (Cocks and Wiersum 2014)

Biocultural diversity is the link between biodiversity and cultural diversity. It is the link between nature and culture. We cannot study biodiversity without understanding how people use the environment. Humans have always had interactions with nature. These interactions have resulted in the development of cultural knowledge and practices for maintaining biodiversity in the areas that they live. Several studies have shown that indigenous groups have a positive influence on the biodiversity of an area. In most parts of South Africa, indigenous groups were forced into Bantustans (homelands) and this resulted in these areas becoming highly degraded. The degradation was a result of having too many people on a small piece of land. Even though people were moved to these areas, they still maintained an appreciation for the vegetation that was found in the area. An example is the Xhosa people who show appreciation for the indigenous Albany Thicket vegetation and refer to it as the Xhosa forest (ihlathi lesiXhosa). This appreciation is strengthened by the fact that they consider these forests as sacred and they carry out a lot of ceremonies there. They believe that their ancestral spirits reside in those forests. In addition to the sacred forests, several landscapes are important for other purposes. Since they are pastoralists, grazing lands are a key resource which they have to manage carefully. This shows how nature shapes the kind of society and how indigenous people practice their culture. It is difficult to separate the two.

Activity 7.1

Use the case study above to assist you in answering the following questions.

7.1.1 How has people's relationship with nature changed?

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7.1.2 What is the isiXhosa name of the thicket?

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7.1.3 State the causes of land degradation.

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7.1.4 What are the benefits of interacting with nature?

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Climate change and the Albany Thicket

While climate change will affect the Albany Thicket Biome, land use issues (particularly long periods of livestock overstocking) do and will continue to pose a major threat to the biome. Domestic livestock (primarily goats) have decimated palatable species to open up dense thickets into bare Karoo-like conditions. The restoration of thicket could not only improve biodiversity, water yields and create jobs; but could help mitigate climate change. Albany Thicket, particularly degraded thicket, has a high potential for carbon storage (DEA 2015). Restoration projects which plant spekboom (*Portulacaria afra*) can help remove carbon dioxide from the atmosphere and restore ecosystem functions to the area. Carbon dioxide is a greenhouse gas, which traps heat from the sun in the atmosphere instead of allowing it to radiate back out into space. These greenhouse gasses act like a blanket warming up the atmosphere, contributing to climate change. Intact Albany thicket stores on average 209 tonnes/ha (76 tonnes/ha in the plants and 133 tonnes/ha in the soil; Mills *et al.* 2005). Degraded thickets can only store 114 tonnes/ha (19 tonnes/ha in the plants and 95 tonnes/ha in the soil; Mills *et al.* 2005). Across the Albany Thicket there is approximately 1.4 million hectares of degraded land that could potentially be restored to intact thicket (Mills *et al.* 2007).

Fence-line comparisons of degrade vs intact thicket, near Steytlerville in the Eastern Cape (Mills et al. 2015).

Activity 7.2

Use the case study above to assist you in answering the following questions.

7.2.1 Describe the process of how Albany Thicket acting as a carbon sink can mitigate climate change.

7.2.2 If 1.4 million hectares of degraded thicket could be restored, calculate the amount of carbon that the thicket could potentially remove from the atmosphere?

7.2.3 Explain how the thicket can be protected from becoming further degraded.

How fire frequency and bark thickness vary across a forest, thicket and savanna? (adapted from Charles-Dominique *et al.* 2017).

Fires are important in maintaining the characteristic tree grass co-existence of savannas. Fires can kill stems of young trees and prevent the trees from growing so big that they shade out and outcompete the grasses. Grass fuels fires. When there are less trees there is more grass and hence more fire, which will prevent trees from establishing. As fires are common in savanna you would expect the trees that live there to have some way of coping with fire. Some trees can survive by resprouting quickly after damage. Others grow mostly underground to avoid being damaged by fire. The juveniles of some of the taller trees will grow tall and only branch out when they have escaped the fire trap. Smaller trees are more vulnerable to fires, as a tree gets taller it eventually escapes the fire trap. Tree bark is also a key protection against fire, with bark thickness and quality important for survival (Charles-Dominique *et al.* 2017).

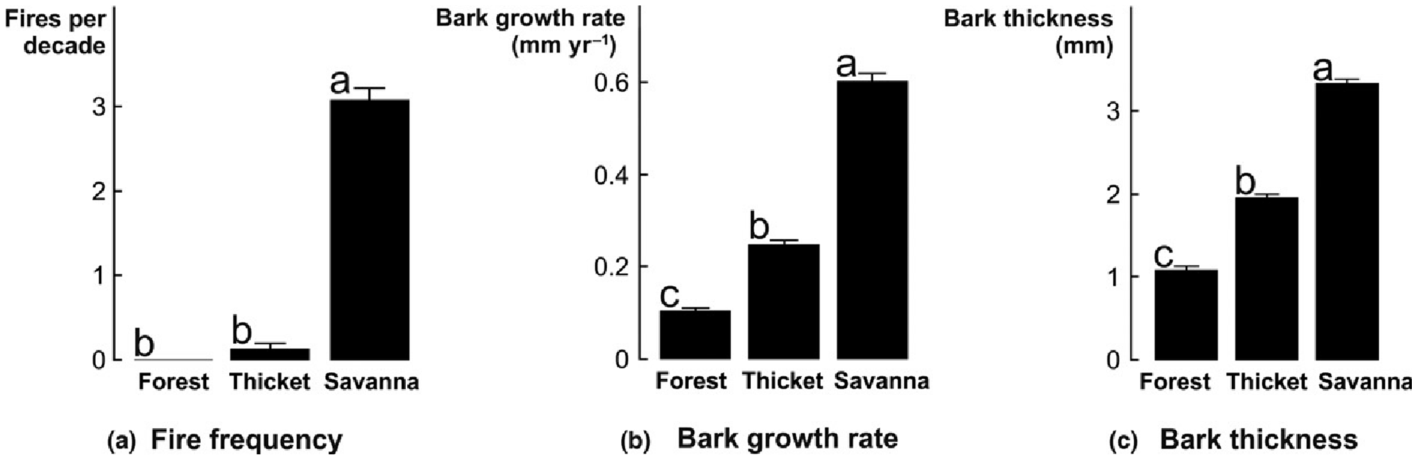

Figure 7c: Fire frequency and bark protection across a forest, thicket and savanna biome (Charles-Dominique et al. 2017).

Activity 7.3:

Use the case study above to assist you in answering the following questions.

7.3.1 Considering the vegetation structure of forests, thickets and savannas, which biome will burn the most frequently?

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7.3.2 Based on figure 7c above how does bark thickness compare across the different biomes? What contributes to the different bark thickness?

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7.3.3 Explain the benefits of faster bark growth rate in an area that receives frequent fires.

8. Indian Ocean Coastal Belt

Figure 8: Indian Ocean Coastal Belt biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Indian Ocean Coastal Belt in iSimangaliso Wetland Park

The Indian Ocean Coastal Belt (IOC) occurs on the east coast of South Africa and it stretches from the border with Mozambique to the northern half of the Eastern Cape. It contains elements of other biomes such as forests, grasslands and thicket. The higher amount of rainfall the Indian Ocean Coastal Belt biome receives sets it apart from the other biomes. The rainfall ranges from 800 mm to 1300 mm per year. Rainfall occurs throughout the year. It is hot and humid during summer and slightly drier during winter.

The Kosi Palm is only found around Kosi Bay, in southern Mozambique and northeastern KwaZulu-Natal in South Africa. Photo: Ricky Taylor / CC BY-NC 4.0

In South Africa Palm-nut Vultures are restricted to a relatively small area of the northern parts of the east coast. Photo: Frans Vandewalle / CC BY-NC 2.0

*Natal wild banana (*Strelitzia nicolai*) is a common feature of coastal vegetation from East London northwards. Photo: Tony Rebelo / CC BY-SA 4.0*

Case Study - Transformation in the Indian Ocean Coastal Belt (SANBI 2018; Jewitt et al. 2015)

Almost a quarter of South Africa's terrestrial ecosystems are threatened, highlighting the growing pressures of our ecosystems and biodiversity. The highest proportion of threatened ecosystem types are found in the Indian Ocean Coastal Belt, Fynbos and Grasslands (Figure 8c). Unsurprisingly these threatened ecosystems also have a high percentage of transformation (Figure 8d; a low percentage of remaining natural vegetation, indicated by the light green).

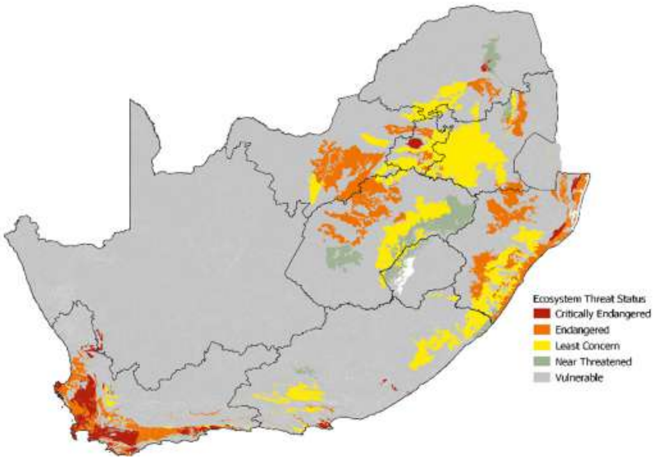


Figure 8c: Threatened terrestrial ecosystems (SANBI 2018)

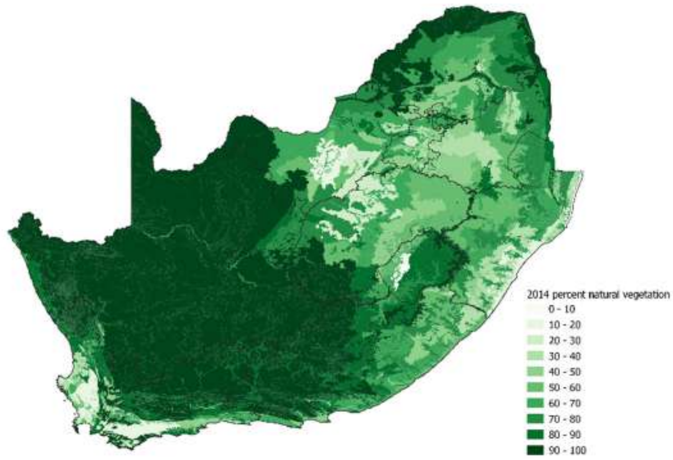
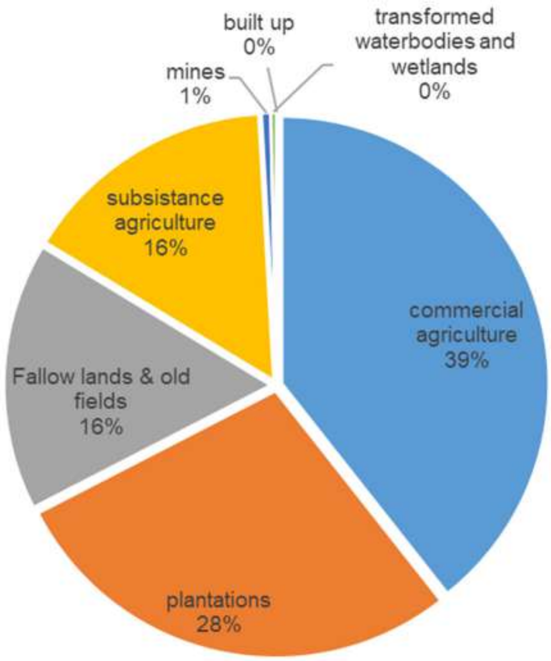


Figure 8d: Percent natural vegetation (SANBI 2018)

The Indian Ocean Coastal Belt is faced with the threat of widespread transformation. In 2014 only 79% of the land across South Africa was in a natural state, in the Indian Ocean Coastal Belt this number is much lower, 58% (Figure 8d). This habitat loss is highlighted by the high threat statuses of ecosystems in this region, as four of the six ecosystem types and 38% of the remaining natural vegetation are threatened. Within Indian Ocean Coastal Belt, and across the rest of South Africa, the clearing of natural vegetation for agriculture is the largest pressure facing terrestrial ecosystems and biodiversity (Figure 8e).



Contribution (percent area) of different land uses to transformation in the Indian Ocean Coastal Belt (SANLC 2018)

Land cover change and habitat loss (transformation) are major drivers of biodiversity loss across the world. Not only does the transformation of natural vegetation fragment the landscape, but it also alters biogeochemical cycles, climate, ecosystem processes and ecosystem resilience. These changes affect the ecosystem goods and services, which many people are dependant on, and are a significant challenge to meeting biodiversity conservation goals.

Activity 8.1:

Study the maps (Figure 8c and 8d) above and answer the questions that follow.

8.1.1 Using Figure 8d, identify at least three regions in South Africa that show very high levels of transformation.

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____

8.1.2 Explain why there is this link between the threat status of an ecosystem (Figure 8c) and the percent natural vegetation (Figure 8d).

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9. Desert Biome

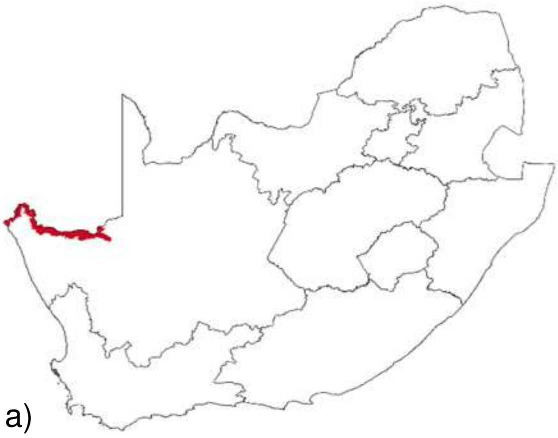
a)

Figure 9: Desert biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Desert near Richtersveld

The Desert Biome is found on the border with Namibia. In South Africa it shares some characteristics with the Succulent Karoo Biome and the Nama-Karoo Biome. The average rainfall for this biome is below 70 mm per year. It is very hot and dry and evaporation is very high. The soil is mostly sandy. Several plants are able to survive in these conditions through various strategies. Some plants are succulents and are able to retain water in their leaves. Other plants grow as geophytes with only a few leaves above the surface for photosynthesis. Other plants access ground water with very deep roots. Along the coast fog can also be a source of moisture in this very low rainfall region.


The Welwitschia is a unique plant that is specially adapted to the conditions of the Namib Desert. Photo: Keita Watanabe / CC BY-NC 4.0


*The Quiver Tree (*Aloidendron dichotomum) is *iconic succulent tree species found in the Northern Cape region of South Africa, and parts of Southern Namibia. Photo Joh Henschel*


*Gemsbok (*Oryx gazelle*) are characteristic animals of the aird regions of southern Africa.*

Activity 9.1:

Drought experiment – Can plants survive without water?

Materials: Plants (choose something that grows fast like tomatoes or any other herbs like coriander or parsley. These can be found at a nursery. You will need at least 6 plants per treatment), Ruler (to measure the plants), Notebook (to record data), Water (to water the plants).

Method:

- Cut the plants so that they have a uniform starting height. Also leave the same number of leaves on each plant for photosynthesis.
- Separate the plants into 3 treatments:
    A. These plants will be watered daily.
    B. These plants will be watered every two days (water and then skip a day).
    C. These plants will not be watered for the duration of the experiment.

The plants will be watered with 20 ml of water. You will need to place the plants in a place that will not have many disturbances. These should be places where not a lot of people pass and where anything else can interfere with the results. The plants should also receive adequate sunlight and should not receive any additional water besides the water that will be given during the experiment.

- The following measurements have to be done every day:
    i. Measure the plant height
    ii. Count the number of leaves
- Carry out this experiment for 10 days and record the results in a table like the one below (this is just an example; you are welcome to design your own). The results should be for every treatment for both the plant height and the number of leaves.

Day	Plant A1 height	Plant A2 height	Plant A3 height
0 (day experiment started. Record all initial values)			
1			

- After 10 days, the data is ready for analysis.

9.1.1 State why more than one plant per treatment was used.

____

____

____

9.1.2 Calculate the average plant height and average number of leaves in each treatment. Use the table below to assist you.

	Plant							
Day	A1	A2	A3	A4	A5	A6	A7	Average
0								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

9.1.3 What are the variables in this experiment?

Dependent:____

Independent: ____

9.1.4 Draw a bar graph of your results.

9.1.5 What conclusions can you take out of the experiment?

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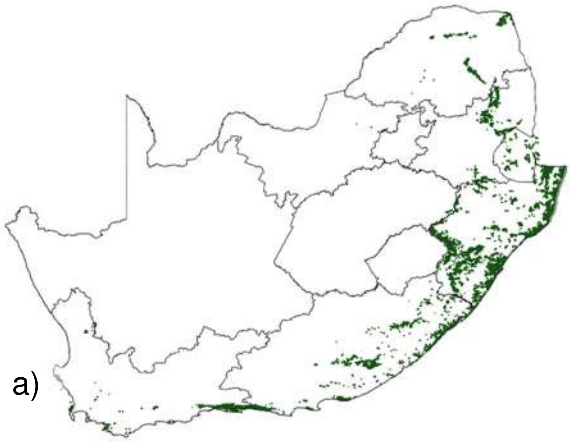
10. Forest Biome



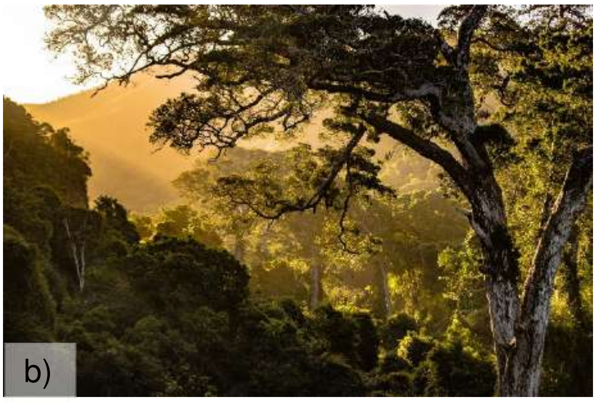


Figure 10: Forest biome of South Africa
a) Distribution of biome (SANBI 2012) and b) Forest vegetation

A forest is an area that is dominated by tall trees with overlapping canopies and there is very little grass cover. The Forest Biome occurs in patches in South Africa. It is spread across several provinces which are KwaZulu-Natal, the Western Cape, the Eastern Cape, Limpopo and Mpumalanga. Forests typically receive more than 525 mm rainfall in winter rainfall areas, in the Western Cape, and more than 725 mm rainfall in the summer rainfall areas, of the eastern parts of the country (Low & Rebelo 1996). These forests are found in frost free patches that rarely burn. Both fire and frost can influence tree growth and even kill trees, preventing trees from growing big enough to create an overlapping canopy. Natural forests are areas that have indigenous tree species growing in them. Forests play a very important role in the functioning of the earth but because of the small area they occupy in South Africa, their role is less marked than that of other South African biomes in ensuring ecosystem services like clean and plentiful water delivery and carbon sequestration.

*The Real Yellowwood (*Podocarpus latifolius*) is the South African national tree. It grows naturally in mountainous areas and forests. Photo: Tony Rebelo / CC BY-SA 4.0*

Samango Monkeys are restricted to the forest patches. Photo: seasav / CC BY-NC-ND 4.0

Ferns are common in the forest understory. Photo: Di Turner / CC BY-NC 4.0

Carbon moves from one point to another in different forms during varying times. These points are referred to as carbon pools, carbon stocks or carbon reservoirs. Some carbon atoms are transferred on a daily basis whilst other carbon atoms may take hundreds or thousands of years if they are stored in a trunk of a tree. When the carbon moves from one pool to another, we call this interaction the carbon flux. The carbon cycle (Figure 10c) is an extremely important process that controls the Earth's temperature and climate by regulating the amount of carbon dioxide in the atmosphere (SA Carbon Sinks Atlas 2017).

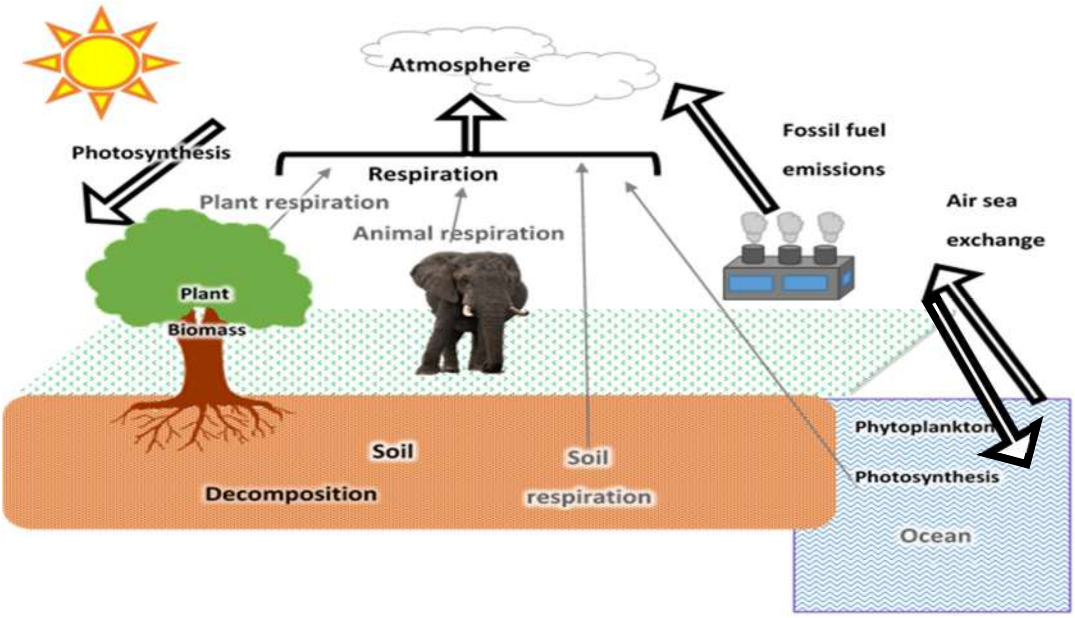


Figure 10c: The carbon cycle (Adapted from *https://www.environment.gov.za/sites/default/files/docs/carbonsinks/southafricanatlas2017****)***

If a carbon stock is able to absorb more carbon than it gives off, we refer to it as a carbon sink. Some examples of carbon sinks are vegetation, soil organic matter, wetlands and the ocean. Carbon sequestration is defined as the transfer of atmospheric carbon dioxide into other carbon stocks such as plants, biomass or into soils (SA Carbon Sinks Atlas 2017). Currently, global carbon sinks are only able to sequestrate approximately half of the carbon dioxide emitted into the atmosphere by human activities (Le Quéré *et al.* 2018).

Biomes differ in the amount of carbon they can store. There are many factors that determine the amount of carbon that is stored in a terrestrial biome such as the type of vegetation, plant productivity, temperature, moisture, soil quality, herbivory, rates of decomposition and fire cycles. While savannas and fynbos store carbon, carbon dioxide is released into the atmosphere when these vegetation types are burnt. In healthy systems this is rapidly reabsorbed when they recover from burning. Grasslands store very little carbon above ground but store enormous amounts of carbon in their soils. We need to protect grasslands from being converted to agricultural land as they are an important carbon pool in South Africa. During agriculture, the soil is often tilled (ploughed) and this causes the carbon to escape from the soil during decomposition. Through farming methods that have very little or no tilling of the soil we can conserve the carbon in the soil (SA Carbon Sinks Atlas 2017).

Activity 10.1

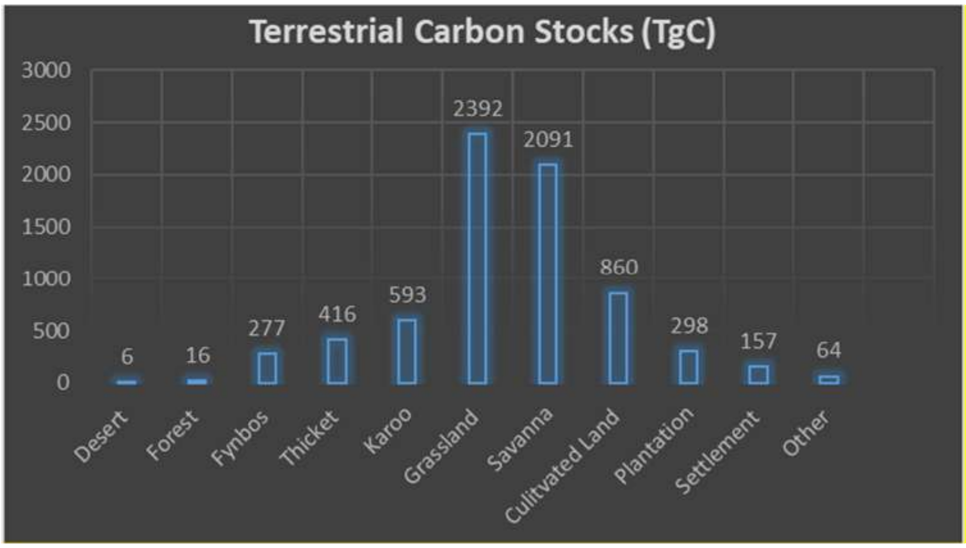


Figure 10b: South Africa's Terrestrial Carbon Stocks adapted from SA Carbon Sink Atlas 2017 (https://www.environment.gov.za/sites/default/files/docs/carbonsinks_southafricanatlas2017.pdf)

10.1.1 Identify the biome in South Africa that has the largest carbon stocks.

10.1.2 State why this biome (answered in 10.1.1) contribute to the largest carbon stocks in South Africa.

10.1.3 Discuss why forests in South Africa have a very small carbon stock.

10.1.4 Explain what the unit Tg represents.

Activity 10.2:

Read the Business Day article provided on the June 2017 Knysna fires and answer the questions that follow.

NATIONAL / SCIENCE & ENVIRONMENT

Study shows how invasive pine trees added fuel to the flames in Knysna fires

06 SEPTEMBER 2018 - 11:24 *by* DAVE CHAMBERS

A burned-out pine plantation near Harkerville shortly after the 2017 Knysna wildfire. Picture: JOHAN BAARD

Invasive pine trees significantly intensified the June 2017 Garden Route fires, scientists said on Thursday.

Pines have invaded more than 90% of the Garden Route National Park's fynbos vegetation at various densities, according to a study published in the journal Fire Ecology.

Acacias and blue gums contributed to the fuel load available for the fire, which burnt 15,000ha, destroyed 800 buildings and left seven people dead, said co-author professor Brian van Wilgen, of the Centre of Excellence for Invasion Biology at Stellenbosch University.

"By increasing the amount of fuel available to burn, the fires become more intense and more difficult to control," said Van Wilgen, whose research team included academics from Nelson Mandela University, South African National Parks and the CSIR.

They found that the severity of the fire, which claimed more than 5,000ha of commercial pine plantations, was significantly higher in plantations of invasive alien trees and in fynbos invaded by alien trees, than in uninvaded fynbos.

Plantations of pine trees in the background, and invasion by escaped pines on the Garcia Pass in the southern Cape. These invasions can substantially increase fuel loads, leading to more intense and damaging wildfires, say scientists. Picture: BRIAN VAN WILGEN

The two-year drought that preceded the fires was the worst on record and contributed significantly to the impact of the disaster, they said.

And they warned that similar fires could become more frequent as global warming takes its toll on the climate of the Southern Cape.

The aim of the study was to assess the climate, weather and fuel factors that contributed to the four-day fires, and used satellite imagery to compare the landscape before and afterwards, including the type of vegetation covering different areas.

Van Wilgen said large tracts of natural vegetation in the southern Cape had been systematically replaced with pine and eucalyptus plantations, increasing biomass from about four tons per hectare to 20 tons.

"Given that more than two-thirds of the area that burned was in one of these altered conditions, our findings demonstrate clearly that fuel loads have substantially increased compared to earlier situations when the landscape would have been dominated by regularly burned uninvaded natural vegetation," he said.

"The conditions that exacerbated the severity of the 2017 Knysna fires will occur again. People need to stay vigilant and implement fire-wise practices, and, more importantly, steer away from placing developments in high-risk areas in the long inter-fire periods.

"Our study underscores the need to implement effective programmes to control the spread of invasive alien plants, and to re-examine the economic and ecological sustainability of commercial planting of invasive alien trees in fire-prone areas."

https://www.businesslive.co.za/bd/national/science-and-environment/2018-09-06-study-shows-how-invasive-pine-trees-added-fuel-to-the-flames-in-knysna-fires/

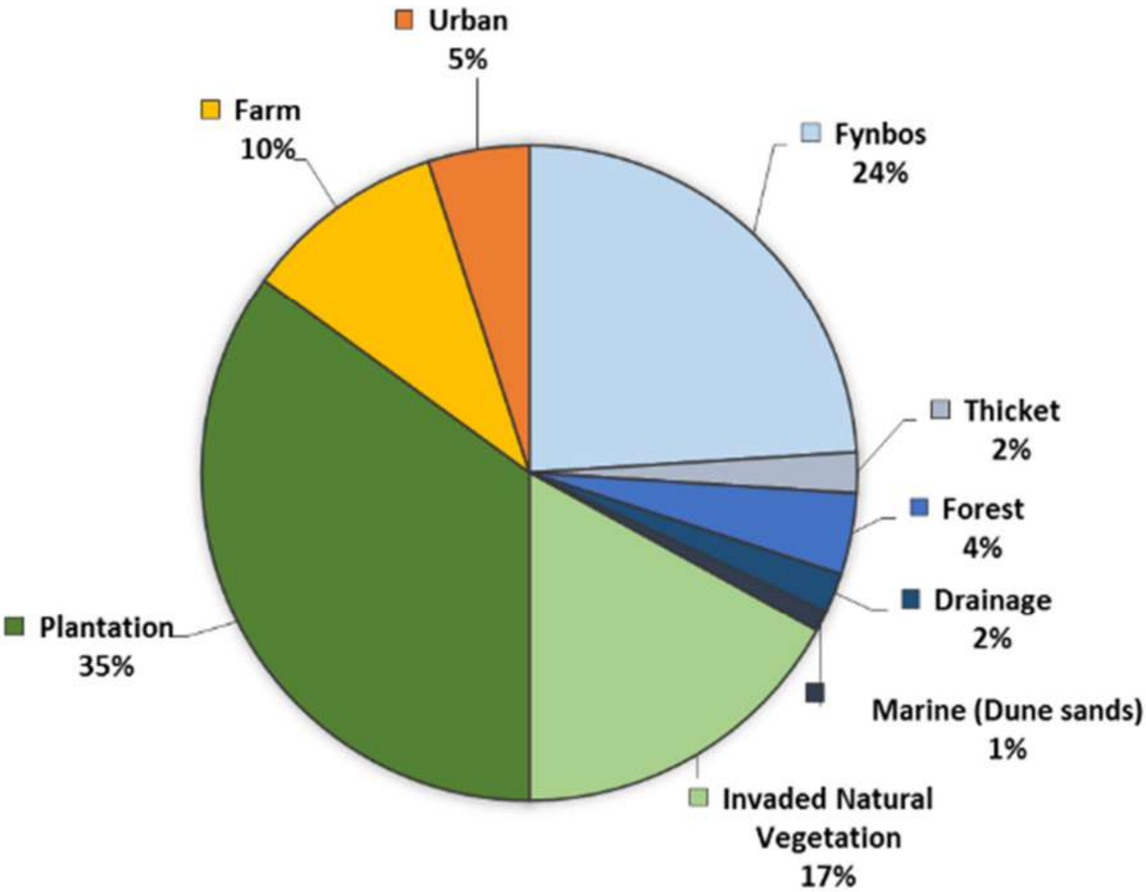


Figure 10c: Percentage area burnt in five natural (blue) and four altered land (Green, yellow and orange) cover categories in the Knysna region, South Africa, in June 2017 (Kraaij et al. 2018)

10.2.1 Use the information in the above graph, calculate the percentage of natural vegetation burnt.

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10.2.2 Identify which forest type was burnt more (natural forest or plantation). Give an explanation of why this forest type burnt more.

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Aquatic Biomes

Aquatic biomes are broadly classified by the amount of salt in the water. Freshwater is defined as having a low salt content such as rivers, lakes and wetlands. Marine biomes contain more salt, such as in estuaries and the oceans (Reece *et al.* 2011).

11. Ponds and lakes

Zeekoevlei is a freshwater lake on the Cape Flats in Cape Town.
Photo: Louise Matschke

These are freshwater bodies that do not flow. They can range from a small pond, of a few square meters, to enormous lakes covering thousands of square kilometres (Reece *et al.* 2011). The oxygen concentration, salinity and nutrient content can differ across the water bodies and can even vary with season. These properties will affect where plants and animals live in the water (Reece *et al.* 2011).

There are very few lakes in South Africa, and it is important to recognise them as special elements within the landscape. Some of these rare water bodies (Rondevlei, Princess Vlei, Zeekoevlei) are found on the Cape Flats in Cape Town. Lake Fundudzi located in the Soutpansberg in Limpopo is sacred and features in Venda folklore. Other important lakes in South Africa include the Wilderness Lakes, a series of lakes near the Garden Route Town of Wilderness in the Western Cape, and Lake Sibaya in Maputaland, far northern KwaZulu-Natal.

Case Study – Lake Sibaya

Adapted from SAEON E-newsletter by Sue J. van Rensburg, SAEON Grasslands Node, (http://www.saeon.ac.za/enewsletter/archives/2018/february2018/doc01) and Smithers *et al.* (2017)

Lake Sibaya is part of the iSimangalisa Wetland Park world heritage site and is a RAMSAR wetland of international importance. Lake Sibaya is the largest freshwater lake in South Africa but is almost completely dependent on groundwater recharge (there are no big rivers flowing into it). This area has seen significant development in recent years from commercial forestry, subsistence agriculture and rural development.

Lake Sibaya dropped by 4 m between 2001 and 2014. The major cause of drop of the lake's water level was 10 years of unusually low rainfall from 2001 to 2011. Using 50 years' worth of data, changes in the lake level have been linked to changes in rainfall. Timber plantations have increased to cover 23% of the catchment. These plantations utilise more water than natural vegetation and have decreased the lake levels by approximately 35%. The local communities also remove lake and underground water for domestic uses, although these uses have little impact on lake level.

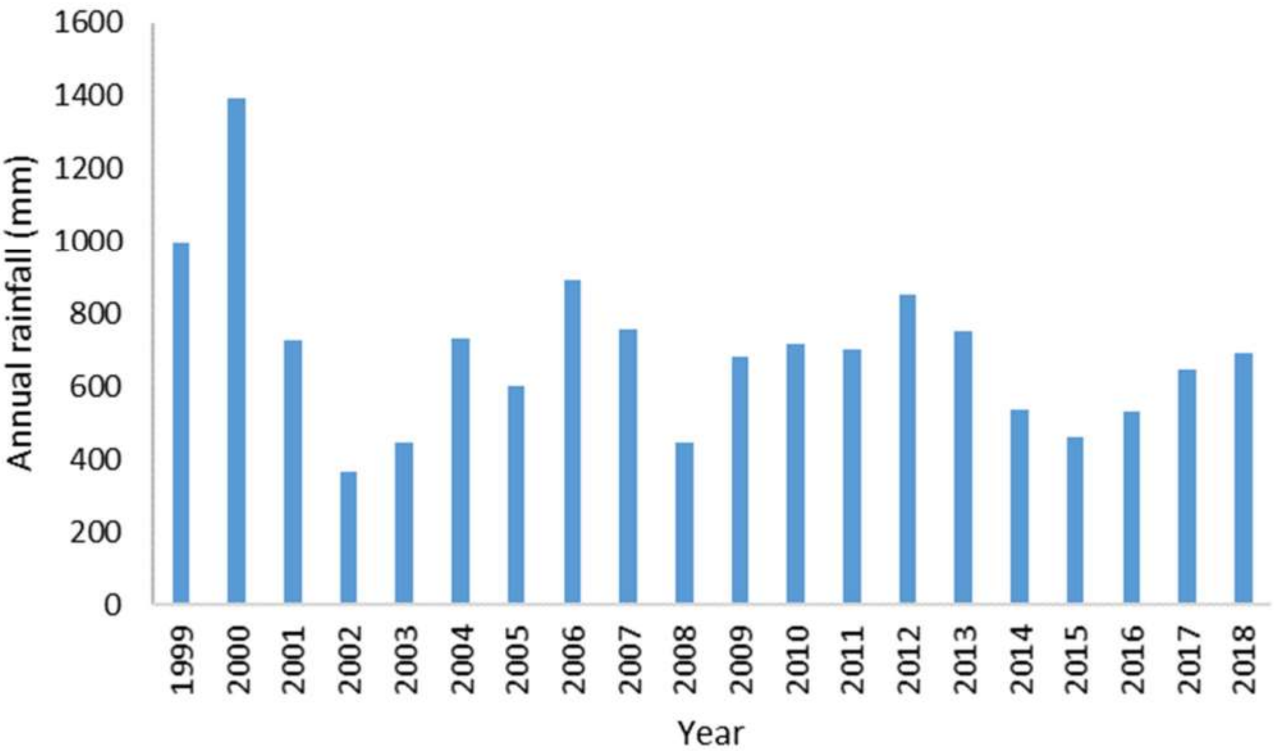

Figure 11a: Annual rainfall for Lake Sibaya between 1999 and 2018 (Precipitation: TRMM 2011)

Figure 11b: Photographs of Lake Sibaya taken between 2015 and 2019. Photographs: Sue J. van Rensburg

Activity 11:

Using the case study, photographs (figure 11b) and graph (figure 11a) above answer the following questions:

11.1.1 Lake Sibaya area received unusually low rainfall between 2000 and 2011 (Smithers *et al.* 2017), as this area typically received between 700mm – 1000mm of rain per year. Based on figure 11a (above) do you think this area received lower than normal rainfall between 2015 and 2018? Justify your answer using figure 11a.

11.1.2 Compare and contrast the above photographs (Figure 11b).

11.1.3 Give an explanation of what is causing the changes in figure 11b?

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12. Streams and rivers

The Orange River

Rivers and streams are flowing freshwater water bodies. Water travels from high lying (often mountainous) areas toward the sea or a lake. As water travels away from its source (the start of a river/stream) it picks up more water as small streams join. These many smaller streams join together to eventually form a large river. The physical and chemical characteristics of a river or stream change as the water travels from the source to the mouth. This means that the plants and animals also differ along different parts of a river or stream (Vannote et al. 1980; Davies & Day 1998).

64% of South African river ecosystems are threatened. The major threats are changes to the hydrological regime, pollution, habitat loss, biological invasions and climate change (SANBI 2018). Changes to the hydrological regime are also known as the flow regime and include everything related to the flow of water (magnitude, frequency, duration, predictability, etc.). Water abstraction, inter-basin transfers, water addition and the building of dams are key threats to changes of a rivers hydrological regime, negatively impacting species, ecosystems and ecological processes. South Africa is a semi-arid, water scarce country and disrupting flow regimes not only applies pressure on biodiversity but also on our water security. Pollution negatively impacts water quality and has led to a decline in freshwater species, negatively effecting biodiversity and the functioning of our rivers. Habitat loss (due to the clearing of land for crops, plantations, human settlements, and mining) and fragmentation is a key pressure on terrestrial habitat impacting all freshwater species. Rivers are some of the most heavily invaded ecosystems globally. Invasive plants are also known to disrupt hydrological regimes due to their high water demand. The observed and predicted increase in temperature associated with climate change will affect the hydrological cycle. The changes in the seasonality, amount and intensity of rainfall will intensify the impacts from the current pressures our rivers are experiencing.

Dry N'waswithaka river bed. Photo: Caitlin Ransom

Not all rivers have flowing surface water all year round. The perennial rivers, with a continuous flow of surface water throughout the year, tend to be the bigger rivers such as the Vaal or Tugela. But many rivers in South Africa remain dry rivers beds until there has been enough rain in the catchment. People also influence the flow of a river. Dams and water extracted from the rivers (for agricultural, industrial or domestic use) reduce the amount of water downstream and could contribute to a river drying up.

Activity 12.1

This activity uses a generalised and simplified river system that is free from all of the threats mentioned above and it is difficult to find a river system like this in South Africa.

Water near the source of a river, especially in mountain headwaters, is usually cool, clear, fast flowing, low in nutrients and has high levels of dissolved oxygen. In these waters near the source, there are few aquatic plants. Animals in this section of the river tend to rely on food (leaves, twigs, fruit) from vegetation that grows near the river. Insect larvae that are found in these fast flowing water are streamlined, with hooks and suckers to help them hold onto the rocks. As the river widens (middle zone), the water slows down and becomes murky and more nutrient rich. Sunlight now reaches the water (as the stream is now wider and trees cannot shade the whole width of the river) increasing the water temperature and making it possible for aquatic plants to thrive. These areas of a river are productive and support more animal species with individuals growing faster than in areas further upstream. Towards the mouth of the river (lower zone) the water is slow flowing, murkier, more nutrient rich but has less dissolved oxygen then further upstream. To cope with the low oxygen levels many animals have large feathery gills (Davies & Day 1998).

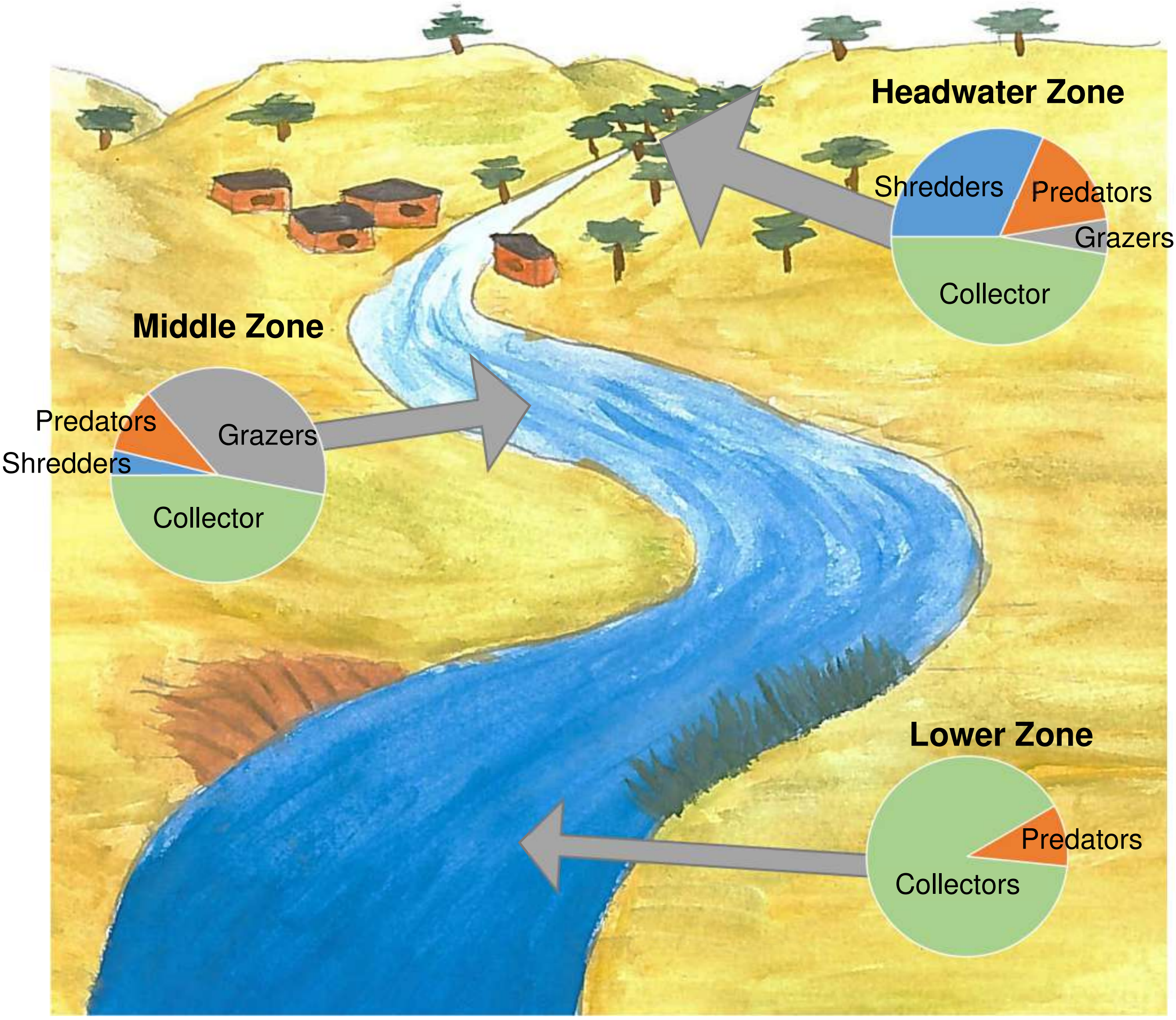
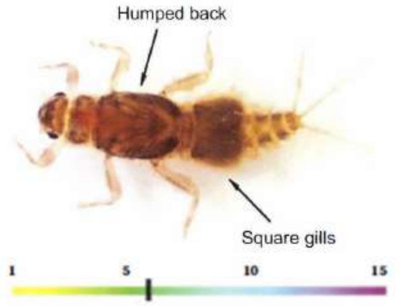
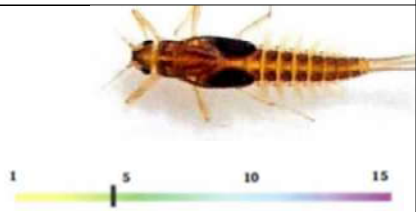
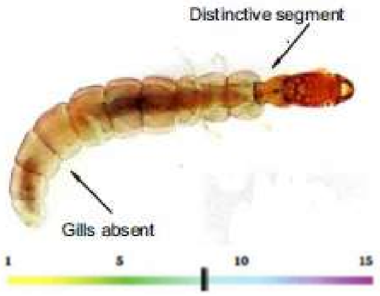
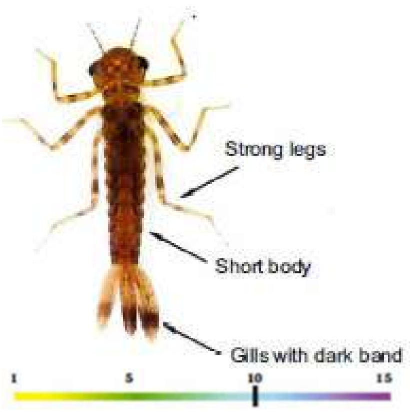
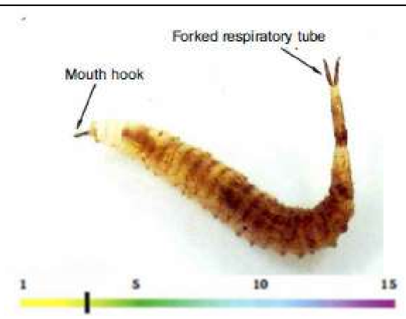


Figure 12: Diagram representing a general river ecosystem, Vannote et al.'s (1980) River Continuum Concept (Diagram adapted from Gerber & Gabriel 2002)

12.1 Use the information in the paragraph and figure 12 above to indicate in the table below where along the river (headwater, middle or lower zone) each invertebrate can be found. The sensitivity scales below each image show how sensitive the invertebrate is to pollution. On this scale, 1 is highly tolerant to pollution and 15 is extremely sensitive to pollution.

No.	Picture (Gerber & Gabriel 2002)	Description (Gerber & Gabriel 2002)	In which zone am I found?
1		This mayfly (Cainfly) is found in muddy areas and slow flowing water. It has two bulging square gills to help extract oxygen from low oxygen environments. They are moderately tolerant to pollution.	
2		This mayfly (Small minnow flies) is found in moderately fast streams. It has leaf-shaped gills along both sides of the abdomen, to help extract oxygen from the water.	
3		This caseless caddisfly (*Parecnontina*) is found in fast flowing streams. There are no gills present along the sides.	
4		This damselfly nymph is found in fast flowing streams. It has a short tapering, streamlined body. This species is found amongst vegetation. Damselflies are predators, feeding on other aquatic invertebrates.	
5		This shore fly larva is found in shallow pools or in stagnant saline water. It has a forked respiratory tube. This respiratory tube, when in contact with the air, allows the larvae to breed even in water with very low oxygen.	

Case Study - Water pollution

Freshwater is one of South Africa's most scarce and precious resources. The challenge is to ensure that it provides us with safe and sufficient drinking water. But the country is facing widespread eutrophication across many of our key water bodies (van Ginkel 2011). Eutrophication is the excessive growth of the plant and especially algae in a water body mainly due to an increase in nutrients. The growth of plants and algae is normally kept in check by factors that limit photosynthesis such as sunlight, carbon dioxide and nutrients (Chislock *et al.* 2013). When fertilizers or sewage ends up in our river systems, nutrients (specifically phosphorus) are no longer limiting growth, therefore we see this explosion of plants (such as invasive water hyacinth) and algae (cyanobacteria or blue-green algae) (van Ginkel 2011; Chislock *et al.* 2013).

Blue-green algae can pose is a risk in drinking and recreational waters to both human and animal health. Blue green algae blooms as a consequence of eutrophication have even been linked to mammal death in Kruger National Park (van Ginkel 2011). Aquatic plants can block waterways and many are invasive (e.g. water hyacinth is from the Amazon basin in South America), negatively affecting our indigenous plants and animals (van Ginkel 2011), but their removal is expensive. Eutrophication also causes 'dead zones' where there is not enough oxygen in the water to support most organisms, this occurs when these algal blooms eventually die off (as something is now limiting their growth) and the decomposition process removes dissolved oxygen from the water (van Ginkel 2011; Chislock *et al.* 2013).

It is clear that people's activities can negatively affect our rivers and freshwater systems. To track and understand the impact, it is important to measure water quality and river health. Using macroinvertebrates (animals without a backbone or bony skeleton that you can see) for biomonitoring is a rapid and cost-effective way of monitoring river health. Aquatic macroinvertebrates living near the bottom of a water body are ideal candidates for biomonitoring because they: 1) only move a little throughout their life, to allow for a better understanding of where pollution impacts are found; 2) They are usually easy to identify and collect and 3) different organisms respond differently to pollution (Graham *et al.* 2004). For example, the damselfly nymphs (no. 4 in Table 12.1) is relatively sensitive to pollution, while the shore fly larvae (no. 5 in Table 12.1) has a much lower sensitivity to pollution. The South African Scoring System (SASS) is based on this concept and uses aquatic invertebrates to monitor water quality and river health in our rivers.

Activity 12.2:

12.2.1 Define eutrophication.

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12.2.2. Identify at least three consequences.

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12.2.3 Explain why aquatic invertebrates are the ideal for biomonitoring. Include at least three reasons for your answer.

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13. Wetlands

Salt Marshes near Geelbek in West Coast National Park.
Photo Caitlin Ransom

Wetlands are areas that are covered by water (or there is water near the surface) for at least part of the year. Wetlands come in many shapes and sizes: such as marshy vleis, along the flooded river banks or streams/rivers or along the banks of a lake or estuary. Most wetlands are found along waterways or in floodplains. Wetlands are highly productive and provide a home for many insects, fish, amphibians and birds. Plants that live in wetlands need to cope with the waterlogged soils, some have developed specialised roots to do this. Wetlands also purify water and act as sponges storing water, while preventing floods and erosion (Reece *et al.* 2011).

Wetlands not only purify water, but also absorb flood water (minimising the impacts of floods) and release water during dry periods. While wetlands provide many benefits to people and the environment, they are not only the most threatened ecosystem in the country but they receive the least protection (SANBI 2019). The Convention on Wetlands (RAMSAR Convention) encourages national action and international cooperation for the conservation and sustainable use of wetlands. Currently there are 26 RAMSAR sites, which are wetlands of international importance, in South Africa.

14. Estuaries

East Kleinmond Estuary, Eastern Cape. Photo: Phakama Nodo

Estuaries occur where freshwater meets the ocean. Plants and animals living here have to deal with a wide range of salinity (saltiness of the water), from almost freshwater to salinity which may be higher than seawater. Estuaries are highly productive and are incredibly diverse ecosystems (Turpie *et al.* 2002). They are important fisheries (both fish and invertebrates), providing food. Estuaries act as nurseries for marine fish, as a link between rivers and the ocean for some species and as a feeding and stopover site for many migrating birds (Turpie *et al.* 2002). Estuaries are one of the most threatened habitats in South Africa. Over the past few decades' estuaries have experienced an increase in human disturbance, exploitation and the development of resorts and marinas. Many of these changes affect the freshwater inflows (which are siphoned off or polluted), which are vital in maintaining estuary function (Turpie *et al.* 2002).

Watch this video (https://youtu.be/Sxs1xD-jHfs) if you want to find out more about the St Lucia Estuary.

15. Marine

The South African marine environment is home to more than 13 000 marine species, with 35% of these species found nowhere else in the world (these species are called endemic). The unique geographic position of South Africa at the southern most tip of the continent results in our waters being influenced by three oceans namely the Indian Ocean on the east coast, the Atlantic Ocean on the west coast and the Southern Ocean. The influence of the three oceans results in high levels of endemism and diversity in South Africa's marine environment. The Agulhas current moves warm water from the tropics down the east coast of South Africa, whereas the west coast is cooled by the Benguela Current that upwells cold, nutrient rich water (Branch et al. 2016). The Southern Ocean brings cold polar water mixing with both the Agulhas and Benguela currents, influencing the south coast region. The South African coast can be split into three major regions: 1) the warm east coast, 2) the cold west coast and 3) the intermediate south coast. The warm east coast is home to a high diversity of species, including many colourful fish and invertebrates, and tropical coral reefs in the far north-eastern region. The west coast has lower diversity but a greater abundance of fish and invertebrates and majestic kelp forests (Branch et al. 2016). The waters surrounding South Africa are home to a fantastic diversity of habitats and ecosystems, from the rocky and sandy shores found along the beach, magnificent kelp forests hugging the west coast to the deep sea canyons and mid-shelf muds, home to weird and wonderful creatures beyond your wildest dreams.

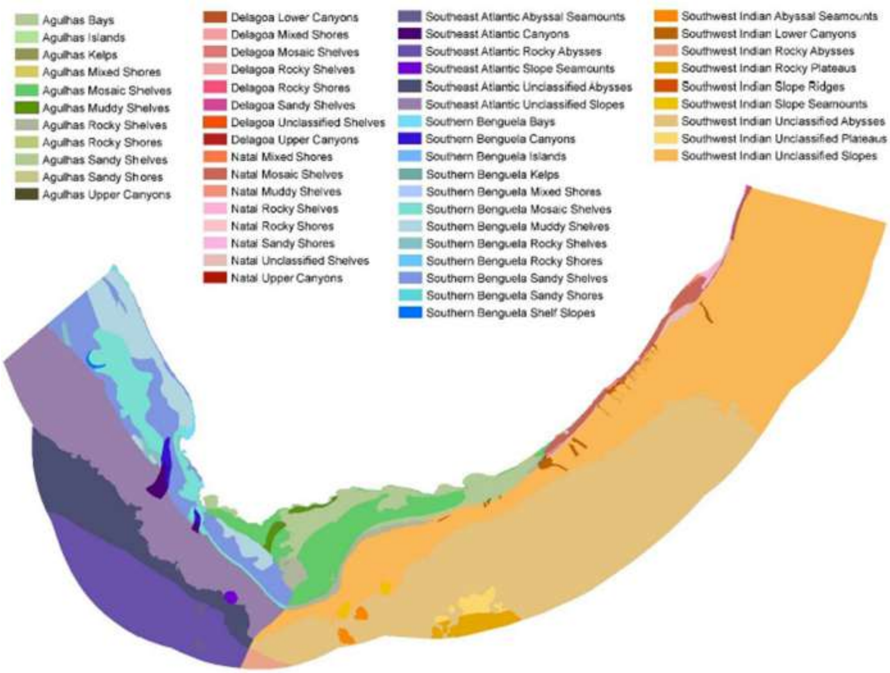


Figure 15.1: Substratum types of South Africa. This is a broader level of classification and can be divided into South Africa's 150 marine ecosystem types. This classification was refined to reflect the substrate and main features using geophysical data or geomorphological units (Sink et al. 2019).

Case Study – Marine Protected Areas

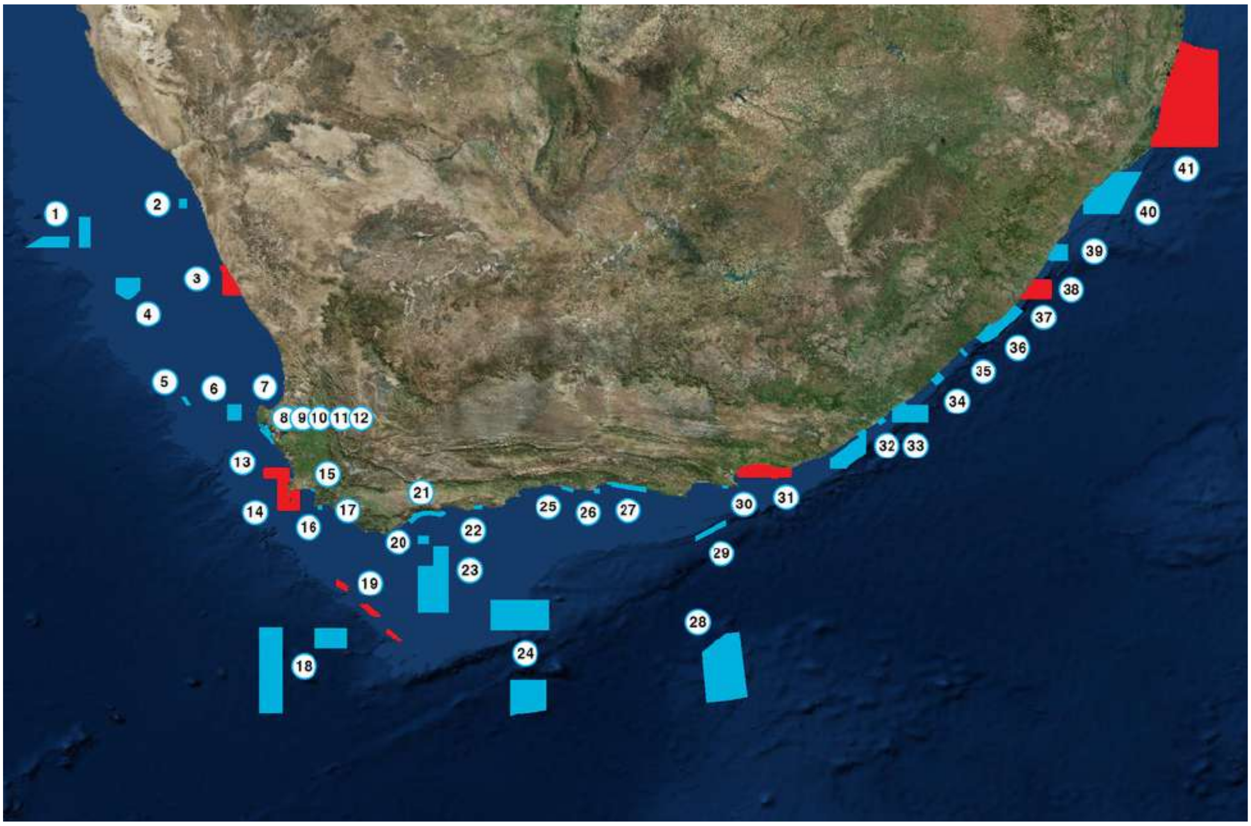
Information derived from www.marineprotectedareas.org.za

Watch the *Mzansi / MzanSea* video: https://youtu.be/LI7Xx21ESoY

This video showcases South Africa's oceans, and was created as a celebration of South Africa's 20 new Marine Protected Areas.

"A Marine Protected Area (MPA) is an area of coastline or ocean that is specially protected for the benefit of people and nature."

~ www.marineprotectedareas.org.za



1. Orange shelf Edge	15. Helderberg	29. Port Elizabeth Corals
2. Namaqua Fossil Forest	16. Betty's Bay	30. Sardinia Bay
3. Namaqua NP	17. Walker Bay	31. Addo Elephant NP
4. Childs bank	18. SE Atlantic Seamounts	32. Amathole
5. Benguela Mud	19. Browns bank Corals	33. Amathole Offshore
6. Cape Canyon	20. Agulhas Mud	34. Dwesa-Cwebe
7. Rocherpan	21. De Hoop	35. Hluleka
8. Malgas Island	22. Stilbaal	36. Pondoland
9. Marcus Island	23. Agulhas Bank Complex	37. Trafakgar
10. Jutten Island	24. SW Indian Seamounts	38. Protea Banks
11. Langebaan Lagoon	25. Goukamma	39. Aliwal Shoal
12. Sixteen-Mile Beach	26. Robberg	40. Uthukela Banks
13. Robben Island	27. Tsitsikamma	41. Isimangaliso
14. Table Mountain NP	28. Agulhas Front	42. Prince Edward Island

Figure 15.2: South Africa's Marine Protected Areas South Africa's 42 MPA lies in the Southern Ocean surrounding the Prince Edward Islands, over 2 000km south-east of Cape Town. The MPA's in red are highlighted in the activity below. (www.marineprotectedareas.org.za)

Marine Protected Areas (MPAs) play an important role in protecting the marine biodiversity, ensuring that people can continue to benefit from the oceans in the future. They can be used to keep marine ecosystems functioning properly, to support fisheries sustainability and to protect the diversity of species living in our oceans.

In 2019 South Africa declared 20 new MPAs, increasing the country's marine territory protection from 0.4% to 5%. The current 42 MPAs ensure that 87% of marine ecosystem types found within South African waters have some protection. While these new MPAs are an important step forward, South Africa needs to work towards additional protection, to meet the Ocean Economy and Sustainability goals of the United Nations. To support the long term goal of 10% ocean protection, new research and planning is needed to identify areas to prioritise for protection.

Well designed and properly managed MPAs have economic, environmental and social benefits. These **benefits** include:

- Biodiversity protection
- Climate resilience
- Fish Forever- *safe place for fish stocks to recover*
- Jobs
- Tourism
- Education
- Research
- Heritage
- Spiritual/Cultural Values
- Sustainable development

Some key **pressures** that our oceans face include:

- Fishing
- Oil & Gas
- Seabed mining
- Poaching
- Coastal development
- Pollution
- Reduced freshwater input
- Climate change
- Acidification
- Invasive species

Marine Ecosystems

South Africa is home to an amazing diversity of life and habitat types in our oceans. Here are a few of the broad marine ecosystems which are found in the waters surrounding our country.

❖ Sandy Shore

Photo: *Caitlin Ransom*

Healthy beaches are important for tourism, recreation and are cultural assets. Beaches are also important ecosystems for nutrient cycling, food supply (for humans and animals), breeding areas for turtles and home to thousands of tiny organisms that live in the sand.

Living on the sandy shore means that animals need to deal with shifting sand, tides and waves. To overcome these challenges many animals (such as plough snails and ghost crabs) burrow into the sand.

South Africa has 45 Blue Flag Beaches. A Blue Flag Beach is an international symbol of quality, with excellence in safety, amenities, cleanliness, environmental information and management.

Pressures on our sandy shores include inappropriate coastal development, mining, reduced freshwater flow and pollution.

❖ Rocky Shore

Photo: *Caitlin Ransom*

Rock pools found in the intertidal zone of a rocky shore are colourful, charismatic and easily accessible ecosystems. Young and old are drawn to these magical habitats. Seafood harvesting along the rocky shores is thought to have played a key role in human evolution.

Rock pools are home to seaweeds, many crabs, anemones, urchins, sea snails, clusters of mussels and oysters, and many other captivating sea creatures.

Pressures on rocky shores include harvesting, invasive species, coastal development, pollution and mining.

❖ Kelp Forest

Photo: Heidi / CC BY-NC 4.0

Kelp forests can be found hugging the west coast and some areas of the south coast of South Africa. Kelp have extraordinary fast growth rates and are found in highly productive, cold and nutrient rich waters. Kelp is a type of large brown seaweed, providing food and shelter for a variety of other seaweeds and animals (including rock lobster, abalone and fish).

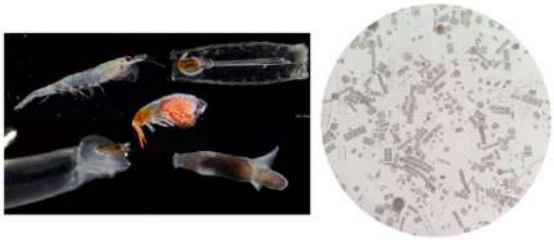
Kelp forests play an important role in buffering coastal communities from waves and storms. Kelp is also harvested and extracts are used in toothpaste, soaps, ice cream, fabric printing and as a fertiliser.

Kelp forests face multiple pressures including fishing, pollution, kelp harvesting, diamond mining (kelps are cut to provide access for mining) and climate change.

❖ Reefs and Banks

South Africa has amazing reefs that attract thousands of scuba divers. Our reef ecosystems can be divided into shallow and deep reefs. The shallow reefs can be divided into 1) hard and soft corals in the iSimangaliso Wetland Park, 2) soft corals and seaweed habitats of Aliwal shoal and 3) the vividly coloured temperate reefs of sponges, soft and lace corals along the south and west coasts. Less is known about the deep reefs, but they are known to have high diversity and endemism. Reefs support important fish species and need protection from mining, underwater noise, pollution, trawling, anchor damage and dumping of dredge spoil.

❖ Open Ocean



Photos: Dr Cristoph Held. Zooplankton and phytoplankton from the Southern Ocean

The open ocean (pelagic) water column is the realm of phytoplankton, the microscopic plants that form the food base of most marine ecosystems and produce half the world's oxygen. The open ocean and the seabed are connected. Seabed structures such as seamounts, canyons and the shelf edge all influence the flow of water, which can influence food availability. Pressures on the open ocean include fisheries (including those that target predators, such as shark's and tuna) and their bycatch (the accidental capture of animals such as birds, turtles or sharks).

❖ Seabed Ecosystems

Photo: SAEON SkiMonkey

The seabed is made up of many different types of ecosystems including soft sandy plains, muddy patches, deep canyons, rocky reefs, seamounts and mixed areas made up of sand, gravel and rocky outcrops. South Africa has 150 different seabed ecosystem types (Sink *et al.* 2019).

- Subantartic Islands

Photo: Tommy Bornman

The Prince Edward Islands are two small islands in the subantarctic Indian Ocean that are part of South Africa. The two islands (Marion and Prince Edward) are located approximately 1769 km south-east of Port Elizabeth, forming the southernmost part of South Africa. Marion Island has an area of 290 km^2, a steep coastline of 72 km and a maximum elevation at Mascarin Peak of 1242 m above sea level. The island is part of the Southern Indian Ocean Islands tundra ecoregion that is host to a wide variety of species that are critical to conservation. As a result, the South African government declared the Prince Edward Islands a Special Nature Reserve in 2003 and 180 000 km2 of ocean around the islands a Marine Protection Area in 2013, one of the world's largest environmental protection areas. Global climate change in the Southern Ocean is causing shifts in the position and intensity of the major frontal systems and changes in oceanic circulation patterns within the region of the islands. The islands' climate has as a result changed significantly over the last few decades, becoming warmer and drier, causing the loss of the ice plateau and permanent snow cover on Mascarin Peak.

Activity 15.1:

Below are descriptions of some of South Africa's Marine Protected Areas*. For each MPA, state at least three broad marine ecosystems that are protected within that MPA, using the descriptions of photographs provided.

- **iSimangaliso Marine Protected Area -** *"miracles and wonder"*

The iSimangaliso MPA is located in northern KwaZulu-Natal. It joins the original Maputuland and St Lucia MPAs and includes an offshore expansion. This MPA protects the beaches used as nesting grounds by leatherback and loggerhead turtles and stunning tropical coral reefs attracting divers from across the world. The new offshore expansion protects submarine canyons, where coelacanths (ancient fish that have been around since dinosaurs roamed the Earth), whale sharks and other interesting species are found.


Important breeding areas for turtles.


Important source of food for local people. Photo: Kerry Sink


Mangroves provide a nursery for fish and sharks.


The vibrant coral reefs of Seven Mile Reef. Photo: Geoff Spiby


Whale Sharks are gentle giants, that feed in the tropical waters near the coast. Photo: rowanwattpringle / CC BY-NC 4.0


Seapen fields provide a nursery habitat for young fish. Photo: ACEP Imida Project

15.1.1. Name at least two broad ecosystems found within the iSimangaliso MPA.

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❖ **Protea Banks Protected Area -** *"Shark Sanctuary"*

The iSimangaliso MPA is located in northern KwaZulu-Natal. It joins the original Maputuland and St Lucia MPAs and includes an offshore expansion. This MPA protects the beaches used as nesting grounds by leatherback and loggerhead turtles and stunning tropical coral reefs attracting divers from across the world. The new offshore expansion protects submarine canyons, where coelacanths (ancient fish that have been around since dinosaurs roamed the Earth), whale sharks and other interesting species are found.

Hammerhead sharks form huge schools.

Divers flock here to explore the stunning reefs.

The Sardine Run occurs every year when large shoals of sardines make their way into the waters of southern KwaZulu-Natal.
Photo: majiedqasem / CC BY-ND 2.0

15.1.2. Name at least two broad ecosystems found within the Protea Banks MPA.

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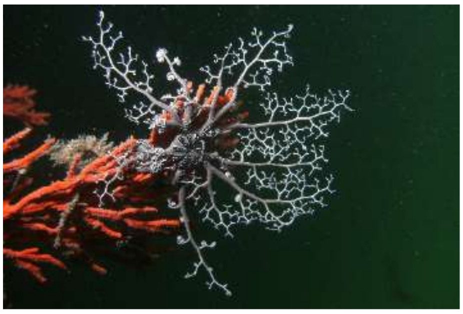
❖ **Addo Elephant National Park Marine Protected Area -** *"The Big Seven"*

Addo Elephant National Park MPA is located near Nelson Mandela Bay, Port Elizabeth. It expands the Big Five, found within Addo Elephant National Park, to create the Big Seven, by including great white sharks and whales (brydes, minke, humpback and southern right) found within the MPA. This region has the highest percentage endemic marine invertebrates and seaweeds along the South African coastline, with many of the species found nowhere else in the country. This MPA protects ecosystems like sandy beaches, coastal dunefield, rocky shore, reefs, an estuary and several offshore islands. The reefs and estuary are key to the recovery of valuable fisheries, such as abalone and kob. The protected St Croix Island and Bird Island are important feeding and breeding grounds for the endangered African penguin and Cape gannet. This MPA attracts many tourists and acts as an outdoor classroom with excellent education opportunities.



These waters are home to many interesting species. Photo: Shirley Parker-Nance

Cape Gannets on Bird Island. Photo: Felix Riegel / CC BY-NC 4.0

These waters are visited by dolphins, whales and sharks.

Endangered African penguin. Photo: Adrian Braidotti / CC BY-NC 4.0

Southern right whales. Photo: Marcia Fargnoli / CC BY-NC 4.0.

Colourful invertebrates like sponges, ascidians and feather stars. Photo: Shirley Parker-Nance

15.1.3. Name at least two broad ecosystems found within the Addo Elephant National Park MPA.

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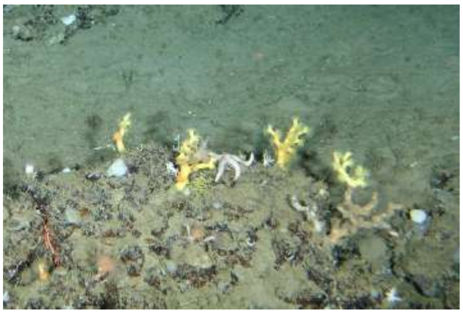
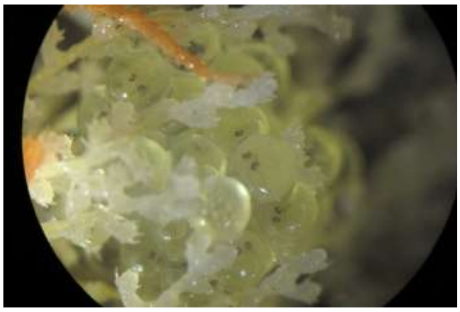
❖ **Browns Bank Corals Marine Protected Area -** *"Coral Kaleidoscope"*

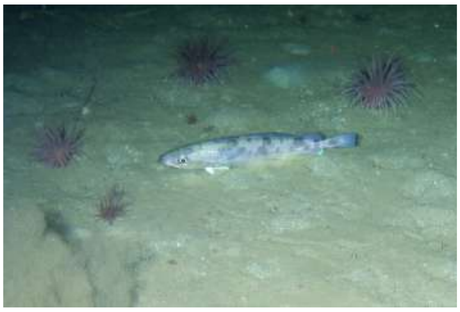
Browns Bank Corals MPA is located south of Cape Town. It consists of three separate areas between 280 and 550m deep, protecting several types of deep sea corals. This MPA is found in areas where trawlers do not venture, as the rough seafloor damages their nets. Fossilised corals, which can hold clues to past climates, have been found here. Scientists have found soft corals filled with fish eggs and they are hoping to discover new species in this area. This region also includes important hake spawning grounds, helping to keep this valuable fishery sustainable and maintaining its eco-certification.



Live cold water corals. Photo: ACEP Deep Secrets Project



Fish eggs in the arms of a bottlebrush soft coral. Photo: ACEP Deep Secrets Project



Hake spawning grounds are found within this MPA. Photo: ACEP Deep Secrets Project)

15.1.4. Name at least two broad ecosystems found within the Browns Bank MPA.

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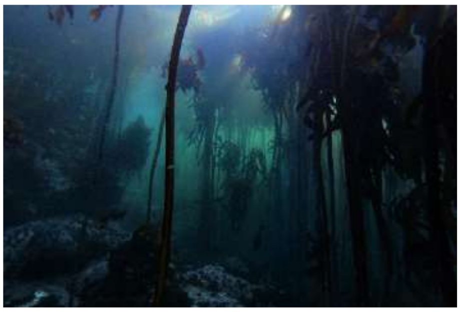
❖ **Robben Island Marine Protected Area -** *"Island Treasures"*

Robben Island MPA is located in Table Bay, Cape Town. Not only is it a historical and cultural World Heritage Site but it provides protection to marine life in a busy maritime area. The waters surrounding the island are home to magnificent kelp forests, west coast rock lobster and one of the few viable stocks of abalone, which has been severely overexploited in South Africa. The island is also a nesting ground for seabirds such as the endangered African penguin, bank cormorants and swift terns.

Table Mountain from Robben Island. Photo: South African Tourism / CC BY 2.0

Safe refuge for abalone. Photo: Peter Southwood / CC BY-SA 4.0



Tall magical kelp forests surround the island. Photo: Heidi / CC BY-NC 4.0

Important breeding ground for the African penguin. Photo: Adrian Braidotti / CC BY-NC 4.0

West coast rock lobster can be found in the kelp forests. Photo: Peter Southwood / CC BY-SA 4.0

Bank cormorants nest and feed here. Photo: Esther Jacobs / CC BY-NC 4.0

15.1.5. Name at least two ecosystems found within the Robben Island MPA.

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❖ **Namaqua National Park Marine Protected Area -** *"Forests and Flowers"*

The Namaqua National Park MPA is located in the Namaqua bioregion adjacent to Namaqualand, Northern Cape. This MPA protects several critically endangered coastal ecosystems along the South African west coast, north of St Helena Bay. This MPA is home to majestic kelp forests, deep muscle beds and the overexploited west coast rock lobster. This area is a nursery ground for one of our most valuable fish species, Cape hake. Although only proclaimed as an MPA in 2019, innovative ecological research has been taking place here since 1976. This provides and important baseline to help understand the effects of changes in the area, such as harvesting, mining, climate change and invasive species. Part of South Africa's climate adaption strategy is to protect this coastline.

The Namaqualand is famous for its flowers. Photo: Kerry Sink

Dense mussel beds provide food for shorebirds and habitat for other species. Photo: Jennifa Mohale

Kelp forests provide refuges for the west coast rock lobster. Photo: Peter Southwood / CC BY-SA 4.0

The rocky and sandy shores of this MPA are an important refuge for shorebirds. Photo: Lee / CC BY-NC 4.0

Cape Fur Seals. Photo: Felix Riegel / CC BY-NC 4.0

Dusky dolphins are found in the productive coastal waters. Photo: Kerry Sink

15.1.6. Name at least two ecosystems found within the Namaqua National Park MPA.

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15.2. Intertidal Zone

The intertidal zone is the area on a shore that lies between the high and low tide marks. The intertidal zone is sometimes underwater and at other times it is exposed to air, as the tides move in and out. This means that the plants and animals living in the intertidal zone have to cope with dramatic temperature changes and the risk of drying out when exposed to the sun when they are out of the water. Species living within the intertidal zone will either be found on the sandy shore or the rocky shore, each of which comes with their own challenges.

Activity 15.1: Tidal Territories

Living in the intertidal zone on a rocky shore means that marine invertebrates are exposed to air and submerged in water multiple times a day due to the changing tides. This creates distinct zones (Figure 15) based on how long and how often an area will be exposed. Spring tides have the greatest difference in height between high and low tide, so you get an extra high and extra low tide. Neap tides have the least difference between high and low tide. Therefore, zone A will only be submerged during spring high tide (occurs every 2 weeks) and zone E will only be exposed during spring low tide.

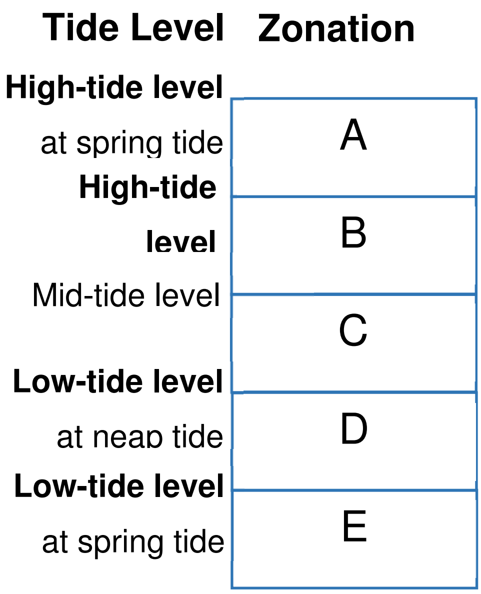

Figure 15: Intertidal zonation along a rocky shore

Table 15.1: Some of the marine invertebrates that you would find along a rocky shore in South Africa (Branch et al. 2016; Branch 2018). Photos taken by Dr. Shirley Nance-Parker.

Photograph	Description
	**Name:** Brittle-star Brittle-stars cannot live out of water. They have long thin arms attached to a small central disk. Their arms break easily, hence the name brittle-star. Brittle-stars hold up their long arms to catch food. Many feed on small particles of dead plant or animal matter.
	**Name:** Sea anemone Sea anemones are soft bodied animals related to corals and jellyfish. They are usually attached to rocks. They have a central mouth surrounded by stinging tentacles. They are predators and use their tentacles to pull prey into their mouths. Some sea anemones are able to survive out of water for a short period of time by closing up tightly and trapping water inside.

	**Name:** Periwinkles These small sea snails can remain out of water for many hours. To save moisture periwinkles cluster together to shade each other or they hide in cool cracks in the rocks. They can also seal the opening of their shells to prevent further moisture loss on the hot rocks. They feed on black lichen which grows on the rocks.
	**Name:** Mussel Mussels are attached to rock, using their "beard" or byssal threads. They rely on the waves to bring their food. Mussels are filter feeders, opening up their shell to suck in the water from which they sieve out their food particles. They are able to tightly seal their two shells together to protect their body tissues inside and prevent moisture loss. Mussels are able to cope with periods outside of water.
	**Name:** Barnacle Barnacles are crustaceans (related to crabs), but they are highly modified. Barnacles are filter feeders. When water flows over a barnacle the top of the shell opens and it extends fans of hairy legs. These legs act as a net sieving out tiny pieces of food. When out of water, barnacles tightly close the plates on top of their shell to avoid drying out and as protection from predation.
	**Name**: Starfish Starfish cannot live out of water. They have tube feet with suckers on the ends. These suckers allow them to stick to rocks but also move around. Red starfish are found along most of the South African coast line. They feed on detritus, dead plant or animal matter.
	**Name:** Limpet Limpets have a strong muscular foot, which allows them to grip tightly onto rocks. The shell is pale and rough, so it does not get as hot as if it were dark and smooth. A limpet will find a specific spot where it fits the rock just perfectly, creating a watertight seal to prevent water loss during periods when it is out of the water. They are grazers and eat algae which grow on the rocks

15.1.1 Use the information in Table 15 to complete the table below. You will need to identify the picture and decide which zone it will likely be found in, giving reasons for your answer. Photos taken by Dr. Shirley Nance-Parker.

	Picture	Who am I?	Which zone?	Why do you think I'm found here?
1				
2				
3				
4				
5				
6				
7				

16. Comparing different climate datasets

The climate in each biome is different. You are provided with different climate datasets from different parts of the country. You are provided with the total rainfall and maximum and minimum temperatures for each month in the table below.

Table 16: Four climate datasets from across South Africa.

		Station 1			Station 2			Station 3			Station 4		
Year	Month	Max T(°C)	Min T(°C)	Rain (mm)	Max T(°C)	Min T(°C)	Rain (mm)	Max T(°C)	Min T(°C)	Rain (mm)	Max T(°C)	Min T(°C)	Rain (mm)
2014	1	32,1	17,7	84,1	23,4	14,2	324,6	36,8	17,5	130,2	21,3	12,3	60,2
2014	2	32,4	18,6	7,6	21,8	13,9	222,3	35,4	16,3	46	22,4	13	24,6
2014	3	28,3	14,3	19,5	21,8	13,1	150,6	36,9	15,9	279,6	17,2	10,1	138,2
2014	4	24,6	11,9	25	19,3	9,5	46	35,7	9	15	19,5	11,8	86,6
2014	5	20,2	9,2	16,4	19	9,1	3,6	33	7	0,4	14,2	8,3	167,6
2014	6	16,7	4,1	4,6	17,5	6,3	0	32,7	3,7	0	11,2	5,9	293,9
2014	7	17,7	4,2	3,2	16,1	6,1	1,8	32,4	2,6	0,6	11,2	5,8	250,4
2014	8	19	7,1	11,7	17,8	7,8	8,9	34,6	4,7	1,6	12,7	7	247,9
2014	9	24,5	9	6,1	23,4	10	20,1	37,3	10,1	2,2	14,5	6,7	47,2
2014	10	26,3	11,7	0,8	19	8,4	135,1	37,5	10,2	10,8	18,1	9,3	31,8
2014	11	27	13,3	0,6	20	9,9	144,8	40,2	13,8	24,6	18	9,3	40,9
2014	12	30,8	16,3	0,5	22,1	12,4	216,4	38,9	12,9	114,8	18,9	10,5	39,9
2015	1	33,8	18,1	0,1	22,9	13,6	236,5	40,3	17,4	20	21,4	11,9	61,5
2015	2	30,2	15,7	0,1	23,5	12,8	90,4	39,7	17,9	50,6	19,2	11,1	25,7
2015	3	30,1	16	0,6	21,4	12,2	147,3	38,3	14,6	12,4	20,7	12	15
2015	4	24,1	11,9	5,6	19,8	10	20,8	33,7	14,8	0,8	17,1	10,4	32,3
2015	5	21,6	9,1	2,9	20,3	10,1	1,8	33,2	12,7	3,6	14,2	8,9	118,6
2015	6	15,9	5,5	54,3	15,6	6,1	6,4	30	6,4	0	11,5	6,7	194,8
2015	7	14,9	4,2	7,9	15,7	6	27,7	34,9	8,4	0,8	9,1	4,5	174
2015	8	20,4	7,1	29,5	20,3	8,6	0	34,8	6,6	0	12,8	7	121,4
2015	9	21,1	8,5	4,3	20,2	9,1	30,5	37,3	9,9	24,8	12,9	7	111,8
2015	10	28,5	12,6	7,7	24,4	11,5	51,1	40,5	15,2	8,6	16,5	9	46,5
2015	11	26,8	12,4	3,1	24,1	9,7	40,9	41,9	12,4	46,8	16,8	9,1	100,3
2015	12	32,3	17	5,1	26	13,6	88,9	42,1	18,9	10,4	20	12,1	27,9
2016	1	33,4	19	41,3	22,5	13,9	249,5	42,1	17,6	51,2	22,9	14,3	23,1
2016	2	32,3	17,3	0,9	23,3	13,8	136,7	42,6	19,7	29,4	20,7	12,6	16,3
2016	3	22,8	13,4	154,9	22,8	13,4	154,9	41	17,3	157,8	22,8	13,4	154,9
2016	4	21,7	12,2	47,2	21,7	12,2	47,2	37,5	15,2	5,6	21,7	12,2	47,2
2016	5	17,4	8,1	28,5	17,4	8,1	28,5	29,4	8,3	31	17,4	8,1	28,5
2016	6	16,8	7,1	7,6	16,8	7,1	7,6	32,4	7,1	1,5	16,8	7,1	7,6
2016	7	14,8	5,4	116,6	14,8	5,4	116,6	31,9	7,3	14,2	14,8	5,4	116,6
2016	8	17,8	7,2	67,1	17,8	7,2	67,1	35,8	7	0	17,8	7,2	67,1
2016	9	21	9,5	28,2	21	9,5	28,2	37,8	11,4	8,6	21	9,5	28,2
2016	10	18	6,9	57,7	18	6,9	57,7	39,7	10,5	34	18	6,9	57,7
2016	11	22,4	11,3	108,7	22,4	11,3	108,7	38,3	15,8	41,1	22,4	11,3	108,7
2016	12	22,7	12,2	187,2	22,7	12,2	187,2	42,1	16,7	85,2	22,7	12,2	187,2
2017	1	33,6	18,1	6,6	21,8	12,8	248,4	36,9	17,4	79,1	19,8	10,9	35,8

2017	2	34,7	18,9	20,1	20,9	13,3	436,6	37,4	18,7	45,1	20,9	11,8	12,4
2017	3	33,3	16,9	6,4	21,9	12	103,4	37,8	15,3	13,9	21	11,8	54,9
2017	4	28,9	13,9	20,4	19,9	10,8	65	35,2	12,2	37,3	20,3	13	46,7
2017	5	25,8	11,7	9,3	17,8	8,9	48,5	32,3	8,8	5,6	16,4	10	28,2
2017	6	20,9	6,9	3,9	16,7	6,7	1,5	32,1	8,2	0	11,6	5,8	213,6
2017	7	21,9	5,8	3,2	16,9	6,3	0	33,3	9,1	2,3	11,1	5,7	124
2017	8	21,5	7,2	3	16,7	5,9	20,1	33,1	8,4	2,3	10,8	5,7	116,8
2017	9	26,2	10,4	3,1	22	9,3	45,7	36,8	9,1	0	13,7	6,8	93,7
2017	10	27,8	11,4	11,9	19,6	7,5	195,4	39	12,3	61,7	14,7	6,9	119,4
2017	11	30,1	14,3	5,5	21,3	9,6	279,8	38,4	14,4	22,3	16,2	8,7	71,4
2017	12	33,1	16,7	1,7	21,2	10,7	367	40	16,2	52	18,6	10,7	40,9
2018	1	35,8	19,5	12,2	22,6	12,4	153,9	40,7	16,1	13,7	20,4	12,4	38,4
2018	2	34,9	19,1	26,1	21,6	12,9	106,2	37,7	18,2	107,6	20,9	12	63,5
2018	3	30,9	16,3	28,8	20,7	12	232,7	37,4	16,8	17	17	10,5	53,8
2018	4	28	14,2	16	19,3	11,2	165,9	34,8	13,8	26,1	16,9	9,9	127
2018	5	25	11,1	9,9	17,3	7,8	28,4	32,7	11,3	10,6	15,3	9,9	120,1
2018	6	21	7,7	9,5	16,6	6	10,9	33	7,3	0,3	12,1	7,7	241,6
2018	7	22,3	7,8	13,7	15,1	5	0,8	29,5	7,8	2,5	13,9	8,3	68,8
2018	8	22,3	7,1	0,7	17	5,5	17,3	35,4	8,5	0	9,3	4,9	193,3
2018	9	31,1	14,2	3,8	22	8,4	17,5	40,3	8,4	3,1	11,1	6,1	204,2
2018	10	31,8	14,6	1,8	20,8	9	143,3	37,2	11,2	6,3	19,8	11,8	32,5
2018	11	33,7	17,7	2,2	22,8	9,9	144,3	40,6	12,6	28,7	17,4	9,2	39,9
2018	12	35,2	18	0	25,1	12,8	228,1	42,3	15,5	67,2	17,9	10,9	93,5

16.1 Describe the factors that need to be considered when you are comparing stations?

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16.2 Complete the table below. Calculate the average annual maximum temperature for each station from table 16 above.

Table 16.2: Average annual maximum temperature (°C)

	Station 1	Station 2	Station 3	Station 4
2014				
2015				
2015				
2016				
2017				
2018				

16.3 Complete the table below. Calculate the total annual rainfall for each station from table 16 above.

Table 16.2: Total annual rainfall (mm)

	Station 1	Station 2	Station 3	Station 4
2014				
2015				
2015				
2016				
2017				
2018				

16.4 Using the table 16 above draw a bar graph for each station showing the monthly rainfall using the 2018 data.

16.5 These four sites are either found in a Savanna (SAEON's Ndlovu Node), Nama/Succulent Karoo (Tierberg), Grassland (Mike's Pass) or Fynbos (Constantiaberg). Using your understanding of rainfall in each biome that you have gained from using this manual, identify in which biome each site is found. Consider during when and how much is rains for each biome.

Station 1: Biome:__________________________

Explain your reason:

____

____

Station 2: Biome:__________________________

Explain your reason:

____

____

Station 3: Biome:__________________________

Explain your reason:

____

____

Station 4: Biome:__________________________

Explain your reason:

____

____

17. Summative assessment
Complete the table below

Biome	Distribution	Rainfall	Some characteristic species	Dominant Vegetation
Savanna				
Grassland				
Nama Karoo				
Fynbos				
Succulent				
Albany Thicket				
Indian Ocean Coastal Belt				
Dessert				
Forest Biome				

18. 60 Seconds of South African Biomes

Each learner would be given a 60 second card. A learner will then describe what is on the card by giving clues and not mention the actual word that is on the card and the other learners will have to guess the item on the card within a time of 60 seconds.

60 SECONDS OF SA BIOMES

- Carnivore
- Grassland
- Carbon Stock
- Endemic

60 SECONDS OF SA BIOMES

- Grazer
- Indian Ocean Coastal Belt
- Carbon Sinks
- Collectors

60 SECONDS OF SA BIOMES

- Bioregion
- Hydrosphere
- Mediterranean Climate
- Predators

60 SECONDS OF SA BIOMES

- Food Chain
- Dessert
- Fauna
- Ecosystem

60 SECONDS OF SA BIOMES

- Ecosystem Engineers
- Forest
- Carbon Pool
- Geophytes

60 SECONDS OF SA BIOMES

- Spekboom
- Indigenous Trees
- Lithosphere
- Biomes

60 SECONDS OF SA BIOMES

- Fracking
- Barnacle
- Biomass
- Abiotic Factors

60 SECONDS OF SA BIOMES

- Marula Tree
- Star Fish
- Coral Reefs
- Exoctic Trees

60 SECONDS OF SA BIOMES

- Fracking
- Wakkerstroom Wetland
- Aghulas Current
- Carbon Sequestration

60Seconds of South African Biomes

60 SECONDS OF SA BIOMES
- Biotic Factors
- Mussel
- Estuaries
- Intertidal Zone

60 SECONDS OF SA BIOMES
- Deforestation
- Oceans
- Periwinkels
- Mopane Tree

60 SECONDS OF SA BIOMES
- Baobab tree
- Brittle Star
- Phytoplankton
- Succulents

60 SECONDS OF SA BIOMES
- Omnivore
- Marine Biomes
- King Protea
- Carbon Dioxide

60 SECONDS OF SA BIOMES
- Vygies
- Serotiny
- Herbivore
- Namaqualand

60 SECONDS OF SA BIOMES
- Catchments
- Wetlands
- Sea Anemone
- Food Web

60 SECONDS OF SA BIOMES
- Alien Invasive Trees
- Biosphere
- Aquatic Biome
- Limpet

60 SECONDS OF SA BIOMES
- Climate Change
- Nama Karoo
- Bush Encroachment
- Benguela Current

60 SECONDS OF SA BIOMES
- Browser
- Transition Zone
- Fynbos
- Photosynthesis

19. Biome Bingo Game

When the clue is given, cross the picture that represents this clue. If you have crossed out three pictures either horizontal, vertical or diagonally then you can call out, "Bingo" and you are the first winner. The game continues to find other winners.

1.) This biome has two main vegetation types within the region, namely, Fynbos and Renosterveld.	*2.)* This is the second largest biome in South Africa.	3.) This Biome is a mosaic of forests, grasslands and thicket.	4.) This biome is fragmented and covers less than 0,25% of South Africa's surface area.	5.) Vegetation here is mainly semi desert shrub land with large amounts of succulents of which Vygies and stonecrops are particularly prominent.
6.) Is found largely in the Namib Desert along the coast of Namibia and does occur in a small part of South Africa, mainly in the Springbokvlakte area of the Richtersveld in the lower Orange River valley.	7.) This biome is the largest of all the biomes in South Africa.	8.) Grass-eating herbivores can be found in this habitat, such as black wildebeest, blesbok and eland. Rodents are also common which makes this biome an ideal hunting ground for birds of prey.	9.) Spekboom is a characteristic shrub of this biome.	10.) A biome that occurs in patches, in areas such as Knysna of the Western Cape as well as KwaZulu Natal, the Eastern Cape, Limpopo and Mpumalanga.
11.) Contains species rich formations of woody plants in South Africa. It has sparse to dense, spiny, evergreen shrub vegetation, with a tree component of varying proportions. Fires are rare in this biome.	12.) Flagship species of this biome • *Stag beetle* • *Micro frog* • *Cape sugarbird* • *Geometric tortoise*	13.) This is the second largest biome in South Africa.	14.) This biome is defined by a well-developed grassy layer with a prominent woody layer of trees and shrubs. Almost every major geological soil type occurs in this biome	11.) Contains species rich formations of woody plants in South Africa. It has sparse to dense, spiny, evergreen shrub vegetation, with a tree component of varying proportions. Fires are rare in this biome.

		
		
		

		
		
		

		
		
		

		
		
		

		
		
		

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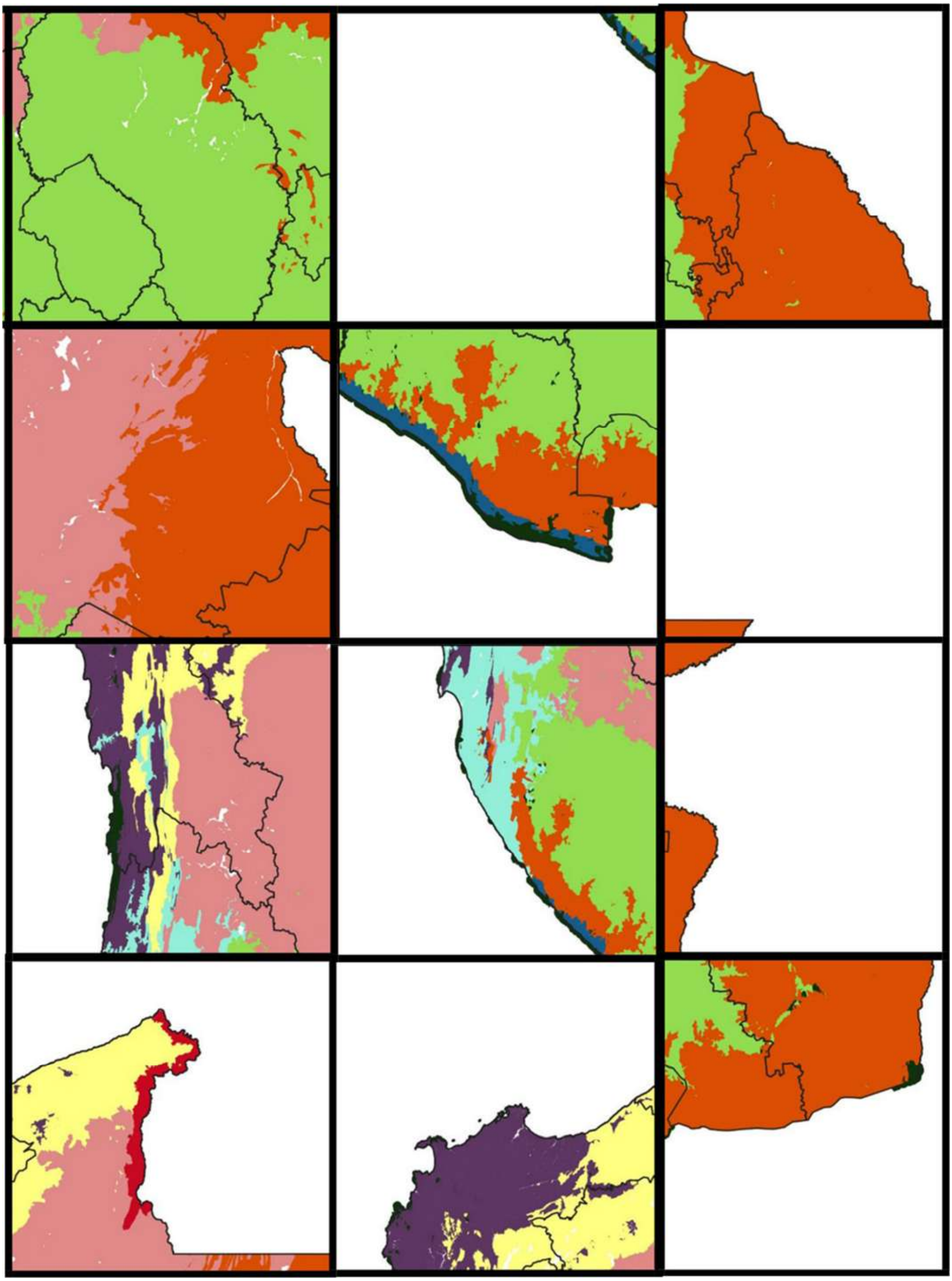
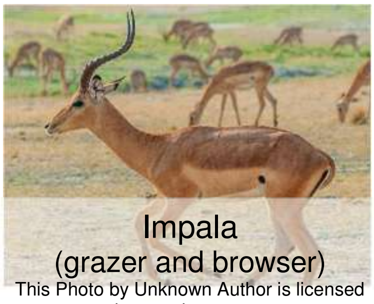
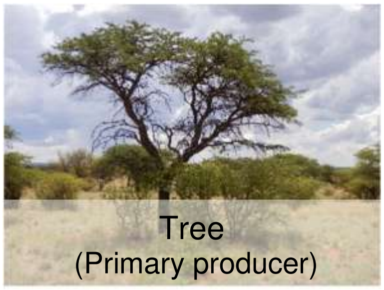
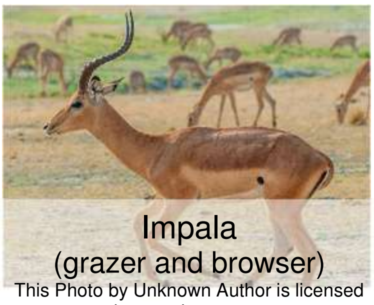
Appendix A:

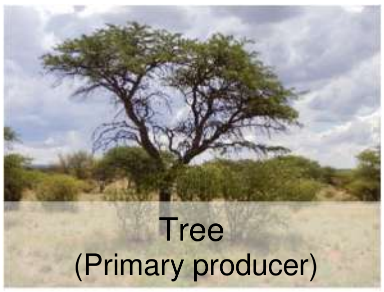


Appendix B: Pictures for food chain and web. Activity 2.2









Appendix C: Memo

Activity 1.1

1.1.1 Describe some biotic and abiotic factors that make up an environment.

Accept any reasonable answer. Biotic (living) such as plants, animals, or any organism. Abiotic (not living) such as temperature, soil, water etc.

1.1.2 Describe other examples of where all the spheres are affected by one event?

Any example where the student can demonstrate that the different spheres are connected. Such as the deforestation example

1.1.3 Compare the difference between the biomes map and the bioregions map?

Bioregions map has more divisions and is more complicated than the simplified biomes map. A biome is a broad classification based on areas sharing similar major growth forms (types of vegetation). Ecoregions are a subdivision of biomes based on variation in the species found within the biome, as not all the vegetation is the same within a biome.

Activity 1.2

1.2.1 Identify the biome that shares borders with the most biomes.

Albany Thicket

1.2.2 List the names of the biomes that share borders with the answer to 1.2.1

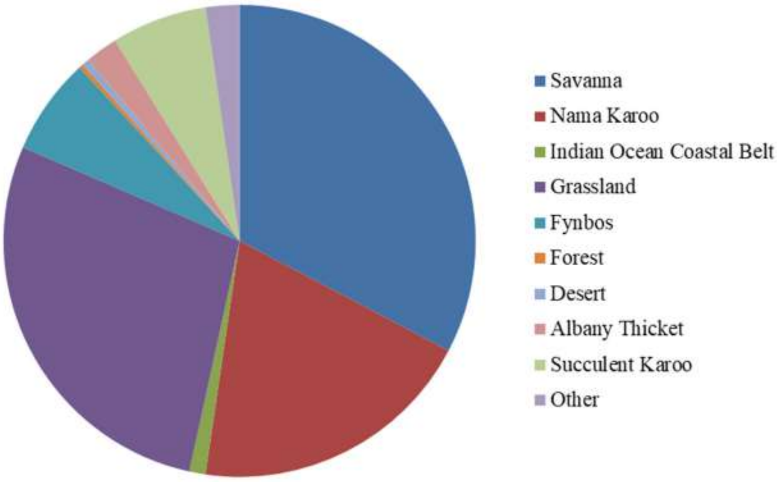
Forest, Fynbos, Grassland, Indian Ocean Coastal Belt, Nama Karoo, Savanna, Succulent Karoo

Biome	Number of Biomes Bordered	Biomes Bordered
Savanna	6	Albany Thicket, Forest, Fynbos, Grassland, Indian Ocean Coastal Belt, Nama Karoo
Nama Karoo	6	Albany Thicket, Desert, Fynbos, Grassland, Savanna, Succulent Karoo
Indian Ocean Coastal Belt	3	Albany Thicket, Savanna, Grassland
Grassland	5	Albany Thicket, Forest, Nama Karoo, Savanna, Indian Ocean Coastal Belt
Fynbos	5	Albany Thicket, Forest, Nama Karoo, Savanna, Succulent Karoo
Forest	5	Albany Thicket, Fynbos, Grassland, Nama Karoo, Indian Ocean Coastal Belt
Desert	2	Nama Karoo, Succulent Karoo
Albany Thicket	7	Forest, Fynbos, Grassland, Indian Ocean Coastal Belt, Nama Karoo, Savanna, Succulent Karoo
Succulent Karoo	4	Albany Thicket, Desert, Fynbos, Nama Karoo

1.2.3 Fill in the table below:

Biome	Area (%)	Area (km^2)	Number of Bioregions
Savanna	32.5	32.5/100 x 1219912 = 39647,14	6
Nama Karoo	19.5	19.5/1000 x 1219912 = 23788284	3
Indian Ocean Coastal Belt	1.1	1.1/100 x 1219912 = 13419.032	1
Grassland	27.9	27.9/100 x 1219912 = 340355.45	4
Fynbos	6.6	6.6/100 x 1219912 = 80514.19	12
Forest	0.3	0.3/100 x 1219912 = 3659.74	2
Desert	0.5	0.5/100 x 1219912 = 6099.56	2
Albany Thicket	2.2	2.2/100 x 1219912 = 26838.06	1
Succulent Karoo	6.5	6.5/100 x 1219912 = 79294.28	6
Other	2.3	2.3/100 x 1219912 = 28057.98	6

1.2.4 Draw a pie chart based on the table above.

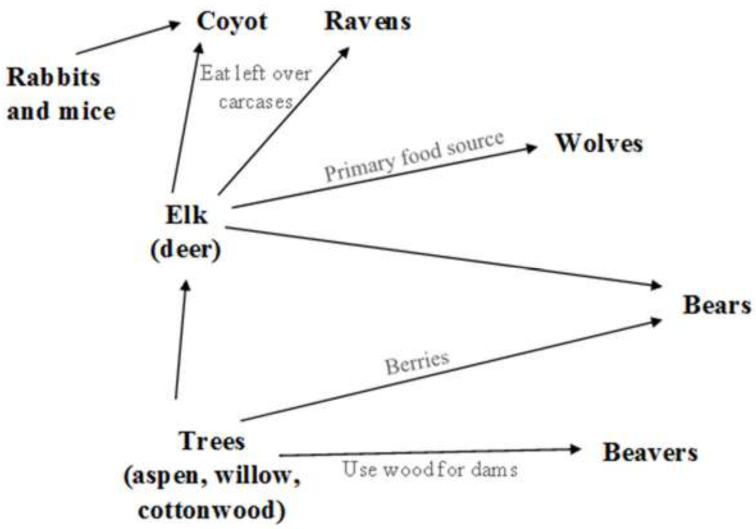


Activity 2 - Food webs, Food chains and Ecosystems

2.1.1 Construct the food chain in the ecosystem at Yellowstone Park.

Trees (aspen, willow, cottonwood) → **Elk (deer)** → **Wolves**

2.1.2 Construct a food web from this ecosystem



2.1.3 How did the introduction of wolves into the park affect the ecosystem of that park?

The wolves changed elk (referred to as deer in the video) numbers, significantly decreasing them and this reduced grazing/browser pressure releasing the native vegetation to recover and re-establish, thereby increasing biodiversity.

The increase in vegetation prevented erosion of the river banks (stabilizing them), resulting in the rivers meandering less, channels deepened and small pools formed

2.2 Use the photographs below to create the following. (Images in Appendix B)

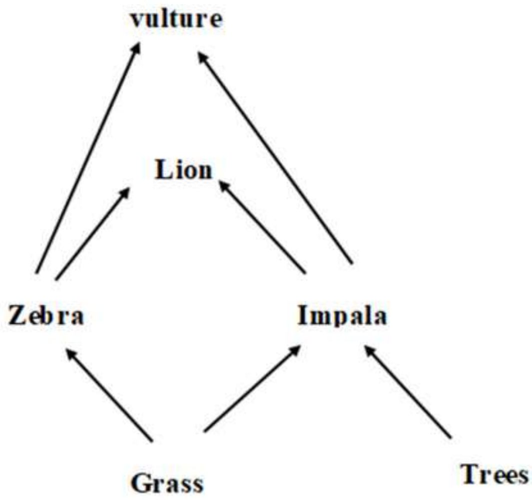
2.2.1 A food chain

Grass → **Zebra/ impala** → **Lion**

OR

Trees → **Impala** → **Lion**

2.2.2 A food web



2.2.3 Explain what could happen if the lions were removed from this ecosystem

Lions in a South African savanna play a similar role as the wolves do in Yellowstone. Lions will control the herbivore numbers

2.2.4 What would happen if elephants were added to this ecosystem

Elephants are ecosystem engineers and will change the landscape. They feed on both grass and trees. Elephants are known to kill trees (reducing the woody cover) which means that more grass will grow but that animals that browse (eat leave) may not have enough food.

3.1 Grasslands provide ecosystem services. What are ecosystem services?

i) provisioning services (e.g. water, food, and genetic resources)
ii) regulating services (e.g. flood attenuation, herbivory, pest control and pollination)
iii) supporting services (e.g. primary production, nutrient cycling) and
iv) cultural services (e.g. recreational, spiritual and cultural benefits)

Activity 3.1

3.1.1 Why is the Wakkerstroom wetland important?

Carbon Sink, maintains biodiversity, supports birdlife, filters pollution, tourism, erosion control, slows down flood waters, any other benefit of a wetland.

3.1.2 What would happen if the grasslands in this region were to be transformed even more?

Loss of biodiversity, water supply affected, increase in alien invasive species.

Activity 3.2

3.2.1 Fill in the blank cells in table 3.1 below.

Table 3.1: The conservation status of grasslands in South Africa (Carbutt 2011)

Bioregion	Total Area (km²)	Protected Area (%)	Protected Area (km²)	Transformed Area (km²)	Transformed Area (%)
Drakensberg Grassland	42177	5.9	2488,44 (42 177 x 0.059)	8220	19.5 (8 200 / 42 177) x 100
Dry Highveld Grassland	117753	1.5	1766,3 (117753 x 0.015)	32735 (117753 x 0.278)	27.8
Mesic Highveld Grassland	125044	1.6 (2001/ 125044) x 100	2001	51693	41.3 (51693 / 125044) x 100
Sub-escarpment Grassland	75615	1.4 (1081/ 75615) x 100	1081	27547	36.4 (27547/ 75615) x 100
Grassland Biome (Total)	36060 (7212 / 0.02	2.0	7212	12007,9 (36060 x 0.33)	33.3

3.2.2 Name the bioregion that will be transformed the most?
Mesic Highveld Grassland

3.2.3 Identify which bioregion is least protected?
Sub-escarpment Grassland

Table 3.2: Land use responsible for the transformation of the grassland biome

Land use Type	Transformation (km^2)	Transformation (%)
Cultivation	97874	27.10
Forestry plantations	9932	2.80
Urban and industrial areas	5843	1.62
Mines and Quarries	933	0.26
Total	114582	31.78

Use the information provided in the table above to answer the questions below.

3.2.4 Determine which land use type is responsible for the most transformation in the grassland biome?
Cultivation

3.2.5 Compare Table 3.1 and Table 3.2. and calculate what percentage that is not accounted for.
1.55%

3.2.6 Describe other activities that could be responsible for transformation in the grassland biome which are not described in this table
Alien/invasive species

3.2.7 Define the term endemic.
It means that plant and animal species are only found in a specific place and nowhere else.

Activity 4.1 Fracking in the Karoo

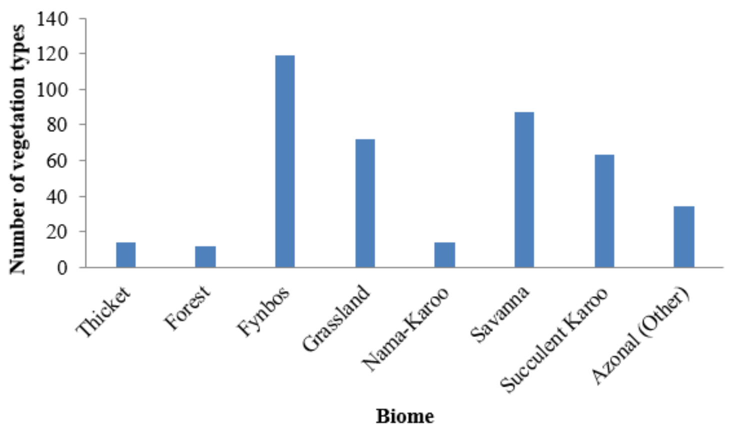
4.1.1 Name the current sources of energy in South Africa?
Coal, Wind, Solar, Hydroelectricity, Nuclear, biomass burning.

4.1.2 Tabulate the advantages and the disadvantages of fracking?

Advantages	**Disadvantages**
Another energy source	Destroys many ecosystems
Create employment	Loss of endemic species
Increase in development	Pollution (e.g. contamination of water)
	Negatively impacts water resources
	Rights of people are impacted

4.1.3 Determine the area of the Nama-Karoo which will potentially be affected by fracking.
174220 km^2 (52 / 100 x 335040)

4.1.4 Draw a graph on the number of vegetation types that are affected by fracking in each biome.



Activity 5.1 - Case Study: Fire Management in the Fynbos (Van Wilgen 2013)

5.1.1 Why is fire an important driver in this biome?
Many fynbos plants are 'born to burn' and only germinate after a fire as the heat from the fire, or chemicals in the smoke, stimulate germination. Serotiny is when plants store seeds in insulated structures such as

cones. Seeds are released when the structures open up, in response to fire as the environmental trigger. Seeds then germinate in the open post-fire habitat, free of predators and plant competitors.

5.1.2 Explain some of the consequences of this increase in the number of fires

Many fynbos plants are 'born to burn' and only germinate after a fire as the heat from the fire, or chemicals in the smoke, stimulate germination. Serotiny is when plants store seeds in insulated structures such as cones. Seeds are released when the structures open up, in response to fire as the environmental trigger. Seeds then germinate in the open post-fire habitat, free of predators and plant competitors.

Increased fire will also affect animals (eg. Bontebok & Sugar birds). The increased frequency of the fire may mean there is no food for them, as with frequent fires some plants will be unable to grow to a size that allows them to flower. For example, Cape Sugar birds depend on Proteaceae from both food and shelter. They shelter and roost in protea bushes and mainly feed on Protea nectar. This means that Sugar birds need the proteas to grow big enough to flower so they can get food (the nectar) and big enough to provide shelter. Frequent fires may mean that the Proteas are not able to grow to a big enough in size that allows them to flower.

Activity 6.1

6.1.1 Calculate what percentage of endemic species for each taxonomic group in table 6.1 below.

Table 6.1: South Africa's three biodiversity hotspots (Rundel and Cowling. 2013).

Taxonomic group	Species	Endemic species	Percent endemism
Plants	6356	2439	38.37 (2439 / 6356 x 100)
Mammals	75	2	2.67 (2 / 75 x 100)
Birds	226	1	0.44 (1 / 226 x 100)
Reptiles	94	15	15.96 (15 / 94 x 100)
Amphibians	21	1	4.76 (0 / 21 x 100)
Freshwater Fishes	28	0	0 (0 / 28 x 100)

6.1.2 Identify the taxonomic group with the highest levels of endemism in the Succulent Karoo

Plants, they are 38.37% endemic to the succulent Karoo.

6.2 Scientist were interested in comparing the plant diversity between the Succulent Karoo and the neighbouring Nama Karoo. Using data adapted from Cowling et al. (1998) in figure 6.3, answer the following questions.

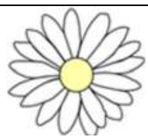
6.2.1 Calculate the plant species richness for each of the quadrates in figure

Succulent Karoo: 7

Nama Karoo: 3

Therefore, the Succulent Karoo has a higher species richness than the Nama Karoo.

6.2.2 Calculate the percent contribution of each species to the plants sampled by each quadrate

No.	Species	Succulent Karoo	Nama-Karoo
1		14.29 (2 / 14 x 100)	0 (0/ 12 x 100)
2		21.43 (3 / 14 x 100)	0 (0/ 12 x 100)
3		21.43 (3 / 14 x 100)	0 (0/ 12 x 100)
4		14.29 (2 / 14 x 100)	0 (0/ 12 x 100)
5		0 (0 / 14 x 100)	8.33 (1/ 12 x 100)
6		14.29 (2 / 14 x 100)	66.67 (8/ 12 x 100)
7		7.14 (1 / 14 x 100)	25.00 (3/ 12 x 100)
8		7.14 (1 / 14 x 100)	0 (0/ 12 x 100)

6.2.3 Which quadrate has the highest species evenness? Explain you answer

Plant species in the Succulent Karoo quadrate are more uniformly distributed (the maximum contribution of a single species is 21%) than those in the Nama Karoo, which is dominated by species 6 (contributing 67%). Therefore, the plant species in the quadrate from the Succulent Karoo are more evenly distributed.

6.2.4 Identify the quadrate with the highest species diversity. Remember that species diversity takes into account both species richness and species evenness.

The Succulent Karoo has a higher species diversity than the Nama Karoo quadrate. This is because the species in the Succulent Karoo are more evenly abundant, unlike in the Nama Karoo quadrate where species 6 is dominant. The Succulent Karoo quadrate also has four more species than the Nama Karoo.

Activity 7.1 - Case Study: Biocultural Diversity

7.1.1 How has people's relationship with nature has changed?

This is a discussion question. Loss of cultural knowledge, carrying out traditional ceremonies, connecting with ancestral spirits. Accept any reasonable answer.

7.1.2 What is the isiXhosa name of the thicket?

Ihlathi lesiXhosa

7.1.3 State the causes of land degradation.

Too many people on a small piece of land.

7.1.4 What are the benefits of interacting with nature?

This is a discussion and it is an open-ended question

Activity 7.2 - Climate change and the Albany Thicket

7.2.1 Describe the process of how Albany thicket acting as a carbon sink can mitigate climate change?

Remove CO_2 – a greenhouse gas (GHG) from the atmosphere. GHG trap heat in the atmosphere, a key contributor to climate change

7.2.2 If 1.4 million hectares of degraded thicket could be restored, calculate the amount of carbon that the thicket could potentially remove from the atmosphere?

Intact (209 $t.ha^{-1}$) – degraded (114 $t.ha^{-1}$) = 95 $t.ha^{-1}$

1 400 000ha * 95 $t.ha^{-1}$ = 133 000 000 (133 million) tonnes of carbon could potentially be removed from the atmosphere.

7.2.3 Explain how the thicket can be protected from becoming further degraded?

Prevent overstocking – don't want the goats to eat everything turning the dense thicket into bare open shrub land.

Activity 7.3 - How fire frequency and bark thickness vary across a forest, thicket and savannah (Charles-Dominique *et al.* 2017).

7.3.1 Considering the vegetation structure of forests, thickets and savannas, which biome will burn the most frequently?

Savannas because there is more grass and grass fuels fire. Thicket and forest have less grass because their canopy is more closed shading out sun-loving grass. There is also far less wind to drive fires in forests and thickets.

7.3.2 Based on figure 7c above how does bark thickness compare across the different biomes? What contributes to the different bark thickness?

Bark is thicker in the savanna. Fires are more frequent in savannas and thick bark is a form of protection.

7.3.3 Explain the benefits of faster bark growth rate in an area that receives frequent fires?

Bark provides protection, if it grows fast after being damaged that means less time that you aren't protected.

Activity 8.1

8.1.1 Using Figure 8d, identify at least three regions in South Africa that show very high levels of transformation?

1) South Western Cape, the Fynbos region, 2) Areas of the North West and Free State, grasslands regions, and 3) The east coast of SA, the IOC region. There is also a highly transformed patch in Lesotho. Look for areas of very light green (almost white), indicating high levels of transformation (0 – 10% natural vegetation remaining)

8.1.2 Explain why there is this link between the threat status of an ecosystem (Figure 8c) and the percent natural vegetation (Figure 8d).

The threatened ecosystems also show high levels of transformation. These regions have very little natural vegetation remaining and it is likely that the remaining natural vegetation may face transformation pressures. Highly transformed ecosystems are also less likely to be to be resilient to the changing conditions expected with climate change

Activity 9.1 - Drought Experiment

9.1.1 State why more than one plant per treatment was used.
Replicates are important because they show that the experiment consistently produced the same results. This means that results are more reliable and more likely to be correct.

9.1.2 Calculate the average plant height and average number of leaves in each treatment. Use the table below to assist you.
The answer will depend on the data that has been collected during the experiment.

9.1.3 What are the variables in this experiment?
Dependent: Height, Number of leaves
Independent: Day

9.1.4 Draw a graph of your results.
Graph depends on your experiment results.

9.1.5 What conclusions can you take out of the experiment?
You would expect those plants that received water to grow quickly and bigger, because they are not under simulated drought condition. But over watering may also negatively affect plant growth. Make sure the learners are able to interpret their results.

Activity 10.1

10.1.1 Identify the biome in South Africa that has the largest carbon stocks.
Grasslands

10.1.2 State why this biome (answered in 10.1.1) contribute to the largest carbon stocks in South Africa?
Grasslands cover a large area and store a lot of carbon in their soils.

10.1.3 Discuss why forests in South Africa have a very small carbon stock?
Forests make up the smallest biome in South Africa.

10.1.4 Explain what the unit Tg represents?
Tg represents teragrams which is 10^{12} and it is one of the units that carbon stocks are measured in.

Activity 10.2

Business Day article on the 2017 Knysna fires

10.2.1 Use the information in the above graph, calculate the percentage of natural vegetation burnt.
33% - invaded natural vegetation is not blue and considered altered land
24% (fynbos) + 2% (thicket) + 4% (forest) + 2 %(drainage) + 1% (marine dune sand)

10.2.2 Identify which forest type that burnt more (natural forest or plantation). Give an explanation of why this forest type burnt more?
Plantations made up 35% of the area burnt by the fire, where natural forests only contributed 4% of the total burnt area.
The exotic trees in the plantations have increased the biomass, meaning there is more fuel for fires.
These plantations have typically replaced fynbos (mainly shrubs), not necessarily the natural forest patches. Natural forest typically doesn't burn.

Activity 11.1

Using the photographs and graph above to answer the following questions:

11.1.1 Lake Sibaya area received unusually low rainfall between 2000 and 2011 (Smithers et al. 2017), as this area typically received between 700mm – 1000mm of rain per year. Based on figure 11a (above) do you think this area received lower than normal rainfall between 2015 and 2018? Justify your answer using figure 11a.
Yes, rainfall for all 3 years was below 700mm. 700mm is only experienced in the drier (more inland) regions.

11.1.2 Compare and contrast the above photographs (Figure 11b)
The water level has dropped between 2015 and 2019. You can see a sand bank to the right of the pictures in the 2019 photo which is not there in 2015. This sand bank is bigger in 2017 than in 2015, but not as big as in 2019.

11.1.3 Give an explanation of what is causing the changes in figure 11b?
Decrease in rainfall along with lowering of the water table by timber plantations. The current human water extraction doesn't impact the water level of Lake Sibaya.

Activity 12.1

12.1.1

No.	Description (Gerber & Gabriel 2002)	Where am I found?
1	Mayfly (Cainfly)	Lower Reasons: muddy, big gills
2	Mayfly (Small minnow flies)	Middle Reasons: moderately fast, gills
3	Caseless caddisfly (*Parecnontina*)	Headwater

		Reasons: fast flowing, no gills
4	Damselfly nymphs	Headwater Reasons: fast flowing, streamlined body
5	Shore fly larvae	Lower zone Reasons: saline (by the sea), respiratory tube

Activity 12.2

12.2.1 Define eutrophication

Excessive growth of plant and especially algae in a water body due to an increase in nutrients

12.2.2 Identify at least three consequences of eutrophication.

- Contaminate drinking and recreational waters
- Aquatic plants can block waterways
- Many aquatic plants are invasive and negatively affect our indigenous plants and animals
- Create 'dead zones' where there is not enough oxygen in the water for many organisms

12.2.3 Explain why aquatic invertebrates are the ideal for biomonitoring. Include at least three reasons for your answer.

- Relatively sedentary, so the only move a little throughout their life, to allow for a better understanding of where pollution impacts are found
- Generally easy to collect and identify
- Different organisms respond differently to pollution
- Rapid and cost effective

Activity 15.1

15.1.1 Use the information in table 15 to complete the table below. You will need to identify the picture and decide which zone it will likely be found in, giving reasons for your answer. Photos taken by Dr. Shirley Nance-Parker

Name	**Reasons**	**Where**
Brittle-star	Cannot live out of water.	**D/E**
Sea anemone	Some sea anemones are able to survive out of water for a very short period of time by closing up tightly and trapping water inside.	**D/E**
Periwinkles	These small snails can remain out of water for many hours.	**A**
Mussel	They are able to tightly seal their two shells to protect their body inside and prevent moisture loss.	**C**
Barnacle	Barnacles tightly close the plates on top of their shell to avoid drying out and as protection from predation.	**B**
Starfish	Starfish cannot live out of water.	**D**
Limpet	A limpet will find a specific spot where it fits the rock just perfectly, creating a watertight seal to prevent water loss during periods when it is out of the water.	**B/C**

Activity 16 - Comparing different climate datasets:

16.1 Describe the factors do you have to consider when you are comparing stations?

Make sure that the units are the same for all the datasets. Make sure that you are comparing the same time periods (can't compare monthly data to yearly data

16.2 Complete the table below. Calculate the average annual maximum temperature for each station from the table above. Average = sum of terms for each station/ number of terms for each station

Table 16.2: Average annual maximum temperature (°C)

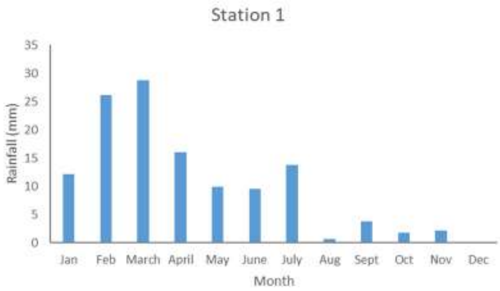
	Station 1	Station 2	Station 3	Station 4
2014	24,97	20,10	35,95	16,60
2015	24,98	21,18	37,23	16,02
2015	21,76	20,10	37,55	19,92
2016	28,15	19,73	36,03	16,26
2017	29,33	20,08	36,80	16,00
2018	24,97	20,10	35,95	16,60

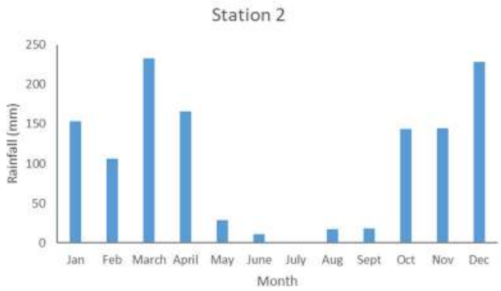
16.3 Complete the table below. Calculate the total annual rainfall for each station from the table above.

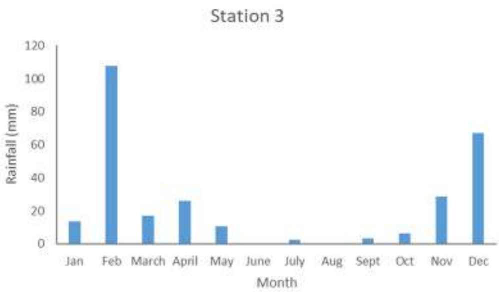
Table 16.3: Total annual rainfall (mm)

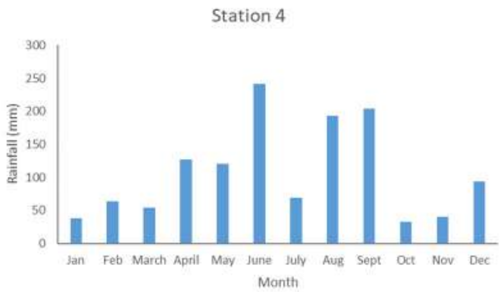
	Station 1	Station 2	Station 3	Station 4
2014	180,1	1274,2	625,8	1429,2
2015	121,2	742,3	178,8	1029,8
2015	845,9	1189,9	459,6	843,1
2016	95,1	1811,4	321,6	957,8
2017	124,7	1249,3	283,1	1276,6
2018	180,1	1274,2	625,8	1429,2

16.4 Using the table 16 above draw a bar graph for each station showing the monthly rainfall using the 2018 data.





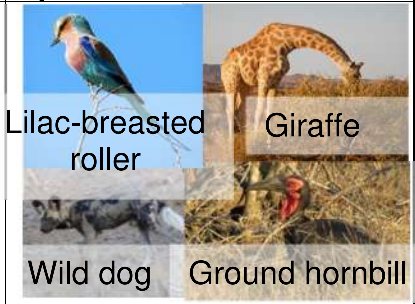
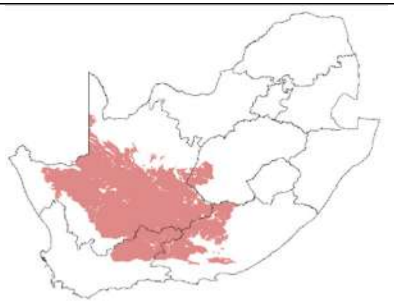


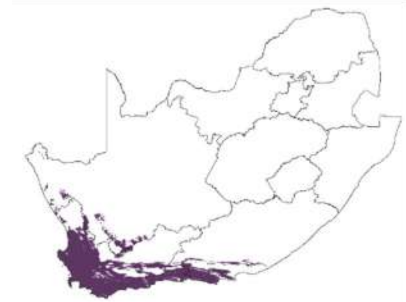
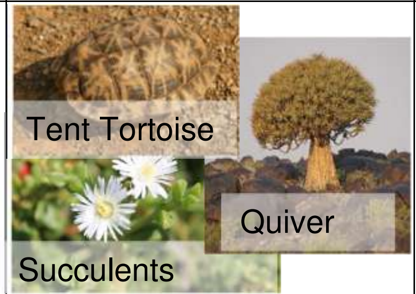
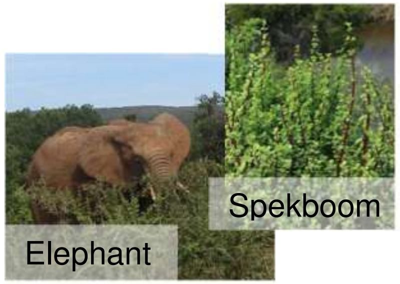


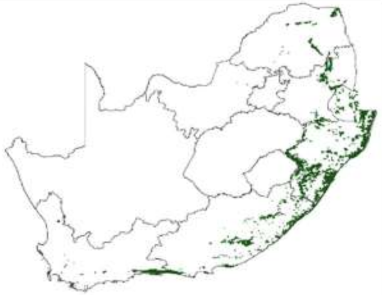
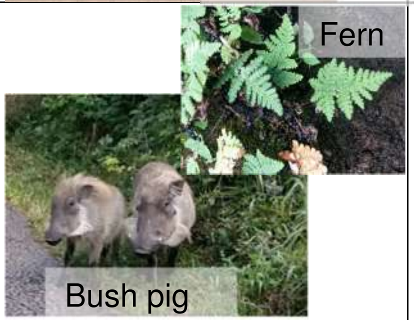
16.5 These four sites are either found in a Savanna, Nama/Succulent Karoo, Grassland or Fynbos. Using the understanding your rainfall in each biome gained using this manual identify in which biome each site is found. Consider during when and how much is rains for each biome

- Station 1: Nama/ Succulent Karoo (Tierberg)
  this site is arid and receives little rainfall
- Station 2: Grassland (Mike's Pass)
  The grassland and savanna biome both receive summer rainfall, except grasslands typically receive higher rainfall than savanna. Station 2 receives more rainfall than the Station 3, therefore Station 2 is the grassland.
- Station 3: Savanna (Ndlovu Node Office)
  Savanna, as this site receives summer rainfall and less rainfall than Station 2
- Station 4: Fynbos (Constantiaberg)
  This site receives winter rainfall

Activity 17: Summative assessment answers

Biome	**Distribution**	**Rainfall**	**Some characteristic species**	**Dominant Vegetation**
Savanna		Season: Summer Average: 235 – 1 000mm per year		 Trees and grasses
Grassland		Season: Summer Average: 400 - 2000mm per year		 Grasses and forbs
Nama Karoo		Season: Summer Average: 70 - 500mm per year		 Small leaved shrubs and grasses

Fynbos		Season: Winter Average: 200 - 800mm per year		 Proteas, ericas and restios
Succulent Karoo		Season: Winter Average: 20 - 290mm per year		 Dwarf succulent shrubs
Albany Thicket		Season: All year Average: 200 - 950mm per year		 Short trees and shrubs

Indian Ocean Coastal Belt		Season: All year Average: 800 - 1300mm per year		 Mosaic of forest, grassland and thicket
Desert		Season: Summer Average annual rainfall: 10 – 80mm Rainfall is highly variable		 Succulents, geophytes
Forest		Summer rainfall regions >525mm per year Winter rainfall regions >725mm per year		 Tall trees.

18. Memo for Bingo Game

1.) This biome has two main vegetation types within the region, namely, Fynbos and Renosterveld. **Fynbos**	*2.)* This is the second largest biome in South Africa. **Nama-Karoo**	3.) This Biome is a mosaic of forests, grasslands and thicket. **Indian Ocean Coastal Belt**	4.) This biome is fragmented and covers less than 0,25% of South Africa's surface area. **Forest**	5.) Vegetation here is mainly semi desert shrub land with large amounts of succulents of which Vygies and stonecrops are particularly prominent. **Succulent Karoo**
6.) Is found largely in the Namib Desert along the coast of Namibia and does occur in a small part of South Africa, mainly in the Springbokvlakte area of the Richtersveld in the lower Orange River valley. **Dessert Biome**	7.) This biome is the largest of all the biomes in South Africa. Savanna	8.) Grass-eating herbivores can be found in this habitat, such as black wildebeest, blesbok and eland. Rodents are also common which makes this biome an ideal hunting ground for birds of prey. **Grasslands**	9.) Spekboom is a characteristic shrub of this biome **Albany Thicket**	10.) A biome that occurs in patches, in areas such as Knysna of the Western Cape as well as KwaZulu Natal, the Eastern Cape, Limpopo and Mpumalanga. **Forest**
11.) Contains species rich formations of woody plants in South Africa. It has sparse to dense, spiny, evergreen shrub vegetation, with a tree component of varying proportions. Fires are rare in this biome. **Nama-Karoo**	12.) Flagship species of this biome • *Stag beetle* • *Micro frog* • *Cape sugarbird* • *Geometric tortoise* • *Bontebok* **Fynbos**	13.) This is the second largest biome in South Africa. **Nama-Karoo**	14.) This biome is defined by a well-developed grassy layer with a prominent woody layer of trees and shrubs. Almost every major geological soil type occurs in this biome **Savanna**	.