fundisa for change

Teaching
Marine Biodiversity

Life Sciences Grades 10–12

Janet Snow, Jone Porter, Sirkka Tshiningayamwe,
Susan Funston & Susan Wiese

environment * society * science * sustainability

This is a teacher education text. Its purpose is to expand educators' knowledge of environmental topics to support the teaching thereof in the curriculum. Teachers and teacher educators should consult CAPS documents and textbooks for specific curriculum content, as these units are not a textbook, but rather a resource for teacher education.

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Contents

UNIT 3 – CAUSES OF MARINE BIODIVERSITY LOSS AND EMERGING RESPONSES

Orientation

Introduction

What is biodiversity?

The variety of living things around us is one of the greatest wonders of life on Earth. 'Bio-diversity' (biological diversity) is the variety of life in an area, including the number of different species, the genetic wealth within each species, the interrelationships between them, and the natural areas where they occur. Biodiversity refers to the life-support systems and natural resources upon which we depend (Enviro Facts, 1993). Within this topic, we learn about species, energy levels, biomes, hotspots, causes of biodiversity loss and how to protect our precious biodiversity.

What is marine biodiversity?

Marine biodiversity refers to the variety of marine related species, genetic wealth within those species, the interrelationships between those species and the marine areas where they occur.

Why is biodiversity important?

Living things cannot exist independently of each other. All living things depend on each other and the non-living environment in a number of ways. To look after ourselves we need to look after all the parts that make up the system of which we are part.

Human activity has been changing ecosystems for thousands of years, but the pace and extent of change has increased rapidly with agricultural and industrial development. South Africa ranks as the third most biologically diverse country in the world, and is thus of major global importance for biodiversity conservation. (Enviro Facts, 2001)

Why is marine biodiversity important?

As the world is covered with approximately 70% water, marine biodiversity is important to protect. Today, just as always, humans are dependent on the Earth's resources, including the oceans, for their livelihood, health and well-being.

How do these units support teaching and learning about marine biodiversity?

As marine biodiversity is specific and requires explicit explanation this *Teaching Marine Biodiversity* resource has been developed, in addition to the Fundisa for Change *Teaching Biodiversity* materials. Marine biodiversity is not separate from teaching biodiversity in general, thus information in the *Teaching Biodiversity* resource will be referred to, allowing teachers to obtain information on biodiversity in general when appropriate.

The topics covered in this Marine Biodiversity resource are:

- Defining key marine biodiversity concepts
    - Introduction into marine species
    - Examples of marine ecological niches
    - Marine trophic levels
    - Marine ecosystems
    - Marine biomes / ecoregions
    - Examples of marine taxonomy
- Roles of marine biodiversity
    - Ecosystem services – marine related
    - Economic benefits of marine biodiversity
- Marine biodiversity loss and emerging human responses
    - Human impacts on marine biodiversity
    - Responses to marine biodiversity loss

These Marine Biodiversity units and the CAPS

The three Marine Biodiversity units have been developed to expand teachers' knowledge and expertise in ways that also support teaching the CAPS Life Sciences curriculum for Grades 10-12 (details provided in the tables below). The Marine Biodiversity units draw on the Biodiversity units but focus on marine systems.

The sections do not follow the sequence of the CAPS; instead the progression is from exploring the concept of biodiversity, the role it plays, the causes of biodiversity loss, and finally, human responses to this loss. In these three units, we support you as a teacher and facilitator or interested reader to:

- Strengthen your subject content knowledge of climate change;
- Enhance your teaching practice; and
- Support your assessment practice.

The units cannot provide all the information or perspectives on marine biodiversity, so teachers also need to consult other knowledge resources. It is also important to review carefully what is presented in textbooks and other biodiversity information sources. A list of these is provided at the end of this resource. You will find links to key concepts in the side bars.

The same is true for the methods and assessment practices suggested here. A more extensive learning resource *Methods and Processes to support Change-Oriented Learning* is provided as part of the Fundisa for Change materials.

In line with the CAPS, each of the three units relevant to teaching Marine Biodiversity in FET Life Sciences includes sections that cover:

- Subject knowledge,
- Teaching practice, and
- Assessment practice.

The Marine Biodiversity units and their relationship to teaching the CAPS

The Marine Biodiversity learning units have been developed to support teaching and learning in the Diversity, Change and Continuity knowledge strand of the Curriculum and Assessment Policy Statement (CAPS) Further Education and Training Phase Life Sciences for Grade 10-12 (Department of Basic Education, 2011). Most of the content on biodiversity in this knowledge strand falls within Grade 10 (Terms 3 and 4) and some falls within Grade 11. For details of the framework see the outlines of each unit below.

The tables in this section summarise the key concepts and processes covered in each unit, and show when and in which grades each of these topics could be taught, according to CAPS.

Unit 1: What is marine biodiversity?

This learning unit covers a number of areas necessary for exploring biodiversity:

1. Exploring key marine biodiversity related concepts (including biodiversity, species, population, genus, community, habitat, ecological niche, ecosystem, trophic levels, biological relationships)
2. South African marine biomes (also known as eco-regions)
3. Taxonomic classification (naming and grouping organisms in a hierarchically ordered system that reveals their natural or evolutionary relationships), with marine examples.
4. Identification instruments or tools (for identifying species) and taxonomic keys.

Table 1a: Unit 1 related topics within the CAPS, showing relevant grades and terms

SUB-THEME	CONTENT	BIODIVERSITY RELATED TOPICS IN CAPS – LIFE SCIENCES	GRADE	TERM
Exploring key marine biodiversity concepts	Examples of Marine Species Ecological Niche Trophic Levels (Marine Related) Marine Ecosystems: ◆ Estuaries ◆ Rocky Shores ◆ Sandy Dunes ◆ Mangroves	**Biodiversity** Enormous biodiversity on Earth (large variety of species, different ecosystems and genetic differences) with an emphasis on the extent of biodiversity and endemism in southern Africa: indigenous and endemic species.	10	4
	Biomes: ◆ Marine Biomes in general ◆ East ◆ South ◆ West	**Biomes** Terrestrial and aquatic biomes of southern Africa and how climate, soils and vegetation influence the organisms found in each. The location of the different biomes in South Africa.	10	3
	Taxonomic: ◆ Examples of marine classification	**Classification schemes** The naming of things in science: species concept and binomial system. Focus on Linnaeus (Carl von Linne) and his role in classification systems: Why do we use Latin?	10	4

Unit 2: The roles of marine biodiversity

This unit explores the roles of marine biodiversity, which include ecosystem services and contributing to human well-being. It also considers the economic benefits (both direct and indirect) of marine biodiversity.

Table 1b: Unit 2 related topics within the CAPS, showing relevant grades and terms

SUB-THEME	CONTENT	GRADE	TERM
Ecosystem services and human well-being	Life support systems and processes Biodiversity resources Livelihood sustenance	10	1, 3

Unit 3: Causes of marine biodiversity loss and emerging responses

This unit explores the causes of marine biodiversity loss, and then how humans are responding to this loss.

Table 1c: Unit 3 related topics within the CAPS, showing relevant grades and terms

<table>
<tr><th>SUB-THEME</th><th>CONTENT</th><th>BIODIVERSITY RELATED TOPICS IN CAPS – LIFE SCIENCES</th><th>GRADE</th><th>TERM</th></tr>
<tr><td>Human Impacts on Marine Biodiversity</td><td>Habitat change
Pollution
Over Exploitation
Invasive Alien Species
Climate Change</td><td>Causes and consequences of the following (relate to conditions and circumstances in South Africa):
◆ Food Security (link with population ecology dynamics)
◆ human exponential population growth;
◆ droughts and floods (climate change);
◆ poor farming practices: monoculture; pest control, loss of topsoil and the need for fertilisers;
◆ alien plants and reduction of agricultural land;
◆ the loss of wild varieties: impact on gene pools;
◆ genetically engineered foods;
◆ wastage.
◆ Loss of Biodiversity (the sixth extinction)
◆ habitat destruction: farming methods, e.g., overgrazing and monoculture, golf estates, mining, urbanisation, deforestation; loss of wetlands and grasslands;
◆ poaching, e.g., for rhino horn, ivory and 'bush meat';
◆ alien plant invasions: control using mechanical, chemical and biological methods; and
◆ indigenous knowledge systems and the sustainable use of the environ-ment e.g., devils' claw, rooibos, fynbos, the African potato (Hypoxis) and Hoodia.

Practical observation of ONE example of human influence on the environment in the local area (e.g. the impact of alien species on biodiversity). Written report on the chosen example.</td><td>11</td><td>4</td></tr>
<tr><td>Responses to Marine Biodiversity</td><td>Policy and Legislation
Reducing Over Exploitation
Marine Reserves</td><td></td><td></td><td></td></tr>
</table>

Unit 1

What is marine biodiversity?

Subject Content Knowledge

This learning unit covers a number of areas necessary for exploring biodiversity and marine biodiversity in particular:

1. Exploring key concepts (including biodiversity, species, population, genus, community, habitat, ecological niche, ecosystems, trophic energy levels, relationships between organisms, adaptation of species to the environment and competition)
2. South African marine biomes or marine eco-regions
3. Taxonomic classification (naming and grouping organisms in a hierarchically ordered system that reveals their natural or evolutionary relationships)
4. Identification instruments or tools (for identifying species)

Unit 1 Marine Biodiversity related topics within the CAPS, showing relevant grades and terms

SUB-THEME	CONTENT	BIODIVERSITY RELATED TOPICS IN CAPS – LIFE SCIENCES	GRADE	TERM
Exploring key marine biodiversity concepts	Examples of Marine Species Ecological Niche Trophic Levels (Marine Related) Marine Ecosystems: ◆ Estuaries ◆ Rocky Shores ◆ Sandy Dunes ◆ Mangroves	**Biodiversity** Enormous biodiversity on Earth (large variety of species, different ecosystems and genetic differences) with an emphasis on the extent of biodiversity and endemism in southern Africa: indigenous and endemic species.	10	4
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Exploring key concepts

It is important to develop a foundation for a progressive understanding of biodiversity. This includes understanding the levels of biodiversity and the associated terminologies. The concept of biodiversity is based upon the principle of hierarchies and the basic building block is the species. Biodiversity refers to life on Earth in all aspects of its varieties. However, biodiversity is a complex concept and one needs to be able to specify what kind of biodiversity is being discussed and how it is being measured.

To teach the topic of biodiversity, it is necessary to define it first and explain key terms associated with it. This enables learners and teachers to develop the necessary vocabulary for understanding the topic.

Biodiversity (biological diversity) (CAPS – Grade 10, Term 4) (Grade 11, Term 1)

This is the variety of life and life systems. There is biodiversity at different levels or components of biological organisation.

> *The variety of living organisms on Earth is yet unknown, with many species still to be discovered. Consider and discuss the implication of this against a background of increasing demand on land and the human impacts on biodiversity.*

The levels/components of biodiversity are:

Biodiversity Component/Level 1 *Ecological Diversity* (Variation of Life Systems)	One component of biodiversity is the variation of life systems or *ecological diversity* (**ecosystem diversity**). This includes a range of aquatic and terrestrial systems. Each ecological system has its own unique environmental conditions that suit certain communities of species.
Biodiversity Component/Level 2 *Species Diversity* (Variety of Living organisms)	This biodiversity component includes a full range of species, known as **species diversity**. This is a range of life forms which occupy and are adapted to different ecosystems. The variety of living organisms includes animals, plants, viruses, bacteria, protists and fungi. Plants are the major producers in nearly all ecosystems, they include trees, shrubs, herbs, bushes, grasses, vines, ferns, mosses, and algae (seaweed is a form of algae). *Species diversity is important in increasing the capability of an ecosystem to be resilient against a background of changing environmental (e.g. climatic) conditions. Species are an important biological resource in that they provide us with products such as food, medicines and raw materials and have a variety of human uses (both known and with future potential).*
Biodiversity Component/Level 3 *Genetic Diversity* (Variability within same species)	This biodiversity component includes the variability within same species of a living organism or **genetic diversity**. *There are variations in the genetic make-up of each individual organism within each species which are important for the maintenance of reproductive vitality, resistance to disease and the adaptation to changing environmental conditions.*

Marine biodiversity

Biodiversity can be defined in several ways, but it generally refers to the number of species types in a particular ecosystem. ***Marine biodiversity*** therefore refers to the species richness and abundance in the world's oceans and seas. And since the world is covered with approximately 70% water, the amount of life in the oceans is enormous. Marine biodiversity is important to protect because today, just as always, humans are dependent on the Earth's resources for their livelihood, health and well-being.

Species

A species is the basic unit of taxonomic or biological classification. This can be elaborated as follows:

a) A *species* is a group of individual organisms that share common attributes but is morphologically, physiologically and biochemically distinct from other groups.

b) Genetically, this is a group of individual organisms that in nature is actually and potentially capable of interbreeding and producing fertile offspring but does not breed with individuals of other groups (i.e. it is reproductively isolated from other such groups). These individual organisms living together in a particular area (*niche*) comprise a natural *population*.

c) Members of a species have a common name, which is subordinate to (falls under) a *genus* (which groups together species with similar attributes). As a result a species has two names in taxonomic classification: the genus name and species name, giving rise to *binomial nomenclature* (a two-name naming system). The genus (*generic*) name is the first word/name of a scientific name of a species, while the second name is used to differentiate the species (denotes the species).

Species that naturally occur in a particular environment are called ***indigenous** species* (as opposed to exotic or non-native species). Some species are indigenous (native) to South Africa, but also to the southern Africa region and to the African continent (e.g. the African elephant, lion, eland, kudu, and wildebeest). However, it should be noted that some species are only found in one specific area of the Earth and are adapted only to such an environment. Such species are termed ***endemic** species*. South Africa has some endemic plant and animal species which are only found in specific sites within South Africa. In terms of the number of endemic species of mammals, birds, reptiles and amphibians, South Africa ranks as the fifth richest country in Africa and the 24th richest in the world (South Africa's National Biodiversity Strategy and Action Plan, 2005).

Marine species

The variety of species which are unique to the marine environment is extensive. For the purpose of this resource we have focused on some species which occur in the Mangrove, Rocky Shore, Sandy Beaches, Sand Dunes and Drift Line sections.

Information on species can be found in Appendix 1.

Population

A population comprises interbreeding members of a single species occupying a particular niche within an ecosystem. A species can include one or more separate populations. Populations of the same species can be geographically (ecologically) separated and can be genetically distinguished from other populations of the same species). The members of a population, while belonging to the same species, are often genetically different from one another (genetic variation).

Genus

This is an intermediate taxonomic ranking category that falls below the family and above the species. A genus comprises a group of species exhibiting similar characteristics.

Community

A *biological community* is made up of the populations of different species occupying a particular locality (site or place) and the interactions between them. The composition of a particular biological community is strongly affected by competition and predation. The biological community together with its physical environment comprises an *ecosystem.*

Habitat

A habitat is the natural home of a living organism, population or community that is the particular environment in which it is normally found.

Ecological niche

This refers to

i. the role that a particular species plays; and
ii. the space that the species occupies in an ecosystem.

A niche includes the unique set of resources that each particular species requires and utilises.

All living things need food. An organism's role in an ecosystem depends on how it obtains its food because this affects how it interacts with other organisms in the ecosystem. The combination of where an organism lives (its habitat), how it obtains its food, and how it interacts with other organisms is one component of its niche.

The second component of an ***ecological niche*** is the role that particular species play in an ecosystem.

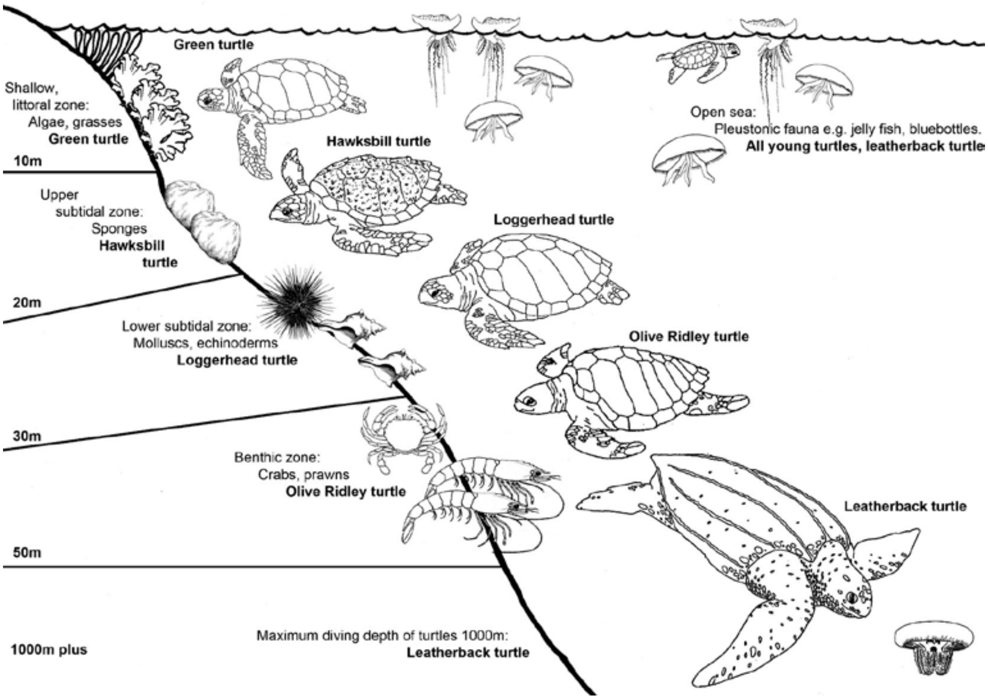
Example of a turtle's ecological niche

Four species of the sea turtles occurring in South African waters are the family of Cheloniidae, the exception being the leatherback which is the sole survivor of the family Dermochelyidae. Both families are in the sub-order Cryptodira, one of the most ancient reptilian orders whose fossil history reaches back 200 000 000 years.

Over the eons of time the numbers of sea turtles have increased and decreased, and competition between species has resulted in the disappearance of some and the spread of others. Along our coast the five surviving species compete neither for food nor space and are an impressive example of the occupation of different niches which leads to a harmonious existence.

Each species occupies a different part of the water column e.g. the green turtle occurs between the surface and 10m deep and feeding off algae and sea grasses whilst the hawksbill turtle's diet is confined to sponges and it occurs mainly between 10 and 20 metres. Although the leatherback turtle moves between the surface and more than 1 000m deep, its diet consists of jellyfish – its mouth is a sharp beak which helps with catching these.

Each species of turtle benefits the oceans. The green turtle, by grazing on algae and sea grasses improves the productivity, preventing shading, overgrowth and decomposition. The hawksbill turtle, by trimming sponges, creates spaces for other species like corals to grow. Leatherback turtle regulate jellyfish populations and consequently enable the survival of more fish eggs and larvae.



Source: Dr G. Hughes and SAAMBR

Example of a fiddler crab's ecological niche

In South African mangrove ecosystems there are five species of fiddler crabs. On first appearance they all appear to live in the same area. If one looks carefully over the mud and sand flats, one will see that each species occurs separately. The individuals never move too far from their burrows which are used as protection against predators. Each species is limited in digging burrows by the grain size of the substrate and how much the bottom of their burrows is inundated by the incoming tide. The sand/mud flats have some areas with coarse sand and some areas with much finer sand, some close to the low tide mark and some further away, thus separating the different fiddler crab species.

The fiddler crabs play an important role in this ecosystem through their burrowing and feeding activities. Burrow excavation increases soil drainage and aeration as well as increasing litter decomposition in the soil. This creates a better environment for plant growth. The first 5mm of soil is turned over as fiddler crabs feed. They remove diatoms, tiny crustaceans and worms as well as bacteria from the grains of sand and deposit fecal pellets. These pellets add organic nitrogen to the soil.

Ecosystem (ecological system) (CAPS – Grade 10, Term 3)

The term *ecosystem* derives from the Greek word *oikos*, meaning living, and *system* referring to an integrated functional unit. An ecosystem is therefore a natural system comprising living organisms (biotic communities), their physical environment (abiotic – soil, water, temperature, light, atmospheric gases, etc.) and the dynamic complex interrelations between them that enables them to function together as a unit (*ecological unit*). For example, an ecosystem in a particular area can be made up of animals, plants, micro-organisms, soil, rocks, minerals, water and the atmosphere interacting with one another. Components of an ecosystem are linked together through cycles such as the water, carbon and nutrient cycles and energy flows. Ecosystems are influenced by internal dynamics and external factors, such as climate, which determine the types of ecosystems resident in a particular area.

Ecosystem diversity refers to the variety of habitats and their associated biological communities and the complex life processes on Earth. Ecosystem diversity is determined by species composition, physical structure and processes within the different ecosystems. There are three main types of ecosystems: *marine* (oceans, deep sea and sea floor, salt marshes, estuaries and lagoons, mangroves and coral reefs); *freshwater* (lake, river and wetland systems); and *terrestrial* (grasslands, forests, woodlands, savannas, fynbos, bush thicket, Karoo, etc.).

Marine ecosystems

There are a variety of marine ecosystems. These can be grouped into:

1. Rocky coast/shores (discussed in depth in Appendix 2)
2. Sandy coast/beaches (discussed in depth in Appendix 2)
3. Mixed coast (rocky and sandy)
4. Mangroves (discussed in depth in Appendix 2)
5. Estuaries (discussed in depth in Appendix 2)
6. Island-associated – Continental islands and their associated sub-tidal habitats are recognised as distinct because they are dominated by land-breeding marine predators – this results in unique features including those related to nutrient input (e.g. from guano) and pressure from predators (e.g. trophic interactions between seabirds, seals and sharks) (Williams et al., 2000). There are 34 island-associated ecosystems in the South African marine environment.
7. Lagoon – South Africa's only lagoon (Langebaan) was not classified as an estuary because it does not receive freshwater from a surface river. Although Langebaan lagoon may be unique in South Africa, comparable systems exist elsewhere in southern Africa such as Sandwich Harbour in Namibia and Baia dos Tigres in Angola.
8. Rocky inshore
9. Unconsolidated inshore
10. Rocky continental shelf
11. Rocky continental shelf edge
12. Unconsolidated continental shelf
13. Unconsolidated continental shelf edge

14. Seamount – This is a mountain rising at least 1 000m from the ocean floor that does not reach the surface (making it distinct from an island).
15. Deepsea sediments – These sediments lie on the bottom (benthic zone). The organisms living on or buried in these sediments are called benthos.
16. Offshore pelagic – This includes the sea surface and the water column beneath it. Abundance of life decreases with increasing depth. The water column just above the benthic zone is called the demersal zone and is home to a variety of fish species.
17. Offshore benthic (the seabed)
18. Offshore pelagic (the water column) – Depth zones reflect patterns in distribution linked to many environmental parameters that influence benthic communities including temperature, light attenuation, topography, wave action, hydrostatic pressure, oxygen minimum zones, currents and food supply.

Estuary, mangrove, rocky shore and sandy beach ecosystems are discussed in more depth in Appendix 2.

Trophic energy levels – marine related (CAPS – Grade 10, Term 3)

Producers (Autotrophs):

Green plants make their own food using materials from the non-living environment. Like plants on land, producers in the marine environment convert energy from the sun into food energy through photosynthesis. Phytoplankton are the most abundant and widespread producers in the marine environment. Other producers include seaweed (a type of microalgae), algae (red, brown and green) and seagrasses (the only flowering plant found in the marine environment).

Primary consumers (Heterotrophs):

Primary consumers are herbivorous organisms that feed directly on primary producers to obtain their energy. Examples of marine ecosystems herbivores are zooplankton, chitons, sea-urchins, sea-hares, limpets and some fish.

Grazers of seaweed not only obtain nutrition from the seaweed but also have a dramatic effect on the distribution and dispersal of seaweeds. In marine ecosystems there are two additional categories of primary consumers:

- *Filter feeders:* They feed by straining suspended matter and food particles from water. The water is passed over specialised filtering structures. The animals that use this method of feeding are mussels, barnacles, oysters, tube-worms, some sea-cumbers, clams, krill, sponges, baleen whales, and many fish.
- *Planktivores:* They feed on planktonic food. Plankton is any organism that lives in the water column and is incapable of swimming against a current. These organisms drift in oceans, seas, and bodies of fresh water. They include drifting animals (zooplankton), protists, archaea, algae, or bacteria (phytoplankton – 'plant drifters'). Individual zooplankton are usually too small to be seen with the naked eye, but some larger species, such as jellyfish are visible. Most phytoplankton are also too small to be seen individually but when large numbers congregate, they may appear as a green discoloration of the water. This effect is due to the presence of chlorophyll in their cells.

Secondary consumers:

These derive their energy from consuming other animals. Examples of marine secondary consumers are: sea stars, crustaceans (crabs), jellyfish, fish (Klipfish, Blennie), birds (oystercatchers), cones, whelks, octopus and nudibranch.

The large primary producers are generally not directly consumed; instead they can be broken down by micro-organisms into detritus.

Tertiary consumers:

These are carnivorous animals that derive their energy from feeding on other carnivores. Examples of tertiary consumers in the marine ecosystems are sharks, some species of fish, lobsters, rays and turtles.

Decomposers (detritivores):

Not all plants and animals die because they are eaten. There are a variety of reasons for plants, animals or parts thereof to become material for decomposition. This dead material becomes food for other organisms. Organisms that feed on large bits of dead and decaying plant and animal matter are called ***detritivores.*** Crabs, sea-cumbers, worms and some sea birds such as seagulls can act as the detritivores in the ocean ecosystems. Even detritivores, however, leave behind some waste materials, parts of the dead plant and animal matter and their own waste. Bacteria and fungi break down these waste materials.

Organisms that get their energy by breaking down the final remains of living things are called ***decomposers.*** Fruit rotting on the ground, a sandwich getting mouldy in the bottom of a locker, and a shrinking pile of seaweed on the beach are all examples of decomposers at work.

Although the decomposers include animals such as maggots and crabs, all of which feed on dead organic matter and reduce it to simpler organic compounds, the most important decomposing agents are fungi and bacteria. The decomposers break down organic matter into its inorganic components (elements and molecules) which are released into the soil for re-use by plants.

Food chains and food webs

The complex feeding relationships between trophic levels in an ecosystem can be described through *food chains* and *food webs.* Energy flows through ecosystems. When a herbivore eats a plant, the food energy that is stored in the plant passes into the herbivore's body. When the herbivore is eaten by another consumer, the food energy that is stored in the herbivore's body passes into that consumer's body.

A model that shows how food energy passes from one organism to another in a feeding pathway is called a ***food chain***. Each organism in a food chain depends on the organism before it in the chain for its food energy. All living organisms are interlinked in a complex food web and the removal of one link can result in the collapse of the whole web.

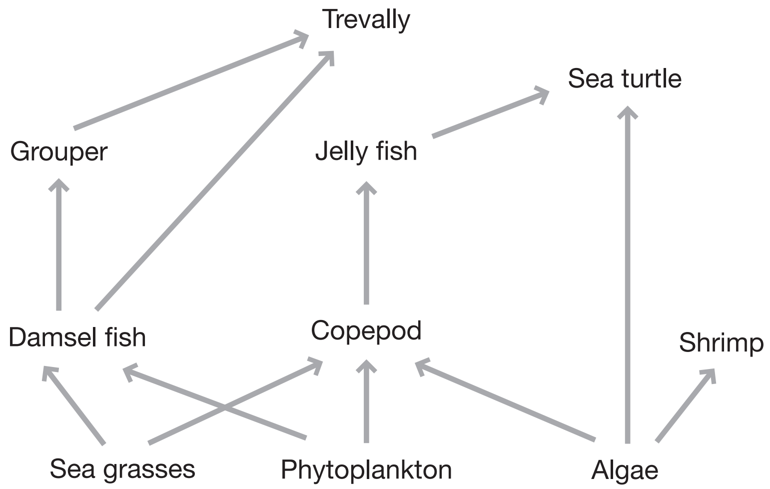
Interesting fact: Diets can change! Gobies begin life as predators, preying on copepods, then on amphipods and then change to a mainly herbivorous diet.

Examples of marine food chains:

- Seaweed → sea urchins → star fish → sea gull
- Phytoplankton → worm → shrimp → blenny → octopus
- Plankton → shrimp → fish → penguin → seal
- Plankton → mussels → octopus → seal

In reality, and most importantly, all food chains are linked to each other to form complex ***food webs.*** The abundance of nutrients and consequent high food production in the sea supports longer chains and more complex food webs than those generally found on land.

An example of a marine food web:

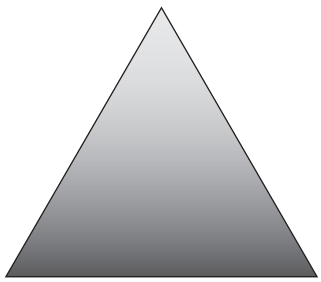


As explained in *Teaching Biodiversity* Unit 1, some organisms form relationships with other different species of living organisms. In this section we will discuss three marine related relationships: parasitism, symbiosis and competition.

ACTIVITY 1

CREATING A MARINE FOOD CHAIN AND/OR FOOD WEB

Ask the learners to develop a marine food chain and/or a food web. They should indicate the different trophic energy levels. The energy levels can be depicted in a descending triangle.



Tertiary Consumers

Secondary Consumers

Primary Consumers

Producers

Decomposers

Relationships between organisms (CAPS – Grade 11, Term 3)

Symbiotic relationships

Symbiosis (meaning living together) describes special relationships between organisms of different species that live closely together, often with some sort of feeding involved. The partners in these relationships may assist each other (positive impact), or harm one another (negative impact), or have no noticeable effect on each another (neutral impact). The main types of symbiotic relationships are mutualism, commensalism and parasitism.

1. **Parasitism**

   In a parasitic relationship, one of the species (the host) is harmed by the relationship. A parasite takes food or shelter at the expense of the host organism. The organism may live inside the other's body or on its surface. In some of these parasitic relationships the host dies and in others, it is important that the host remains alive. Examples of parasitic relationships in the ocean:

   - Several different crustacean parasites can be found on the skin, fins and gills of fishes.
   - Barnacles attach to the bodies of whales. The whale is not harmed greatly, but may have some pain or itching.

2. **Commensalism**

   Commensalism is a relationship where one of the organisms benefits greatly. The other is not helped, but neither is it harmed or damaged from the relationship. In other words, this is a one-sided symbiotic relationship.

   - The relationship between a shark and the small fish that swim below it. The fish use the ragged tooth shark as cover from other prowling sharks. The fish benefit in this relationship; the shark is not affected.
   - The remora is a fish that attaches itself to the body of a large fish such as a shark. It 'hitchhikes' a ride and eats the leftovers of the food that the shark catches.

3. **Mutualism**

   Mutualism is a close relationship where both parties benefit from the relationship, and it can be longlasting.

   - In the ocean, certain species, like shrimps and gobies, will clean fish. They remove parasites, dead tissue and mucous, and in return they get a meal.
   - The cleaner shrimp cleans the parasites and dead tissue from eels. The eel gets a healthy clean mouth and skin; the shrimps eat the parasites and are protected by the eel, so they both benefit from the relationship.
   - Clown fish have mucous on their skin which protects them from the stinging tentacles of the sea anemone. They take refuge amongst the tentacles, which are avoided by most other fish. In return they scare off the big butterfly fish that eat anemones.
   - The relationship between a goby fish and a shrimp is one of mutualism. The

shrimp digs a burrow into the sand and both organisms live there. The shrimp is almost blind, but the goby fish tenant will alert the shrimp when a predator is near.

Adaptation of species to their environment

In order to survive, all creatures have had to adapt to survive. Adaptation is when the species becomes suited to a habitat during the process of evolution. It can take many generations for the adaptation to take place. The types of adaptation can include their swimming styles, hunting methods, and defensive mechanisms, as well as their physical appearance (shape, colours, and textures).

Species have adaptations to avoid predation.

Examples are:

1. **Avoid detection**

   - Cowries avoid detection by enveloping their shell in their fleshy mantle. The octopus changes both colour and texture to blend in.
   - The ghost pipe fish uses its shape and colour to camouflage itself from predators. It appears as just another piece of loose coral, sweeping in and out with the surge and currents. Similarly, the leaf scorpion fish (or paper fish,) acts like a leaf, and it is very difficult to spot them.
   - Rays and skates flap their wings to glide.
   - Jellyfish pump water to propel themselves.

2. **Poisonous or unpalatable**

   - Sea-anemones have stinging cells.
   - Sponges may have bright colours and have spicules which may be toxic.
   - Sea anemones have stinging cells.
   - Nudibranchs, or sea slugs, use their colour to their advantage. Some use neutral colours to blend in with their environment. Others do the exact opposite, and use bright colours to attract attention and warn predators that they are either distasteful or poisonous.

3. **Protective structures**

   - Shells, spines, exo-skeletons can protect a species.

Competition (CAPS, Grade 11, Term 3)

1. **Intraspecific competition**

   Competition can occur between individuals of the same species. Intraspecific competition can cause changes in population size over time. This occurs because individuals become crowded as a population grows. Since individuals within a population require the same resources, crowding causes resources to become more limited. Some individuals eventually do not acquire enough resources and die or do not reproduce. This reduces population size and slows population growth. For example, sea urchins of the same species that are competing for resources, will compete with each other.

2. **Interspecific competition**

   This is competition that occurs between different species. Species also interact with other species that require the same resources. Consequently, interspecific competition can alter the sizes of many species' populations at the same time. When species compete for a limited resource, one species eventually causes the population of other species to become extinct. This means competing species cannot live together in the same area because the best competitor will exclude all other competing species. For example, think of an octopus competing with sharks for lobsters.

ACTIVITY 2

EXPLORING MARINE BIODIVERSITY
Outdoor investigations and media analysis

See page 32 in the *Methods and Processes* booklet.

Learning focus:

Development of scientific knowledge (information) and understanding of biodiversity and related concepts, critical analysis, visual art, report writing and presentation skills.

Resources:

Selected articles on local marine biodiversity issues from local newspapers or magazines or from the Internet, dictionaries (scientific dictionaries where possible) and Life Science textbooks. You can task the learners to find these articles where resources are available.

i) Media analysis – identifying key words and concepts

Vocabulary development (scientific literacy) (Grade 10, term 3)

Divide the learners into groups and ask them to list the different terms and concepts that they come across in the selected article. Ask them to find and discuss the meanings of these different terms in the group. Ask the learners to summarise the main focus/theme of the article according to their own understanding. The group should then present the topic and explain the terms to the class.

ii) Media analysis – article review, critical analysis

(Grade 10, term 4; Grade 11, term 1)

Using the same article, ask the learners in the group to discuss the main points the article is trying to make. Are these points supported by relevant facts? What are the underlying assumptions? Do they agree with the proposed viewpoint of the author(s)? Ask them to suggest how the message contributes to responses to biodiversity loss. The learners should write down their deliberations as an article review report.

iii) Outdoor investigation – Show and tell (listening with intent – information transfer)

(Grade 10, term 3)

Take learners to a nearby natural coastal area and ask them to take detailed notes of observations and information provided. Explain to them the type of ecosystem that you are investigating (seek the help of an experienced guide/conservationist if necessary). Point out the different species in the environment and their natural habitats. Explain to them the relationships between the different components in the ecosystem and discuss the roles of the different species. Ask them to write an essay describing the ecosystem and the different relationships of the components within it (using their notes). In the essay they should include a drawing representing what they saw during the visit.

Biomes (CAPS – Grade 10, Term 3)

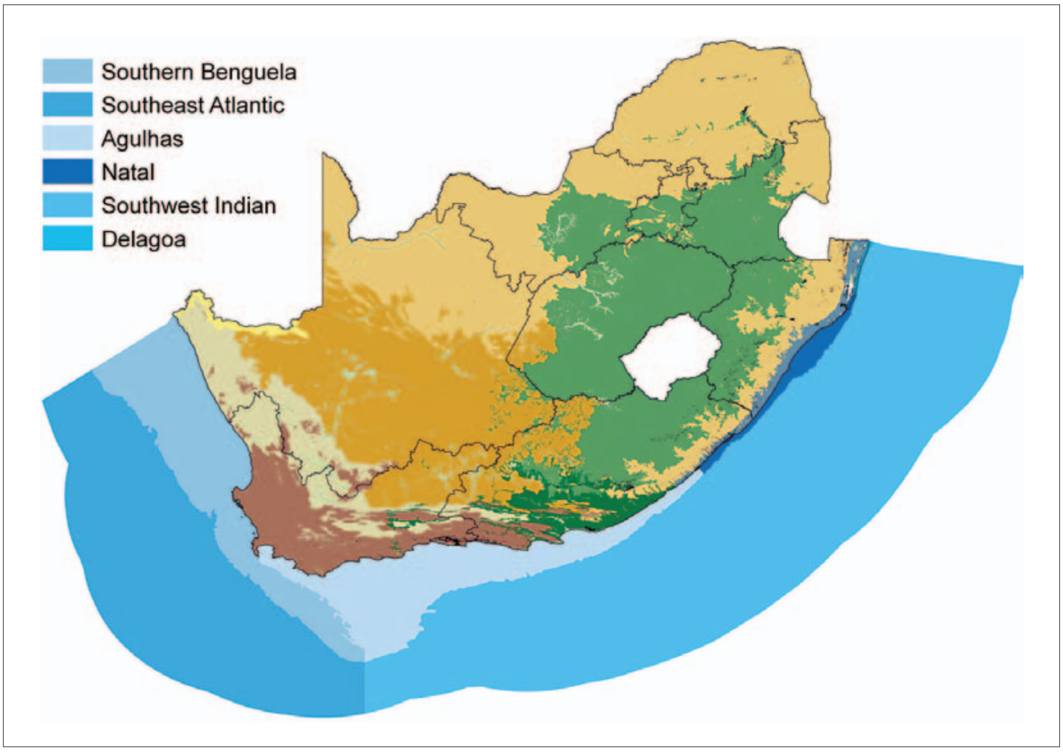
Biomes are a global classification of ecologically similar areas on Earth. These are major biotic communities (ecological communities of plants and animals) of broad regional significance (*ecoregions*), extending over large areas, defined mainly by the dominant forms of vegetation and prevalent climatic conditions. Biomes fall under three categories: terrestrial (including savanna and temperate grasslands, tundra, desert, tropical rainforest, deciduous and coniferous forests), freshwater and marine.

The concept of biomes and terrestrial biomes of South Africa are discussed in *Teaching Biodiversity* Unit 1, pp 17–20.

Marine biomes (eco-regions)

South Africa has a coastline of about 3000 km. Much work has been done to look at the marine equivalents of biomes, which are called eco-regions. Identification of eco-regions was based on a broader unit of classification that would be similar to the terrestrial biomes classification. The biogeographic differences within the areas (which extend 500m inshore of the coastline and 200 nautical miles offshore) account for significant differences in species composition and even ecology in many of these habitat types, accommodating several broad ecosystem groups.

Figure 1.1: Marine eco-regions



Source: South African National Biodiversity Institute (2013), LIFE, *The state of South Africa's Biodiversity, 2012.*

An eco-region is an area where species are mainly homogenous (similar), and which is clearly distinct from adjacent systems. The eco-regions reflect major differences linked to temperature, nutrients and productivity.

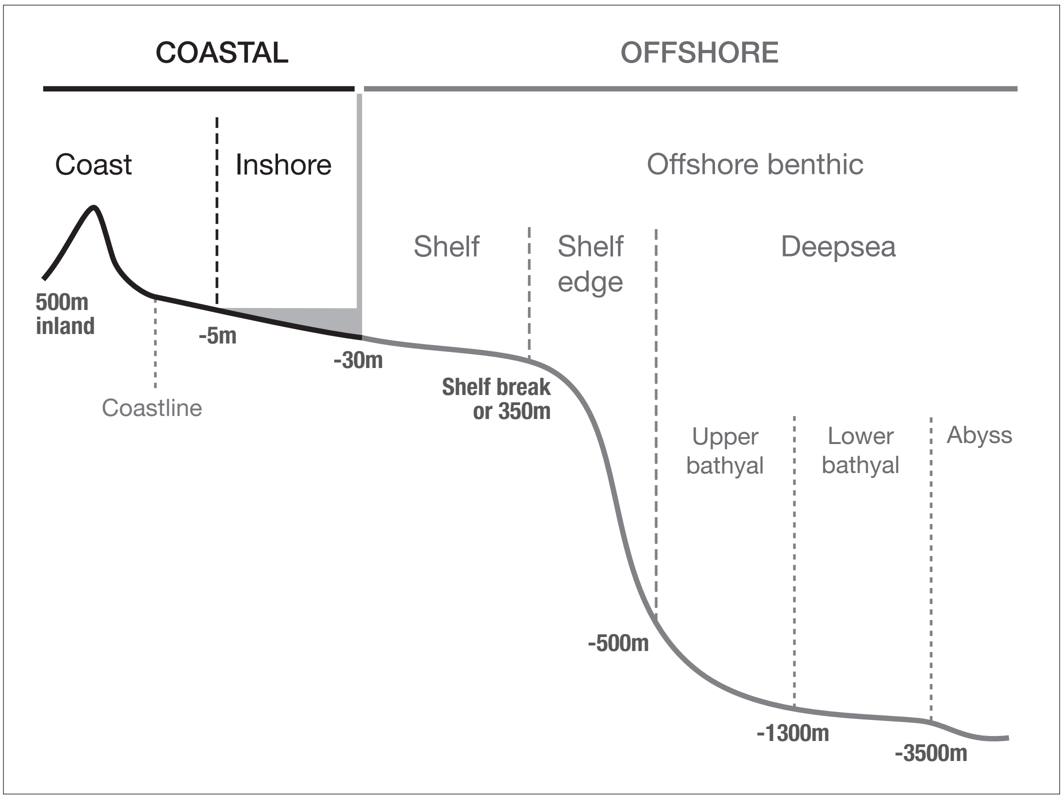
Six distinct eco-regions have been identified in South Africa. Four include the coast, continental shelves and shelf edge (see Figure 1.2):

- Southern Benguela Eco-region – Sylvia Hill to Cape Point;
- Agulhas Eco-region – Cape Point to Mbashe River;
- Natal Eco-region – Mbashe River to Cape Vidal;
- Delagoa Eco-region – Cape Vidal northwards.

Two eco-regions consist of the upper and lower bathyal zones, and the abyss:
(see Figure 1.2)

- Southeast Atlantic Eco-region,
- Southwest Indian Eco-region.

Figure 1.2: The coastal and off-shore components of the eco-regions



With a coastline that stretches over 3000km, from the cool temperate waters of the south-east Atlantic Ocean to the subtropical Indian Ocean bordering Mozambique, South Africa is located at the confluence of two great currents, the cold Benguela Current on the west coast and the warm Agulhas Current on the east coast. This contributes to the high levels of marine biodiversity and species endemicity found within the region. The upwelling of cold, nutrient-rich waters along the west coast contributes to the high marine biodiversity of this area, supporting vast fish and invertebrate species, while the warmer, less productive waters of the east coast still support a range of marine biodiversity.

ACTIVITY 3

BIOMES/ECO-REGIONS

Learners can develop a 'What and Where' chart or table which lists the different biomes. The table or chart should contain the following details:

1. What is the biome? (name and what coastal and/or offshore components are included in that marine biome)
2. Where is the marine eco-region? (short description of where it occurs)

Taxonomy derives from the Greek word *taxis*, meaning arrangement.

Living organisms are grouped according to their observed fundamental similarities and separated according to their differences.

Taxonomic Classification (CAPS – Grade 10, Term 4)

The naming of living things has been with humankind since our origins. Ever since people have been able to speak, they started to name living organisms around them. The cumulative information derived from interacting with living organisms and their subsequent naming was essential for human survival. For example, the naming of edible and poisonous plants was necessary in order to communicate the acquired experiences to other members of the human community. Folk classification has played a significant role in the ordering of living organisms based on their uses, characters or habits. Folk taxonomies are however shallow in hierarchy, at times combining related species into one name or separating the same species into different names.

Modern *taxonomic classification* or *systematics* refers to the theory and practice or science of naming (*identification*) and grouping or organisation (*classification*) of organisms in a *hierarchically ordered system* that reveals their natural or *evolutionary relationships*. By grouping together similar species, it is easier to identify them. The hierarchical categories are termed *taxa* (singular is *taxon*). In the classification process each species belongs to a genus, each genus belongs to a family, and so on through order, class, phylum, and kingdom. The associations within the hierarchy reflect evolutionary relationships, which are deduced typically from morphological and physiological similarities between species, and more recently from analysis of genetic compositions. The basis of taxonomic classification is therefore shared similarities or *homologous features*.

Examples of hierarchy of taxonomic ranks in two marine species:

INCREASING COMPLEXITY OF RELATIONSHIPS (MORE INCLUSIVE)

RANK	EXAMPLE 1: BOTTLENOSE DOLPHIN (*Tursiops truncatus*)	EXAMPLE 2: ZEBRA FISH (*Diplodus cervinus*)
Kingdom	Animalia	Animalia
Division/phylum	Chordata	Chordata
Class	Mammalia	Teleostomi
Order	Cetacea	Perciformes
Family	Delphinidae	Sparidae
Genus	Tursiops	Diplodus
Species	truncatus	cervinus
Variety	Atlantic Ocean and Indian Ocean varieties	Subspecies hottentotus

INCREASING SPECIFICITY (LESS INCLUSIVE)

Modern taxonomic classification is largely accredited to the work of Carolus Linnaeus (Carl Von Linne), drawing from his main work in the volumes *Species Plantarum* (1753) covering global flora and *Systema Naturae* (1758) covering global fauna. Linnaeus chose Latin and this is still used as the universal language for taxonomic classification. During his time Latin was considered the language of wise people.

The main reason for continuing to use one language in taxonomic classification is to ensure that each species is called by the same name everywhere throughout the world (every language has different names for the same species and this makes it complicated). However, Latin is now considered a 'dead' language (very few people speak or use it), meaning that the name given to an organism will not change over time. Latin also has the advantage that words can be added together to make one-word descriptions, which are shorter and simpler than, for example, the English translation.

Linneaus laid the foundation for binomial nomenclature (a binary naming system), based on the use of two Latin names in identifying (naming) species. The Linnaean binomial nomenclature has been adopted in modern taxonomic (scientific classification) systems as the conventional way of naming species. Linnaeus used five taxonomic ranks in naming living organisms: class, order, genus, species and variety. He grouped the living organisms based on shared physical (homologous as opposed to analogous) characteristics. This system has subsequently been revised to include Darwinian evolutionary (*phylogenetic*) relationships.

Currently five main kingdoms of living organisms are recognised. These are:

- Bacteria (Monera)
- Fungi
- Protozoa or Protists (Protista)
- Plants (Plantae) and
- Animals (Animalia).

The species remains the basic unit in the biological classification of living organisms. The kingdoms are summarised in the table below.

Kingdoms of living organisms

KINGDOM	KEY FEATURES	LEVEL OF ORGANISATION	EXAMPLES OF SPECIES IN THE KINGDOM
Monera (Bacteria)	Body comprises a protein membrane cell wall and genetic material (no nucleus), microscopic in size and usually parasitic. Distinguished by shape of the cell (circular, rod shaped, etc.)	Prokaryote (before the cell – without nuclei and membrane – bound organelles), unicellular. Individuals reproduce by binary fission and are normally found in groups in the forms of chains or colonies.	True bacteria (eubacteria) and cyanobacteria (blue-green algae)
Protista	Body comprises cell with intracellular organelles including a nucleus. Microscopic in size and water dwelling. Some contain chloroplasts with chlorophyll and are photosynthetic	Eukaryotic, most unicellular, some multicellular. Most have hair like body extensions (cilia or filaments) for movement and feeding.	Unicellular protozoans and unicellular and multicellular (macroscopic) algae with cilia and flagella Dinoflagellata e.g. zooxanthellae *Symbiodinium microadriaticum* – living in the tissue of some corals

	(algae, autotrophs), while others feed by ingesting other organisms (heterotrophs). Mobile.		Seaweeds: ◆ Brown algae e.g. sea bamboo *Ecklonia maxima* (largest local kelp) ◆ Green algae (alternatively classified under plantae by a number of scientists) e.g.ribbon sea lettuce *Ulva fasciata* ◆ Red algae (alternatively classified under plantae by a number of scientists) e.g.hedgehog seaweed *Nothogenia ovalis*
Fungi	Macroscopic. Haploid and dikaryotic (binucleate) cells, multicellular, generally heterotrophic, without cilia and eukaryotic flagella. Multicellular and visible with the naked eye. Mainly saprophytic, i.e. non- photosynthetic, digest and absorb dead organic matter (leaves, bark and wood, found on seagrasses, wood and leaves in saltwater mangroves as well). Sessile.	Eukaryotic, multicellular, tissue level of organisation. Reproduce through spores.	Mushrooms, toadstools, yeasts, moulds, mildew, rusts, smuts, puffballs Oil eating fungi, fungal infections on fish *Ichthyophonus gasterophilum*
Plantae	Macroscopic. Haploid-diploid life cycles, mostly autotrophic, retaining embryo within female sex organ on parent plant. Have cellulose cell walls. Range in size from minute plants, to herbs and shrubs, to huge tall tree specimens. Mainly sessile (stagnant) and photosynthetic.	Eukaryotic, multicellular, tissue level of organisation. Some have non-vascular tissue (mosses and liverworts) and the rest have vascular tissue (containing xylem and phloem vessels). Some reproduce through spores and rely on water (mosses, liverworts and ferns), some produce naked seeds (gymnosperms), while some produce flowers (angiosperms).	Mosses, ferns, woody trees, shrubs, bushes, climbers and non-woody (herbs, reeds, grasses) flowering plants
Animalia	Macroscopic. Multicellular animals, without cell walls and without photosynthetic pigments, forming diploid blastula. Range from minute animals to giant specimens. Feed on other organisms (heterotrophs), are mobile, communicate through sound. Include animals with backbones or internal skeletons and developed limbs (chordates), animals with external skeletons and six or more legs (arthropods – insects, spiders, crabs), animals with soft body and hard outer shell (molluscs) and long segmented soft bodies (worms).	Eukaryotic, multicellular, tissue and organ level of organisation (reproductive, digestive, gaseous exchange, nervous, blood and circulatory, sight, smell, thought and speech).	Sponges, worms, insects, crustaceans, echinoderms e.g. sea urchins (only marine), fish, amphibians (not marine), reptiles, birds, and mammals **Porifera:** ◆ Chili pepper sponge *Tedania anhelans* East Coast ◆ Crumb-of-bread sponge *Hymeniacidon perlevis* West & south coast **Cnidaria:** ◆ Plum anemone *Actinia mandelae* **Arthropoda:** ◆ West coast rock lobster *Jasus lalandi* **Mollusca:** ◆ Brown mussel *Perna perna* **Echindermata:** ◆ Red starfish *Callopatiria granifera*

			Chordata: ◆ Bony fish - Shad/elf *Pomatomus saltatrix* ◆ Reptile – loggerhead turtle *Caretta caretta* ◆ Bird – kelp gull *Larus dominicanus* ◆ Southern right whale *Eubanaena australis*

Note: Some scientists classify green and red seaweeds as protists while others classify these as plants.

Identification instruments or tools

Key issue:

Identification instruments provide a method for easily identifying species. They vary greatly in form. They can be used to identify the biodiversity found in a particular geographical area, or in a related group of organisms (for example, animals, aquatic plants, fish, birds), or in a particular grouping (for example, crab species in southern Africa).

The quick identification of species in the field requires the use of simple tools or instruments that are easily accessible. These are what one can refer to as the 'quick and dirty' methods of identifying species as they are usually based on an artificial classification system that does not follow the scientific approach to classification. The main aim of tools is to aid the user to find the right name for a plant quickly. Some identification tools are discussed below.

Identification guides

Identification guides work in a similar way to taxonomic keys. However, in a guide the key distinguishing features of each species are usually lumped together in a species description, which is often accompanied by an illustration or photograph of the specimen. The user can then compare the description and illustration or photograph with their own specimen. Most guides combine the use of a key and the species description to help with identification.

Taxonomic keys (CAPS – Phylogenic tree – Grade 11, Term 1)

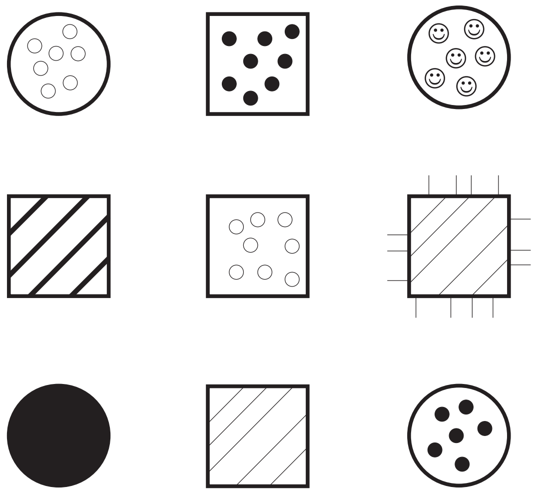
Taxonomic keys are tools used to help with identifying an unknown species. A key provides a structure for sorting through a great deal of information, enabling quicker identification based on fundamental differences. The simplest and most often used key is the *dichotomous key*. Here the keys are structured in a set of couplets, based on two mutually exclusive choices (contrasting or opposing descriptions) of a particular feature, hence the term *dichotomous keys*. The user chooses a description that best fits the unknown specimen. Once the decision is made this then leads to the next couplet and the next, a progression based on accepting a certain feature and rejecting the other until the final identification (conclusion) is reached. During the identification process one moves from large distinguishing features to smaller differences.

ACTIVITY 4

DEVELOPING A TAXONOMIC KEY

Taxonomic keys are tools used for the identification of species (see description above). For this activity, learners will create two taxonomic keys – based on the identification of shapes.

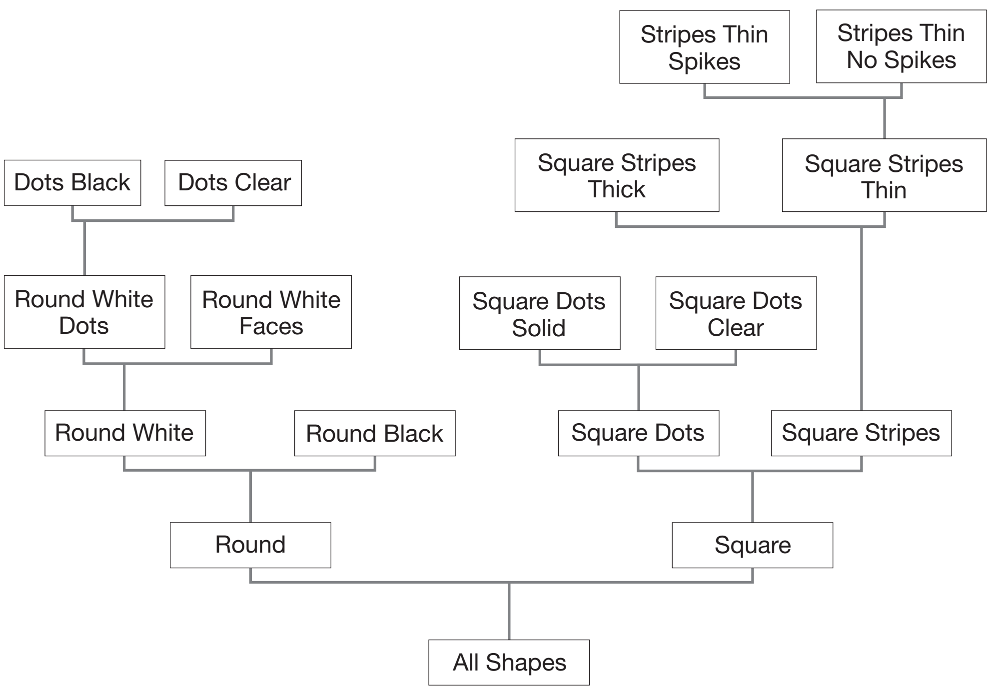
The teacher supplies the learners with different shapes with different features. An example is presented below:



(The shapes can be given labels such as A, B, C).

Taxonomic key 1

Learners have to create a 'key-tree' for the shapes.



Taxonomic Key 2

Learners have to create an "If-Key". (Depending on the level of the learners, the facilitator might have to demonstrate the concept to the learners prior to their creating this key.)

Using the shapes above, the learners develop "If statements" for each level of the key.

An example is:

1. If the shape is round go to 2
   If the shape is square go to 5
2. If the round shape is black – then it is Shape G
   If the shape is white, go to 3
3. If the shape is white and has faces – then it is Shape C
   If the shape is white and has dots, go to 4
4. If the shape is white and has black dots – then it is Shape I
   If the shape is white and has clear dots – then it is Shape A
5. If the shape is square and has dots go to 6
   If the shape is square and has stripes go to …
6. If the shape is square, has dots and …

Possible outcomes of the activity

- By using basic key criteria, the concept of keys is made simple.
- Be careful not to assume that learners will make the connection between the model and real biological keys (it may help if the teacher indicates the similarities between the keys created and the keys in a field guide).

Teaching Practice

Within these biodiversity learning units there are a range of possible **pedagogical approaches** (methods) for the teaching and learning processes for the topic of biodiversity.

Biodiversity is about life forms and life systems and is therefore to a large extent a **practice-oriented** subject. However, this does not imply that **theoretical** as well as other **classroom-based activities** are not possible. A mixture of practical action-oriented aspects in real life contexts as well classroom-based activities can facilitate learning on this topic. These include **investigative, experiential, learning by doing** and **deliberative methods** as discussed in the Introductory Core Text and *Methods and Processes* books. Some activities are suitable for groupwork while some are individual activities. Using a diverse range of teaching and learning approaches creates opportunities for learners to actively engage in the learning process.

Biodiversity as a topic will require:

i) the development of **language skills**, in this case with regard to scientific literacy on *key terms and concepts* employed in biodiversity;

ii) the development of **analytical skills** as employed in

a. appreciating the enormous variety of life and life systems in the local (and global) context(s) and the need to conserve it;
b. the classification of biodiversity and the theory/theories behind taxonomic classification;
c. the conceptualisation of how different living organisms are interrelated in nature and the natural processes within ecosystems;
d. recognising the different roles of biodiversity and relating this society and to human well-being;
e. understanding the impacts of human activities on biodiversity, their inter-related nature and their implications to human well-being; and
f. appreciating the role of science in the development of the range of responses to biodiversity loss;

iii) the development of **critical decision-making skills** with regard to

a. development of relevant contextualised responses to biodiversity loss;
b. debating and discussing critical issues relating to biodiversity issues;

iv) the development of **mathematical skills** and their application in real life contexts of biodiversity.

Teacher activities have been interspersed into the first section (Subject Content Knowledge); these give suggestions for various methods for teaching biodiversity.

Assessment Practice

Assessment activities will vary according to the content knowledge that is being assessed. The table below illustrates some possible links between the content in this learning unit and assessment activities and skills.

Linking content knowledge to assessment processes

CONTENT KNOWLEDGE SECTION	SECTION SUMMARY	ASSESSMENT ACTIVITY	KEY ASSESSMENT SKILLS (VERBS)
Definition of key biodiversity concepts	The concept of biodiversity is based upon the principle of hierarchies and the basic building block is the species. Understanding the levels of biodiversity and the associated terminologies. South African biomes.	1. Review of selected texts/ articles on biodiversity to identify key terms and concepts. (Grade 10, 11) 2. Investigation of a local natural ecosystem (Grade 10) [Practical activity]	Define, describe, list, name, observe, recall, illustrate, measure, record (draw)
Taxonomic classification	Taxonomic classification as a systematic process of naming and identifying living organisms following the system developed by Carolus Linneaus. Hierarchical classification/ranking process.	1. Identification and classification of organism in the school yard or garden or beach if nearby (Grade 10, 11) [Practical activity] 2. Development of a simple taxonomic key (Grade 10, 11) [Practical activity]	Identify, name, organise, categorise, list, classify, select, differentiate, design, develop, use/application of knowledge

CAPS Life Sciences assessment focus

Below are the CAPS Life Sciences Grade 10-12 specific aims and their related assessment focus:

1. **Knowing Life Science concepts**
   This refers to knowledge of biodiversity concepts, processes, phenomena, mechanisms, principles, theories, laws, models, etc. This includes the acquisition of knowledge on biodiversity; understanding and making links between ideas and concepts; applying biodiversity knowledge in new and unfamiliar contexts; and analysing, evaluating and synthesising scientific knowledge, concepts and ideas.

2. **Investigating phenomena in Life Sciences**
   This refers to the practical ability to carry out investigations and solve problems about biodiversity. This includes listening to instructions, handling and using equipment and apparatus, making observations, measuring, recording, interpreting data and designing investigations on biodiversity.

3. **Appreciating and understanding the history, importance and application of Life Sciences in society**
   This refers to realising the relevance and application of the science of biodiversity in real life contexts (socio-biology and animal behaviour, plant pathology, game manage-

ment, environmental impact studies, preservation of biodiversity, palaeontology, palaeoanthropology, agriculture, horticulture, environmental law, science journalism, biotechnology, genetic engineering, etc); understanding the historic development; and appreciating the relationships between indigenous knowledge systems and modern science on biodiversity.

The above aims can be linked to possible assessment activities as shown below.

Linking aims to assessment activities

SPECIFIC AIM	COGNITIVE SKILLS	ASSESSMENT FOCUS	EXAMPLES OF ASSESSMENT ACTIVITIES
Knowing Life Science (Biodiversity) Concepts	*Knowing Biodiversity Science* – knowledge of biodiversity terms, concepts, processes, phenomena, mechanisms, principles, theories, laws, models, etc.	This will involve assessing learners' ability to state, name, label, list, define and describe aspects of biodiversity (e.g. concepts, terms, issues, etc.)	◆ Defining what the term biodiversity means (building a conceptual framework) ◆ Describing the different levels of biodiversity ◆ Defining the terms species, population genus, community, habitat, niche, ecosystem, biome, etc. ◆ Naming and listing the different organisms living in a selected area
	Understanding Biodiversity Science – understanding of the conceptual framework of biodiversity, recognition of the hierarchical organisation of biodiversity, development of taxonomic ranking systems	Learners will be assessed on their ability to explain, compare, rearrange, give an example of, illustrate, calculate, interpret, suggest a reason, make a generalisation, interpret information or data, predict, select, differentiate aspects of biodiversity	◆ Categorising and classifying food items in the kitchen ◆ Categorising, differentiating and classifying living organisms in an area ◆ Develop/create food chains and food webs
	Apply knowledge of biodiversity in new and unfamiliar contexts – use of knowledge in a new way and application of knowledge in new/unfamiliar contexts	Assessing learners' ability to demonstrate, interpret, predict, compare, differentiate, illustrate, and select relevant aspects of (knowledge and information on) biodiversity and use it to design solutions to biodiversity problems	◆ Demonstration of knowledge of biodiversity in an area (types of ecosystems, different species and their habitats) ◆ Design/suggest solutions to local biodiversity problems
	Analyse, evaluate and synthesise biodiversity knowledge, concepts and ideas – analysis, evaluation and synthesis of biodiversity knowledge, concepts and ideas in different contexts	Assessment of learners' ability to appraise, argue, judge, select, evaluate, defend (a point of view), compare, contrast, criticise, differentiate, distinguish and discuss biodiversity issues	◆ Identification/appraisal of the human impacts on biodiversity in specific context ◆ Compare and contrast levels biodiversity in natural and developed areas ◆ Discuss the implications of colonial era conservation practices on local communities ◆ Critically evaluate the effects of elephant culling
Investigating Phenomena in Life Sciences (Biodiversity)	Following instructions on biodiversity investigations	Ability of learners to follow instructions on use of equipment and safety procedures	◆ Identifying dangers of wild animals and plants (dangerous animals and poisonous plants and animals)

SPECIFIC AIM	COGNITIVE SKILLS	ASSESSMENT FOCUS	EXAMPLES OF ASSESSMENT ACTIVITIES
Investigating Phenomena in Life Sciences (Biodiversity) *(cont.)*	Handle equipment or apparatus for biodiversity investigations	Ability of learners to name, know and use equipment appropriately	◆ Naming of equipment and apparatus for biodiversity investigations (rulers, tape measures, binoculars, magnifying glasses, etc.) ◆ Using measuring equipment, using identification guides and keys
	Make observations during biodiversity investigations	Ability of learners to draw, describe, group according to similarities and differences, measure, comparing before and after, observe results, count	◆ Visiting a local conservation area and using identification guides and keys to correctly identify different species in an area ◆ Drawing the different species occurring in the area ◆ Observing the types of ecosystem, their major constituents and interrelationships between the different components ◆ Grouping/classifying organisms into their right taxa according to their similarities and differences ◆ Counting living organisms found in a particular area
	Record information or data from biodiversity investigations	Learners' ability to draw, describe, construct tables, graphs	◆ Compiling a list of living organisms (plants and animals) occurring in a particular area ◆ Describing different types of ecosystems ◆ Recording different weeds occurring in the school garden ◆ List the different taxa for an organism ◆ Draw food chains and food webs
	Measure biodiversity aspects	Learners' ability to know what to measure, how to measure, understand accuracy and estimation	◆ Measuring and comparing species diversity in a natural and a lived area ◆ Make an audit (identify and measure and record the impact) of the school's carbon footprint that negatively impacts on biodiversity
	Interpret biodiversity information	Ability of learners to convert information from one form to another (e.g. table to graph), analyse and extract information, apply knowledge, recognise patterns or trends, understand limitations, make deductions	◆ Develop a simple key for identifying organisms in a particular area ◆ Observe biodiversity in a lived area and describe the impacts of human activities on biodiversity
	Design/plan biodiversity investigations	Learners' ability to identify a problem, investigate a situation, select apparatus or equipment and/or materials, selecting appropriate materials and tools, suggest ways of recording results, write a design brief, identify specifications and constraints, design solutions to problems	◆ Design an instrument (questionnaire) for carrying out a survey of plant use in a local community ◆ Carry out a plant use survey in the area ◆ Investigate threatened and endangered species in your area and explain the causes of these threats ◆ Design a public survey form to test the public opinion about elephant culling. Test this form through a survey of opinions of this within the class. Show results in a pie graph.

Summative assessment

Summative assessment in the Further Education and Training Phase Grade 10-12 for Life Sciences comprises the following components as outlined in the table below.

Formal assessment

GRADES	FORMAL SCHOOL-BASED ASSESSMENTS	END-OF-YEAR EXAMINATIONS
10 and 11	25% including a mid-year examination	75%
12	25% including mid-year and trial examinations	External examination: 75%

The formal (summative) school-based assessment comprises a test and/or exam and practical task in each school term. The end-of-year examinations comprise two written examinations and a practical examination. It is therefore essential to include assessment of practical tasks as well as written tasks or tests when planning for assessment.

Assessment methods and instruments

A variety of assessment instruments/tools can be employed in the assessment process of these Biodiversity learning units. These include those listed in the table below.

A list of some possible assessment methods and instruments/tools

ASSESSMENT METHODS	ASSESSMENT TOOLS/INSTRUMENTS
Case studies and open problems	Checklists, assessment grids and rubrics
Classroom-based discussions	Discussion checklist
Computer-based assessments	Multiple choice questions (MCQs)
Direct observation	Observation sheet
Self-assessment	Self-assessed questions
Peer assessment	Peer-assessed questions
Essays	Essay checklist
Knowledge tests	Short answer questions
Learning logs/diaries	Checklists, assessment grids and rubrics
Mini-practicals	Practical checklist
Orals	Oral assessment checklist
Portfolios	Portfolio of Evidence guideline/checklist
Poster sessions	Poster checklist
Presentations	Presentation checklist
Quizzes	Checklists, assessment grids and rubrics
Problems	Checklists, assessment grids and rubrics
Projects	Project checklist
Interviews	Questionnaires

ASSESSMENT METHODS	ASSESSMENT TOOLS/INSTRUMENTS
Reflective practice assignments	Practical checklist
Practical demonstrations	Practical checklist
Reports (on practicals)	Report forms
Simulated interviews	Interview questionnaire
Written examinations	Multiple question examinations, single essay examinations, modified essay questions (MEQs), multiple choice questions (MCQs)

It should be noted that there is no hard and fast rule as to which type of assessment tools should be used with particular assessment types. Some assessment tools can be used across a range of assessment methods. It is also essential to employ a variety of assessment methods and instruments as well as to provide interesting and challenging tasks that are imaginative and engaging to the learners and yet still meet the required assessment objectives.

Conclusion

In this Marine Biodiversity Unit 1 we explored the concept of biodiversity, with a focus on marine biodiversity, and the related key concepts and terms. An overview of the organisational aspects of biodiversity was provided as well as the taxonomic classification tools. In Unit 2 we will discuss the roles or ecosystem services of biodiversity, with a focus on marine biodiversity.

Unit 2

The roles of marine biodiversity

This unit explores the roles of biodiversity, which include ecosystem services and contributing to human well-being. Ecosystem services are the various benefits that ecosystems provide. Biodiversity plays an important role in the provision of various ecosystem services necessary for sustaining human life on Earth. In CAPS, *ecosystem services and human well-being* are covered in Grade 10, Terms 1 and 3.

Subject Content Knowledge

This section will provide information on ecosystem services as well as the economic benefits (direct and indirect) of ecosystems.

Ecosystem services

The various benefits of ecosystems can be discussed according to (see Figure 2.1):

- Provisioning (Food, freshwater, wood and fibre, fuel)
- Regulation (Climate regulation, flood regulation, disease regulation, water purification)
- Cultural services (Aesthetic, spiritual, educational, recreational)
- Supporting services (Nutrient cycling, soil formation, primary production)
- Ethical considerations.

Marine related ecosystem services

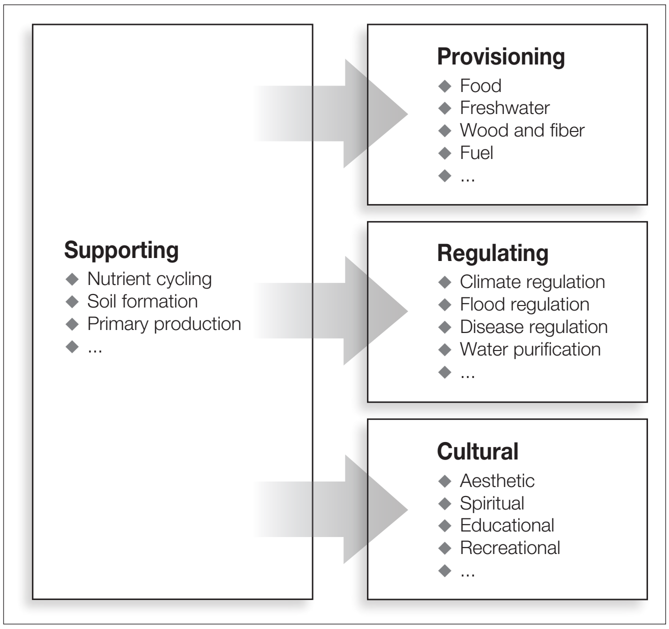
Provisioning ecosystem services

Estuaries provide a source of food, especially protein. An example is Kosi Bay in northern KwaZulu-Natal where fish traps have been used for centuries. The fish traps are constructed in such a way as to allow small fish to escape.

Estuaries are focal points for community and business activities along our coast. Job opportunities (from petrol stations to bait and fishing tackle shops) are created through meeting the variety of needs of local people and visitors using the estuaries.

Estuaries are also a source of invertebrate bait harvesting by recreational fishermen.

Figure 2.1: Biodiversity ecosystems services



Source: MA 2005

Regulating ecosystem services

Estuaries regulate disturbances from natural events by control and dampening of flood waters and by providing refuges from droughts. Soil loss is prevented by estuary vegetation like reed beds and mangroves. This accumulation of sediment leads to nutrient supply for the food web. These areas provide essential nursery grounds for fish and crustaceans, contributing to human food production.

Estuaries are very effective at purifying water; one unique feature of estuaries is the presence of bivalve molluscs, which actively filter particulate matter in water. The effects of human induced events are dampened e.g. estuaries assist with breakdown of waste and detoxify pollution. The general degradation of these ecosystems globally has severely compromised their capacity to provide clean water for communities.

Coastal dunes and mangroves act as important buffer zones along the coast against serious weather events like large storms or even tsunamis. The beach and foredune areas constantly supply sand that moves between the inshore environment and the beach at different times of the year.

Dune forests and mangroves serve as significant carbon sinks, slowing the rate of global climate change and ocean acidification.

Cultural ecosystem services

Estuaries are an important location for cultural activities such as baptisms. They also provide aesthetically pleasing locations for housing developments and holiday accommodation. They are frequently utilised for tourism and recreational activities such as boating, fishing, swimming and water sports.

Supporting ecosystem services

Estuaries are used:

1. By fish, either as a permanent home, to spawn, or as a nursery area;
2. As a breeding ground for crustaceans;
3. As a feeding ground for birds, especially waders, and water birds, also flamingos, pelicans, sea birds, cormorants, kingfishers, and herons; three main groups are found on the basis of diet:
    a. those feeding on vegetation;
    b. those feeding on invertebrates;
    c. those feeding on fish;
4. As a feeding ground and rest area for migrating birds;
5. By hippos and crocodiles;
6. By zooplankton and invertebrates.

Benthic species aerate and release nutrients from sediments and process both living and dead plant material, making energy and nutrients available to other species.

Ethical considerations

Ecosystem services are dependent on living organisms (biotic elements) and their interactions with the physical (abiotic) elements of the environment. Sustaining ecosystem services is therefore only possible if these interactive processes are maintained to provide or produce these services. Continuous provision of these ecosystem services through biodiversity conservation enables sustained human well-being and poverty reduction. The Millennium Assessment places human well-being as the central focus for assessment. At the same time it recognises that “biodiversity and ecosystems also have intrinsic value”. This means that biodiversity has a value in and for itself, irrespective of its usefulness for someone else (Millennium Ecosystem Assessment, 2005:1).

Evernden (1993) has argued that ecology’s approach of scientific analysis can detract from our experiences of the beauty and intrinsic value of the natural world – which is a learning process in itself. We become conditioned to ‘classify’, ‘evaluate’ and ‘manage’ the diversity of life around us without necessarily listening, appreciating or caring.

ACTIVITY 5

LOCAL MARINE SERVICES
Investigative Method – Exploring Indigenous Ways of Knowing

See page 25 in the *Methods and Processes* booklet.

Learners could investigate the traditional cultural, ethical and provisional services in a marine area. Information could be obtained by questioning elders in the community, faith leaders and/or specialists. Learners could work in groups to obtain and report on the information or as individuals.

An example of a traditional practice in some cultures in South Africa is the grounding up and boiling of the roots of the coastal silver oak (*Brachylaena discolor*) to treat stomach ache and ulcers. Learners could conduct a mini-research project to obtain information on the traditional cultural practices (related to marine resources) which occur, or traditionally occurred, in their communities.

Economic benefits of marine biodiversity

Placing a monetory value to biodiversity is difficult due to the various local and national benefits which may be affected in different ways. For example, eco-tourism not only affects the local economy but the national gross income. In some regions biodiversity affects the exporting gross domestic income (for instance, fishing in the Western Cape). Biodiversity can have a direct and indirect economic benefit to a country and a local region.

Direct economic values

Direct economic values of biodiversity can be derived from recreation, tourism, property development opportunities and direct sales.

- People will travel far to see specific species, populations, communities, ecosystems and biomes. An example is the recreation and tourism on the coastline throughout South Africa. Each year many national and international tourists visit the region to see the whales. Tourism is the faster growing economic sector with nature-based tourism (or eco-tourism) being an important component of the tourism sector. Visitors to places of scenic beauty like beautiful beaches and unique ecosystems, require support and services. This create jobs and opportunities for small businesses.

- People will pay more for a house with a view and which is close to an area rich in biodiversity.
- Natural resources (like fish) can be sold locally, nationally or internationally.

See page 14 in the *Methods and Processes* booklet.

ACTIVITY 6

TOURISM AND BIODIVERSITY (1)
Information Transfer Method – Guided Questioning

Two activities have been suggested for Tourism and Biodiversity (Tourism and Biodiversity 1 or 2). The first activity involves Guided Questioning and the second involves Scenario Planning.

For this activity the educator uses probing (although structured) questions to direct the learners' thinking about the effects of biodiversity on tourism.

For example: The facilitator encourages learners to reply to questions which will identify the current tourism operations in a particular area, why the tourists are attracted to the area and if these attractions rely on the ecosystems (biodiversity). Possible questions could be:

1. Are there holiday destinations or tourist attractions near to "X" (a specific coastal area)?
2. Are these destinations reliant on the ecosystem services? Thus does biodiversity play a role in the tourist attractions?
3. Are there other biodiversity based attractions in the area which are not currently been utilised by tourists? Could these attractions be developed into attractions in the future?
4. How does the tourism in the area affect the local economy?
5. What kind of activities or products could be developed or created to improve the tourists' enjoyment or services?
6. What would happen if the biodiversity was reduced or lost? What would happen to the eco-tourism?

The facilitator should allow for a progressive flow of appropriate questions rather than pre-defining questions. The question examples above could act as a guideline.

Possible outcomes of the activity

Learners feel involved in the learning process, grow in confidence and motivation for learning when given an opportunity to think issues through for themselves and when they feel as if their suggestions are being heard.

ACTIVITY 7

TOURISM AND BIODIVERSITY (2)
Deliberative Educational Method – Scenario Planning

See page 35 in the *Methods and Processes* booklet.

For this activity the learners create two scenarios. One scenario relates to the effects of low biodiversity on tourism, while the other scenario looks at the effects of a scenario rich in biodiversity. These two scenarios could be related to their circumstances and displayed in a key format or table format.

An example is:

BIODIVERSITY	
Low biodiversity area	**Rich biodiversity area**
No eco-tourism	Attracts eco-tourist
Limited honey available	Due to flowers bees can make honey
Limited medicinal plants	Biodiversity allows for growth of medicinal plants
etc.	etc.

Possible outcomes of the activity

- The process could stimulate debate and critical understanding of what is possible in different scenarios;
- Learners are exposed to diverse perspectives and options.

ACTIVITY 8

BIODIVERSITY AND THE ECONOMY
Deliberative Educational Method – Creative Thematic Presentations (Community Theatre/Education Theatre)

See page 34 in the *Methods and Processes* booklet.

For this activity a drama production can be developed. An example of a presentation is given below. The concept is for the participants to develop presentations which relate to marine biodiversity and the economy, focusing on a local situation. The emphasis should not be on the presentation specifically but rather the message within the presentation. The ability to perform or act is not essential; it is more important to concentrate on the story being 'told'.

The use of Creative Thematic Presentations allows for the improvisation (or making up) of scenarios and/or a message. Three components which could be dramatised are:

A. An issue (or problem);
B. The effects of the issue;
C. Possible solutions to the issue.

The learners should be divided into small groups of about five people who become the 'actors'. It is not necessary to create a script; rather allow the 'actors' to develop their own words. The presentation could mimic people in the community (e.g. traditional healer, chief, mayor, leader, etc.) who the audience should be able to recognise. The more locally significant the presentation, the better. Minimal props should be used – if any are required at all.

For a Creative Thematic Presentation related to Biodiversity and Economy the facilitator could divide the learners into groups. Each group is to:

1. Identify natural resources that are sold which are obtained from marine biodiversity.
2. Each group is to develop a creative thematic presentation which shows the links between the biodiversity ecosystems services and the direct or indirect economic effects. This presentation should only be around 3 – 5 minutes.
3. The groups could also develop a presentation which indicates what would happen if the biodiversity was lost.

Different groups could highlight different aspects, e.g. one group could indicate what happens in the case of a healthy marine biodiversity system and one could develop a presentation which highlights the effects of an area with very little biodiversity.

An example of a creative thematic presentation
SETTING THE SCENE

The roots of the coastal silver oak (*Brachylaena discolor*) are ground up and boiled and used to treat stomach ache and ulcers. If herbalists remove a high percentage of coastal silver oak tree roots from one area, the growth of the plant is compromised and this reduces the herbalists ability to collect and sell the product in the future.

Creative Thematic Presentation 1 (the issue and effect)

- Some of the actors become a tree (possibly one person on the shoulders of another).
- A man/woman dressed like a herbalist asks young boys to cultivate the roots.
- The boys cut the roots off the ‘tree’.
- The ‘tree’ starts off by saying something along the lines of “oh that tickles” but as the boys move around the tree, cutting off the roots, the ‘tree’ should get very concerned and make comments on how the ‘boys’ are killing it, and fall over.
- Boys take the roots to the herbalist who is very pleased.
- The herbalist sells the roots. The herbalist enacts how he/she would use the medicine from the tree (a tea made for fevers and eye complaints). The person drinking the medicine gets better.
- The next time the herbalist wants to make the medicine, he goes to the area where the tree was – but now there are no trees. The herbalist cannot sell the roots.
- A sick person is not able to get the medicine so does not get better.

Creative Thematic Presentation 2 (the solution)

Community members enact how the loss of the tree affects them.

- Women in the community go to the herbalist and explain that if all the roots had not been taken he/she would still have roots for his/her herbs now.
- The presentation can be redone where only some of the roots are removed.
- The 'tree' continues to grow, and is very happy.
- The herbalist has a continuous supply of roots, and is able to sell the roots.
- The sick person gets better.
- The community members are happy because the cultural perspectives are still understood.

Indirect economic values

The indirect economic (or biodiversity provision category) benefits of ecosystems include:

- material goods such as food, water, medicine, fibre and fuel;
- genetic resources for agriculture from the direct use of fauna and flora for livelihood sustenance;
- fishing and gathering of edible products;
- construction materials.

The economic benefit of obtaining provisions from the biodiversity in an area will result in reduced economic expenditure to obtain those provisions elsewhere.

Rural communities are often directly reliant on biodiversity for their livelihood. They rely on the ecosystem services for food through hunting, fishing and gathering of edible products. They also use local biodiversity for the provision of various products such as fuel energy, construction materials, utility items, water and medicine. Wild vegetables (both indigenous and naturalised) as well as fish are an important food source in many rural households. Research is finding that diets can be significantly improved by traditional wild food harvesting practices to supplement commercially cultivated crops.

Teaching Practice

Refer to the Teaching Practice section in the previous learning unit (see page 30) as many of the general points on teaching practice are relevant for this learning unit too. Teaching activities have been interspersed into the subject knowledge section.

Assessment Practice

Refer to the Assessment section in Marine Biodiversity learning unit 1 (see pages 31–35), as many of the general ideas are relevant here. The table below gives some assessment activity examples and illustrates some assessment skills specifically relevant to this unit.

CONTENT KNOWLEDGE SECTION	SECTION SUMMARY	ASSESSMENT ACTIVITY EXAMPLES	KEY ASSESSMENT SKILLS (VERBS)
Role of biodiversity	Diverse range of services provided by biodiversity (to human kind and to the environment), both realised and the future potential.	Survey of local plant uses (Grade 11) [Practical activity]	Design/plan an investigation, measuring, recording, illustrate (draw graphs), interpretation

Conclusion

In Marine Biodiversity Unit 2 we looked at the roles or ecosystem services of marine biodiversity. We discussed the provisioning, regulatory, cultural, supporting and ethical services provided by marine biodiversity. Direct and indirect economic benefits were suggested. In Unit 3 the causes of marine biodiversity loss and the emerging responses to these losses is presented.

Unit 3

Causes of marine biodiversity loss and emerging responses

This unit explores the causes of marine biodiversity loss, specifically the impacts of humans on biodiversity, and then how humans are responding to this loss. Human Impacts on Biodiversity are covered in CAPS in Grade 11, Term 4.

Subject Content Knowledge

Human impacts on marine biodiversity

Key issue:

It is important to recognise the diverse drivers of biodiversity change (direct and indirect), mostly human induced, and the complex interrelated nature in which these drivers impact on biodiversity in reality.

Human (development) activities have both direct and indirect effects on biodiversity, leading to changes in the provision of ecosystem services by the environment. Human (anthropogenic) activities that impact on biodiversity include agriculture, industry, urbanisation, transport, excessive extraction of biological resources. These are referred to as the drivers of biodiversity loss (losses of different components of biodiversity) (Millennium Ecosystem Assessment, 2005). Drivers of biodiversity loss are both local and global in nature. It should be noted that changes in biodiversity are usually the result of multiple drivers and the interactions between these.

The reliance of South Africa's increasing population on the ocean for food, recreation, transport and mineral extraction has subjected marine biodiversity to pressures that are changing the structure of marine communities. The status of South Africa's marine resources is represented in the table below.

Status of South African marine resources

STATUS	PERCENTAGE	SPECIES
Optimally exploited	48.1%	Shallow-water hake; yellowtail; oysters; anchovy; sardine; squid; South Coast rock lobster; prawns; kelps; South East Atlantic skipjack; Atlantic big eye tuna; Indian Ocean big eye tuna
Uncertain	29.6%	Agulhas sole; Cape horse mackerel; Patagonian toothfish; white mussel; South Atlantic swordfish; Indian Ocean albacore; Indian Ocean skipjack; Atlantic yellowfin tuna
Overexploited	14.8%	Deep-water hake; West Coast rock lobster; Indian Ocean yellowfin tuna; Southern bluefin tuna
Underexploited	7.4%	Round herring; seaweeds

Source: WWF-South Africa: Fisheries Facts and Trends South Africa, 2011.

The Sixth Extinction?

Discuss the implications of the following passage:

Scientists agree that the Earth is currently undergoing a new wave of mass extinction that rivals the five great mass extinctions of the geological past. While past extinctions have been caused by geophysical events (climate change, plate tectonic movements, collision between the Earth and extra-terrestrial bodies/comets, and volcanic eruptions), the current wave of extinctions is human induced (biotic).

This sixth extinction is believed to have two phases, the first phase being the effect of the dispersal of humans to occupy different parts of the earth (100 000 years ago). The second phase was the effect of the agricultural revolution (10 000 years ago) and the subsequent industrial revolution.

The main factors contributing to the sixth extinction are:

i) transformation of the landscape (habitat change),
ii) over-exploitation of species,
iii) pollution, and
iv) introduction of invasive aliens species.

The main causes (direct drivers) of marine biodiversity loss are: habitat change, pollution, invasive alien marine species, overexploitation, mariculture and climate change (Secretariat of the Convention on Biological Diversity, 2010).

1. Habitat change, habitat degradation and loss of habitat

All plants and animals rely on their habitats for food, water, shelter and living space. Increased coastal development is destroying species' habitats on a huge scale. Coastal developments include building construction, provision of recreational facilities, marinas, car parks, etc. Bad agricultural practice and erosion affects marine habitats too. Damming rivers, causeways, weirs and incorrect bridge construction can change water flow into marine ecosystems. An example is the effects on 'fish ladders' which can obstruct fish migration.

With the exception of some estuaries and those bays in which harbours have been developed, notably Saldanha Bay, Table Bay, Durban Bay and Richards Bay, development has had little impact on the marine biota. This is largely because of the small number of urban centres along the South African coastline and the exposed nature of the coast (which mitigates against the construction of engineering structures). Mangrove forests are also subjected to unsustainable harvesting and are being cleared for agricultural uses, salt production and human settlements. Loss of mangrove habitat has an impact on productivity of artisanal and commercial shrimp and crab fisheries.

ACTIVITY 9

HABITAT LOSS
Information Transfer Educational method – Game

See page 16 in the *Methods and Processes* booklet.

This brief fun activity demonstrates the loss of appropriate habitat for a particular species. For this activity any marine species may be chosen as a representative. In this example we will use an African black oystercatcher – more information on this and other marine species can be found in Appendix 1.

Learners are to create a circle (representing the habitat for oystercatchers). One or two learners (representing the oystercatcher) move around inside the circle. The "habitat" learners could chant or sing about their habitat (rocky shores). The facilitator moves around the "habitat" and removes a person from the circle. As a person is removed from the circle, the facilitator can indicate the reason for removing that component of the "habitat", for example; waste pollution, estuary bank development changing feeding areas, domestic dog disturbance, vehicles riding over nests, large scale harvesting of mussels. This will result in the circle becoming smaller. Each time a person is removed from the circle the space for the "oystercatcher" will become less, until the "oystercatcher" is forced to "fly away" and leave the "habitat" area.

Petroleum, diamond and dune mining

Mining has an obvious impact on substrates and a consequent impact on the associated biodiversity. This can extend to the indirect impacts like the cutting of kelp for diver access to gullies for suction pumps.

More than 300 offshore oil and gas wells have been drilled in South Africa. Most wells have been drilled in less than 250m water depth on the west and south coasts with likely expansion along the east coast. Impacts include localised habitat damage, physical disturbance and smothering, localised pollution, and the risk of catastrophic oil spills from a well blowout. The heavy use of South African waters by shipping, together with the dangerous seas, can cause vessels to hit reefs or run aground resulting in major spills.

The spill from the iron-ore carrier Treasure in 2000 had an impact on over 40 000 penguins within 10 days.

2. Pollution

Pollution can be broadly divided into two categories:

1. Liquid chemical and increased nutrient loads e.g. sewage and fertiliser; and
2. Litter mainly originating from land-based activities with a small proportion from shipping.

Coastal and marine ecosystems are under extreme pressure from pollution from both land-based and marine-based sources. Among these are: uncontrolled discharges of industrial waste and sewage from coastal settlements; refuse blown or washed out to sea; general and toxic wastes deliberately dumped at sea; and oil spills and leaks. All these have a cumulative effect on the marine food chains and food webs. Residues of fertilisers are also washed down in rivers and contribute to eutrophication of coastal waters and the development of algal blooms and toxic red tides. In South Africa, plastics contribute largely to marine litter. Their persistence in the marine environment poses a threat for marine organisms that ingest or become entangled in plastic waste. Sea-birds, seals and turtles are among the most affected. For example, marine turtles often mistake plastic bags floating in the sea for jellyfish, and eat them. This may choke turtles to death or prevent them from eating properly.

3. Invasive marine alien species

Deliberate or accidental introduction of invasive alien species in marine ecosystems have altered community structure and functions. Invasive species like Mediterranean mussels can compete with indigenous species for space, nutrients and sunlight. A dense invasion of aquatic plants can alter the flow of rivers and stream, disrupting the aquatic ecosystem. Reduction of light penetration reaching the deep portions of the water systems, and changes in bank vegetation resulting in erosion, alter and affect the aquatic environment.

The discharge of ballast water from ships entering South African waters brings with it the risk of introducing invasive marine species. More than 22 million tonnes of ballast water is discharged in South African ports and harbours annually (Sink & Atkinson, 2008) from sources all around the world.

Biofouling has also become a major concern at the national and international level. Many countries have banned the practice of cleaning ships' hulls at sea in an effort to prevent the release of organisms into the marine environment. South Africa has not yet implemented such a ban (Attwood et al., 2000).

While 84 marine alien species have been identified along the South African coast, only eight are classified as invasive. The most widespread and ecologically important invasive alien species along the South African coast is the Mediterranean mussel. This aggressive invader is currently the most dominant invertebrate on west and south coast rocky shores, outcompeting many other species within those communities. It has spread over 2 000 km of coastline.

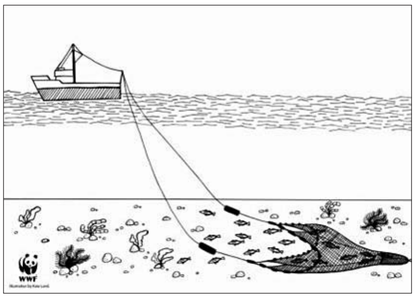
4. Overexploitation / overharvesting

Marine and coastal fishery resources are extremely important in Africa, both to national economies and to the livelihoods of local communities. The impacts of direct exploitation have therefore been experienced most dramatically by humans in South Africa, but there are also declines in the populations of some targeted species such as the Southern Right Whales. Similarly the populations of a number of important linefish species have been reduced to a point where population size and catch per unit effort are less. Amongst invertebrates, populations of lobster and abalone are greatly reduced, as are those of mussels in some areas such as the Transkei. Several species of invertebrates, particularly the mud and sand prawns are harvested for bait. The physical impact (habitat change) of trampling and harvesting are considered to be more harmful then the reduction in standing stocks.

The life history of species can make them more or less vulnerable to overfishing. Factors which determine a species' vulnerability to harvesting include: are they resident or migratory; where and for how long do they spawn and associated breeding behaviour; how many young are produced; do they mature at a young age or after a number of years?

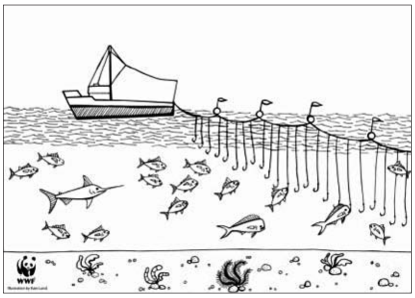
Commercial and recreational fishing

There are many different fishing methods e.g. trawling, long-line and rod-and-line fishing, each with its own type of pressure on fish species and their associated ecosystems whether in the form of bycatch – species not being targeted (in trawl and long line fisheries) or benthic habitat degradation (in trawl fisheries).



Trawling (©WWF-SA/Katy Lund)

Population increases, both inland and in coastal centres, have also contributed to increasing demand for fish and seafood. Improved technology has increased the potential volume of fish catches and contributed to the depletion of fish stocks. Exploitation can also be in the form of recreational activities such as boating and water-skiing.



Line-fishing (©WWF-SA/Katy Lund)

Other pressures come from the shark control programme and kelp and invertebrate harvesting in the coastal environments.

Subsistence harvesting has been operating in South Africa for centuries but has only recently been recognised as a sector of South African society. More than 30 species in a range of ecosystems across the country are targeted used various fishing methods. The dominant activity is the harvesting of invertebrates from rocky shores e.g. mussels and limpets. The majority of the 30 000 participants are found in the Eastern Cape and KwaZulu-Natal. Due to the steady increase in harvesters, harvesting has reduced the abundance and size of certain species as well as introduced changes to the structure of some of the rocky shore communities.

5. Mariculture

Mariculture (seafood farming) operations along the South African coast take the form of in situ marine operations (i.e. those using long-lines, rafts, racks or cages suspended directly in the sea) and land-based operations that abstract sea water, pass it through the culture facility, and then return it to the marine environment.

Biodiversity concerns associated with mariculture include nutrient enrichment and chemical pollution, impact of diseases and escaped genetically modified animals on wild animals as well as localised habitat alteration.

6. Climate change

Increasing sea surface temperature and ocean acidification can have a detrimental effect on the growth, reproduction and survival of many different marine species. Relatively quick increases in temperature over a short term have impacted corals, for example resulting in coral bleaching (the loss of zooxanthellae and sometimes the death of large sections of coral reefs, with the consequent loss of the very high biodiversity associated with these coral reefs. Increasing acidification of the sea results in many marine invertebrates not

Appendix 3 (sections of *EnviroKids* Vol. 34(3), 2013) provides information on *Climate change and our oceans, Changing marine life* and *Ocean change and people.*

developing strong exoskeletons or shells. This makes them more vulnerable to predation and reducing the ability to grow affecting their survival.

The effect of climate change is exacerbated when considered in conjunction with all the above common threats. Each of these above threats cannot be looked at in isolation; they have a cumulative effect in which the whole is definitely more than the sum of the parts.

ACTIVITY 10

CLIMATE CHANGE AND MARINE BIODIVERSITY

This activity involves the development of various skills: recall (listening with intent), critical analysis, problem solving, decision making, deliberation, conflict resolution, research and report writing, action learning for transformation, environmental values clarification.

Ask your learners to read the articles from the EnviroKids magazine (see Appendix 3). Divide the learners into groups. Ask each group to discuss the negative effects of climate change on one of the topics (issues) in the articles. After they have discussed the issue they should write down the points and present them. The group should analyse and report on the effects that a specific climate change issue would have on the ecosystem services. The groups are to present on what actions they would be able to take in order to:

- Reduce the causes of climate change;
- Help the marine ecosystems.

Responses to biodiversity loss

Key issue:

Responses to biodiversity loss are quite varied. However, no singular response is effective on its own. Each response is a continuous learning process and in some instances certain responses can have negative implications. An integrated approach to biodiversity conservation is more feasible.

Considering the important role of marine ecosystems and biodiversity to humankind and to the marine environment in general, several responses to reduce the human impacts on marine biodiversity have emerged (together with responses to biodiversity in general). These responses promote the implementation of local biodiversity conservation initiatives, drawing on the synergic link between local biodiversity and human well-being. At the regional and global level, effective responses enable the development of shared goals and programmes such as regional treaties and agreements.

Some examples of emerging responses specifically related to marine biodiversity conservation are given below.

Marine Protected Areas (MPA)

South Africa has 23 proclaimed MPAs (2012), the oldest was established in 1964. Seven do not permit any use, seven have both no-take and limited extractive use zones and nine allow some extractive use throughout the MPA.

The objectives of South African MPAs are:

- Protection of species and the physical features on which they depend;
- Help fishery management by protecting spawning stock, allow stock recovery, increasing stock abundance in adjacent areas and provide pristine communities for research;
- Reduce conflict between users.

Reducing over exploitation

Co-management

Co-management initiatives have reduced the impacts of some subsistence harvesting on the KwaZulu-Natal coast. Committees have been set up in each area with representatives of the harvesters, representatives of the nature conservation authorities. Resource harvesting monitors have been selected from local communities and trained to capture information on daily harvests – species, size and quantity. Members of harvesting groups have been elected and trained in key resource management principles as well as biology of species being harvested. These co-management committees have worked to develop local regulations and solutions to overharvesting challenges.

South African Sustainable Seafood Initiative

A number of the world's and South Africa's fish stocks have collapsed due to unsustainable fishing. The SASSI programme was initiated by WWF South Africa in collaboration with a number of networking partners in 2004 in order to educate participants in the seafood trade, from wholesalers to restauranteurs, supermarkets and fishmongers through to seafood lovers.

Appendix 4 is a copy of the SASSI Consumer Seafood Guide – World Wildlife Fund – South Africa.

There are three objectives:

- Promote voluntary compliance of the law through education;
- Shift consumer demand away from over-exploited species to more sustainable options;
- Create awareness around marine conservation issues.

A consumer species list has been developed that categorises species into three groups:

- **GREEN** (best choice) – these can handle current fishing pressure;
- **ORANGE** (think twice) – there are reasons for concern either because the species is depleted, or the type of fishery may cause severe environmental damage and/or has high bycatch of other species or the life-history of the species makes it vulnerable e.g. late maturing;

- **RED** (don't buy) – these are either from collapsed populations or have extreme environmental concerns or lack proper management or are illegal to buy or sell in South Africa.

Consumers are encouraged to ask questions before buying fish:

- What is it?
- Where is it from?
- How was it caught?

More information on the programme is available at www.wwfsassi.co.za, or wwfsassi.mobi (for cellphones)

This programme is slowly increasing its profile across the country. Due to consumer demand, seafood sellers and restaurants are finding out about the programme and considering how they can contribute to ensuring that there are fish to sell in the future.

Policy and legislation

National legislation

In addition to protection of the environment in general, laws in South Africa for the protection of the marine environment include the following:

- **Integrated Coastal Management Act (ICM)**, 1 December 2009 – This falls under the umbrella of the National Environmental Management Act (NEMA) of 1998. This establishes a system of integrated coastal and estuarine management regimes that protects the coast and maintains its natural functioning, whilst ensuring that development and the use of coastal resources is sustainable.

- **Marine Living Resources Act (MLRA)**, 18 of 1998 – This covers the management of South Africa's marine living resources and their environment.

See page 12 in the *Methods and Processes* booklet.

ACTIVITY 11

MARINE BIODIVERSITY CONSERVATION
Information transfer method – Talks and presentation

Invite a resource person from a local environmental organisation or government institution to give a talk to your class about marine biodiversity and the need for its conservation. Alternatively you can take your learners on a guided tour visit to a marine related facility (e.g. aquarium and/or nature conservation reserve which incorporates marine ecosystems). Ask the learners to take notes on what is said or what they observe. The learners should then write an essay on what was said or on what they saw and were told with regard to biodiversity conservation.

Teaching Practice

Refer to this section in learning unit 1 (see page 30) as many of the general points on teaching practice are relevant here too. Teaching activities have been interspersed into the subject knowledge section.

ACTIVITY 12

TEACHER ACTIVITY

1) Work with the Life Sciences curriculum. Look at the three specific aims outlined in the document and map out the skills associated
2) Choose one or two of the activities in the Marine Biodiversity units and list all of the skills that could be developed through the activity, related to the three specific aims.
3) For each skill describe how the activity can develop this skill and consider some of the challenges that you as a teacher might have in supporting the development of this skill (Do you and/or your learners have the necessary prior knowledge? Do you have the relevant knowledge resources to develop the necessary skill? Are there any fundamental skills not yet in place that might hinder the development of this particular skill? Are there any logistical or structural problems associated with developing this skill?)
4) Reflect on the overall strengths and weaknesses of this method (use the Methods & Processes booklet and the Core Text to help facilitate this reflection)

Assessment Practice

Refer to this section in learning unit 1 (see pages 31–35), as many of the general ideas are relevant here. The table below gives some assessment activity examples and illustrates some assessment skills specifically relevant to this unit.

CONTENT KNOWLEDGE SECTION	SECTION SUMMARY	ASSESSMENT ACTIVITY	KEY ASSESSMENT SKILLS (VERBS)
Responses to Biodiversity issues	Varied emerging responses to biodiversity concerns and their (positive and negative) implications	1. Role play of park-community conflict (Grade 11) 2. Research on energy sources and their implications (Grade 11)	Recall, debate, discuss, predict, critically analyse, solve problems, use knowledge, write/ synthesis Design/plan an investigation, using equipment properly and safely, measuring, recording, interpretation

Conclusion

In Unit 3 we have highlighted the influences affecting marine biodiversity. The impacts emphasised were: habitat loss, change and degradation, pollution, invasive alien marine species, overexploitation or overharvesting, mariculture and climate change. Some of the responses to these biodiversity losses were introduced in the discussions about Marine Protected Areas, reducing over exploitation and national legislation.

This biodiversity resource draws together biodiversity aspects across the Grade 10-11 Life Sciences curriculum as contained in CAPS. This is intended to create/provide a progressive understanding (conceptual and logical coherence) of the topic while covering the required aspects in the curriculum.

This resource provides an elaboration of the concept of marine biodiversity and its related terms. It then contextualises marine biodiversity in relation to its benefits to humankind and the environment in general, the human impacts on marine biodiversity (causes of biodiversity loss) and the emerging responses to marine biodiversity loss.

It is important to realise that knowledge on marine biodiversity is continually evolving and that learners should acknowledge that while some knowledge is factual, some of it is contested and uncertain. There is a reality beyond what we actually know and thus even factual knowledge is constantly being challenged and updated.

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Resource material relating to Marine Biodiversity

The following resource materials could be used as supplements to this resource.

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Appendices

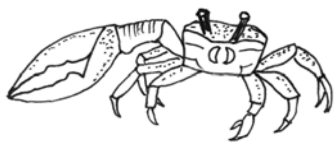
Appendix 1

Marine species

Illustrations by Sylvia Jacobs

Mangrove species

Fiddler crabs (*Uca* species) – Phylum Arthropoda



Fiddler crabs are small, gregarious, and can form extensive colonies; they are amphibious and are very sensitive to ground vibrations, running to shelter when alarmed. They walk sideways, raised on the tips of eight clawless legs. Their stalked eyes can be folded into a groove. There are five different species in South Africa.

When submerged, they breathe in the normal crustacean way, when on land their gills, which are small and stiff, do not adhere together which would reduce the area for absorption. Blood vessels richly endow the gill cavity walls and act as extra absorptive surfaces and the apertures to the gill cavity are small and fringed with hairs to minimise water loss. In addition a stream of air is constantly pumped through the gill chamber oxygenating the water inside.

Male fiddler crabs have one large brightly coloured claw (chela) which may develop either on the right or left side and which may equal the rest of their body weight. The cheliped is elaborately jointed and is held across the body in a folded horizontal position. It is waved in courtship, and defense, as a symbol of the crab's sex and status. The males entice the females by 'waving, calling or beckoning'. Courtship is a complicated sign language, each species having a unique set of movements which all the males of that species follow; this strategy ensures that the female only pairs with a male of the same species. Mating takes place above ground and the female retains the eggs on her body. Aggressive behaviour is normal in a fiddler crab colony and is intensified during the mating season.

Fiddler crabs are detritivores, feeding almost nonstop at low tide. The female uses both chelae; the male manipulates the mud with his small chela into balls. Their mouthparts are adapted for sorting and choosing food items from the mud, only swallowing the food, discarding the mud in small round pellets as pseudo-faeces.

Both sexes construct their burrows which act as a refuge at high tide and are in constant use, and are frequently cleaned and re-excavated. At the end of the burrow is a turning circle. Before the high tide the crabs retreat to their burrows sealing off the entrance with a plug of mud, both air and oxygenated water percolates down. The burrow is still of vital importance at low tide and is central to their activities, providing water, refuge, and as a centre for territorial and mating behaviour.

Sesarmid crabs – Phylum Arthropoda

These crabs vary greatly in size, their bodies and legs are dull brown or black. Their chelae are sturdy and powerful and may be bright depending on the species. *Neosarmtium meinertii*, the red mangrove crab is the largest of the three types.

They are tolerant of infrequent tidal flooding and inhabit the upper levels of the mangroves, usually in the densely-shaded area among the roots of the black mangroves (*Bruguiera gymnorrhiza*) and the yellow mangroves (*Ceriops tagel*). Where the mud is thick and water-logged, fiddler crabs are not normally found.

Sesarmid crabs build permanent burrows in communal groups, and during the period of low tide they remain in their burrow, usually only emerging for forays for food emerging before high tide and climbing upwards to avoid the water. This is not necessary except at spring highs due to their location.

Sesarmids are omnivorous, feeding mainly on plant matter. They are very sensitive to ground vibrations and can feel leaves falling; food, once located, is brought back to the burrow and eaten there. Their chelae hold the food item and the mouthparts tear and cut small sections for digestion.

Adaptations for respiration while out of water include oxygenated water passing through the gill cavity continuously as happens under marine conditions but this water is re-directed over aeration plates on the body surface. The circulating water is expelled from the gill chamber at an opening just above the mouth, from where it follows lateral grooves and then spreads over intricate grids of raised bristles on the cheeks and sides of the crab. Then it is finally re-channeled into the gill chamber at points near the bases of the rear legs. Circulation is maintained by a pumping action, water being replenished from free-standing water in the burrow.

Mudskippers (*Perioptthalmus kalolo*) – Phylum Chordata

Mudskippers are small fish with a heavy blunt head and the body narrows down the tip at the tail. Their eyes are large, bulbous, and raised above the head, and adapted to sharp visualization of small prey and are specifically modified for intense colour vision. The delicate eyeballs are covered by a layer of thick, transparent skin to protect them from desiccation. Having no tear ducts, they periodically spin the eyes downwards into the wet sockets to moisten them. Their body is smooth and has a mottled grey-brown colour.

The pectoral fins are very well developed, and retain a membranous fin-rayed appearance. They have a fleshy base and an elbow-like bend, which enables the fish to 'walk' in an action known as crutching. They extend both pectoral fins forward in unison, then transfer their weight onto the pelvic fins which spread out sideways, forming highly flexible 'fans' which both support them and grip the substrate. They swim slowly completely submerged and can 'skelter' across the water. Swimming with just their eyes protruding and their pectoral fins held out and acting as wings, their tail generates enough thrust for a short flight completely above water.

When feeding and needing to escape from predators they use a 'skipping' motion. Before each leap, the tail bends forward to one side, and pushes down in the mud. The pelvic fins thrust them upward, their body straightens, and they propel into the air and use their pectoral fins as stabilizers during the flight.

Respiration is by means of gills both in the water in the normal way and on land. On leaving the water they take a gulp of air, then close the opercular passage, resulting in sealed gill chambers, each having residual water and air, both of which have to be periodically expelled, then quickly replaced. The water is replaced by vigorous underwater pumping by the mouth, and air by gulping, therefore they never go too far from the water. Swallowing of insect prey results in the opercular slits opening, releasing the water and air suddenly which is audible.

Mudskipper males make a burrow in soft mud, or among white mangrove pneumatophores (aerial roots) to raise their young. Each burrow has a twin opening at the mud surface and each has an encircling turret built up from the excavated material. The openings lead to a common chamber which is permanently filled with water. Once the burrow is complete, the male becomes very territorial. Both defense and courtship exhibit a display involving both dorsal fins. After courting mating takes place at the burrow site and the eggs are laid on the walls.

The young, which are totally aquatic, remain in the burrow for a while, becoming amphibious after metamorphosis. As adults, they are amphibious and insectivorous.

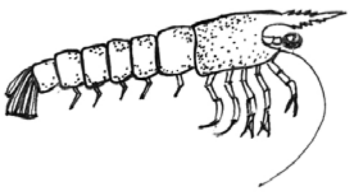
Climbing whelk (*Cerithidea decollata*) – Phylum Mollusca

Climbing whelks are frequently found on tree trunks and change their position according to tidal fluctuations. They feed on microscopic organic particles extracted from the mud, returning repeatedly to the same tree.

Mangrove whelk (*Terebralia palustris*) – Phylum Mollusca

These are found only at ground level. They feed during low tide on the mud eating minute plants and fallen mangrove leaves.

Swimming prawns (*Fenneropenaeus indicus*) – Phylum Arthropoda



The first three pairs of walking legs of swimming prawns are clawed. They are bottom dwellers in estuaries from a post larval stage but spawn at sea. Swimming prawns are omnivorous, feeding on detritus and scavenging. They are edible.

Carid prawns (*Macrobrachium* species) – Phylum Arthropoda

Carid prawns have two pairs of clawed walking legs. They live their entire life in the estuary. They feed on organic detritus and scavenge. This species is an important part of the estuarine food web.

Burrowing sand and mud prawns (*Upogebia* and *Callianassa* species) – Phylum Arthropoda

These eat detritus, sifting organic matter. They are a popular bait species.

Sand dune plant species

Low creeping pioneer plant species colonise and help bring about dune stability. The plants adapt by having creeping stems and by being fast growing. Some are succulents and have a thick cuticle to protect them from salt spray.

Scaevola (*Scaevola plumieri*)

This is a very important pioneer and dune stabilizing plant in the fore-dunes. Salt accumulates in the older yellow leaves and is disposed of when the leaves drop off.

Beach-bean (*Canavalia* rosea)

This is also a pioneer plant and provides shelter for roosting and nesting birds such as sandplovers. It is a strong tough creeper, has mauve flowers and a bean like seed.

Dune-fig (*Carpobrotus dimidiatus*)

The dune-fig is a succulent perennial creeper, its long trailing stems bind the sand. The leaves are fleshy and succulent. The sap can be used to treat blue-bottle stings, and provides food for bushbuck and duiker.

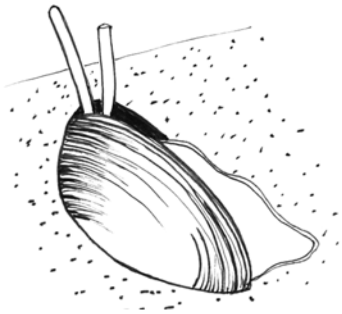
Animals on sandy beaches

Plough snails – Phylum Mollusca

Bullia scavenge on dead or dying animals that are washed up on the beach, they are extremely sensitive to certain chemicals and they test the water using their siphon. They spend most of their time under the sand with just the tip of their siphon extended. When they emerge from the sand, they turn on their back and spread their huge foot which simulates a sail and they surf up the beach. After they are deposited on the sand they look for food. After finding a food source they thrust out their long proboscis and suck up their meal, becoming inactive once the water rises above the mid-tide level, this process is then repeated in reverse, they are then washed back to their original position.

The presence of plough snails is usually an indication of a safe swimming beach.

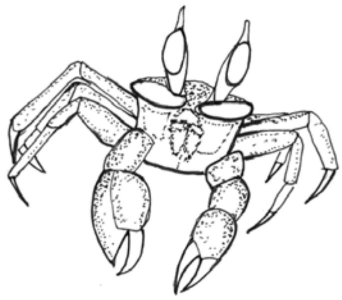
They are repelled by a chemical released by both skates and rays, their predators.



White mussels – Phylum Mollusca

Species of *Donax* have shells that are pointed anteriorly and blunt posteriorly and burrow on sandy beaches that have strong wave action and back out on incoming waves and reburrow with great speed as the wave recedes. Ridges across the blunt, back end of the shell help to anchor while burrowing. They filter feed using their inhalant siphons which are fringed with infolded tentacles which keep out swirling sand grains. Their exhalent siphons are longer. Their siphons are bitten off by both fish and sanderlings and they are preyed on by oystercatchers and gulls, fish and rays. They are collected for bait.

Ghost crabs – Phylum Arthropoda

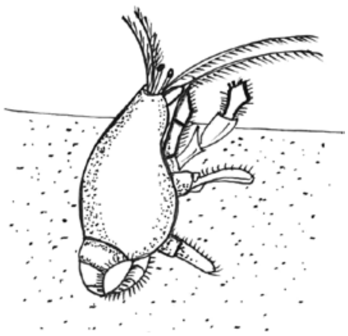


Ghost crabs are the only species of crabs that live in the intertidal zone of sandy beaches. They dig holes up to a metre deep, down to the water table. At the bases of their legs are tufts of hairs that are able to suck up water from damp sand which keeps their gills wet.

Their eyes are large and wrap around and mounted on erect stalks giving them a wide field of vision and maximum all-round night vision. They swivel back into grooves for protection when they enter their burrow. One nipper is enlarged and used in defense. Their long legs enable them to run very fast and they are extremely sensitive to ground vibrations.

Ghost crabs are mainly nocturnal. They scavenge and prey on juvenile turtles and other species. There are three species of ghost crabs locally.

Mole crabs – Phylum Arthropoda



Mole crabs live in the surf zone. A tough exo-skeleton protects their barrel-shaped body when they are rolled up and down the beach by the waves. Their legs are highly modified and are unsuitable for walking. Using their last two pairs of limbs, they dig backward into the sand excavating a hole they then 'row' themselves into the hole with their remaining legs. They use their last pair of thin and flexible walking legs to reach inside their gills and remove any sand particles that maybe present. The body ends in a telson (tail-fan) fringed with hairs which both prevents sand grains from entering the gill chamber and protects developing eggs. To trap organic particles they use their modified very long antennae which have long fringes of hairs that are rolled up while the animal is tossed by the waves.

Mole crabs are preyed on by fish and rays and are harvested for bait.

Isopod and amphipod – Phylum Arthropoda

Both are marine species and are numerous in most marine habitats.

Isopods have a flattened, segmented body, the first seven segments have walking legs. Flap-like appendages on the abdomen are used for swimming. They can roll into a ball for protection. Some isopods are parasitic on fish

Amphipods are laterally flattened and their first two pairs of legs form enlarged nippers. Beach amphipods can hop.

Both amphipods and isopods burrow and scavenge and are preyed on by fish and birds.

Rocky shore species

Barnacles – Phylum Arthropoda

Barnacles, once settled, are the only sessile group of crustaceans aside from parasitic forms and are exclusively marine, some species being commensal on whales, turtles and other animals.

Barnacles are hermaphroditic, they usually cross-fertilize. This is achieved by them having a very long penis which can be 3 times their length. Eggs are brooded until they hatch as free-swimming nauplius larvae which are released into the sea. The nauplius larvae changes into a cyprid larvae which then metamorphose into the adult.

Settling larvae are attracted to adults by the proteins in their shells. Before settling they do a circular dance which serves to space them out before finally settling and attaching to the substrate by suctional pads at the end of their antennae. The cyprid then pours cement from glands located in the base of the first antennae and glues its front end to the substrate, while standing on its head. A vertical wall of 4-8 shell plates overlap and are held together either by living tissue or by interlocking teeth, completely ringing the animal, an operculum is present - formed by additional plates. The body is flexed backwards so that the appendages are directed towards the aperture and 6 pairs of long branching thoracic appendages (cirri) equipped with setae (chitinous bristles) are used for suspension feeding after opening the operculum.

Barnacles are major fouling organisms.

Limpets – Phylum Mollusca

Limpets have a cap-shaped shell, are herbivorous with a very long radula (ribbon-like ‘tongue’) and have a very long gut. They are very efficient grazers with each tooth row having many replaceable teeth. They scrape algae off the substrate.

Limpets cling tightly to the substrate by adhesion. Limpets occupy a home scar to which they return. The pear limpet, *Scutellastra cochlear,* maintain algal gardens which they fertilize and guard territorially.

The keyhole limpets have a hole in the apex of the shell through which protrudes a siphon carrying the anus. Water containing oxygen is drawn into the mantle under the front of the shell and exits with its waste out through the keyhole.

Slipper limpets are filter feeders, they do not move around and occur in piles, one on top of the other.

Nerites and turban shells – Phylum Mollusca

Nerites possess a thick, globular shell and a hard calcareous operculum which also has a peg-like projection on the inner surface that seals the opening tightly. The underside of the shell is flattened to fit tightly against the rock. They are herbivorous and nocturnal.

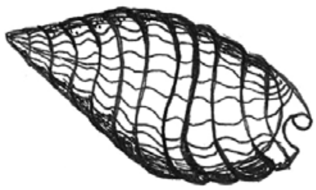
Nerites lay papery white oval, egg-capsules on the substrate, each containing a large number of eggs about 2mm in length which produce planktonic larvae.

The alikreukels have heavy, thick shells, their operculum is thick, white and chalky and the outer surface has densely-packed coarse nodules.

The winkles (top shells) are herbivorous.

Cowries – Phylum Mollusca

There is a narrow slit running the full length of the shell, both lips are ridged, they have no operculum. For defense they are able to extend both mantle lobes which may be pigmented and have branching sensory lobes, over their shell. The mantle also deposits successive layers of enamel-like crystal onto the shell surface which keeps the shell shiny.



Whelks – Phylum Mollusca

These species are predators or scavengers using their tubular proboscis to capture their prey; their shell has a notch to accommodate their long siphon used for smelling out food. Their narrow radula is housed in a long tubular proboscis which can be extended to reach into prey. Whelks lay their eggs inside tough capsules. Only some eggs within each capsule develop, the remaining ‘nurse eggs’ are eaten by the developing embryos.

Zoanthids – Phylum Cnidaria

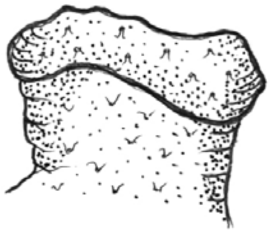
Zoanthids form large encrusting anemone-like colonies, the individual animals are joined together by a continuous fleshy base, some species can totally retract their polyps. Being interconnected they are able to pass digested food between polyps. Zoanthids use their stinging cells to capture zooplankton but also depend on their symbiotic zooxanthellae (unicellular algae within their tissue) for part of their nutrition.

Chitons – Phylum Mollusca

Chitons have eight overlapping transverse valve plates held together in a tough leather-like girdle (coat of mail). The articulated plates allow the animal to fit tightly against curved surfaces or to roll into a ball if dislodged. The area around the mantle is the girdle which is thick and stiff and may have hairs or bristles.

Chitons are unique in having sensory organs which are located all over the shell in minute vertical canals and which respond to light. Some species exhibit homing behaviour. Chitons are slow moving, nocturnal and herbivorous using their wide, many-toothed radula to scrape minute algae off the rocks.

Unlike most molluscs, most are dioecious, males release sperm, fertilization takes place either in the sea or the mantle cavity of the female, the eggs are enclosed in a spiny envelope in strings or singly, some species brood eggs.

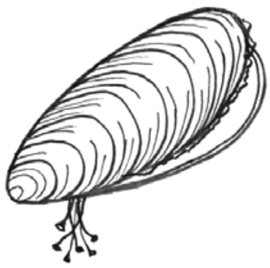


Sponges – Phylum Porifera

Sponges are asymmetrical and are a single animal, adult sponges are the only sessile animal, growing throughout their life, and grow as encrusting forms on the rocky shore, performing a vital role (especially on coral reefs) by filtering the water. The water enters via small holes, collar cells create a current and the clean water leaves through bigger holes.

Sponges consist of a number of different cells which co-operate to form an individual. Support is provided by connective tissue containing a skeleton made of spicules. These spicules can be used as a defense mechanism because they are fiercely irritant to animals which brush against it.

Most sponges are hermaphroditic and can reproduce both sexually by releasing eggs and sperm, and asexually by budding, and sponges have great powers of regeneration.



Mussels – Phylum Mollusca

The most common species on the coast are the brown mussel *Perna perna* in the south and east and the black mussel *Choromytlus meridionalis* in the south and west. The two valves are held together by an elastic hinge ligament made of protein and are laterally compressed. The valves are pulled together by the abductor muscles. Being filter-feeders they have no radula, and secure themselves to the substrate by byssus threads secreted by a gland in their foot. The threads harden by a process called tanning.

Their head is poorly developed, and their gills are large and equipped with vibrating, microscopic filaments (cilia) which pump in water, bringing in food and oxygen. Mussels reproduce by broadcast spawning; the gonads are large, orange in the females and cream in the males.

Mussels are an important food source for fish, sea-stars, octopuses and lobsters.

Sea anemones – Phylum Cnidaria

Sea anemones are mainly solitary, attaching their body to the substrate with the muscular adhesive disc. They have a hydrostatic skeleton, the mouth forms a pharynx that functions as a valve preventing water loss. Their body wall is divided into partitions.

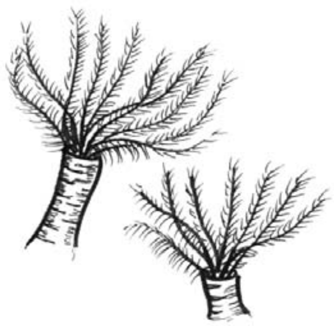
They are carnivores, the mouth is encircled by tentacles with stinging cells with which they capture their prey. They are mainly sessile but can move and some species can swim.

Sea anemones can reproduce both sexually by broad cast spawning, and asexually by budding , or, two mouths may develop and the animal splits in half, or by leaving a bit of the disc behind which will develop. The plum anemone *Actinia equine*, is well adapted to the intertidal zone and to prevent desiccation closes up tightly during low tide, they also brood their young within the body.

Polychaete or segmented worms – Phylum Annelida

These may be divided into two groups; most have soft lobe-like appendages which usually have bristles or chaetae which are used like legs. Each segment has its own muscular, reproductive and excretory organs.

1. Errantia are mobile active forms, mostly carnivorous, having well-developed heads with eyes, sensory appendages, and big jaws for capturing prey.
2. Sedentaria mainly live in permanent tubes or burrows manufactured from mucous, mud, sand or by binding together pieces of algae.



The feather-duster worms (*Sabellastarte longa*) have a double crown of spirally-arranged feathery filaments on the head which extract oxygen, and capture food. They are extremely sensitive to movement and withdraw instantly.

The Cape reef worm (*Gunnarea capensis*) forms massive banks of sandy tubes, solidly cemented together, they use chaetae to form a horny plug to seal the tube.

Ascidians – Phylum Chordata

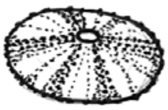
These are the most advanced of the invertebrates. They are permanently attached to the substrate and encased in a hard tunic or test made of cellulose. The body is surmounted by two openings:

1. siphon for the intake of water, food and oxygen
2. siphon for the excretion of waste and carbon dioxide

Circular muscles regulate the openings, contraction of the body wall, compresses the body, forcing water out through the siphons in jets; this periodic squirting is characteristic of all ascidians. The large internal gills act as a pump. At the base of the pharynx which is highly specialised for filter feeding and has tiny holes, stigmata, which sieves the water, is the small heart which first pumps blood in one direction and then reverses the flow.

They may be either solitary or colonial and interconnected, and are the only animals to synthesize cellulose in large quantities. Most are simultaneous hermaphrodites and both broadcast spawn or brood depending on the species. Development leads to a tadpole larva which displays all the chordate characteristics.

Sea urchins – Phylum Echinodermata



Sea urchins have a globular body encased in a calcium carbonate shell like structure, biologically known as a 'test'. Projecting from the test are spines which articulate on a ball and socket joint and which can be moved in any direction, and are used both for locomotion and defense. Some species of fish e.g. dominos gain protection amongst the spines. Sea urchins are preyed on by some fish e.g. triggerfish, whose eyes are set high on their head to avoid the spines.

Five double rows of tube feet run down the sides; they are able to grip the substrate firmly and hold pieces of algae while they are eating. Between the spines and tube feet are pedicellariae – small claw-shaped structures thought to keep the body surface clean.

Locomotion is achieved by a water vascular system involving the tube feet and hydraulic pressure, movement in sea urchins is closely related to feeding activity.

Most species are grazers, scraping algae and other organisms from the substrate, and feed using five large teeth and calcareous plates called pyramids, known as Aristotle's lantern.

Some species bore into rocky depressions for protection from wave action.

Sea cucumbers – Phylum Echinodermata

Sea cucumbers are elongated and sluggish and they lie on their side. Tentacles which are modified tube feet and highly retractile surround the mouth at one end, and they are suspension or deposit feeders.

Gas exchange is achieved by a system of respiratory trees located in the coelom which consists of a main trunk with many branches. Water circulates by means of a pumping action. The cloaca dilates, filling with sea-water, the sphincter closes, the cloaca contracts and water is forced into the respiratory trees, this procedure is repeated six to ten times, then all the water is expelled in one action.

Sea cucumbers use two different defense techniques:

1. Some species have evolved Organs of Curvier' - when threatened the sea cucumber directs the anus towards the intruder, the body wall contracts, and by rupture of the cloaca, sticky tubules which can entangle the intruder are shot out, after which they are regenerated.
2. Some species eviscerate their organs, which then also regenerate.

Sea cucumbers differ from all other echinoderms by only having one gonad. Most are dioecious and most broadcast spawn, some species brood.

Hermit crabs – Phylum Arthropoda

Hermit crabs use empty gastropod shells as a mobile home. They do not kill the gastropod. Their body is modified to reverse into the shell. Their legs are adapted so that they can grasp the shell. The left nipper is enlarged and serves to seal the shell opening. They are scavengers.

Rock crabs – Phylum Arthropoda

Numerous species are found, they have square, box-like bodies, and stalked eyes.

The most common species in the east is the Natal rock crab, *Grapsus grapus tenuicrustatus* and in the west and south is the Cape rock crab *Plagusia chabrus.* They have well developed legs and small nippers and are omnivores.

Fish in tidal pools – Phylum Chordata

The juvenile stages of many species shelter in rock pools, the most common resident species are gobies, blennies, klipfish, suckerfish and eels. Tide pool fish tend to be small and both gobies and blennies can skip across rocks from one pool to the other.

Algae

Seaweeds are a form of algae. They may be green, red or brown absorb nutrients through a leaf-like frond and attach themselves with a holdfast, and reproduce by spores. Seaweeds photosynthesise, provide a habitat, shelter and a food source. They may be jointed to help withstand wave action and are the foundation of the food web.

Coralline seaweeds load their tissues with calcium carbonate which provides protection from grazers.

Cape and Natal rock oysters – Phylum Mollusca

They are unusual in that their two valves differ, the right being flat, the left is convex, and attaches first, and they lie on their sides cementing the lower valve to the substrate. The valves are hinged and held together by an elastic ligament.

Oysters are filter feeders and can pump large amounts of sea water through their sieve-like gills to extract food and oxygen by beating cilia. The food particles caught in the mucous strings are moved to the mouth.

Oysters start off as males and may change sex many times. Eggs are fertilised in the mantle cavity, sperm is drawn in by the feeding current. Juvenile mussels and oysters are called spats.

The shell is opened wide and closed violently at intervals, each time expelling clouds of veliger larvae, which settle, and then cement down the left valve with drops of cement secreted by the gland, that in mussels secretes the byssus threads.

Bird species – Phylum Chordata

Birds which frequent sandy beaches include terns, gulls, sandpipers, sanderlings and oystercatchers.

African black oystercatcher

These are Southern Africa's second rarest coastal breeding bird. They have a jet-black body with pink legs and a bright orange bill and eyes. They occur on rocky and sandy shores and along estuary banks.

They feed on limpets, whelks, rock and sand mussels, pencil bait as well as a variety of worms. They rarely eat oysters! Where they are abundant they control the density of limpets, allowing the development of algal beds which support a range of other invertebrates, which are in turn eaten by small wading birds.

They are more common on islands off the West Coast. They occur in flocks of up to 100 birds but these are divided into territorial pairs. They mate for life and breed once a year at the beginning of summer. They lay their two or three eggs in a scraped hollow on the rocky or sandy shore. The eggs and chicks are very well camouflaged.

Oystercatchers are very sensitive to disturbance by beach-goers, dogs and vehicles and are threatened by coastal developments which destroy their habitat. Avoid frightening these birds unnecessarily and prevent dogs or children from chasing them. Breeding adults are easily stressed and they may even desert their nests if they are disturbed too often. Disturbance may create an opportunity for kelp gulls to prey on eggs or chicks. Try not to step on the well-camouflaged nests, eggs and chicks. You can help the African black oystercatcher survive by simply being considerate towards this rare and endangered species.

Driftline species

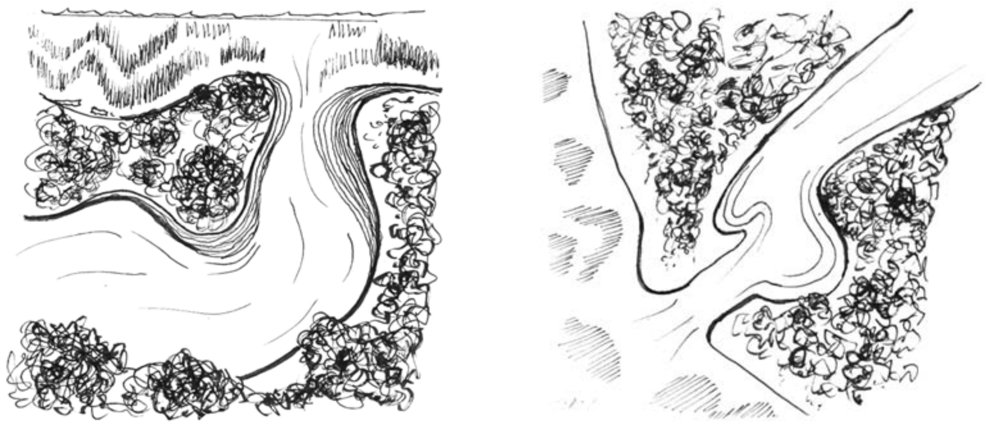
Onshore winds may drive a variety of floating cnidarian species such as jellies, blue-bottles, *Porpita*, and *Vellela* species. Other driftline species include *Spirula spirula*, cuttlefish shells, algae, gastropod shells, sponge, crustacean moults, mermaids purses (shark egg cases), whelk spawn, *Janthina janthina* and the smooth brown seed of the sea bean *Entada gigas* (a climbing plant growing on the sides of rivers).

Appendix 2

Examples of Marine Ecosystems

Illustrations by Sylvia Jacobs

Estuaries



Examples of estuaries

Estuaries form where a river meets the sea. They are the meeting point, a transition zone between fresh river water and the marine environment, and can be extremely productive: they act as nutrient traps and are rich in biodiversity. Each estuary's features are determined by rainfall, geology and the interaction between river water and sea water and are the result of the physical and biological features.

Estuaries can consist of a number of different habitats such as:

1. the water column;
2. salt marshes, reeds, and grasses;
3. mangroves in certain areas;
4. intertidal banks and reed beds and submerged rocks; and
5. sandy and muddy bottoms.

Estuaries are dynamic, with each tidal change resulting in changes, as well as after heavy rain and floods or during droughts. The species that are adapted and can tolerate these changes thrive on the nutrients and food provided by these systems.

Physical conditions of estuaries

Salinity

Every tide brings a change in salinity, the mouth being the most salty area. The sea and river water does not mix uniformly: sea water being denser, sinks. This layering protects those bottom living organisms that are fresh water intolerant. Some species migrate to cope with changes in salinity; others regulate the concentration of salts in their tissues through a process called *osmoregulation* which results from osmosis and diffusion.

Temperature

The ocean has a relatively constant temperature. In estuaries the temperatures change with the tides and weather. The head of an estuary has a greater variation than the mouth.

Desiccation

This refers to water loss from an organism. This happens in an estuary as a result of the lowering of the tide. Animals that burrow are not normally affected. Animals such as crabs that feed out of water have to keep their gills wet and have adaptations such as water-absorbent hairs at the base of their back legs and tiny ridges and hairs on the chest which allow for the re-circulation of water and the absorption of oxygen.

Tidal flow

Currents in estuaries are the result of both tidal action and river-flow and directly affect the substrate and may wash organisms out to sea. Maintaining their position in the estuary is a problem for planktonic forms and floating species. The sand prawns *Callianassa kraussi* have adapted by eliminating their planktonic stage; the eggs hatch into miniature adults and burrow. The snail *Nassarius kraussianus* broods its eggs thereby reducing their larval stage.

Oxygen shortage

High temperatures, organic debris and waterlogged soil are contributing factors to a depleted oxygen supply.

Rainfall, floods, drought and siltation

Low rainfall and seasonal rainfall both affect estuarine life. Floods scour the river beds and banks and excessive siltation both smothers and fills in the estuary. Deposited sediments are stabilised by plant growth which helps to avoid erosion, and are trapped by mangrove roots where they are present.

The estuary mouth may be kept open by tidal currents and waves. Coastal currents can build up sand bars across the mouth. Prolonged closure of an estuary mouth can have serious effects on the salinity, water levels and nutrients. Some species require estuaries in order to complete their life-cycles. Closure of the estuary restricts this process. The artificial opening of estuaries is governed by legislation, as is dredging.

Major types of estuaries

1. Permanently open (Breede River, Mlalazi)

These systems maintain a permanent connection with the sea, and have a marine component, with seawater entering the mouth in different amounts.

2. River mouths (Orange River, Thukela)

These estuaries also maintain a permanent connection with the sea, but with minimal tidal intrusion into the river channel.

3. Temporarily open/closed estuaries (van Stadens, Mhlanga)

This system is the most common on our coastline, and is created by smaller rivers that maintain insufficient flow to allow a permanent connection with the sea. A sand bar develops during the dry season and prevents direct access to the sea.

Kosi Bay Estuary

4. Estuarine lakes (Kosi Bay, Lake St. Lucia)

These are large bodies of water that may or may not have a permanent connection with the sea. They may be linked to the sea by a channel of varying length and limited tidal exchange.

5. Estuarine bays (Durban Bay, Richards Bay)

These are large water bodies characterised by a wide mouth and strong tidal exchange and are marine dominated.

Fish species that use estuaries

As many as 100 species are wholly or partially dependent on South African estuaries, while up to 400 species frequent estuaries at some time during their life-cycle. Their ability to tolerate changes in salinity determines how far they can penetrate an estuary.

There are five major groups:

1. ***Estuarine resident species***
   These species complete most, if not all of their life cycle within estuaries and tend to be detritivores or planktivores. Common species include mullet, spotted grunter, stumpnose, river bream, dusky kob, and glassies.

2. ***Marine migrant species***
   These species spawn offshore and enter from the sea, the estuary serving as an important nursery area. Larvae or juveniles enter and mature to either a sub-adult or adult stage, then leave to complete their life cycle in the sea. Some species enter estuaries to gather energy (by feeding) for spawning.

3. ***Marine stragglers***
   These species enter by accident, often on tidal currents and, not tolerating reduced salinity, die if they do not return quickly.

4. ***Catadromous and anadromous species***
   Catadromous migrate from fresh water to spawn at sea. Anadromous species migrate from the sea to spawn in fresh water. These species have both a freshwater and a marine phase in their life cycles and use the estuary as a transit route between the two.

5. ***Freshwater species***
   These species come from a riverine environment and may have relatively high salinity tolerances.

The Knysna seahorse *Hippocampus capensis* is endemic to the Knysna, Keurbooms and Klein Brak estuaries and is threatened by pollution, habitat destruction, boating, collecting and development.

Many species of invertebrates such as worms, crustaceans and molluscs inhabit estuaries.

Plant communities in estuaries

The ability of an estuary to support plants and animals depends mostly on the physical and chemical characteristics of the water column and sediments, and changing conditions also determine when they come and go (succession).

There are six different plant communities in our estuaries:

1. ***Micro-algae, phytoplankton*** produces oxygen during photosynthesis. When dense populations die, the decaying process can consume so much oxygen that fish and other organisms die.

2. ***Macro-algae***
   i. Thread-like filamentous forms and
   ii. Attached leafy forms.

3. ***Macrophytes***, these submerged large plants have stems and leaves e.g. eelgrass can survive desiccation and provide important habitats.

4. ***Salt marshes*** develop at high elevations, they may be flooded daily and they provide protection for some invertebrates such as crabs.

5. ***Mangroves***, which are the only tree species adapted to live in salty tidal waters, may develop in muddy, wave protected areas. They stabilise banks by shedding a lot of leaves and they provide food for species such as Sesarmid crabs. Their extensive root systems trap silt and provide a home and safety for various species.

6. ***Reeds and sedges*** occur mainly in the middle and upper reaches; they reduce water flow, stabilise banks, help prevent erosion, and provide materials for craft work and construction.

Mangroves

Mangrove swamps develop in the littoral, intertidal coastal zone in both the tropics and sub-tropics between latitude 32° N and 38°S in muddy waterlogged soil, in areas protected from wave action, often fringing estuaries and coastal lagoons and on the leeward side of islands. They do not become established on exposed tracts of coastline and depend on a muddy substrate for the initial propagation and subsequent perpetuation of the seedlings.

Example of a mangrove ecosystem

Examples of a mangrove ecosystem – uShaka Sea World.

A mangrove swamp is a collection of salt-tolerant trees (halophytes) that have special adaptive mechanisms for coping with high salinity which varies according to the species.

Mangroves line about 8% of the world's coastlines, where they filter pollutants from river runoff and help prevent silting up of the adjacent marine habits, and by trapping muddy riverine sediments may aid the establishment of corals in clearer silt free waters offshore. In Southern Africa there are 15 sites of mangrove communities between Inhaca Island and the Nahoon River in the Eastern Cape.

Mangrove swamps are areas rich in biodiversity and they support a large marine food web. A wide diversity of both plants and animals are associated with mangroves and they play an integral role in the estuarine food chain. Mangroves also help protect coastlines from erosion and provide a home and nursery area for fish, invertebrates, birds and other species.

Mangroves are the only trees adapted to living in salt water: they face the challenge of being rooted in oxygen-deficient, water saturated soil and are only found in sheltered estuaries. Mangrove trees only grow up to a point just beyond the high water mark of spring tides.

Mangrove trees produce enormous amounts of leaf litter, as well as twigs and bits of bark, which drop into the water. Some of this immediately becomes food for animals such as the Sesarmid crabs, but most is broken down by both fungi and bacteria, which in turn becomes food for fiddler crabs, fish and other invertebrates. These animals in turn produce waste which, along with even smaller mangrove litter, is consumed by molluscs, amphipods, marine worms, and small crustaceans which then provide food for fish and other animals.

Before pioneer plants can colonise an area the soil must be suitable; certain biological processes must have commenced in the alluvial mud, converting it from a suspension of mineral and organic particles to a nutritive soil.

Mangrove trees

Five species of mangrove trees occur. White mangroves and black mangroves predominate in South Africa. Red mangroves, yellow mangroves and Tonga mangroves are also present.

White mangroves *– Avicennia marina*

- This is the first species to establish therefore is a pioneer species.
- White mangrove trees grow to around 12m.
- White mangroves provide shade which allows black mangroves to establish.
- They do not have tap roots; instead they have a highly adapted, extensive, shallow horizontal cable root system. The roots radiate out from the base and anchor the tree firmly in the loose substrate, and are the framework from which subsidiary roots with more specific functions develop.
- Numerous smaller branching roots grow down which also provide anchorage.
- Vertical pencil roots, the pneumatophores, grow up and act as ventilating chimneys, allowing the subterranean portion of the tree to respire.
- The white mangroves also tend to develop a covering of different species of algae, the Bostrichia species.
- White mangroves are soft and corky and have a maze of channels connected internally with the air spaces of the main roots and have small openings called lenticels through which the gaseous exchange of O_2 and CO_2 takes place at low tide.
- Fine rootlets are produced by the pneumatophores just below ground level; their function is to absorb nutrients.
- White mangroves flower from September to February in dense clusters, the fruits also develop during this time and are pale, muted green capsules, each containing a single seed.
- Most of the fruits are shed during the equinox in March; the seed, though very well developed, does not germinate before it is shed.
- Seed dispersal is by the tides, germinating immediately after rooting in a suitable location.
- The bark of white mangroves is used in the tanning industry and the wood for building.

Black mangroves *– Brugiera gymnorrhiza*

- Black mangrove trees can reach 18m.
- Black mangroves are a secondary species in the succession process.
- They become established in the shade provided by the white mangroves.
- The root system is essentially the same as in white mangroves and is modified both for stabilisation in loose mud, and for respiration. They have no tap roots.
- The numerous cable roots which are produced at the base of the trunk are often extended into buttresses above ground and they also emerge and re-enter the soil at intervals to form knee roots used for aerial respiration.
- Both anchor and nutritive roots emerge directly from the cable roots.
- The leaves which are large, have a very shiny upper surface, and having no salt glands, age rapidly, abscise (fall off) frequently, with leaf scars being visible.
- Black mangroves flower most of the year.
- The seed, the cigar shaped hypocotyl, starts growing immediately it is mature while

still enclosed in the fruit and still on the parent tree, and may become embedded in the mud of the parent habitat as soon as it has fallen, otherwise dispersion is on the tides.

- The wood of black mangroves is very dense. Black mangrove trees are used to build dhows and as building timbers.

Red mangroves – *Rhizophora mucronata*

- Red mangrove trees can reach 9m.
- This species is not abundant locally but is the most widespread species worldwide.
- They tend to form a thick, marginal hedge alongside the creeks and gullies that run through the mangrove habitat and can survive in deep water.
- Red mangroves have well developed aerial root systems, known as 'prop roots', all having lenticels, develop directly from the tree trunk, high above the ground, arching away from it, and branch freely before entering the soil.
- These prop roots emerge from all sides of the trunk at different levels and form a formidable mass.
- There are no tap or cable roots.
- The end of each prop root terminates in a group of nutritive stabilising roots just after it enters the soil.
- The leaves of red mangroves are similar to the black mangrove leaves but at the tip of each leaf is a distinctive sharp point (the 'mucro').
- Red mangroves flower mainly in summer.
- Seed development is very similar to black mangroves, although the hypercotyl is much longer, anything up to 300mm
- Red mangroves are secondary colonisers, making use of conditions established by other species.

Yellow Mangroves – *Ceriops tagel*

- This tree is also a secondary coloniser in succession.
- This low tree only reaches 6 metres.
- They have a variable root system – knee roots and prop roots.
- The bright yellow-green leaves are blunt ended and relatively small.
- The wood is yellow and very durable.
- They flower in summer.
- The hypocotyls are about 7.5cm long.

Tonga Mangroves – *Lumnitzera racemosa*

- These mangroves are not found further south than Kosi Bay.
- This tree is also low and bushy.
- They have some knee roots but the roots are not extensive above ground.
- The leaves are ovate with blunt tips and wavy edges.

- They flower in early summer.
- The seeds are water resistant and can float to increase dispersal.

Mangrove associated species

1. ***Hibiscus*** *(Hibiscus tiliaceus)*
   This species is found along lagoon and river bank edges. The bark is very tough and fibrous and used as rope, twine, and for sewing mats.

2. ***Bush-tick Berry*** *(Chrysanthemoides monilifiora)*
   Small bunches of black or red fruit on the Bush-tick Berry bush were an important Koi food and are eaten by birds. This is an important secondary species on the dry edge of mangroves, grows to 3m, has fleshy leaves with silver hairs that help reduce water loss.

3. ***Water berry*** *(Syzygium cordatum)*
   This tree has oblong, edible berries. For purple dye, the skins of ripe water berries are boiled with leaves for 4-5 hours.

4. ***Reeds*** *(Phragmites australis)*
   These tall reeds are used for building fences and bomas. The hollow reeds are used for tobacco pipe stems, as flutes, and also ground into an ointment for burns.

5. ***Coastal silver-leaf*** *(Brachylaena discolor)*
   Wood of this tree can be used to make fire sticks. The leaves are silvery underneath and have hairs to help prevent water loss.

6. ***Salt Marsh Rush*** *(Juncus krausii)*
   The stems are used for the traditional sleeping mats, icansi, which are presented at weddings as gifts.

Animals of the mangrove community

There are three groups which can make use of mangroves but they are not exclusive to the mangroves.

1. Those animals associated with mud – many species are adapted to behave in precisely rhythmic patterns, corresponding with the tides and are either
   a. burrowers, spending the duration of the high tide in protective holes, e.g. fiddler crabs (burrowers unintentionally provide an important service by mixing the surface layers and allowing oxygen to penetrate the mud)
   b. wanderers, which move with or ahead of the tide or climb into the trees e.g. climbing whelks

2. Those species restricted to the waterways, e.g. fish

3. Those species living in the canopy e.g. birds (like the mangrove kingfisher), spiders, snakes and insects.

Example of rocky shores

Rocky shores

The intertidal rocky shore is one of the most stressful habitats for both plants and animals, the shallow rocky reefs take the full force of the waves, therefore rock-living species are firmly attached and adapted to cope with the pounding waves. All the vital functions of life such as respiration, excretion, and reproduction must be adapted to function in two completely different environments, both in and out of water and there is great competition for both food and space.

Both plants and animals are zoned in bands on the rocky shore according to their ability to withstand exposure to air and desiccation. As most animals can only feed while submerged, survival becomes more difficult higher up on the shore where immersion times are shorter.

For most species it is the presence or absence of other species that determines what can live where, and not the ability of a particular species to tolerate physical stresses which means that when we interfere or over-harvest one species we can change the structure of the community. In some cases predators prevent one species from monopolising a habitat and ascidians, some algae, mussels and barnacles are controlled this way. Limpets and winkles compete and influence where other species live. Grazers influence algal settling and growth.

Seaweeds thrive in the sunlit shallows and provide a sheltered environment for animal communities. The intertidal zone is the area between the highest high tide and the lowest low tide. The infratidal zone lies below the low tide mark.

Rocky shores play a vital role by:

1. Providing a home and shelter to many species (irregularities in underwater rock features provide additional habitats for marine life);
2. Providing a site of attachment for many species;
3. Providing a nursery area for juvenile fish.

Rocky shore zonation

1. ***Littorinia Zone***

   This is the highest zone and lies above the reaches of neap tides and is only submerged at spring tides. Very few species are able to survive these harsh conditions.

   Three species of mollusc, littorina and tufts of algae are present.

   Littorina can survive for months in a dormant state. Their gills for respiration are reduced, enabling the gill cavity to be used as a primitive lung. To avoid the heat from the rocks they hang by a mucous thread, after withdrawing their body and sealing the opening, first with mucous then by the operculum.

   Small animals tend to be found highest up the shore and the larger ones further down.

   At high spring tides the snails emerge to scrape algae using their radula.

2. ***Oyster Belt*** *(this zone only occurs on the East Coast)*

   The rock oyster forms a distinct band in the upper intertidal zone.

3. ***Upper Balanoid Zone***

   This zone supports a few plants, barnacles, limpets and winkles are present.

4. ***Cochlear Zone***

   This zone is dominated by limpets, specifically the pear limpet (Scutellastra longo-costa) on the south coast with the addition of black mussels and anemones on the West Coast.

5. ***Lower Balanoid Zone***

   This area supports species such as gastropods, limpets, barnacles, sponges, sea-urchins, zooanthids, algae, chitons, sea-stars, tube worms and mussels.

Adaptations for life on a rocky reef

Species inhabiting the intertidal zone have to be adapted to withstand this harsh environment and conditions such as:

1. ***Desiccation***

   Some species avoid desiccation by spending the low tide in pools and under ledges and on algae or by closing their valves or operculum. The shape of their bodies plays a role in determining the length of time an organism is able to survive during low tides. Many gastropods have an operculum which seals and both protects against predators and helps prevent desiccation.

2. ***Temperature***

   The shape, colour and texture all play a role in reducing heat uptake. During low tide organisms are exposed to high temperatures, and then during high tide temperatures drop. Heat gain and loss take place through various ways such as solar heat from the sun, and heat from both the air and substrate.

3. ***Light***

   For algae the strength of light received is a vital issue for photosynthesis and both its shape and location influence the amount of light it gets.

4. Species with broad flat surfaces maybe found higher on the shore, their broad flat leaves being able to maximise the short time available for photosynthesis.

5. ***Salinity and oxygen levels***

   Both can fluctuate in rock pools during low tide and rain. During photosynthesis the water can become over-saturated with oxygen.

6. ***Wave action***

   Wave action can be used to an advantage by filter-feeding organisms.Many species take shelter during high tide or attach themselves firmly to the substrate. Body shape, texture and structure both assist in reducing the force of waves. A rough surface assists in reducing turbulence.

Note:

SAFETY during an excursion to a Rocky Shore is important. Never allow learners to go near the edge. Tell them not to turn their backs on the sea. Warn learners to stand still if a wave catches them unawares. Remember some rocks may be very slippery.

Sandy beaches

The composition of sandy beaches depends on the material available and on the energy of the waves. Most beaches are composed of sand, gravel, or pebbles produced from rock erosion, and the fragmented shells and exoskeletons of marine organisms.

Example of sandy beach

A typical beach has three zones

1. Foreshore, or intertidal zone, the area between low and high tides;
2. Near shore, the seaward side of the foreshore;
3. Backshore, the area above high tide.

Sandy beaches are unstable and subjected to sand-blasting and are dynamic with the constant movement of the sand and wave action is the main factor influencing sandy beaches. Sandy beaches are a harsh environment and are subjected to extreme conditions, and the changing tides.

Animals living on sandy beaches burrow to avoid high temperatures, desiccation and wave action and are either filter feeders or scavengers. Living up high on the shore are a different group of animals that have adapted to being air breathing, and emerge at low tide to feed by scavenging.

Sandy beaches filter and purify large amounts of sea water. They are threatened by pollution, bait-harvesting, vehicle traffic and development.

Zones

The fauna on sandy beaches are zoned:

1. ***The Supralittoral zone*** (driftline), the habitat of air-breathing crustaceans and insects.
2. ***The Midlittoral zone***, colonised mainly by isopod crustaceans, white mussels (*Donax species*), Bulia (plough snails) and ghost crabs.
3. ***The Sublittoral zone***, containing a range of molluscs, crustaceans and worms, species that are unable to withstand exposure to air.

Marine interstitial animals

Marine sands are home to a complex community of animals that live in the water filled spaces between sand grains. They face three basic problems: desiccation, the water may become stagnant resulting in their being too little oxygen, and there may be too little food available.

The spaces between the sand grains (the interstites) form a complex three dimensional maze through which the animals breathe, feed, move and reproduce. The interstites are small and the sand shifts as water flows over and through the bottom. Species such as nematodes, turbellarians, segmented worms, and copepods dominate the interstites.

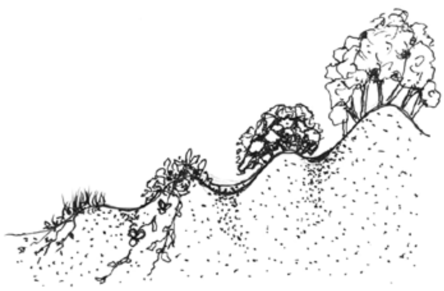
Adult interstitial animals are in the size range of plankton and to overcome the risk of being washed out of the sand, they have adhesive organs which are composed of two different types of glands. One secretes the adhesive and cements the animal to the substrate, making a temporary, but strong attachment to sand grains. The other, the releasing gland, secretes the de-adhesive, that breaks the attachment. The sand grains are tumbled by the waves but eventually settle.

Another adaptation to their lifestyle is internal fertilisation, the storage of sperm to ensure fertilisation of their few eggs.

Sand dunes

Sand dunes form when sand that is deposited onshore by the sea, dries and is then blown inland. Dunes develop in the area behind the backshore which together with the upper beach face supplies the sand. For dunes to develop, this sand has to be continually replaced on the beach by wave action.

The dunes closest to shore are called foredunes, behind them is a primary dune ridge and a secondary dune ridge. These anchored vegetated dunes are important for the protection they provide against coastal erosion, the zones show evidence of plant succession. On some coasts, non-vegetated mobile dunes occur, which move in response to the prevailing winds.



Example of dune succession

Sand dunes are the natural barrier between the marine and terrestrial world, and form a unique ecosystem and provide a habitat for animals such as insects, spiders, reptiles and nesting birds. Sand dunes are dynamic, very porous, and are poor conductors of heat.

Plant Communities

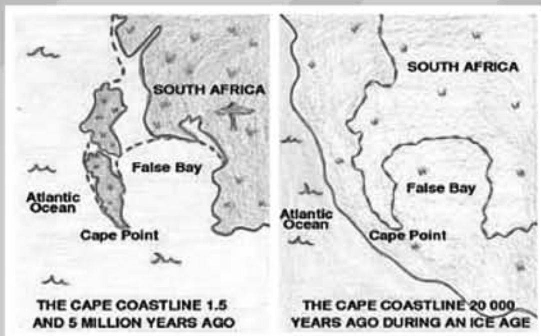
Low creeping pioneer species of plants help bring about dune stabilisation in this extreme habitat that is exposed to the sun, spray and changes in the temperature, wind and tides. The plants adapt by having creeping stems and by being fast growing. Some are succulents and have a thick cuticle to protect them from salt spray. (Examples of dune plants are given in the section under Marine Species.)

CLIMATE CHANGE AND OUR OCEANS

The increasing amount of carbon dioxide gas in the air is causing our world to heat up. This is called global warming and it is causing climate change. How will this affect our oceans?

SEA LEVELS IN THE PAST

Climate change is not new. There have been several very long periods when world temperatures have either risen or fallen. As the world cools, large ice sheets form at the poles and over the land and sea levels drop. When the world warms and the ice melts, sea levels rise again. Millions of years ago, parts of the Cape Flats and the Cape Peninsula in the Western Cape were under the ocean (see the map). That's why the 'flats' are so sandy. Table Mountain and Cape Point were islands in the ocean. Then some 20 000 years ago an ice age caused sea levels to fall so much that the coastline was way out in the sea and you could have walked across False Bay or to Robben Island!



Art Lauren de Vos

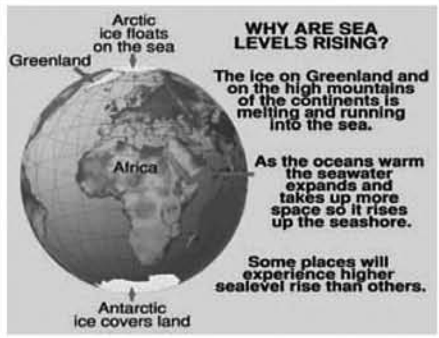


Illustration Roberta Griffiths

The islands of the Maldives may vanish underwater.

Photo Civvi/Wikimedia Commons

OCEANS ARE RISING

Thick ice sheets over Greenland, the Arctic and the edges of Antarctica are melting as the planet warms. This is causing sea levels to rise in some places. South Africa's oceans have been rising by 2 cm every 10 years but this is expected to increase as the ice melts. Low-lying land and islands are at risk of flooding, especially during big storms. Melting ice sheets also add freshwater to the oceans, diluting the salty seawater. This may change the flow patterns of ocean currents and affect the climate of nearby land.

A CONVEYOR BELT IN THE SEA

The oceans absorb heat from the sun and the ocean currents spread the heat around the world. The main ocean current works like a giant conveyor belt moving warm, less salty water from the equator to the poles (see map). It also moves cold, saltier water away from the poles and towards the equator. The cold and warm currents keep the equator from overheating, and the poles from freezing forever.

▼ *The thick Greenland ice sheet is melting*

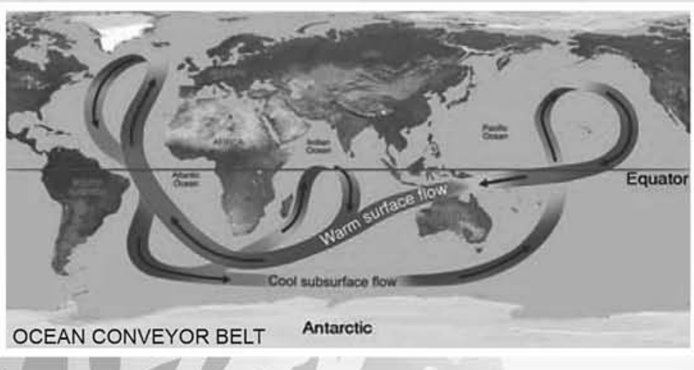


Illustration JPL Wikimedia Commons

Photo Christine Zenino/Wikimedia Commons

◄ *Ocean currents are like giant rivers of seawater flowing around the world.*

CURRENTS AND CLIMATES

The air exchanges heat with the ocean below, so air from a cold ocean is cool and dry, but warm and wet over a warm ocean. You can see this in a hot bath – the air above is steamy and warm! Our Atlantic coast with its cold Benguela current has a cool climate with little rain. But the KwaZulu-Natal coast is hot and wet because of the warm Agulhas current. If these ocean currents change due to global warming, some places could have quite different climates.

Art Lauren de Vos

Photo iStockphoto

Polar bears dig holes in the ice to catch seals in the water below.

MELTING ICE

Thick ice sheets form in winter at Earth's poles as the sea surface freezes. Then, in summer the ice starts to melt and only the very thick ice stays frozen. But, with global warming the melting each summer is speeding up, and the ice is disappearing over Greenland and the Arctic sea. This is affecting the Arctic polar bears as they need ice from which to hunt seals in spring and early summer. The ice is now melting earlier than usual and the bears are becoming thin and in poor condition. With less ice around they are not able to catch enough food to fatten up during the summer and to survive the long winter months.

STORMY WEATHER

As ocean temperatures rise, the oceans expand and water evaporation from the sea surface increases. This adds more water vapour to the air, causing stronger and more frequent bad storms and floods. Some countries are replanting mangrove swamps and building high barricades to prevent storm damage along the coast.

Giant waves from a strong typhoon can cause lots of damage. ▶

Photo Wikimedia Commons

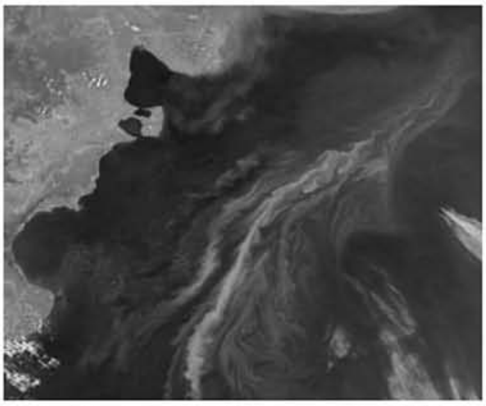


Photo Nasa Earth Observatory/Wikimedia Commons

The blue and milky white areas show a giant phytoplankton bloom in the sea.

THE GOOD NEWS

Oceans reduce the effects of climate change because their billions of tiny ocean plants, called phytoplankton, absorb carbon dioxide to make their food. When they die they sink to the ocean bottom and their carbon is locked away for millions of years. It is estimated that the oceans have absorbed nearly one third of the carbon dioxide released into the air through mankind's activities in recent years. However, while oceans are natural carbon sinks (they store carbon), this can affect ocean life (see page 12).

Words Lauren de Vos

Changing marine life

Climate change affects the oceans in various ways (see page 4), but how are the marine plants and animals coping with the changes? Read about this below, and see page 12 to find out how the oceans are becoming more acid.

Moving along the coast to keep warm or cool

Each species (kind) of seaweed or animal can only survive within a particular temperature range. As sea temperatures change they will have to move elsewhere to find water that suits them better. On the east coast water temperatures are rising so tropical species such as ghost crabs and corals are moving further south, and tropical fish are entering river estuaries where they have never been found before. In the Western Cape the sea is actually getting colder so kelps, lobsters, penguins and other cold-water species are heading for warmer water past Cape Point and on towards the south coast.

Kelp plants have moved into False Bay and along the south coast.

When sea levels rise, walls like this will stop ghost crabs from moving up the beach.

Ghost crab.

Moving higher up the shore

Many marine animals live only at a very particular height on the seashore. Here they spend just the right amount of time in and out of the water as the tide goes up and down. As sea levels rise, the animals will also have to move upwards. This is not a problem if there is somewhere to move to, but in some places there is no more up! For example, many east coast rocky shores consist of flat rock platforms near low tide, with sand above. With rising sea levels, the rocky shore seaweeds and animals will have nowhere to move to, as they can't survive on sand. Similarly, air-breathing animals like the beach ghost crabs would have to move higher up the beach, but if people have built roads or walls at the top of the beach, the animals will have nowhere to go!

Changes in reproduction and growth

Most sea animals are cold-blooded and so their rate of growth is influenced by water temperature. The warmer the water the faster they grow. However, the signal for them to breed is also usually a change in water temperature. Changing ocean temperatures can lead to animals breeding at the wrong time when there may be no food, or the right conditions and shelter for their babies to survive. For example, many baby fish enter estuaries to keep safe and find food. If the adults breed at the wrong time, the estuary mouth may be closed and only open later in the year, by which time the babies will have died.

The babies of White steenbrass shelter and feed in estuaries.

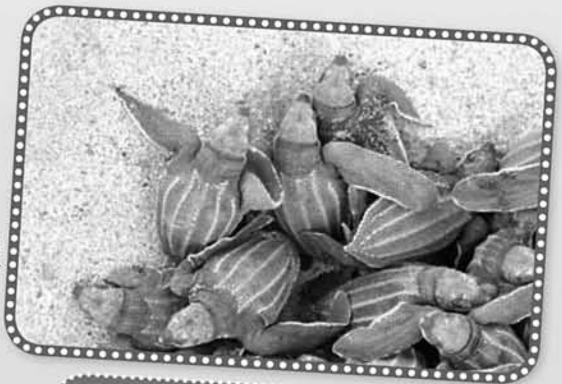


Photo iStockphoto

Newly hatched leatherback turtles emerging from their nest.

Egg development is also often determined by temperature. Not only do the eggs hatch faster in warmer conditions, but the sex of the babies may also be determined by temperature! For example, turtles lay their eggs in nests on beaches and researchers have found that eggs hatched at lower temperatures are almost all male, while eggs hatching at above 30°C all are female. If beach temperatures rise too much there will be no males to breed with the female turtles!

Dying of heat

If world temperatures rise too high, both land and marine animals will start to die. Cold-water species such as penguins are known to abandon their eggs on very hot days. Ocean corals are also very sensitive to small rises in temperature. When the water is too warm they lose the tiny plant (algal) cells that live inside their bodies that they depend on for food. This is called coral bleaching because the coral goes white and dies. As water temperatures increase, bleaching is killing large areas of coral reef in Asia and on Australia's Great Barrier Reef.

Photo Laszlo Ilyes/Wikimedia Commons

▲ Bleached coral.

Photo Bruno de Giusti/Wikimedia commons

Living coral is often brightly coloured. Spot the little fish! ►

Words and photos Charles Griffiths

OCEAN CHANGE AND PEOPLE

Sea levels and temperatures are rising due to climate change, and as a result the distribution, abundance and behaviour of marine animals and plants are changing. This will influence the lives of people around the world. While the effects will vary in different places, here are some of the changes that we are seeing today.

Purse-seine ships fish for anchovy or sardines.

Photo Oceana Fishing Group

DAMAGE TO PROPERTY

In many places along the coast it is common to see houses, roads and railway lines built far too close to the sea. As sea levels rise there will be more frequent flooding and damage to these structures. This will be especially damaging if extra strong storms occur during high spring tides. To prevent this we would have to build stronger and higher seawalls to protect buildings and roads that should not have been built so close to the sea.

This play park is in danger of being washed away by the sea.

FISHERIES ON THE MOVE

Digital art Matthew Griffiths

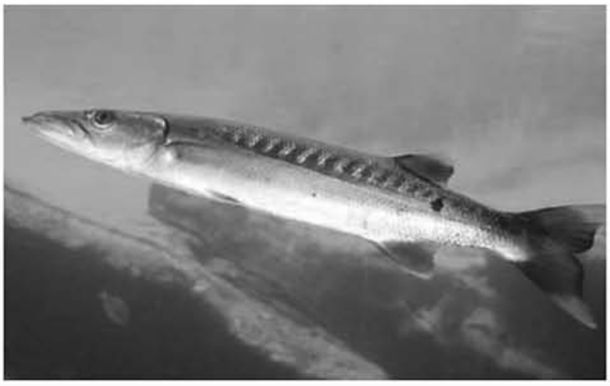
When the distribution patterns of fish and other marine animals change, they affect people who rely on the ocean for food and jobs. However, these changes are not always bad – some people can benefit. For example, as the water along the south coast cooled in recent years, there was a large increase in rock lobsters (crayfish) in this area. While the West Coast fisheries suffered, the appearance of lobsters on the south coast created a new fishing industry. From 2003–2008 the sardine and anchovy stocks suddenly moved from the west to the south coast. The fishing boats had to move to Mossel Bay to catch the fish, far from the fish factories at Saldanha. The fish had to be trucked over-land to reach the factories at great cost. Many West Coast communities lost their jobs because of these changes, and Gannet populations shrunk because there were no fish for them! Luckily the sardines are now returning to the West Coast.

NEW INTERACTIONS

As animals move to new areas, species come into contact with one another in new and different ways. Rock lobsters were once rare on the south coast, which was home to many sea-urchins and abalone (perlemoen). While small, the baby abalone shelter beneath the urchin's spines. Now that lobsters are common on the south coast, they have eaten almost all the sea-urchins. Without the sea-urchins, baby abalone are no longer protected from predators and very few survive. This is bad news for the abalone industry that is already suffering because of uncontrolled over-harvesting by poachers!

Baby abalone hide under sea-urchin for protections. ►

RECREATIONAL USERS



Climate change is affecting the distribution patterns of fish species that are caught by recreational anglers. Tropical fish species such as River bream, Cat-faced rock cod and Barracuda, a popular game fish, are being caught much further south than in the past. A bonus for divers and the tourist industry is that more tropical, brightly coloured fish and corals are now being found on reefs in northern KwaZulu-Natal.

◄ *Barracuda are large, fast predators and can chase fish at up to 43 km per hour!*

CONSERVATION AND TOURISM

Conservation areas are usually found in places where important species are most common. However, if these species move away due to climate change, they may leave the reserves that were made to protect them! For example if our Loggerhead and Leatherback turtles move down the coast to breed in cooler sand (see page 7), they may no longer be protected.

Loggerhead turtle.

Tourists want to see unusual or special animals and plants, but if these species move or disappear peoples' jobs will be lost. An example of this has happened on the West Coast where penguins were once abundant. The penguins have moved and made new colonies on the south coast. This has created new tourism opportunities at Boulders Beach in Cape Town and at Betty's Bay, but it has been bad for tourism on the West Coast.

The Boulders Beach penguins attract many tourists. ►

Words and photos Charles Griffiths

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KEY TO SYMBOLS

⊘ Specially protected species

◪ Local improvement projects underway (only applicable in SA)

fish — Species in the RED list with a black background are illegal to sell in South Africa. Either specially protected or recreational "no sale" species. Never buy these.

CONSUMER SEAFOOD GUIDE

GREEN - BEST CHOICE

CERTIFIED SUSTAINABLE SEAFOOD MSC www.msc.org

Always look for MSC eco-labelled products, such as the South African offshore trawled Hake , for the best choice in wild capture products. SASSI supports the MSC as the leading eco-label for wild capture fisheries products. For more info and a comprehensive list of MSC certified products, visit www.msc.org.

- Anchovy ◪
- Calamari (Squid)
- Horse Mackerel/ Maasbanker (midwater trawl)*
- Hottentot (line caught)*
- Kob (farmed in SA on land)*
- Monk
- Mussels
- Oysters
- Rainbow Trout (farmed in SA)*
- Sardines (South African) ◪
- Snoek (South African)
- Tuna (pole caught ONLY)*
- Yellowtail

*See www.wwf.org.za/sassi for details

The GREEN LIST includes the most sustainable choices from the healthiest and most well managed populations. These species can handle current fishing pressure, or are farmed in a manner that does not harm the environment.

ORANGE - THINK TWICE

- Abalone (farmed)*
- African Sharptooth Catfish (farmed)*
- Carpenter (line caught)*
- East Coast Spiny Lobster
- Geelbek/Cape Salmon (line caught)*
- Hake (SA longline)*
- Kingklip
- Kob (farmed at sea or line caught)*
- Ling (New Zealand Kingklip)
- Panga (line caught)*
- Pangasius/Basa (farmed)*
- Prawns
- Red Roman
- Sole (East Coast) ◪
- Tuna (local longline)*
- West Coast Rock Lobster
- White Stumpnose (line caught)*
- Yellowtail (locally farmed)*

*See www.wwf.org.za/sassi for details

Exercise caution when choosing these as there are reasons for concern, either because the species is depleted as a result of overfishing and cannot sustain current fishing pressure, or because the fishing or farming method poses harm to the environment and/or the biology of the species makes it vulnerable to high fishing pressure.

RED - DON'T BUY

- Black Musselcracker/ Poenskop
- Dageraad
- Kob (trawl caught)* ◪
- Red Stumpnose/ Miss Lucy
- Sharks (trawl caught)*
- Skates and Rays*
- Tuna (imported longline)*

NO SALE SPECIES

- Baardman/Belman
- Blacktail/Dassie
- Brindle Bass ⊘
- Bronze Bream
- Cape Stumpnose
- Galjoen
- Garrick
- King Fish
- Knife Jaw
- Natal Stumpnose
- Natal Wrasse ⊘
- Potato Bass ⊘
- Red Steenbras ⊘
- River Snapper
- Seventy-four ⊘
- Spotted Grunter
- West Coast Steenbras
- White Musselcracker
- White Steenbras

*See www.wwf.org.za/sassi for details

Don't buy these species because they are either from unsustainable populations, which are collapsed and/or have extreme environmental concerns and/or lack appropriate management, or are illegal to buy or sell in South Africa (No sale species). Dealing in illegal species will result in prosecution. No sale species are reserved for recreational fishers, who need a valid fishing permit, may not sell their catch and must adhere to specific regulations.

Find out more about recreational fishing regulations and Marine Protected Areas on our SASSI mobi site at wwfsassi.mobi

NOT ON THE LIST?

Only the most popular seafood species have been included on this pocket card. For a more complete list, check our website.

ALWAYS ASK THE FOLLOWING QUESTIONS

What is it? Where is it from? How was it caught or farmed?

You have the right to know what you are eating. Remember – You have a choice. Make it Green!

SASSI PARTICIPATING RESTAURANTS AND RETAILERS

SASSI works closely with a number of key partners. Visit our website (www.wwf.org.za/sassi) to find participating retailers and supporting restaurants.

CONSUMER SPECIES LIST

This list tells you about which seafood species are legal and more sustainable choices. These species have been assessed by considering the stock status, the environmental effects of fishing and the management in place to reduce these effects or maintain the stock at healthy levels.

Visit our website for more details on which farming and fishing methods are the most environmentally friendly.

FISHMS BROUGHT TO YOU BY iVeri

Simply text the name of the fish to the number 079 499 8795 and you will immediately get a message telling you whether to tuck in, think twice or avoid completely! Normal network rates apply.

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fundisa for change

A partnership programme for environmental learning and teacher education

environmental affairs
Department: Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Eco-Schools

basic education
Department: Basic Education
REPUBLIC OF SOUTH AFRICA

South African NATIONAL PARKS

water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

Murray & Roberts

RHODES UNIVERSITY
Where leaders learn

WESSA

environmental LEARNING RESEARCH CENTRE

WESSA Share-Net

SANBI

delta environmental centre

UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI

UNISA university of south africa

UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA

UNIVERSITEIT STELLENBOSCH UNIVERSITY

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Environment Learning and Teaching

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GreenMatter