

An Ocean Literacy Toolkit for Namibia

A guide for ocean education in Namibia

Authored by the Namibia Nature Foundation and Blue Marine Foundation

Ministry of Education, Arts and Culture

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The NIMPA+ Project

December 2024

This toolkit was produced as part of the NIMPA+ project through a collaborative workshop process. A three-day knowledge-sharing workshop was held in Swakopmund, Namibia, in November 2023. The workshop had a total of 29 participants from Namib Desert Environmental Education Trust (NaDEET), United Nations Educational, Sciences and Cultural Organisation (UNESCO), Community Skills Development Centre (COSDEC), National Institute for Educational Development (NIED), Ocean Conservation Namibia (OCN), MFMR, EduVentures, UNAM and teachers from five different Namibian schools and was facilitated by NNF and Blue Marine Foundation.

There was a two-day follow up workshop that was held in Swakopmund Namibia, in November 2024, to review the progress made on the toolkit. This workshop had a total of 25 participants from NADEET, UNESCO, COSDEC, OCN, MFMR, EduVentures, SANCCOB, #Aonin Association, NIED, MEFT, NAMCOB and teachers from two different schools and was facilitated by NNF and Blue Marine Foundation.

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Foreword

More than 70 percent of our Earth's surface is covered by water, with the vast ocean shaping the very features of our planet. The ocean is not just a distant expanse, it is a major influence on weather and climate, intertwining itself with every aspect of human life.

Namibia, blessed with a large coastline stretching for 1,572 kilometres, finds itself deeply connected to the ocean. This connection is beautifully captured in the Seven Principles of Ocean Literacy, particularly in Principle 6, which emphasizes that human life is indeed connected to the ocean. The ocean affects every human life by supplying essential resources such as freshwater. Most rain originates from the ocean, where water evaporates and condenses into clouds in the atmosphere, and then falls back to the surface as precipitation.

The ocean also supplies oxygen, food, medicines, mineral and energy resources. For these reasons, it is fair to say that human life is intertwined with ocean life, a coexistence that also supports millions of jobs and drives national economies.

But why is the ocean important? There are many reasons why the ocean is significant in our lives, but here are the top five: it provides climate regulation; it is a source of food; many job industries are connected to the ocean; livelihoods are supported by the ocean; and it certainly contributes to economic progress. These are just a few of the countless reasons why the ocean is vital and why it is necessary to care for it. I challenge you to come up with more, as many as you can.

Additionally, we are within the UN Ocean Decade (2021-2030), a decade where we are encouraged to accelerate the implementation of Sustainable Development Goal 14 for the conservation and sustainable use of the ocean, seas and marine resources.

As you explore this Ocean Literacy Toolkit, the most important thing to remember is that the ocean and humans are inextricably connected. The health of the ocean directly impacts the health and well-being of all life on Earth. Let this toolkit be your guide to understanding, appreciating, and protecting our ocean.

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An introduction to Ocean Literacy

What is ocean literacy?

Every person on earth is connected to the ocean, from the food we eat to the air we breathe. No matter where you live, be it by the coast or many miles inland, the ocean features in your life every single day. We sometimes forget that humans are part of the natural world, rather than simply being observers or outsiders. Although we still have much to learn, what we do know is that our very existence is impossible without a healthy ocean, and that the health of our ocean is under threat.

Ocean literacy is defined as an understanding of how you impact the ocean and how the ocean impacts you.

Around the world, more and more people are learning about how we are connected to the ocean. An ocean literate person understands the essential principles and fundamental concepts of the ocean, knows how to communicate them to others and feels confident to make smart choices about the ocean and its resources. We need ocean literacy throughout Namibia, across all levels of society. Starting with the individual and building up into the community, we intend to bring ocean literacy to everyone.

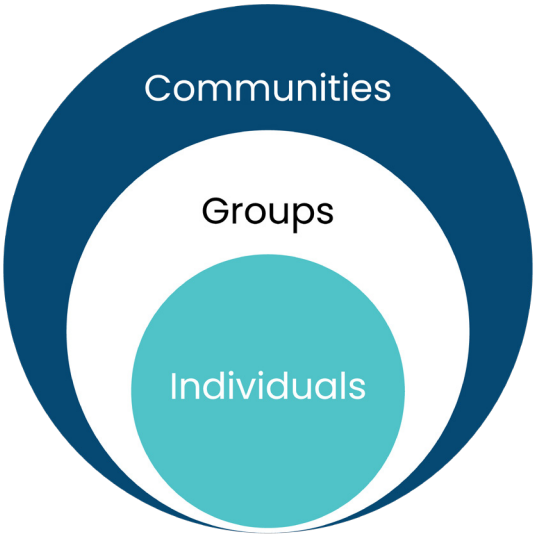
There are seven essential principles of ocean literacy that have been globally agreed and championed by **IOC-UNESCO**:

1. Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of the earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

The global ocean literacy movement

The idea of ocean literacy was founded in the United States in the early 2000's. After a series of workshops involving hundreds of scientists, educators and policy makers, the "*Ocean Literacy Guide*"[1] was published, which defines the seven key principles.

Soon after, more documents were published including an ocean literacy teaching framework, which guides educators on how to best teach their students about these principles[2]. Over a decade later, UNESCO published *Ocean literacy for all: A toolkit*[3], which summarised all the global knowledge and looked to implement ocean literacy within the framework of Education for Sustainable Development (ESD).



Building Ocean Literacy up Through Society, GRID-Arendal

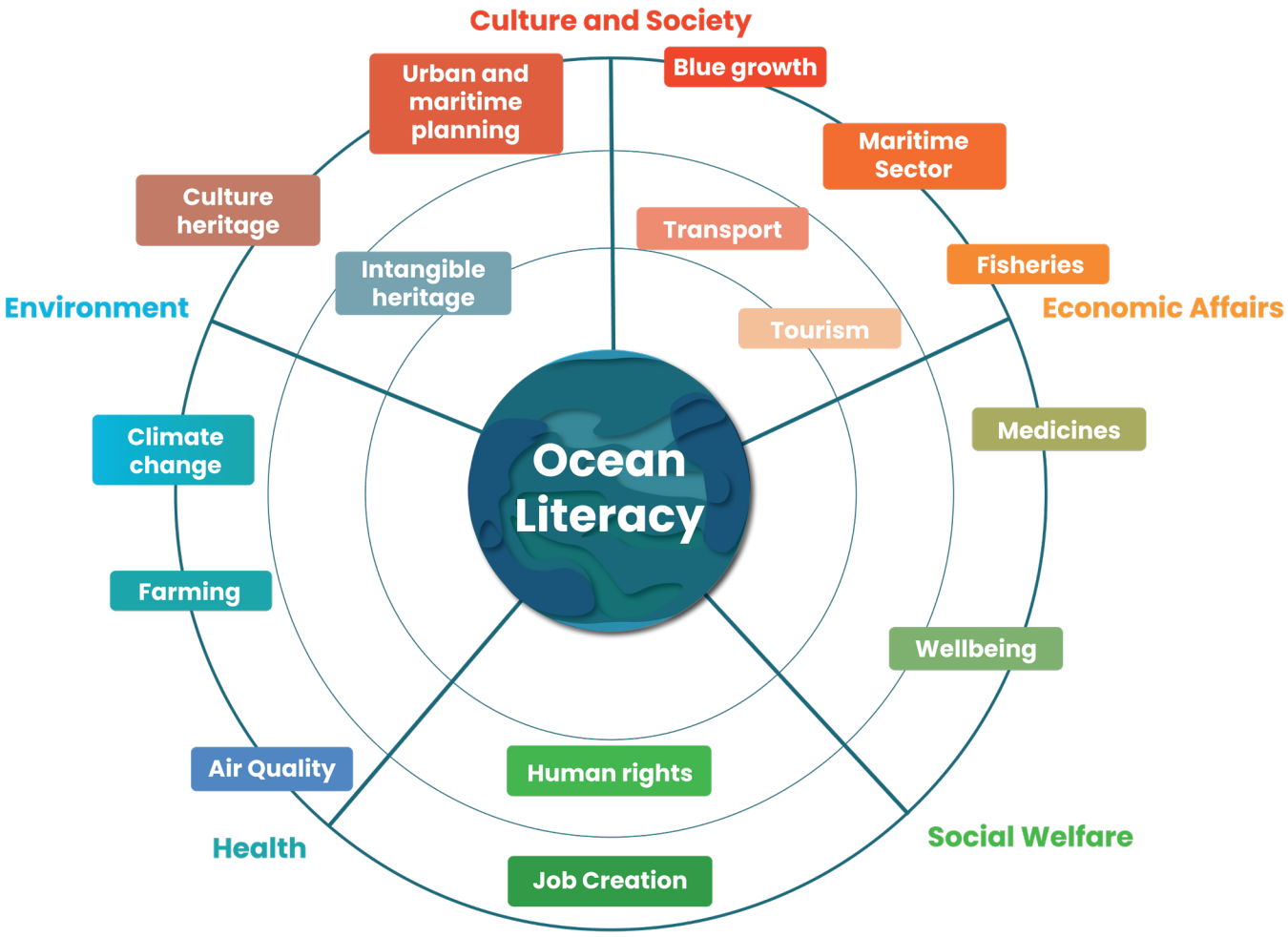
Why do we need ocean literacy in our changing world?

Our world is changing, and the ocean is no exception. As the climate changes, populations grow and technology advances, we must seek to understand how our blue planet will look in five, ten or one hundred years' time. We need a clean and healthy ocean to support us economically, socially and environmentally. If we protect the ocean now, it can protect us into the future.

An ocean literate nation can works towards policies and support initiatives that help sustain a healthy ocean. From 2021-2030, we are in the "Global Ocean Decade", so now is the perfect time to act. The Ocean Decade, launched by the United Nations, aims to support efforts to reverse the decline in ocean health and gather ocean advocates worldwide to build an action plan.

On top of this, we have an obligation to meet the targets of the United Nations Sustainable Development Goals (UNSDGs). Goal 14 is "Life Below Water", which asks us to conserve and sustainably use the oceans, seas and marine resources for sustainable development. We must not forget Goal 4, "Quality education", which asks us to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Young people are increasingly anxious for change in the face of the climate emergency and are demanding better education on sustainability topics that define their future. Within the matrix of the Ocean Decade, Ocean Literacy is needed now more than ever.



Building ocean literacy up through society, GRID-Arendal

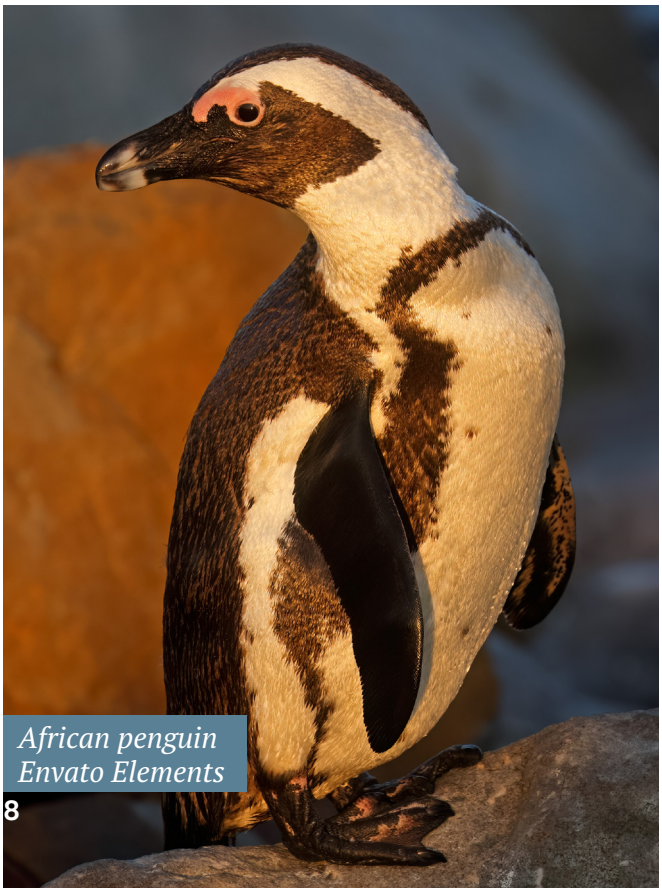


Namibia's Ocean Literacy Toolkit

The purpose of this toolkit

Through this toolkit, we aim to:

1. Improve awareness and perceptions of the ocean in Namibia.
2. Equip educators across Namibia to teach Ocean Literacy.
3. Provide a starting point for integrating Ocean Literacy into the national curriculum.
4. Build support for sustainable use of the ocean and develop the skills required to address sustainability challenges.
5. Inspire a generation of ocean advocates who have the knowledge and tools to protect Namibia's ocean and secure a healthy future.



African penguin
Envato Elements

How to use this toolkit

This toolkit is intended to be an introduction to ocean literacy for both formal and informal educators. Although designed as a guide for educators, we hope that this toolkit can be used anywhere, by anyone, in Namibia who wants to learn more about Ocean Literacy.

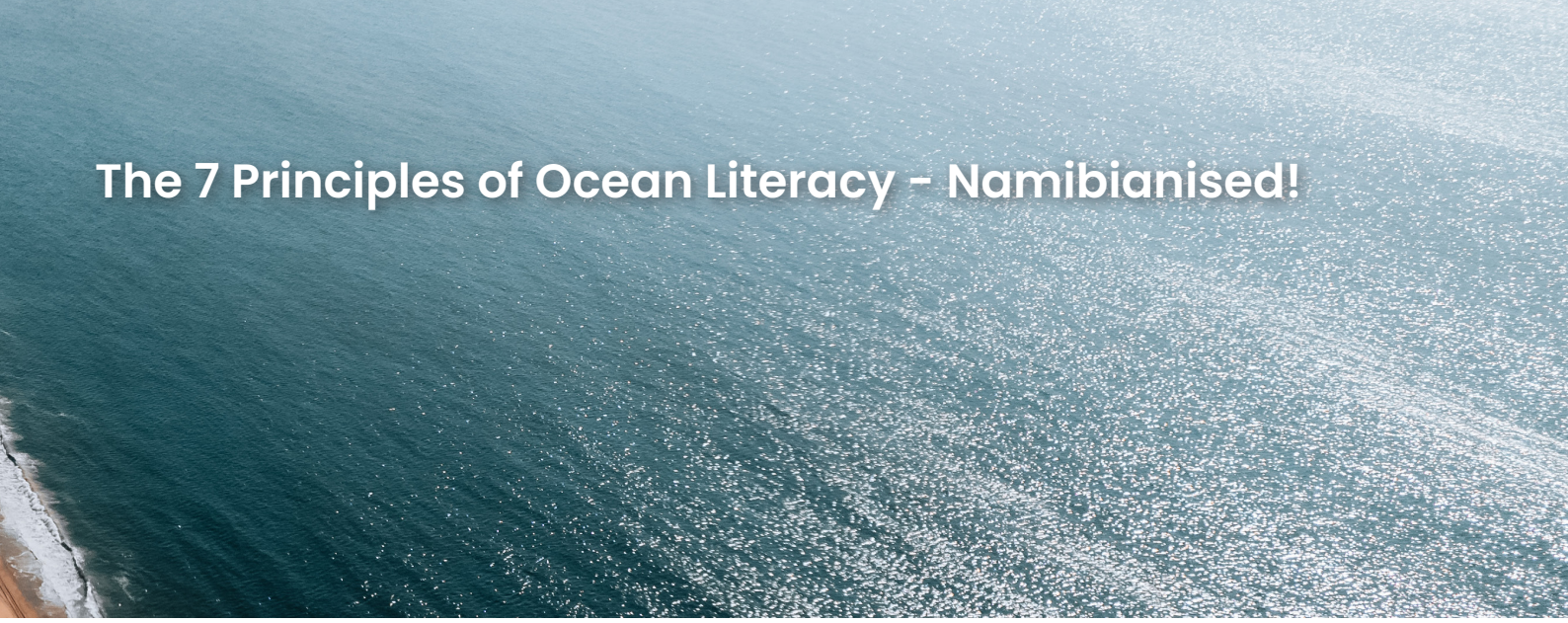
This toolkit provides the broad knowledge required to understand the concept of ocean literacy and brings each ocean literacy principle into the Namibian context using relevant examples. For each of the seven principles, you will find background information, learning objectives, Namibian case studies and activity ideas.

We hope that this toolkit forms a comprehensive starting point, which can be used by ocean advocates as a springboard to further learning. We have worked collaboratively with the committed organisations who have paved the way for ocean literacy in Namibia to date - Eduventures, Namib Desert Environmental Education Trust (NaDeet), the Benguela Current Convention and the Centre for Marine Environmental Education and Sustainability (CeMEES). Together we aim to build on existing work and centralize information in a resource freely accessible to anyone.

We encourage the use of other resources available online and in libraries. We also encourage those with available resources to explore outdoor education, field trips and practical experiences to complement this document.

Throughout this toolkit, look out for:

- *"Did you know?"* boxes, which provide quick facts to inspire and amaze your learners.
- Words **underlined and in bold** are defined in the glossary.
- The QR Code for links to materials for further reading.

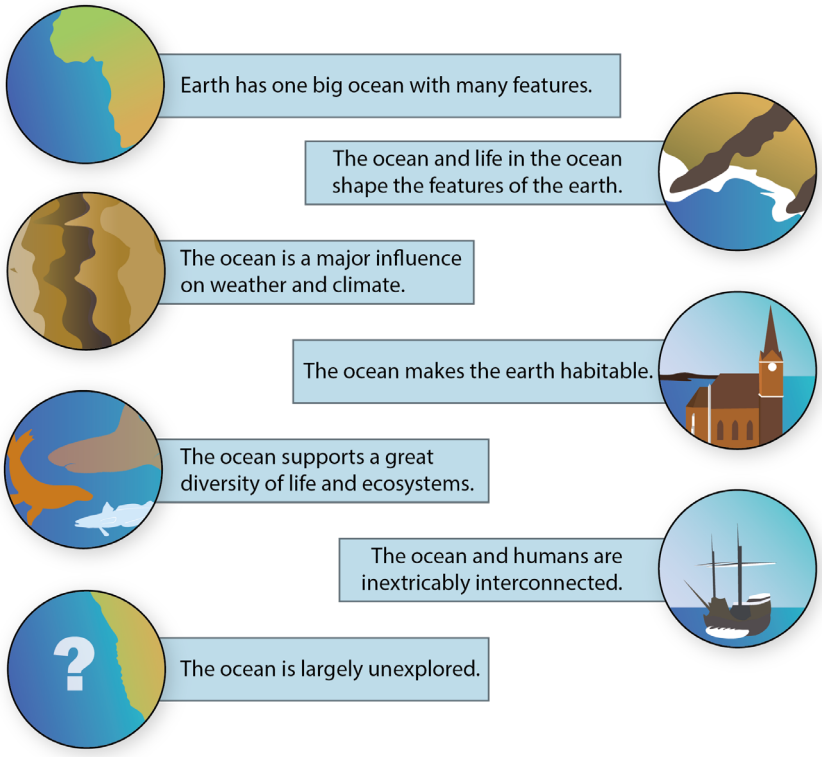


The 7 Principles of Ocean Literacy - Namibianised!

The relationship between Namibians and the ocean is complicated. With only a small proportion of the population living along the 1,572 kilometre coastline, and colonial powers forcing early coastal settlers inland, coastal culture is not traditionally strong. Much of the coast faces extreme weather conditions and cold waters.

Due to this, feelings of disconnect, apprehension or even fear are common. With our most famous stretch of coastline being named "The Skeleton Coast", it is clear to see why these feelings may prevail. But despite being challenging for human habitation, Namibia's coastline is home to world-famous populations of marine **biodiversity**. From sandy beaches and towering dunes to vast salt pans and islands overflowing with squawking seabirds, our coastline is spectacular. A glimpse beneath the waves reveals tangled kelp forests, rocky reefs and a vast, nutrient-rich open ocean. As is common around the world, ocean literacy rarely features in school curricula, meaning most Namibians are not exposed to ocean literacy. We head into adulthood knowing only of the ocean from what we watch, read or hear about in our spare time, or perhaps from experiences visiting the coast.

Exposure to ocean literacy across Namibia is therefore limited by geographic location, social and financial context, personal interest and exposure. Many Namibians could not recognise the iconic, often endangered marine species, and many have never dipped more than a toe into the ocean. Throughout the remainder of this toolkit, we will explore Namibia's magnificent ocean under the framework of the seven essential principles of ocean literacy.



UNESCO's 7 Principles of Ocean Literacy, GRID-Arendal

Principle 1: The earth has one big ocean with many features.

Background

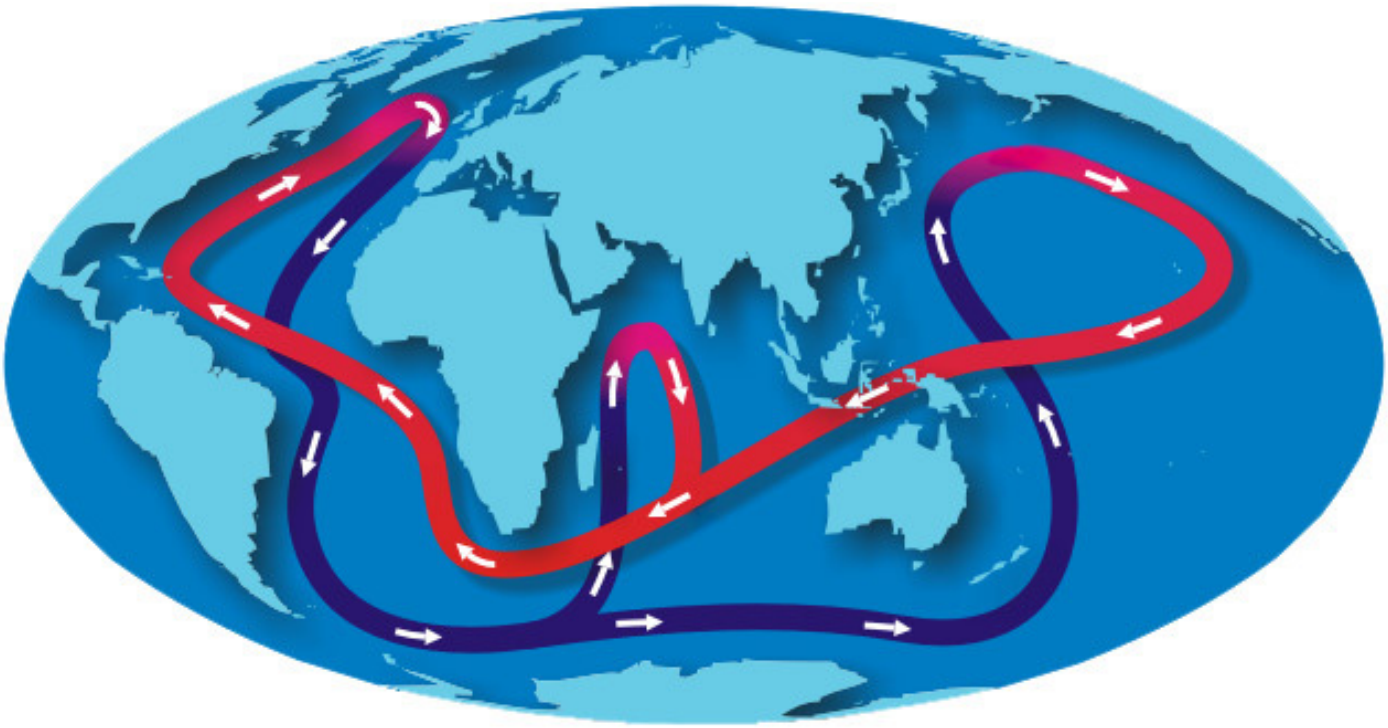
Planet earth has one giant ocean, divided up into the Atlantic, Pacific, Indian, Arctic, and Southern Ocean basins. The ocean basins vary in size, with the Pacific being the largest and the Arctic being the smallest. Namibia borders the Atlantic Ocean, which is the second largest at over 1.06 million square kilometres, which covers about 20% of earth's surface. The Atlantic Ocean spans most of the globe from top to bottom, joining the Arctic Ocean in the North and the Southern Ocean in the South. The resources from the Atlantic Ocean are abundant, and essential to Namibia, however they are not infinite.

There is one interconnected ocean circulation system across the globe, which is sometimes called the "global ocean conveyer belt". It is powered by winds, sun, tides and the rotation of the earth. This conveyer belt not only moves water, but everything in it. Animals, nutrients and heat can all move around the ocean. Along the coast of Namibia is the Benguela Current, a major **cold-water upwelling system** that brings cold, nutrient rich waters from the deep ocean to the surface (see case study 2). **Evaporation** and **precipitation** link ocean currents and the water cycle together. As well as ocean currents, sea levels can change. This is the average height of the ocean relative to the land, taking into account the effect of the tides. Sea levels change when plate tectonic movements change the size or shape of the ocean basins.

Today, sea levels are rising as ice caps melt and the water expands as it warms. Most of Walvis Bay town is just 2m above sea level. Between 1980 and 2030, scientists think that sea levels will have risen by around 20cm, meaning several metres of land could be lost to the ocean[4]. Hentiesbay, Swakopmund and Lüderitz will also be impacted by sea level rise in coming years, so we must take mitigation measures to lessen the impacts on these communities.

Each ocean basin has lots of geological features like ridges, trenches and islands. The Walvis ridge is a major feature off Namibia's coast. It is a 3,000-kilometre-long ancient underwater mountain chain formed by volcanic activity. Towards the South, near Lüderitz, there is a collection of special islands. This feature attracts some of Namibia's most impressive marine life, including African penguins, fur seals, whales and dolphins, and is therefore given special protection as the ***Namibian Islands' Marine Protected Area*** (NIMPA).

The chemical properties of the ocean are also unique. The sea is, of course, salty. We see evidence of this in Namibia's coastal salt pans, for example at Cape Cross. Because Namibia is a dry, arid country, we use desalination plants to remove the salt from seawater, turning it into freshwater. Seawater also has high density, a lower freezing point than freshwater and is slightly "basic" (pH of less than 7).



The Great Ocean Conveyor Belt - *The dark blue line represents the deep, cold water current. The red line indicates shallower and warmer current'*

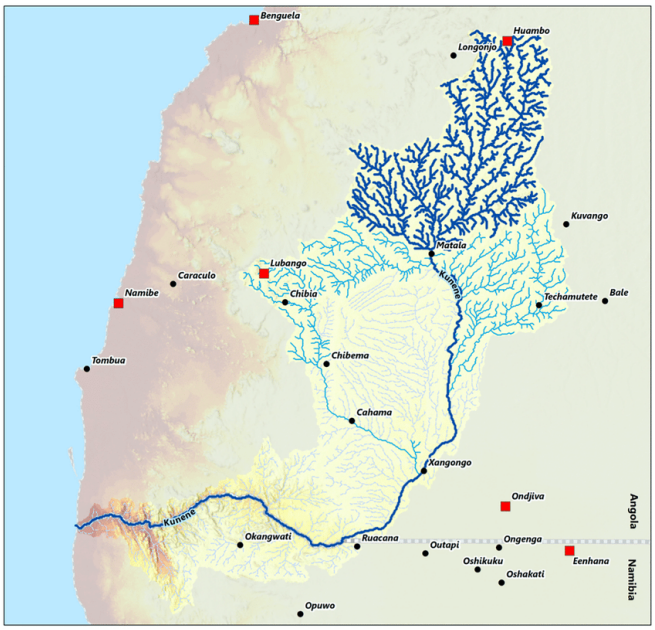
(National Oceanic and Atmospheric Administration)



Namibian Sea Life
Envato Elements

Lakes, rivers and waterways are all connected to the ocean, either physically, or as part of the water cycle. In Namibia, the major rivers feeding into the ocean are the Kunene, Orange, Swakop, Kuiseb and Omarurui.

But these rivers carry more than just water – they carry sediments, pollutants and nutrients too, which can both support and harm marine life. Some rivers flow all year round (we call these **perennial rivers** e.g. the Orange), whereas some only flow during the wet season (we call these **ephemeral rivers** e.g. the Kuiseb).



Detailed map of the Kunene River Basin, Richard Meissner and Jeroen Warner

Case Study 1: The Walvis Ridge

The Walvis Ridge underwater mountain chain stretches all the way from the coast of Namibia to the South Atlantic Island of Tristan de Chuna. These formed because around 120 million years ago, the surface of the earth moved over a volcanic hotspot which caused the crust to melt and bubble up into the ocean, cooling over many years to form mountains.

Today, the giant ridge acts as a barrier to water flow. As water hits the ridge, it is forced upwards towards the surface, taking nutrients with it. This is known as upwelling. The upwelling of nutrients attracts lots of marine life, making this region biologically important.

The Namibian government want to protect this important **ecosystem**, so it has been declared an "Ecologically and Biologically Significant Area". However, only part of the Walvis Ridge lies in Namibian's waters – the other part is in the "high seas", which belong to no government. This area is protected by the Biodiversity Beyond National Jurisdiction (BBNJ) treaty, which aims to ensure the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction.

To better protect the whole of the Walvis Ridge, Namibia is trying to officially extend the **Exclusive Economic Zone** (an area in which the country has the right to explore and use the sea's resources, including to fish, drill for oil, and mine for minerals) to incorporate the entire Walvis Ridge.

Case Study 2: The Benguela Current

Along the coast of Namibia, we see two major currents coming together: The Angola Current comes down from the North, and the Benguela Current comes up from the South.

The Benguela Current is particularly important in Namibia as it forms the base of the **Benguela Current Large Marine Ecosystem**. This ecosystem is home to most of Namibia's iconic species and is crucial for our fisheries. The Benguela Current is driven by south-easterly trade winds that have blown across the southern tip of Africa.

As the winds blow warmer surface water northwards and the turning of the earth pulls water away from the land, cooler waters from the deep sea must rise to fill the gap – another case of upwelling! This water, which is from around 200-300m depth, is full of nutrients. Tiny organisms called **phytoplankton** benefit from the nutrients, and their populations grow. The phytoplankton are then eaten by small marine creatures such as copepods, krill and larval fish, which are eaten by larger marine creatures such as horse mackerel, sardines and seals, fuelling the entire food chain. One critical feature within the Benguela Current system is the Lüderitz Upwelling Cell, located off the coast of Namibia near the town of Lüderitz. This upwelling cell significantly contributes to the nutrient supply and productivity of the Benguela ecosystem.

Sometimes, the Benguela Current becomes unpredictable. A global weather phenomenon, called the **El Niño Southern Oscillation (ENSO)** causes the temperature of the sea in the Pacific Ocean to vary. Believe it or not, these warming and cooling events in the Pacific have a large effect on the Atlantic, due to interconnected ocean currents. We call the warmer period "**El Niño**" and the cooler period "**La Niña**". During El Niño, the Benguela upwelling doesn't bring as many nutrients to the surface, which can impact the availability of food for the whole ecosystem.

Did you know?

- *70% of the Earth's surface is covered by the ocean, which contains 97% of water on earth.*
- *The Atlantic Ocean, at its deepest, is over 8300 metres deep.*
- *"Walvis" means "Whale" in Afrikaans and Dutch.*

Learning obectives

a. Identify the five ocean basins on a map, highlighting the Atlantic as Namibia's ocean.

b. Name a major geological feature of Namibia's ocean.

c. Describe the Benguela Current and explain upwelling.

d. Discuss the reasons for sea level rise and acknowledge the impacts on Namibian coastal towns.

e. Recall some chemical properties of seawater (salty, dense, basic).

f. Name a major Namibian river and explain how rivers and the ocean are related.

g. Recognise that the resources provided to Namibia by the ocean are not infinite.

Learning obectives Answers

a. Atlantic Ocean, Pacific Ocean, Indian Ocean, Arctic Ocean, Southern Ocean.

b. The Walvis Ridge.

c. The Benguela Current is a cold-water upwelling system that brings nutrient-rich water from the deep ocean to the surface. This upwelling occurs because of south-easterly trade winds pushing warm surface water northwards, allowing cooler water from below to rise and fill the gap.

d. Sea level rise is caused by: Melting ice caps, water expanding as it warms, several Namibian coastal towns like Walvis Bay, Swakopmund, Lüderitz, and Henties Bay are only a few meters above sea level and could be impacted by rising sea levels, potentially losing land to the ocean.

e. Salty, Dense, Basic

f. The Orange River is a major Namibian river that flows into the ocean. Rivers carry water, sediments, pollutants, and nutrients to the ocean, influencing marine life. Some rivers are perennial (flowing year-round), while others are ephemeral (flowing only during the wet season).

g. Highlight that resources from the Atlantic Ocean, while abundant, are not infinite. This highlights the importance of sustainable use and conservation of these resources for Namibia.

Curriculum Links to Jr. Secondary

Geography ▶ Climatology ▶ Forming of condensation ▶ The ocean's place in the watercycle

Geography ▶ Geomorphology ▶ Internal Forces ▶ Mid-oceanic ridges, volcanic island arcs (Walvis ridge)

Geography ▶ Regional Geography ▶ Namibia's Physical features (Walvis Ridge and coastal islands)

Suggested Activities

Primary schools: Sea Level Rise Experiment[5]

In this simple experiment, students will investigate the impacts of melting land ice and sea ice on sea level rise.

Equipment list:

- 2 clear Tupperware boxes.
- 2 small wooden blocks or flat stones of the same size.
- ~16 ice cubes.
- Some tap water.
- Sticky notes or labels.

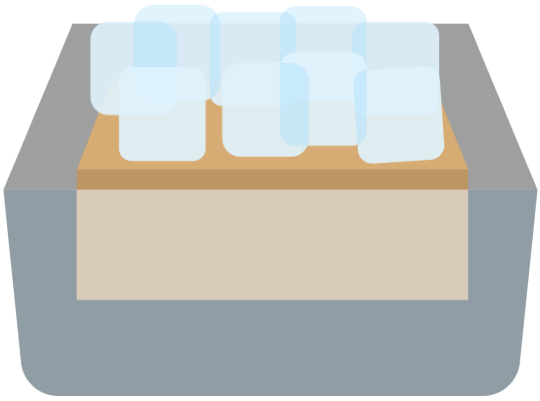
Students should now understand:

- That melting sea ice doesn't impact sea level, but melting land ice does.
- The impacts that rising sea levels might have on low-lying land.

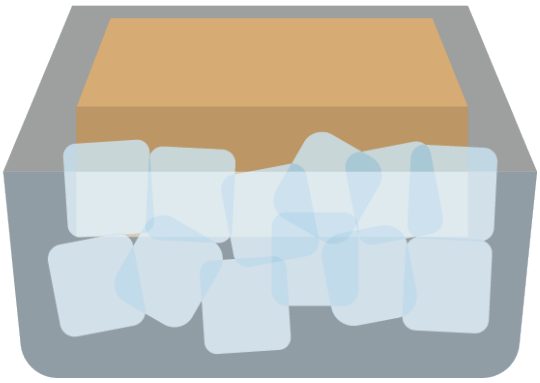
Instructions:

1. Take the Tupperware boxes and place a block or stone of the same size in each.
2. Label one box "land ice" and one box "sea ice."
3. Place half of the ice cubes in the "land ice" box, on top of the block or stone. Place the remaining half of ice cubes in the "sea ice" box, next to the block or stone.
4. Add equal amounts of water to both boxes and mark the water level on the outside of the Tupperware box with a pen.
5. Leave the ice to melt.
6. Once all the ice is melted, mark the new water level on the box.
7. You will see that the water level in the "land ice" box has risen, but in the "sea ice" box it has not.

Land ice



Sea ice





Fur Seal
Envato Elements

Secondary schools: Upwelling Experiment[6]

In this simple experiment, students will visualise how winds over the ocean's surface cause upwelling.

Equipment list:

- Large, clear rectangular container.
- Water (represents the seawater).
- Blue liquid food colouring (represents nutrient-rich seawater from the deep)
- Pipette or turkey baster.
- A fan.

Instructions:

1. Place the container on a flat surface.
2. Fill ¾ with water.
3. Pipette a whole bottle of food colouring into the bottom of the container and let it settle.
4. Position the fan so it blows across the top of the water and turn it on.

Students should now understand:

- *That wind across the ocean's surface causes water from the deep sea to upwell and bring nutrients to the surface.*

Further Reading

Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code below or visiting: **bit.ly/m/ocean-literacy-toolkit**

Principle 2: The ocean and life in the ocean shape the features of the earth.

The shape, size and location of the ocean has changed throughout time. Some parts of the ocean were once dry land, and some parts of the land were once covered by ocean. Many minerals and **sedimentary rocks** found on land today have their origins in the ocean. In fact, most of the Sahara Desert, now one of the dryest places on earth, used to be under the sea.

At the top of Brandberg, Namibia's tallest mountain, marine sediments and fossils can be found. This impressive 2573m mountain was formed around 130 million years ago during the early **Cretaceous period**. During this period, violent volcanic activity broke up **Gondwanaland**, the giant supercontinent, and formed the continents we recognise today.

Due to this tectonic event, the level of the land and sea changed dramatically, enough for the entire South Atlantic Ocean to be formed. The power of **tectonic plates** is enough to cause the expansion and contraction of whole continents and seas.

Erosion is the wearing away and removal of rock, soil or other earth materials by wind, waves, and weather. The ocean has huge erosive power, and shapes much of our coastline. An impressive example is the Bogenfels Arch, located in the diamond region, south of Lüderitz in the coastal Namib desert. The arch is 55m tall and has been carved out from millions of years of powerful wind and wave action.

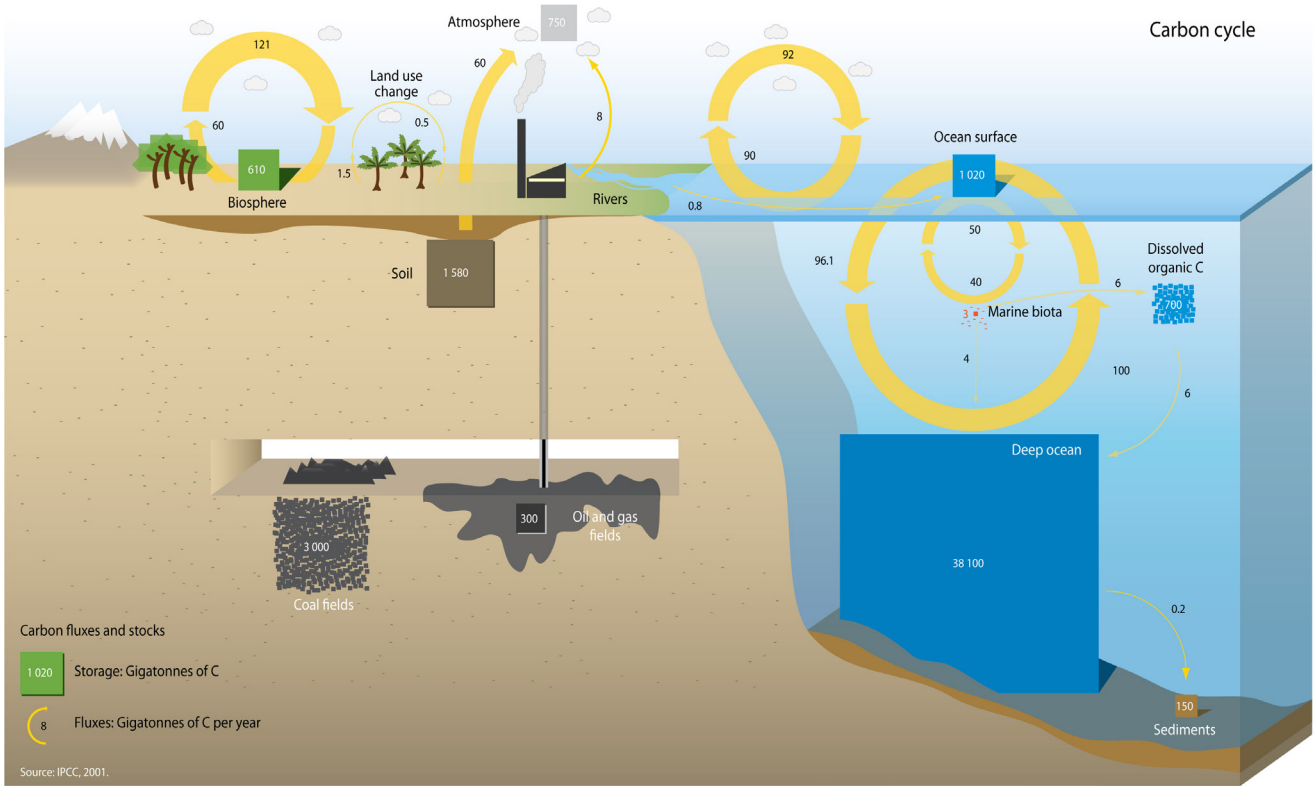
Minerals, chemical elements and compounds cycle regularly between the land, ocean, atmosphere and living things through **biogeochemical cycles**. Marine organisms, particularly the small **microorganisms**, are crucial in these cycles – their life, growth and death drive biogeochemical cycles in the ocean. The marine carbon cycle is especially important, because the ocean is the largest store of carbon on the planet!



Bogenfels, Photo: Ragnihild and Neil Crawford



Brandberg, Photo: European Space Agency



We sometimes refer to the ocean as a **carbon sink**, meaning it locks carbon away that might otherwise end up as **carbon dioxide** (CO_2) in our atmosphere. The ocean is therefore extremely important in our fight against climate change.

However, as the ocean absorbs CO_2, it reacts with seawater to form an acid. An increase in seawater acidity can harm marine animals like lobsters and corals that have hard shells or skeletons. Normally, carbon in the ocean combines with **calcium** to make **calcium carbonate**, which is needed to form strong shells and bones.

With higher acidity, calcium carbonate is less readily available, meaning it is more difficult for animals to build and maintain their shells. Their shells might become weaker, leaving them more at risk to predators and disease. We must reduce our climate impact to protect iconic Namibian species like the **Lüderitz Rock Lobster**.

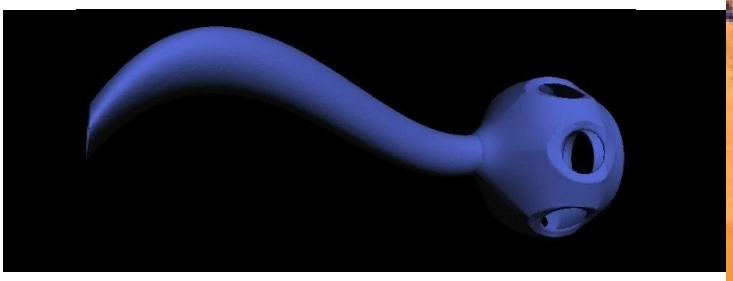
Case study 1: The oldest shelly fossils in the world

"Namacalathus" is a mysterious fossil, first discovered in Namibia. It is one of the earliest known forms of **multicellular life**, so early in fact, that scientists are not even sure if it is an animal, or some other type of extinct life form altogether. What we do know is that Namacalathus lived in the shallow ocean between 540 and 530 million years ago.

Fossils show that they had cone shaped or cylindrical shells that were anchored to the seafloor, perhaps even arranged in reef-like structures. The Namacalathus fossils were found in the year 2000, in central, inland Namibia, many miles from today's ocean!



Luderitz Crawfish festival, Photo: GRID-Arendal



Namacalathus 3D Render, Alchetron

Case study 2: The Namib Sand Sea

The Namib Sand Sea is one of Namibia's natural wonders. Designated as a **UNESCO world heritage site**, this region of northern Namibia is home to some of the oldest, tallest and most varied sand dunes in the world.

Despite being hundreds of kilometres away, most of the sand in this Namib has ultimately been washed down from the Orange River. Where the Orange River meets the sea, sand is washed out by ocean waves and dragged northwards by strong ocean currents. Westerly winds then push the sand back onshore and deposit it further north, accumulating in the Namib Sand Sea.

This deposited sand is constantly shaped and sculpted by the wind, creating a dynamic landscape of dunes. The dunes are a distinctive reddish-orange colour due to the high content of a mineral called **iron oxide** in the sand, originating inland in the Orange River **watershed**. Sand in other regions of Namibia, like Swakopmund, also has this signature red colouration.

The Namib Sand Sea is the only desert in the world that has sand dunes influenced by coastal fog. This belt of fog, which can travel as much as 80km inland, is formed because of the difference in temperature between the cold Benguela Current and the warm desert sand. Rolling in from the ocean in the early mornings, this fog brings moisture and breathes life into an otherwise arid landscape.

Did you know?

- *Fossils are formed when hard animal parts (like bones and shells, that don't decay) are replaced or coated by minerals when buried in mud.*
- *The ocean locks away around a quarter of all the carbon, and 90% of all the excess heat humans produce every year.*
- *Every year in April and May, Lüderitz holds the Crayfish Festival to celebrate its famous rock lobster.*

Namib Sand Sea, UNESCO, Photo: Paul van Schalkwyk

Curriculum links

Geography ▶ Geomorphology ▶ Discover basic rock types (Marine fossils, sedimentary)

Geography ▶ Geomorphology ▶ Weathering and erosion (Bogenfels)

Geography ▶ Regional Geography ▶ Namibia's Physical features (Brandberg and Bogenfels)

Life Sciences ▶ Ecosystems ▶ Cycling of nutrients ▶ Major ecological cycles, including the water and carbon cycles

Learning Objectives

a. Explain how we know that Brandberg used to be underwater.

b. Explain how we know that sea level used to be different than it is today. Use an African example in your answer (the Sahara Desert).

c. Identify Bogenfels and describe how it was formed.

d. Label the parts of the ocean carbon cycle.

e. Explain how the physical structure and landscape of the Namib sand sea is shaped by the ocean.

Suggested Activity

Investigating the erosive power of the ocean[7]

Equipment list:

- Small cup.
- Soil or sand.
- Water.
- A straw.
- A large plate, dish, or waterproof tablecloth (if doing the experiment inside).

Instructions:

We recommend you do this activity outside to prevent mess!

1. Pack soil or sand into the cup, with a little water if needed, as if making a sandcastle. Repeat this about 4 times, placing the castles next to each other.
2. Turn the sand or soil out onto the ground (or the plate / dish / tablecloth if doing this inside).
3. Blow on the soil/sandcastles using the straw to represent wind erosion. Observe what happens.
4. Gently sprinkle the water on the soil/sandcastles to represent rain. Observe what happens.
5. Start pouring the water on the soil/sandcastles to represent a river flowing or ocean waves. Observe what happens.

Learning Objectives Answers

a. Marine sediments and fossils can be found at the top of Brandberg, Namibia's tallest mountain. These marine fossils wouldn't be present on a mountain peak unless the area was once submerged underwater.

b. The Sahara Desert, currently one of the driest places on Earth, used to be under the sea. This indicates significant changes in sea level over geological time.

c. Bogenfels Arch is an impressive natural arch located in the diamond region of Namibia. It is 55 meters tall and was carved out by millions of years of powerful wind and wave action, highlighting the erosive power of the ocean in shaping coastlines.

d. See infographic

e. The Namib Sand Sea is formed through the following ocean-related processes: **Sediment transport:** The Orange River carries sand from inland to the ocean. Ocean currents and waves then transport this sand northwards. **Wind action:** Westerly winds push the sand back onshore, depositing it in the Namib Sand Sea. These winds constantly shape and sculpt the dunes.
Coloration: The high iron oxide content in the sand, originating from the Orange River watershed, gives the dunes their distinctive reddish-orange colour.

Further Reading

Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code below or visiting: **bit.ly/m/ocean-literacy-toolkit**

Students should now understand:

- *Rivers and oceans have the most erosive power, followed by rain and then wind.*

Principle 3: The ocean is a major influence on weather and climate.

Background

The ocean is undoubtably the single largest influence on the weather conditions we experience day-to-day, and the climate events we experience year-to-year. Without the ocean, temperatures and rainfall on land would be much more variable between day and night, through the seasons and across different geographical locations. Three major systems link the ocean with our weather and climate: energy, water and carbon.

1 – Energy

The ocean brings stability to our climate, absorbing, storing and transporting much of the sun's **solar energy** that passes through the atmosphere. When sunlight (insolation) hits the ocean surface, water molecules absorb the energy and turn it into heat.

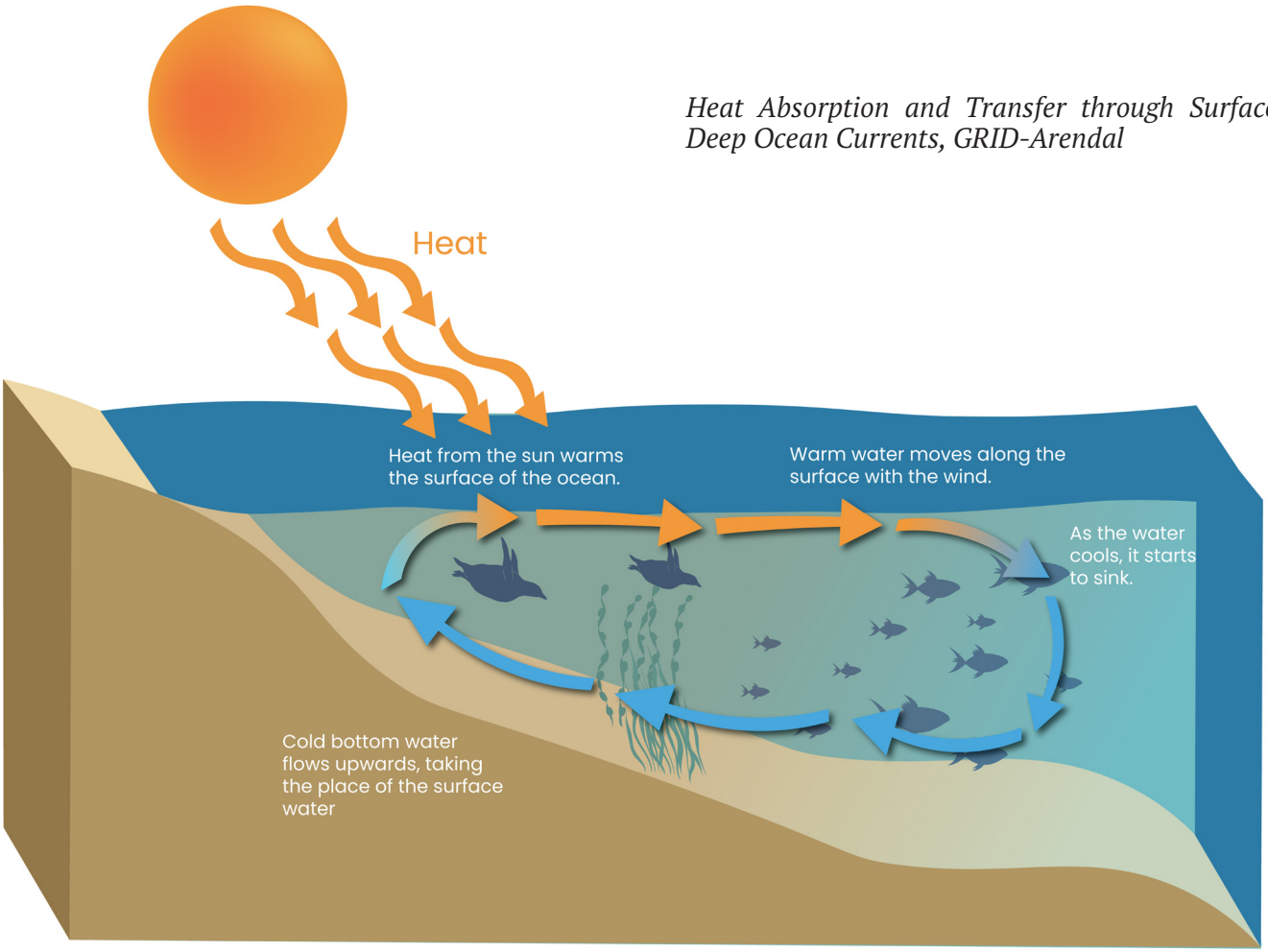
Once absorbed, this heat mixes through the layers of the ocean via **convection** and moves through predictable ocean circulation patterns around the globe. In general, ocean currents transport heat from warmer regions to cooler regions, which explains why many ocean currents travel from the equator to the poles, and vice versa. In Namibia, we have the warm Angola current moving down from the North, and the cold Benguela Current moving up from the south.

2 – Water

Evaporation and condensation are crucial processes linking the ocean with our weather and climate. In warm parts of the world, there is more **evaporation** from the ocean. When this evaporated moisture rises, it cools and **condenses** again, and hurricanes and cyclones can form. Most of the water that falls as rain on land originally evaporated from tropical oceans.

Namibia is one of the most **arid** countries on earth. This is primarily because of the cold Benguela Current running parallel to the Namibian coastline. The current brings cold air to the coast, so there is less evaporation, fewer clouds can form and less rain falls over the land. In coastal areas like Swakopmund, proximity to the cold ocean brings mild temperatures and foggy weather throughout the year. Further inland, the seasons are more distinct, fog cannot form, and temperatures are higher.

Water vapour, in the form of clouds, traps heat like a blanket over the earth. But in Namibia's desert regions, with clear skies at nights and few clouds, the desert becomes very cold, even after a hot day. In cloudier climates, such as in Swakopmund, the highs and lows in temperature are much less extreme.

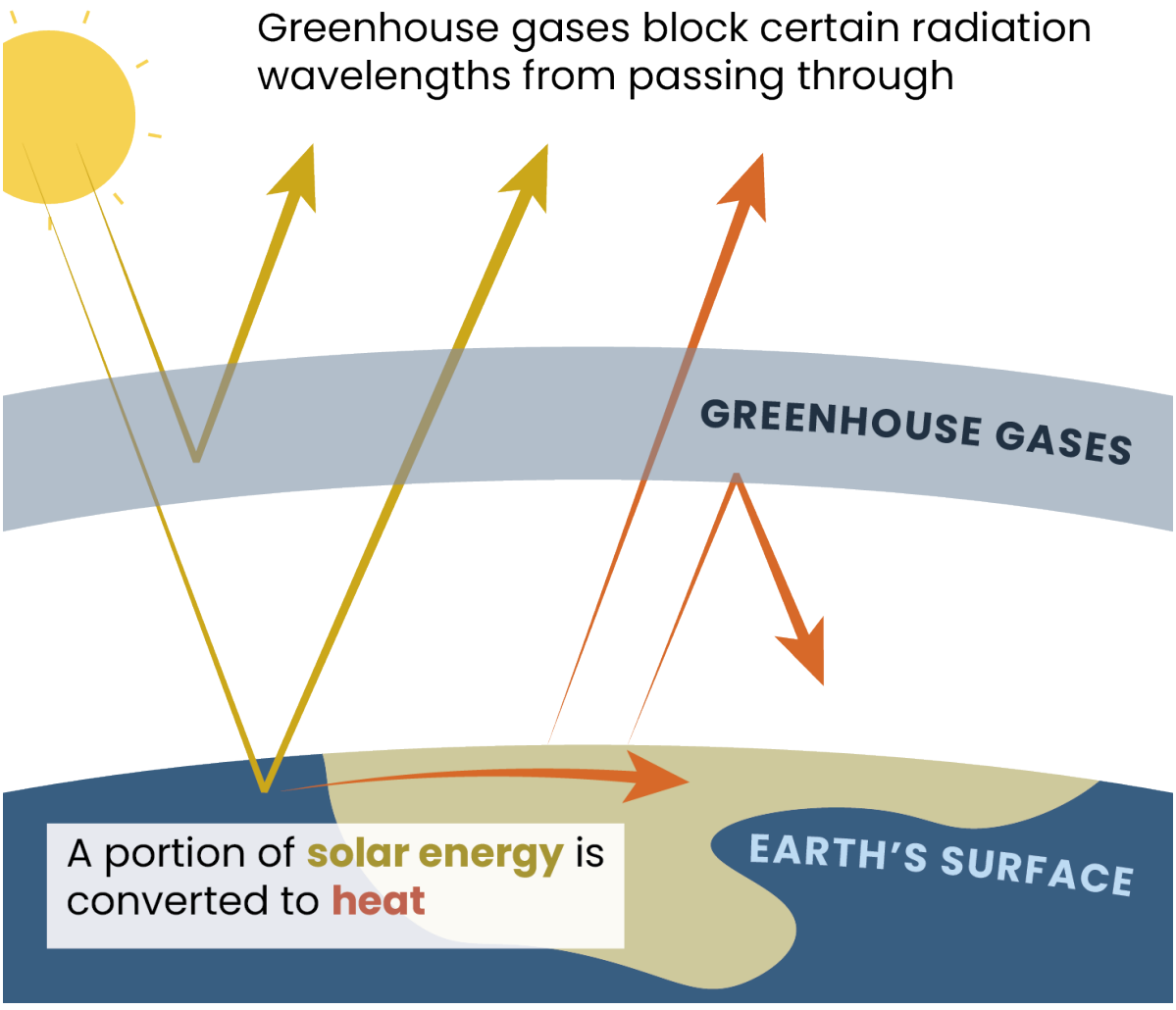


Heat Absorption and Transfer through Surface and Deep Ocean Currents, GRID-Arendal

Carbon dioxide (CO_2) and methane (CH_4) are both **greenhouse gases** that contain carbon. Greenhouse gases trap more of the sun's heat energy, leading to a warming effect here on earth. The strongest warming effect is generally felt in regions where the climate is already hot and dry, like Namibia. It is estimated that about half of all carbon dioxide and methane in the atmosphere is absorbed by the ocean, meaning the ocean has a major role in the **greenhouse effect** by regulating the amount of greenhouse gases in our atmosphere.

Through the earth's history, there have been abrupt changes in climate that are linked to the ocean. For example, in the Younger Dryas period, the heat circulation system of the north Atlantic broke down, making the northern hemisphere much colder and the southern hemisphere much hotter, as heat was no longer being distributed around the globe as normal. More recently, in 2019, a Benguela Niño event off the coast of Angola demonstrated how abrupt climate change can impact Namibia's oceans. This event was characterised by warm sea surface temperatures due to weakened alongshore winds and increased freshwater input through rain and river runoff. These conditions led to significant environmental impacts, which resulted in low rainfall and high temperatures in Namibia (2019 drought). This highlights the complex interaction between our ocean and atmosphere on both long- and shorter-time scales.

The complex and delicate relationships between energy, water and carbon in our ocean and atmosphere are at risk. If we continue to burn fossil fuels, putting more and more greenhouse gasses into the atmosphere, one or more of the cycles mentioned above could become unbalanced, which could have dramatic physical, chemical, biological, economic, and social consequences.



The Greenhouse Effect, GRID-Arendal



Cyclone from space

Envato Elements

Case study 1: Why is the weather so different in Namibia compared to Mozambique?

Namibia and Mozambique are both southern African countries, sitting at a similar latitude, but on opposite coasts of the continent. So why is their weather and climate so different?

Weather in Namibia – The Benguela Niño

Namibia is one of the world's most arid countries, with high temperatures and very little annual rainfall. The Northeast usually receives some rainfall (around 650 millimetres) each year, but the southwest coastal regions receive almost no rainfall and so rely heavily on fog for moisture, which is present in the coastal belt one in every three days[8]! The weather patterns experienced across Namibia are strongly influenced by the cold Benguela ocean current causing low evaporation and cold winds. During global El Niño periods when the ocean is warmer, global weather patterns change and Namibia tends to receive slightly less rain. There is a slightly higher chance of rain in Namibia in La Niña periods when the ocean is cooler.

As well as the global El Niño Southern Oscillation (ENSO), Namibia has its own "Benguela Niño", which occurs when warm waters push down from Angola over an extended period during the summer season.

Weather in Mozambique – Tropical Cyclones

Mozambique has a typical tropical climate, with hot, wet weather and a tendency to experience tropical storms. Coastal Mozambique receives up to 1200 millimetres of rain per year, whereas inland areas tend to receive less, around 600 millimetres[9]. The weather of Mozambique is influenced by the warm Mozambique current moving southwards from the Indian ocean due to the trade winds. This warm current has several cyclonic "**eddies**" which contribute towards extreme events.

	Namibia	Mozambique
Location	Southwest Africa	Southeast Africa
Climate type	Arid	Tropical
Rainfall	Generally lower	Generally higher
Coastal climate	Cooler and foggy	Warmer and wet
Inland climate	Warm and wetter	Cooler and drier
Coastal ocean current	Cold Benguela Current	Warm Mozambique Current
Extreme events	Drought and storm surges	Tropical storms (cyclones)



Coastal storm
Envato Elements

Case study 2: The extreme weather events of 2013-2014

In 2013 and 2014, Namibians truly saw the power of the ocean and its influence on weather and climate. Much of Namibia's coastline experienced "**storm surges**", a type of extreme weather event where sea level rises due to stormy, low-pressure conditions. wMany of Namibia's coastal towns and communities, like Walvis Bay and Lüderitz, became flooded, which damaged infrastructure, homes and local businesses. Wildlife was also affected, with floods eroding beaches and dunes that are needed by nesting birds and sea turtles.

To help protect against future storm surges, there are several actions that can be taken:

1. Strengthen early warning systems, so that coastal communities have more time to prepare.
2. Design storm-proof or "resilient" infrastructure, which is less likely to be damaged by extreme events.
3. Protect and restore coastal habitats like wetlands, as they act as natural flood defences.
4. Educate and prepare people living close to the coast.

The Kunene, Erongo, Omusati, and Omaheke regions are some of the most likely to suffer from low rainfall and consequent drought. Drought causes vegetation to suffer, so grazing of livestock becomes difficult – many people lose their livestock to starvation or disease and are forced to begin farming crops instead. Between 1992 and 2019, six national drought emergencies have been declared[10].

Did you know?

- *The water temperature in the coastal Benguela current region is generally about 10-15°C.*
- *The **Gulf Stream,** a warm ocean current that brings temperate weather to western Europe, is weakening with climate change, which might make this region much colder!*
- *Over ¾ of all greenhouse gas in the atmosphere is CO_2. Other greenhouse gases include methane and nitrous oxide.*

Curriculum links

Geography ▶ Climatology ▶ Forming of condensation ▶ The ocean's place in the water cycle

Geography ▶ Climatology ▶ The climate of Namibia ▶ Influenced by distance from the coast/ocean

Geography ▶ Climatology ▶ Distinguish between weather and climate

Geography ▶ Regional Geography ▶ Namibian climate ▶ Know the factor that influence Namibia's climate (e.g. ocean currents)

Life Sciences ▶ Ecosystems ▶ Cycling of nutrients ▶ Major ecological cycles, including the water and carbon cycles

Learning Objectives

a. Identify the three processes that control weather and climate (carbon, water, energy).

b. Name Namibia's warm and cold ocean currents and explain patterns of warm and cold-water movements around the globe.

c. Describe the effect the El Niño and La Niña may have on Namibia's weather.

d. Understand that Namibia does not experience cyclones, but that countries with warmer seas do (e.g. Mozambique).

e. Explain how the ocean takes in carbon dioxide and produces oxygen (phytoplankton, marine plants and algae).

f. Give an example of when the ocean caused a major change in climate (Younger Dryas).

g. Identify some consequences of climate change (physical, chemical, biological, economic, and social).

Learning Objectives Answers

a. **Energy:** The ocean absorbs, stores, and transports **solar energy** from the sun, influencing temperature patterns globally. **Water:** **Evaporation** and **condensation** processes involving the ocean significantly impact rainfall and cloud formation. **Carbon:** The ocean absorbs and stores a large amount of carbon dioxide, a greenhouse gas, influencing global temperatures.

b. **Cold Benguela Current:** This current flows northwards along the Namibian coast, bringing cold air and reducing **evaporation**, leading to **arid** conditions and coastal fog. **Warm Angola Current:** Located further north, this current brings warmer water but has a lesser influence on Namibia's climate compared to the Benguela Current. Generally, warm-water currents move away from the equator towards the poles, while cold currents flow from the poles towards the equator. This helps distribute heat around the globe.

c. **El Niño:** A global climate event characterised by warmer-than-average sea surface temperatures in the central and eastern equatorial Pacific Ocean. During **El Niño** events, Namibia tends to receive slightly less rain. **La Niña:** The opposite of El Niño, with cooler-than-average sea surface temperatures in the equatorial Pacific. La Niña periods might bring slightly more rain to Namibia.

d. **Namibia:** The cold Benguela current suppresses evaporation and storm formation, leading to an arid climate with no cyclones. **Mozambique:** Influenced by the warm Mozambique Current, Mozambique experiences a tropical climate with higher rainfall and is susceptible to tropical cyclones.

e. **Marine organisms,** particularly **phytoplankton** (microscopic marine plants and algae), play a crucial role in capturing **carbon dioxide** from the atmosphere through **photosynthesis**.

f. **The Younger Dryas** period is used as an example where a disruption in the North Atlantic Ocean's heat circulation system led to significant global climate changes: colder temperatures in the northern hemisphere and warmer temperatures in the southern hemisphere.

g. **Physical:** Changes in sea level, extreme weather events like storm surges and droughts. **Chemical:** Ocean acidification caused by increased carbon dioxide absorption. **Biological:** Disruption of marine ecosystems due to changing temperatures and acidification. **Economic:** Impacts on fisheries, tourism, and infrastructure due to climate change effects. **Social:** Displacement of communities due to rising sea levels, conflicts over water resources.

Suggested Activities

Giant carbon cycle class role play[11].

Equipment list:

- 7 "team area" signs. These can be printed or simply written on A4 paper.
- Land plants team area
- Ocean plants team area
- Land animals team area
- Ocean animals team area
- Atmosphere team area
- Ocean team area
- Fossil fuels team area
- Blue tac / sticky tape

Instructions:

1. Move all furniture and obstacles in the room so students can move around freely.
2. Stick the 7 "team area" signs up around the space.
3. Assign each student to a team, we suggest:
    1. Land plants team ~4
    2. Ocean plants team ~2
    3. Land animals team ~2
    4. Ocean animals team ~1
    5. Atmosphere team ~6
    6. Ocean team ~9
    7. Fossil fuels team ~6 You can scale these numbers up and down depending on class size.
4. Send the students to their team area.
5. Read out the following rounds and ask the children to act them out:

Step 1: *Plants absorb carbon (dioxide) from the atmosphere*. 4 of the atmosphere team join the land plants, and 2 join the ocean plants.

Step 2: *Animals eat the plants which contain carbon.* 2 land plants join the land animals, and 1 ocean plant join the ocean animals.

Step 3: *Animals and plants use the food which releases carbon.* 2 land animals and 2 land plants join the atmosphere. 1 ocean animal and 1 ocean plant join the ocean.

Step 4: *Carbon is exchanged between the ocean and atmosphere*: 2 ocean swap places with two atmospheres. ***This is a balanced cycle.***

Step 5: *Humans burn fossil fuels releasing carbon dioxide.* 1 fossil fuel stays in the ground, and 5 join the atmosphere.

Step 6: *The ocean absorbs excess carbon dioxide from the atmosphere.* 2 atmospheres join the ocean. ***This is an unbalanced cycle.***

Further Reading

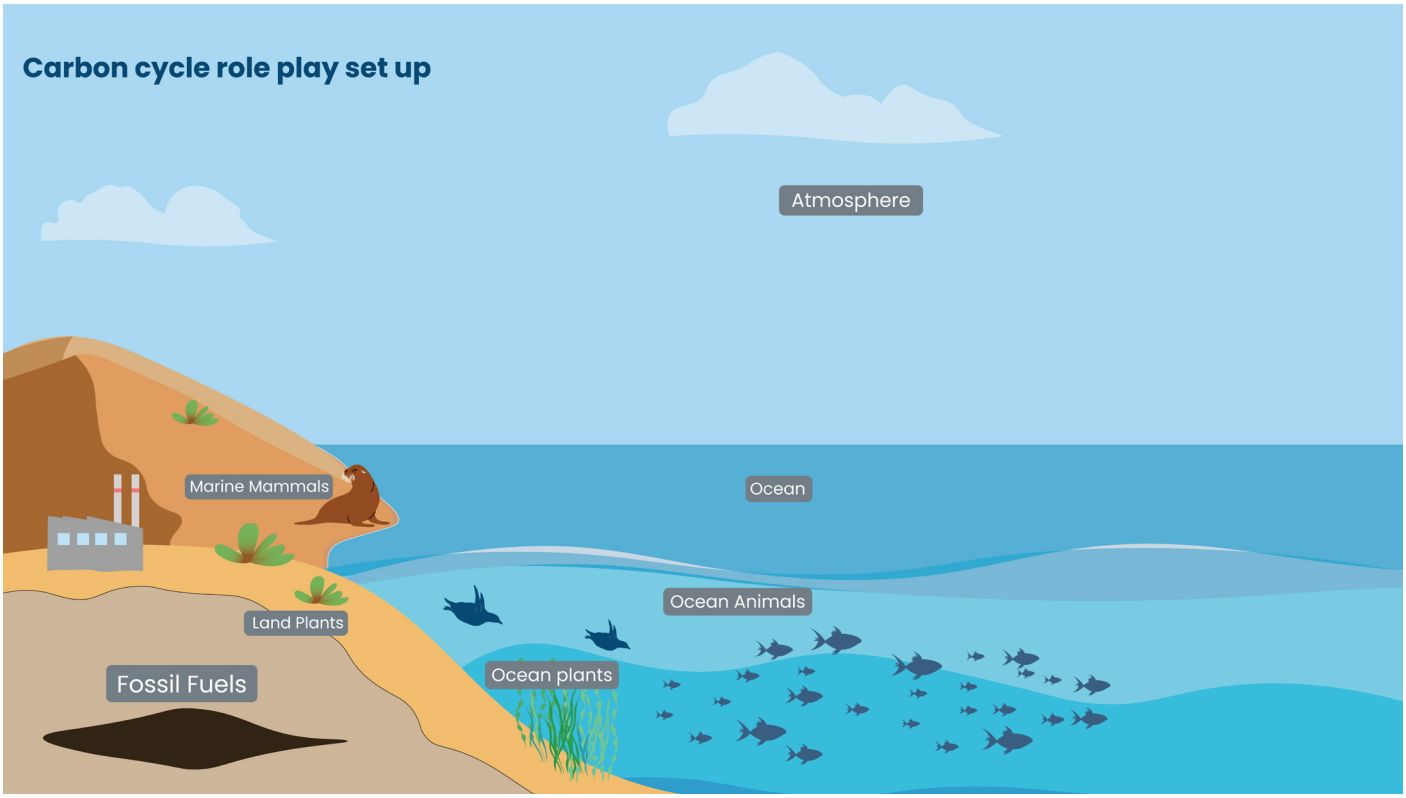
Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code or visiting: **bit.ly/m/ocean-literacy-toolkit**

Students should now understand:

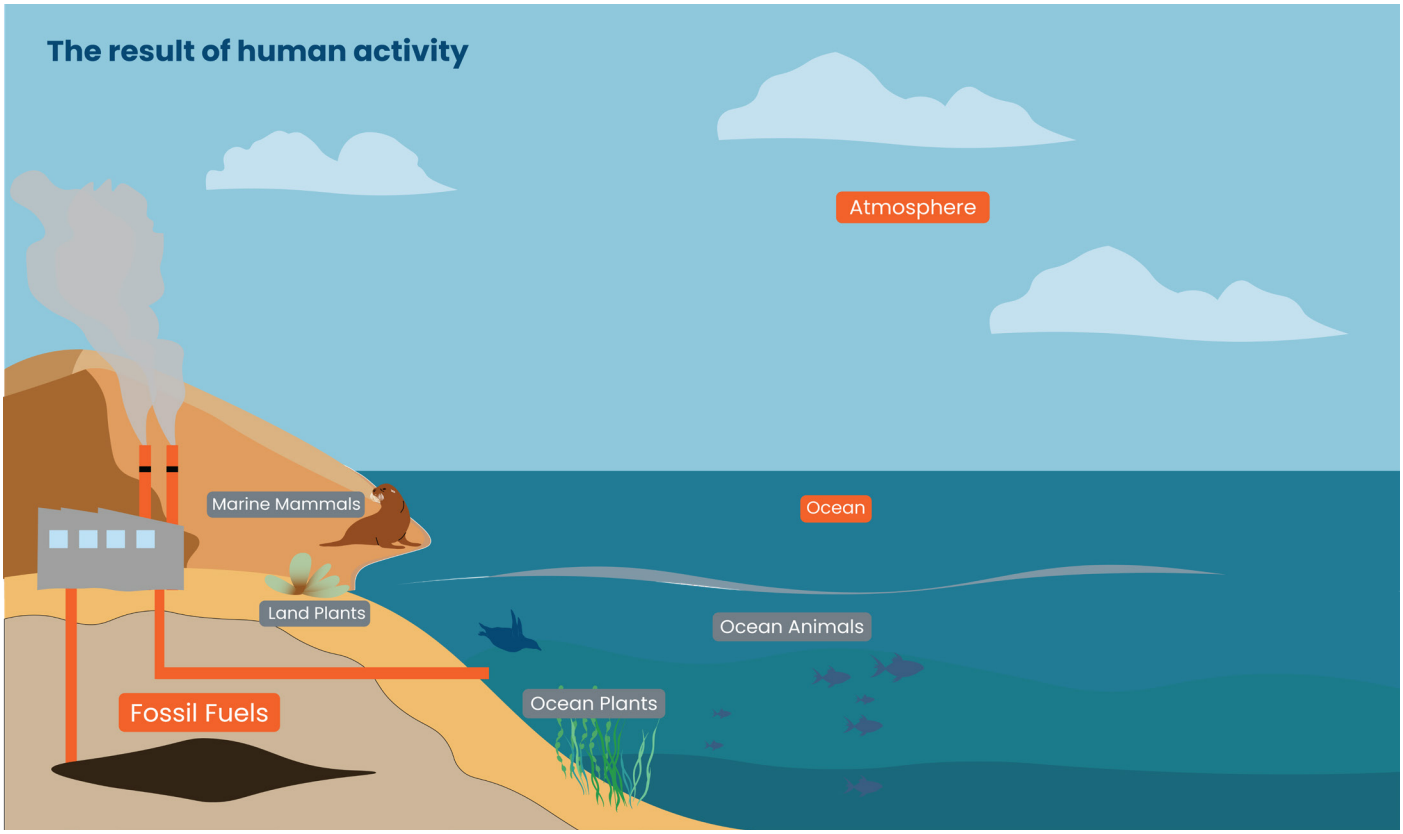
- *That by extracting and burning fossil fuels the carbon balance is disrupted.*



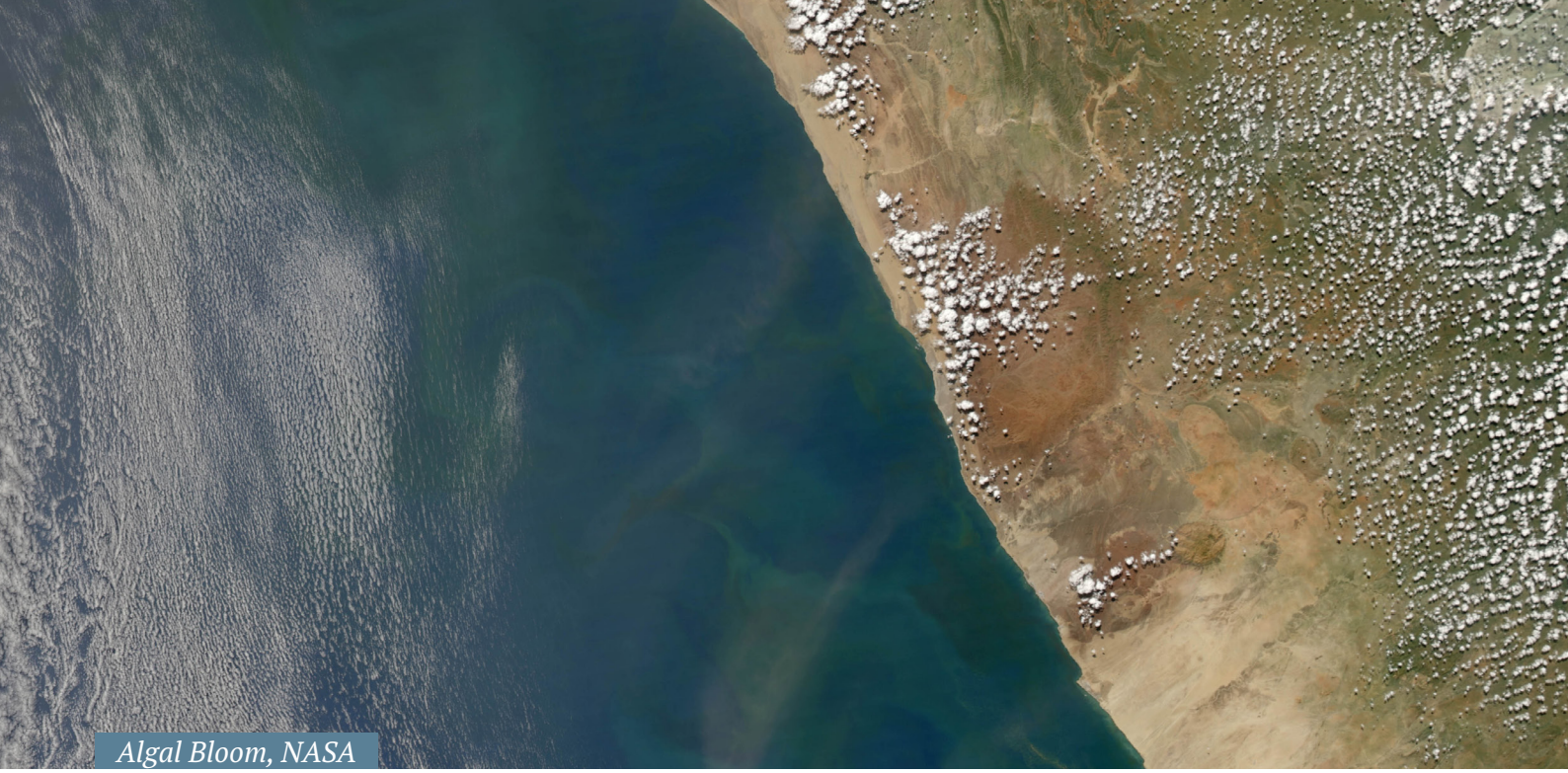
Sandwich Bay, Namibia
Envato Elements



A balanced carbon cycle, GRID-Arendal



An unbalanced carbon cycle, GRID-Arendal



Algal Bloom, NASA

Principle 4: The ocean makes the earth habitable.

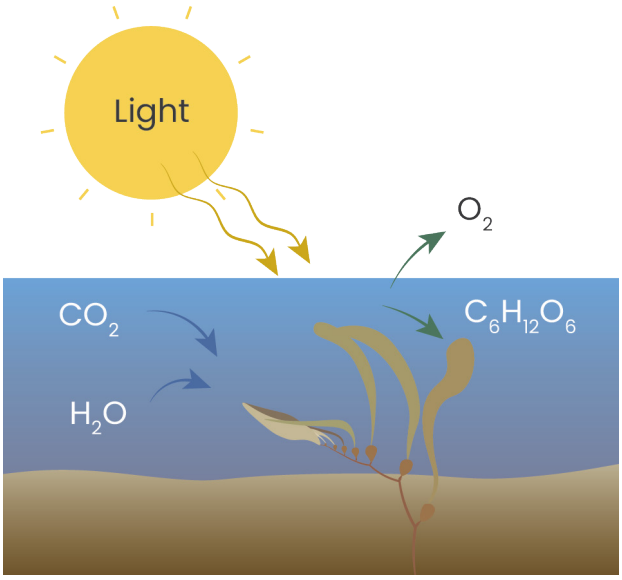
Background

We often think that most of the oxygen we breathe comes from rainforests on land, but in fact, more than half of it comes from the ocean. Marine plants and seaweeds (**macroalgae**), like **mangroves**, **seagrass** and **kelp** produce oxygen just like land plants through photosynthesis, the process which turns sunlight, water and carbon dioxide into energy and oxygen. This oxygen is essential for humans, but also for all animal life on earth. Organisms that photosynthesise are known as "primary producers."

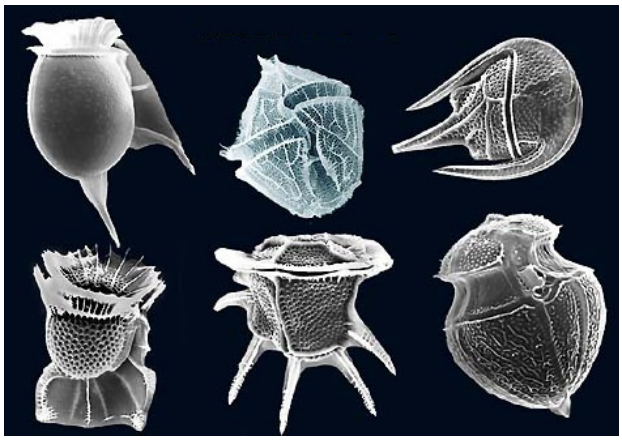
As well as marine plants, microscopic, single-celled organisms (called **phytoplankton**) that live in the ocean are fantastic at producing lots of our oxygen. These organisms live in the upper, sunlit layers of the ocean where they can photosynthesise.

Because of the rich nutrients brought up from the Benguela current, phytoplankton grow very well off the coast of Namibia and form the base of the rich food chain. In perfect conditions, phytoplankton can bloom, multiplying rapidly. The green bodies of these tiny organisms create colourful currents, sometimes in such numbers that they can be seen from space![12]

Some marine habitats (specifically mangroves, seagrass and saltmarsh) do more than just produce oxygen. These **Blue Carbon** Habitats are also fantastic at storing carbon dioxide, often much more efficiently and for much longer than terrestrial rainforests. This is extremely important in helping us fight against climate change and keeping the earth suitable for human habitation.



The Process of Photosynthesis, GRID-Arendal



Phytoplankton, Flickr User fickleandfreckled

Case study 1: Kelp

In Namibia's cool coastal waters, kelp grows abundantly, specifically the species known scientifically as *Ecklonia maxima*. This giant, brown seaweed forms dense underwater forests, producing lots of oxygen, sucking up carbon (known as sequestration), and providing shelter for many marine animals.

This kelp is also important for livelihoods in Namibia as it is harvested to add nutrients to agricultural land and to feed farmed **abalone**, an important source of employment and livelihoods in northern regions and in Lüderitz respectively.



Kelp, NOAA

Case study 2: Guano

Guano used to be harvested in Namibia to supplement agriculture, as it contains high amounts of nutrients like nitrogen, potassium and phosphorus, all of which are needed for plants to grow. Seabirds extract nutrients from the ocean via their food (mainly fish) and produce waste (excrement). This was then used on the land, to produce crops to eat and sell, which exemplifies how closely the ocean, land and humans are linked through nutrient cycles. This practise is now prohibited.

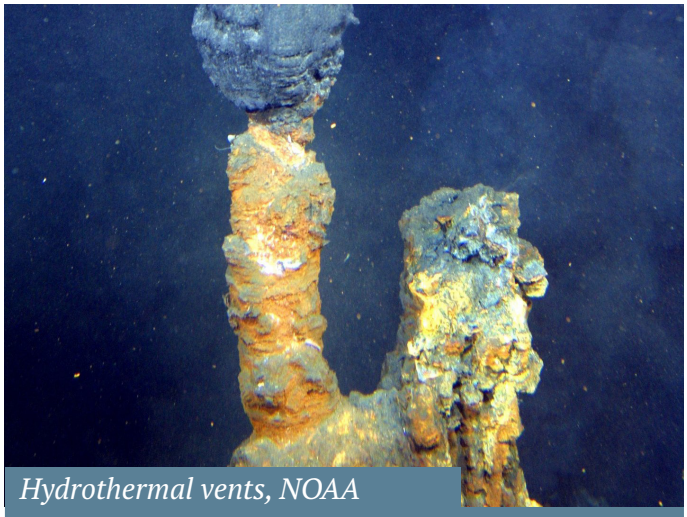
Coastal islands like **Ichaboe Island**, which is now a marine protected area to protect globally important seabird populations, have been harvested for guano for hundreds of years. Bird Island, between Swakopmund and Walvis Bay, was artificially constructed in the 1930s specifically to collect guano, which is processed in Swakopmund and shipped to Europe, bringing significant income to Namibia[13]. Look back at principle 3 for more detail on how the ocean makes earth habitable through the regulation of earth systems like the nutrient, water and carbon cycles.



Ichaboe Island NIMPA+

Guano extraction sometimes displaced or caused disturbance to seabirds, reducing breeding success. It also created hollows on some islands, allowing rain to accumulate, which on occasion flooded nests of some seabird species and also reduced breeding success. This contributed to the drastic decline in seabird populations.

As well as supporting all life on earth today, the ocean is thought to be the very place where life began. We have evidence that in earth's early oceans, simple organic molecules were formed, which are the building blocks for life. This might have happened near high-energy environments like **hydrothermal vents**. From these tiny molecules, the first organisms were created, which evolved into the millions of species we see in the ocean and on land today.



Hydrothermal vents, NOAA

Did you know?

- *When too many nutrients are available (for example, when nutrients are washed into the ocean from industry or agriculture), phytoplankton may grow out of control and form harmful algal blooms. These blooms can produce toxic substances that have damaging effects on fish, shellfish, birds, and even people[14].*

Curriculum links

Geomorphology ▶ Internal forces ▶ Hydrothermal vents

Economic geography ▶ Economic activities in Namibia ▶ Marine activities e.g. Kelp and Guano

Life sciences ▶ Ecosystem ▶ Cycling og nutrients ▶ Major ecological cycles e.g. nutrients and guano

Life sciences ▶ Nutrients ▶ Know the characteristics and functions of inorganic and organic nutrients (guano example)

Life Sciences ▶ Ecosystems ▶ Role of sun in an ecosystem (phytoplankton)

Learning Objectives

a. Explain what phytoplankton are and how they make oxygen.

b. Identify a hydrothermal vent and describe how life might have formed there.

c. Define guano and discuss how it is important to the nutrient cycle.

Suggested Activities

Phytoplankton art.

In this art and craft session, students will observe and recreate intricate phytoplankton.

Equipment list:

- Any art and craft materials available (pencils, paint, coloured paper, collage materials, natural materials etc.)
- Microscope photographs of phytoplankton (more available online).
- Ministry of Fisheries and Marine Resources is able to provide phytoplankton samples to a limited number of schools on request, which can be viewed if your school has microscopes.

Instructions:

1. Show students printed or digital photos of several types of phytoplankton from under a microscope.
2. Give them 30mins -1 hour to create a piece of art inspired by phytoplankton.

Students should now understand:

- *That although phytoplankton are not visible to the naked eye, they have intricate and highly evolved structures.*

Learning Objectives Answers

a. **Phytoplankton:** Microscopic, single-celled organisms living in the sunlit upper layers of the ocean.

Oxygen production: They perform photosynthesis, using sunlight, water, and carbon dioxide to create energy and oxygen. This process is similar to how land plants make oxygen.

b. **Hydrothermal vent:** An opening in the ocean floor where hot, mineral-rich water erupts from Earth's crust.

Possible role in life's origin: These vents provide energy and essential chemicals (like hydrogen sulfide) that might have been crucial for the formation of simple organic molecules, the building blocks for life, in Earth's early oceans.

c. **Guano:** Seabird excrement (waste) rich in nutrients like nitrogen, potassium, and phosphorus.

Importance in nutrient cycle: Seabirds accumulate nutrients by feeding on fish in the ocean. Their **guano** deposits these nutrients back onto land, enriching the soil. This helps plants grow, continuing the cycle of nutrients between the ocean, land, and living things.

Further Reading

Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code below or visiting: **bit.ly/m/ocean-literacy-toolkit**

Principle 5: The ocean supports a great diversity of life and ecosystems.

Background

Namibia's ocean is home to an enormous range of organisms, from giant humpback whales to shoals of tiny pilchards. Even smaller than pilchards are the **microorganisms**, which despite being microscopic, are the most abundant type of organisms and contribute around 90% of the ocean's **biomass**[15]. Examples of ocean microbes are the phytoplankton (mentioned in principle 4) as well as bacteria and viruses. These microbes are vital to life in the ocean as they form the base of the food chain.

Ocean food webs also support life on land. For example, Namibia's abundant fur seals hunt in the ocean for fish and squid, but come on land in large colonies to breed, for example at Cape Cross. Land predators, like brown hyenas and black-backed jackals, scavenge on dead seals washed ashore, or may even prey on weak or injured seals. It has been discovered that a pair of lionesses on the skeleton coast have learnt how to hunt roosting seabirds during the nighttime, again bringing the ocean food web onto land[16]. This outlines the importance of all organisms in the ecosystem at difference trophic levels. In this case the black-backed jackals are in the tertiary trophic level and are top predators.

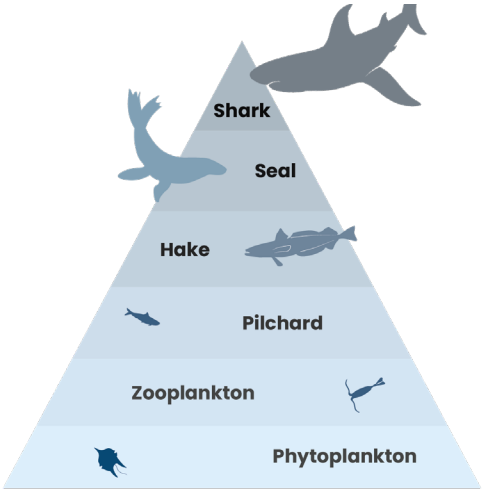
Removing them and any other secondary or tertiary predators from the ecosystem destabilizes the entire ecosystem. This then explains the importance of an ecosystem approach to conservation. Similarly, in the example above, if humans overfish pilchard or hake, there will be an overgrowth resulting in overpopulation of zooplankton and an increase in competition among the seal population, resulting in high mortality and low survival of seals.

The **diversity** of life in the ocean is generally much greater than on land or in freshwater habitats. Diversity of life operates on multiple levels: **genetic diversity, species diversity** and **ecosystem diversity**. For example, there are thought to be around 1000 species of marine fish in Namibia and only 18 species are commercially exploited (8 species including seals are **Total Allowable Catch**, while 10 are **bycatch**). Around 90% of the space for life on earth is in the ocean, so there is a greater variety of habitats available, leading to more opportunities for differences to evolve between organisms. From the shallow coastal regions to the open ocean, ocean ecosystems change dramatically.

Compared to other ocean ecosystems across the globe, Namibia's oceans have relatively low **species richness** but high **species abundance**. This means there are fewer diverse types of organisms, but of those organisms, there are many individuals (and a high biomass). This occurs because of the Benguela upwelling system. Just a few species of primary producers tend to dominate in upwelling systems, meaning although there is a lot of food available, it is not varied.



Brown Hyena, J.P Roux



Trophic Levels of the Marine Ecosystem GRID-Arendal

This means only animals adapted to eating certain species of phytoplankton can thrive here. These well-adapted species will outcompete others, and their populations increase. This pattern is then repeated up the food chain. In addition to this, the upwelling zone has extreme conditions like cold water and strong currents, so only specialised species adapted to this can survive and thrive.

Throughout the global ocean, life is influenced by **abiotic**, or non-living environmental factors, such as oxygen, salinity, temperature, pH, light, pressure and substrate type. The unique combination of these factors in each ocean location creates a **niche**. A niche is the set of conditions within which an organism can survive.

Sometimes, if one or more of these factors is absent or unsuitable, two organisms team up and share their skills. In Namibia's deep sea, where there is no light and little food, the bobtail squid has developed a **symbiotic relationship** with a species of light-emitting bacteria. The bacteria that live in a special light organ inside the squid's body, where it is fed on sugars and amino acids. In return, the bacteria glow, **camouflaging** the squids outline and reducing the chance of predation.

Case study 1: Coastal Namibia

The Walvis Bay lagoon and salt pans are internationally recognised as a **Ramsar Wetland Site**, providing crucial habitat for an estimated 150 species of bird, including the famous flamingos. Up to 150,000 **migratory** birds spend the summer in Walvis Bay, to avoid the cold winters in Europe and Siberia[17]. Lagoons and estuaries often provide important nursery or spawning grounds for species that usually live out in the open ocean.

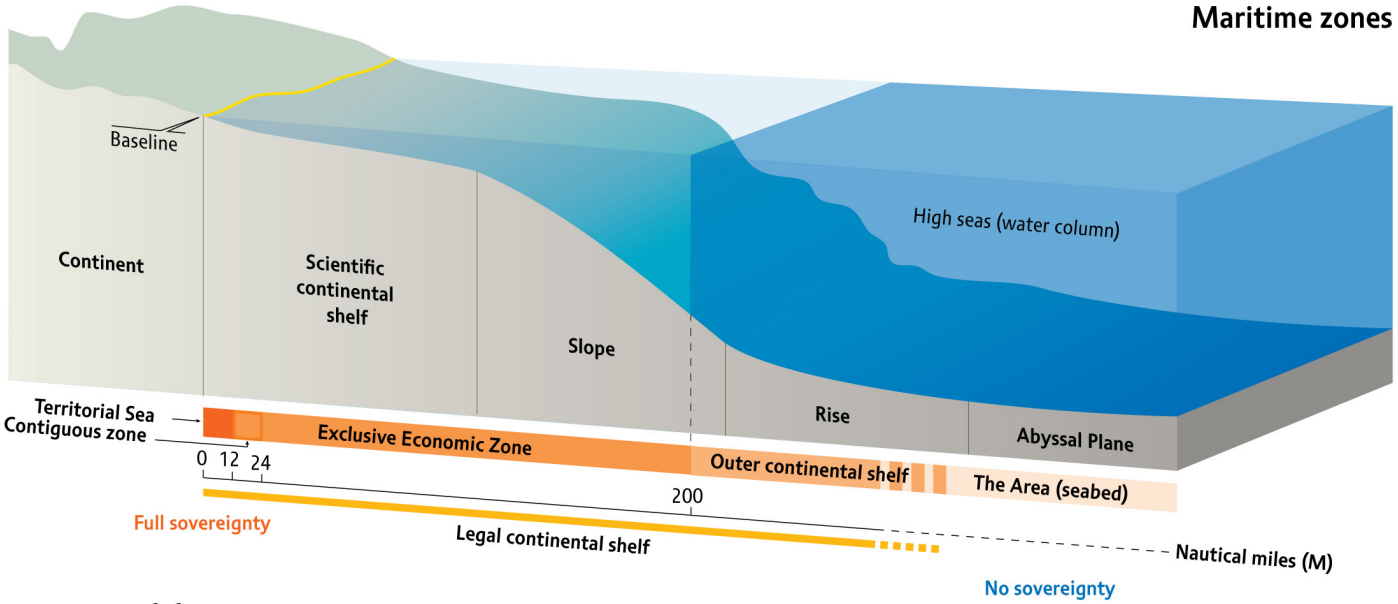
Rocky shores characterise southern Namibia's coastline, for example around Lüderitz, where a collection of small rocky islands, within the **Namibian Islands' Marine Protected Area** (NIMPA), are home to Namibia's entire breeding population of Cape gannets and almost all of Namibia's endangered African Penguins.

These islands are being studied by scientists to gather information needed to put better protection in place. These seabirds are well adapted to breeding in these crowded, rocky outcrops by having specialised nesting strategies like building compact nests, sharing parental care and food forages, and timing their breeding to match peak food availability.

Distinctive **zonation patterns** characterise rocky shores worldwide. These patterns can be determined by tides, wave energy, predation and other factors. As the environment transitions from shallow water to dry land, different animals and seaweeds become dominant. Common species in Namibia are barnacles, limpets, crabs and bivalves (like mussels and oysters).



Walvis Bay, Photo: NASA



GRID-Arendal



Heaviside's Dolphin, Luderitz Namibia, Joachim Huber



Orange Roughy, NOAA

Did you know?

- *Some cetaceans, such as the Heaviside's dolphin, are found nowhere else in the world except the Benguela Ecosystem*
- *Cape Cross is home to the largest fur seal colony in the world! There are thought to be 210 000 seals there.*
- *The most famous example of a symbiotic relationship is the algae (called **zooxanthellae**) that live inside corals, giving them their vibrant colours and feeding the coral with sugars and protein in return for protection.*

Case study 2: Open ocean in Namibia

Namibia is a hotspot for whales and dolphins, known collectively as **cetaceans**. Cetaceans live in the "**pelagic zone**", which is the open ocean or water column. They are adapted to this vast, featureless environment through their streamlined, powerful bodies suitable for swimming long distances, blubber to keep warm and **echolocation** abilities. Echolocation is like a biological sonar system that uses high frequency sounds to locate prey, navigate and communicate.

Albatrosses are the world's largest seabirds. The endangered Atlantic Yellow-Nosed albatross roams above Namibia's waters on its two-metre wingspan. They are sometimes solitary, or sometimes fly in small groups, only coming together in larger groups around fishing vessels, where they have learnt there is an abundance of food. Sadly, albatross often get tangled in fishing lines or nets and are caught as **bycatch**.

Projects like the Namibia Nature Foundation's "Albatross Task Force" are working hard to protect seabirds such as albatrosses and petrels by introducing measures to reduce seabird bycatch, reducing deaths by fishing operations and studying albatross behaviour.

Case study 3: Deep Ocean in Namibia

In Namibia's deep open ocean, there is no sunlight, photosynthesising organisms like phytoplankton cannot exist. Instead, many deep-sea ecosystems are underpinned by **chemotrophic bacteria** that can utilise the chemical energy produced at underwater geological features like hot springs, hydrothermal vents and methane seeps. Some nutrients fall down from the water column above as "**marine snow**", which supplements deep ocean food chains.

The **Orange Roughy** is a deep-sea fish often found in aggregations around underwater mountains (seamounts), like the Walvis Ridge. This fish is extremely slow growing and can live for over 100 years. They are relatively inactive, using little energy other than when feeding or breeding - an adaptation which allows them to live in the nutrient-poor deep sea.

The orange roughy is also adapted to the deep sea through its extreme tolerance to pressure, which is necessary when living with the weight of the whole water column above you! Orange roughy are commercially valuable so are of interest to fisheries, scientists and conservationists nationwide. The orange roughy was so seriously **overfished**, that a **moratorium** was placed on the species in 2008, and the fishery has not yet been reopened[18].

Curriculum links

Life Sciences ▶ Characteristics of living organisms ▶ Identifying organisms

Life Sciences ▶ Interactions in an ecosystem

Life sciences ▶ The role of sun and significance of energy transfer

Life sciences ▶ Classification of living organisms ▶ Latin names

Life Sciences ▶ Global Warming ▶ The ecological impacts of Global Warming

Learning Objectives

a. Give examples of very small and very large organisms in Namibia's ocean.

b. Recall what a microbe is and explain why they are important.

c. Recognize that much of Namibia's biodiversity lives in the ocean, and that many of these groups don't exist on land.

d. Describe the interactions and adaptations in a Benguela food web.

e. Recall what percentage of space for life is in the ocean (90%).

f. Name some environmental factors that define an ecosystem.

g. Recall the term "chemotrophic bacteria" and explain why they are important.

h. Describe a zonation pattern on Namibia's rocky shore.

i. Identify and describe an important estuarine / lagoon system in Namibia (Walvis Bay)

Learning Objectives Answers

a. **Very small: Microbes** (e.g., **phytoplankton**, bacteria, viruses)

Very large: Humpback whales, whales, dolphins

b. **Microbes:** Microscopic organisms, including bacteria, viruses, and some types of fungi and protists.

Importance: Despite their tiny size, microbes are the most abundant organisms in the ocean and contribute significantly to the ocean's biomass (around 90%). They form the base of the food chain and play a crucial role in nutrient cycling.

c. **The ocean's diversity** is much greater than land or freshwater habitats. Many unique species call the ocean home, and these groups may not have equivalents on land

d. **Upwelling system:** The Benguela upwelling system brings cold, nutrient-rich water to the surface, promoting phytoplankton growth.

Limited food variety: Due to the dominance of a few phytoplankton species, only organisms adapted to consuming these specific types thrive. These well-adapted species outcompete others, leading to a population increase.

Specialized adaptations: Species in the Benguela system need adaptations to survive the cold water and strong currents, like the well-adapted fish species.

e. **Around 90% of the space for life on Earth is in the ocean.** This vast space allows for a greater variety of habitats and opportunities for organismal differences to evolve.

f. **Oxygen, Salinity, Temperature, pH, Light, Pressure, Substrate type**

g. **Chemotrophic bacteria:** Bacteria that obtain energy from chemical compounds rather than sunlight.

Importance: In deep-sea ecosystems where sunlight is absent, chemotrophic bacteria using chemical energy from geological features like hydrothermal vents become the foundation of the food chain.

h. **Its distinctive zonation patterns** on rocky shores, influenced by factors like tides, wave energy, and predation. As the environment transitions from shallow water to dry land, different organisms become dominant. Examples include barnacles, limpets, crabs, and bivalves (mussels and oysters) occupying specific zones.

i. **Walvis Bay lagoon and salt pans:** This Ramsar Wetland Site provides crucial habitat for an estimated 150 bird species, including flamingos. Up to 150,000 migratory birds use the lagoon as a breeding ground during harsh winters in Europe and Siberia. Estuaries and lagoons often serve as important nursery or spawning grounds for marine species.

Suggested Activities

Fieldtrip or virtual fieldtrip

If the funds are available to your school, we suggest taking a field trip to the coast! Alternatively, you can take a virtual fieldtrip using Google Earth Street View. In both cases, ask students to answer questions such as the examples below.

Primary fieldtrip questions:

- What does this part of the coast look like? Describe some of its features e.g. rocky, sandy, boggy?
- What plants and animals can you see here? Or what do you think might live here?
- Pick your favourite animal you have seen at the coast. Describe some of its features and explain why they are useful? E.g. this crab has a shell, which protects it from predators.
- Have you seen any people at the coast today? If so, what were they doing? How might this disturb the animals and plants that live here?
- What jobs might people have here at the coast / seaside?

Secondary fieldtrip question examples:

- What types of ecosystems are present along this coastline (salt marshes, rocky shores, and sandy beaches)?
- What plants and animal species have you observed here? Or what do you think might live here?
- What are some adaptations of plants and animals to the coastal environment?
- How do human activities impact coastal ecosystems, such as pollution or development?
- What role do coastal ecosystems play in providing important services such as coastal protection, fisheries, and recreation?
- What opportunities exist for sustainable tourism along the coast?
- How do scientists monitor and study coastal ecosystems, and what technologies do they use for research and conservation efforts?

Further Reading

Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code below or visiting: **bit.ly/m/ocean-literacy-toolkit**



Principle 6: The ocean and humans are inextricably connected.

Background

The connections between humans and the ocean are ancient, widespread and complicated. Early inhabitants of the coast included the Khoe-speaking Topnaar people (Aonin) documented as settling in Walvis Bay along the central Namib coast. For several centuries their cultural livelihoods connected them deeply to ocean resources.

These 'Hurinin ('People of The Sea') had a rich tradition of songs, poems and dances specifically related to fishing and their reliance on the ocean. During the colonial rule they were forced out of these coastal areas, disrupting their centuries-old cultural traditions and ocean connectivity. Today, although the harsh environment of Namibia's coastline means coastal habitation is challenging in many areas, we are seeing vast expansion of coastal populations, for example in Long Beach. Every Namibian, whether you live inland or coastally, has a link to, and therefore a responsibility for our ocean.

Much of the food we eat either comes from or is dependent on the ocean. Namibia is a fishing nation, with the industry being located in Walvis Bay. Key Namibian dishes like hake fillet, Lüderitz rock lobster and oysters are all harvested from our own waters. Walvis Bay is also the home of NAMPORT, the national port authority of Namibia. **NAMPORT** is essential for the functioning of several key industries and employment sectors, including fishing, transport, mining, petroleum and salt exports.

These industries are crucial for Namibia's economy but must be conducted in a responsible way that minimises harm to the marine environment. Ports can be polluting, with oil and chemicals leaking into the ocean, and can also be responsible for habitat removal or damage during their construction.

Ocean tourism in Namibia is important too. The beach town of Swakopmund attracts thousands of visitors every year. Tourists visit the ocean for its **aesthetic value**, relaxing qualities, beautiful scenery and abundant wildlife. Tourist or not, the ocean is known for bringing benefits to both physical and mental health. Surfing, for example, is popular near Swakopmund.

It is a great form of exercise as well as being rejuvenating for the mind. Even deeper emotional connections are held by Namibian communities that have existed in harmony with the ocean for thousands of years. The Topnaar community's connection with the ocean includes, conservation, spiritual beliefs, and cultural identity, reflecting a holistic relationship with their environment. This connection is testament to their deep-rooted understanding and respect for the natural world, which is central to their way of life and survival.



Scuba Divers, Photo: Dimitris Poursanidis



Hurinin, from 'HURININ People of the Sea, One ocean hub

Humans benefit greatly from the ocean, but this can come at a cost. Advances in technology, changes in lifestyle and growth of populations worldwide mean the pressure we are putting on the ocean is greater than ever. We pollute the ocean with plastic, and chemicals from industry and farming.

We take too many fish and damage whole ecosystems. Climate change and **ocean acidification** are causing globally important ecosystems like coral reefs to expel the **symbiotic algae** living within them, making them bleach white. This makes them much more susceptible to disease and death. We spill oil, dump waste, and often ignore the ocean as "out of sight and out of mind". But we know that the oceans resources are not infinite!

What can we do to turn the tide? Individual and collective actions are needed to effectively manage ocean resources for all. On an individual level, we can change our everyday habits to be more ocean friendly by avoiding single use plastics, reducing our carbon footprint, and only eating fish caught in a sustainable way. As communities, we can raise our voices to demand better marine management, for example through writing to elected leaders and asking them to do more. We must protect our ocean so that it can protect us.

Case study 1: The Hurinin (People of the Sea) of Namibia

The Hurinin, also known as the "People of the Sea," are an indigenous community in Namibia, originally settling in Walvis Bay along the central Namib coast. Their way of life was deeply intertwined with the ocean, relying on fishing, traditional practices, and marine resources for their sustenance and cultural identity. Historically marginalised, the Hurinin have faced significant challenges in asserting their rights and preserving their cultural heritage, particularly in the face of coastal industrialisation and environmental degradation.

During colonial times, the Hurinin experienced displacement and marginalisation. Their lands were encroached upon by colonial settlers, leading to a loss of traditional fishing grounds and access to marine resources. Post-independence, while Namibia has made strides in recognising indigenous rights, the Hurinin continue to struggle for formal acknowledgment of their status and the protection of their cultural practices that once connected them so intrinsically to the sea.



Namibian Coastline, Photo: GRID-Arendal

Key Issues

1. **Environmental Degradation**: Industrial fishing, mining, and tourism have significantly impacted marine ecosystems, threatening the livelihoods of the Hurinin. Overfishing and pollution have diminished fish stocks, crucial to their traditional diet and economy.
2. **Land Rights**: The Hurinin have limited formal land rights, making it difficult to secure their territories against encroachment from commercial enterprises. This lack of recognition hampers their ability to sustain traditional practices.
3. **Cultural Preservation**: With modernisation and outside influences, the Hurinin culture faces erosion. Traditional knowledge related to fishing and marine stewardship is at risk of being lost.
4. **Political Representation**: The Hurinin have struggled to have their voices heard in local and national governance. Their representation in decision-making processes regarding marine resource management and land use remains inadequate

Today, the Hurinin people are seeking to strengthen their political voice and representation. They have a rich tradition of storytelling and oral history, which plays a crucial role in preserving their cultural identity.

These stories often include elements of marine life, local legends, and the teachings of ancestors, helping to pass down knowledge about sustainable fishing practices and the importance of the ocean in their lives. This oral tradition not only connects them to their heritage but also reinforces their deep relationship with the sea. The Hurinin elders are supported to record the stories, music, dances and other traditions that once exemplified and celebrated their ocean culture and livelihoods. By documenting the Hurinin's traditional knowledge and practices, they hope to legitimise their territorial claims and strengthen their position in negotiations with policymakers.

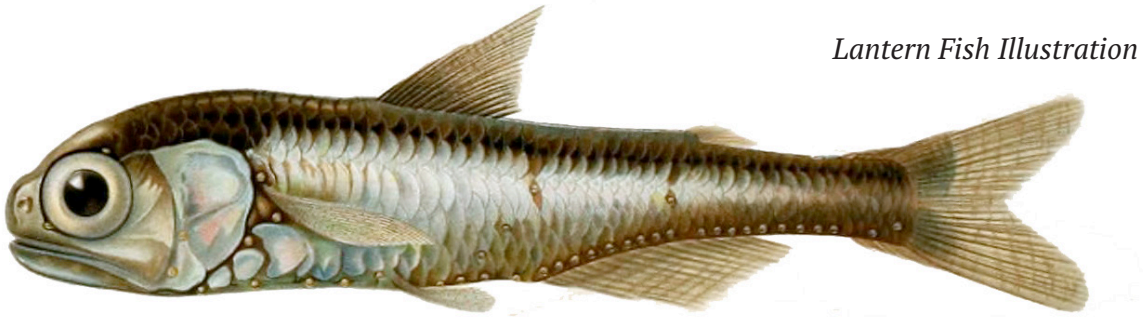
Case study 2: The Namibian Fishing Industry – Sardines

Sardines, specifically the South African pilchard, are small, silver fish that eat phytoplankton, and are an important food source for much of the Benguela food web, as well as being an important protein source for humans. Once abundant in Namibia's waters, sardines supported a thriving fishing industry and many people living in coastal communities.

Since the 1960s, the population has plummeted by 99.5% due to overfishing and environmental factors like ocean-warming events and low oxygen. With fewer sardines, the Benguela ecosystem has become dominated by gobies and jellyfish, which are neither commercially valuable nor provide the energy required by larger animals in the ecosystem, like the critically endangered African Penguin, Cape Gannett and Cape Cormorant.

Some people think that an increase in the seal population is responsible for the decline in sardines. In fact, seals are top predators, so healthy populations indicate an abundance of their food source, which is mainly gobies and lanternfish. In general, it is the **commercially fished species,** like sardine, that are declining, which indicates overfishing is occurring[19]. The Ministry of Fisheries and Marine Resources (MFMR) oversees Namibia's commercial fisheries and must ensure that economic productivity is balanced with ecosystem health. They use a system called **TAC (Total Allowable Catch),** which uses scientific recommendations to determine how much of a fish stock can be fished each year.

However, across the world, scientific advice is being ignored and fish stocks are declining. From 2018-2020, a fishing pause (**moratorium**) was implemented in attempt to help the sardine populations recover[20]. With the fishery still under a moratorium and populations still struggling, we must all work together with the MFMR to encourage sustainable management of sardines.



Lantern Fish Illustration

Case study 3: Namibian Islands' Marine Protected Area

The 9,500 km2 Namibian Islands' Marine Protected Area (NIMPA) is an iconic area of outstanding marine biodiversity, supporting globally significant populations of seabirds and marine mammals, and important marine industries and it covers 1.7% of Namibia's waters. Despite being Africa's second largest marine protected area (MPA), it is threatened by overfishing, mining, pollution, live marine mammal harvesting and large Aquaculture development.

It has one adjacent human settlement; the town of Lüderitz and many of its people do not even know the NIMPA exist. Lack of local awareness for the value of marine benefits, and low capacity to diversify marine-related income opportunities has limited the resilience of Lüderitz's 15,500 residents. Given the proximity of the NIMPA and its unique biodiversity, there is significant opportunity to demonstrate and strengthen the multiple ecological, economic, and social benefits that this stunning ecosystem provides.

The marine tourism industry is modest, with currently only two operators based in Lüderitz taking visitors to the islands and on whale-watching expeditions. By re-activating management of NIMPA and addressing key threats to the coastal ecosystem, there is potential to secure, and quite possibly expand the livelihood options of Lüderitz's residents. Namibia would benefit from increased advantage derived from a functioning marine ecosystem. Namibia is unlike most other coastal nations. Only about 200,000 people live on Namibia's entire coastline, and historically there has not been a traditional coastal culture. Namibian communities are generally therefore less connected and less incentivised to be involved in ocean management; instead, governance tends to be centralised and top-down, rather than participatory.

By connecting coastal communities with the benefits that they receive from marine ecosystems, there is opportunity to increase ocean literacy, improve local welfare and harness local support for marine protection, as has been achieved in terrestrial settings. A recovered and flourishing marine ecosystem off the coast of Namibia could support local thriving fishing and tourism industries, maintain globally important biodiversity and connect Namibians with their coast and the global marine conservation effort.

Case study 4: Namibia's Ocean Future

There are several new and emerging ocean industries that pose both challenges and opportunities for Namibia's environment and economy. Mining for **phosphate**, for example, poses a risk to marine habitats. Phosphate is needed for agricultural fertilizers and is currently sourced from rocks on land. But several companies have applied to mine phosphate from the seabed, notably the Sandpiper Project in Namibia. This could be extremely profitable, bringing income and jobs.

However, marine phosphate mining could cause widespread destruction to the fragile seabed ecosystem, causing physical damage, sediment plumes, spills, leaks and accidents. It might also release heavy metals which could be ingested by fish and make our seafood unsafe to eat. Although marine phosphate mining is not yet happening, it is on the horizon for Namibia[21].

Hydrogen can be used as a fuel, much like natural gas. While natural gas is a **fossil fuel** and non-renewable, hydrogen can be produced in a more climate-friendly way. To make hydrogen, a reaction called **electrolysis** is used, which splits the water molecules into hydrogen and oxygen. This electrolysis requires energy, which if taken from renewable sources, gives rise to "green hydrogen production". Namibia has high potential for solar and wind power so there is an exciting opportunity to generate significant income, increase national energy security, and help **decarbonization** worldwide - which in turn supports the sustained health of the ocean.

Did you know?

- *Lanternfish, a seal's favourite food, are thought to be the most numerous vertebrates on earth!*
- *About 14,000 people are directly employed in ocean jobs in Walvis Bay[22].*
- *Sardines of different species are found across the world. They are common in Sardinia and Italy, which gives them their name.*
- *Hurinin folklore revolves around the concept of the sea as a living entity, often personified in stories. For example, some tales feature a benevolent sea spirit who protects the community's fishermen and guides them to abundant fishing grounds.*

Curriculum links

Agricultural Science ▶ Fish Farming ▶ Advantages and disadvantages of aquaculture

Geography ▶ Economic Geography ▶ Marine economic activities in Namibia

Life sciences ▶ Ecosystems ▶ People, food and the environment

Life sciences ▶ Classification of living organisms ▶ Latin names

Life Sciences ▶ The body's immune systems ▶ Prevention and curing of diseases

Learning Objectives

a. Discuss why it is so important to recognise the voices and rights of the Hurinin people?

b. Describe how Namibia gets extra drinking water from the ocean (desalination).

c. State what NAMPORT is, describe its function and how it supports other ocean economies.

d. Talk about marine heritage in Namibia.

e. Recognise that overfishing of sardines has been a major human impact on Namibia's ocean.

f. Identify three negative human impacts on the ocean.

g. Describe how Namibia's coastal population is changing.

h. Identify three ways we can care for the ocean.

Learning Objectives Answers

a. **The Hurinin people** have a deep-rooted understanding and respect for the ocean, reflecting a holistic relationship with their environment. This traditional knowledge can be invaluable for sustainable ocean management.

Recognizing their rights helps protect their cultural heritage and traditional practices, which often involve sustainable fishing practices and respect for the marine ecosystem. Including their voices in decision-making processes ensures a more inclusive approach to ocean governance, potentially leading to more sustainable solutions.

b. **The Erongo Desalination Plant**, which uses a process to remove salt from seawater, creating freshwater for inland areas of Namibia.

c. **NAMPORT** is the national port authority of Namibia. Its function is to manage and operate Namibia's ports, ensuring efficient and safe handling of cargo and passengers. This supports other ocean economies by facilitating:

Fishing: Ports serve as landing points for fish caught at sea, supporting the fishing industry.

Transport: Ports allow import and export of goods transported by ships, vital for Namibia's economy.

Mining and Petroleum: Ports facilitate the export of mined resources and petroleum products.

Salt exports: Ports enable the export of salt, another key industry.

d. **The Hurinin people:** Their cultural connection to the ocean through fishing practices, songs, poems, and dances represents a deep historical relationship with the sea.

Traditional knowledge: The Hurinin possess traditional knowledge about sustainable fishing practices and the importance of the ocean, which contributes to Namibia's marine heritage.

Coastal communities: Namibia's coastal towns and their connection to the ocean for centuries are part of its marine heritage.

e. **Overfishing of sardines** is a major human impact. It caused a 99.5% population decline, disrupting the Benguela food web and impacting other species like penguins and gannets.

f. **Overfishing:** Depletes fish stocks and disrupts marine ecosystems.

Pollution: Plastic, litter, chemicals from industry and farming pollute the ocean, harming marine life.

Habitat destruction: Activities like coastal development and destructive fishing practices damage habitats and marine life.

g. **A vast expansion of coastal populations** in some areas, like Long Beach. This suggests an increase in human presence along the coast, potentially impacting the ocean environment.

h. **Individual actions:** Reduce single-use plastics, lower carbon footprint, choose sustainably caught fish.

Community action: Advocate for better marine management by contacting elected officials.

Supporting sustainable practices: Encourage practices that promote healthy fish stocks and minimize environmental harm.

Suggested Activities

Froot loop fisheries game[23]

In this fisheries simulation game, students will discover how to manage a fishery.

Equipment list:

1. Medium-sized bowls (one per group of 4)
2. 10 x 4 different colours of Froot Loops per group (these are the "stock" fish species)
3. 20 Cheerios per group (these are the "non-target" fish species. *Note, you can play the game without Cheerios if they are not available.*
4. Paperclip (one per student)
5. Fork (one per student)
6. Spoon (one per student)
7. Timer or stopwatch

Instructions:

1. The aim of the game is to catch "stock fish" (Froot Loops) in a sustainable way.
2. Key definitions for the game:
    a. Stock fish – the fish species you are trying to catch, the target species.
    b. Bycatch – species caught and/or killed accidentally, the non-target species.
3. For each group…
    a. Add the Froot Loops and Cheerios to your bowl. This is your fishery.
    b. Give each student a paperclip, fork and spoon. This is your fishing equipment.
4. Each group of students will complete 3 "seasons" of fishing, each lasting 15 seconds. Between each season, the stock fish reproduce. Double the number of coloured fruit loops in each bowl.
    a. Season 1 – using paperclip.
    b. Season 2 – using fork.
    c. Season 3 – using fork and spoon.
5. Record data in a table like this at the end of each season:
6. After the three seasons, ask students to answer the following questions.
    a. Did your fishery survive all 5 years? Why or why not?
    b. What happened to the fish stock as your fishing gear became more efficient (when you started using forks and spoons?)
    c. Which gear type caught the most bycatch (Cheerios?)

Students should now understand:

- *How gear type and efficiency impacts how many fish you can catch, how sustainable a fishery is, and how much bycatch is killed accidentally.*

Further Reading

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Season	Gear type *(fishing equipment)*	Starting stock size *(double the remaining stock size from the last season)*	Your catch *(number of stock fish)*	Remaining stock size *(after the fishing season)*	Bycatch *(Cheerios caught)*
1	Paper clip	40			
2	Fork				
3	Spoon and fork				

Principle 7: The ocean is largely unexplored.

Background

Of the entire, vast global ocean, only about 5-10% of it has been explored. Because of Namibia's extensive coastline, large ocean territory and extreme conditions, it is likely this percentage is even smaller on a national level. The progress of ocean exploration in Namibia has also been slowed by a lack of funding and resources compared to countries in the global north.

However, Africa is gaining significant attention and support through initiatives such as the One Ocean Hub and the National Commission on Research, Science and Technology. The next generation of ocean champions will be crucial in shaping our future as an ocean nation. Over the coming decades, it will become increasingly important to explore the ocean, not only for curiosities sake, but for solutions to global problems, such as the need for medicines, renewable energy and food to support a growing population.

For example, the possibility of using kelp in medicinal products is currently being explored in Lüderitz by an ocean innovation company called Kelp Blue. Some compounds found in kelp have **antioxidant** and **anti-cancerous** properties that we may be able to harness for human health benefits[24].

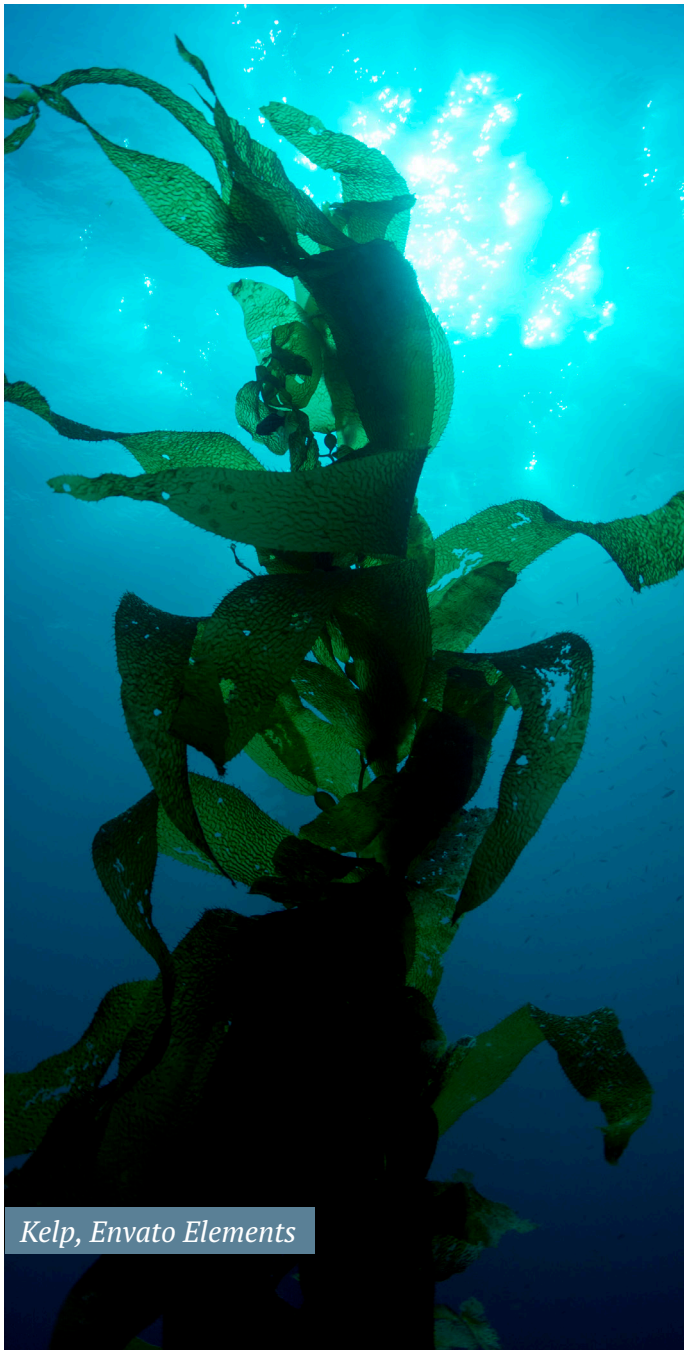
With further exploration of the ocean and its resources, we must take extreme care to consider the sustainability and environmental impact of this new knowledge. Over the past century, we have exploited the ocean beyond its limits, and we cannot continue to do so. Innovation and research are essential to ensure we benefit from the ocean within its **ecological limits**. In addition to this, all ocean exploration must operate lawfully, and within management restrictions, both of which are in place to keep exploration safe and controlled.

Institutions like the University of Namibia (**UNAM),** Namibian University of Science and Technology (NUST) and NNF Marine team and MFMR NatMIRC are extremely important in shaping our understanding of the ocean. UNAM has a specialised Marine and Coastal Resources Research which used **multidisciplinary** research to promote understanding and development of marine science[25] now even artificial intelligence (AI) are also crucial in ocean exploration. AI is being used to identify species, process data, and conduct monitoring much faster than humans can, meaning more of our unexplored ocean can be studied and understood[26].

Case study 1: Submarine expeditions with Ocean X.

We still have so much ocean to discover, especially in the depths. An international expedition called Ocean X aims to reveal these unseen depths for the very first time through groundbreaking science and storytelling. Ocean X have already discovered 180 species of fish, filmed the giant squid in the deep for the very first time, and put a tracking tag onto a shark using a **submersible**!

As well as ground-breaking science, Ocean X are committed to bringing the stories of discovery back to everyone here on dry land. They have advanced underwater cameras and production teams to capture footage in extreme conditions. They are also producing education programmes, films, exhibits and games to help tell the story of the ocean. Through expeditions like this, more people are aware of what lives in the deep sea, how important it is, and why we need to protect it.



Kelp, Envato Elements



Namibian Coastline, Photo: NIMPA+

Case study 2: Ocean careers in Namibia

In Namibia, there are a huge range of ocean careers available. As we explore and understand more of our ocean, ocean jobs are likely to become an even greater part of Namibia's economy and society. Some people think that to have a career in the ocean you need to study fisheries science or marine biology, but this is no longer the case! Across all subjects, trades and walks of life, understanding our ocean must be **collaborative** and **multidisciplinary**.

Take a look at the list below for some ideas:

- Marine engineering
- Aquaculture technician
- Fishing
- Fish processing
- Environmental teaching or educating
- Tour guiding
- Craft based careers, using ocean products
- Chef or cooking
- Navigation and shipping
- Oceanography or geography
- NGOs
- Ministries (Fisheries of Environment)
- Ocean artist or photographer
- Ocean storyteller, e.g. journalism or social media
- Librarian
- Campaigner/advocacy
- Researcher
- Project manager or administrator
- Marine or coastal ranger
- Diver
- Aquatic Veterinarian
- Marine economist
- Maritime Lawyer
- Navy
- Oil and gas industry
- Renewable energy
- Ocean sports careers
- Captain Skipper

Did you know?

- *The first submersible in the world was built in 1620!*
- *You can study fisheries science at UNAM.*
- *Scientists are exploring new ways to get Omega-3 into our diets, and the solution might be algae!*



School of fish

Curriculum links

Entrepreneurship ▶ Entrepreneurial traits and cuture ▶ Describe components of the natural environment ▶ Marine business opportunities

Geography ▶ Economic Geography ▶ Marine economic activities in Namibia

Learning Objectives

a. Explain why Namibia's ocean is less explored than some other places on earth.

b. Give an example of how exploration of the ocean might aid our survival (eg medicines from kelp).

c. Recall the term "ecological limits" and recognize that extraction from the ocean must occur within ecological limits.

d. Summarise the Ocean X mission and describe a submersible.

e. Name some ocean careers in Namibia.

Learning Objectives Answers

a. Limited resources: Compared to countries in the global north, Namibia has less funding and resources for ocean exploration.

Large area and extreme conditions: Namibia's extensive coastline and vast ocean territory with challenging environments make exploration more difficult.

b. Kelp Blue, a company exploring the possibility of using kelp for medicinal products. Certain compounds in kelp show potential for human health benefits like antioxidants and anti-cancer properties.

c. Emphasize the importance of sustainability. We cannot continue exploiting the ocean beyond its capacity. Exploration and innovation should focus on benefiting from the ocean while respecting its ecological limits.

d. Ocean X Mission: Aims to explore the unseen depths of the ocean through scientific research and storytelling.

Submersible: A specially designed vehicle capable of withstanding high pressure and allowing humans to explore the deep ocean for scientific research and observation. Ocean X uses submersibles to access the deep sea and collect valuable information.

e. Science and Research: Oceanography, geography, fisheries science, marine biology, researchers, project managers.

Conservation and Management: Marine or coastal ranger, environmental teaching, NGOs, ministries (environment and fisheries).

Resource Management and Industry: Fishing, fish processing, aquaculture technicians, marine engineering, navigation and shipping, oil and gas industry, renewable energy.

Communication and Education: Ocean storyteller (journalist, social media), librarian, educator, tour guide.

Creative Industries: Ocean artist, photographer, craft-based careers using ocean products.

Other: Chef (cooking with seafood), lawyer (maritime law), captain/shipper, navy, diver, aquatic veterinarian, marine economist, campaigner/advocacy.

Suggested Activities

Ocean Careers poster

In this poster activity, students will communicate what they have learn about the ocean to encourage more young people to consider an ocean career.

Equipment list:

- Poster making materials, either digital (computers) or physical (paper, colouring pencils).

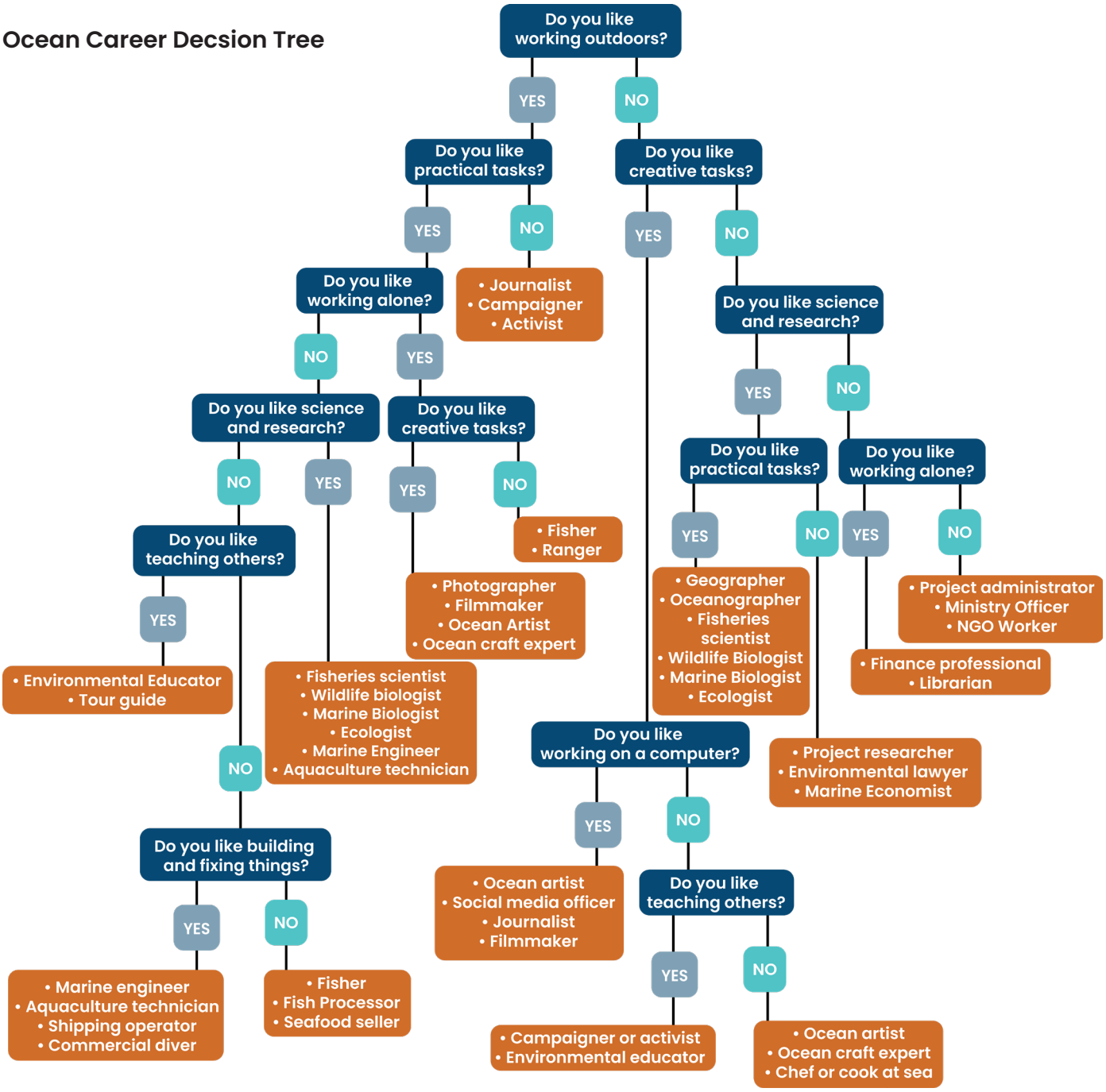
Instructions:

1. In pairs, students should create a poster about ocean careers.
2. The aim is to encourage or enthuse other students about ocean literacy and ocean careers.
3. Students should use captivating graphics or drawings and short, snappy information.
4. They can use what they have learnt from the previous 7 principles to add fun facts and important information.

Further Reading

Find out more about the 7 Principles of Ocean Literacy by scanning the QR Code or visiting: **bit.ly/m/ocean-literacy-toolkit**

Ocean Career Decsion Tree



Students should now understand:

- *What ocean careers are available.*
- *How to communicate their thoughts to others in an engaging way.*
- *You can narrow down ocean career choices based on what you already know about yourself and your skills.*
- *The ocean offers vast and diverse opportunities for exciting and meaningful careers.*
- *The ocean needs the support of an informed, engaged and ocean literate workforce to sustain, protect and conserve it for years to come.*

Suggested Activities

Ocean Careers decision tree

In this activity, students will reflect on their own interests and preferences to see which ocean careers might work for them.

Equipment list:

- Decision tree.

Instructions:

- Based on your own interests, answer the yes/no questions until you reach an Orange box.

Glossary

- **Abalone** – Refers to a group of large marine mollusks belonging to the Haliotidae family.
- **Abiotic** – Refers to non-living factors or components in an ecosystem or environment.
- **Aesthetic Value** – It is the quality or attributes of an object, artwork, environment or experience that are pleasing or beautiful to perceive and appreciate.
- **Antioxidant** – They are molecules that help prevent or slow down the damage caused by free radicals in the body.
- **Anti-cancerous** – It is substances or treatments that have the ability to prevent, inhibit or treat cancer.
- **Arid** – Refers to a climate or environment that is extremely dry, with little to no rainfall and low humidity levels.
- **Benguela Current Large Marine Ecosystem** – It is a vast marine ecosystem located along the southwestern coast of Africa, encompassing coastal waters of Namibia, Angola and South Africa. It is named after the Benguela Current, a cold ocean current that flows northward along this coast.
- **Biodiversity** - It is short for biological diversity, and it refers to the variety of life forms found in a particular ecosystem, region, or the entire planet.
- **Biogeochemical Cycles** – They are pathways through which elements or compounds are exchanged between living organisms, the environment (geosphere, hydrosphere and atmosphere) and the Earth's crust.
- **Biomass** – Refers to the total mass of living organisms in a given area or ecosystem, typically expressed in terms of weight per unit area or volume.
- **Biotic** – Refers to living organisms and the interactions between them within an ecosystem.
- **Blue Carbon** – It is the carbon stored in coastal and marine ecosystems, primarily in mangroves, salt marshes and seagrass meadows. These ecosystems are highly efficient at capturing and storing carbon dioxide (CO2) from the atmosphere through photosynthesis and storing it in their biomass and sediments.
- **Bycatch** – It is the unintentional capture of non-target species (including fish, mammals, birds and other marine organisms) during fishing operations.
- **Calcium** – It is the chemical element with the symbol Ca and atomic number 20. It is one of the most abundant minerals in the Earth's crust and is essential for various biological processes in living organisms, including humans.
- **Calcium Carbonate** – It is a chemical compound with the formula CaCO3 and is commonly found in nature as limestone, chalk and marble.
- **Camouflaging**- Refers to the act of concealing or disguising something, often to blend into the surroundings or to avoid detection.
- **Carbon Dioxide** – Is a colorless, odourless gas composed of one carbon atom bonded to two oxygen atoms.
- **Carbon Sink** – Is any natural or artificial reservoir that absorbs more carbon dioxide from the atmosphere than it releases, effectively removing carbon dioxide from the air and storing it.
- **Cetaceans** – They are a group of marine mammals characterized by their aquatic lifestyle, streamlined bodies and lack of hind limbs.
- **Chemotrophic Bacteria** – They are type of bacteria that obtain energy by oxidizing chemical compounds rather than relying on sunlight for energy (like phototrophic organisms such as plants).
- **Cold-Water Upwelling System** - Refers to a phenomenon in oceanography where deep, nutrient-rich waters rise to the surface, typically along coastlines.
- **Collaborative** - It is the act of working together with others to achieve a common goal or objective.
- **Commercially Fished Species** – Refer to fish, shellfish and other aquatic organisms that are harvested form the ocean, rivers, lakes or other bodies of water for the purpose of sale and trade. These species are targeted by commercial fishermen and fisheries for their economic value.
- **Condensation** - It is the transition by which gas or vapor transitions into a liquid state.
- **Convection** – It is a process of heat transfer that occurs through the movement of a fluid (such as air or water) due to differences in temperature within that fluid.
- **Cretaceous Period** – Was the third and final period of the Mesozoic Era, lasting from

approximately 145 million years ago to 66 million years ago.

- **Decarbonization** – Refers to the process of reducing or eliminating (CO2) emissions, particularly those stemming from human activities such as burning fossil fuels for energy production, transportation, industry and agriculture.
- **Desalination** – The process of removing salt and other minerals from seawater or brackish water to produce freshwater suitable for human consumption, agriculture irrigation, industrial use and other purposes.
- **Echolocation** - It is the biological process used by certain animals, primarily bats and some species of whales and dolphins, to navigate and locate objects in their environment by emitting sounds and interpreting the echoes that bounce back.
- **Ecological Limits** – Refers to the boundaries or constraints imposed by natural systems on the capacity of ecosystems to support life and sustain ecological processes.
- **Ecosystem** – It is a complex community of living organisms (biotic factors) interacting with each other and their non-living environment (abiotic factors).
- **Ecosystem Diversity** – It is the variety and richness of ecosystems within specific geographical area or across the entire planet.
- **Eddies** – They are circular or spiral currents of water that form in oceans, rivers or other large bodies of water and they typically occur when there is a disturbance or irregularity in the flow of water.
- **El Niño** - It is a climate phenomenon chracterized by the abnormal warming of surface ocean waters in the eastern tropical Pacific Ocean
- **El Niño Southern Oscillation (ENSO)** - It is when warmer than average sea surface temperatures develop in the central and eastern Pacific Ocean, particularly along the coast of South America. This warming disrupts normal weather patterns and atmospheric circulation, leading to changes in precipitation, temperature and atmospheric pressure across the globe.
- **Electrolysis** – It is a chemical process that uses an electric current to drive a non-spontaneous chemical reaction.
- **Ephemeral Rivers** - Also known as intermittent rivers or seasonal rivers, are watercourses that flow only during certain times of the year or in response to specific climatic events, such as rainfall or snowmelt.
- **Erosion** - It is the process by which soil, rock, or sediment is gradually worn away and transported by natural agents such as water, water, wind, ice or gravity.
- **Evaporation** – It is the process by which a liquid substance changes into a gaseous state.
- **Exclusive Economic Zone** – As defined by the 1982 United Nations Convention on the Law of the Sea (UNCLOS), refers to an area extending up to 200 nautical miles (approximately 370 kilometers) from a coastal state's baselines. Within this zone, the coastal state has exclusive rights to explore and exploit natural resources, both living and non-living, in the waters, seabed, and subsoil.
- **Fertilizers** – They are substances or mixtures of substances applied to soil or plants to supply essential nutrients that promote plant growth and increase crop yield.
- **Fossil Fuel** – They are hydrocarbon-based energy resources formed from the remains of ancient plants and organisms that lived millions of years ago.
- **Genetic Diversity** – Refers to the variety of genetic characteristics within a population, species, or ecosystem.
- **Gondwanaland** – Refers to a supercontinent that existed during the Paleozoic and Mesozoic eras, approximately 550 million years ago and began to break up during the Jurassic (about 180 million years ago).
- **Greenhouse Effect** – It is a natural process by which certain gases in Earth's atmosphere trap heat from the Sun, preventing it from escaping back into space.
- **Greenhouse Gases** – They are gases in the Earth's atmosphere that have the ability to trap heat. They allow sunlight to enter the atmosphere freely, but they absorb and re-radiate infrared radiation, which effectively warms the planet's surface.
- **Guano** – It refers to the excrement of seabirds, bats, or seals, especially when it accumulates in significant quantities on islands or coastal areas.
- **Gulf Stream** – It is a powerful and warm ocean current that originates in the Gulf of Mexico, flows along the eastern coast of the United States, and then crosses the Atlantic Ocean towards Europe.
- **Hydrothermal Vents** – Are fissures in the ocean floor from which geothermally heated water emerges.
- **Ichaboe Island** – It is a small, rocky island located off the coast of Namibia in southern Africa.

- **Inextricably** - It is an adverb that describes a situation where something is so closely intertwined or interconnected with something else that it cannot be separated or disentangled from it.
- **IOC-UNESCO** – The Intergovernmental Oceanographic Commission (IOC) is a body within the United Nations Educational, Scientific and Cultural Organization (UNESCO) that focuses on ocean research, observations and capacity building.
- **Iron Oxide** - Refers to a chemical compound composed of iron and oxygen atoms.
- **Kelp** – It refers to large brown algae belonging to the order Laminariales and these seaweeds typically grow in underwater forests along rocky coastlines in cool, nutrient-rich ocean waters
- **La Niña** - It is cooler than average SST in the central and eastern Pacific Ocean. These events often lead to enhanced trade winds, increased upwelling of cold water along the equator, and changes in atmospheric circulation patterns.
- **Lüderitz Rock Lobster** – It is scientifically known as *Jasus lalandii*, is a species of spiny lobster found along the coasts of South Africa and Namibia.
- **Macroalgae** – Also known as seaweeds, are large, multicellular algae that are visible to the naked eye.
- **Mangroves** – They are a group of trees and shrubs that grow in coastal intertidal zones, brackish water, and saline coastal swamps.
- **Marine Snow** – Refers to a continuous shower of organic and inorganic particles that slowly drift down through the water column in the ocean.
- **Methane** – It is a chemical compound with the molecular formula CH4. It is the simplest alkane and the main component of natural gas, which is a fossil fuel.
- **Microorganisms Or Microbes** – They are tiny living organisms that are too small to be seen with the naked eye.
- **Migratory** – Refers to the act of moving from one place to another, typically over long distances, often in a cyclical or seasonal pattern.
- **Moratorium** – Temporary suspension or halt of a particular activity, practise, or law.
- **Multicellular Life** – Refers to organisms composed of more than one cell working together in a coordinated manner to carry out various functions.
- **Multidisciplinary**- Refers to an approach or perspective that involves the integration of knowledge, methods and insights from multiple different disciplines or fields of study.
- **Namibian Islands' Marine Protected Area NIMPA** – This MPA encompasses several islands along the Namibia coast, including Penguin Islands, Mercury Islands, Seal Islands, Ichaboe Islands and Possession Island.
- **NAMPORT** – Stands for Namibian Ports Authority and it is the state-owned entity responsible for managing and operating the ports of Namibia, facilitating maritime trade and logistics activities.
- **NGO** – It is a legally constituted organization that operates independently of government control and is typically driven by a particular social, environmental, or humanitarian mission.
- **Niche** – Refers to the specific role or position that an organism occupies within its ecosystem, including its interactions with other organisms and its physical environment.
- **Ocean Acidification** – It is a process driven by the uptake of carbon dioxide (CO2) from the atmosphere by the ocean, resulting in a decrease in the pH of seawater.
- **Orange Roughy** – It is a species of deep-sea fish belonging to the family Trachichthyidae. It is known for its distinctive bright orange coloration and its longevity, with individuals known to live for up to 100 years or more.
- **Overfished** – Refers to a situation in which the rate of fishing or harvesting of a particular species exceeds its natural reproductive capacity, leading to decline in the population size and potentially compromising its long-term sustainability.
- **Pelagic Zone** – Refers to the open water column of the ocean, away from the bottom and shorelines and it typically divided into several depth-based layers.
- **Perennial Rivers** – They are rivers that flow continuously throughout the year, regardless of seasonal changes or fluctuations in precipitation.
- **Phosphate** – Refers to a chemical compound containing the phosphate ion (PO43-), which consists of one phosphorus atom bonded to four oxygen atoms.
- **Photosynthesis** – It is the biological process by which green plants, algae and some bacteria convert light energy from the sun into chemical energy in the form of glucose (a type of sugar), while also releasing oxygen

as a byproduct.

- **Phytoplankton** – They are microscopic, photosynthetic organisms that drift in the upper layers of oceans, seas, and freshwater bodies.
- **Precipitation** – Refers to any form of water, in liquid or solid state, that falls from the atmosphere to the Earth's surface.
- **Ramsar Site** – It as wetland area designated under the Ramsar Convention, an international treaty aimed at conserving and sustainably managing wetlands of international importance.
- **Seagrass** – Refers to a group of flowering plants that growing underwater in marine environments, forming dense underwater meadows in shallow coastal waters.
- **Sedimentary Rocks** – They are one of the three main types of rocks found on Earth's surface, alongside igneous and metamorphic rocks.
- **Solar Energy** – Refers to the radiant energy emitted by the Sun, which can be harnessed and converted into usable forms of energy for various human purposes.
- **Species Abundance** – Refers to the number of individuals of a particular species within a defined area or ecosystem.
- **Species Diversity** – Refers to the variety and abundance of different species within a particular ecosystem or geographical area.
- **Species Richness** – Refers to the number of different species present in a particular ecological community or area.
- **Storm Surges** – They are sudden and abnormal rises in sea level that occur during severe weather events, particularly tropical cyclones, hurricanes and typhoons.
- **Submersible** – Is a type of underwater vehicle or vessel designed to operate beneath the surface of water.
- **Symbiotic Relationship** – It is a close and long-term interaction between two different species living together in close physical proximity.
- **Total Allowable Catch (TAC)** – Refers to the maximum amount of a particular fish species or group of species that can be legally harvested from a specific fishery or fishing area within a given time, typically on an annual basis.
- **Tectonic Plates** – They are large, rigid pieces of the Earth's lithosphere, the outermost layer of the Earth.
- **UNAM** – The University of Namibia is the largest and leading public university in Namibia, located in the capital city of Windhoek.
- **UNESCO World Heritage Site** – Is a landmark, area, or site that is recognize by the UNESCO as having outstanding universal value to humanity.
- **Vertebrate** – It is an animal belonging to the subphylum Vertebrates, characterized by having a backbone or spinal column composed of vertebrae, which encloses and protects the spinal cord.
- **Water Vapour** – It is the gaseous form of water.
- **Watershed** - Is known as a drainage basin or catchment area, is an area of land that drains all the rainfall and snowmelt into a common outlet, such as a river, lake, reservoir, or ocean.
- **Zonation Patterns** – Refer to the spatial arrangement or distribution of organisms and ecological communities along environmental gradients within a particular habitat or ecosystem.
- **Zooxanthellae** – Are single-celled, photosynthetic algae that live in the tissues of certain marine organisms, particularly coral polyps, jellyfish and some of sea anemones.

ENDNOTES

1 Ocean Literacy: The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages (original 2006).

2 Ocean Literacy Scope and Sequence for Grades K–12, the Alignment of Ocean Literacy to the Next Generation Science Standards

3 Ocean Literacy for All: A Toolkit. UNESCO

4 Sea-level rise in Namibia 2009.pdf (the-eis.com)

5 Investigating sea level rise — Science Learning Hub

6 SmileForScience - YouTube

7 Easy Experiment to See How Erosion Changes the Earth's Surface (youtube.com)

8 Atlas of Namibia_03 Climate.pdf (the-eis.com)

9 mozambique_climate_vulnerability_profile_jan2013.pdf (climatelinks.org)

10 Namibia-drought-assessment-report-2022.pdf (ifrc.org)

11 Carbon cycle role play | STEAM Activities | Encounter Edu

12 Phytoplankton and Hydrogen Sulfide off the Coast of Namibia (nasa.gov)

13 Seabird guano_1996.pdf (the-eis.com)

14 What are phytoplankton? (noaa.gov)

15 Marine Microbes | Smithsonian Ocean (si.edu)

16 Planet Earth III Episode 1 Coasts - Everything you need to know (bbc.com)

17 Walvis Bay Lagoon | Birdingplaces

18 Orange Roughy (seafo.org)

19 Seal Harvest | OCNamibia

20 Why the Namibian moratorium on sardine fishing must continue (conservationnamibia.com)

21 Marine Phosphate Mining | OCNamibia

22 www.namport.com.na

23 About Blue Marine Foundation - The Sea We Breathe

24 Kelp Blue – Blue water farming for a sustainable planet

25 Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC) - UNAM (edu.na)

26 Unlocking the power of AI for ocean exploration — MBARI Annual Report: 2022


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