Bridging the Ocean

Part 1

Oceanic Cycles

authored by the
All-Atlantic Ocean Youth Ambassadors

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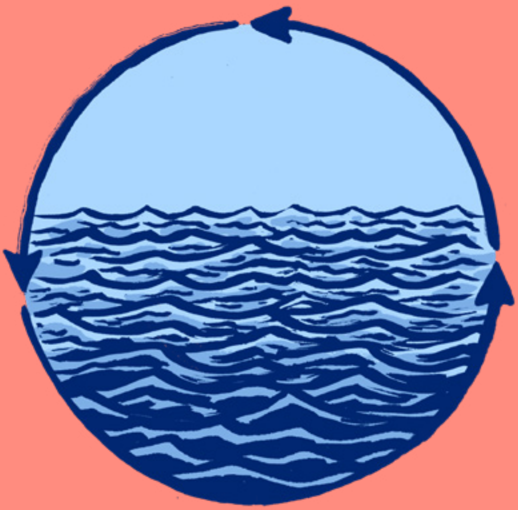
The **All-Atlantic Ocean Youth Ambassadors** believe that collaboration is a strong foundation to successful initiatives that work towards protecting the marine environment; and we are grateful to all contributing parties for their inputs, expertise and funding.

Introduction

This booklet series aims to bridge gaps between people and the ocean to encourage citizens to become stewards of the ocean and its resources. Conversations around ocean conservation are often filled with terminology that excludes many people who may not understand some of the complex concepts and processes, but are wanting to learn and be a contributing part of the conversation. Through *Bridging the Ocean* we hope that people feel welcomed to the ONE ocean that we love and are all a part of so that we can start to engage more freely with each other without the separations of geography, technicalities, language or workstream. It is up to all of us to protect this beautiful shared blue space and we can only do so to the best of our ability when we are well-informed.

Oceanic Cycles

In a closed system, matter can neither be created or destroyed. Earth is considered to be a 'closed system', a system that does not allow material to transfer in or out. Therefore, the amount of matter on Earth stays the same, meaning that matter can only cycle and exist in different states at various stages of its cycle. In this first volume of the Bridging the Ocean series, we will focus on the marine cycles that we most frequently encounter in the context of climate change. These cycles are: the water cycle, carbon cycle and biological pump and the food web.



The Water Cycle

The water cycle shows us the different stages that water travels through as it makes its way around our planet . These different stages include water in all three of its forms (solid, liquid, gas). From space, Earth looks like a giant blue sphere. This is because 70% of the earth's surface is covered by water. Meaning, if you closed your eyes and randomly chose to travel to a place on the globe, 7 times out of 10 you would end up in the ocean instead of land.

What is the water cycle? For it to be a cycle, the water should start from a point and end up coming back to the same point.

The Cycle Explained

Let's make our starting point somewhere in the sea, perhaps the Atlantic Ocean (meaning water starts in the liquid stage). As the sun shines bright, the water absorbs heat energy transferred by the sun and turns into water **vapour** (a gas), marking the beginning stage of the water cycle called **evaporation**. Through evaporation, water moves from the water surface (**hydrospace**) into the air (**atmosphere**).

As water vapour rises up into the atmosphere, with high **altitude** and lower temperature, the vapour changes to tiny droplets (a liquid) that link together to form clouds in the sky. This process is called **condensation**. The wind will move the clouds from their original place above the ocean to different regions (for example over land) with different temperatures. Colder temperatures force the droplets of water to combine even further, making larger and larger droplets until the atmosphere cannot hold them anymore! These water droplets pour down as rain (or as hail/snow (a solid) in **subzero** degrees Celsius). This phenomenon is called **precipitation**.

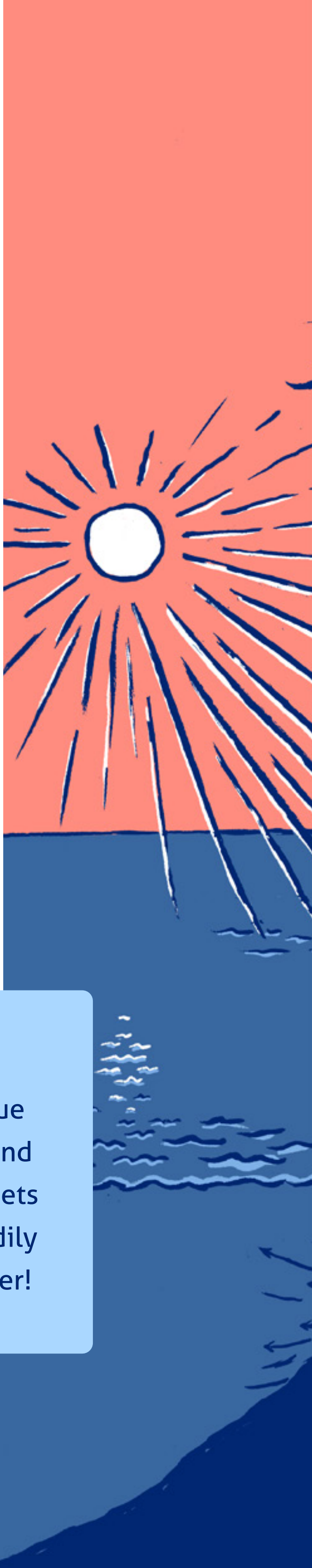
The exact location where the precipitation happens is essential to understanding the next process!

As the rain lands, it leads to runoff. Runoff is the process where water runs over the surface of the earth. Rain, or melting snow from mountains, form into streams. These streams eventually join other waterways, such as channels, rivers, lakes, and seas. All waterways on Earth are, in some way, connected to the ocean. By being back in the ocean, we have returned to our starting point of the cycle. The cycle then begins all over again.

You may be asking, but what if the water that precipitates gets absorbed by soil? In this instance, it moves deep into the earth (biosphere). This process is called infiltration, where the water moves down and increases the level of groundwater. Groundwater is the water that is used for human's drinking water reserves. Eventually, the water that is not absorbed by our bodies will be flushed out of us, flushed down the sewer system, and can end back in the ocean once more, taking us all the way back to our starting point again!

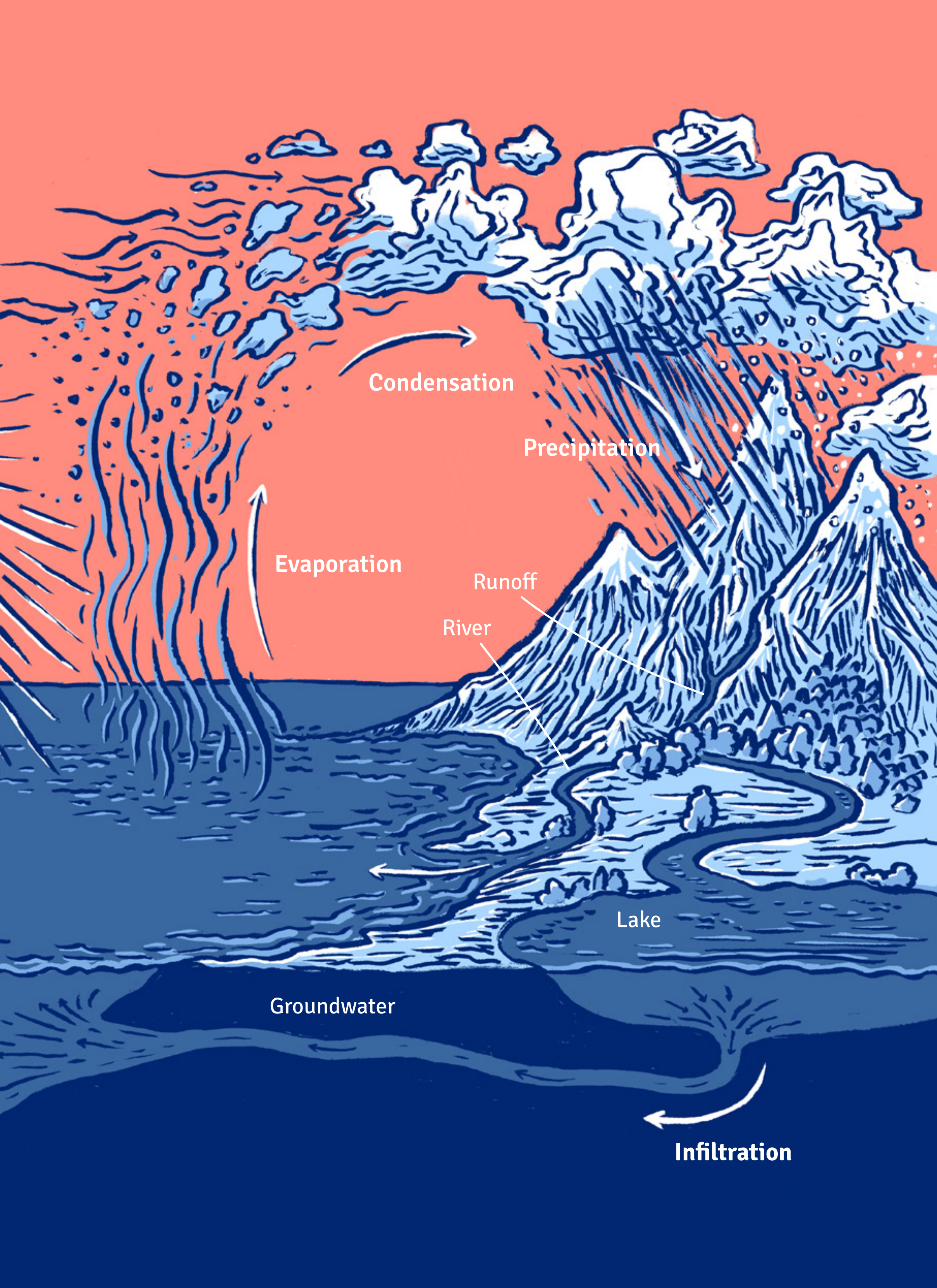
Conclusion

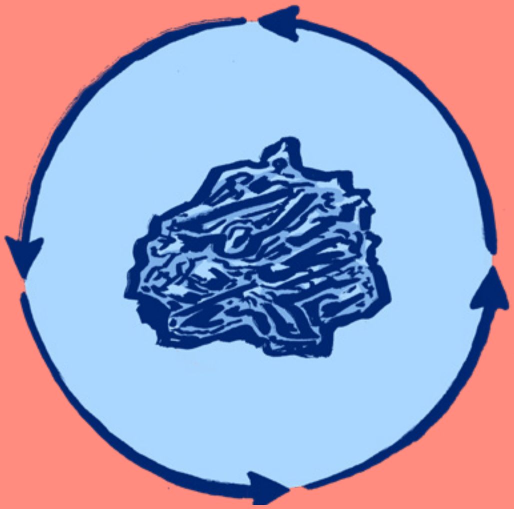
The water cycle is the earth's way of recycling its water. The water you are drinking now may be the same water that was once available to dinosaurs! However, even though freshwater seems abundant, there is actually a limited supply of it on Earth, and without the water cycle, we would definitely run out of clean freshwater (water suitable to drink).



Now You Know

3% of the water available on our blue planet is freshwater. YES, just 3%! And 2% of it is stored in glaciers, ice sheets and groundwater, so only 1% is readily available to humans as drinking water!


Condensation
Precipitation
Evaporation
Runoff
River
Lake
Groundwater
Infiltration



The Carbon Cycle

Carbon is the fourth most abundant element in the universe. Most carbon is stored in rocks, while the rest is stored in the ocean, atmosphere, soil, plants, and fossil fuels. The storage of carbon in these various **reservoirs** prevents most of it from escaping into the atmosphere, which is what causes the average global temperatures to increase. As we know, **global warming** is one of the major challenges we face when it comes to the effects of climate change, and this is largely due to **greenhouse gases**. Carbon dioxide is a very important and effective gas when it comes to controlling the earth's temperature. Without carbon in our atmosphere, earth would be uninhabitable. However, too much carbon in the atmosphere is proving to also make the Earth a more difficult place for humans and animals to comfortably live.

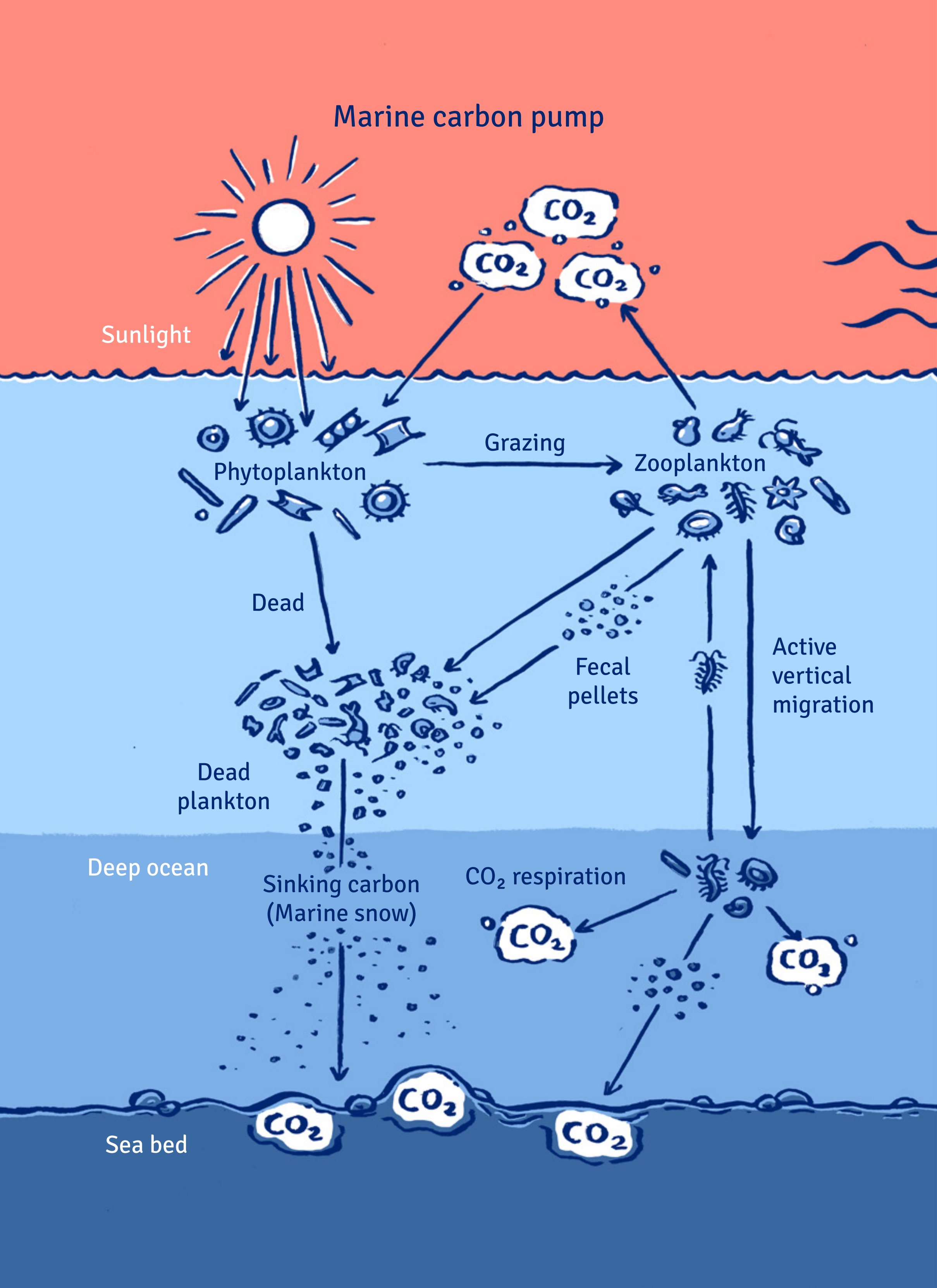
The marine carbon pump explains the cycling of carbon in the ocean, from surface waters to the deep sea and seafloor. Now more than ever, in the face of climate change, it is important to understand this cycle, as the ocean has the capability to **sequester** (store) carbon for hundreds to thousands of years. For ease of understanding, the carbon cycle will be separated into the carbon component and the biological component. However, it is important to remember that these two components are effectively one cycle, and always operate together.

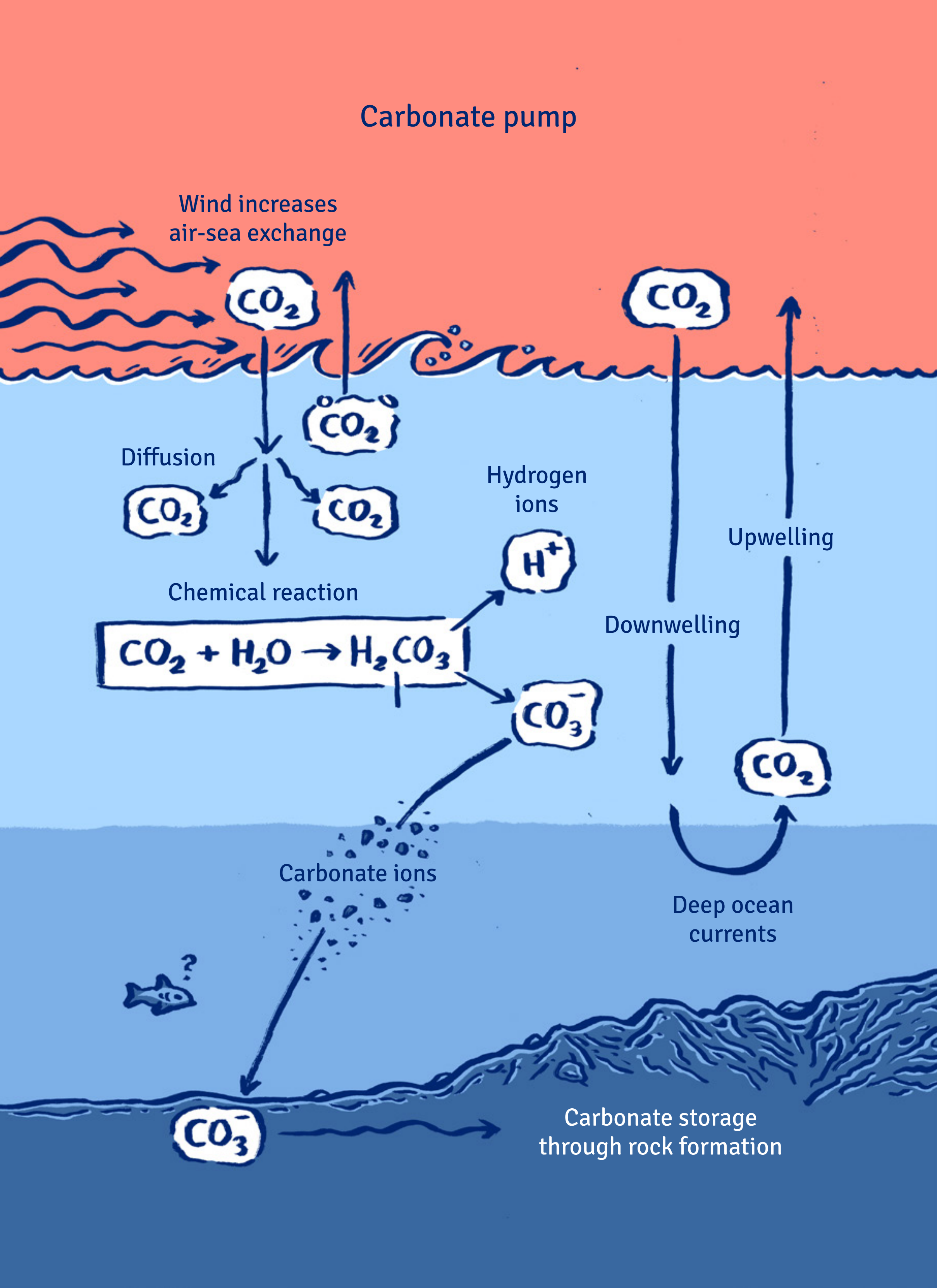
The Cycle Explained

Carbon moves through the ocean in three main ways (we refer to these ways as 'pumps'): the physical carbon pump, the carbonate pump, and the biological carbon pump.

Through the physical pump, carbon in the form of carbon dioxide (CO_2) is taken in via an **air-sea exchange**. This is where the surface waters interact with the air above them. This can be done by waves lapping on the ocean's surface and trapping/releasing CO_2. On a larger scale, this can be done via **downwelling**. Following the air-sea exchange, CO_2 **diffuses** (spreads out) in the ocean. As it diffuses, a reaction takes place where CO_2 breaks down and bonds with the hydrogen **atoms** from water molecules, creating bicarbonate. Bicarbonate then breaks down into hydrogen **ions** and carbonate ions. This is what we call the carbonate pump. The carbonate ions then sink into deep ocean waters where, over time, they form rocks. These rocks are capable of storing carbon for a very long period of time. The amount of CO_2 that diffuses and dissolves in the sea surface water depends on variables such as wind, sea surface mixing, concentrations of CO_2, and the temperature of the water.

The marine carbon pump cycle also begins at the ocean surface, when marine **phytoplankton** use sunlight and **inorganic** carbon dioxide through a process called **photosynthesis**, to produce **organic matter**


Marine carbon pump
CO_2
CO_2
CO_2
Sunlight
Phytoplankton
Grazing
Zooplankton
Dead
Fecal pellets
Active vertical migration
Dead plankton
Deep ocean
Sinking carbon (Marine snow)
CO_2 respiration
CO_2
CO_2
CO_2
CO_2
CO_2
Sea bed


Carbonate pump
Wind increases air-sea exchange
CO2
CO2
CO2
Diffusion
CO2
CO2
Hydrogen ions
H+
Upwelling
Chemical reaction
CO2 + H2O → H2CO3
Downwelling
CO3-
CO2
Carbonate ions
Deep ocean currents
CO3-
Carbonate storage through rock formation

(such as carbon). Some of this carbon, transformed by phytoplankton, is then grazed upon by animals higher up the food web, such as **zooplankton**. This carbon is then excreted by animals in the form of **fecal pellets** (which contain carbon) and sink to deeper waters. The phytoplankton which are not grazed upon by other animals will eventually die and sink as **detritus** to deeper waters. Some zooplankton feed on phytoplankton at the surface during the night, and then actively migrate (swim) to deeper waters during the day, therefore excreting fecal pellets directly in deeper waters. Sinking carbon particles, made up of dead phytoplankton/zooplankton and faecal pellets are often referred to as 'marine snow'. A large proportion of the carbon detritus/marine snow that sinks is recycled back to surface waters before reaching the deep ocean through processes such as the physical mixing of waters (eg. currents) or by being grazed upon by other organisms (bacteria, zooplankton, fish) as it sinks. However, when carbon eventually reaches the (often undisturbed) expanse of the deep ocean, it can take thousands of years to resurface. This carbon can move in the **global conveyor belt**, or it can contribute to forming the rocks on the seabed. This is why the ocean is an excellent **carbon sink**!

Conclusion

The marine carbon pump is important for the planet and society, as it plays a part in global climate regulation and reducing the levels of carbon dioxide in the atmosphere. It is estimated that carbon dioxide levels would be 50% higher than they are today without the marine carbon pump! The atmosphere now contains more carbon than at any time in at least two million years due to **anthropogenic** activities. Therefore, we need to be aware of how we impact natural cycles, such as this one, and how these impacts will change under future climate scenarios. It is absolutely crucial that we find ways to alleviate pressures on our marine carbon pump so that it can continue to maintain important balances that allow for animals to thrive and for us to live. Ultimately, the best and most direct way is to reduce greenhouse gas emissions. Another great way of managing our carbon emissions is through fostering the resurgence of whale populations, as well as top predators. Healthy biomass and biodiversity allows for the uptake of CO_2 to keep atmospheric concentrations at a safe level.

Now You Know

- Phytoplankton introduced in the biological pump are responsible for 2 of every 3 breaths we take! This is because they produce oxygen as a bi-product of the CO_2 they use to grow and thrive.
- Carbon dioxide emissions have averaged 410 parts per million (ppm) every year since 2011, which is 60 ppm above the atmospheric CO_2 concentration scientists, climate experts, and governmental leaders have agreed to be safe.
- The ocean is called a carbon sink because it takes up more carbon than it gives out. Cold waters, such as the Southern Ocean, are able to hold more gases like CO_2, and therefore are the most efficient carbon sink regions.
- Whales are natural carbon sequesters! Because of their long life span and large size, whales accumulate carbon in their bodies. When they die, they sink to the bottom of the ocean; sequestering an average of 33 tons of CO_2, taking that carbon out of the atmosphere for a very long time.

The Food Web

Food webs exist both on land and in the ocean. Food webs are simply considered the "what-eats-what" in natural environments. These can be looked at as individual food chains that form a web, as many different marine organisms can make use of the same food source, resulting in a web-like structure, rather than a straightforward 'chain'.

The Cycle Explained

In marine ecosystems, organisms belong to different **trophic levels**. In each of these trophic levels organisms play different roles and make use of different food sources. The first level is known as **primary producers** and these organisms, consisting of microorganisms, such as bacteria and phytoplankton, as well as seaweed and seagrasses, are considered **photoautotrophs**. Photoautotrophs make use of the sun's energy through a process called photosynthesis, where they convert nutrients and carbon dioxide into organic matter that they use as food. At this trophic level, there are more than 1 million bacterial cells in every drop of seawater! Therefore, these microorganisms are important actors in the **microbial loop**, where bacteria break down **detritus** and release nutrients for other organisms in the ocean.

The organisms belonging to the next trophic level are generally **herbivores** that feed on plants, such as seaweeds and seagrasses, and are known as **primary consumers**. These include zooplankton, such as jellyfish and **larvae** that feed on small drifting organisms, **microalgae**, and **diatoms**. This trophic level also includes larger animals and marine **invertebrates**, such as surgeonfish, parrotfish, turtles, and sea urchins.

The herbivores are often preyed on by **carnivores**, which are known as **higher order consumers**, and constitute the next trophic level. Organisms within this trophic level include various fish species, as well as octopuses and squid that feed on invertebrates and other smaller marine animals. However, smaller carnivores are often hunted by larger animals at the top of the oceanic food chain. These organisms are known as **apex predators**. This trophic level includes finned, feathered, and flippered animals, such as sharks, tuna, dolphins, penguins, and seals. They are at the top of the food chain as they are rarely preyed upon, and often cannot be hunted by a species on a lower trophic level.

This means that most apex predators can only be actively hunted by other apex predators. Some have no natural predators at all, such as orcas and crocodiles.

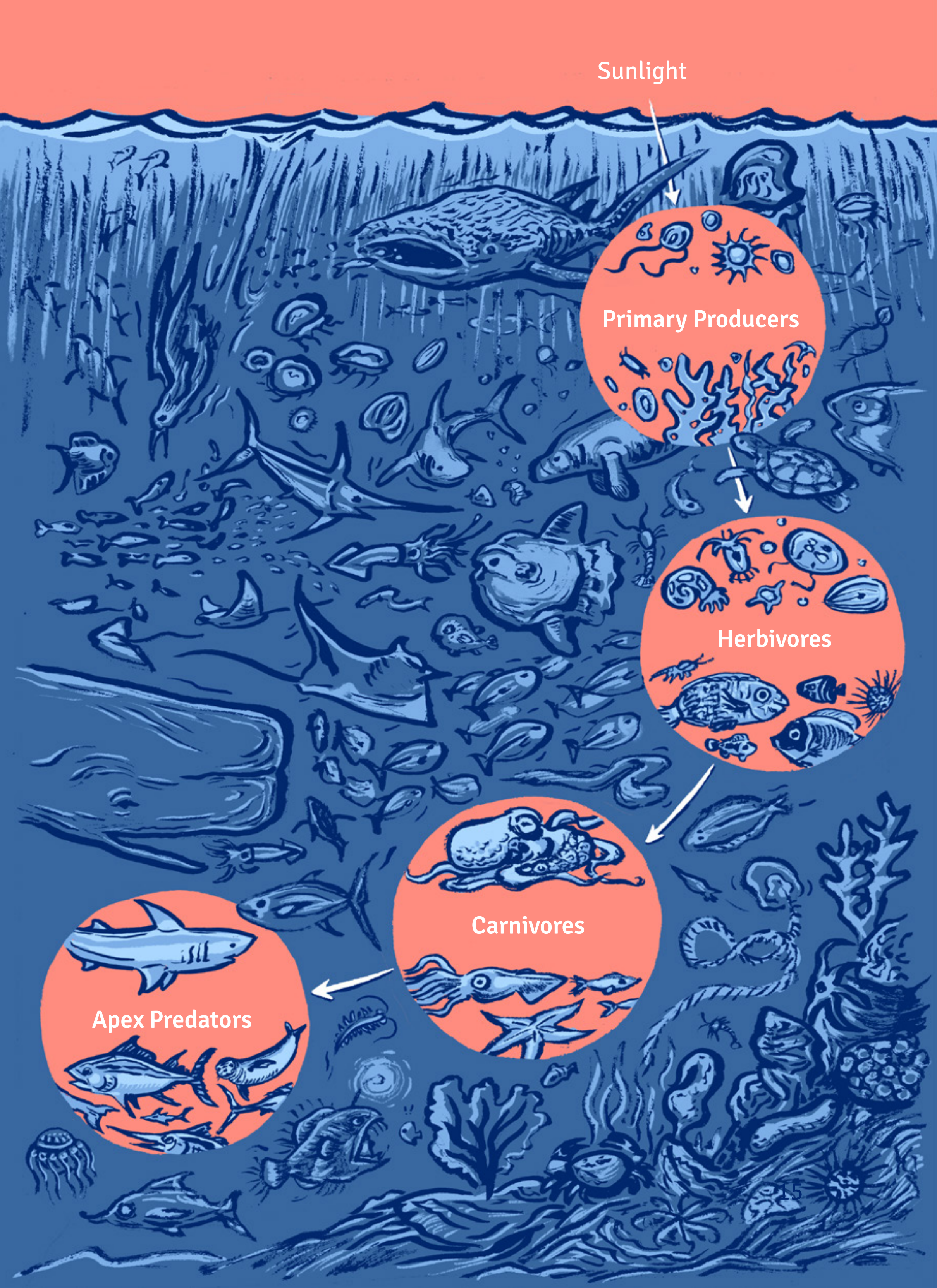
In rare circumstances there can be an overlap between trophic levels, as some marine organisms are **omnivores**, which means that they can eat both plant and animal matter. All these interactions between the various trophic levels results in a complex oceanic food web.

Conclusion

The oceanic food web also contributes to the land-based food web as it acts as an important source of nutrients for terrestrial organisms and humans. However, the marine food web is under pressure due to **anthropogenic** forces, such as pollution, **habitat** destruction, and **overfishing**. Therefore, if the marine environment isn't carefully managed and protected, many food sources may become limited. This could lead to a food security issue for animals (both land and marine), and also to billions of humans that rely on seafood for protein and nutrients.

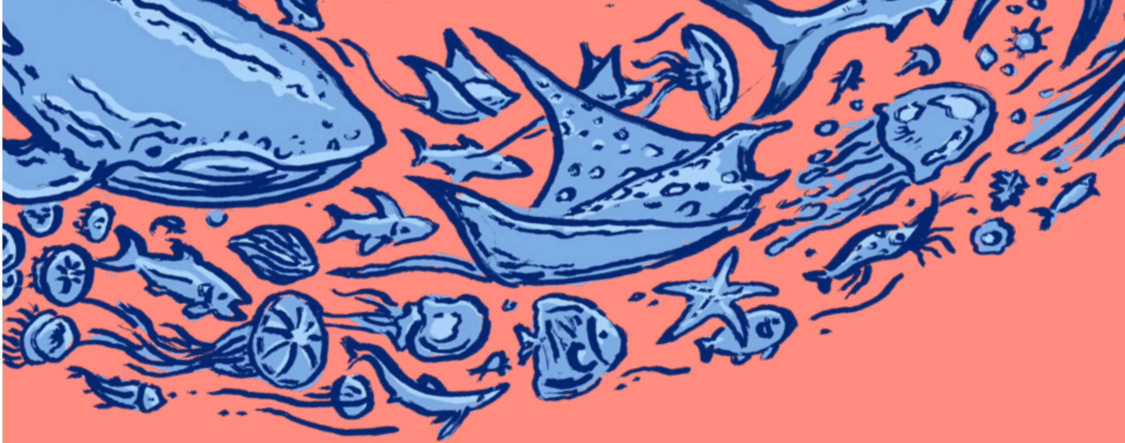
Now You Know

- Humans are considered the 5th and top consumer in the food web, beating even apex predators. Therefore, it is our responsibility to protect the ocean and all the marine life therein.
- Taking **scientific stock** of marine organisms helps inform which animals and areas need to be protected from **overfishing**.
- The largest **migration** on earth happens in the ocean every day! This is known as the diel vertical migration, where some organisms move to the uppermost layer of the sea at night for food, and return to lower layers during the day.


Sunlight
Primary Producers
Herbivores
Carnivores
Apex Predators

Conclusion

We now know that the earth is a closed system and that all the matter that has ever existed still exist today. Cycles are just mechanisms through which this matter moves and transforms. You will have noticed that each of the cycles we explored in this volume are linked to one another. All the matter on Earth needs to move around the entire planet; and it would not be able to do that without cycles like these that interact with one another. With these important interactions, we can begin to understand that an anthropogenic activity in one cycle may have an effect on another cycle. This raises the importance of understanding the extent to which we have the ability to harm, but also to repair, our natural environment. This is no different for cycles in the ocean - all our human activities have a significant impact on our marine environment, whether it is on the actual ocean itself or the animals that call it home. It is therefore essential that we strive to be committed **stewards** of the ocean in the ways that we can individually identify with. Conservation of our marine environment must start with ourselves, through daily habits that protect the different cycles that are essential for our existence.



Blue Schools

The All-Atlantic Blue Schools Network (AA-BSN) Joint Pilot Action aims to promote Ocean Literacy and society awareness, with no geographical, cultural, social, or language boundaries through the connection of educational structures. The AA-BSN works towards cultivating space for and encouraging citizens to be ocean-engaged through enhanced Ocean Literacy activities. This helps to create responsible and active generations that contribute to the ocean's sustainability through an international collaborative programme of different National Blue Schools Networks at the Atlantic Ocean level.

AAOYA

The All-Atlantic Ocean Youth Ambassadors (AAOYA) are a group of dedicated individuals from all walks of life and backgrounds, who promote sustainable development and stewardship of the Atlantic Ocean. Within the context of the All-Atlantic Ocean Research Alliance and the AANChOR-CSA, Ambassadors develop campaigns and communication strategies to reach out to local communities, students and civil society, engage decision makers, as well as work with local media to promote the conservation and protection of the Atlantic Ocean for future generations. Ambassadors lend their capacities to various AANChoR Joint Pilot Actions, such as the AA-BSN, to support the implementation of the Galway and Belém Statement.

About the Authors

Eloïse Savineau has a B.Sc in Marine Biology, a M.Sc. in Oceanography and is currently undertaking her Ph.D. in Biological Oceanography at the National Oceanography Centre Southampton, United Kingdom. She is also the Belgian AAOYA representative. Her research aims to investigate zooplankton ecology in the twilight zone, to better understand how carbon is cycled and stored in this part of the ocean. Eloïse has a strong interest in ocean literacy and bridging the gap between scientists and the public, to empower citizens to get involved in ocean science and advocacy.

Marissa Brink-Hull is a Marine Scientist, holds a PhD in Genetics and is a South African AAOYA representative with a passion for education and promoting ocean stewardship. Currently, she is a postdoctoral research fellow at the University of Cape Town, South Africa, where her research is focused on assessing the microorganisms associated with various aspects of integrated multi-trophic aquaculture (IMTA) systems as part of an EU-project ASTRAL (All-Atlantic Sustainable, Profitable and Resilient Aquaculture) that will contribute to the development of sustainable aquaculture across the Atlantic.

Othman Cherkaoui Dekkaki is a young Mathematician who obtained his master's degree in 2017 in Applied mathematics: Help in decision making from the Mohammed V University in Rabat, where he is currently pursuing a PhD in the same field with a research focus on Optimization, Modelling, Optimal Control to assist decision-makers in their decisions. During this time, he has had the pleasure to give talks and teach classes about the importance of Modelling and Help in decision making. He believes that coming together as a community, including youth in decision making, would tremendously help us in sustainability topics.

Thando Mazomba, qualified Marine Biologist, Physical Oceanographer and Environmental Scientist, is a South African AAOYA to AANChOR. Using her qualifications, Thando works to contribute to the expansion of communities of care for the blue and green space for the justice to come; she is an intersectional environmentalist at the core of her being. Thando is a marine manager at a metocean consulting company as well as a co-founder and director at The Beach Co-op, an NPO that effectively connects people, institutions and organisations through evidence-based education and experiential learning to keep South Africa's beaches clean and healthy and to protect and enhance ocean health.

Glossary

A

Air-sea exchange A process where gases and particles exchange at the interface of the atmosphere and seawater.

Altitude The height of an object or point in relation to sea level or ground level.

Anthropogenic activities Human-induced activities.

Apex predator Animals at the top of the food chain that prey on other animals.

Atmosphere The atmosphere is the whole mass of air/gases that envelope the planet.

Atom The smallest particle of an element that can ever exist.

C

Carbon sink A carbon sink is anything that absorbs more carbon from the atmosphere than it releases.

Carnivore Animals that eat other animals (meat).

Condensation The conversion of a vapour to a liquid.

D

Detritus Waste or debris of any kind.

Diatoms A group of microalgae found in marine environments.

Diffuse To spread over a large area or volume.

Downwelling Oceanographic phenomenon whereby surface waters converge and are forced downwards in the water column, transporting gases to deeper waters.

E

Evaporation The process of turning from liquid into vapour.

F

Fecal pellets An organic excrement (poop), mainly of invertebrates.

G

Global conveyor belt A system of currents that transport water throughout the globe.

Global warming A gradual increase in the overall temperature of the earth's atmosphere generally attributed to increased levels of carbon dioxide and other pollutants released into the atmosphere.

Greenhouse gases a gas that contributes to the greenhouse effect by absorbing heat from the Earth. (The greenhouse effect is the process by which heat from the Earth's atmosphere warms the planet's surface to a temperature above what it would be without this atmosphere).

H

Habitat The natural home or environment of an animal, plant, or other organism.

Herbivore Animals that feed on plants.

Higher order consumer Organisms that are on a higher trophic level than those below them.

Hydrospace The region beneath the surface of the ocean.

I

Inorganic carbon Carbon that is not available to animals as energy/food. Eg. Carbon dioxide.

Invertebrates: Animals that do not have a vertebral column (backbone).

Ion A charged atom. It can be negatively or positively charged depending on whether it has lost or gained a valence electron.

L

Larvae The immature form of animals that need to undergo transformation to change into their adult form.

M

Microalgae Phytoplankton typically found in freshwater and marine systems, living in both the water column and sediment.

Microbial loop The microbial food web in an aquatic environment, whereby dissolved organic carbon is returned to higher trophic levels.

Migration daily/seasonal/yearly movement of animals from one region to another.

O

Omnivores Organisms that eat both plant and animal matter.

Organic carbon Carbon that is available to animals as energy/food.

Overfishing Overfishing is the removal of a species of fish from a body of water at a rate that the species cannot restore itself, resulting in those species becoming underpopulated in that area.

P

Photoautotroph Any organism that derives its energy for food synthesis from light.

Photosynthesis The process by which green plants and some other organisms use sunlight to synthesize nutrients from carbon dioxide and water.

Phytoplankton Are referred to as the *grass of the sea*, being the primary producers of the ocean, the same way grass is one of the primary producers on land. Comes from the Greek word *phyto*, meaning *plant*.

Plankton Marine/aquatic organisms that are unable to swim against currents/tides/waves, etc.. The word plankton comes from the Greek word *planktos*, meaning *wanderer* or *drifter*.

Precipitation rain, snow, sleet, or hail that falls to or condenses on the ground

Primary consumer The second trophic level and are herbivores that eat primary producers.

Primary producer Form the first trophic level and consist of plants and various microorganisms that can convert light energy or chemical energy into organic matter.

R

Reservoirs A reservoir is also a large supply of something.

S

Scientific stock calculating the size and dynamics (how long they live/ mean age/how fast they reproduce) of a fish species' population in an area to understand how much can be fished sustainably.

Sequestration: The long term removal of carbon dioxide from the atmosphere.

Stewards A person whose responsibility it is to take care of something.

Subzero (of temperature) lower than zero degrees Celsius; below freezing for water.

T

Trophic level Organisms sharing the same function in the food chain.

V

Vapour a gaseous substance suspended in the air, especially one normally liquid.

Z

Zooplankton Refers to drifting animals. Comes from the Greek *zoo*, meaning *animal*. Jellyfish are considered zooplankton!

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Bridging the Ocean
Part 1: Oceanic Cycles

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BUILDING AN ALL ATLANTIC OCEAN COMMUNITY
Implementing the Belém Statement

ALL-ATLANTIC BLUE SCHOOLS NETWORK

ALL-ATLANTIC OCEAN RESEARCH ALLIANCE
Creating an Atlantic Ocean Community by Implementing the Galway and Belém Statements