SEQUENCE D

WHY ARE THE OCEAN AND CRYOSPHERE IMPORTANT TO US?

Very often, in order for people to understand why we should take care of something, they need to understand why that something is important to us. As such, this sequence focuses on the importance of an equilibrium in the ocean and cryosphere systems, mainly from the point of view of human communities.

The first lesson reviews the consequences of climate change for ocean and cryosphere ecosystems, while also taking into account the ecosystem services they provide us with. A special focus on the food webs of different polar and marine ecosystems is drawn in the second lesson. The third lesson, which we highly recommend you adapt to your local context, is aimed at helping students realize that some of the services provided go beyond basic livelihood issues, and reach the realm of cultural, historical and spiritual heritages.

LESSON LIST

◉ Core lesson ○ Optional lesson

◉	D1	**Consequences of climate change on ecosystem services** Natural sciences The students create a conceptual framework showing the ecosystem services the ocean and cryosphere provide. They explore how climate change impacts those ecosystem services.	page 96
◉	D2	**Food webs and ecosystems** Natural sciences Through a role-playing game, the students explore polar and marine food webs. They learn that in ecosystems, all organisms interact with and depend on each other for their survival.	page 102
○	D3	**Humans, the ocean and the cryosphere** Social sciences / Visual or performing arts This session is to be adapted to local contexts. An example is provided. Through documentary research and or an artwork / artistic performance, the students learn about the cultural importance of ocean and cryosphere for human populations across history.	page 123

LESSON D1
CONSEQUENCES OF CLIMATE CHANGE ON ECOSYSTEM SERVICES

MAIN SUBJECTS
Natural sciences

DURATION
- Preparation: 25 min
- Activity: 1 h 30

SUMMARY
The students create a conceptual framework showing the ecosystem services the ocean and cryosphere provide. They explore how climate change impacts those ecosystem services.

KEY IDEAS
- Humans need various ecosystem services provided by the ocean and cryosphere: oxygen, food, freshwater, climate regulation, coastal protection, cultural services.
- The Earth system is a complex system in which everything is interconnected.
- Climate change resulting from human activities affects the ocean and cryosphere, as well as human livelihoods.

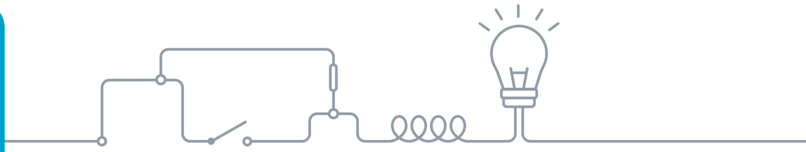
KEYWORDS
Ecosystem services, complex system, human activity, human livelihoods

INQUIRY METHOD
Documentary analysis

PREPARATION 25 MIN

MATERIALS
- **WORKSHEETS D1.1, D1.2, D1.3**;
- A large paper sheet to stick all the stickers;
- Glue.

LESSON PREPARATION
Print **WORKSHEETS D1.1** and **D1.2**, one copy for each group of 3 to 4 students. Print only one copy of the extra stickers on **WORKSHEET D1.3** (each group gets a different sticker).



TEACHER TIP
This lesson has two main objectives: 1) to review the links between climate change and the ocean and cryosphere ecosystems studied in the previous lessons, and 2) to understand how these links will have several consequences on the ecosystem services provided and on human livelihoods.

INTRODUCTION 20 MIN

Start by asking the students to think about the different impacts of climate change on the ocean and cryosphere that they learned about in the previous lessons and note each *concept* on the whiteboard. Some of the concepts suggested by the students should match the stickers provided in **WORKSHEET D1.1**.

TEACHER TIP
"Concept" refers to a simple statement that corresponds to an idea you want the students to take away (validated by the scientific community, and not an initial representation). **One concept = one sentence.** It is not a keyword, a question, or even a "notion" (which tends to involve intuitive knowledge). Example: "The concentration of CO_2 in the atmosphere is increasing."

Continue the discussion with the students: *Why do we care about these changes in the ocean and cryosphere? What do we need the ocean and cryosphere for in our lives?* Note the answers on the whiteboard, again in the form of concepts. Some of the concepts suggested by the students will certainly match the stickers provided in **WORKSHEET D1.2**.

PROCEDURE 40 MIN

1. Divide the class into groups and give each group the list of the concepts needed to build the first part of the conceptual framework ("Mechanisms" stickers, **WORKSHEET D1.1**). If some of the concepts suggested by the students are pertinent but not mentioned in the list provided, let the students add a new sticker for each concept suggested and validated by

the class. In order to save time (or to adapt to your own objectives), you could cut out the listed "concepts" stickers beforehand.

2. Ask the students to place the stickers in a logical order, indicating the connections between them with arrows. For example, an arrow could mean "leads to" or "is due to".

3. Once they have managed to put all the "Mechanisms" stickers into a logical order, give them the "Services" stickers, **WORKSHEET D1.2**.

TEACHER TIP
Depending on the level of your students, you could give them the "Mechanisms" stickers first and then the "Services" stickers, or give them all stickers at the same time.

Organising the different stickers to build a conceptual framework.

Presentation in front of the whole class.

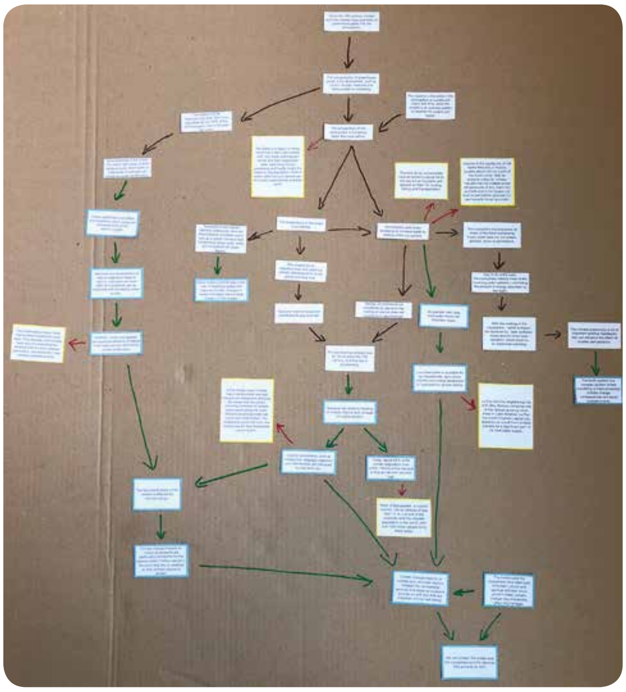
4. Once they have finished their conceptual framework, tell them that each group will also represent a population of one region of the world. Give each group an extra "Local community" stickers provided in **WORKSHEET D1.3**. Each group has to include this extra sticker in their framework logically. To do so properly, they have to think about how their community will be affected by climate change and which ecosystem services will no longer be available for them. Ask the students to list possible solutions for their community.

5. A representative of each group presents the conceptual framework and the solutions for his/her community.

WRAP-UP 30 MIN

Compare and discuss the different solutions with the class. Discuss on how many of the ecosystem services provided by the ocean and cryosphere are being affected by climate change. You can also take advantage of the discussion to go further into the social consequences of climate change. *(Some communities can adapt, others cannot: what does the ability to adapt depend on? Resources? Education? Other factors? Some will have to migrate, becoming climate refugees.)*

TEACHER TIP
This lesson also helps evaluate what the students have learned during the project. Mistakes or missing parts may lead to a deeper discussion to recall the logical sequence that may have been poorly retained or not completely understood. For this activity, there is not a single right answer, and the conceptual frameworks prepared by the students may all be different. What is important is their way of thinking and explaining their organization and links between the concepts.



Conceptual framework. One of the many possible framework solutions.

OPTIONAL EXTENSION
Work with a visual arts teacher to produce a mural painting about the services provided by the ocean and cryosphere and how these services are threatened by climate change.

BACKGROUND FOR TEACHERS

The term **ecosystem services** emerged in the 1970s to raise public awareness of biodiversity conservation. It is a concept which frames ecosystem functions as goods and services for the human population. The Convention on Biological Diversity (1992) defines ecosystems as *“a dynamic complex of plant, animal, and micro-organism communities and the non-living environment, interacting as a functional unit”*. Interactions within the ecosystem can produce various important services for human societies.

The ecosystem services approach aims to evaluate man-made pressures by incorporating ecology and economics. It identifies ecological functions and translates them into economic units. As an ecosystem functions using its natural resources, it produces goods and services that increase human wellbeing. The concept of ecosystem services examines how people depend on ecosystems, what benefits ecosystems provide in a utilitarian sense, and how to better manage and protect ecosystems for the benefit of both nature and people.

There have been several attempts to classify the different kinds of services ecosystems supply. One common typology is the Millennium Ecosystem Assessment. This framework divides ecosystem services into four groups: provisioning services, supporting services, regulating services and cultural services (see pages 12-13 of the Scientific Overview for further details). Below you can find a non-exhaustive description of the different provisioning, supporting, regulating and cultural services that the ocean and the cryosphere provide us with.

PROVISIONING AND **SUPPORTING** SERVICES

They provide us with **mineral resources** (from the deep-sea).

They provide us with **air** to breathe, **freshwater** to drink and **food** to eat.

They provide us with **energy.**

90% of the world’s **trade** is carried by sea and it is, by far, the most cost-effective way to move goods and raw materials around the world.

The cryosphere is an important source for rivers in mid- and low-latitude mountains

Approximately 3 billion people in the world rely on seafood as their primary **source of protein**.

The oceans are home to large **biodiversity.**

The water of melting glaciers and snow flows into rivers. Hydroelectric plants on rivers can produce electricity.

The movement of water (waves, tides and currents) and temperature and salinity gradients can be converted into electricity.

We use **freshwater** in households, agriculture, industry.

Oceans are needed for **fishing**, but also **fish and shrimp farming**.

The **phytoplankton** in the oceans supply an estimated 80% of the world's **oxygen**.

There are many distinct marine ecosystems and the oceans host more **biomass** than the continents.

REGULATING SERVICES

Owing to its high **albedo** and cold water, the cryosphere plays a key role in mediating **global and regional climate.**

The ocean's **inertia** and **currents** play a key role in mediating **global and regional climate.**

Cryosphere's high albedo helps regulating the amount of radiation absorbed by the Earth's surface.

The cryosphere regulates and adjusts to river runoff.

The oceans are an important **heat sink** and have already absorbed 90% of the globalwarming heat.

The oceans contribute to the waste-water treatment.

The oceans are an important **CO_2 sink**: they have absorbed almost 30% of the anthropogenic CO_2 in the past 200 years.

Marine and coastal ecosystems protect the coasts against **natural hazards** (storms, tsunamis and costal erosion).

CO_2 is dissolved in seawater and uptaken by phytoplankton.

Plants and sediments of vegetated coastal ecosystems, such as mangrove forests, seagrass beds and saltmarshes, play an important role in sequestering CO_2 (the blue carbon).

CULTURAL SERVICES

The oceans (especially the coasts) and the cryosphere (the snowy mountains and the polar regions) provide us with important **recreational services.**

The oceans and the cryosphere are part of the human cultural and spiritual richness since ancient times.

The services underlined are already, or are expected to be in the near term, adversely affected by climate change.

WORKSHEET D1.1

MECHANISMS

The temperature of the atmosphere is increasing faster than ever before.

The global mean sea level has rise by around 15 cm since 1900, and this rise is accelerating.

Atmospheric and ocean temperature increases lead to melting of the cryosphere.

Melting of continental ice contributes to sea level rise; melting of sea ice does not contribute to sea level rise.

The cryosphere encompasses all areas of the Earth comprising frozen water (sea ice, ice sheets, glaciers, snow or permafrost).

Seawater thermal expansion contributes to sea level rise.

The oceans are an important CO_2 sink: they have absorbed almost 30% of the anthropogenic CO_2 in the past 200 years.

The climate system has a lot of important positive feedbacks that can amplify the effect of smaller disruptions.

Because it is white, the cryosphere reflects most incoming solar radiation, controlling the amount of energy absorbed by the Earth.

Once dissolved in the ocean, CO_2 reacts with water to form carbonic acid, leading to a drop of seawater pH known as ocean acidification.

The weather is the state of the atmosphere at a particular place and time, while the climate is an average pattern of weather for a particular region.

The oceans are an important heat sink and have already absorbed 90% of the extra heat from global warming.

Since the 19^{th} century, human activities have released large quantities of greenhouse gases into the atmosphere.

The concentration of greenhouse gases in the atmosphere, such as carbon dioxide, methane and nitrous oxide, is increasing.

The temperature of the ocean is increasing.

With the melting of the cryosphere, “white surfaces” are replaced by “dark surfaces”: these absorb more solar radiation, which leads to additional warming.

Temperature and salinity (density) differences drive the thermohaline circulation, which acts as a global conveyor belt transporting ocean water within and across all ocean basins and depths.

SERVICES

The oceans and cryosphere have been part of human cultural and spiritual wealth since ancient times: climate change may irreversibly affect this heritage.	Rising sea levels lead to flooding of coastal regions and increased coastal erosion.	Today, about 40% of the human population lives within 100 km of the sea and is thus at risk from rising sea levels.
As marine currents play a key role in mediating global and regional climate, changes in ocean circulation have a large impact on the climate.	Seashells and exoskeletons of marine organisms made of calcium carbonate are more difficult to build and can be dissolved with increasing ocean acidity.	Coastal ecosystems, such as mangroves, seagrass meadows and saltmarshes, are menaced by sea level rise.
Shellfish, corals and plankton are essential elements of marine food webs and are affected by ocean acidification.	The large biodiversity of the oceans is affected by climate change.	Less freshwater is available for households, agriculture, industry and energy production (in hydroelectric power plants).
The Earth system is a complex system where everything is interconnected: climate change consequences are never isolated.	We can protect the ocean and cryosphere and the services they provide us with.	Ocean acidification will affect phytoplankton, which supplies an estimated 80% of the world's oxygen.
Climate change impacts on coastal and mountain regions threaten the recreational services that these ecosystems provide and are important for our wellbeing.	Climate change impacts on marine ecosystems are particularly worrisome for the approximately 3 billion people worldwide who rely on seafood as their primary source of protein.	

WORKSHEET D1.3

LOCAL COMMUNITIES

Most of Bangladesh, a coastal country, has an altitude of less than 12 m. Bangladesh has one of the highest population densities worldwide, with over 160 million people living there today.

La Paz, and the neighbouring city of El Alto, in Bolivia, comprise one of the fastest-growing urban areas in Latin America. La Paz, the world's highest capital city, depends on runoff from Andean glaciers for a significant part of its freshwater supply.

The Inuit Arctic communities have an ancient cultural link to sea ice ecosystems and depend on them for hunting, fishing and transport.

In the Kerala coast of India, many communities live near mangroves. Mangroves buffer wave action, providing protection for people and and infrastructures along the coast. Mangroves also provide fuel wood and small timber. The inhabitants catch fish from the nearby sea for their household consumption.

The Sahel is a region in Africa which has a semi-arid climate, with very weak and irregular rainfall and high evaporation rates. Agriculture is very precarious and hardly meets the needs of the population. When a water deficit occurs, famine can hit human communities and their cattle.

Yakutsk is the capital city of the Sakha Republic in Russia, located about 450 km south of the Arctic circle. With an extreme subarctic climate, Yakutsk has the coldest winter temperatures of any major city on Earth and is the largest city built on permafrost.

The livelihoods of many small island states depend on coral reefs. They provide communities with food security from fisheries, revenue from tourism, erosion prevention, and protection from extreme weather events.

LESSON D2
FOOD WEBS AND ECOSYSTEMS

MAIN SUBJECTS
Natural sciences

DURATION
~ Preparation: 25 min
~ Activity: 1 h – 1 h 30

SUMMARY
Through a role-playing game, the students explore polar and marine food webs. They learn that in ecosystems, all living organisms interact with and depend on each other to survive.

KEY IDEAS
~ Changes in the ocean and the cryosphere systems affect living organisms.
~ Ecosystems are fragile.
~ The disappearance of a single element from an ecosystem can disrupt the entire food web, eventually affecting humans as well.

KEYWORDS
Ecosystem, fragile equilibrium, food web

INQUIRY METHOD
Role-playing game / multimedia activities + mural painting

PREPARATION 25 MIN

MATERIALS

- **WORKSHEETS D2.1, D2.2, D2.3, D2.4, D2.5, D2.6, D2.7, D2.8, D2.9, D2.10, D2.11, D2.12, D2.13;**
- Yarn (so that each species of the food web of the worksheets can be hung around the neck of each student);
- String (yarn will do as well) to extend between groups of students (long enough, at least 2 m, and more than one per student).

Multimedia resources: multimedia activities Food webs, videos (acidification and corals; mangroves). See page 182.

LESSON PREPARATION

→ **Option 1:** Choose one or several food webs to work on, and print the corresponding worksheets: Coral reef (**WORKSHEETS D2.1, D2.2, D2.3**), Kelp forest (**WORKSHEETS D2.4** and **D2.5**), Arctic Ocean (**WORKSHEETS D2.6** and **D2.7**), Mangrove (**WORKSHEETS D2.8** and **D2.9**), North Sea (**WORKSHEETS D2.10** and **D2.11**), Antarctica (**WORKSHEETS D2.12** and **D2.13**).
Make a necklace for each species in the food webs (the image of the species, glued on cardboard + yarn, for example). Each student will represent a species and hang the corresponding necklace around the neck, so that his / her hands are free to hold the strings that connect him / her to other species.

→ **Option 2:** Connect to the multimedia activities (see page 182). If the Internet connection is too weak or inexistent, the multimedia activities can be downloaded ahead of time. Refer to the instructions on the OCE's website.

TEACHER TIP
The goal of this lesson is to explore the consequences of climate change on food webs, but it does not focus on the study of the food webs in themselves. A preliminary lesson about the different species can be introduced to build the food webs beforehand.

INTRODUCTION 10 MIN

Recap the different consequences of climate change on the ocean and cryosphere. Ask the students: *What consequences could the various climate change phenomena (like cryosphere melting, rising sea level, ocean acidification, etc.) have for animals and plants in the ocean or cryosphere ecosystems?* Write the students' suggestions on the whiteboard.

PROCEDURE 35 – 70 MIN

OPTION 1 (35 MIN) – ROLE-PLAYING GAME

1. Inform the students that they will now play the ecosystem game. Give each student a card corresponding to a species that is part of a food web (provided in the **WORKSHEETS**) and several pieces of string. Different ecosystems are available with different levels of complexity depending on the grade you are teaching. The food webs can be chosen depending on the level of the students, their previous knowledge of the ecosystems, and their geographical area.

Assign each student one specie, following the ratio:

→ **Example 1 – Coral reef food web**
WORKSHEETS D2.1, D2.2, D2.3
- 1 student for each of these species: shrimp, triggerfish, parrotfish, butterfly fish, Moorish idol, damselfish, octopus, turtle, grouper, blacktip shark;
- 2 students for sponge and coral;
- For the remaining students: 1/3 play phytoplankton, 1/3 play macroalgae, 1/3 play organic matter.

→ **Example 2 – Kelp forest food web**
WORKSHEETS D2.4 and D2.5
- 1 student for each of these species: crab, starfish, kelp bass, sea otter, sea lion, orca;
- 2 students play abalone, sea urchin, clam;
- For the remaining students: ½ play phytoplankton, ½ play kelp.

→ **Example 3 – Arctic food web**
WORKSHEETS D2.6 and D2.7
- 1 student for each of these species: seal, walrus, polar bear, bowhead whale, little auk;
- 2 students for copepod, krill, Arctic cod, clam;
- For the remaining students: ½ play phytoplankton, ½ play ice algae.

→ **Example 4 – Mangrove food web**
WORKSHEETS D2.8 and D2.9
- 1 student for each of these species: mangrove snapper, brown pelican, red ibis, periophthalmus, crocodile;
- 3 students play shrimp, crab, mangrove periwinkle, annelid;
- The remaining students play mangrove trees.

→ **Example 5 – North Sea food web**
WORKSHEETS D2.10 and D2.11
- 1 student for each of these species: herring, Atlantic mackerel, spiny dogfish, grey seal, herring gull, blue mussel, oystercatcher;
- 2 students play shrimp, jellyfish;
- 3 students for krill;
- For the remaining students: ½ play phytoplankton, ½ play organic matter.

→ **Example 6 – Antarctic food web**
WORKSHEETS D2.12 and D2.13
- 1 student for each of these species: toothfish, penguin, albatross, cuttlefish, Weddell seal, leopard seal, orca, humpback whale;
- For the remaining students: 2/3 will play phytoplankton and 1/3 krill.

Make sure the students understand that phytoplankton, ice algae, macroalgae, mangrove and kelps are the most abundant organisms, at the base of the food web. Top predators are always less abundant, but they need a lot of individuals from the species they feed on to have enough food to eat.

2. Read the text of all species with the students.

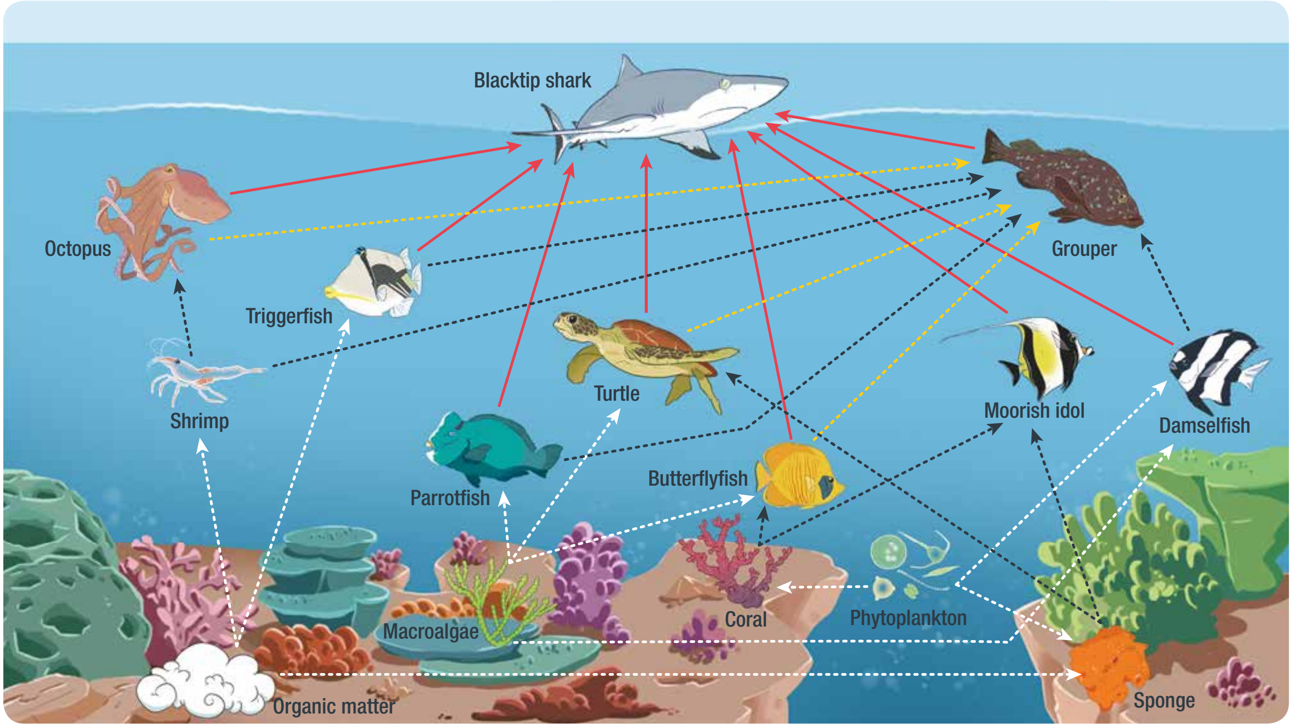
3. The students have to figure out on which species their species depends on for living (which species it can eat). Start from the beginning of the food web (phytoplankton, macroalgae, ice algae, mangrove or kelp), and continue up the food web to the predators. They will hold a string per species they depend on, which hold the other end of each string. Ask the students in turn to explain their choice of connections.

"Krill student" connecting to the rest of the food web.

Phytoplankton necklaces.

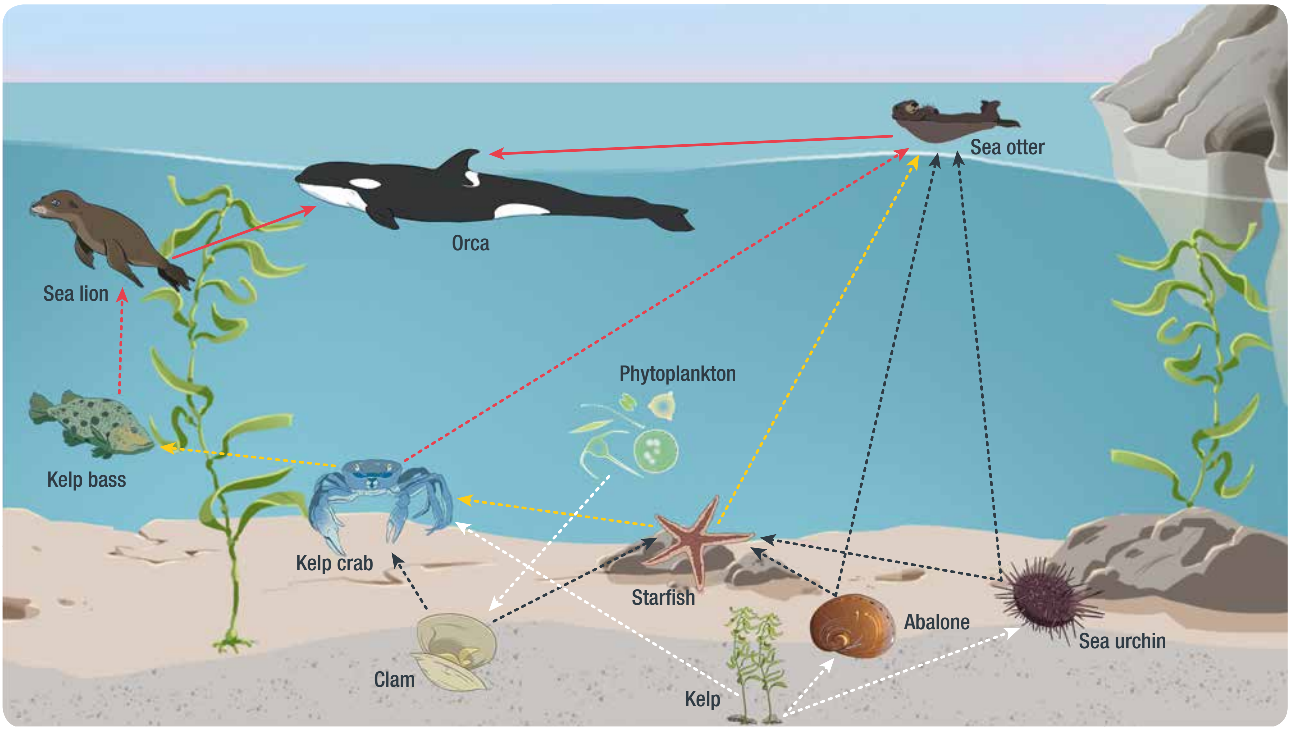
Solution for Worksheets D2.1, D2.2, D2.3

Example 1 – Coral reef food web



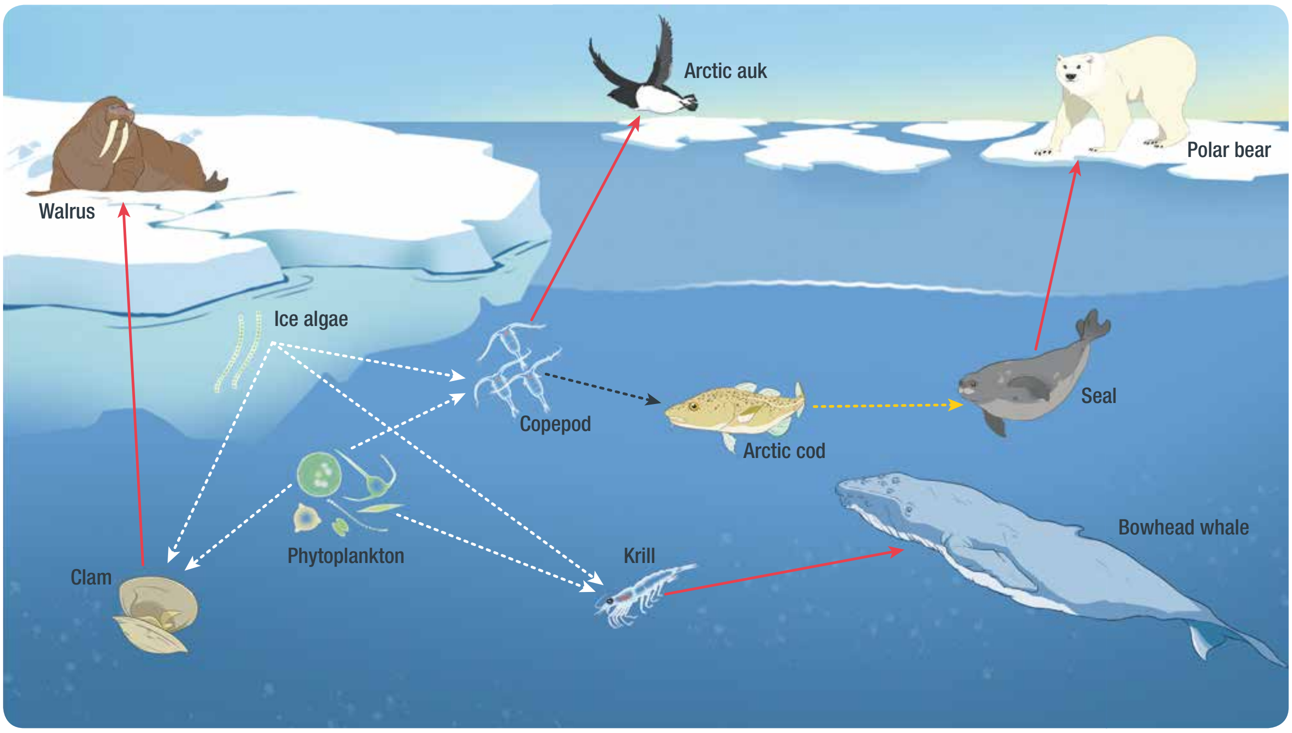
Solution for Worksheets D2.4 and D2.5

Example 2 – Kelp forest food web



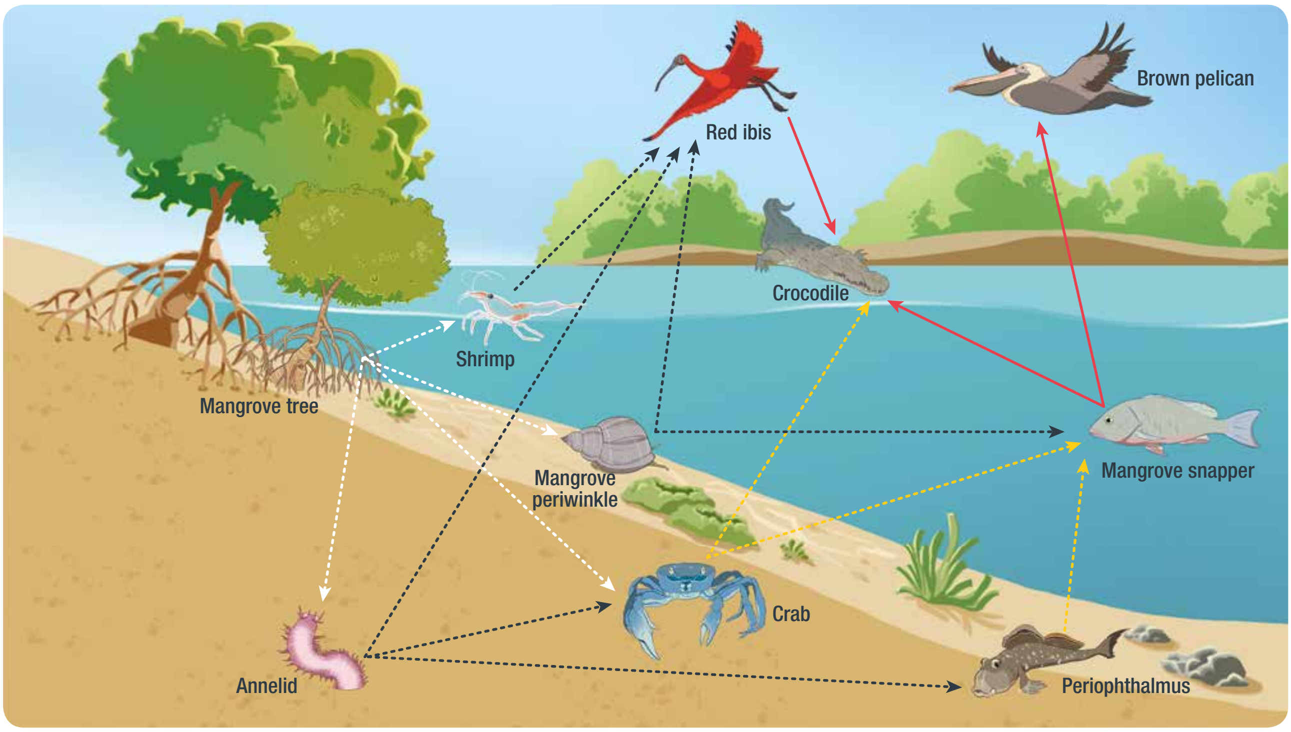
Solution for Worksheets D2.6 and D2.7

Example 3 – Arctic food web



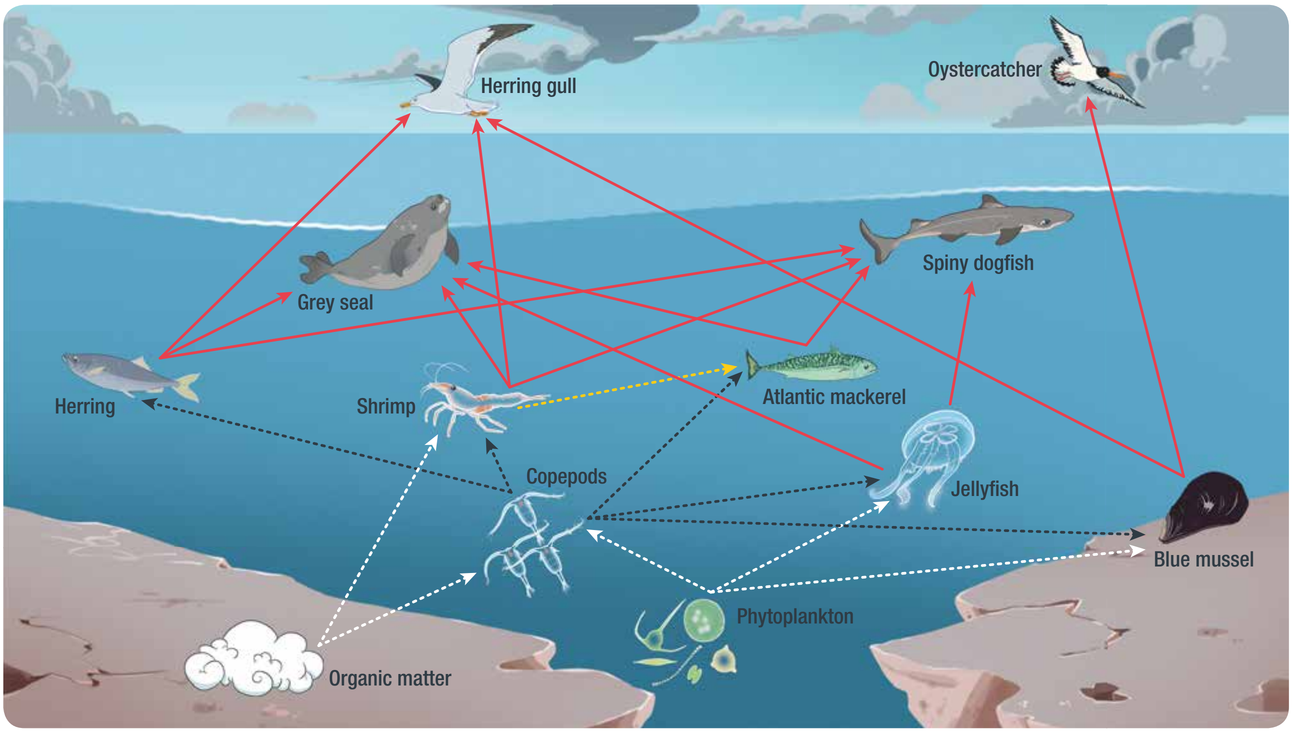
Solution for Worksheets D2.8 and D2.9

Example 4 – Mangrove food web



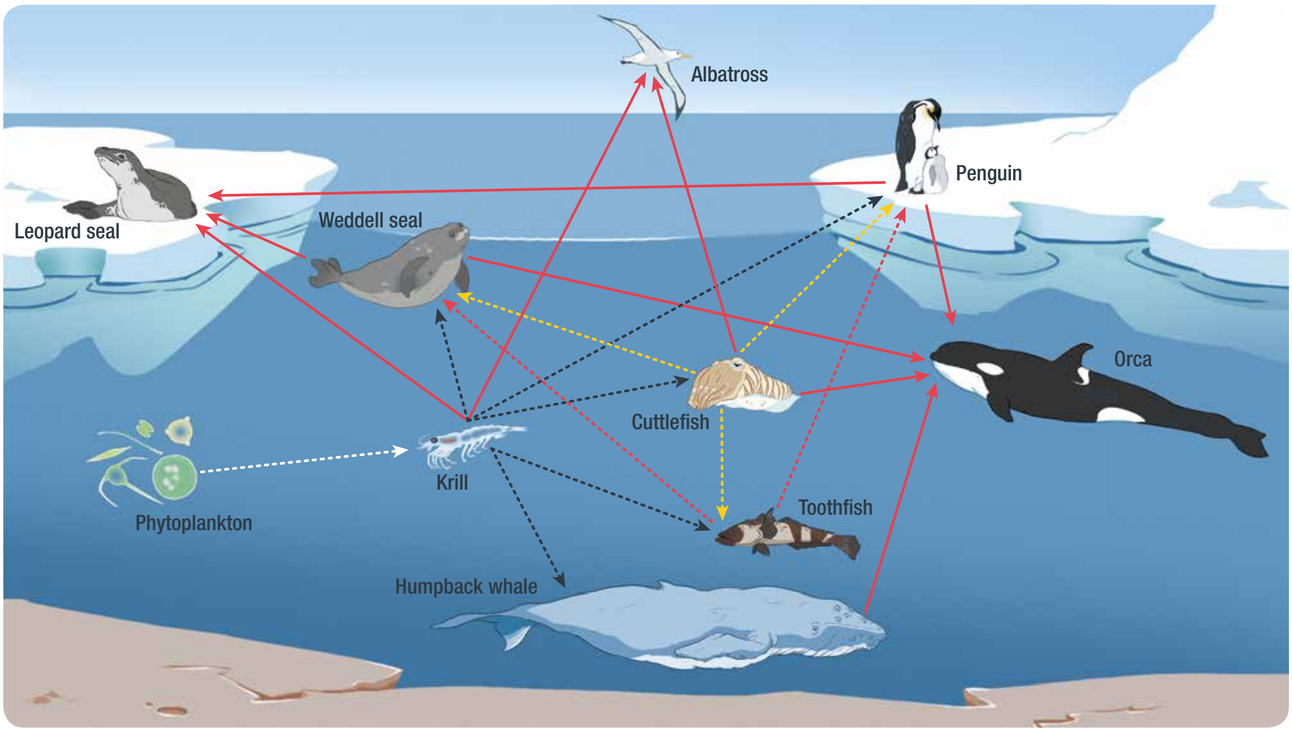
Solution for Worksheets D2.10 and D2.11

Example 5 – North Sea food web



Solution for Worksheets D2.12 and D2.13

Example 6 – Antarctic food web



4. Once the ecosystem is set (all species are connected and everyone agrees on all connections), you can suggest different disruptions to these ecosystems. You can review the student suggestions you wrote on the whiteboard, and add some of those suggested below for the corresponding food web. If one species dies due to a perturbation of its ecosystem, the student sits down on the floor, releasing the strings connecting it to all its predator and prey species. A species can also die when it no longer has food (all its prey species are sitting down on the floor).

Example 1: Coral reef food web

- When water temperatures are unusually high (e.g. during marine heatwaves), coral bleaching can occur. Corals bleach when the polyps expel the symbiotic algae that live inside their tissues. Bleaching leads to the destruction of coral reefs, which are home to approximately 25% of all marine species. Bleached corals continue to live for a while but will die of starvation if water temperatures do not fall again, allowing their symbiotic algae to return.
- Like many reef-forming organisms, corals are made of calcium carbonate and are very sensitive to changes in the pH of sea water. Due to the absorption of man-made CO_2 from the atmosphere, the pH of seawater is falling, leading to ocean acidification. This affects the corals, in particular, which struggle to form their hard skeletons, altering overall reef structures. Certain phytoplankton species are also affected by ocean acidification.
- Other aspects of climate change can also affect coral reef ecosystems, including rising sea levels, increasing occurrence of extreme weather events associated to tropical cyclones, increasing extreme wave heights and altered ocean circulation patterns.
- When combined, all of these impacts dramatically alter the ecosystem function of coral reefs, as well as the services they provide to people worldwide.

Example 2: Kelp forest food web

- Kelp does better at a temperature around 10 to 15°C. They do not survive at a water temperature higher than 20°C. Climate-induced increase in seawater temperature will most likely affect primary production (by kelps), having consequences in the whole food web.
- Some species of sea urchin prefer warmer water. With the increase in water temperature and the decrease in sea otter populations due to hunting, populations of sea urchin are therefore likely to increase drastically. Their grazing pressure could considerably reduce kelp populations and affect the whole ecosystem.

Example 3: Arctic food web

- As the water temperature rises, sea ice melts. Sea ice is the habitat of walruses and seals, the favourite food of polar bears. None of these animals can survive without ice.
- As well as being the habitat of large animals, sea ice also hosts a type of microalgae which only develop in the ice: ice algae. Despite being microscopic, ice algae form large colonies which can reach a few metres below the surface of the ice. In areas covered by ice, ice algae are the main food source for the rest of the Arctic food web. Climate-induced decreases in sea ice will lead to a decrease in ice algae, affecting the whole food web.
- Little auks feed on copepods species specific to cold waters. The warming of their water will alter their diet. The birds will then struggle to find food and their populations will decline.

Example 4: Mangrove food web

- Over the last 50 years, almost half of the world's mangroves have disappeared to make way for shrimp aquaculture and coastal development, or have been used as fuel. Global warming and coastal squeezing due to sea level rise further stress mangrove forests, eventually leading to their disappearance. Although mangroves represent only 1% of the world forests, they store a significant quantity of carbon. Their disappearance could lead to the release of an important amount of CO_2 into the atmosphere.
- Mangroves are the home of shrimp and juvenile fish. Their disappearance have a consequent impact on fisheries.

Example 5: North Sea food web

- Because of the warming of seawater, phytoplankton communities have already started to move northward. This may lead to a reduction in zooplankton (copepods) stocks. Following the northward shift of their food, fish will also move north. Without food, seabirds may struggle to find food causing their population to decline.

Example 6: Antarctic food web

- Krill feed on organisms that can be found under sea ice. Sea ice also protects them from predators. If global warming causes sea ice to retreat, krill will be affected.
- Ocean acidification affects existing shells and the formation of new shells made of calcium carbonate (a chemical compound particularly vulnerable to pH changes). As ocean acidity increases (pH drops), certain phytoplankton species are also affected.
- Ice is the habitat of penguins and seals. Climate-induced ice retreat puts their lives at risk.

Example of an Antarctic food web mural done by students (APECS-France).

5. You can play the same game with different food webs. The students should realize that all living beings are interconnected and that it is important to maintain a balanced ecosystem.

TEACHER TIP

Primary producers, such as phytoplankton, are "fed" by the sun (via photosynthesis). This means that the students representing them never have to sit down, unless directly affected by climate change consequences.

6. After the game has been played with different ecosystems and climate change consequences, place all role-playing cards on the whiteboard. Ask the students to draw each of the links between species that were represented in the game, connecting all species with arrows, starting with those that are at the basis of the food webs.

OPTION 2 (35 MIN)– MULTIMEDIA ACTIVITIES

Instead of doing the role-playing game, you can use the multimedia activities provided ("Food webs" multimedia activities).

WRAP-UP 10 MIN

Discuss the interdependence of all organisms in ecosystems, how ecosystems have a fragile balance that must be maintained, and the consequences for humans if this balance is not preserved.

OPTIONAL EXTENSION (2 H) – ECOSYSTEM FOOD WEB MURAL

Each student draws a species from the chosen food web, alone or with its predator/prey, on a landscape A4 sheet of paper. Within your class, predator/prey ratios should be respected, in order to avoid having 30 orca per class and only 5 penguins, for example. With the help of your students' drawings, you can create a large mural depicting an ecosystem and its species.

BACKGROUND FOR TEACHERS

ECOSYSTEM

All living things from a given environment form a functional whole, within which the different elements, living things and abiotic factors (the "non-living" elements, such as climate-related factors, type of soil, chemical elements present, etc.) interact. The English botanist Arthur Tansley suggested the term "**ecosystem**" at the beginning of the 20th century to describe this whole, which is the basic ecological unit, in order to qualify an environment and the conditions that characterize it. Tansley also coined the term "biotope". The living things that populate a given biotope are referred to as the biocoenosis. So, we get:

ecosystem = biotope + biocoenosis.

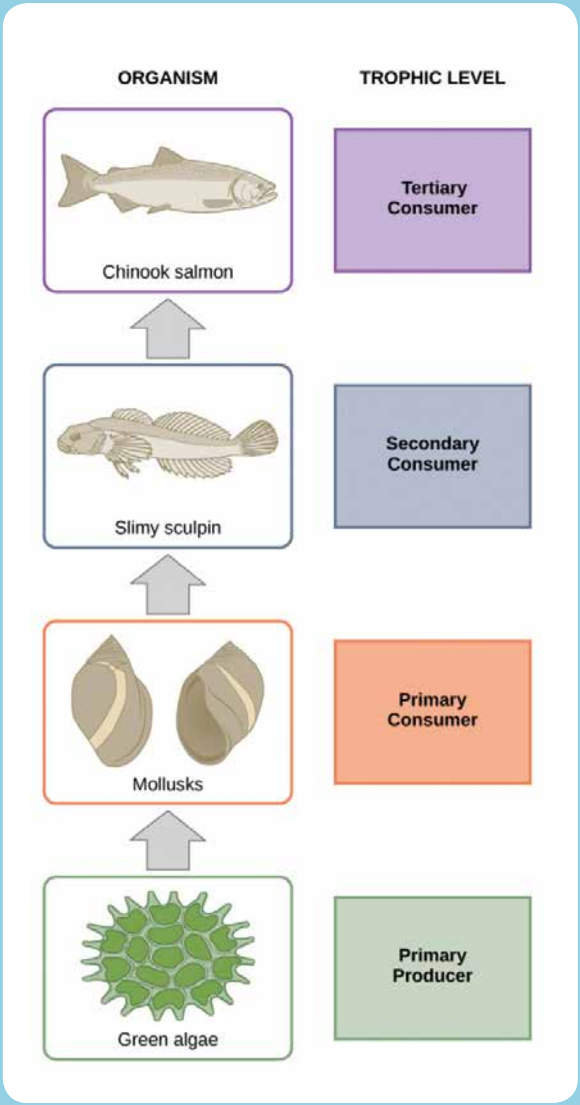
There are a multitude of marine and coastal ecosystems, including estuarine ecosystems, coral reefs, beaches, ocean floor ecosystems and mangrove forests. The cryosphere can also be part of marine ecosystems, which is the case in Arctic and Antarctic ecosystems. However, the cryosphere is also present in numerous terrestrial ecosystems such as Himalayan ecosystems and tundra ecosystems, for example. Each is characterised by a number of abiotic factors and living beings.

Aside from the variations caused by seasons, ecosystems can be affected by various regular or sporadic fluctuations (tidal level, storms, snowfall, etc.), which change the distribution of the different species. While ecosystems evolve over time to reach a state of equilibrium known as "climax", this equilibrium may be easily broken if the functioning of the ecosystem is disrupted, by human activities or climate change for example.

FOOD WEBS

Each ecosystem is structured by **trophic relations**, in which every organism represents a **prey** or a **predator** for another one. Those relations can be viewed as chains, symbolising "who is eaten by whom". However, the reality is more complex, because **food chains** are actually **food webs**, meaning that an organism may eat several species and a species may be eaten by multiple organisms.

Autotroph organisms are always the basis of every food web. These organisms, such as plants and phytoplankton, can produce their own food using light, water, carbon dioxide or other chemical compounds. They are also called **"primary producers"**. Autotrophs are then eaten by heterotrophs, which are not capable of producing their own food. **Heterotroph** organisms can be differentiated into several categories, such as **primary, secondary or tertiary consumers**, depending on their position in the food web (if they directly eat the autotrophs, or instead they eat heterotrophs that eat autotrophs, and so on). When drawing a food web, the arrows conventionally symbolize "is eaten by".



Example of a food chain.

As all species in an ecosystem are interconnected, even the slightest disruption in a species population, or the loss of a single species, can affect all others that depend on it. Considering that a species needs particular environmental conditions (including specific climatic conditions) to thrive, any disruption in these conditions may result in an imbalance of the entire food web with widespread consequences in the ecosystem.

WORKSHEET D2.1

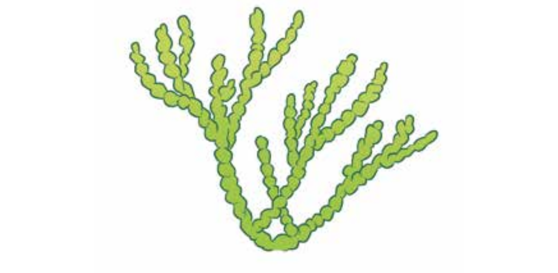
CORAL REEF FOOD WEB 1/3

PHYTOPLANKTON

Phytoplankton are microscopic organisms floating in the sun-lit upper layer of the ocean. Like plants, phytoplankton use sunlight, water, CO_2 and dissolved minerals for photosynthesis and to produce organic compounds. Phytoplankton are a primary producer, at the base of the food web.

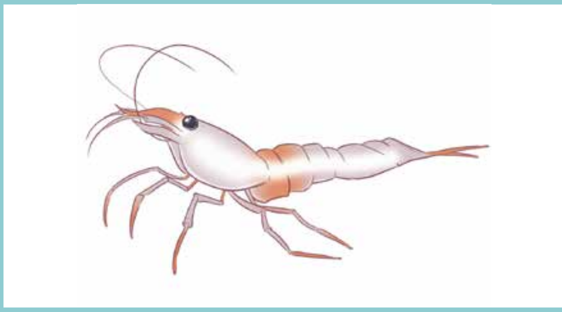
ORGANIC MATTER

Refers to a large pool of carbon-based compounds in seawater that comes from the remains of plants and animals, and their waste products. Descending clumps of organic carbon can resemble snowflakes and are known as “marine snow”. Shrimp and triggerfish feed on organic matter.



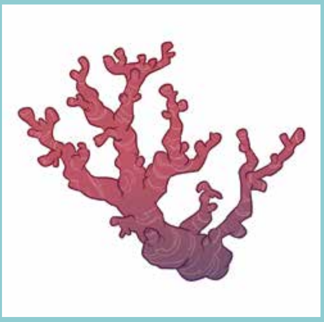
MACROALGAE

Macroalgae, like seagrasses, typically occur in shallow water where there is enough light for growth. They are primary producers, like phytoplankton. They serve as a food source and habitat for crustaceans and molluscs, but also for fish such as parrotfish, butterfly fish and damselfish (which farm macroalgae), as well as turtles.



SHRIMP

Shrimp inhabit the seabed and shallow waters near coasts and estuaries. Shrimp feed on organic matter they find on the seabed, and hide in the sand to escape predators such as octopus and groupers.



CORAL

Corals are animals. They have tiny tentacle-like arms that they use to capture food (phytoplankton) from the water and sweep it into their mouth. Most structures we call “coral” are in fact made up of hundreds or thousands of tiny coral creatures called polyps. Each soft-bodied polyp secretes a hard outer skeleton made of calcium carbonate. Most corals contain algae. Residing within the coral’s tissues, these algae take up the coral’s waste products. In turn, the corals draw on the oxygen and organic products supplied by the algae.

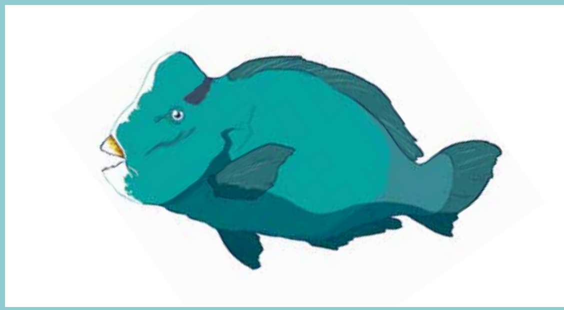
SPONGE

Sponges are found in a wide variety of shapes and colours and are often mistaken for plants. They are animals with bodies full of pores and channels allowing water to circulate through them. As water flows through a sponge’s porous exterior, the sponge gains some forward motion, receives food (phytoplankton) and oxygen, and dispels waste. They serve as food for Moorish idols and turtles.

CORAL REEF FOOD WEB 2/3

TRIGGERFISH

Triggerfish are brightly coloured fish that live in tropical shallow waters. They feed on organic matter and are eaten by sharks and grouper.

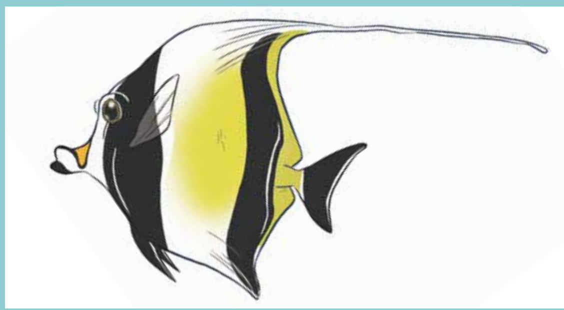


PARROTFISH

Parrotfish live in tropical and subtropical waters. With their parrot-like beak they scrape macroalgae from corals and rocky substrates. They are eaten by sharks and grouper.

BUTTERFLYFISH

Butterflyfish are small, brightly coloured bony fish. They need corals to hide in, and feed on corals and macroalgae. They are eaten by sharks and grouper.



MOORISH IDOL

With characteristic disk-like striped bodies, Moorish idols feed on sponges and corals. They are eaten by sharks.

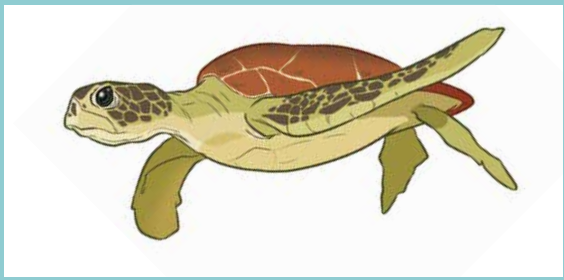
DAMSELFISH

Damselfish are small, brightly coloured fish that live in or near coral reefs. They feed on macroalgae, which they farm, and phytoplankton, and are eaten by grouper and sharks.

OCTOPUS

The octopus is a soft-bodied mollusc and has eight muscular arms, each equipped with two rows of suckers. It mainly eats shrimp and is eaten by sharks and grouper.

CORAL REEF FOOD WEB 3/3

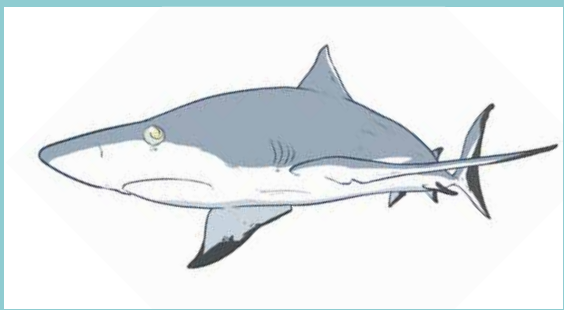


TURTLE

Turtles are reptiles with a bony or leathery shell and flippers, that live in the ocean but, every year, they go ashore on sandy beaches to lay their eggs in the sand. They eat macroalgae and sponges. Their predators are sharks, and young turtles can also be eaten by grouper.

GROUPER

Groupers are large fish with heavy bodies belonging to the sea bass family. They have a big head and a wide mouth. They usually eat fish such as damselfish and are eaten by sharks. They eat fish (such as damselffish, butterflyfish, parrotfish and triggerfish), crustaceans (such as shrimps), and octopus. Large grouper can even eat turtles.



BLACKTIP SHARK

The blacktip shark usually lives in coastal tropical and subtropical waters around the world, including brackish habitats. Blacktip sharks eat all types of fish, octopus and turtles.

KELP FOREST FOOD WEB 1/2

PHYTOPLANKTON

Phytoplankton are microscopic organisms floating in the sun-lit upper layer of the ocean. Like plants, phytoplankton use sunlight, water, CO_2 and dissolved minerals for photosynthesis and produce organic compounds. Phytoplankton are a primary producer, at the base of the food web.

KELP

Kelps are a type of brown macroalgae occurring in temperate and Arctic waters. Like other macroalgae, they typically occur in shallow water where there is suitable light for growth. They are primary producers, like phytoplankton. They serve as food source and habitat to sea urchins, abalones and crabs.

SEA URCHIN

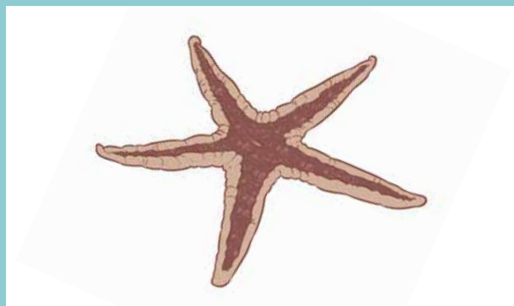
Sea urchins are spiny marine animals living on the seabed. They are typically between 3 and 10 cm in diameter. Sea urchins move slowly and feed on macroalgae. They are the most important herbivores in kelp forests. Their predators include sea otters and starfish.

ABALONE

Abalone are marine snails. They live on the seabed and feed on kelp and other macroalgae. Abalone are eaten by sea otters and starfish.

KELP CRAB

Kelp crabs live in the seabed amid kelp forests. In summer, kelp crabs eat kelp and macroalgae. In winter, when the macroalgae die, they turn to an animal diet and eat clams and starfish. Sea otters are major kelp crab predators, but they are also eaten by kelp bass.



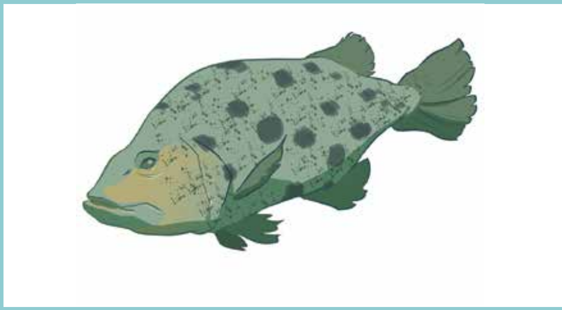
STARFISH

Starfish – or sea stars – live on the seabed. They have a central disc and five arms. They feed on sea urchins, abalone, clams and other shellfish. They serve as food for crabs and sea otters.

KELP FOREST FOOD WEB 2/2

CLAM

Clams are a type of shellfish (5 cm across). They feed on phytoplankton and are eaten by crabs and starfish.

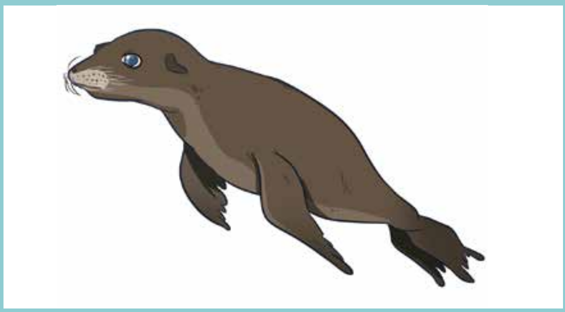


KELP BASS

The kelp bass is a species of marine fish living in kelp forests. It feeds on crustaceans such as crabs and is eaten by sea lions.

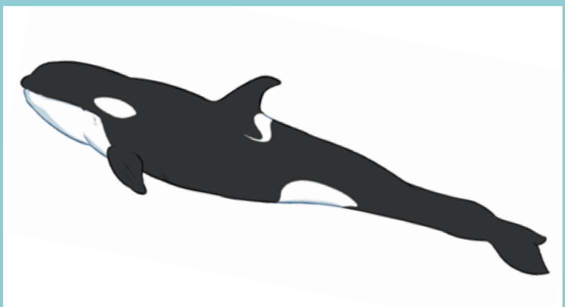
SEA OTTER

The sea otter is the smallest marine mammal. It typically weighs between 14 and 45 kg. Sea otters stay warm thanks to their exceptionally thick coat. They prey on sea urchins, starfish, abalone and crabs. They are hunted by orcas.



SEA LION

The sea lion is a marine mammal related to seals and walruses. A male sea lion weighs an average of 300 kg, while a female weighs around 100 kg. Sea lions feed on fish (kelp bass) and are eaten by orcas.



ORCA

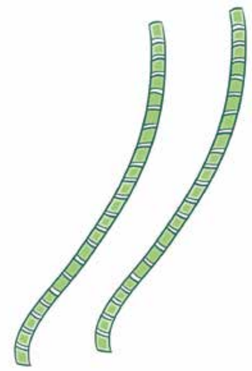
The orca is found in the Arctic and the Southern Oceans and can go as far as tropical seas. It is a highly social animal that lives in families. Its hunting techniques are highly developed and it feeds on large animals, such as sea otters and sea lions.

WORKSHEET D2.6

ARCTIC FOOD WEB 1/2

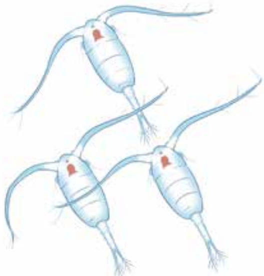
PHYTOPLANKTON

Phytoplankton are microscopic organisms floating in the sun-lit upper layer of the ocean. Like plants, phytoplankton use sunlight, water, CO_2 and dissolved minerals for photosynthesis and to produce organic compounds. Phytoplankton are a primary producer, at the base of the food web.



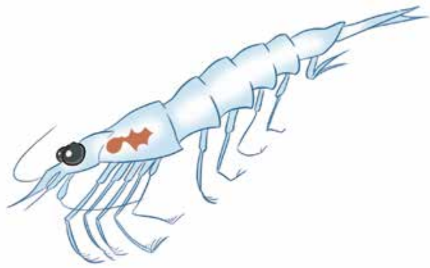
ICE ALGAE

Ice algae are primary producers which develop in the sea ice. They uses sunlight, CO_2 and water to produce organic matter. Despite their microscopic size, they can form chains of a few metres, and animals usually prefer them to phytoplankton due to their higher nutritional value. Hence, they are eaten by clams, copepods and krill.



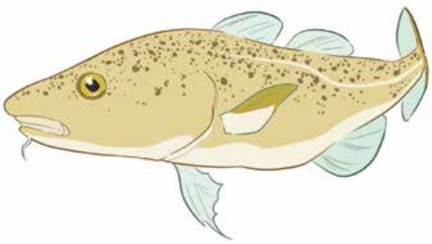
COPEPOD

Copepods are a type of zooplankton, tiny animals drifting with the ocean currents. They are 1 to 5 mm long. They feed on phytoplankton and ice algae and are eaten by fish like Arctic cods and by birds like little auks.



KRILL

Krill, as copepods, are part of the zooplankton. They can be a few centimetres long and weigh up to 2 g. Krill are filter feeders – they filter phytoplankton out of the water and also eat ice algae. They are eaten by whales.



ARCTIC COD

Arctic cods (about 30 cm long) live in the cold waters of the Arctic Ocean and around Greenland. They feed on copepods and are eaten by seals.

CLAM

Clams are a type of shellfish (5 cm across). They are related to other molluscs such as snails and octopus. They filter phytoplankton and ice algae that reach the seabed and are eaten by walruses.

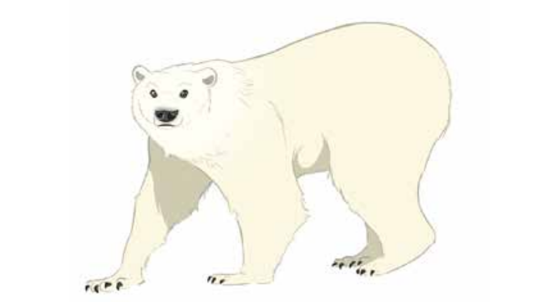
ARCTIC FOOD WEB 2/2

SEAL

The Arctic Ocean is home to several seal species (ribbon seals, bearded seals, ringed seals, spotted seals, hooded seals and harp seals). These large marine mammals mainly eat fish (Arctic cods) and are eaten by polar bears.

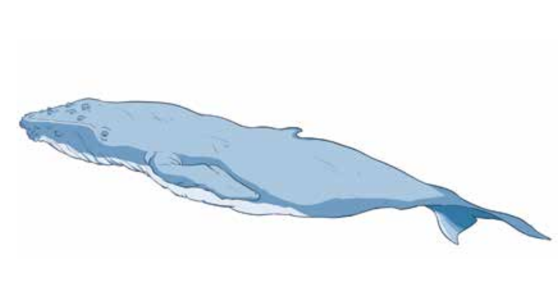
WALRUS

Walruses are large marine mammals (up to 1,700 kg) that inhabit Arctic waters. They are easily recognised by their tusks. Their blubber enables them to spend a lot of time diving in the cold Arctic waters to find their favourite food: clams.



POLAR BEAR

Polar bears are the largest land carnivores that can weigh more than 650 kg. They have a thick white fur to keep them warm. Polar bears spend most of their time on sea ice hunting for seals.



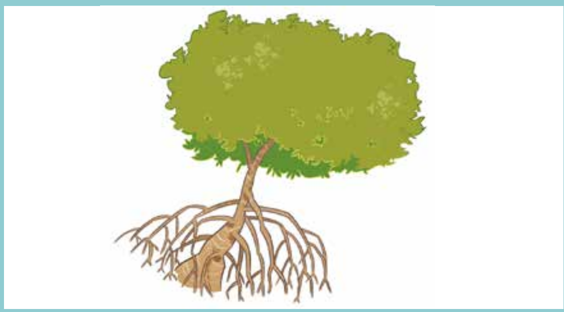
BOWHEAD WHALE

There are 17 different types of whales living in Arctic waters. The bowhead whale is the only baleen whale (toothless whales that filter food from seawater) living there all year round. They only eat krill.

LITTLE AUKS

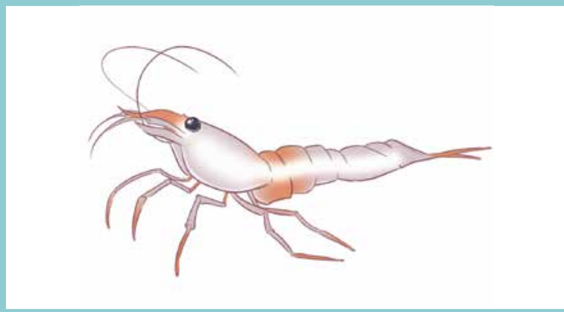
Little auks are among the most common and smallest seabirds in the North Atlantic, weighting only 150 g. They prefer regions with cold currents and avoid more temperate waters. Little auks feed on copepods.

MANGROVE FOOD WEB 1/2



MANGROVE TREE

Mangrove trees grow in large colonies in tropical and sub-tropical coastal areas regularly flooded by tides. The large amount of detritus (leaves, twigs, barks, flowers and seeds) they create can be eaten by crabs, shrimp, sea snails and annelids.

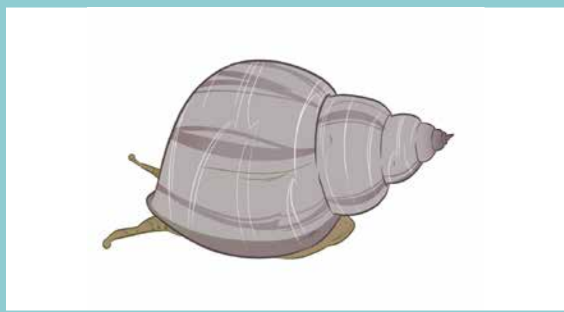


SHRIMP

Shrimp use the muddy bottoms as their homes. Shrimp feed on mangrove detritus they find on the seabed and hide in the sand to escape their predators, such as the red ibis.

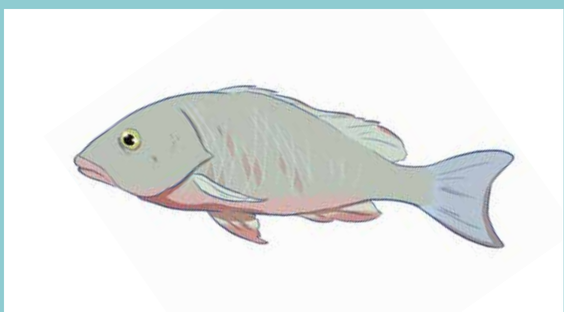
CRAB

Crabs are the most abundant animals in mangroves. Crabs come out of their burrows at low tide to feed on mangrove detritus and annelids. They are eaten by crocodiles and mangrove snappers.



MANGROVE PERIWINKLE

This species of sea snail lives mainly above sea level, on the branches and roots of mangrove trees. It feeds on mangrove detritus and is eaten by mangrove snappers and red ibis.



MANGROVE SNAPPER

The mangrove snapper is typically greyish red and up to 40 cm long. It feeds mostly on small fish such as the periophthalmus, sea snails (such as the mangrove periwinkle) and crabs. It can be eaten by brown pelicans and crocodiles.

BROWN PELICAN

The brown pelican is the smallest of the pelican family. It brown pelican nests in secluded areas such as mangroves. It mainly feeds on fish like the mangrove snapper.

WORKSHEET D2.9

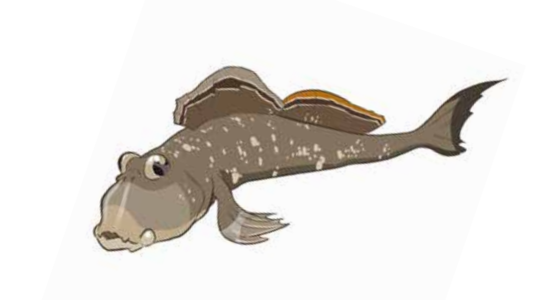
MANGROVE FOOD WEB 2/2

RED IBIS

The red ibis has special feet to move on mud. With its long and thin beak, it can feed within mud by eating shrimp, annelids and sea snails, such as the mangrove periwinkle. Crocodiles can catch red ibis while they are feeding.

ANNELID

Annelids are microscopic worms living in burrows within the mud. They feed on mangrove detritus deposited on the mud, and are eaten by periophthalmus, crabs and red ibis.



PERIOPHTHALMUS

The periophthalmusIt lives mostly in mud and sand bottoms, but can also be seen on mangrove branches, as it can live temporarily out of the water. It feeds on annelids and is eaten by mangrove snappers.

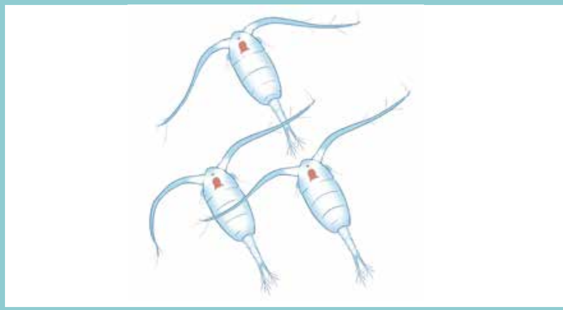
CROCODILE

The crocodile is an opportunistic carnivorous predator. It usually hunts its prey by ambushing them, and then either dragging them underwater so they drown or swallowing them whole. It can eat a variety of prey, including fish (mangrove snapper), birds (red ibis) and crabs.

NORTH SEA FOOD WEB 1/2

PHYTOPLANKTON

Phytoplankton are microscopic organisms floating in the sun-lit upper layer of the ocean. Like plants, phytoplankton use sunlight, water, CO_2 and dissolved minerals for photosynthesis and produce organic compounds. Phytoplankton are a primary producer, at the base of the food web.

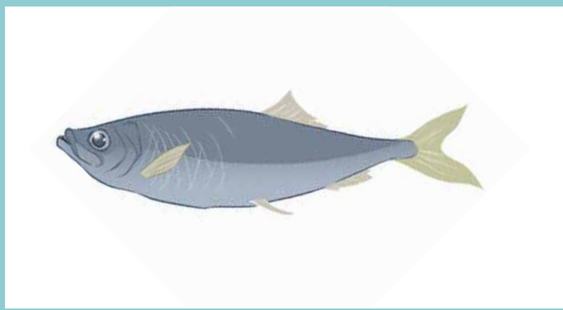


COPEPODS

Copepods are a type of zooplankton, tiny animals drifting with the ocean currents. They are 1 to 5 mm long. They feed on phytoplankton and are eaten by shrimp, herring, mackerel, jellyfish and blue mussels

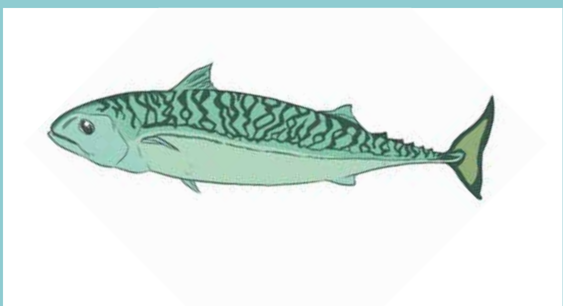
ORGANIC MATTER

The ocean holds a lot of organic matter that comes from dead animals and plants or from animals' faeces. This organic matter accumulates as sediment on the seabed. Descending clumps of organic carbon can resemble snowflakes and are known as "marine snow", serving as food for copepods and shrimp.



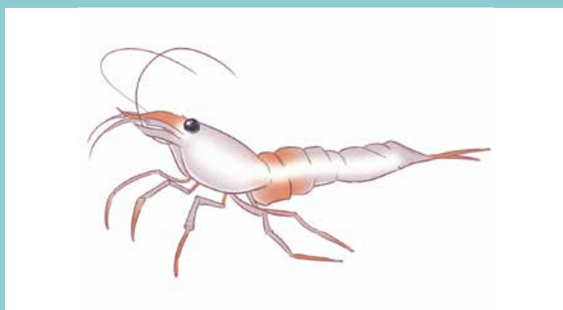
HERRING

Herring live in the open ocean close to the surface. They swim in huge schools and feed on krill. Herring serve as food for species as diverse as spiny dogfish, grey seals, and herring gulls.



ATLANTIC MACKEREL

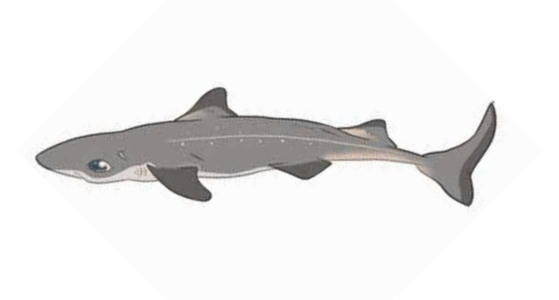
Atlantic mackerel inhabit the open ocean, between the surface and a depth of 200 m, as well as coastal waters. They are constantly in motion and form huge schools. Mackerel feed on copepods and shrimp and their predators include grey seals and spiny dogfish.



SHRIMP

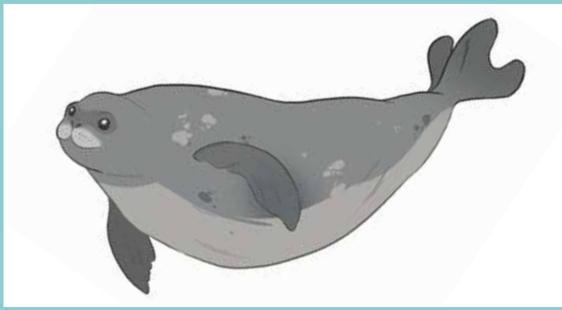
Shrimp inhabit the seabed and shallow waters near coasts and estuaries. They feed on copepods and organic matter. Shrimp hide in the sand to escape their predators: spiny dogfish, grey seals, Atlantic mackerel and herring gulls.

NORTH SEA FOOD WEB 2/2



SPINY DOGFISH

The spiny dogfish is a small shark (approximately 1 m long). It lives in the open ocean at depths between 50 and 200 m. Spiny dogfish hunt in large groups, feeding on other fish such as herring and Atlantic mackerel, and on jellyfish and shrimp or even oystercatchers.

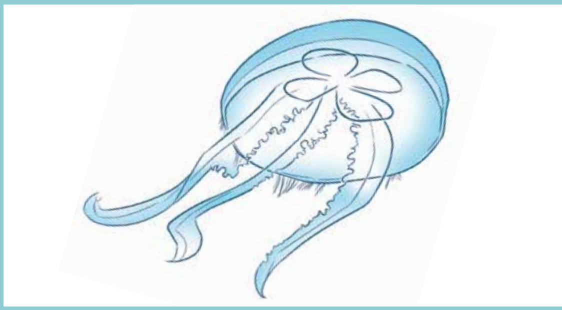


GREY SEAL

Grey seals live in huge colonies on sand or rocks along the coast. They are carnivores and very fast swimmers, diving for their prey at depths of up to 70 m. Grey seals eat almost everything: fish, such as herring and Atlantic mackerel, but also shrimp and jellyfish.

HERRING GULL

Herring gulls are the most common gulls on North Sea shores. They prefer to breed on steep cliffs to protect their eggs and hatchlings from predators on the ground. Herring gulls are omnivores and feed, among others, on herring, Atlantic mackerel, shrimp and blue mussels.



JELLYFISH

Jellyfish can swim but usually drift with the ocean currents and are thus classified as zooplankton. They catch their prey with their four tentacles. Jellyfish feed on phytoplankton and zooplankton like copepods. Spiny dogfish and grey seals are among their predators.

BLUE MUSSEL

Blue mussels are bivalve molluscs living in the intertidal zone. They attach to rocks or to one another, forming large mussel beds. They are filter feeders, feeding on phytoplankton and zooplankton (such as copepods). Their predators are birds like oystercatchers or seagulls, such as the herring gulls.

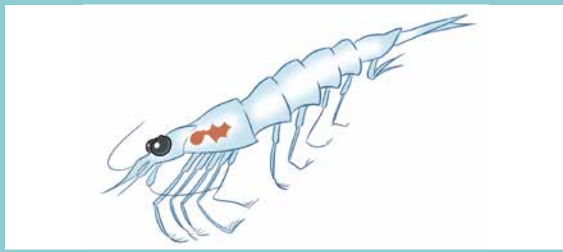
OYSTERCATCHER

Oystercatchers are widespread in the Wadden sea and other shallow intertidal zones. With their long orange beaks, these birds can open the shells of blue mussels to eat them.

ANTARCTIC FOOD WEB 1/2

PHYTOPLANKTON

Phytoplankton are microscopic organisms floating in the sun-lit upper layer of the ocean. Like plants, phytoplankton use sunlight, water, CO_2 and dissolved minerals for photosynthesis and produce organic compounds. Phytoplankton are a primary producer, at the base of the food web.



KRILL

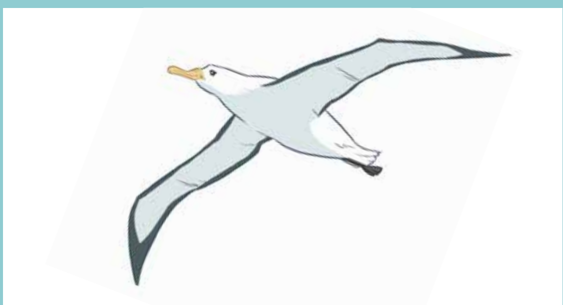
Krill are a type of zooplankton, tiny animals drifting with the ocean currents. They can be a few centimetres long and weigh up to 2 g. Antarctic krill are one of the most abundant multicellular species in the world (est. 500 million tons). Krill are filter feeders – they filter phytoplankton out of the water. They serve as food for all animals in the Antarctic food web except orca.

TOOTHFISH

This fish from the Antarctic is caught at a depth of 2000 m. Toothfish eat krill and cuttlefish, and are eaten by seals and penguins.

PENGUIN

Penguins breed on the pack ice (sea ice not landfast) in Antarctica during the winter. Females lay a single egg that the adults keep warm on their legs, while taking turns to go fishing at sea. Its elongated shape and fin-like wings (penguins do not fly) allow them to swim underwater. They eat krill, cuttlefish and toothfish, and are eaten by leopard seals and orcas.



ALBATROSS

The albatross is a seabird. It has the record for the largest wingspan of all current bird species (which can reach more than 3 m). It nests in colonies on isolated islands. Albatross eat cuttlefish and krill.

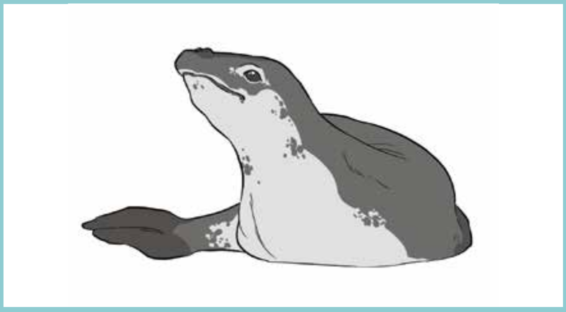
CUTTELFISH

The cuttlefish is a fast-growing shellfish. It has eight arms and two longer tentacles that they use to catch their preys. Cuttlefish eat krill and serve as food for seals, orcas, albatross, penguins and large fish such as toothfish.

ANTARCTIC FOOD WEB 2/2

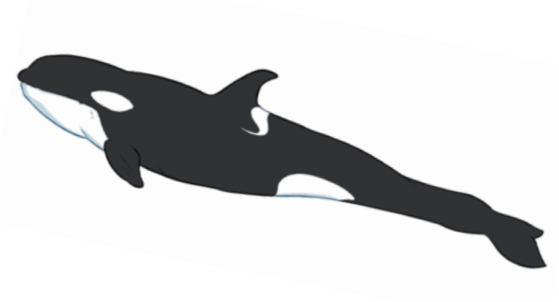
WEDDELL SEAL

The Weddell seal is between 2 and 3 m long and can live up to 20 years. It is an exceptional diver and can stay underwater for more than an hour in search of food (krill, cuttlefish and toothfish).



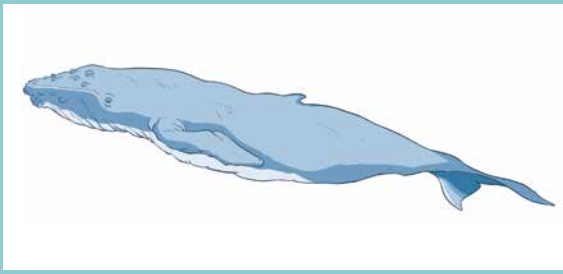
LEOPARD SEAL

The leopard seal is a powerful predator of up to 4 to 5 m long that weighs more than 500 kg. It is a solitary animal and can live for more than 20 years. Leopard seals eat penguins, krill and Weddell seals.



ORCA

The orca is found in both the Arctic and Southern Oceans, and can go as far as tropical seas. It is a highly social animal that lives in families. Its hunting techniques are highly developed and it feeds on large animals, such as seals, whales, cuttlefish and penguins.



HUMPBACK WHALE

The humpback whale is generally 14 to 15 m long and weighs about 25 tons. It lives in the world's oceans and breeds near the equator. It migrates either to the Arctic or Antarctic when summer arrives and the pack ice melts. Humpback whales feed on krill and are eaten by orcas.

LESSON D3
OCEAN AND CRYOSPHERE CULTURAL SERVICES

MAIN SUBJECTS
Social sciences / Visual or performing arts

DURATION
~ Preparation: 20 min
~ Activity: 2 h

SUMMARY
This session should be adapted to local contexts. An example is provided.
Through documentary research and / or an artwork / artistic performance, students learn about the cultural importance of the ocean and cryosphere for human populations across history.

KEY IDEAS
~ The oceans and cryosphere have influenced and influence our history, culture and economy.
~ Before the use of coal, gas and (petroleum) oil, whale oil was an important energy source.
~ There is a strong link between polar exploration and the whale industry: the discovery of Spitzbergen and of Antarctica opened new territories for whale hunters, contributing to an increase in whale hunting.
~ The number of whales has decreased dramatically since then, but today populations are starting to increase again.

KEYWORDS
Whaling industry, polar exploration, economy, whale oil

INQUIRY METHOD
Documentary analysis

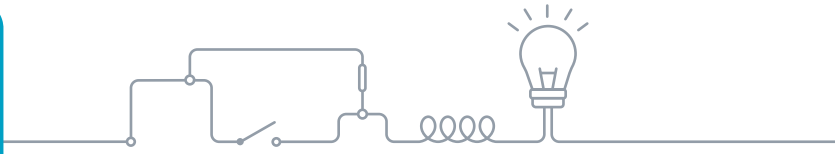
PREPARATION 20 MIN

MATERIALS

- **WORKSHEETS D3.1, D3.2, D3.3**;
- Long paper sheet (to produce a timeline);
- Computer / tablet / mobile with Internet access;
- World map.

LESSON PREPARATION

1. List the websites that can be used for the documentary study (a first list is provided below).
2. Print the **WORKSHEETS D3.1, D3.2, D3.3**, one per student (or group of students).



INTRODUCTION 10 MIN

Start by asking the students: *What were the main sources of energy before the use of oil, gas and coal? What was used to power city lighting before gas and electricity?* The answer is whale oil.

PROCEDURE 1 H 40

PART 1 (50 MIN) – WHALE OIL

1. Calculate the number of whales needed every day to light the 5,000 lamps in the city of London in 1740, considering that:

- A sperm whale could provide about 30 barrels of oil (a barrel being 158 litres of oil);
- A lamp would burn around 2 litres in 10 hours.

Answer: about one whale per night was “burnt” in the city of London.

2. Ask the students to put together a timeline of the whale industry from Basque whaling, through to Antarctic and South Georgia whaling using the links provided in **WORKSHEET D3.1** as information sources. With the help of **WORKSHEET D3.1**, they can conduct their online research independently.

3. Using the information they find, highlight the link between the exploration of the Arctic and Antarctic and the whale industry. Think about the impact exploration had on the economy. The students can write a small text or give a small talk. Make sure you also discuss the reliability of the different information sources provided.

PART 2 (50 MIN) – TODAY’S OIL

4. With **WORKSHEETS D3.2** and **D3.3** the students can analyze and answer the questions about the new maritime routes that are opening up due to sea ice melting in the Arctic.

Following the questions in the end of **WORKSHEET D3.3**, debate with the class on what they think the causes and implications of the opening of these new maritime routes are.

WRAP-UP 10 MIN

Discuss the parallel between the consumption of whale oil and today's consumption of fossil fuels (as two examples of exploited resources) and the search for new maritime routes that will allow access to new oil fields. (The Arctic is considered to have high potential for new oil field finds, which are currently too expensive to exploit due to their inaccessibility, but this will change as sea ice melts and new maritime routes facilitate exploitation. Not only maritime transport companies will benefit from sea ice melting, but also oil companies).

BACKGROUND FOR TEACHERS

From the 11th to the 17th century, maritime exploration helped shape the global economy. The main fuel used from the 16th to the 19th century was wood, but most lamp oil was from whales. Whale oil was also used for heating and cooking. Moreover, the oil of sperm whales was used for the lubrication of high-quality engines. Baleens were used for making women's corsetry and whale meat was commonly eaten.

Due to their multiple uses, whales were intensively hunted, and their populations decreased very rapidly until the early decades of the 20th century. Whale hunters were forced to seek new whale populations living in places further from European coasts in order to address the increasing demand for whale oil. For example, the discovery of Spitsbergen (part of the Svalbard archipelago, in northern Norway), which was known for its large whale population, attracted many whale hunters and led to fishery disputes, especially between Dutch, English and French vessels. Later on, the decrease in Arctic whale populations due to overfishing, and the exploration of new territories and polar lands, pushed whaling fleets to seek places where they could find migrating whales, such as South Georgia and Antarctica.

Nowadays, commercial whale hunting has almost stopped and whale populations are recovering.

The importance of whale products at the end of the 20th century can be seen as a parallel to today's fossil fuel consumption: it is widespread, used in all sectors of our society, our economy depends very strongly on it and… it is a finite resource with multiple impacts on the Earth's ecosystems.

WORKSHEET D3.1

POLAR EXPLORATION

- → https://en.wikipedia.org/wiki/History_of_Antarctica
- → https://en.wikipedia.org/wiki/Arctic_exploration
- → https://www.rmg.co.uk/discover/explore/exploration-endeavour/polar-exploration
- → https://www.canterbury.ac.nz/media/documents/oexp-science/gateway-antarctica/gateway-antarctica-activities/The-History-of-Antarctic-Exploration.pdf

WHALING

- → https://en.wikipedia.org/wiki/Whaling
- → https://www.whalefacts.org/whale-hunting/
- → https://www.whalingmuseum.org/learn/research-topics/overview-of-north-american-whaling/whales-hunting
- → http://www.scran.ac.uk/packs/exhibitions/learning_materials/webs/40/whaleoil_overview.htm
- → http://www.petroleumhistory.org/OilHistory/pages/Whale/prices.html

SHIPPING ROUTES

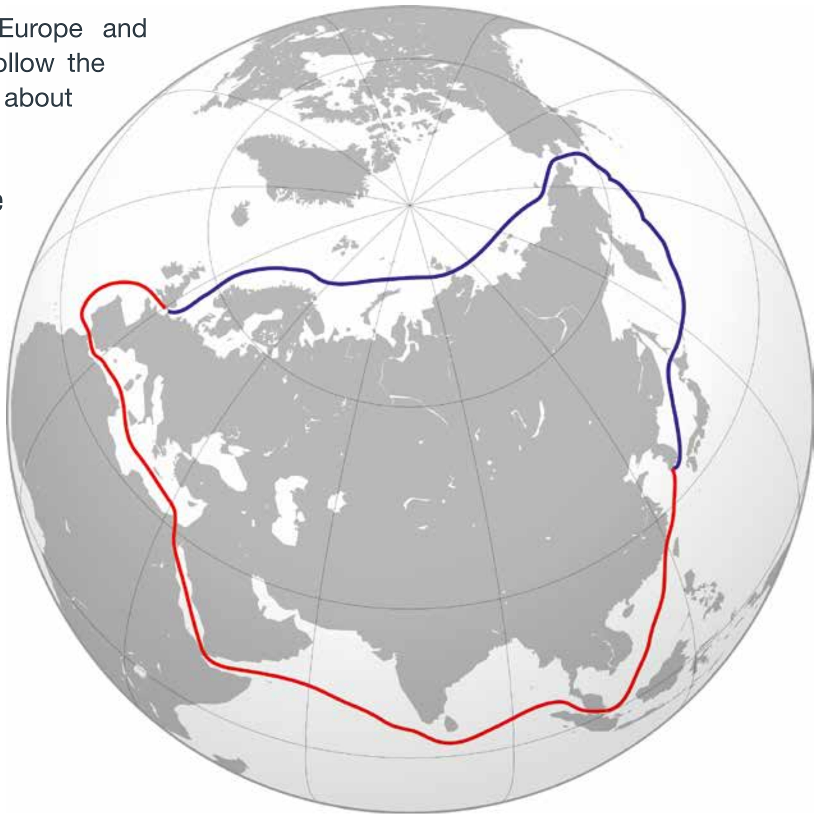
- → https://www.maritime-executive.com/editorials/the-arctic-shipping-route-no-one-s-talking-about
- → https://www.britannica.com/place/Northwest-Passage-trade-route
- → https://en.wikipedia.org/wiki/Northeast_Passage
- → https://en.wikipedia.org/wiki/Northwest_Passage

WORKSHEET D3.2

The figure below shows a photo of a container ship. Container ships are cargo ships that transport their load in truck-sized containers. A large share of maritime cargo is transported with container ships.

When transporting goods between Europe and Asia, large container ships currently follow the red path (called the maritime silk road): about 21,200 km in approximately 50 days!

➔ **Why do you think they can't follow the blue path (the Northern sea route)? It is only around 14,062 km long and travel time would be two weeks shorter.**



WORKSHEET D3.3

Look again at these images that you already know from a previous lesson.

- Do you remember what the difference was between these two images?
- Can you draw the blue path of the previous figure on both images?
- Do you think large container ships could take the blue path in 1979? What about in 2015?

Source: NASA – https://svs.gsfc.nasa.gov/4435

Nowadays, some vessels already take the Northern sea route, but they usually have to be escorted by expensive icebreakers (which are very strong ships capable of breaking the sea ice to create a passage for vessels that follow). Since this is dangerous and expensive, few maritime transport companies choose to use this route.
For container ships, it was almost impossible to take the Northern sea route until very recently: In September 2018, the ice-class ship, Venta Maersk (in the figure of **WORKSHEET D3.2**), finally made it: it was the first container ship to take the Northern sea route (the blue path), and only needed an icebreaker escort for a few days.

- Why do you think Venta Maersk finally made it in 2018, almost without an icebreaker escort?
- Do you think this is good or bad? Why?
- Who do you think will benefit most?

Note: Ice-class ship – a ship capable of navigating through sea ice.