

2023

GLOBE LAC REGIONAL OFFICE – LAC ACADEMIC PEDAGOGICAL COMMITTEE

HYDROSPHERE

Image: Matt Hardy



LEARNING ACTIVITIES

THE GLOBE PROGRAM



The GLOBE program is an international hands-on science learning program that brings together students, educators and scientists from around the world in the study of Earth system science. The main goals of this program are to improve science education, raise environmental awareness, and create a greater understanding of the Earth as a system. For more information visit www.globe.gov

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Aquatic Macroinvertebrates as Indicators of Water Quality

GLOBE		SDG Partners	Type of Activity
Areas	Associated Protocols		
Hydrosphere	Dissolved oxygen, Conductivity, pH, Temperature, Transparency.	6 (Clean water and sanitation)	Exploratory

Overview

When talking about Biological Indicators of Water Quality, we observe that only a few organisms can satisfy these requirements. Aquatic macroinvertebrates are considered as the best bioindicators of water quality. Bioindicators are used in addition to physicochemical analyses; their advantages are that they are not limited to the time of taking the sample; They allow to discover of changes produced over time since living organisms present evolutionary adaptations to specific environmental conditions and have limits of tolerance to the different alterations of the same, which allows having a particular historical vision of the events that occurred in a period, depending on the dynamics of the biological communities present.

Time

2 classes

Prerequisites

Basic knowledge of ecosystems, food webs, populations, meteorology, and water quality.

School-level

High school students.

Purpose

Conduct a water quality assessment using aquatic macroinvertebrates as indicators of hydrobiological resources.



Student outcomes

- ✓ Identify the aquatic macroinvertebrates present in a body of water.
- ✓ Assess water quality using macroinvertebrates as bioindicators.

Background

Biological indices are used in addition to physicochemical analyses, although with their application, it is impossible to identify existing pollutants; their advantages are that they are not limited to the time of taking the sample; They allow to discover changes produced over time, since living organisms present evolutionary adaptations to specific environmental conditions and have limits of tolerance to the different alterations of the same, which allows having a particular historical vision of the events that occurred in a period, depending on the dynamics of the biological communities present.

Thus, for example, if in a given area of a river, there are high values of oxygen, low turbidity, low color, and low conductivity, but oligochaetes, mollusks, and chironomids dominate the fauna present, there is no doubt that in that site most of the time conditions of high pollution predominate and that the moments of cessation of this are so brief, which are insufficient to bring about significant changes in the structure of the community.

Numerous biological indices are based on communities of algae, macrophytes, bacteria, fish, and various groups of invertebrates. However, the most advanced and widespread natural methods among the specialized literature are those based on the composition of the benthic macroinvertebrate community, which are those organisms that have a size greater than 0.3 mm in length and lack a backbone, such as crabs, insects (larvae, pupae, and adults of some orders), mollusks, turbellarians, annelids, among others. With the presence/absence of these organisms, biotic indices can be calculated, which are systems for classifying water quality by giving a score. Biological methods, never excluding physicochemical quality, are relatively simple, fast, and inexpensive, making them ideal for monitoring, surveillance, and control of watersheds.

Guiding Research Questions

Scientific concepts

- Bioindication for water quality assessment
- Aquatic macroinvertebrates.
- Habitat types of aquatic macroinvertebrates.
- Lifestyles of aquatic macroinvertebrates

Materials and tools

- 1) Metal or plastic mesh net of about 1.0 m²
- 2) Triangular or "D-net" type hand net
- 3) Bucket.
- 4) Plastic bags or containers.
- 5) 70% alcohol



- 6) Markers
- 7) White trays.
- 8) Fine-tipped tweezers.
- 9) Magnifying lenses (Magnifier)
- 10) Stereomicroscope (optional)

What to do and how to do it

1. Sampling

To collect the most remarkable possible diversity of macroinvertebrates, it is essential to carefully explore the sampling site to cover all possible habitats, i.e., bottom substrate (sand, stones, mud, vegetation debris); aquatic plants (floating, emerging, and submerged); tree roots, etc. To obtain comparable results, the sampling effort should cover an area between 10 and 20 m² and be done for 20 or 30 min.

Sampling should not be carried out after heavy rains, as there may be a loss of local organisms or others being swept away by the current. Sampling should be done in large rivers on both banks, as the fauna may differ due to shade, meanders, bottom composition, and eventual contamination.

In the case of streams with stony substrates, the most used qualitative method is the screen network; that is, only the diversity of species is determined, but not their abundance per unit area. It consists of a metal or plastic mesh net of approximately 1.0 m² fastened on each side by two sticks of 1.5 m in length. While one person holds the mesh over the bottom of the river, another removes the bottom against the current; The removed organisms are trapped in the mesh with the substrate.

The vegetated shores are usually affluent in macroinvertebrate fauna. There live especially larvae of odonates, Hemiptera, mollusks, and crustaceans. Qualitative sampling with a triangular or "D-net" handset is the most commonly used for these sites. With the help of these nets, a sweep is made along the banks with vegetation, thus trapping the organisms existing there.

For all the above methods, it is recommended to take five aftershocks to cover different points of the cross-section of the water course.

The samples collected by the different methods are washed, preferably in a limnological bucket, with mesh at the bottom (less than 0.5 mm), and the organisms are then taken to the laboratory and stored in bags or plastic containers with 70% alcohol, adequately labeled, for separation, identification, and counting.

2. Treatment of samples

The samples are placed in white, well-lit trays, and with the help of fine-tipped tweezers, the organisms present are extracted, taking care not to mistreat them. The substrate is carefully removed from one end of the tray to the other until it is ensured that no organisms remain. It should be noted that when you do not have enough experience, many organisms



can go unnoticed, either because of their size or because they are camouflaged with the remains of vegetation or mineral substrates. This work must be performed or supervised by appropriately trained persons. The samples are stored in 70% alcohol in adequately labeled bottles.

3. Identification of aquatic macroinvertebrates

Macroinvertebrates are identified in a stereo microscope with the help of existing literature.

BMWP method

The Biological Monitoring Working Party (BMWP) index was created in England in 1970 as a simple and rapid method to assess water quality using macroinvertebrates as bioindicators; For the application of the index, it is only necessary to reach the family level and the data are qualitative, that is, it gives information on the presence or absence of organisms. The index allows estimating the quality of an aquatic ecosystem from the valuation of the aquatic species that inhabit it; Each species is assigned a specific value according to its tolerance to pollution ranging from 1 to 10 so that the most tolerant families obtain a lower score than those that require a better quality of the waters in which they live. The sum of the values obtained for each family at a sampling point shall give the degree of contamination of the same. The higher the sum, the lower the contamination of the point studied.

Scores assigned to the different families of aquatic macroinvertebrates to obtain the BMWP

Family	Score
Anomalopsychidae, Atriplectididae, Blephariceridae, Ptilodactylidae, Chordodidae, Gripopterygidae, Lampyridae, Odontoceridae, Perlidae, Polymitarcyidae, Polythoridae, Psephenidae	10
Coryphoridae, Ephemeraeidae, Euthyplociidae, Gomphidae, Hydrobiosidae, Leptophlebiidae, Limnephilidae, Oligoneuriidae, Philopotamidae, Platystictidae, Polycentropodidae, Xiphocentronidae	9



Atyidae, Calamoceratidae, Hebridae, Helicopsychidae, Hydraenidae, Hydroptilidae, Leptoceridae, Naucoridae, Palaemonidae, Pseudothelphusidae, Trichodactylidae, Saldidae, Sialidae, Sphaeriidae	8
Ancylidae, Baetidae, Calopterygidae, Coenagrionidae, Crambidae, Dicteriadidae, Dixidae, Elmidae, Glossosomatidae, Hyalellidae, Hydrobiidae, Hydropsychidae, Leptohiphidae, Lestidae, Ochtheridae, Pyralidae	7
Aeshnidae, Ampullariidae, Caenidae, Corydalidae, Dryopidae, Dugesiidae, Hyriidae, Hydrochidae, Limnichidae, Lutrochidae, Lymnaeidae, Megapodagrionidae, Mycetopodidae, Pleidae, Staphylinidae	6
Ceratopogonidae, Corixidae, Gelastocoridae, Gyrinidae, Libellulidae, Mesoveliidae, Nepidae, Notonectidae, Planorbidae, Simuliidae, Tabanidae, Thiaridae	5
Belostomatidae, Chrysomelidae, Curculionidae, Ephydriidae, Glossiphoniidae, Haliplidae, Hydridae, Muscidae Scirtidae, Empididae, Dolichopodidae, Hydrometridae, Noteridae, Sciomyzidae	4
Chaoboridae, Cyclobdellidae, Hydrophilidae, Physidae, Stratiomyidae, Tipulidae.	3
Chironomidae (cuando no es la familia dominante), Isotomidae, Culicidae, Psychodidae, Syrphidae	2
Haplotaxida, Tubificidae	1

Classification of waters and their ecological significance according to the BMWP index



Class	Quality	BMWP Value	Meaning	Colour
I	Good	≥150	Very clean waters	Dark Blue
		123-149	Unpolluted water	Light Blue
II	Acceptable	71-122	Slightly contaminated: contamination effects are evident	Green
III	Doubtful	46-70	Moderately polluted water	Yellow
IV	Criticizes	21-45	Heavily polluted water	Orange
V	Very critical	<20	Heavily polluted water, critical situation	Red

Suggested Resources

To learn more, the following resources are suggested:

Guide to the identification of aquatic invertebrates: http://www2.udec.cl/~lpalma/Palma2013_Guia_identificacion_Macroinvertebrados_preview.pdf

Aquatic macroinvertebrate identification booklet: Guide to participatory monitoring: https://www.researchgate.net/publication/342248615_Cartilla_de_identificacion_de_macroinvertebrados_acuaticos_Guia_para_el_monitoreo_participativo

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Forests retain water

GLOBE		Associated SDG	Type of Activity
Spheres	Associated Protocols		
Hidrosphere	Dissolved Oxygen, Conductivity, pH, water temperature, Transparency.	6 Clean Water and sanitation 15 Life on Land	Exploratory
Atmosphere	Precipitation, Water Vapor		
Biosphere	Biometry, Tree Height		

Overview

Using a simple model of the physical shape of a forest, we can examine the physical reasons that allow water retention in forests, allowing water vapor to condense into droplets that feed our water sources. Understanding this phenomenon will allow us to assess the importance of our forests and moors.

Time

1 class

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School-level

Primary school students.

Purpose

Identify the physical characteristics that allow water retention in forests.

Students outcomes

- ❖ Design a simple model of a forest simulator.
- ❖ To bring the student closer to the understanding of the water cycle.



Background

Forests play a fundamental role in regulating temperature and the water cycle, that is, the process by which water is transported in different forms of precipitation from the air to Earth, where forests and vegetation in general, recycle that precipitation and it returns to the atmosphere, completing its journey.

The natural capacity of forests to intercept and evaporate a greater amount of water than other types of vegetation or other surfaces to capture a greater amount of water through their deeper root systems than those of other types of vegetation and; Filtering and improving the quality of water has also become more important after the water crisis, which affects a large part of the world's population.

Finally, clean fresh water has become a key asset of the 21st century, as continued increases in demand and global change-induced drought are causing chronic shortages in many countries. Forests are essential in the stable supply of clean fresh water and related ecosystem services, such as drinking water, protection against floods, erosion, and landslides, and climate regulation.

Guiding Research Questions

Why can't places without trees or vegetation hold water?

Scientific concepts

- Ecology.
- Conservation.
- Climate change.
- Precipitation.

Materials and Tools

- Three-eighths of black cardboard.
- Frost. (Purpurin)
- Sheets.
- Scissors.
- Scotch tape.

What to do and how to do it

1. Before doing the experiment you have to do the tree simulators, like this:
2. Make fifteen 20cm x 30cm rolls of paper, with a diameter of approximately 2cm.
3. Make cuts along the paper roll halfway.
4. Then roll the paper into a funnel shape.
5. Lay out the paper strips to make it look like a tree.



6. Paste the rolls, in a grid shape on black cardboard.

Now you have a tree-planting simulator!

1. Now make thirty rolls of paper, but in this case in all shapes and sizes.
2. Glue them haphazardly to the other poster board.

You already have a tropical forest simulator!

1. Approximately 30 cm from the poster board and 10 cm from the surface, blow a teaspoon full of frost onto the tree planting simulator.
2. Repeat the same procedure for the forest simulator.
3. Repeat the same procedure on a black card that does not have trees.

To observe:

Where was the frost concentrated? In which case is the frost retained? In which case was it not?

Suggested resources

To learn more, the following resources are suggested:

What role do forests play in the water cycle? https://efi.int/forestquestions/q7_en

Trees and Water: Don't Underestimate the Connection
<https://forestsnews.cifor.org/62808/los-arboles-y-el-agua-no-underestimate-let's-connect>

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Groundwater

GLOBE		Associated SDG	Type(s) of activity/ies
Sphere	Protocols		
Atmosphere	Precipitations	6 (Clean water and sanitation) 7 (Affordable and non-polluting energy) 12 (Responsible production and consumption) 13 (Climate action) 14 (Underwater life) 15 (Life of Terrestrial Ecosystems)	Exploratory
Biosphere	Land cover. Phenology. Tree height.		
Pedosphere	Infiltration. Humidity. Temperature		
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. S		
Bundle	Agriculture ENSO Oceans Rivers and lakes Water cycle. Water quality Soils Meteorology		

Overview

To explore the water cycle in tropical, temperate, and cold zones, and the fundamental role of groundwater in the hydrological cycle, students conduct a simulation experiment with simple materials that allows them to observe the behavior of water well.

Time

1 or 2 classes

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School Level

Elementary and high school students.

**Purpose.**

- *Clarify certain scientific concepts, such as the hydrological cycle and groundwater, more concisely and understandably for the target audience. This will help students better understand the significance of the experiment and its connection to real-world issues.*
- *Include specific instructions and details for the experiment, such as the exact measurements for the gravel and sand layers and the amount of contaminants to add, to ensure consistent and accurate results across all groups.*
- *Provide more context and background information on the negative impacts of human activities on the natural water cycle and potential solutions or actions that can mitigate these impacts. This will help students understand the importance of preserving and protecting our freshwater resources.*
- Understand the natural water cycle and the alterations produced by human activities.
- Analyze their connection to the water cycle and the need to mitigate the negative impacts produced by human activities.

Student Outcomes:

- Design a simple simulation model of a freshwater well.
- To bring the student closer to the understanding of the water cycle.
- Analyze the impact of human activities on the natural water cycle.

Introduction

Groundwater is a natural freshwater resource located at the surface level in the earth's crust. They are usually found in impermeable geological formations called aquifers. Groundwater plays a fundamental role in human activity and the maintenance of ecosystems.

The Food and Agriculture Organization of the United Nations (FAO) defines this type of water as water located below the earth's surface and occupying the pores and fissures of rocks.

Groundwater is housed in sites where the water is kept at a constant temperature similar to the area where it is found. These places are called aquifers and are geological formations made up of different porous and impermeable layers that allow freshwater storage underground.

In particular cold regions, this type of water is expected in a frozen state. On the other hand, in arid or semi-arid regions, groundwater is the only source of fresh water in the area.

Another critical point about groundwater is its fundamental role in the hydrological cycle. On the one hand, rainwater seeps into rivers and lakes and can reach the surface as springs. On the other hand, another part of this resource seeps into the earth's surface and reaches



aquifers, where it can remain for years. In addition, part of this groundwater flows through the soil and reaches the oceans, thus maintaining a balance in the water cycle.

Guiding Research Questions

Where does the water that falls from the sky in the form of rain or snow come from?

How do human activities affect the water cycle?

Scientific Concepts

- Water cycle
- Human uses of water
- Water availability
- Water quality
- Ecology

Material and Tools

- One clean spray bottle (like any cleaning product spray bottle)
- 1-liter plastic bottle
- One cylindrical stick or a fat marker pen
- One piece of plastic netting
- Scissors
- Gravel
- Soil
- Tape
- Contaminants: lemon juice, soap, dye, salt.

What to Do and How to Do It

Beginning

- Generally, water for human consumption is captured in reservoirs or wells, depending on whether it is surface water or groundwater.
- With this experiment, students will understand how a well works and how groundwater contamination occurs.
- First, the groups must build their well, test if and how it is contaminated, and determine their location.
- To begin, divide the students into five groups.

Development

Perform the following experiment to simulate a freshwater well.

Preparation:



1. Construction of the well

Carefully cut the plastic bottle in half. We will use the bottom part.

Wrap the plastic mesh around the stick, holding it tightly with adhesive tape (without sticking to the post).

Place the stick with the mesh inside the bottle, close to the wall, not in the center.

Add gravel (ensuring the stick is kept straight) up to over half of the bottle (about 3/4).

On top of the gravel, add a layer of sand (about one finger thick).

Now comes the tricky part! Carefully remove the stick, leaving the rolled-up mesh inside the container.

Add 200 ml of water from the side very slowly until the gravel is covered, but not the sand.

The sprayer is placed inside the hole of the rolled mesh.

The sprayer is operated several times to check that it works.

Keep squeezing the sprayer so the water inside is extracted and collected in a glass. What color is it?

1. Contaminate the well

You will need to contaminate the well constructed by the students. To do this, carefully add the following to each well:

Group 1: a glass of water and lemon juice (will simulate acid rain).

Group 2: a glass of clean water (will affect that the groundwater has not been contaminated).

Group 3: a glass with water and dissolved salt (simulates seawater, contamination by sea intrusion).

Group 4: add the dye on the sand layer (mimics soil contamination with fertilizers and pesticides). Very slowly, pour a glass of clean water to wash away the stain.

Group 5: a glass of soapy water (simulates water contaminated by household detergents).

For the third time, you can add water to the wells - this time only clean water - so that the students can check that, despite this, the water still comes out slightly contaminated; this way, they will realize that once an aquifer is contaminated, it is very complicated to decontaminate and restore it.

Observation:

Students should extract the groundwater with the sprayer. What is the water like now? (In the case of salt water and lemon water, students should lightly wet their fingers and taste the flavor).



Students should determine whether or not their well is contaminated and, depending on the type of contaminant, indicate its location.

Closing

Questions for reflection:

Which type of water is easier to contaminate: surface water from lakes, rivers, seas, or groundwater?

What types of elements can contaminate groundwater?

Which type of water is easier to clean: surface water or groundwater?

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Gummy bear osmosis

GLOBE		SDGs Associated	Type of Activity
Spheres	Associated Protocols		
Hydrosphere	Salinity Conductivity	13 (Climate action)	Exploratory

Overview

Participants will understand how density works.

Time

30 minutes

Prerequisites

None

School-level

Primary school students.

Purpose

This activity will help participants understand the concept of density and how water density can change with temperature.

Student's outcomes

- Understand density and specific gravity;
- Understanding of osmosis;

Background

Density is the 'lightness' or 'heaviness' of materials of the same size. Density indicates how large the molecules are and how close they are to each other in a given substance. The larger and closer together the molecules are, the greater the density of the substance (figure 1). Density is determined by how heavy something is compared to its volume. We say that a metal spoon has a greater density than a wooden spoon of the same size because the metal spoon is heavier. Which has greater density: a tennis ball or an iron ball of the same size?

The density of water is roughly 1 gram per milliliter however, this can change if you

- Change the temperature, for example, hot water has a lower density than cold water and for that reason hot water floats as a body above cold water.



- Add other substances to it, for example, saltwater is denser (1025 kg/m³) than fresh (1000 kg/m³) because of all the salts that are dissolved in the water.

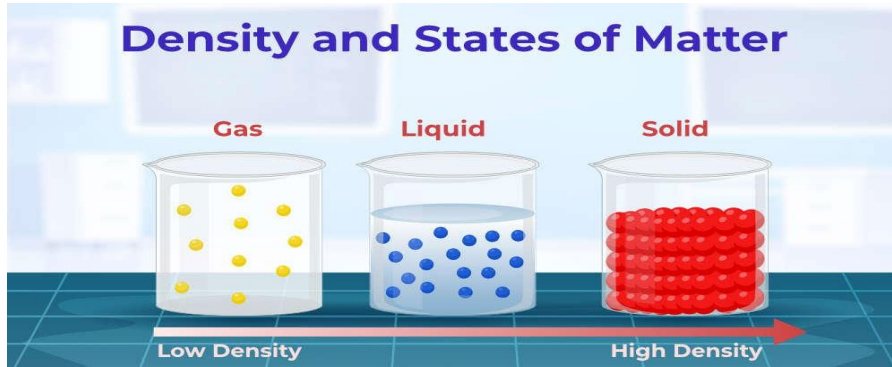


Figure 1 Density and states of matter. Source: <https://media.geeksforgeeks.org/wp-content/uploads/20230311110034/Density.jpg>

The gummy bear experiment has to do with osmosis (figure 2). This is the process by which water moves from an area with a lot of water to an area with less water, e.g., from a solution with a lot of water to a highly concentrated solution (less water). The gummy bear is semi-permeable. What does that mean? It can pass water molecules but not large molecules.

In your body, the cell membrane regulates what enters and leaves your cells using osmosis. The different concentrations of sugar, proteins, DNA and water between the inside and outside of the cell ensure that materials can flow in and out of the cell. But unlike our gummy bears, which are semi-permeable, our cells are selectively permeable; meaning that this process only allows specific material to enter and exit the cell membrane.

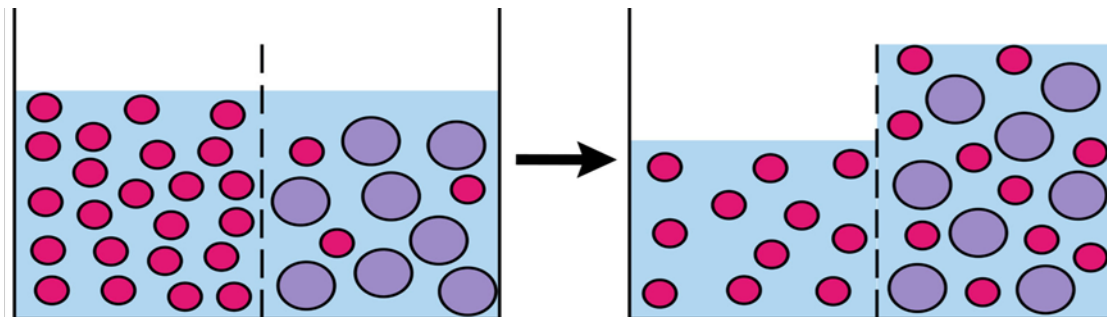


Figure 2 Osmosis. The red dots represent water and the violet dot is the solute particles. The water molecules pass through the membrane to reduce the concentration of the solution. Note how the solute particles cannot pass through the membrane. Source: <https://www.science-sparks.com/wp-content/uploads/2018/09/Osmosis-Diagram-1536x536.jpeg>

Seawater has a higher density than pure water. This is because seawater contains a lot of chemicals which causes a high salinity, the high salinity makes the water dense. The higher the salinity, the higher the density (more salt in the water). The density of seawater plays an important role in causing ocean currents and circulating heat. The dense water sinks below the



less dense water (Do you think that the dense water has a higher or lower temperature than the less dense water?).

Deep water is denser than shallow water. The water molecules are packed together more tightly because of the weight of water above pushing down. Rainfall, evaporation and solar radiation can cause the salinity and temperature of the ocean to rise and fall, subsequently affecting the density and causing water to sink or rise. This principle drives the deep ocean currents that circulate the world.

As a result of climate change, the ocean is gradually taking up additional heat. Even the smallest rise in temperature can have a big impact. For example, if you raise the temperature of 1 liter of water, from 20°C to 21°C. It would increase in volume by 0.21 milliliters. This may seem like a tiny increase, but the ocean contains about 1,400,000,000 cubic kilometers of water. Even a tiny increase adds up to a very large increase in volume and causes a substantial sea level rise.

Guiding Research Questions

- *What happens when you put the gummy bear in the water with salt and sugar?*

Scientific concepts

- Density
- Osmosis

Materials and Tools

- A pack of gummy bears
- Salt
- Sugar
- 4 bowls
- Water
- Optional: stopwatch and scale or ruler.

What to do and how to do it

Beginning

In the case of a large group, divide the participants into groups of 2 people. Give every group 3 bowls of water of the same temperature (room temperature, hot or cold).

Development

1. Pour the same amount of water into 3 dishes and measure the temperature. The bowls should have enough water to cover the gummy bears completely.
2. Add salt to the water in 1 of the bowls and sugar to another.
3. Place a red gummy bear in each bowl. Set aside 1 gummy bear to use later for comparison. Now we have to wait (start the stopwatch)!
4. After a while, you will see one of your gummy bears start to swell. How big can it get? It's up to you to find out.



5. Now compare the puffy gummy bear with the normal gummy bear. Do you see a difference? Do you know what happened?
6. Repeat the experiment with hot water. Measure the temperature of the water before continuing the experiment. Is there a difference?
7. Repeat the experiment with cold water. Measure the temperature of the water before continuing the experiment. Is there a difference? How did the temperature impact the experiment?

Closing

Discussion/Reflection

This process happened much faster when the gummy bear was in pure water because the water concentration difference between pure water and the gummy bear was the largest. The gummy bear in the salt water did not swell as quickly because the water concentration difference between the salt water and the gummy bear was less different. We call this difference a **concentration gradient**. The gummy bear in the salt water also did not grow as big because the water stopped moving in the gummy bear once the water concentration in the gummy bear and the salt water became the same.

Additional tests

1. Try different amounts of salt or sugar in the water. Can you predict the change in size as the salt or sugar concentration in the water increases?
2. What happens if you try this with hot and cold water?
3. Does the color of the gummy bear matter?
4. Is there a waterbody in your area? How does the density change after it rains? Or when it is dry? Are there any other changes in the water (e.g. the water is clearer, darker/murkier)? How can you measure this change? You can use the GLOBE Conductivity (for freshwater water bodies such as rivers, lakes, or ponds) or the GLOBE salinity protocol (for saltwater water bodies such as salt lakes) to measure this change.

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Homemade acid-base indicator

GLOBE		Associated SDG	Type of Activity
Spheres	Associated Protocols		
Hydrosphere	pH.	6. Clean Water and Sanitation	Exploratory
Pedosphere	PH.		

Overview

pH measurements directly indicate the habitability of a body of water for aquatic life. It is interesting to follow the parameters of the water cycle and the pH annually and then compare different bodies of water.

Time

Two classes

Prerequisites

Basic knowledge of ecosystems, food webs, populations, meteorology, marine currents, water quality, and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School level

last years of primary, secondary.

Purpose

Develop students' skills through chemistry lessons involving the topic of pH.

Student outcomes

- ✓ Identify the methodology for obtaining acid-base indicators from purple cabbage and red rose petals.
- ✓ Classify different substances or products of everyday life as acidic, basic, or neutral, employing an acid-base indicator.

Background

Various techniques and instruments are used to indicate the pH value of a solution, some more precise than others, but which allow characterizing an acidic, basic, or neutral substance.



Among the procedures and instruments used are universal indicator paper, pH meters, colorimeters, and those that are homemade as homemade pH indicators.

pH is a chemical property that measures the degree of acidity or alkalinity of aqueous solutions. By definition, pH is the negative logarithm of proton activity (H^+) in an aqueous solution.

The pH uses a measurement scale whose fluctuation ranges from 0 to 14. It is based on the principle that the equilibrium constant of water dissociation is 10^{-14} .

Acids and bases are important in the pharmaceutical, food, and biotechnology industries, among others. A specific pH conditions many processes, and some variation would cause its alteration. All substances have a specific pH value, and their usefulness is derived according to this.

In soils, pH is a significant chemical property because it indicates how acidic or alkaline the soil solution is, where the roots and soil microorganisms take their nutrients.

Various techniques and instruments are used to indicate the pH value of a solution, some more precise than others, but which allow characterizing an acidic, basic, or neutral substance. Among the procedures and instruments used are universal indicator paper, pH meters, colorimeters, and those that are homemade as homemade pH indicators.

Many natural and synthetic substances have a coloration that depends on the pH of the solutions in which they dissolve. Some of these compounds, which have been used for centuries to determine the acidity or alkalinity of water, are still used as acid-base indicators.

The acid-base indicators are weakly acidic or basic organic substances which present different colors when they are in their protonated or deprotonated form; this means that they change their color depending on the pH.

Guiding Research Questions

How do pH indicators or meters work?

What is the correct way to measure pH?

What does the coloring on the meter indicate?

Scientific concepts

- Ecosystems
- Changes in the populations of some species
- Interrelationships of matter and energy in ecosystems
- Ocean currents
- Environmental risks and vulnerability



Materials and tools

- 1) 200 grams of cabbage.
- 2) 200 grams of red roses. (5 or 6 roses)
- 3) 2 beakers of 500 ml.
- 4) 2 mortar and pistil.
- 5) 5 glass glasses.
- 6) 2 pipettes of 10 mL.
- 7) 1 filtration funnel.
- 8) 1 filter paper.
- 9) 1 thermometer.
- 10) 2 flasks.
- 11) 2 jars or dark bottles.

What to do and how to do it

1. Beginning

Each group of students, of about four members, will be organized to perform this practice. The teacher can manage the number of members of the groups depending on the number of students per course and the conditions available in the classroom or laboratory of the institution.

2. Development

1. With the help of the scale, weigh the amount of purple cabbage indicated above.
2. Cut the cabbage leaves into small pieces and add them to the mortar.
3. Wet the cabbage leaves by adding 20 ml of water; with the help of the pistil macerate.
4. Place 200 ml of water in the beaker and heat to a boiling point.
5. When the water reaches the boiling point, add the contents of the mortar and boil for 15 minutes.
6. Subsequently, the beaker's contents are lowered from the flame and left to stand until the contents reach room temperature.
7. Filter the contents to separate the solid substances from the extract obtained.



8. Store in a glass or dark plastic container in a refrigerator for use in the next session.

For the preparation of the acid-base indicator of red rose petals should be repeated the process used with purple cabbage

3. Ending

Each group shall take the test tubes with the help of the masking tape list or the test tubes from one to twelve according to the order of the substances used. Next is the order of the substances:

1. Vinegar
2. Aspirin
3. Baking soda
4. Liquid soap
5. Toothpaste
6. Hydrogen Peroxide
7. Sodium Hypochlorite – (Clorox)

- Each group takes 3 ml of each substance and adds them to the above tubes.
- Add 3 ml of water to each of the marked tubes.
- Add 3 ml of the acid-base indicator from purple cabbage in each tube.
- Discuss the following scenarios and answer the following questions:
- What colors do the different substances present?
- When water is added to each tube, do the substances undergo any changes?
- What does the color of homemade acid-base indicators depend on?
- When is the acid-base indicator added in each of the tubes that will be colored?
- Does the type of coloration depend on the substance in which the indicator is located?

Suggested Resources

To learn more about this phenomenon, the following resources are suggested:

The pH Game https://www.globe.gov/documents/10157/381040/hydro_chap_es.pdf

pH https://www.globe.gov/documents/10157/381040/hydro_chap_es.pdf protocol

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Lava lamp

GLOBE		SDGs Associated	Type of Activity
Spheres	Associated Protocols		
Hydrosphere	Salinity Conductivity	13 (Climate action)	Exploratory

Overview

Participants will understand how density and polarity work.

Time

30 minutes

Prerequisites

None

School-level

Primary school students.

Purpose

This activity will help participants understand the concept of density and polarity and how water density can change with temperature.

Students outcomes

- Understand density and the impact of temperature on density;
- Understand polarity and how nonpolar and polar fluids interact with each other.

Background

Density is the 'lightness' or 'heaviness' of materials of the same size. It indicates how large the molecules are and how close they are to each other in a given substance. The larger and closer together the molecules are, the greater the density of the substance. Density is determined by how heavy something is compared to its volume. We say that a metal ball has a greater density than a wooden ball of the same size because the metal ball is heavier.

Polarity is the quality of having two oppositely charged poles. When atoms combine to form a molecule they either share or exchange electrons. True molecular compounds are formed when two or more atoms share electrons, resulting in what is called a **covalent bond**. These bonds are very strong and require a good deal of energy to break. Compounds formed with covalent bonds do not conduct electricity, do not have a positive or negative charge, and are referred to as



nonpolar because they are not very soluble in water. Oil molecules are nonpolar, this is why oil and water don't mix.

Polar molecules, on the other hand, are readily soluble in water. They are formed when atoms exchange an electron to form a bond called an **ionic bond**. These bonds are strong because the atoms have become more stable due to either losing or gaining an electron (called ionization). Molecules formed from ionic bonds are not true molecules because the electrons are not shared but exchanged. Water molecules are "polar" because they have a lopsided electrical charge that attracts other atoms. The end of the molecule with the two hydrogen atoms is positively charged. The other end, with the oxygen, is negatively charged. Just like in a magnet, where the north poles are attracted to the south poles ("opposites attract"), the positive end of the water molecule will connect with the negative end of other molecules.

Whenever we have an oil spill in the environment, we can see it float on the water. An oil spill refers to the accidental release of oil into the environment, typically occurring in bodies of water such as oceans, rivers, or lakes. Oil spills have significant environmental and ecological consequences. Because oil has nonpolar molecules and a lower density, it forms a thick layer on the surface of the water. This prevents sufficient amounts of sunlight from entering the surface, and also reduces the level of dissolved oxygen in the water, causing harm to marine life.

Guiding Research Questions

- *What happens when you mix the oil and food coloring with the water?*
- *What happens when you put effervescent tablets in the water?*

Scientific concepts

- Density
- Polarity

Material:

- A clean plastic bottle, try to use one with smooth sides
- Water
- Vegetable oil (or you can use mineral or baby oil instead, and also use discarded vegetable oil that is filtered)
- Effervescent tablets (such as Alka Seltzer)
- Food coloring

What to do and how to do it

Beginning

Pose the guiding questions and then explain the scientific concepts necessary to begin the activity.

Development

1. Fill the bottle approximately 1/4th (1 quart) with water.



2. Pour the vegetable oil into the bottle until it is almost full. You may want to use a measuring cup with a spout or a funnel. You may have to wait a few minutes for the oil and water to separate.
3. Add a few drops of your favorite food coloring. Watch the color sink through the oil. Did the drops of dye mix immediately with the water or did they float for a few minutes?
4. Break your effervescent tablet in half and drop some of it into the bottle.
5. You can take a flashlight, turn off the lights and drop another half tablet into the bottle. Shine your flashlight through the bottle, now you have your own lava lamp.

Closing

Discussion/ Reflection

1. Why does the oil float on the water (hint: there are 2 reasons for this)?
2. Why does the food color mix with the water but not with the oil?
3. When you add the tablet, it sinks to the bottom and begins to dissolve. As it dissolves, it makes gas, carbon dioxide. Why do the bubbles float to the top (hint: think of the density of water in different states)? The air bubbles bring up some colored water. When the air comes out of the colored water bubble, the water sinks. Why do you think this happens?
4. Real lava lamps use a polar and non-polar liquid but instead of effervescent tablets, it uses a lamp to make the denser liquid rise. How does the lamp help the denser liquid rise? What happens when it gets to the top?

Additional experiments

- What happens when you put the cap on the bottle after dropping the effervescent tablet in?
- What if you drop a whole tablet in it?
- When it stops bubbling, sprinkle some salt into your lava lamp. What is happening?

While mixing oil and water in lava lamps is cool, what would happen if oil spilt into a waterbody that is used by animals, plants and or humans? If you are curious about oil spills in the environment, please look at the oil spill experiment!

How to properly dispose of used oil?

Don't throw used oil down the drain or toilet as it will cause all kinds of issues. Instead, put the oil in an old or used nonrecyclable container with a lid (such as a cardboard milk or juice carton or a similar wax- or plastic lined paper container) and dispose of it in the garbage.

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Manufacturing a Tube for Measuring Water Transparency

GLOBE		Associated SDG	Type of activity
Sphere	Protocols		
Hydrosphere	Water Transparency	3 (Good health and well-being) 6 (Clean water and sanitation)	Application Motivation

Overview

Students will learn how to make a transparency tube that they can use for transparency measurement in shallow and moving water.

Previous requisites

None

School Level

Secondary

Purpose

To learn how to make a homemade transparency tube, using materials that are readily and inexpensively available.

Student Outcomes

- To build their own instrument with guidance from the teacher
- To understand the concept of scale and units of measurement
- To apply manual skills in making instruments
- To solve a practical exercise through group work.
- To understand the concepts of precision in scientific instruments

Introduction

Water transparency can be measured through two different techniques depending on the watercourse to be studied. One is the Secchi disk, which is used where there is deep, still water, and is measured in the body of water itself. The other is the transparency tube, which is used once the water is extracted from the water body with a bucket, and immediately poured into the transparency tube. In the latter case, the light penetrates from both the surface of the tube and the sides, unlike the Secchi disk where the light penetrates the water body only from



the surface. Although both techniques measure the transparency of water, they are not comparable to each other due to the differences mentioned above. See figure 1.

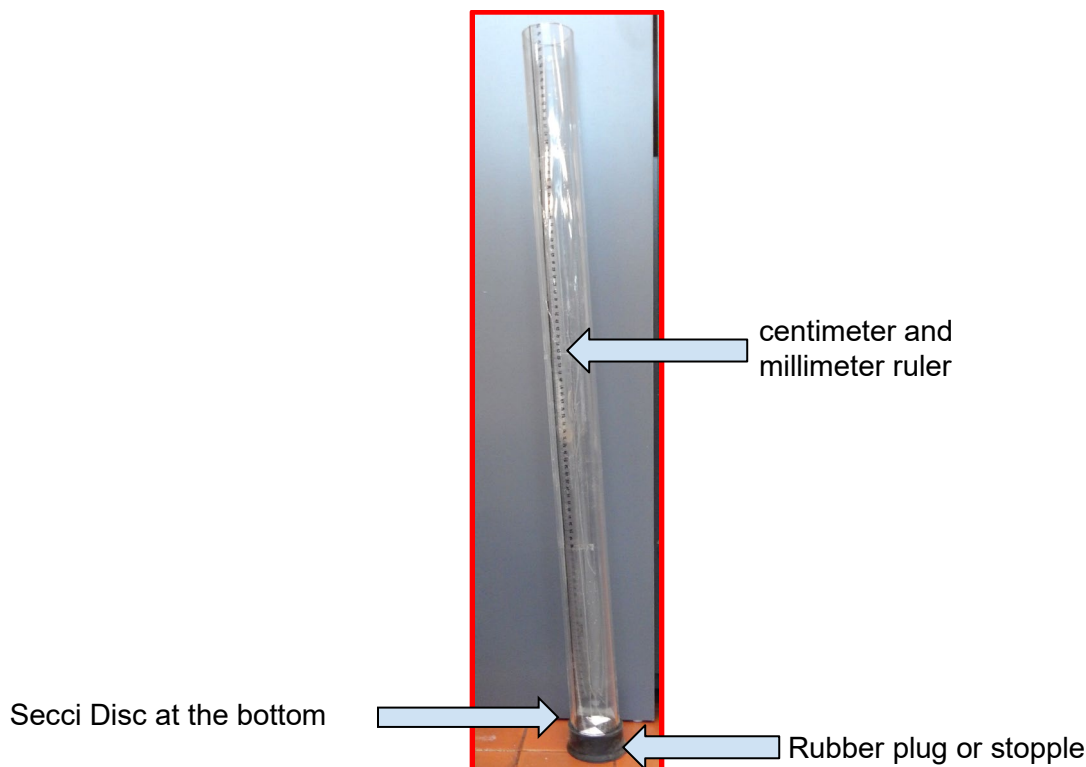


Fig. 1.

Guiding Research Questions:

- What type of scale should I use for the measurement?
- Are there materials more suitable than others for manufacturing the tube? Why?
- Will it have the same usefulness as a purchased tube?
- How does accuracy influence the development of measuring instruments?
- What is the purpose of placing a Secchi disk at the bottom of the tube?

Scientific Concepts

Water is a solvent.
 Over time, water can deteriorate some materials.
 Different materials have specific properties and can be more or less durable.
 Scales / units of measurement

Materials and Tools

- One acrylic, clear plastic, polycarbonate tube or similar
- A millimeter ruler
- Acetate sheets
- 2 inches (5 cm) wide adhesive tape
- A stopple, a rubber plug or other object for sealing the bottom of the tube
- Scissors or a cutter
- A fine-tipped black permanent marker
- A styrofoam (depending on the country) or wooden board



- Optional: black paint and a paintbrush
- Glue suitable for the material to be used
- Optional: a drill with drill bit for wood or iron



Fig. 2: Materials

What to Do and How to Do it

Beginning -

Pose the guiding questions and then explain the scientific concepts that you consider necessary to begin the activity.

Development -

1. Take an acrylic, transparent plastic or PVC tube, depending on what you can get where you live. In this case, an acrylic tube of 5 cm in diameter and 1 m in length bought in an acrylic factory will be used. You could also use a transparent plastic tube that is sold in some countries as containers for light tubes or something similar that is rigid enough to hold the water when it is full.

The tube should be 60 cm minimum and up to 120 cm maximum. It is always ideal to have between 100 and 120 cm, so that, when the waters are very clear and have practically no particles, it is possible to measure exactly the centimeters of transparency. In this case, if we were to use a short tube of 60 cm, the transparency would probably exceed the length of the tube, and when the measurement is made, "more than 60 cm" should be indicated and it would not be possible to determine exactly how many centimeters of transparency the body of water had.

2. Different methods can be used to assemble the transparency tube ruler.

Method A. Take an acetate sheet and using a millimeter ruler, mark the centimeters and millimeters on the sheet with a fine-tipped black permanent marker. Mark the centimeters first and then every five millimeters. In order to mark the 10 millimeters of a 1 cm, the marker would have to be extremely fine so that all the marks do not join together in one. A marker that will



not rub off with water should be used since this instrument will be exposed to water internally and externally (see Figure 3).

Method B. Photocopy a transparent ruler on an acetate sheet, then just cut the section and repeat it along the length of the tube. In the example in figure 4 you can see the actual photocopy of a numbered 30 cm ruler, and the other sections are photocopies covering the numbers so that they can be added after the first section to complete the total length of the tube.

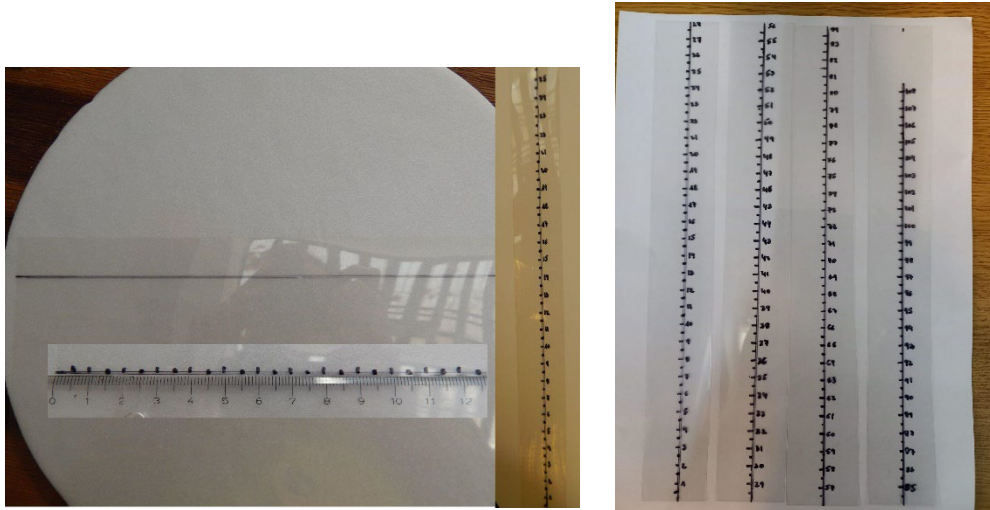


Fig. 3

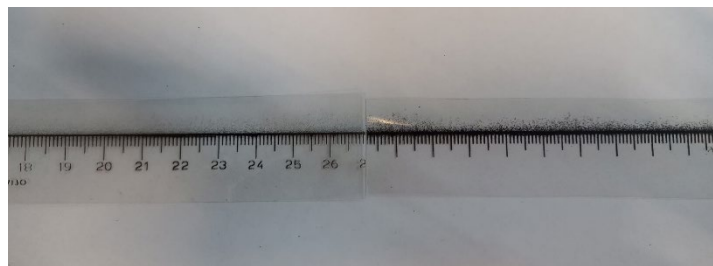


Fig. 4

C Method. Draw the ruler directly on the transparency tube with the white permanent marker using a ruler as a guide.

Note: Be careful to keep the scale accurate when trying to print a ruler downloaded from the internet. Generally, when printed on paper or acetate sheets, the scale does not maintain the actual size, even though the file from which it was downloaded may make this clear. It is recommended in this case, once the sheet is printed, to check the centimeter measurement with a real ruler.

3. When using either the method A or B, cut the rulers printed on the acetate into strips of 2.5 to 3 cm wide at the most.



4. Take the stopple or rubber plug you have to seal the bottom of the soil pipe and test it. It should be of adequate diameter so that the diameter of the tube fits very well (5 cm in this case) so that the water does not escape.

5. When you put in the stopple, note that it is 3 or 4 centimeters high, which will cause a few centimeters of tube to be inside the stopple and the light does not penetrate that section. A solution for the Secchi disk surface that is painted on the bottom of the tube to be at the height of where the ruler ends is to mark the tube with a permanent marker at that height, and then glue the ruler from the marked edge so that the zero centimeter coincides with the edge. (See figures 5 to 7).

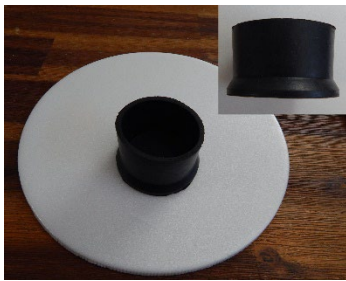


Fig. 5



Fig. 6



Fig. 7

6. Now it is necessary to fill those centimeters that are left under the mark of the edge of the stopple with some material that will not be damaged by water, so that the Secchi disk can be painted on the upper part of the tube. One solution is to cut styrofoam disks of the inner diameter of the tube and glue them together as if it were a wafer until reaching the height of the line painted with a marker (see figures 8 to 11). Once they are glued, they are tested on the stopple to see if they cover all the height needed. If more discs are needed, more will be added until that height is reached (Figures 12 and 13).

7. Next, paint the Secchi disk on the disk remaining on the surface with acrylic paint or a black permanent marker. To do this, mark the four quadrants with a square, and paint two of the opposite quadrants (Figures 14 to 16). Some other material, such as a plastic or acrylic plug or a wooden insert previously waterproofed with paint, could also be used to fill in the stopple.

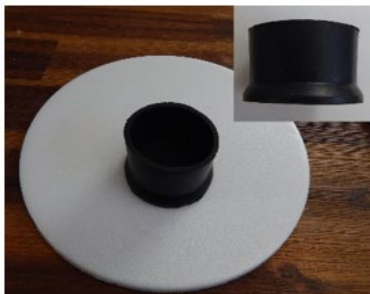


Fig. 5



Fig. 6



Fig. 7



Fig. 8



Fig. 9



Fig. 10

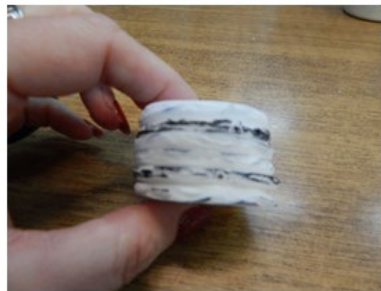


Fig. 11



Fig. 12



Fig. 13



Fig. 14



Fig. 15



Fig. 16

8. At this point, place the insert into the rim, and then tighten the transparency tube to the rim and insert. If there is any doubt that it will not fit tightly and water may leak out, some type of contact cement (for rubber and acrylic) or silicone can be placed between the outer wall of the tube and the stopple (Figures 17 to 19).

9. Align the acetate rulers on the tube, one next to the other from the edge of the ruler (zero centimeter) taking care to respect the full centimeters at the joints of the rulers. Tape the rulers to the transparency tube with a 5 cm wide adhesive tape in a single straight line.



Fig. 17



Fig. 18



Fig. 19

10. An optional step includes drilling a hole 5 or 6 mm in diameter, one or two centimeters above the mark of the stopple to function as a drain valve, so that when you fill the tube with water, if it is exceeded, with the valve you can drain the water little by little until you no longer see the disc at the bottom. This can be done with a drill and a drill bit for wood or iron. This step is not essential because you can also fill the tube little by little until the disc is no longer visible.

Ending -

It is suggested to practice the use of the transparency tube by introducing different variables to the measurement so that students understand the importance of doing it correctly to obtain quality data:

- with the manufactured tube and a purchased one if available to determine how accurate the manufactured instrument is.
- practice measurements in the shade (e.g. under a tree), in the sun, and in the shade cast by their own bodies to check for differences between observation conditions.
- make the observations on a cloudy day or time and then with a clear sky to understand if the sunlight hits the increased transparency of the water.
- experiment with the measurements when they are taken every 10-15 min to understand how the speed at which the water particles settle to the bottom of the transparency tube and how quickly the Secchi disc is no longer visible.

Explain to students that it is essential to perform all three transparency measurements under exactly the same conditions to obtain valid and standardized measurements.

Frequently Asked Questions:

Is using the transparency tube the same as using the Secchi disk?

No, actually both instruments are used in different bodies of water. If the water is deep and still, you will use a Secchi disk for your transparency measurements. If the water is shallow or flowing, you will use a transparency tube (or turbidity tube). Since different instruments are used in both cases, the data obtained are not comparable with each other.



Oil Spill Clean-Up Experiment

GLOBE		Associated SDGs	Type of Activity
Sphere	Associated Protocols		
Hydrosphere	Water Transparency Salinity/conductivity	14 (Life below water)	Exploratory
Bundle	Ocean, Water quality	15 (Life on land)	

Overview

Participants will learn the effect of oil spills on our ocean and wetlands and the process of removing it from the environment.

Time

60-90 minutes

Prerequisites

Lava lamp experiment.

School-level

Primary school students.

Purpose

This activity will help participants understand what happens after an oil spill to help them become aware of the harmful impact of oil spills.

Student outcomes

- Understand the interaction between oil, water, and floating objects;
- To test the different methods of cleaning up oil spills, and
- To observe the effects of oil spills on bird feathers.

Background

Oil spills occur when oil is accidentally released into bodies of water like oceans, rivers, or lakes, often due to accidents involving ships, and during oil exploration, transportation, or storage. They can have significant environmental consequences, harming marine life by blocking sunlight and reducing oxygen levels. Oil spills can also contaminate shorelines, disrupt the food chain, and impact coastal communities that rely on fishing and tourism (figure 1).



Different types of oil behave differently in the environment. Light oils like gasoline and diesel are volatile and toxic, while heavy oils like bunker oils or crude oils can persist for months or years, smothering organisms and causing chronic health effects (figure 2). Oil spills mainly impact animals like sea turtles, whales, and dolphins that come to the surface to breathe. During most oil spills, seabirds are harmed and killed in greater numbers than other kinds of creatures. The spilt oil can persist in the environment for years, causing damage to the food chain and disrupting the balance of the ecosystem.

Plant life, such as mangroves, can also be severely affected by oil exposure. The mangrove roots, and those of other plants, become smothered (heavy oils), killing the trees and poisoning the soil, causing worms and other soil animals to die. Long-term exposure to oil can lead to the poisoning of plants and animals for generations.

Cleaning up oil spills is a challenging and time-consuming process that can take weeks, months, or even years to fully address. Major oil spills, like the [Deep Water Horizon or British Petroleum Oil Spill](#) in 2010, can have devastating impacts on marine ecosystems and wildlife, with long-lasting effects that may take years to recover from (figure 3).



Figure 1 Oil spill in Mauritius after a bulk carrier ran aground on 25 July 2020. Source: <https://acortar.link/BWrecm>



Figure 2. Persistent oil (left) and non-persistent oil (right).
 Source: <https://www.itopf.org/knowledge-resources/documents-guides/fate-of-oil-spills/>

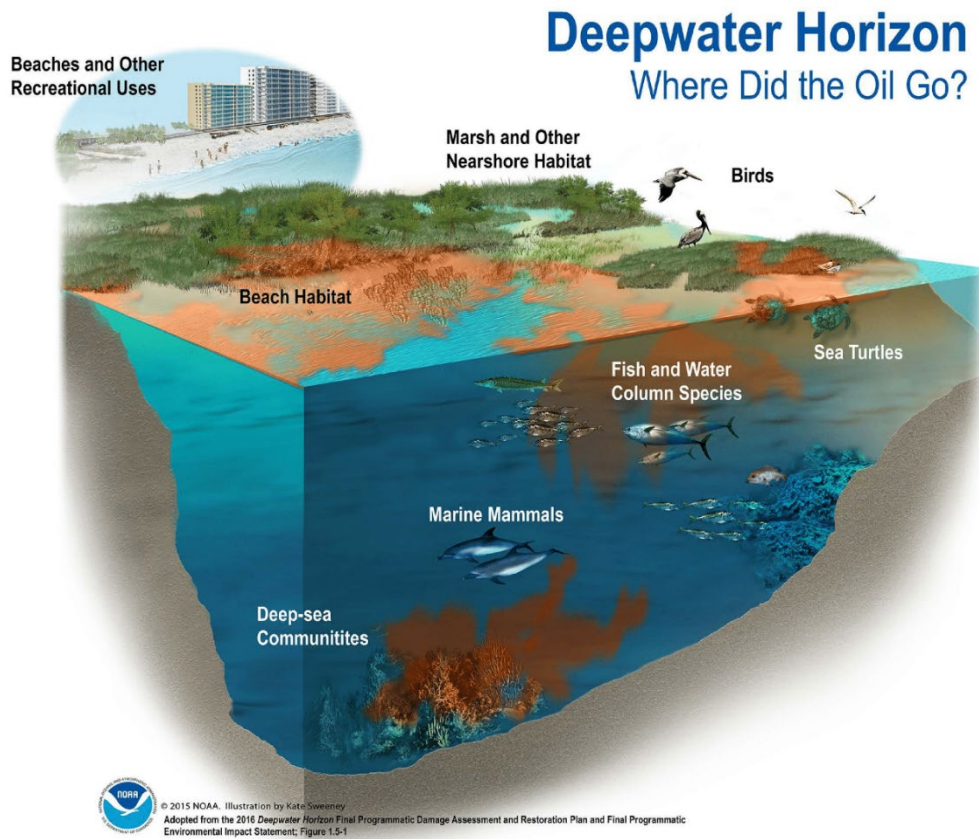


Figure 3 Deepwater Horizon Oil spill. Source: 2015 NOAA



Guiding Research Questions

- *What happens when oil gets in the water?*
- *Is it possible to clean an oil spill?*
- *What is the impact of an oil spill on birds?*

Scientific concepts

- Pollution
- Water density
- Water transparency

Materials and Tools

- A large aluminum cooking pan with water
- Sand
- Blue and black food coloring (optional)
- Vegetable or motor oil
- Cotton Balls
- Feathers
- Dish Soap
- Shampoo
- Spoon
- Permanent marker

What to do and how to do it

Beginning

Divide the participants into groups of 2 or 3.

Pose the guiding questions and then explain the scientific concepts necessary to begin the activity such as density and polarity (See Lava lamp activity for more information about these concepts).

Development

1. Have students form a slope of sand at one end of a large aluminum cooking pan to simulate an ocean shore (make sure that the X is not covered). Blue food coloring can be added to the water to represent a blue sea, but the water can also be left as is. Can you see the X?
2. Mix the oil with the black food color and add it to the water to simulate an oil spill;
3. Rock the pans back and forth gently to produce waves and observe the behavior of the oil. Can you clearly see the X at the bottom of your pan?
4. Experiment with different tools to try to find the best way to clean up the oil, such as by sponging it with cotton balls or skimming it from the surface of the water using spoons or cups. After removing most of the oil, can you see the X on the bottom of your pan? Is it



more or less visible than before you cleaned the oil? Is it more or less visible than before the oil spill?

5. Study a feather. Natural oils on a feather cause water to flow off it. Watch how it recovers after water treatment.
6. Place the feather in a pan with clean water. Does it float? Shake and dry it well with tissue paper or toilet paper and put it in the sun for a while. Does it still look the same after it gets wet?
7. Place the feather in a pan with water and black oil. What happens to it?
8. Try to remove the oil from the feather using different cleaning products. Dry the feathers with paper towels or tissues and leave them in the sun. Do they look fluffy again?
9. Place them back in a pan with clean water. Do they still float as before?

Closing

To observe:

- How does the oil move in the water? Why does it move like that (hint: density)?
- Compare the transparency of the clean water to that of the polluted water. Is there a difference? How will that impact plants and animals in the water?
- How is the oil carried to the shore?
- Which method worked best to remove the oil?
- Were you able to remove all the oil?
- What happened to the feathers after they came in contact with oil?
- What happened to the feather after the oil was removed? Did it look the same as before it had come into contact with the oil?
- How long did it take to clean the feathers? What do you think happens to birds when oil gets on their feathers? Can they clean their feathers themselves?

Discussion

Was the oil removed everywhere? How well will your efforts work in the event of a real oil spill? Which conditions could be different? Discuss which materials people use in the event of an oil spill, such as floats to prevent the oil slick from drifting; suckers (biological material that sucks up the oil), and how these materials correspond to the material used by the participants.

Additional tests

- Did the pH change after removing the oil from the water? Why did this happen? How do you think this will affect the aquatic and terrestrial flora and fauna?

Read more about oil spills and oil spill cleanups on these sites:

- <https://www.noaa.gov/education/resource-collections/ocean-coasts/oil-spills>
- <https://appliedsciences.nasa.gov/what-we-do/disasters/oil-spills>
- <https://www.unep.org/news-and-stories/story/how-manage-damage-oil-spills>



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Organic Matter Retains Water

GLOBE		Associated Protocols	Associated SDG	Type of Activity
Spheres				
Hydrosphere	Dissolved oxygen, Conductivity, Transparency, pH,	6 Clean water and sanitation 15 Life on Land	Exploratory	
Atmosphere	Precipitation.			
Biosphere	Land Cover			
Pedosphere	Soil characterization, Soil infiltration,			

Overview

Water flows tirelessly, moving with the earth's inclinations, winds, tides, and flight like water vapor. However, thanks to plants and especially our forests and moorland, water stops and flows to drier lands downstream.

Through this activity, you will discover how vegetation covers retain water in the soil; this is a crucial idea to understanding the importance of forests and moors in the conservation of the currents of water sources.

Time

1 class

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School level

Basic primary school students.

Purpose

Evaluate the water retention capacity of the organic matter present in the soil.

LEARNING ACTIVITY



Student outcomes

- ✓ Understand the importance of forests and moors in conserving water source currents.
- ✓ Evaluate the water retention performance of organic matter.

Background

Organisms in soil, including microorganisms, use plant and animal residues and organic matter derivatives as food. As waste and organic matter break down, excess nutrients (nitrogen, phosphorus, and sulfur) are released into the soil in forms that plants can use. Waste products produced by microorganisms contribute to the formation of soil organic matter.

The continuous addition of plant residues and other organic matter through their transformation by soil organisms provides the capacity for soil self-recovery. Sticky substances on worms' skin and those produced by fungi and bacteria help clump the particles together. The living part of the soil is responsible for maintaining water and air availability, providing nutrients to plants, destroying pollutants, and maintaining soil structure. This contributes to the renewal of porosity through tunneling and the formation of sticky substances associated with biological activity. Consequently, soil can store more water and become a carbon dioxide sink.

Organic materials can provide physical cushioning against raindrops and direct insolation. The decomposition of dead roots provides descending channels through which water can reach the lower levels of the root zone. Meso-aerobic organisms create tunnels and channels with the same result. The water cycle decreases ineffectiveness if the processes are affected.

Guiding Research Questions

What is the importance of water retention of organic soils such as forests and moors?

Scientific concepts

- Ecology.
- Conservation.
- Climate Change.
- Precipitation.

Materials and tools

- one funnel.
- Thick pebbles.
- Thin pebbles.
- Earth.
- Dried leaves
- Green leaves
- Coffee filter paper.



- one container
- one large glass of water
- one large empty glass

What to do and how to do it

- Cover the bottom of the funnel with a paper filter.
- Fill the bottom of the funnel with thick stones and then with thin stones.
- Add the contents of the glass of water through the funnel. On the other side of the funnel, place the other glass, write down the time the water passes, and calculate the amount of water that reaches the second glass.
- Fill the funnel again. Make the background the same way with a paper filter, then with thick and thin pebbles, add soil, then dry and green leaves.
- Add the water from a glass, careful not to be watered on the outside.
- Place the second glass in the goose of the funnel, count the time it takes to pass the water, and calculate the volume of water that reaches the second glass.

To observe:

- In which case did the water run faster? Why?
- In which case did the water run slower? Why?
- In which case did less water reach the second glass? Why?

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Sedimentation and filtration in wetlands

GLOBE		SDGs Associated	Type of Activity
Spheres	Associated Protocols		
Hydrosphere	Transparency	13 (Climate action)	Exploratory
Biosphere		14 (Life below water) 15 (Life on land)	

Overview

Participants will create a model to demonstrate how wetland plants reduce water flow and contribute to the settling of potentially hazardous substances. Participants will also learn how plants in mangrove swamps retain sediment (= sand, mud, shells) so that they do not end up in lakes, rivers, creeks, and the ocean.

Time

1 class

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School-level

Primary and secondary school students.

Purpose

Participants will learn how plants in mangrove swamps filter runoff and retain sediment (= sand, mud, shells) so that they do not end up in lakes, rivers, creeks, and the ocean.

Students outcomes

- Help students better understand how mangrove forest's function
- Help students understand the importance of mangrove forests
- Help students understand sedimentation and filtration

Background



A wetland is an area of land that is covered with water all year round, or for part of the year. The soil in wetlands can become waterlogged: this means that the soil is full of water, like a sponge. Most large wetland areas often include a combination of different types of freshwater systems. Between 300 million and 400 million people live close to and depend on wetlands. They support the cultivation of rice, a staple in the diet of half the world's population. Wetlands are important because they:

- Store carbon and help fight climate change,
- Clean and filter water,
- Revive biodiversity
- Boost ecotourism
- Help protect the land against erosion and floods.

Wetlands take many forms including rivers, marshes, bogs, mudflats, ponds, swamps, billabongs, lagoons, lakes, floodplains, and mangroves.

Sedimentation: The settling and accumulation of sediments

Filtration: Filtration is the process in which solid particles in a liquid or a gaseous fluid are removed by the use of a filter medium that permits the fluid to pass.

When wetlands trap and bind sediments to build soils, they provide essential services to people and adjacent ecosystems. Mangroves are well known and increasingly appreciated for their role as coastal defenses – preventing coastal erosion and protecting adjacent villages from storm surges and sea level rise. By filtering suspended particles, mangroves generate clean water and protect adjacent coral reefs from excess sedimentation.

Securing adequate sediment provision in mangrove systems is critical for conservation and restoration efforts. Natural hydrological systems must supply adequate amounts of sediment to prevent sediment starvation on the one hand – and prevent sediment oversupply on the other. The aerial roots of mangroves retain sediments and prevent erosion. By slowing the water flow, they cause the water to “settle,” facilitate the settling of sediments, and reduce the outflow of fallen leaves and branches.

For example, mangrove soils can be maintained or even grow vertically upward through the accumulation of sediments and organic matter. In some places, vertical growth may be sufficient not only to maintain mangroves but also to keep pace with rising sea levels. Mangrove systems suffering from an imbalance of sediment supply will lose their efficiency in providing coastal resilience and clean water. Moreover, any attempt at planting or facilitating the natural succession of mangroves will fail if seedlings cannot tap their roots into stable soils. Mangrove soils can act as sponges against excess rainfall and flooding, buffer coastal erosion, and can shield communities in extreme weather.

Mangrove forests also protect fish and other animals that live in these areas from substances that come from land. When mangrove plants slow down rainwater, the sludge (or mud) that comes off land ends up around the roots and trunks of the plants. This helps to protect the ocean from an



accumulation of silt and sediment (=sand, mud, shells). By preventing the accumulation of silt, the mangrove trees ensure that the gills of fish and other aquatic animals do not become clogged and the eggs of these animals do not become covered with silt (if this happens they cannot hatch). Excess sediments or silt in the mud can also be bad for the plants growing in the water because it blocks sunlight, which is necessary for photosynthesis. It also helps protect water from contaminants, such as fertilizers and chemicals sometimes used in agriculture. The other plants that occur in the mangrove forests absorb these substances so that they cannot enter the water. If the mangrove forests were not there, these substances would pollute the rivers, creeks, ocean, and groundwater.

When mangrove plants slow down rainwater, the sludge or mud ends up around the roots and trunks of the plants. This helps protect the ocean from a build-up of sediment, which can clog the gills of fish and other aquatic animals and cause their eggs to disappear into the subsurface. It also helps protect water from pollutants and other impurities because the other wetland plants found there can absorb and use the nutrients and other chemicals contained in the sediment. If the Wetlands were not there, these substances would pollute the rivers, creeks, oceans and groundwater. Both coral reefs and seagrass beds rely on the water-purifying ability of nearby mangrove forests to keep the water clear and healthy.

Guiding Research Questions

- *What happens when sediments suspended in water can settle?*
- *What happens when polluted water goes through a mangrove forest?*

Scientific concepts

- Pollution
- Filtration
- Sedimentation
- Erosion

Materials and Tools

- 1-liter bottle or jug (clear)
- Different sediment types such as large and small stones, sand, fine sand particles, and clay
- Pieces of sponge;
- Flat plate, piece of wood or plastic;
- Two shallow containers;
- Glue

What to do and how to do it



Beginning

Divide the participants into groups of 2 or 3.

Pose the guiding questions and then explain the scientific concepts necessary to begin the activity.

Allow the participants to collect different sediment types outside (sand, clay, and other ideas..) (or ask them to bring it from home).

Development

1. Mix the different sediment types (sand, clay, etc.) in the bottle until it is about half or three-quarters full. The bottle is then further filled with water and covered with the cap.
2. Shake the bottle until everything is well shaken and place the bottle on a table (figure 1). Watch the time and start counting down.

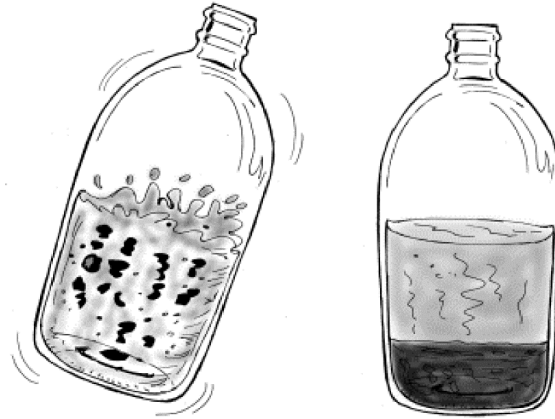


Figure 1 Bottles with sediments before and after shaking

3. Check the bottle with sediment; it will take a while for it to sink in. How long did it take for everything to sink in? Did the sediment settle in layers, i.e. according to particle size?
4. Place the plate/ wood/ plastic on a slope in your container (try to rest it on the edge of the container). This is supposed to represent a damaged wetland, where the plants have all died or been removed. Water enters the 'Wetland' via a creek, flows through the Wetland, and ends in a lake or ocean.
5. Now pour your mixture into the plate and let it flow into the container (figure 2). How long does it take for the mixture to get into the container?
6. Wash the board and stick the sponges on it (rough side down). Let this dry thoroughly.
7. Wet the sponges slightly. This now represents a 'healthy wetland' where plants but also the soil ensure that silt and sediments are retained and do not end up in the ocean.
8. Make another mixture and repeat step 3 with the 'healthy Wetland' and the second container (figure 2). How long does it take for the mixture to get into the container?

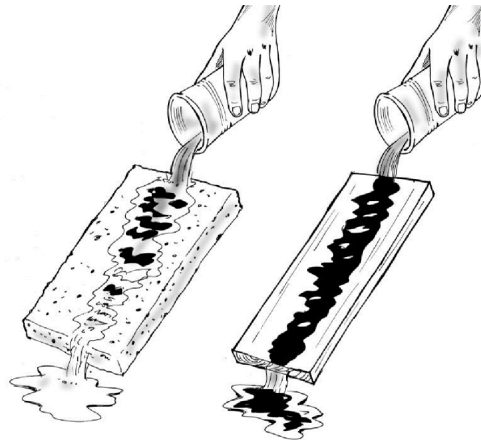


Figure 2 Water going through a “healthy wetland” vs a “damaged wetland”.

9. Compare the water coming from the 'damaged Wetland' with the water coming from the 'healthy Wetland'. Does it look different? If so, what is the difference?

Closing

Discussion/Reflection

- Do you think more sediment would sink to the bottom if the water flowed quickly or slowly?
- How can wetlands reduce the water flow (hint: think of the roots/ plants in the water)?
- In which Wetland does the water drain faster?
- In which Wetland will you get more settling of sediments, the damaged one or the healthy one? Why?
- From which of the two 'Wetlands' will cleaner water flow? Why? Test your theory by looking at the transparency of the water from both wetlands using the GLOBE transparency protocol. Were you right?
- What will happen to the water that is downstream and adjacent to the sea if a canal or well is dug in the Wetland?
- How will the removal of or damage to wetlands affect the quality of the water where the Wetland borders the sea?
- What will be the impact on humans?

Additional questions

- Can you think of any other functions of wetlands?
- Are there wetlands in your area? If yes, what kind of wetlands do you have in your area?
- If possible, visit a wetland in your area. Try to figure out if it is a wetland that always has water or if there are periods during which the wetland is dry. Are there any migratory birds in this area?
- Are there rivers or creeks that run into the wetland? If yes, what type of contaminants can these waterways expel into the wetland (look at the surrounding area of these rivers and creeks)



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Water cycle and human activities

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Atmosphere	Air Temperature, Surface temperature. Wind Precipitations. Relative Moisture. Water vapor. Aerosoles.	6 (Clean water and sanitation) 7 (Affordable and non-polluting energy) 12 (Responsible production and consumption) 13 (Climate action) 14 (Underwater life) 15 (Life of Terrestrial Ecosystems)	Exploratory
Biosphere	Cobertura terrestre. Fenología. Altura de árboles.		
Pedosphere	Infiltration. Humidity. Temperature		
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. Salinity. Nitrates.		
Bundle	Agriculture ENSO Oceans Rivers and lakes Water cycle. Water Quality Soils Meteorology		

Overview

To explore the water cycle in tropical, temperate, and cold zones, students conduct a simulation experiment with simple materials that allows them to observe the rate of evaporation and condensation. They also follow the melting of ice. They then analyze global maps of rainfall and snowfall records over the last 20 years and analyze the impact of human activities and climate change on the water cycle. This activity facilitates understanding the water cycle, the changes generated by human activities, and the problems caused by these changes.

Time

2 or 3 classes

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.



School Level

Primary and high school students.

Purpose

- Understand the natural water cycle and the alterations produced by human activities.
- Analyze their connection to the water cycle and the need to mitigate the negative impacts produced by human activities.

Students outcomes

- To design a simple simulation model of the water cycle in tropical, temperate, and cold zones.
- To bring the student closer to the understanding of the water cycle.
- To analyze the impact of human activities on the natural water cycle.

Introduction

We can find water on our planet in vapor, liquid or solid state moving from one place to another. We have illustrated these movements with a water cycle diagram, allowing us to see where water is located and where it can move to. Water moves great distances through watersheds, the atmosphere, and the ground. But it can also impact tiny scales in our bodies, plants, and other organisms.



Figure 1. Water cycle. Source: USGS <https://on.doi.gov/3MMBMqD>



Figure 1 illustrates the natural movement of water. With the energy it receives from the Sun, liquid water from oceans, rivers, and lakes evaporates and passes into the atmosphere. We call this process **evaporation**. Snow and ice can also disappear without passing through the liquid state in **sublimation**. But animals and plants also contribute water vapor in the process of **transpiration**, which also reaches the atmosphere.

As water vapor rises in the atmosphere, colder air transforms the steam into water droplets through **condensation**. When the ground is cold, water vapor can condense into droplets near the bottom, forming fog, and if the temperature is cold enough, ice crystals form instead of liquid water droplets.

En las nubes las gotas o los cristales de hielo aumentan de tamaño y se vuelven pesados para sostenerse en el aire, por lo tanto, caen al suelo en forma de lluvia, nieve y otros tipos de precipitación.

Water returns to the oceans as precipitation falls into the sea or rain falls on land and then flows into the ocean through rivers. Some water that falls with **rainfall** is stored in rivers or lakes for a long time, but in other cases, it forms temporary puddles that evaporate quickly.

Some of the snow and ice that falls as precipitation may be stored in [glaciers](#) on mountaintops or ice sheets such as in Antarctica.

The oceans store 96% of the water. Ocean water is salty; salt water is found in some saline lakes. The remaining 4% is freshwater stored in liquid form in lakes, artificial reservoirs, rivers, and wetlands. Water in solid form is stored in glaciers and ice sheets at high altitudes or near the poles. The ground can also keep frozen water, which is called permafrost. Liquid water in the soil is stored as soil moisture. At greater depths, the soil stores groundwater in aquifers found within rock cracks and pores.

As it moves, water changes form between liquid, solid, and vapor. Circulation mixes water in the oceans and transports water vapor into the atmosphere. In the atmosphere, water moves by evaporation and precipitation. Water moves on the earth's surface through snowmelt by runoff and water flow in rivers, lakes, etc. Water moves into the ground through infiltration and recharges groundwater. Groundwater flows within aquifers and may return to the surface through natural discharge in rivers, the ocean, and springs.

The sun's energy and the force of gravity drive the continuous movement of water. The sun's energy evaporates liquid water. Evapotranspiration is water moving into the atmosphere from the land surface and oceans. Gravity causes water to flow downward over land. It causes rain, snow, and hail to fall from clouds.

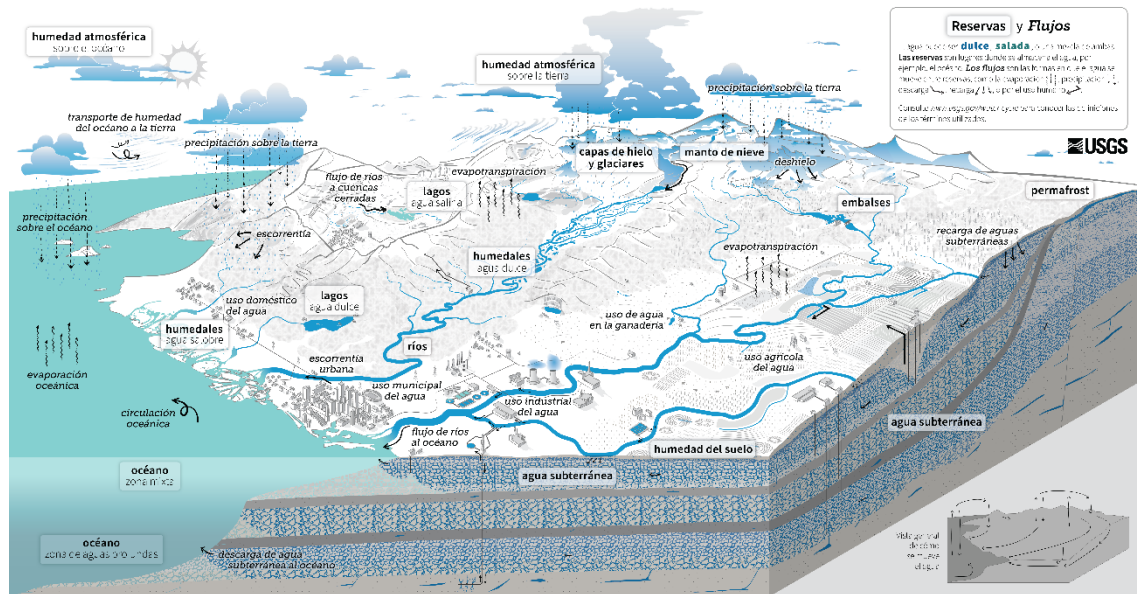


Figure 2. Water cycle. Source: USGS. Link to larger image <https://on.doi.gov/3oiyxPs>

Human activities alter the [water cycle](#). Figure 2 illustrates different human uses of water that change the natural process. For example, a reservoir formed when a dam is built on a river allows water to accumulate behind the dam, creating an artificial lake. Other examples include changing river courses, draining wetlands, using aquifers, etc. In addition, we use this water in our homes and cities to produce food: we use it for agricultural irrigation and livestock grazing. We also use water in industrial activities such as power generation, mining, and aquaculture. By using water, we affect its quality. In agricultural and urban areas, irrigation and precipitation wash fertilizers, pesticides, and other pollutants into rivers and groundwater. Power plants and factories return water at higher temperatures and with pollutants to rivers. Runoff carries chemicals, sediment, and wastewater into rivers and lakes. Polluted water can cause harmful algal blooms, spread disease, and damage natural ecosystems.

Guiding Research Questions

Where does the water that falls from the sky as rain or snow come from? How do clouds form?

How does melting ice affect sea level? How do melting mountain glaciers affect rivers and lakes in the short and long term?

How do human activities affect the water cycle?

Scientific concepts

- Water cycle
- Human uses of water
- Water availability
- Water quality
- Ecology



Materials and Tools

- Snack-size plastic bag with zip-top closure
- Permanent marker
- Water at different temperatures: cold (10 °C or below), room temperature (20 °C), and hot (30 °C or 40 °C)
- Liquid measuring cup
- Spoon
- Strong adhesive tape
- Blue food coloring
- Sand
- Pebbles 4 cm or less (that will fit in the bag).
- Ice cubes
- Incandescent lamp to provide heat (or look for a wall that gets a lot of sun during the day).

- **What to do and how to do it**

- **Beginning to**

Show your students the [current rainfall around the world](#). Is it raining now in or near your location? Look at the differences in rainfall intensity over the last 30 minutes, 24 hs, and seven days. Is it raining in the same places, or did it move to other locations?

Ask your students to hypothesize where the rainwater originates and why it falls.

- **Development**

Perform the following experiment to simulate the water cycle in tropical, temperate, and cold zones.

Preparation:

1. Draw the Sun, clouds, and rain on three plastic bags and mark the water level. Label each: Tropical Zone, Temperate Zone, Cold Zone.
2. Add blue dye to water at different temperatures.
3. Prepare each bag:



Fig. 3. Preparation of the experiment. Source: Science Buddies



- a. Tropical zone: add sand, stones, and hot colored water.
- b. Temperate zone: add sand, stones, and the colored water at room temperature.
- c. Cold ar rocks, cold-colored water, and ice cubes.

The rocks represent the mountains. Choose stones that are above the water level. Some of the sand should be submerged, and some above the water representing the continents.

The three bags should have the same amount of water, sand, and stones.

4. Carefully close each bag, always keeping it vertical.

5. Tape the bag with a solid tape to a window or wall where it will receive the sun's heat, or you can simulate the sun with a lamp. If it is cloudy, it is best to use a lamp.

Observation

1. Observe the bag every 1 to 2 hours to see what happens.
2. Record what you observe in the different bags. What happens in the plastic bags? What happens to the water? What happens to all the bags at the same time? What happens to the bag with the ice cubes?
3. Can you explain your observations?
4. What processes did you observe in your experiments that were similar to rain? Where did the rainwater come from?
5. Did the water level in the bags change? Where is the ice after a while?

Read the introduction and explain the processes he observed inside the bags.

1. How did the experiment mimic the water cycle?
2. Why did it take longer for some of the bags to rain?
3. What happened to the water level in the bag with the ice cubes? What might happen to the sea level if sea ice melting increases?

To find out the variations in rainfall over the last few years, show the [global rainfall map](#) and the [snowfall](#) maps. To analyze them, consider the following questions:

1. Do you observe seasonal variations?
2. Are the changes similar in recent years?
3. What could happen if temperatures increase due to climate change?

Analyze the [water cycle diagram with water uses](#) considering the following questions: which human activities require the most water? Why does water quality change after using water for human activities?

For further discussion, divide the class into groups, assign each group an article to analyze:

- a) [Cómo la actividad humana está alterando los ciclos de lluvias y sequías en la cuenca del río Amazonas](#)
- b) [El calentamiento lleva a sequías y precipitaciones extremas más frecuentes e intensas](#)



c) [Aumenta la evaporación de los lagos](#)

d) [Satélites muestran cómo el ciclo del agua en la Tierra se acelera a medida que el clima se calienta](#)

Bring the groups together and ask them to comment on the article they analyzed. Generate a discussion about changes in the water cycle due to human activities and climate change.

Ask how your students and their families use water.

Discuss impacts and possible mitigation measures.

- **Closing**

Students can make a poster of the water cycle and alterations due to human activities. You can also post a section with ideas for mitigating negative impacts.

Suggested Resources

To learn more, the following resources are suggested:

Glaciers: Inventory of the world's glaciers - Randolph Glacier Inventory

<https://www.glims.org/maps/glims>

Rivers and lakes: Evaporation of water in lakes. Global Lake Evaporation Volume - GLEV

<https://zernity.users.earthengine.app/view/glev>

Animated water cycle <https://youtu.be/3CI6jCDWWYI>

Global snow map (Período: Marzo 2000 hasta Enero 2023)

https://earthobservatory.nasa.gov/global-maps/MOD10C1_M_SNOW

Global map of total rainfall (Período: Junio 2000 hasta Abril 2023)

https://earthobservatory.nasa.gov/global-maps/GPM_3IMERGM

Current precipitation map <https://gpm.nasa.gov/data/visualization/global-viewer>

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Water Microbiology

GLOBE		Associated SDG	Type of Activity
Sphere	Protocols		
Atmosphere	Precipitation.	6 (Clean water and sanitation) 7 (Affordable and non-polluting energy) 12 (Responsible production and consumption) 13 (Climate action) 14 (Underwater life) 15 (Life of Terrestrial Ecosystems)	Exploratory
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. Salinity. Nitrates.		
Bundle	Agriculture ENSO Oceans Rivers and lakes Water cycle. Water quality Soils Meteorology		

Overview

Through this activity students understand that water from a river or any body of water can be clean, but not drinkable because it is not treated. Students will build a homemade microscope and will be able to observe two water samples: one from the tap and the other from a river.

Time

1 class

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School Level

Elementary and high school students

Purpose

- To understand the importance of microorganisms present in water and their behavior in their environment.
- To understand the relationship between water quality and human health.

LEARNING ACTIVITY



Student Outcomes

- To bring the student closer to understanding the microbiology of water.
- To design a simple microscope model.

Introduction

Water, an essential element for humans, animals and plants, frequently acts as a vehicle for the transmission of microorganisms.

International standards establish or recommend quality requirements for water for human consumption. In general, the standards establish that water is bacteriologically fit for consumption if it is free of pathogenic microorganisms of enteric and intestinal parasitic origin.

In order to study the relationship between water quality and human health, it is necessary to introduce the concept of microbiology, and from this to assess the presence of microscopic organisms in drinking water, the competitive and/or synergistic effects of the different species and the possibility of applying disinfection technologies.

The microbiological variability of natural waters encompasses numerous organisms and includes eukaryotic cells (algae, protozoa and fungi), prokaryotic cells (bacteria) and viruses (microorganisms with zero synthesis capacity).

The importance of knowing the microorganisms present in water bodies and their behavior in their environment lies in the possibility of implementing technologies to eliminate them and thus control waterborne diseases.

Guiding Research Questions

What is the microbiological quality of our school water?

How do human activities affect water bodies?

Scientific Concepts

- Human uses of water
- Water availability
- Water quality
- Ecology

Material and Tools

- 1 long-range green laser pointer
- Sample of water from a puddle or river.
- Tap water sample
- Object to act as a holder
- 2 large syringes
- Rubber bands
- Adhesive tape



What to Do and How to Do It

Beginning

You have two clear water samples that appear to the naked eye to be the same and clean. The students must find out if they are drinkable.

Choose the surface on which to project the image, it can be the parde, if it is white and smooth. Otherwise, you can place on it a screen or large white paper.

Development

Perform the following experiment to build a homemade microscope:

1. Create a structure with the stand and rubber bands or tape to keep the syringe placed upright.
2. Take a water sample with the syringe.
3. Fix the syringe with rubber bands or adhesive tape.
4. Press the syringe so that a drop is hanging, but does not fall.
5. Place the laser pointer aligned with the drop of water so that it passes through it, at a distance of 1 to 2 cm.
6. Hold down the button on the pointer using a rubber band to press it and make sure it passes through the drop and the image is projected.
7. Turn off the light.
8. What did you observe? Tiny microorganisms will appear moving. They managed to magnify the image by 1000.
9. Repeat the same thing using the other syringe and tap water. What did you observe? In principle, you should not see any microorganisms.
10. You can add a third sample of tap water with some food coloring to give it a non-drinking appearance. In principle, no microorganisms should be present. You can also add a few drops of sodium hypochlorite (Bleach - Clorox) to the river water and observe if it has less or no microorganisms.

Closing

From the observation students will be able to construct their own microbiological catalog of species. Ask students to draw the observed microorganisms. Additionally, they can classify and identify them according to their characteristics (shape, size, type of movement).

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What happens in the puddles?

GLOBE		Associated SDG(s)	Type of Activity(s)
Sphere	Protocols		
Atmosphere	Air and surface temperature. Wind direction and speed. Rainfall.	6 (Clean water and sanitation)	Exploratory
Biosphere	Land cover. Height of trees.		
Pedosphere	Infiltration. Humidity. Temperature	14 (Life Below Water)	
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. Salinity. Nitrates.	15 (Life on land)	
Package	Water cycle. Water Quality Meteorology		

Overview

Students will play a crucial role in this practical exploration of their environment. They will actively observe where puddles form after rain and estimate the lifespan of these temporary wetlands. Applying their mathematical skills, they will calculate the area and depth of the puddle. Drawing on their scientific knowledge, they will measure water pH and other water quality variables. They will also identify the organisms that use the puddles for different purposes, fostering a deeper understanding of the ecosystem around them.

Time

2 or 3 classes

Prerequisites

Basic knowledge of ecosystems, ecology, conservation, and meteorology.

School level

Elementary and secondary school students.



Purpose

- Understand temporary wetlands and their importance to living things.

Student outcomes

- Describe the characteristics of puddles as temporary wetlands.
- Measure and record puddles to estimate their area and depth
- Characterize the water quality of the puddles and their changes over the days
- Observe and record the organisms that use puddles (reproduction, cooling, drinking water, etc.)

Background

After rain, it's common to find puddles in various locations. Rainwater can either infiltrate the soil or run off the surface when it reaches the ground. When there's a depression in the ground, the runoff water accumulates, forming a puddle. However, the water that forms puddles can also be part of a river or stream that starts to decrease in flow and forms puddles parallel to its course. Sometimes, the water that forms puddles comes from human activities that remove water, such as pipes or taps with leaks. The shape, size, depth of the puddle, and how long it lasts can vary greatly. Some puddles are temporary; water infiltrates or evaporates quickly, while others can last for several months, especially in areas where the terrain is not very steep. All puddles are characterized by standing water.

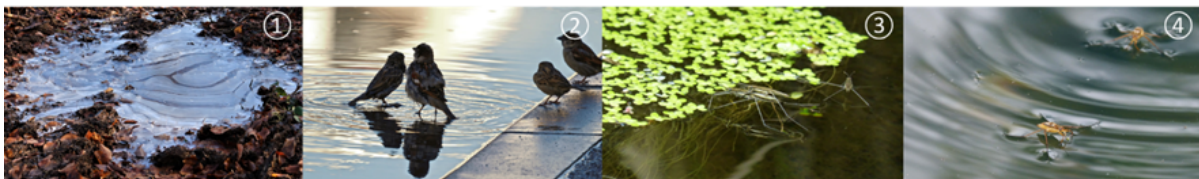


Fig. 1. (1) Puddle with frozen surface. (2) Birds bathing in a puddle. (3) Floating plants and insects in the puddle. (4) Insects use the surface tension of water to move around. Photos: Pixabay.

Puddles are ephemeral ecosystems that depend on environmental conditions. Once the water supply stops or weather conditions change, puddles evaporate or infiltrate the soil. This causes the aquatic habitat that had been established to disappear. Puddles can host a great diversity of organisms that have evolved to survive and reproduce in these transient conditions, such as tadpoles, snails, amphipods, daphnias, copepods, mosquito larvae, and other aquatic insects, and sometimes small fish are found. In addition, puddles are visited by other organisms, such as pets and birds, who use them to drink water or bathe on a hot day; birds often use them for food. Migratory birds use them as rest stops on their journeys. Some insects and birds get mud to build their nests. Your observations of these organisms are crucial to our understanding of these ecosystems.

Environmental conditions in puddles can change rapidly. The amount of water can increase after rain or decrease drastically due to solid evaporation and infiltration on hot, sunny days. This change in water level affects water temperature fluctuations. The temperature in the puddles depends on the sun exposure, the direction and intensity of the wind, etc. The temperature can vary significantly between day and night. In some regions, puddles tend to



freeze, forming a layer of ice at the top. Puddles usually have little dissolved oxygen because the water has little movement, and oxygen decreases as the temperature rises. The influx of organic matter and other pollutants can also reduce the amount of oxygen.

For this reason, some organisms, such as mosquito larvae, have adapted to take oxygen from the air. Puddles are highly exposed to pollution, e.g., runoff can carry agricultural or industrial chemicals, motor oils, garbage, and sewage discharge (especially in urban areas). Wind and rain can cause the deposition of dust, nitrogen oxides, etc.

Due to their small size and accessibility, puddles are excellent for carrying out biodiversity research (identifying the species present in the puddle and those that visit the puddles, interactions between organisms, etc...), water quality (temperature, pH, turbidity, oxygen dissolved in water, nutrients, presence of pollutants, sources of pollution, etc.), response of organisms to environmental changes. If mosquito larvae are found, it is essential to identify the genera and species to determine if species that transmit diseases of health risk, such as dengue, Zika, and others, reproduce. It is also interesting to analyze the land cover around the pond. For example, if you have tree cover that protects the puddle from drying out, if you are exposed to agricultural pollutants, etc.

Guiding Research Questions

If there are no puddles where you are, take a moment to look around. Where might puddles form in the next rain? What factors might influence this? Your curiosity and questions are critical to our exploration.

If there are puddles:

- How do you suppose the water got into the puddle you're looking at? (Due to rainfall-runoff, human activities, a decrease in the water level of a river or stream, etc.)
- How big is the puddle?
- Will it go away quickly or last a few months? Why do puddles disappear?
- Are there bird tracks or insect tracks around the puddle?
- Look into the puddle: What organisms do you find? Is the bottom visible, or is the water murky? What color is the water?
- Are organisms observed, actively swimming, or fixed on the bottom?
- Are there traces of contamination? (wrappings, oil, others)

Scientific concepts

- Water cycle in rural and urban areas
- Human uses of water
- Water availability
- Water quality
- Ecology



Materials and Tools

- Wooden, plastic, or metal stakes
- Thread (preferably sturdy thread, not easily cut)
- Depth measuring meter
- pH strips
- Kits to measure water quality (dissolved oxygen kits, alkalinity, nitrates).
- Water transparency measurement equipment
- Conductivity measurement equipment
- Cell phone magnifiers to identify aquatic insects
- Net to capture aquatic insects
- Light-colored plastic trays to identify aquatic insects found.
- Spoon

What to do and how to do it

- Beginning

Note: Before doing this activity, check the rainfall forecast for your location.

On a rainy day in your locality, show your students the [current rainfall in the world](#). Do you show the rain in or near your locality? Notice the differences in rainfall intensity over the last 30 minutes, 24 hours, and seven days. Does it rain in the same places or move to other areas?

Ask your students to hypothesize where puddles will likely form at school or nearby areas. How long will those puddles last? What could different agencies use them for?

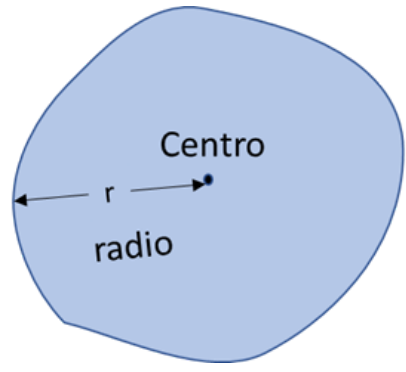
- Development

Divide the class into groups to make different check-ins in different puddles. At the end of the task, they switch to another puddle.

Group 1: Estimate the area and depth of the puddle

Calculation of the area. You can measure this by tracing with threads and stakes.

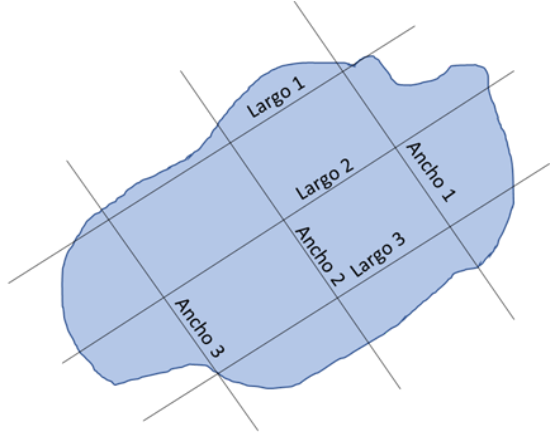
Method 1: If the puddle is relatively circular.



$$\text{Área} = \pi r^2$$

$$\pi = 3,14$$

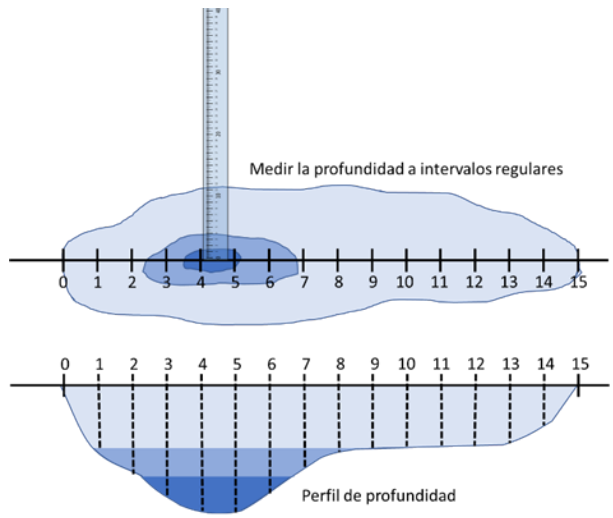
Method 2: If the puddle doesn't resemble any geometric shape



$$\text{Área} = \text{Largo (Promedio)} \times \text{Ancho (Promedio)}$$

Note: If the puddle is small, take a picture of the puddle above using a selfie stick. Then, overlay a transparent gridded sheet over the photo.

Depth:



Sketch the depth profile of the puddle.



Group 2: Measure water quality.

Use pH strips to record the pH of the water. (If you have soil test kits, you can measure dissolved oxygen in water, alkalinity, conductivity, transparency of water, etc.)

Measure the pH of all nearby puddles and compare.

Group 3: Organisms in the Puddle

Observe and record the organisms you find. Bathing birds, aquatic insects, eggs, mosquito larvae, tadpole larvae, copepods, etc...

Gather the groups and ask them to share their observations about puddles, similarities, and differences. Did the puddle sizes vary? What happened to the quality of the water and the organisms they found?

You can return the following week, repeat the observations, and compare them with previous ones to detect changes.

- Closing

Students can make a poster about life in puddles, the adaptations of organisms to live in a temporary habitat, and the environmental conditions that intervene for a puddle to disappear quickly or remain longer.

Note: Activity based on Puddle Wonders! Aquatic Project Wild.

Suggested Resources

To learn more, the following resources are suggested:

Global map of total rainfall (Period: June 2000 to April 2023)

https://earthobservatory.nasa.gov/global-maps/GPM_3IMERGM

Map of current rainfall: <https://gpm.nasa.gov/data/visualization/global-viewer>

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Aquatic Plants Invasion

GLOBE		Associated SDGs	Type of Activity
Spheres	Associated Protocols		
Hydrosphere	Water Temperature, pH, Dissolved Oxygen, Eléctrical Conductivity, Nitrates, Transparency and Macroinvertebrates	6 (Clean water and Sanitation) 13 (Climate Action)	Exploratory
Atmosphere	Air Temperature, Surface Temperature, Precipitation	14 (Life Below Water) 15 (Life on Land)	
Biosphere	Land Cover		
Bundle	Rivers and Lakes		

Overview

Series of satellite images of more than 20 years are compared to observe changes in water hyacinth cover in reservoirs in tropical areas. A case is analyzed with satellite images processed in false color to make measurements of areas covered by water hyacinth. Students analyze local impacts and possible uses of water hyacinth and explore ways of management

Time

3 or 4 classes

Prerequisites

Basic knowledge of ecosystems, food webs, populations, meteorology, water quality and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

Upper Primary School, High School and University students

Purpose

To analyze the phenomenon of water hyacinth invasion in artificial reservoirs and its impacts in tropical areas

Student Outcomes

- To understand the impact of water hyacinth invasion in artificial reservoirs on human activities, health and the environment



- To analyze changes by observing image series since 2000
- To interpret false color processed satellite images and conduct surface measurements from different years in Valsequillo Reservoir
- To explore variables that may influence the invasion of water hyacinth

Background

The water hyacinth or water lily (*Eichhornia crassipes*) is an aquatic plant that contains air chambers that allow it to float. Because of its purple and white flowers, it is used for ornamentation in parks, gardens, etc. It is a species native to the Amazon and De La Plata river basins. Many bodies of water in the world have been colonized by the water hyacinth for more than 50 years. The International Union for Conservation of Nature (IUCN) included it in the list of the 100 most invasive species in the world. This plant, under favorable conditions, reproduces very quickly and it is estimated that it can double its mass in 2 weeks (Watch video [Invasive Species Corpoboyaca: Water hyacinth](#) or [A Dangerous Beauty, the Water Hyacinth](#)).

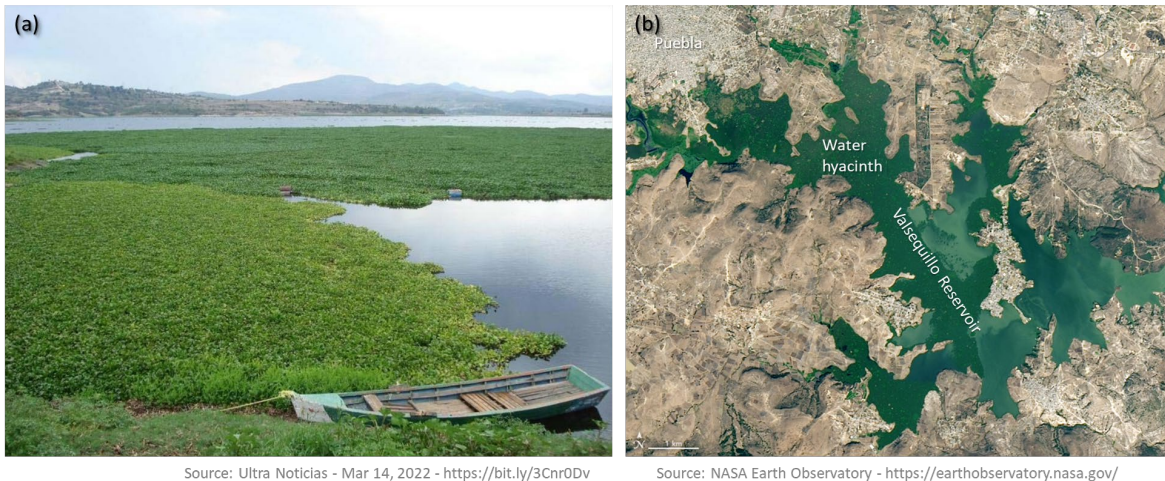


Fig. 1. Photo of water hyacinth in the Valsequillo Reservoir, Mexico (a). Landsat 8 satellite image taken on January 9, 2020 (b) showing the surface of the same reservoir covered by water hyacinths.

Scientific research has shown that water hyacinths have increased in reservoirs and lagoons in tropical areas in much of the world in recent decades, despite efforts to control them (e.g. Mexico, Colombia, Spain, several countries in Africa and Asia) (Watch video [Invasive Alien Species - Aquatic Plants](#) or [Low Level Maintenance Control](#)). This increase is associated with changes in land cover and inputs of pollutants to water bodies produced by runoff (from areas that were deforested, or crop fertilization, increased urbanization and sewage, etc.) that contribute phosphorus and nitrogen to the water. Water pollution with nutrients favors the growth of these plants, but water hyacinth can even grow in environments contaminated by heavy metals. They can retain cadmium, zinc, copper, manganese, mercury, chromium and arsenic. Among the main problems they cause are the obstruction of waterways, hydroelectric power plants, irrigation and drainage networks, etc. They also block the penetration of sunlight below the water surface producing a decrease in oxygen, altering the structure and function of the ecosystem, e.g. the reproduction of invertebrates and fish affecting the entire food web can also move towards a process of eutrophication. This generates socio-economic problems associated with aquaculture, fisheries, tourism, electricity production, water supply, etc. With their intricate branches and roots they trap plastics, retain them for a long time and transport



them over long distances. In addition, water hyacinths provide habitat for the development of disease vector organisms, for example, they facilitate the reproduction of mosquitoes causing the increase of diseases such as dengue fever, yellow fever, etc. that affect nearby communities. Because of these problems, different methods are used for their removal (mechanical, physical and biological).

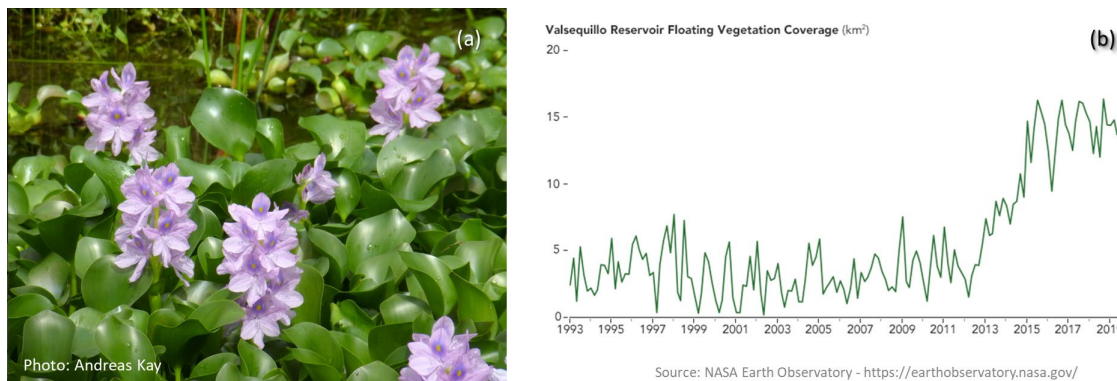


Fig. 2. Flowering water hyacinth (a). Changes in the cover of floating water hyacinth in the Valsequillo Reservoir, Mexico.

In addition to its ornamental use, the water hyacinth is also used as a bioremediatory to remove heavy metals and insecticides from contaminated environments. Extracted from the aquatic environment, it is used to produce ethanol, biogas, green manure (compost) and as food for some poultry (Watch the video [Extraction and use of water hyacinth](#)).

Studying water hyacinth invasions is important for designing control systems. Temperature variations cause changes in the density and extension of water hyacinth. It does not resist frost and prolonged cold temperatures below 5°C and, when temperatures are above 37°C, its growth is affected. Precipitation provides nutrients through runoff and helps the plants to spread in lakes and reservoirs. Currently, water hyacinths are widespread in tropical regions, but climate change could expand their distribution to latitudes that are now temperate and limit their growth. The rapid invasion of water hyacinths is generally associated with a pollution problem, even in their native range, in shallow and polluted waters. Water hyacinth coverage can be easily detected in satellite images. In Google Earth Engine it is possible to analyze time series of Landsat satellite images to detect changes.

Guiding Research Questions

- What was the historical range of water hyacinth distribution?
- What impact do water hyacinth invasions have on aquatic ecosystems?
- What are the characteristics of ecosystems that are invaded by water hyacinth?
- What are possible causes of the increased area covered by water hyacinths?
- How do water hyacinth densities vary throughout the year?
- What is the relationship among air temperature, water temperature, and precipitation to the area covered with water hyacinth?
- What types of land cover (urban, crop, industrial, etc.) exist around a reservoir or lake where water hyacinth invasion has occurred?
- What is the trend in year-on-year variation?
- Is water hyacinth invading water bodies near your location? What impacts did you detect?



Scientific Concepts

- Ecosystems
- Changes in the populations of some species
- Interrelationships of matter and energy in ecosystems
- Water quality. Eutrophication
- Environmental risks and vulnerability

Materials and Tools

Videos:

1. Comisión Federal de Electricidad (2022) *Extracción y aprovechamiento del lirio acuático*. YouTube <https://youtu.be/JCOeLO4oCx8> [In Spanish]
2. Corpoboyacá (2021) *Especies Invasoras Corpoboyaca: Buchón de agua*. YouTube <https://youtu.be/l2dcwVTpllw> [In Spanish]
3. PNUD México (2020) *Especies exóticas invasoras - Plantas acuáticas*. YouTube <https://youtu.be/xnBmof4c5Cw> [In Spanish]
4. UF/IFAS (2021) *Low Level Maintenance Control*. YouTube <https://youtu.be/XtjfdZtia5I>
5. USACE (2020) *A dangerous beauty, the water hyacinth*. YouTube <https://youtu.be/fV4A64TMz6k>

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Google Earth Engine Timelapse: Compilation of satellite images from several years.

1. [Valsequillo](#) Reservoir, México. [Changes observed from satellite](#).
2. [Peñitas](#) Reservoir, México (with aquaculture). [Changes observed from satellite](#).

Satellite images processed in false color to highlight the state of the vegetation in the Valsequillo Reservoir:

1. Landsat 7 ETM+ L2 images- January: [2000](#) – [2001](#) – [2002](#)
2. Landsat 8-9 L1 images - January: [2014](#) – [2015](#) – [2016](#)
3. Sentinel 2 Images - January: [2017](#) - [2018](#) – [2019](#) – [2020](#) - [2021](#) - [2022](#)

Note: The images are hosted on [Sentinel Hub EO Browser](#). To take measurements, you must create a free account. Check your language on the top left.

General Tools: [Mentimeter](#) (creates word cloud) - [Cmap Cloud](#) (to make concept maps)



What to Do and How to Do It

Beginning

1. Watch the videos "[Invasive Species Corpoboyaca: Water buchon](#)", "[Invasive Alien Species - Aquatic Plants](#)" and "[Extraction and use of water lilies](#)" or [A Dangerous Beauty, the Water Hyacinth](#) and [Low Level Maintenance Control](#).

Development

1. Using the information from the videos and the introduction, brainstorm ideas and then create a word cloud or concept map.
2. Look at recent images of the [Valsequillo](#) and [Peñitas](#) Reservoirs in Google Earth. In the Peñitas Reservoir, observe the impact of water hyacinth on floating cages used for aquaculture.
3. Using Google Earth Engine Timelapse, ask your students to compare the changes observed from satellites at [Valsequillo](#) and [Peñitas](#) (you can change the images automatically or stop each year).
4. Divide the class into student groups to analyze the satellite images of the Valsequillo Reservoir. (The resolution of the images varies according to the type of satellite. Recently launched satellites have better resolution, but Landsat 7 images allows us to know how the reservoir was more than 20 years ago).
 - Distribute 2 or 3 images to each group (You must be logged in to access the tools menu in Sentinel Hub EO Browser).
 - January images for the years [2000](#) – [2001](#) – [2002](#) - [2014](#) – [2015](#) – [2016](#) - [2017](#) - [2018](#) – [2019](#) – [2020](#) - [2021](#) - [2022](#)
 - Ask your students to use the ruler tool to delineate areas covered by water hyacinth.
5. Bring all the groups together and ask them to show the data obtained from each satellite image. Compare the area covered by water hyacinth in the different years and discuss considering the following questions:
 - Are there trends of increasing or decreasing area covered?
 - Which years stand out as having less water hyacinth cover? Which years have greater cover?
 - What variables might be influencing this (consider environmental variables and changes in land cover around the reservoir, changes in town size, etc.)?
 - Did any areas of the reservoir remain without water hyacinth cover? Did any regions remain unchanged? To what can this variation be attributed?

6. Ending

Complete the concept map above with the analyzed example and the comparison of satellite images from different years.

Frequently Asked Questions

How can I observe water hyacinth cover from satellite images? With Sentinel Hub EO Browser and the false color combination highlighting the infrared band. You can also use other band combinations such as NDVI.

Where can I find false-color processed satellite imagery? In Sentinel Hub EO Browser you can search for images from anywhere in the world.



What are the best dates to compare satellite images? The Landsat and Sentinel satellites pass over a certain site on some days, not all. For a better view of the Earth's surface, you should choose images with few clouds and compare the same month in different years.

Tutorial [EO Browser](#)

Suggested Resources for Further Information

As an extension of this activity, you can compare the images with temperature and precipitation data for the analyzed site, significant reduction events due to water hyacinth management (by manual, chemical, biological extraction methods).

To learn more about this phenomenon, we suggest reading one of the articles:

Harun, I., Pushiri, H., Amirul-Aiman, A. J., & Zulkeflee, Z. (2021). Invasive water hyacinth: ecology, impacts and prospects for the rural economy. *Plants*, 10(8), 1613. <https://www.mdpi.com/2223-7747/10/8/1613> [in English]

Rodríguez-Lara, J. W., Cervantes-Ortiz, F., Arámbula-Villa, G., Mariscal-Amaro, L. A., Aguirre-Mancilla, C. L., & Andrio-Enríquez, E. (2022). Lirio acuático (*Eichhornia crassipes*): una revisión. *Agronomía Mesoamericana*, 33(1). <https://dialnet.unirioja.es/descarga/articulo/8218098.pdf> [In Spanish]

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Kriticos, D. J., & Brunel, S. (2016). Assessing and managing the current and future pest risk from water hyacinth, (*Eichhornia crassipes*), an invasive aquatic plant threatening the environment and water security. *PloS one*, 11(8), e0120054. <https://bit.ly/3R0nJ1z>

Lowe S., Browne M., Boudjelas S., De Poorter M. (2000) *100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database*. The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), Auckland. <https://bit.ly/3jvmxai>

Wright, C. (28 June 2022). Remote Sensing Tracks Down “Plastic Plants” in Rivers. Researchers are using remote sensing to track floating mats of plastic trapped in water hyacinth plants. *EOS. AGU*. <https://bit.ly/3PCrx7y>



Glacier Retreat

GLOBE		Associated SDG	Type of Activity
Spheres	Associated Protocols		
Atmosphere	Air temperature. Surface Temperature. Clouds. Precipitation.	6 (Clean Water and Sanitation) 13 (Climate Action) 14 (Life Below Water) 15 (Life on Land)	Exploratory
Biosphere	Land Cover.		
Pedosphere	Soil Moisture. Soil temperature. Frost Tube		
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Water Transparency. Salinity. Nitrates.		
Bundle	Water Cycle. Water Quality. Rivers and Lakes.		

Overview

Satellite images and maps are analyzed to determine glacier fluctuations over the last 20 years or more. Glaciers and fluctuations are located, and the impacts of temperature increase on glacier extent and new lake formation are compared.

Time

4 or 5 classes

Prerequisites

Basic knowledge of ecosystems, meteorology and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

Upper Primary School, High School and University students

Purpose

To understand the impact of ice loss on glaciers and the changes in the interrelationship among the spheres of the Earth System



Student Outcomes

- To compare satellite data on snow cover, net radiation, Earth's surface temperature and cloud fraction to establish relationships.
- To analyze cases of glacier cover changes, the formation of new water bodies due to ice melting and their impact on ecosystems and human activities.
- To consider the impact of human activities on climate change and glacier retreat.
- To outline hypotheses of possible consequences on human activities from the disappearance of glaciers in some regions.

Background

Low [temperatures](#) and snow [precipitations](#) are essential for the formation and maintenance of [glaciers](#). The largest ice sheets are located in the [poles](#) and are important for their influence on climate regulation and their contribution to changes in sea level. In the Andes, glaciers are found above the snow line, where cold temperatures maintain the ice all year round. Glaciers are considered sensitive indicators of climate change because they respond quickly to changes in temperature and precipitation. The WMO (World Meteorological Organization) report on the "2021 *State of the Climate in Latin America and the Caribbean*" notes that warming is accelerating in the region and precipitation patterns are changing. As a result, The Andes glaciers have lost much of their mass and are in retreat. The WGMS (World Glacier Monitoring Service) monitors some of the world's benchmark glaciers and documents the [fluctuations](#). The rapid retreat of tropical glaciers is considered one of the most visible indicators of global warming. The degree of glacier retreat varies, but small glaciers are more vulnerable. Many of the Andean glaciers have already disappeared and this situation increases the risk of water scarcity for populations, production, hydroelectricity generation and ecosystems.

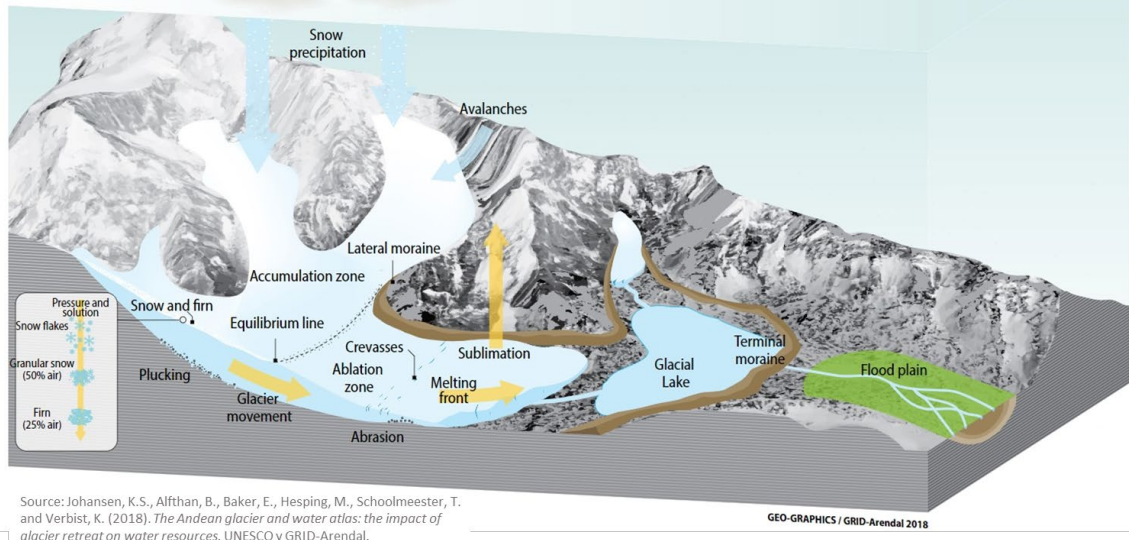
The formation of glaciers depends on latitude, altitude and annual precipitation. As snow accumulates, it compresses the snow already deposited and creates a dense layer, called firn. If snow continues to accumulate, the pressure increases and the firn becomes more compact until it becomes solid glacier ice that begins to flow by the effect of the force of gravity on its own mass, or by sliding or internal deformation. Glaciers have an upper accumulation zone, where the snow mass is deposited, and a lower ablation zone, where the glacier mass is lost. The ablation process can occur by melting, erosion, wind, and frontal sliding. The area between the zones where accumulation equals ablation is called the equilibrium line, the area that marks the boundary between new snow and old snow that is exposed after melting. When periods of greater ablation or greater snow accumulation occur, this equilibrium disappears and the glacier can advance or retreat.

The albedo is the ability of surfaces to reflect solar radiation. Glaciers influence the global climate because their reflective capacity of ice and snow is important for regulating the temperature in the atmosphere. Dark surfaces have a low albedo, absorb more energy and warm up. White surfaces, such as snow, have a higher albedo and reflect much of the sun's energy back into space.

The high albedo of the snow keeps the surfaces cold, but as the glaciers shrink, the dark ground that absorbs radiation is exposed, causing warming and further enhancing the melting of the surrounding snow. Soot particles, also known as black carbon, travel long distances and are often deposited on glaciers, darkening their surface and causing further melting. This phenomenon is more frequent in glaciers that are relatively close to large cities.



Glacier mass balance



Source: Johansen, K.S., Alfthan, B., Baker, E., Hesping, M., Schoolmeester, T. and Verbist, K. (2018). *The Andean glacier and water atlas: the impact of glacier retreat on water resources*. UNESCO y GRID-Arendal.

GEO-GRAPHICS / GRID-Arendal 2018

Fig. 1. Snow accumulation and ablation zones on a glacier.

Glaciers provide water to most of the large rivers in South America. The headwaters of the great basins in the high areas of the Andes usually receive more precipitation than the plains. In addition, glaciers and snow-covered areas constitute a significant reserve of water that is released during snowmelt and are particularly important in regions with large seasonal variations and low levels of precipitation.

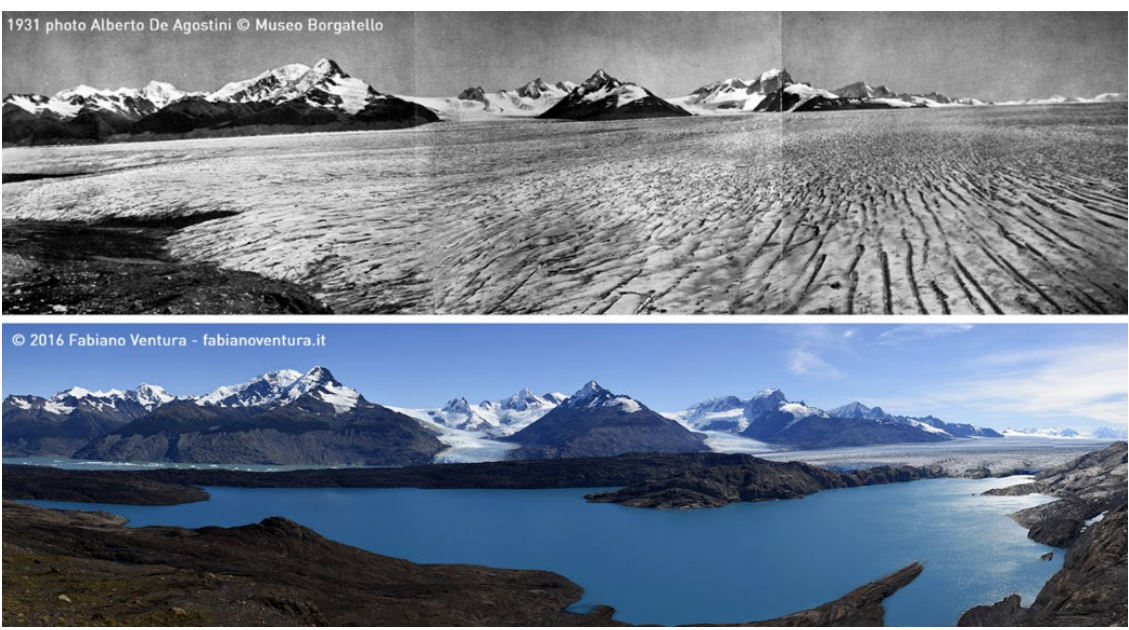


Fig. 2. Comparison of photographs of Upsala Glacier, Argentina taken in 1931 and 2016.



Glacier retreat can be quantified by comparing old photographs with current ones as in Figure 2, and also by satellite imagery, as shown in Figure 3.

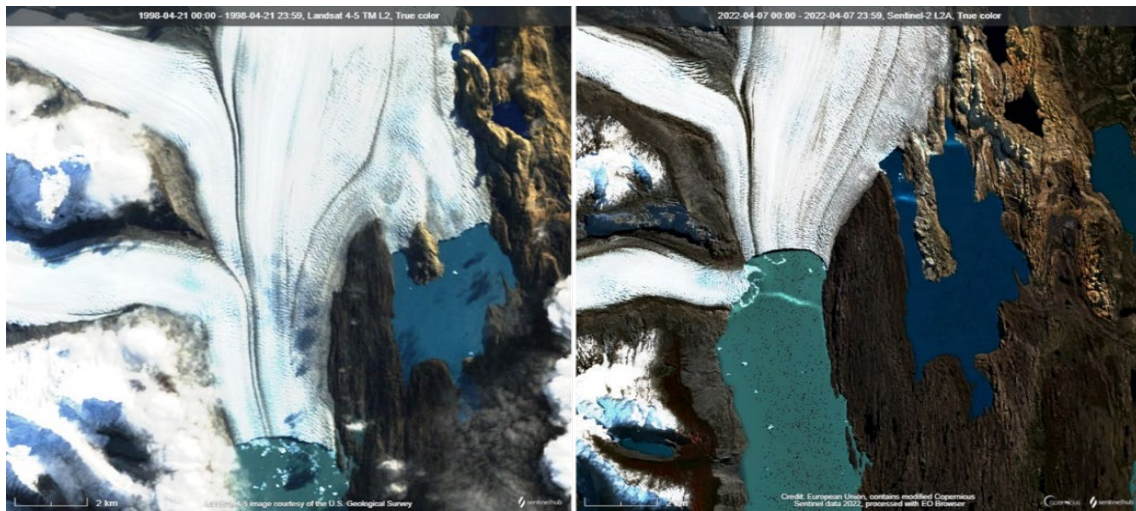


Fig. 3. Satellite images of the Upsala Glacier in Argentina. The recent Sentinel-2 L2A image from April 2022 (right) shows ice loss at the glacier front and edges when compared to the Landsat 4-5 TM L2 image from April 1998 (left).

The loss of ice causes river levels to decrease and increases the risk of drought. Where river flows have been documented over long periods of time, these trends can be observed.

To assess the condition of a glacier, glaciologists measure the annual mass balance which is the result of the snow accumulation (mass gain) and melting (mass loss) during a given year. The mass balance reflects the atmospheric conditions during a hydrological year. By measuring the mass balance over a long period, it is possible to observe trends.

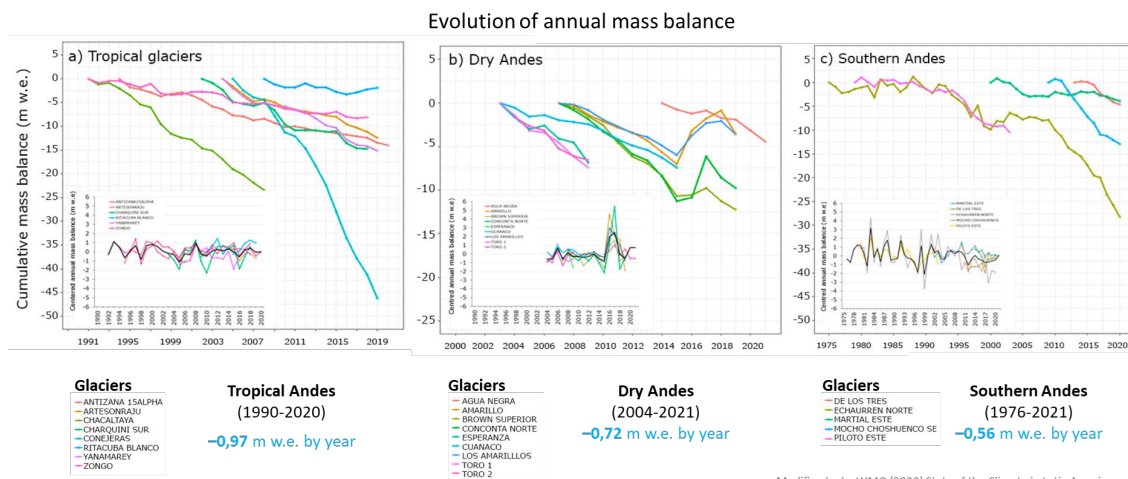


Fig. 4. Decrease in the annual mass balance of Andean glaciers.



Figure 4 shows the ice mass trends in recent years in the Andes region by the World Glacier Monitoring Service (WGMS). Glaciers in the tropical Andes have lost -0.97 (meters of water equivalent) between 1990 and 2020. Analyses using satellite imagery show significant reductions in glacier area in recent decades. The Dry Andes and the Southern Andes also show the same trend of retreat. In the future, glaciers throughout the Andes are expected to continue to retreat and the resulting hydrological changes will impact communities and ecosystems. Therefore, knowing and monitoring changes in ice cover is the first step in understanding and designing mitigation measures for impacts.

Guiding Research Questions

- How does the extent of glaciers change?
- What kind of changes are observed?
- Are there new lakes around the glaciers?
- To which watersheds do the glaciers you are studying contribute water?
- What is the relationship among temperature, precipitation and the formation of an ice cover?
- What is the impact of changes in ice cover on ecosystems and people's lives?
- What human activities impact glaciers on a large scale?
- How can changes in the cryosphere be measured?

Scientific Concepts

- Ecosystems
- Cryosphere
- Land Cover
- Electromagnetic Spectrum
- Satellite Images - False Color Composite

Materials and Tools

- ArcGIS StoryMaps <https://storymaps.arcgis.com/>
- Global maps - Records of the last few years:
 1. Snow cover - <https://go.nasa.gov/3fYZPFQ>
 2. Net radiation received by the Earth's surface - <https://go.nasa.gov/2T2EwDJ>
 3. Earth's surface temperature - <https://go.nasa.gov/3rQKN7T>
 4. Fraction of clouds that regulate the Earth's temperature - <https://go.nasa.gov/2JavOOV>
- Cases of changes in some glaciers:

Case 1. Glaciers of the Sierra Nevada del Cocuy, Colombia:

1. Google Map - [Location](#)
2. Google Earth (Sequence [1985 to 2020](#))
3. Wordview ([comparison](#) 1986 and 2021)
4. EO Browser - (seasonal changes): [January](#) - [August](#)

Case 2. Quelccaya Glacier, Peru:

5. Google Map - [Location](#)
6. Google Earth (Sequence [1985 to 2020](#))
7. Wordview ([comparison](#) 1985 and 2022)
8. EO Browser - (seasonal changes): [April](#) - [September](#)



Case 3. Glaciers in Ancohumá (Cordillera Real), Bolivia:

1. Google Map - [Location](#)
2. Google Earth (Sequence [1985 to 2020](#))
3. Wordview ([comparison](#) 1986 and 2022)
4. EO Browser - (seasonal changes): [May](#) - [September](#)

Case 4. Upsala Glacier, Argentina:

1. Google Map - [Location](#)
2. Google Earth (Sequence [1985 to 2020](#))
3. Wordview ([comparison](#) 1985 and 2022)
4. EO Browser - (seasonal changes): [April](#) - [September](#)

Case 5. Southern Patagonian Ice Glacier (HPS-12), Chile:

1. Google Map - [Location](#)
2. Google Earth (Sequence [1985 to 2020](#))
3. Wordview ([comparison](#) 1985 and 2021)
4. EO Browser - (seasonal changes): [Febrero](#) - [September](#)

Case 6. Several glaciers in Sierra de Sangra, on the Chile-Argentina border:

1. Google Map - [Location](#)
2. Google Earth (Sequence [1985 a 2020](#))
3. Wordview ([comparison](#) 1985 y 2022)
4. EO Browser - (seasonal changes): [February](#) - [September](#)

Supplementary material to analyze all the cases locating each glacier in:

1. Glacier Inventory - [GLIMS](#) and it records nearby glaciers
2. Glacier Fluctuations - [WGMS](#) for ice fluctuations in recent years
3. Drought Atlas - to know the variation of humidity over long periods of time. [SADA](#) [In Spanish] to know the variation of humidity over long periods of time. (Data is currently available for some countries).

What to Do and How to Do It

- Beginning

Show your students the [Global Snow Cover Map](#) and note the changes for different months of the year around the world. Compare the same month in different years.

Compare snow cover with: a) [Net Radiation](#), b) [Land Surface Temperature](#) and c) [Cloud Fraction](#). Look again at the changes in different months of the year and the same month in different years to see how they match.

Have your students record the years with the highest and lowest ice cover. Also have them record the overlaps of these years with net radiation, surface temperature, and cloud fraction.

Ask students to develop some hypotheses about possible causes of changes in snow cover.



- **Development**

1. Divide the class into groups and assign one case to each group to discuss.
 - a. Look at the current satellite image on Google Map. What do you see in that image (glaciers, forest, rivers, lakes, plantations, cities, roads, etc.)? What type of cover do they correspond to (Urban, Suburban, Roads, Forest, Prairie, Crops, Ice, Rocks, Water, etc.)?
 - b. Open the Google Earth sequence and observe the changes in each year. Record the major changes (e.g., changes in ice extent, glacial lake formation, changes in vegetation cover, etc.).
 - c. Compare Landsat images (old) and Sentinel images (current). Record the observed changes.
 - d. Compare recent Sentinel images in EO Browser with the combined bands for false color composite. What seasonal changes are seen in the images? (Consider this combination of bands that highlights vegetation in red and allows for clearer visualization of snow on the ground.)
2. Ask your students to create a presentation about the case study. They can make a story with maps (using ArcGIS StoryMaps), or a slide presentation.
3. Bring all the groups together, ask them to explain the cases they discussed and compare the similarities among the cases.
4. If you have glaciers nearby or are in a watershed where water availability depends on glacier ice, you can use the same tools to analyze their status and changes in recent years. You can also supplement with field measurements. If you do not have glaciers nearby you can analyze other cases and compare them. Resources:
 - a. Location of glaciers in the world - GLIMS <https://www.glims.org/maps/glims> (See bibliography for glacier inventories and specific reports in different countries)
 - b. WGMS 's Glacier Fluctuations - <https://wgms.ch/fogbrowser/>
 - c. SADA 's Drought Atlas - <https://sada.cr2.cl/> [In Spanish] (This atlas has information for some countries, but it is being updated to be extended to other regions.)

- **Ending**

Because of the relevance of this issue, it is important to develop outreach information materials. Students can make a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the cases they analyzed and highlighting the importance of glaciers for ecosystems and communities.

Frequently Asked Questions

Where do I find satellite images? - Worldview - EO Browser - Google Earth - Google Map

Where do I find glaciers? - GLIMS is a database of the world's glaciers. You can download glacier contours and place them in Google Earth.

Where do I find glacier retreat information? WGMS is a database of glacier fluctuations around the world. It has information on some reference glaciers.



Where can I consult satellite images? - Worldview - EO Browser

Suggested Resources for Further Information

As an extension of this activity students can consult satellite images from different dates and locations to explore other glaciers. The GLIMS and WGMS databases have specific information. There are also national glacier inventories (see link of interest). Worldview and Google Earth have stored images since the 1980s.

Other Resources:

Drought Atlas <https://sada.cr2.c> [In Spanish]

Snow Cover and Sea Ice Cycle at the Poles <https://svs.gsfc.nasa.gov/4995>

WGMS Fluctuation of Glaciers - <https://wgms.ch/fogbrowser/>

GLIMS Glacier Inventory - <https://www.glims.org/maps/glims>

Article:

Yanes, J. (2022) [Glaciers Are Disappearing at an Unprecedented Rate](#). OpenMind BBVA.

Global maps:

1. Snow cover since the year 2000 - <https://go.nasa.gov/3fYZPFQ>
2. Land temperature since the year 2000 - <https://go.nasa.gov/3rQKN7T>

Links of interest:

National Water Authority - ANA. Peru. Glaciers. <https://bit.ly/3CHhqLs>

Chilean Glaciers Foundation <https://www.glaciareschilenos.org/>

Institute of Hydrology, Meteorology and Environmental Studies - IDEAM. Colombia. Glaciers in Colombia. <https://bit.ly/3rFJwR1>

National Glacier Inventory. IANIGLA. Argentina. <https://www.glaciaresargentinos.gob.ar/>

Glaciology Laboratory. Chile. <https://glaciologia.cl/>

Videos:

NASA Climate Change (2021). *Global Warming from 1880 to 2021*. Youtube: <https://youtu.be/haBG2IlwbwA>

NASA Climate Change (2021). *NASA: Sea level rise*. List: Earth Minute. Youtube: <https://youtu.be/msnOHuPep9I>

NASA Climate Change (2021). *NASA: Earth has a fever*. List: Earth Minute. Youtube: <https://youtu.be/nAuv1R34BHA>

NASA Climate Change (2021). *NASA: Usual suspects*. List: Earth Minute. Youtube: <https://youtu.be/dLGbqip78IE>

NASA Climate Change (2022). *Climate Spiral*. Youtube: <https://youtu.be/jWoCXLuTIkl>

NASA Climate Change (2022). *Global Warming Broken Down by Latitude Zone: 1880-2021*. Youtube: <https://youtu.be/f6FMS7mJatM>

NASA Climate Change (2022). *Watching the Land Temperature Bell Curve Heat Up (1950-2020)*. Youtube: <https://youtu.be/1YiqIWWMPHM>

Tutorials by: [Worldview](#), [EO Browser](#), [Story Map](#)



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- NASA Earth Observatory (2000 to 2022) *Snow Cover*. Global Maps. https://earthobservatory.nasa.gov/global-maps/MOD10C1_M_SNOW
- NASA Earth Observatory (2013) *Tropical Climate History...Shrinking*. <https://go.nasa.gov/3yqLjgu>
- NASA Earth Observatory (2013) *Upsala Glacier Retreat*. <https://go.nasa.gov/3rGihWp>
- NASA Earth Observatory (2016) *Glacier Change Threatens Andes Communities*. <https://go.nasa.gov/3Vd2nAo>
- NASA Earth Observatory (2016) *Retreat of the Sierra de Sangra Glaciers*. <https://go.nasa.gov/3EpS1qX>
- NASA Earth Observatory (2017) *Ice on the Move in Patagonia*. <https://go.nasa.gov/3yqxcrx>
- NASA Earth Observatory (2017) *North Patagonian Icefield*. <https://go.nasa.gov/3RUW0Pu>
- NASA Earth Observatory (2017) *South Patagonian Icefield*. <https://go.nasa.gov/3rIKxri>
- NASA Earth Observatory (2018) *Glacial Retreat at a Non-glacial Pace*. <https://go.nasa.gov/3rGqC37>
- NASA Earth Observatory (2018) *Melting Beauty: The Icefields of Patagonia*. <https://go.nasa.gov/3EsBfal>
- NASA Earth Observatory (2019) *Is HPS-12 the Fastest Thinning Glacier?* <https://go.nasa.gov/3ejpdWq>
- NASA Earth Observatory (2022) *Chilean Volcano Low on Snow*. <https://go.nasa.gov/3CkYd0y>
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- NSIDC (2022). *Sea Ice Index Daily and Monthly Image Viewer*. https://nsidc.org/data/seaice_index
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ISC(WDS)/IUGG(IACS)/UNEP/UNESCO/WMO, World Glacier Monitoring Service, Zurich, Switzerland. https://wgms.ch/downloads/WGMS_GGCB_04.pdf

WMO (2022) *State of the Climate in Latin America and the Caribbean 2021*. WMO-No 1295. <https://bit.ly/3GsLBI6>



Remote Sensing – Hydrosphere

GLOBE		SDG Partner/s	Type of Activity/s
Sphere	Protocols		
Atmosphere	Air temperature. Surface temperature. Wind direction and speed. Rainfall. Relative humidity	11 (Sustainable cities and communities) 13 (Climate action) 14 (Life below water) 15 (Life on land)	Exploratory
Biosphere	Land cover. Biometrics. Phenology		
Pedosphere	Soil characterization. Fertility. Humidity. pH. Temperature		
Hydrosphere	Water temperature. pH. Alkalinity. Electrical conductivity. Transparency. Salinity. Nitrates.		
Package	Agriculture Oceans Rivers and Lakes Soils Towns Water quality		

Overview

The basic concepts of remote sensing are explained to analyze satellite images of two cases: the turbidity of the water of the Río de La Plata at its mouth in the sea and the melting of the HPS-12 glacier in Chile. Satellite images processed with a combination of bands and indices are used. In addition, students can try different combinations of bands and apply other specific indices to highlight some features.

Time

4 or 5 lessons

Prerequisites

Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.



School level

High school and college students

Purpose

Understand the application of wave properties, use satellite sensors and satellite images to obtain information from the Earth, and process it to observe changes, trends, and interrelationships between the biosphere, atmosphere, hydrosphere, and pedosphere.

Student outcomes

- Know the types of electromagnetic waves satellite sensors use to obtain information from the Earth system.
- Identify changes and trends in satellite imagery.
- Apply combinations of the bands assigning the colors Red (R), Green (G), and Blue (B) to identify specific features in the field.
- Apply specific indices to analyze different features in satellite images.
- Analyze the variations of turbidity of the water at the mouth of the La Plata River.
- Analyze the rate of melting of the HPS-12 glacier in Chile.

Background

Remote Sensors

Remote sensing is acquiring information remotely using remote sensors. A camera is a sensor that allows us to obtain information from objects at a distance. Our eyes are sensors that enable us to obtain information from our environment. To study the Earth, sensors are placed on satellites, the International Space Station, airplanes, drones, etc. Fig. 1.

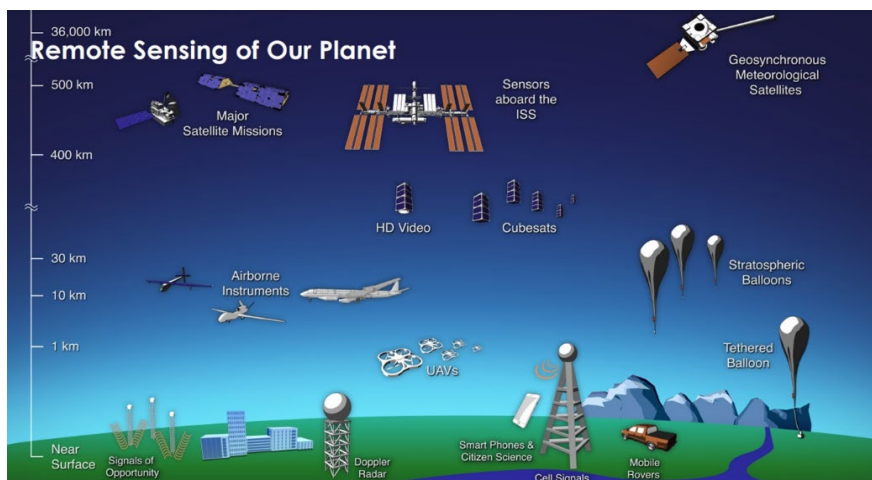


Fig. 1. Different types of remote sensors that obtain information from Earth. Source: <https://svs.gsfc.nasa.gov/30892>



Remote sensors provide a global perspective and a large amount of data from the atmosphere, hydrosphere, pedosphere, and biosphere that allow us to know the current state, study trends with historical information (e.g., [Record of 20 years of rain and snow](#)), and use them for data-driven decision making. NASA has its [fleet of satellites orbiting the Earth](#), and some satellites operate in consortium with other countries (several of them belong to the [Latin American and Caribbean](#) region). An example of this is the [International Afternoon Constellation](#), formed by a collaborative group of satellites from different countries that travel a synchronized orbit with the sun, passing at approximately 13:30 local solar time, with a difference of seconds to minutes between them (for this reason it is called the Evening Constellation). This constellation of satellites makes almost simultaneous observations with a wide variety of sensors that are very useful for conducting research, issuing alerts, making decisions, etc. Fig. 2.

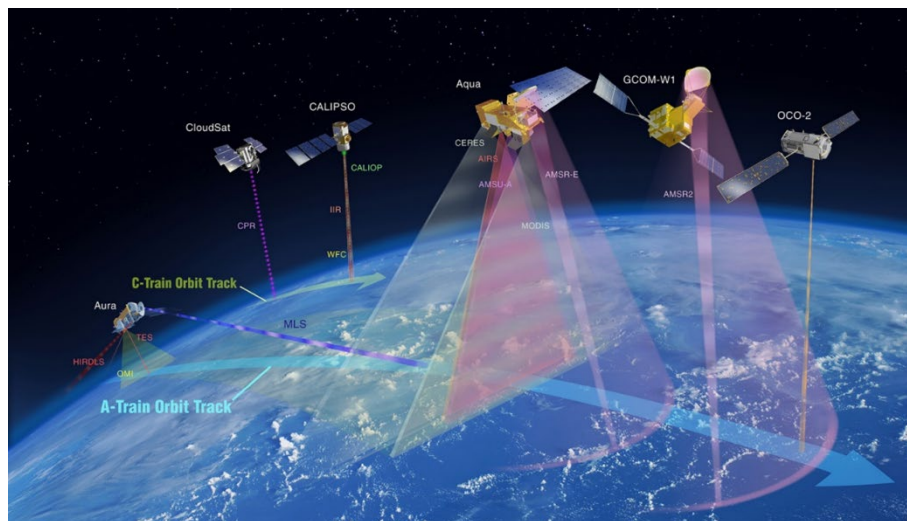


Fig. 2. International Afternoon Constellation. Source: <https://atrain.nasa.gov/>

Some sensors are passive; that is, they detect the electromagnetic waves reflected by the earth's surface when illuminated by the sun or when it emits light (e.g., the night lights of cities). Most passive sensors operate in the electromagnetic spectrum's [visible](#), [infrared](#), and [microwave](#) portions. Passive sensors measure land and sea surface [temperature](#), [vegetation](#) properties, [clouds](#), [aerosols](#), and soil moisture. However, they have limitations because they cannot penetrate the dense cloud cover that regularly covers the tropics. Active sensors emit waves that bounce off the earth's surface and return. Most operate in the [microwave](#) band of the [electromagnetic spectrum](#), allowing them to penetrate the atmosphere (e.g., radar). These sensors measure vertical aerosol profiles, [forest structure](#), [precipitation](#) and [winds](#), sea surface topography, and ice.

The Sun is the primary source of energy observed by satellites. Different types of surfaces reflect different amounts of solar energy. Albedo is the property of anybody to reflect incident radiation. For example, snow is a transparent surface and has a high albedo (it reflects up to 90% of incoming solar radiation). The ocean is dark, with low albedo (it reflects only about 6% of incoming solar radiation and absorbs the rest). When energy is absorbed, it is re-emitted, usually at [longer wavelengths](#). In the case of the ocean, the absorbed energy is re-emitted as



infrared radiation. The amount of energy surfaces reflect, absorb, or transmit varies depending on the wavelength.

Spectral bands and signatures

As the reflected energy varies according to the surface type, it can be used to identify different characteristics of the Earth; it works just like our fingerprints and is called a spectral signature. Thanks to the spectral signature, it is possible to identify different types of rocks and minerals, clear and turbid water, soil moisture, different types of vegetation, state of vegetation, etc.). Fig. 3.

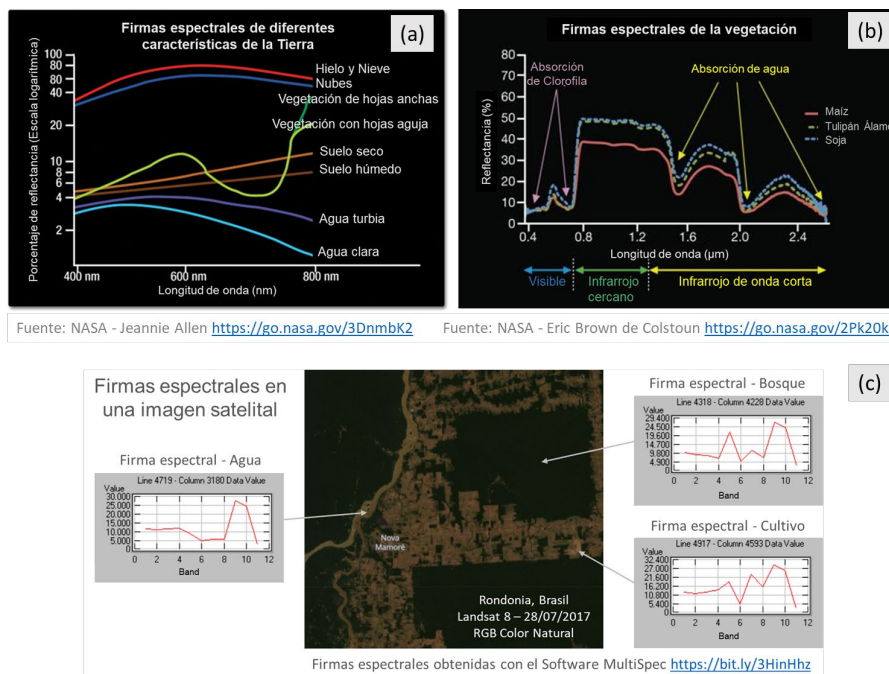


Fig. 3. Spectral signatures: (a) of different characteristics of the Earth. (b) vegetation. (c) Examples of spectral signatures in different pixels of the satellite image of Rondônia, taken by the Landsat 8 satellite on 07/27/17.

A digital image comprises pixels (or boxes) whose color represents a number each. Therefore, an image is an array of grayscale numbers ranging from 0 (white) to 255 (black). Any other value within that range is a variation of gray. (Fig. 4)

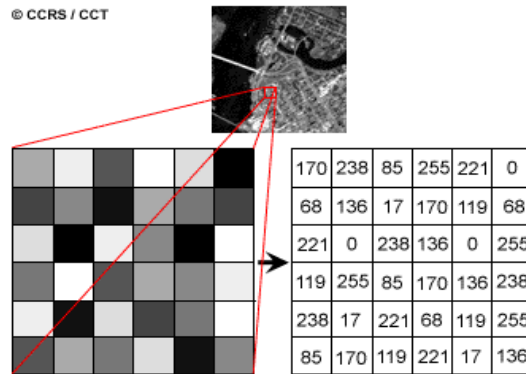


Fig. 4. Satellite image and numerical matrix of a Landsat 7 satellite image band. Each pixel (or frame) represents a terrain area of 30m x 30m and a certain brightness color. Source: <https://www.nrcan.gc.ca/>

Each satellite image has multiple bands representing different electromagnetic spectrum wavelengths [Fig. 5 (a)]. The sensors on most satellites use everything from infrared to ultraviolet, including visible light. The bands represent data from visible regions and infrared (shortwave infrared, near-infrared, and mid-infrared). [Fig. 5 (b)] When We combine the bands in an RGB image to obtain a color similar to the natural one, we are working with three matrices, one per color channel: Red (Red), Green (Green), and Blue (Blue). [Fig. 5 (d)] As with grayscale images, 0 represents the absolute absence of color, and 255 represents the total presence of hue for a particular channel. One of the RGB colors is assigned, and the false color is obtained to observe other aspects reflected in infrared bands or others in wavelengths that our eyes do not perceive. [Fig. 5 (c)]

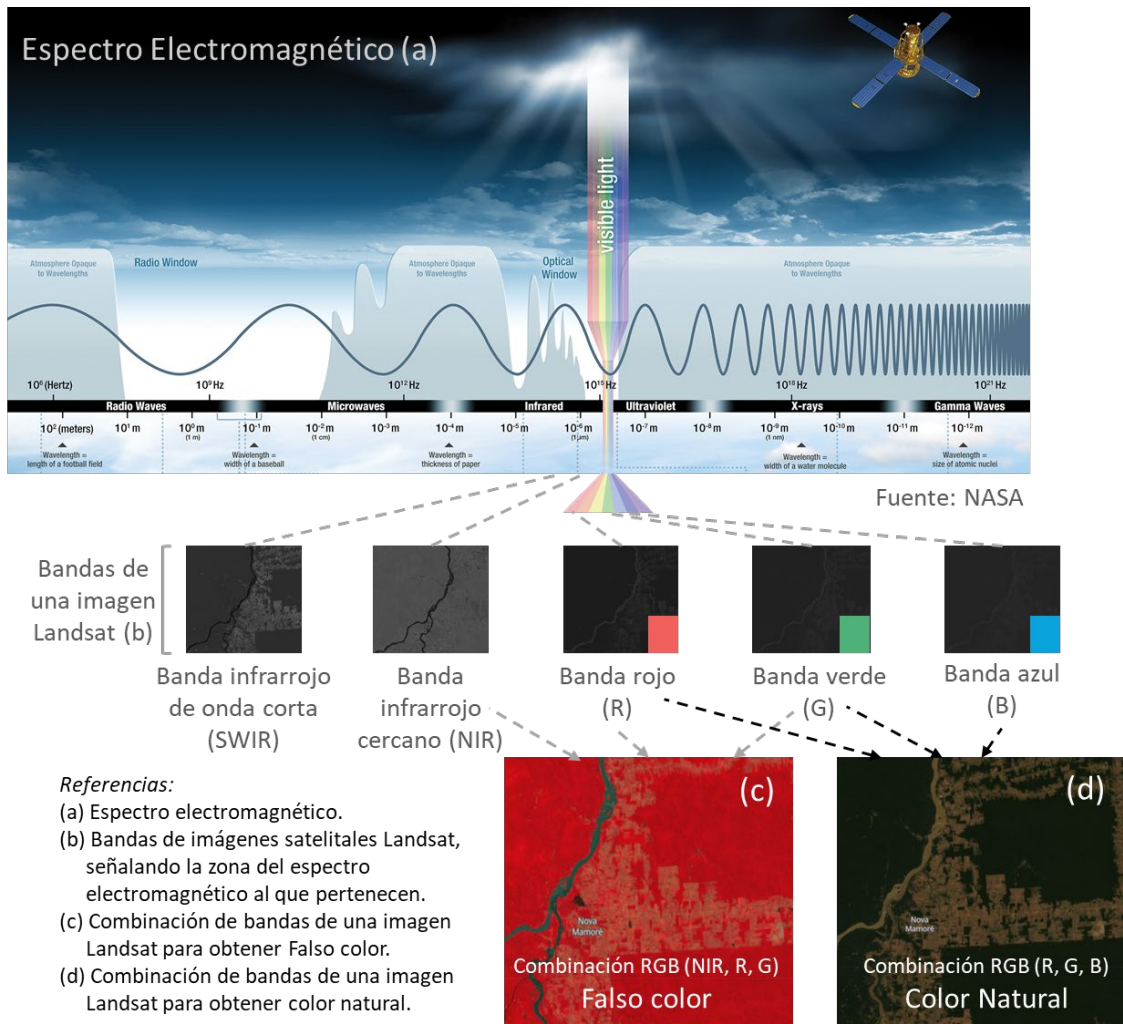


Fig. 5. Combination of bands of Landsat satellite imagery to visualize different aspects. Sources: NASA and Landsat.

Indexes

As satellite images are matrices, it is possible to perform calculations with them to detect other elements not visible with the color scheme. The indices are obtained from calculations with the matrices that form each band of the satellite images. This calculation is performed using some specific [software](#), and as a result, a new image is obtained where the pixels related to the parameter we are measuring are graphically highlighted. The vegetation indices



emphasize vegetation cover parameters: density, leaf area index, chlorophyll activity, and others. For example, details of changes in vegetation cover are easily analyzed by applying indices. The Normalized Difference Vegetation Index (NDVI) is the most widely used, but several similar indices exist. The NDVI allows estimating vegetation quantity, quality, and development based on measuring the intensity of radiation from some bands of the electromagnetic spectrum that vegetation emits or reflects. The bands vary according to the type of satellite. Some viewers automatically generate the most common indexes. High NDVI values indicate healthy vegetation; low values indicate that vegetation is drying out (may be due to water stress, disease, fire, etc.). Fig. 6.

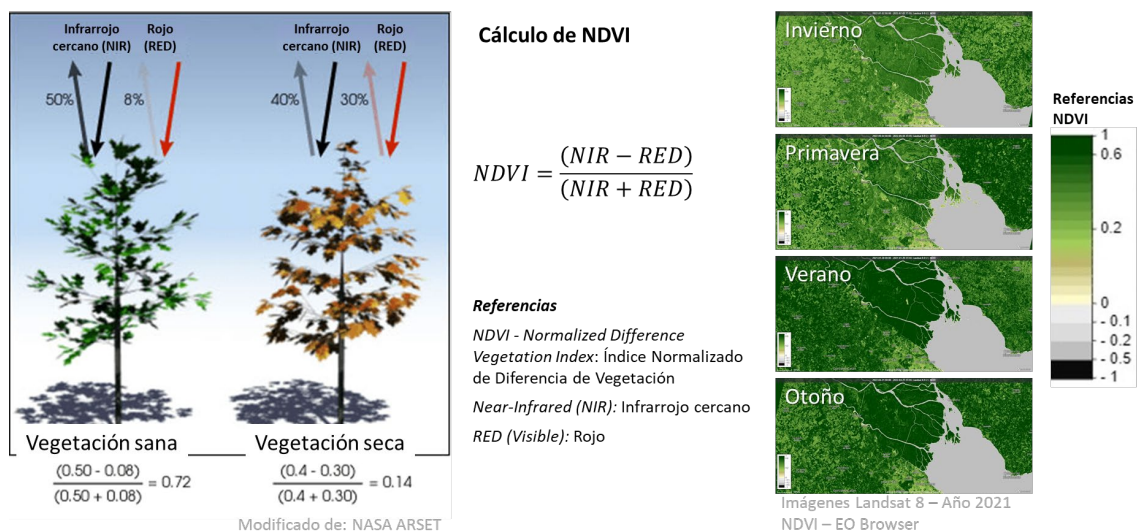


Fig. 6. Calculation and satellite images of the Paraná River Delta processed with the NDVI index. Seasonal changes in vegetation are detected with different color intensities.

Spectral indices have been developed to analyze different aspects of satellite images that have applications in ecology, agriculture, disasters (floods, fires, etc.), aquatic resources, geology, etc. All use calculations using different bands of satellite imagery.

Guiding Research Questions

- Why does water turbidity vary throughout the year? Is it related to rainfall and temperature?
- What are the causes of glacier melt? What are the consequences?
- Why do you use different combinations of bands and specific indices to visualize some land cover characteristics?

Scientific concepts

- Ecosystems. Rivers. Lakes. Glaciers
- Land coverage.
- Waves and the electromagnetic spectrum.
- Graphics. Histograms
- Satellite images



Materials and tools

1. ArcGIS StoryMaps <https://storymaps.arcgis.com/>
2. Worldview <https://worldview.earthdata.nasa.gov/>
3. EO Browser App <https://apps.sentinel-hub.com/eo-browser/>

Seleccionar idioma

Herramientas para seleccionar combinación de bandas e índices

Herramientas de mediciones

Clic en personalizar para abrir Composite

Arrastrar las bandas para hacer la combinación.
En este ejemplo R(B11) G(B12) B(B07) que permite ver características del desierto

Arrastrar las bandas para hacer el índice.
En este ejemplo Índice de Suelo Desnudo (BSI - Bare Soil Index)

Cálculo índice BSI

$$BSI = ((Red+SWIR) - (NIR+Blue)) / ((Red+SWIR) + (NIR+Blue))$$

$$BSI (Sentinel 2) = (B11 + B4) - (B8 + B2) / (B11 + B4) + (B8 + B2)$$

Paleta para asignar colores al índice

Fig. 7. Infographic of EO Browser App tools.

Case analysis:

Case 1: Turbidity at the mouth of the Río de la Plata.

- Google Map - [Location](#)

Worldview

- Compare images from [2000 and 2022](#)



- Seasonal turbidity ([July and December](#))
- Environmental conditions. a) Average monthly [rainfall](#), b) [Temperature of the earth's surface](#), and c) [Water temperature](#)
- Generate a [video](#) in Worldview with each data group queried.

EO Browser (see tools in Fig. 7):

1. Sentinel image 13/08/22: [False](#) color, [True color](#)
 2. Sentinel Image 06/12/22: [False](#) color, [True color](#)
- Use the ruler (on the right of the screen) to measure the dispersion of sediments from the mouth to the sea. Also, measure the area of sediment in the sea.

In EO Browser images, do the following:

1. See false-color images and analyze seasonal changes.
2. Select Highlight Optimized Natural Color (on the left of the screen) and compare with false color images. (Consider that sedum. ent albedo is higher at visible wavelengths.)
3. To make a new **combination of bands**, go to customize (left below) and select **composite**.
 1. Drag the bands to the circles to make the RGB combination: (R) 3, (G) 4, and (B) 8.
 2. Compare the sharpness with which you observe the discharge of sediment from the river concerning previous visualizations.
4. **Generate an index.** To improve the analysis, use the Normalized Difference Turbidity Index (NDTI), which is sensitive to changes in the turbidity of water bodies.
 1. Go to Customize (left below) and select **Index**. The formula for placing the bands appears. At site A (locate band B4) and site B (locate band B3), corresponding to the following calculation:

$$\text{NDTI} = (\text{RED} - \text{GREEN}) / (\text{RED} + \text{GREEN})$$

$$\text{NDTI (Sentinel 2)} = (\text{B4} - \text{B3}) / (\text{B4} + \text{B3})$$

- b. Then go to the **threshold** and select a color palette for the image.
 - c. Refer to the histogram (on the right of the screen), and open the menu of the index you are looking at (on the left) to see the reference of the colors. Analyze the histogram by comparing the values with those in the reference.
 - d. You can draw an area and do the same analysis for that particular sector.
 - e. Go to the ruler and measure the area with sediment in each image.
5. Make a presentation by comparing the results of both images

Case 2: [HPS-12 Glacier](#) Melting Analysis

- Google Map - [Location](#)
- [Climate graph // Weather by Month of](#) the average temperatures and rainfall. (Optional: Map of the [World's glaciers](#) and [watersheds](#))

Worldview:

1. Compare images from [1985 and 2021](#).



- Select the ruler (bottom right) and measure the distance the glacier retreated in the 2021 image.
 - Select the area (bottom right) and measure the melted ice surface.
 - They can change year and month to measure melting in other periods.
2. Download the most representative images or generate a [video](#) in Worldview with the analyzed data.

EO Browser (see tools in Fig. 7)

1. Sentinel-2 Image: February 2020 - True Color and [False Color](#)
2. Sentinel-2 Image: February 2021 - True Color and [False Color](#)
3. Sentinel-2 Image: February 2022 - True Color and [False Color](#)

In EO Browser images do the following:

1. See images from different years and analyze changes.
2. Select the NDVI index (on the left of the screen) and then the histogram (on the right of the screen). Compare the results of the images. If you want to measure a specific area, you can draw the area and then select the histogram.
 1. Do the same for NDMI (Moisture Index), NDWI (to detect water bodies), and SWIR (to know the water present in vegetation and soil).
 2. Check the **histogram** (on the right of the screen), and open the menu of the index you are looking at (on the left) to see the reference of the colors. Analyze the histogram by comparing the values with those in the reference.
 3. You can draw an area and do the same analysis for that particular sector.
3. To do the **band combination**, go to customize (left below) and select **composite**.
 1. Drag the bands to the circles to make the merge to make the RGB combination: (R) 11, (G) 8, and (B) 4.
 2. Compare the sharpness with which you observe the vegetated area for previous visualizations.
4. **Generate an index**. It is difficult to differentiate between clouds, snow, and ice. Indexes have been developed to visualize the different coverages; in this case, they are of interest (**NDGI**) Normalized Difference Glacier Index and (**NDSII**) Normalized Difference Snow Ice Index. Both indices are used to detect glaciers and monitor their changes.
 1. Go to Customize (left below) and select **Index**. The formula for placing the bands appears.

For the NDGI (Normalized Difference Glacier Index), at site A (locate band B3) and at site B (locate band B4) corresponding to the following calculation:

$$\text{NDGI} = (\text{GREEN} - \text{RED}) / (\text{GREEN} + \text{RED})$$

$$\text{NDGI (Sentinel 2)} = (B3 - B4) / (B3 + B4)$$

b. Then go to the **threshold** and select a color palette for the image.

For NDSII (Normalized Difference Snow Ice Index), at site A (locate band B3) and at site B (locate band B8) corresponding to the following calculation:



$$\text{NDSII} = (\text{GREEN} - \text{NIR}) / (\text{GREEN} + \text{NIR})$$

$$\text{NDSII (Sentinel 2)} = (\text{B3} - \text{B8}) / (\text{B3} + \text{B8})$$

- c. Then go to the **threshold** and select a color palette for the image.
 - d. For both indices, refer to the histogram (on the right of the screen), and open the menu of the index you are looking at (on the left of the screen) to see the reference of the colors. Analyze the histogram by comparing the values with those in the reference.
 - e. You can draw an area and do the same analysis for that particular sector.
5. Make a presentation comparing the results of the visualizations generated for the different years analyzed.

What to do and how to do it

- Beginning

Show your students the following videos: a) [NASA: Mission to Earth](#), b) [NASA shows two decades of snow and rain](#), and c) [The electromagnetic spectrum. Introduction](#). Brainstorm how satellite technology studies the Earth and monitors its changes.

- Development

1. Ask students to read the introduction to this activity and make a concept map with the information. (*The introduction provides the basic fundamentals of remote sensing with links to expand the information or clarify aspects if necessary*).

2. Divide the class into groups and assign a case to each group for analysis.

a. Look at the current satellite image on Google Maps. What do you see in that image (forest, desert, crops, cities, roads, rivers, glacial lakes, ice fields, etc.)?

b. Analyze the rainfall and temperatures of that place.

c. Analyze the event in Worldview and make a video or download the most representative images.

Note: In WorldView, you can change month and year, bottom left

d. Consult the EO Browser images, and analyze the banding combinations and indexes. Use the combinations and indexes indicated (if you wish, you can try different bands and analyze the visualization).

3. Ask your students to give a presentation about the case under discussion. They can make a story with maps (ArcGIS StoryMaps), a slide show, or a video.

4. Gather all the groups and ask them to explain the cases analyzed.

5. Complete the concept map with the main characteristics of each case analyzed.

- Closing

Due to the relevance of both events, it is important to develop dissemination materials. Students can create a story with maps ([Story Map](#)), a video, or flyers to post on social networks summarizing the cases analyzed.



Frequently asked questions

Where do I find satellite images? – Worldview – Google Earth – Google Map

Where do I find information on global environmental conditions and population?
[ResourceWatch](#) gathers information from different sources.

Suggested Resources

As an extension of this activity, students can consult satellite images of different dates and places to explore other sites of interest and even different events. You can use GLOBE Program protocols to perform manual measurements in your environment or download data from measurements made by others. It can also perform environmental measurements to complement research based on satellite imagery.

Websites

- NASA. (2023) Eyes on the Earth. <https://eyes.nasa.gov/apps/earth/#/> (satellites that take images of the Earth)
- USGS (2021) *Common Landsat Band Combinations*. <https://on.doi.gov/3wAKJvd> (Band combinations with Landsat images)
- USGS (2022) *What are the best Landsat spectral bands for my research?* <https://on.doi.gov/3HEMdLf>
- GISGeography (2022) *Sentinel 2 Bands and Combinations*. <https://gisgeography.com/sentinel-2-bands-combinations/> (Band combinations with Sentinel images)

Videos:

- NASA Climate Change (2021) *How NASA Satellites Help Model the Future of Climate*. Youtube: <https://youtu.be/iAUFVUzZlhl>
- NASA Climate Change. (2021) *NASA: La humedad de la Tierra*. Youtube: <https://youtu.be/YPgmdRYrvjU>
- NASA Climate Change. (2021) *NASA: La Tierra tiene fiebre*. Youtube: <https://youtu.be/R5RcCc3qWMY>
- NASA Climate Change. (2021) *NASA: Las nubes*. Youtube: <https://youtu.be/R5YYdEATivg>
- NASA Climate Change. (2021) *NASA: Los vientos oceánicos*. Youtube: <https://youtu.be/MJSaIFy0CsE>
- NASA Climate Change. (2021) *NASA: Me llamo Aerosol*. Youtube: <https://youtu.be/Dr4Dkm1Ud1E>
- NASA Climate Change. (2021) *NASA: Misión a la Tierra*. Youtube: <https://youtu.be/M0HHZ9vRlpk>
- NASA Climate Change. (2021) *NASA: Problema de gas*. Youtube: <https://youtu.be/4ZvAEQLWDTs>
- NASA en Español (2020) *La NASA muestra dos décadas de nieve y lluvia*. Youtube: <https://youtu.be/HVxosovHlnw>



- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 3. Microwaves*. Youtube: <https://youtu.be/UZeBzTI5Omk> [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético 3. Microondas*. Youtube: https://youtu.be/OCxFv_KDdZE]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 4. Infrared Waves*. Youtube: <https://youtu.be/i8caGm9Fmh0> [Español. Traducido por: Dpto. Electricidad Electrónica (2017) *El espectro electromagnético 4. Infrarrojo*. Youtube: <https://youtu.be/DgZKWfRRxKw>]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 5. Visible Light Waves*. Youtube: <https://youtu.be/PMtC34pzKGc> [Español. Traducido por: Dpto Electricidad Electrónica (2017) *El espectro electromagnético 5. Luz visible*. Youtube: <https://youtu.be/BVbbkzygf94>]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum 6. Ultraviolet Waves*. Youtube: <https://youtu.be/QW5zeVy8aE0> [Español. Traducido por: Eldador (2011) *El espectro electromagnético 6. Luz ultravioleta*. Youtube: <https://youtu.be/IOKEbZgB2II>]
- ScienceAtNASA (2011) *Tour of the Electromagnetic Spectrum. Introduction 1*. Youtube: <https://youtu.be/lwfJPc-rSXw> [Español. Traducido por: Antenas y Salud (2015) *El espectro electromagnético. Introducción 1*. Youtube: <https://youtu.be/K-up0o96Vhw>]

Other Resources:

Tutoriales de: Worldview ([video corto](#), [video completo](#), [sitio web](#), [ideas para el aula](#)) EO Browser ([sitio web](#) o [video](#), [infografía](#)) , [Story Map](#)

Traducción automática: [Videos](#), [Sitios web](#)

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Sargassum in the coasts

GLOBE		Associated SDG	Type of Activity
Spheres	Associated Protocols		
Biosphere	Land Cover (in the coasts)	6 (Clean Water and Sanitation) 13 (Climate Action) 14 (Life Below Water)	Exploratory
Hydrosphere	Water Temperature, Dissolved Oxygen, Salinity, Nitrates, Transparency, pH.		
Bundle	Oceans		

Overview

Information from satellite imagery processed with the *Floating Algae Index* and maps are analyzed to determine the impacts of sargassum growth at local and regional scales. Current information is compared to the massive bloom event that occurred in 2018. Students analyze local and regional impacts and potential commercial uses of sargassum, and explore ways to engage citizen science participation.

Time

3 or 4 classes

Prerequisites

Basic knowledge of ecosystems, food webs, populations, meteorology, marine currents, water quality and ICT. Ability to interpret satellite images and maps. Ability to locate points using latitude and longitude.

School Level

Upper Elementary, High School and University students

Purpose

To analyze the "Great Atlantic Sargasso Belt" phenomenon and its impact on the Caribbean coasts

Student outcomes

- To know the impact of the "Great Atlantic Sargasso Belt" phenomenon in the Caribbean coasts on human activities, health and the environment
- To interpret satellite images processed with the Floating Algae Index and maps of different coastal areas of the Caribbean
- To analyze the annual seasons of massive sargassum blooms and compare with the years of greatest impact
- To explore information on possible contributions as citizen scientists



Background

The macroalgae called sargassum or "seaweed" is a group of species belonging to the genus *Sargassum* that includes large brown or blackish-green algae containing gas-filled vesicles that allow them to float. Sargassum is very abundant and forms large floating masses in the open ocean that can extend for many kilometers. Historically, it was found in an area between the Gulf of Mexico and the North Atlantic Ocean, forming the Sargasso Sea. Sargassum provides habitat, food, shelter and breeding grounds for many marine species such as fish, sea turtles, seabirds, crabs, shrimp and others. Some species live their entire lives in this habitat, such as the *sargassum fish*, others only live in the early stages of their lives, including commercially important fish such as *mahi mahi*, *jack mackerels* and *amberjack*. When the sargassum loses its buoyancy, it sinks to the sea floor providing energy in the form of carbon to deep sea fish and invertebrates, contributing to the deep-sea food web.

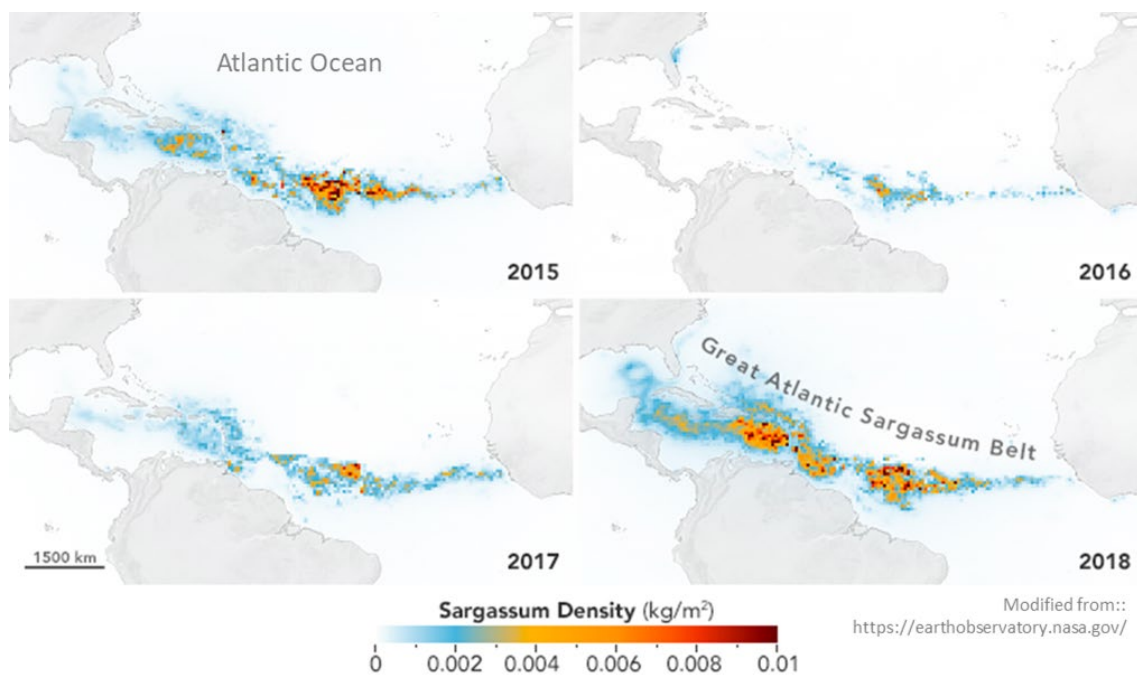


Fig. 1. Changes in sargassum densities

The presence of sargassum in the Caribbean coasts has been constant over time, but since 2011 massive quantities of sargassum transported by currents began to arrive, affecting different locations throughout the year. In the following years the blooms increased reaching dimensions never seen before in 2018. Scientists called this phenomenon the "Great Atlantic Sargasso Belt". These blooms caused economic impacts (in: tourism, fishing, nautical activities), environmental impacts (disturbance of marine species because when sinking in large quantities it can suffocate corals, mangroves and seagrasses; it also produces beach erosion) and even sanitary impact (the decomposition of algae releases gasses, including hydrogen sulfide that emits an odor similar to rotten eggs, and cases of nausea, headaches, skin rashes and respiratory issues have been detected). Watch the videos "[El sargazo enferma el Caribe Mexicano](#)", and the articles "[El Caribe se une contra el sargazo](#)" and "[¿Podrá la ciencia resolver el problema de las algas en las playas del Caribe?](#)" [In Spanish] or video "[Caribbean struggles with smelly seaweed invasion](#)" and the articles "[Caribbean nations join forces against giant seaweed bloom](#)" and [Can science solve the seaweed problem on Mexican beaches?](#)



Satellite images provide a valuable contribution to the monitoring of algae and to the prediction of their arrival to the coasts. Direct sampling in the ocean is also of great relevance in understanding water quality. While more research is needed on large sargassum blooms, scientists suggest that this algal belt is formed by the input of key nutrients- in spring and summer mainly by discharge from the Amazon River, but also the Orinoco and other rivers that add nutrients, which may have increased in recent years due to increased deforestation and fertilizer use in the watersheds.



Fig. 2. Sargassum harvesting in the coasts of Mexico. Source: <https://quintanarooohoy.com>

In the winter, upwelling of nutrients from deep to shallow waters occurs off the west coast of Africa where sargassum grows. Ocean currents then transport the sargassum to different regions. Salinity and temperatures also influence sargassum growth. To detect sargassum in satellite images and monitor its movements, the *Floating Algae Index* (FAI) is used. Recently, the *Alternative Floating Algae Index* (AFAI) was incorporated and other specific indexes are being developed to differentiate sargassum from other floating algae. Managing large quantities of sargassum is an economic, infrastructure and equipment challenge for its collection, transport and storage. Ways of using sargassum are being explored in the chemical and food industry with the production of gels, as fertilizers, biogas, fodder, extraction. The main difficulties for its use are the annual variation in the volume of sargassum that reaches the coasts, and its rapid decomposition.

Guiding Research Questions

- What's sargassum and what is its historic area distribution?
- What is the role of sargassum in marine ecosystems?
- What are the impacts of mass bloom events? What is the "Great Atlantic Sargasso Belt"?
- What are the possible causes of sargassum mass blooms?
- How do the sites and densities of sargassum arriving onshore vary throughout the year?
- What is the trend in annual variation?
- Has sargassum affected your area? What impacts did you detect?

Scientific Concepts

- Ecosystems



- Changes in the populations of some species.
- Interrelationships of matter and energy in ecosystems
- Ocean currents
- Environmental risks and vulnerability

Materials and Tools

Video:

El País (2019) *El sargazo enferma al caribe mexicano*. YouTube <https://youtu.be/qFcrIfDoYXw> [In Spanish]

Reuters (2021) *Caribbean struggles with smelly seaweed invasion*. YouTube https://youtu.be/quG2ul_vLf4 [In English]

Articles:

1. Guzmán Hormazábal, L. (2019) *El Caribe se une contra el sargazo*. SciDev.Net <https://bit.ly/3deu6yX> [In Spanish]
2. Guzmán Hormazábal, L. (2019) *Caribbean nations join forces against giant seaweed bloom*. SciDev.Net <https://bit.ly/3vtpE5s> [In English]
3. Jolley, A. (2021) *México: ¿Podrá la ciencia resolver el problema de las algas en las playas del Caribe?* National Geographic. <https://bit.ly/3JDdLQB> [In Spanish]
4. Jolley, A. (2021) *Can science solve the seaweed problem on Mexican beaches?* National Geographic. <https://on.natgeo.com/3VIBFig> [In English]

Satellite images processed with the *Floating Algae Index* (FAI) from online sargassum monitoring:

1. CERMES. Sargassum. Outlook Bulletin. <https://bit.ly/3SCZEPH>
2. NOAA. AOML (2022) *Experimental Weekly Sargassum Inundation Report*. <https://bit.ly/3SvKATC>
3. SIMAR (2022) Cobertura diaria del Sargazo (acumulado de 7 días previos) <https://bit.ly/3QpZE3b>
4. USF (2022) CARICOOS. *Imágenes de Algas Flotantes (Sargazo)* <https://bit.ly/3zFCGP1>
5. USF. OOL (2022) *Satellite-based Sargassum Watch System (SaWS)*. <https://bit.ly/3PcDPDb>

What to Do and How to Do It

1. Beginning

1. Watch the videos “[Caribbean struggles with smelly seaweed invasion](https://youtu.be/quG2ul_vLf4)” and read the articles “[Caribbean nations join forces against giant seaweed bloom](https://bit.ly/3deu6yX)” and [Can science solve the seaweed problem on Mexican beaches?](https://on.natgeo.com/3VIBFig)

2. Development



1. Ask your students about the role of sargassum in marine ecosystems and then make a conceptual map with the expressed ideas.
2. Divide the class into small groups to analyze satellite images processed with the Floating Algae Index. Assign each group an area to analyze:
 - Look at images from the latest [CARICOOS](#) images and images from previous months on the [USF Optical Oceanography Laboratory website](#). (Use the calendar to choose dates). You can download the images to view them in Google Earth in more detail.
 - For the Gulf of Mexico area see [SIMAR](#)
 - Have there been any changes in the last few days?
 - Look at the maps in the [weekly reports](#), corresponding to the same dates of the analyzed images and the [quarterly sargassum bulletin](#).
 - During which months do the highest concentrations occur and in which months do they decrease? What explanations can you suggest for these changes?
 - Does the analyzed site have large variations in sargassum concentration?
 - Compare the current image of the analyzed site to any day in July and August 2018. What changes can you visualize?
3. Bring the groups together and share the sites they analyzed.
4. Did all sites receive sargassum? Did any region remain unchanged?
5. Did the densities of sargassum vary from site to site? To what can this variation be attributed?
6. Are there differences in sargassum densities between the open ocean and the coasts?

3. Ending

Complete the previously made concept map above with the examples of sites they analyzed and the comparison with 2018.

If your school is in a region affected by this phenomenon, you can showcase some citizen science projects where your students can participate on a voluntary basis or organize participation as an extension of this activity. For participation options see the publication "Sargassum White Paper - Turning the crisis into an opportunity" (from [page 43](#) onwards)

Frequently Asked Questions

How can I observe sargassum rafts in the open ocean and on the coasts from satellite images? The Floating Algae Index (FAI) is used, recently the Alternative Floating Algae Index (AFAI) was added and other specific ones are being developed to differentiate sargassum from other floating algae.

Where can I find satellite images processed with the FAI index? In CARICOOS and in the Optical Oceanography Laboratory (OOL) bulletins.

Where can I find maps with the history of sargassum arrival events in the Caribbean coasts? In SIMAR.

Suggested Resources for Further Information

As an extension of this activity, students can look for citizen science projects to join them, either by identifying species of sargassum that reach their area or by reporting the state of the coasts.

To learn more about this phenomenon, the following resources are suggested:

LANOT (2022) *Visualizador de Sargazo* <https://bit.ly/3p6btjm>



NADIS app (In development) – Download from Google Play <https://bit.ly/3P8ehHF>
 NOAA (2022) *CoastWatch OceanViewer* (Select Sargassum Insitu)
<https://cwcgom.aoml.noaa.gov/cgom/OceanViewer/>

UNEP-CEP (2021) *Sargassum White Paper – Turning the crisis into an opportunity*. Ninth Meeting of the Scientific and Technical Advisory Committee (STAC) to the Protocol Concerning Specially Protected Areas and Wildlife (SPA) in the Wider Caribbean Region. Kingston, Jamaica. <https://bit.ly/3A4AP7A>

Tutorials: [Worldview](#), [EO Browser](#), [Story Map](#)

Bibliography

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Johns, E. M., Lumpkin, R., Putman, N. F., Smith, R. H., Muller-Karger, F. E., Rueda-Roa, D. T., Hu, C., Wang, M., Brooks, M. T., Gramer, L. J. & Werner, F. E. (2020). The establishment of a pelagic Sargassum population in the tropical Atlantic: biological consequences of a basin-scale long distance dispersal event. *Progress in Oceanography*, 182, 102269. <https://bit.ly/3A32Exj>

Lapointe, B. E., Brewton, R. A., Herren, L. W., Wang, M., Hu, C., Mcgillicuddy, D. J., Lindell, S., Hernández, F. J. & Morton, P. L. (2021). Nutrient content and stoichiometry of pelagic Sargassum reflects increasing nitrogen availability in the Atlantic Basin. *Nature communications*, 12(1), 1-10. <https://go.nature.com/3BN4zXR>

NASA Earth Observatory (2012) *Life in the Sargasso Sea*. <https://go.nasa.gov/3vIsG6w>

NASA Earth Observatory (2022) *Scientists Discover the Biggest Seaweed Bloom in the World*. <https://go.nasa.gov/3SBaxkW>

The GLOBE Program (2022) *Ocean Protocol Bundle*. <https://bit.ly/3vK1KmA>

Wang, M., Hu, C., Barnes, B. B., Mitchum, G., Lapointe, B., & Montoya, J. P. (2019). The great Atlantic sargassum belt. *Science*, 365(6448), 83-87. <https://par.nsf.gov/servlets/purl/10126160>