Educational Modules
Deliverable 6.4.

Co-funded by the European Union

UK Research and Innovation

Grant Agreement no. 101059877

Document Summary

Topic	HORIZON-CL6-2021-BIODIV-01-04
Grant Agreement Number	101059877
Start date of the project	01.09.2022
Project Coordinator	Angel Borja
Work Package	WP6
WP Co-Leader(s)	AZTI, Scitation
Deliverable Title	Educational modules
Deliverable Number	6.4.
Deliverable Beneficiary	Scitation
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Dissemination level	Public
Submission date	21st July 2026

How to cite | Leal, M.C., Pouso, S., Koulouri, P., Uyarra, M.C. 2026. GES4SEAS Deliverable 6.4. Educational Modules. 148 pp.

GES4SEAS (Achieving Good Environmental Status for maintaining ecosystem services, by assessing integrated impacts of cumulative pressures) project is funded by the European Union under the Horizon Europe program (grant agreement no. 101059877). Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or UK Research and Innovation. Neither the European Union nor the granting authority can be held responsible for them.

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1. GES4SEAS Project Summary

Human activities at sea (e.g., maritime transport, extraction of living and non-living resources, etc.) and coastal areas (e.g. agriculture, leisure and recreation, etc.) have expanded considerably, leading to an increased level of pressures and subsequent degradation of ocean health and, ultimately, human health. Single and cumulative impacts of these activities are likely to increase, driven by human demands and enhanced by climate change.

Human activities evolve following socio-economic drivers leading to pressures, which often are studied in isolation from each other even though their impacts on marine ecosystems can interact, making the effects cumulative (e.g. synergistic, antagonistic or a combination). Knowledge on these interactions and their cumulative effects in the marine environment has increased in recent years, but huge challenges still remain to be solved. Thus, there is little predictability with which to inform decision-making processes, especially on ecological tipping points, which, if exceeded, could lead to a point of no-return for the system. In this context, an ecosystem-based management (EBM) approach to the management of human activities at sea and on land should ensure that the combined pressure of such activities is kept within levels compatible with the requirements of Good Environmental Status (GES) (within the Marine Strategy Framework Directive – MSFD), against a background of climate change. This means that the capacity of marine and coastal ecosystems to respond to human-induced changes is not compromised, enabling the sustainable use of marine goods and services by present and future generations.

Thus, the main objective of GES4SEAS is to inform and guide marine governance in minimizing human pressures and their impacts on marine biodiversity and ecosystem functioning, while maintaining the sustainable delivery of ecosystem services. This will be achieved through developing an innovative and flexible toolbox, tested, validated, demonstrated and upscaled, in the context of adaptive EBM approach. The toolbox will allow competent authorities to assess and predict the effect of multiple stressors (including climate change) and pressures from human activities, at the national, sub-regional, regional and European level. Ultimately, this will ensure they achieve GES, and support different policies at national, European and global levels (e.g. Birds and Habitats Directives (BHD), Biodiversity Strategy 2030, United Nations Sustainable Development Goals (SDG)).

Stakeholders and the key competent authorities (including national, regional and European levels) are integrated in a Practitioner Advisory Board (PAB) to co-create and validate the toolbox and the EBM approach. This will result on a real problem-solving approach with iterative and incremental development steps.

GES4SEAS will also rely on existing multi-actor networks to involve and engage with stakeholders. This multi-actor approach will ensure that the research and deliverables are relevant to marine managers all around the world. Lastly, it is important to highlight that the toolbox will be tested and demonstrated at 11 Learning Sites (LSs) covering all European regional seas (and also overseas), and environments. Thus, it is expected that GES4SEAS will achieve Technological and Societal Readiness Levels 6. This will be achieved by the participation of 20 partners, covering the four European regional seas as well as Canada.

It is expected that GES4SEAS will:

- Operationalize integrative and holistic solutions for EBM, based upon a software toolbox for analyzing, assessing and mapping cumulative pressures, GES and ecosystem services.
- Provide evidence (and training) to key stakeholders of the benefits of using the toolbox that will be developed in GES4SEAS for assessing the environmental status of marine waters and the ecosystem services considering the effects of multiple pressures so opt for using it.
- Ensure the EBM approach and guidelines for the management of Invasive Alien Species (IAS), harmful algal blooms (HABs) and jellyfish, the approach for monitoring top predators are used by end-users.
- Investigate, using models, the best ways to obtain thresholds of GES/non-GES status and tipping points (system breaking points).
- Reach and engage a wider society, and specifically relevant stakeholders, educators, and young people, on key messages steaming from this project, so GES4SEAS contributes to societal ocean literacy and responsible behaviours.

2. D6.4 Summary and Objectives

Deliverable 6.4 “Educational Modules” is one of the key exploitation outputs of GES4SEAS, prepared within Work Package 6 under the lead of Scitation (Science Crunchers), with AZTI and HCMR. It translates the project’s science and its six key messages into a complete, ready-to-use educational resource for marine educators, teachers, learners and relevant stakeholders, compiling six interconnected modules — one per key message — designed to raise ocean literacy and foster responsible attitudes and behaviours towards the sea. The six modules are:

- Module 1 — Healthy seas for healthy human societies.
- Module 2 — Pressures in the marine environment: 1 + 1 is not always 2.
- Module 3 — Good Environmental Status and how it can affect your health and life (Black Sea case study).
- Module 4 — Tipping points: small changes that trigger big shifts.
- Module 5 — Ecosystem-Based Management: managing the whole or the hole.
- Module 6 — Ocean optimism: rewriting the narrative of our seas.

Each module is structured pedagogically, opening with learning outcomes and a sequence of lessons that combine accessible text, embedded videos and infographics (including GES4SEAS materials such infographics and animated videos), real-world case studies from the project’s Learning Sites and partners, and “check your understanding” activities. Each module closes with final considerations and a curated set of additional resources linking to complementary lesson plans from established initiatives (e.g. the Network of European Blue Schools, MED EDUC, the IOC-UNESCO Ocean Literacy toolkit). The modules are self-contained yet sequential, so they can be used individually or as a progressive learning pathway.

2.1 Objectives

The objectives of this deliverable are to:

- translate the six GES4SEAS key messages and some of the project’s scientific outputs into accessible, classroom-ready educational content for marine educators, teachers and learners.
- strengthen ocean literacy and promote responsible ocean behaviours by helping different audiences (including citizens) to understand both the pressures facing the sea and the solutions available, including the GES4SEAS approach and tools.
- provide a flexible, modular and reusable resource that supports educators across disciplines and can be adapted to different age groups and national contexts.

- ensure the long-term exploitation of GES4SEAS outputs by embedding them in widely used, lasting ocean-literacy platforms beyond the lifetime of the project.

2.2 Uploading to ocean literacy portals for long-term impact

To maximise, reach and ensure impact well beyond the project's end, the educational modules are being uploaded to and hosted on established ocean-literacy portals, in close cooperation with their host organisations so the materials fit each platform. More specifically, they are being hosted on the OceanTeacher Global Academy (OTGA) of IOC-UNESCO (www.oceanteacher.org), which reaches over 8,000 users (i.e., educators) from more than 130 countries and connects the resource to the global ocean-science and capacity-development community; and on the EuroGOOS ocean-literacy platform (https://eurogoos.eu/ocean-literacy-resource-library/), whose ocean-literacy working group sits on the GES4SEAS Practitioner Advisory Board, providing a direct route into European ocean-observing and education networks. Dissemination is further extended through REEDUCAMAR and the Network of European Blue Schools. In addition to host these modules in GES4SEAS website, hosting them on these portals ensures the modules remain findable, freely accessible and maintained after GES4SEAS concludes, are embedded in recognised international education providers, and continue to support societal ocean literacy for years to come — turning a project output into a lasting legacy of GES4SEAS.

3. Module 1 | Healthy seas for healthy human societies

3.3 Introduction to M1

Humankind is heavily reliant on healthy marine ecosystems. Our seas provide valuable resources, like food, energy, and medicines. Moreover, they support jobs and economies, offer recreational opportunities, and play key roles in climate regulation. The healthier the seas the more services they provide.

To sustain them and ensure clean, healthy, and productive seas, a good balance between the socio-economic needs and socio-ecological goals is needed. In this way, the ocean can potentially support human needs for social and economic development, without compromising the conservation of our seas. Human activities must be done sustainably and with sufficient knowledge to take informed management decisions to protect and conserve the ocean.

In this first module, we will explore the reasons behind why a healthy sea is a central piece for healthy human societies. We cover what makes the sea important for our livelihoods, as well as what makes a healthy ocean and a healthy society.

3.4 Learning Outcomes

By the end of this Module, you should be able to:

- Recognize the importance of healthy seas to human societies
- Identify what makes a healthy ocean
- Define a healthy society

3.5 How to proceed

Complete the following activities as they appear in the Lessons below.

To succeed in this Module, you need to successfully complete the following lessons:

- **Lesson 1:** Why is the sea important
- **Lesson 2:** What makes a healthy ocean
- **Lesson 3:** What is a healthy society?
- **Lesson 4:** Wrap up-Healthy seas for healthy human societies

3.6 Lesson 1: Why is the sea important to human societies – the value of healthy seas

In this lesson, you will learn the value of healthy seas and why the sea is important to human society.

The lesson will cover the following course learning outcomes:

- Recognize the importance of healthy seas to human societies

Watch this video

To get started, watch this short video on some of the key features of our oceans: https://www.youtube.com/watch?v=MfWyzrkFkg8

Read this

Covering about 71% of the Earth's surface, the oceans contain 97% of the planet's water, where the Pacific Ocean alone is larger than all of the landmasses combined. The oceans play a number of important roles – from supporting thousands of plant and animal species, influencing weather patterns and controlling the climate, to providing food and jobs to millions of people worldwide.

Did you know that some of the largest animals (such as the blue whale) and some of the smallest organisms (like the pygmy seahorse) on Earth; and that the tree of life has 34 branches (phyla) in the oceans, 17 in freshwater and only 15 on land?

What percentage of the Earth's surface is covered by oceans?

- [ ] 60%
- [x] 71%
- [ ] 75%
- [ ] 65%

Check

Reuse <> Embed H-P

What percentage of the Earth's water is found in the oceans?

- ○ 70%
- ○ 85%
- ◉ 97%
- ○ 99%

Check

Reuse <> Embed H-P

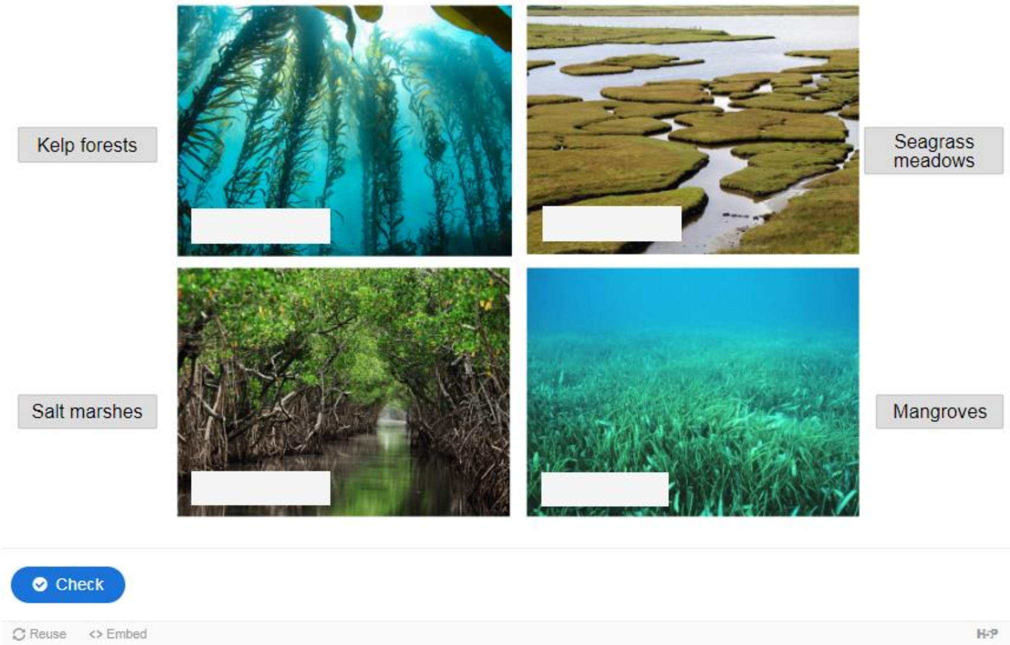
What is the average depth of the ocean?

- ◉ 3,682 meters
- ○ 5,000 meters
- ○ 2,000 meters
- ○ 7,000 meters

Check

Reuse <> Embed H-P

As mentioned, oceans also support human livelihoods by providing us with abundant resources and job opportunities. For example, mangroves provide a wide range of benefits such as coastal protection, climate regulation, food and other services to human societies. Besides mangroves, there are many more coastal marine ecosystems important for human societies. Can you correctly associate some of these coastal marine ecosystems?



- **Kelp Forests:** These underwater ecosystems offer critical habitat and feeding grounds for a variety of marine species, many of which have a high commercial value. Additionally, kelp absorbs carbon dioxide during photosynthesis, mitigating climate change effects and improving water quality. Communities adjacent to kelp forests also benefit from boosted ecotourism, as these environments are popular among divers and marine enthusiasts. In addition to food, seaweeds are also harvested for aquaculture feed, bioplastics and other materials. As a versatile resource providing new jobs across the world, kelp farming is projected to continually grow as an industry.
- **Salt Marshes:** Salt marshes serve as buffers between the ocean and the land, protecting shorelines from erosion caused by storms and rising sea levels. They are also exceptional at filtering pollutants from water, ensuring healthier coastal environments. They also sustain fishing communities and local economies by acting as nurseries for many marine species.
- **Seagrass Meadows:** Seagrass meadows stabilize the seafloor, clarify the surrounding water, and sequester significant amounts of carbon, helping to control carbon dioxide levels. They also provide crucial nursery habitats for numerous fish species, supporting local fishing communities

and local businesses as well, by maintaining the health of coral reefs and other marine life that attract tourism.

Curiosities

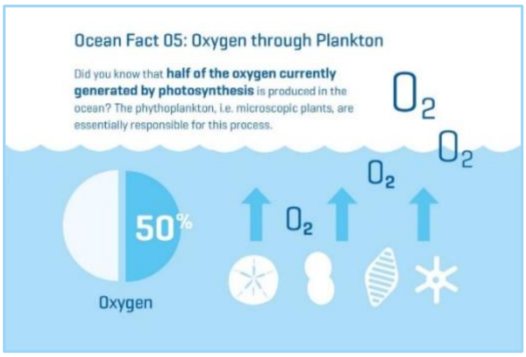
- Giant kelp is harvested from kelp forests and used as a binding agent in products like ice cream, cereal, ranch dressing, yogurt, toothpaste, lotion and more.
- One acre of salt marsh can absorb up to 1.5 million gallons of floodwater, which is equivalent to more than 2.25 Olympic-size swimming pools.
- Seagrasses can form dense underwater meadows, some of which are large enough to be seen from space (https://science.nasa.gov/earth/earth-observatory/).
- Mangrove forests shelter more than 1,500 species and 15% of those species are threatened with extinction.

Even when living in urban areas, we still depend on the ocean.

- 90% of traded goods are transported over the sea;
- The annual per capita consumption of aquatic foods is around 20 kg (https://fao.org/3/cc0461en/online/sofia/2022/consumption-of-aquatic-foods.html);
- 40% of people live within 100km from a coast (https://www.oecd.org/en/topics/ocean.html).

Watch this video

Half of the oxygen is produced by the ocean: https://www.youtube.com/watch?v=Z05wURG5wmw



3.7 Lesson 2: What makes a healthy ocean?

In this lesson, you will learn what makes a healthy ocean.

The lesson will cover the following course learning outcomes:

- Identify what makes a healthy ocean

Watch this video

Healthy oceans, healthy planet:

https://www.youtube.com/watch?v=p3TZQ8EIZSk&pp=ygUNaGVhbHRoeSBvY2Vhbg%3D%3D

Read this

Knowing why the sea is so important to human societies and how it sustains them helps us to understand how an unhealthy sea can affect individuals and communities. When 14 million tons of plastic (https://iucn.org/resources/issues-brief/marine-plastic-pollution) find their way into the oceans annually, they also find a way back, e.g. into the seafood we eat. When we are the source of the problem, then we must also be the solution!

Despite this, we cannot get back to a pristine ocean. So, what can get then? What are the elements of ocean health that help us understand how close we are to solving the problem? "Ocean health" describes a state where we can say the ocean is "in good shape" or has a "good status". In this state, the processes in the ocean are working properly, do not drift out of balance, and the system is considered "stable".

While we may not be able to restore the oceans to their pristine state, we can aim to improve its health. The term "ocean health" refers to the condition in which the ocean operates effectively, maintaining stability and balance within its processes.

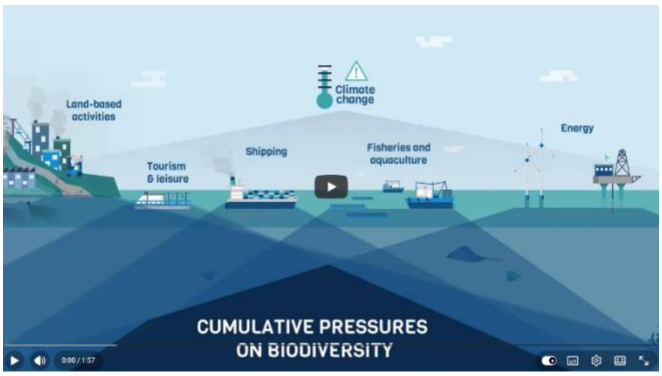
This healthy state is characterized by a well-functioning ecosystem that remains balanced and stable and is resilient to changes and stresses.

By understanding the various elements that are implied in this “good status” of the oceans, we can assess how to effectively address environmental challenges.

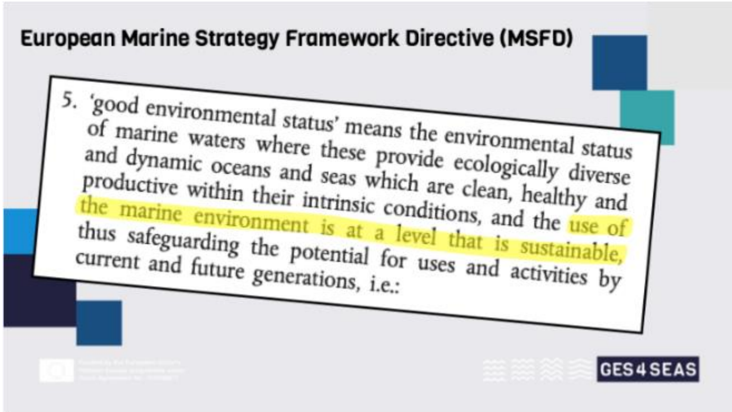
Watch this video

A healthy ocean can also be defined by the absence of threats and (human) pressures. healthiest ocean must be the one without humans on earth!

https://www.youtube.com/watch?v=TRarrJGQK20&t=28s



Some programs (such as the European Marine Strategy Framework Directive, MSFD) also have "sustainable use" in their definition of "good environmental status" (i.e. proper tourism, eating fish, produce energy, shipping, land reclamation, coastal defense, ...).



In practical terms, ocean health is a balance between conservation and human exploitation. It starts as a scientifically defined concept of nature, but in practice ends up as a policy-defined reachable target, sometimes far away from what science defined.

The most difficult part is to agree on such a common goal and then to really take the action to achieve it.

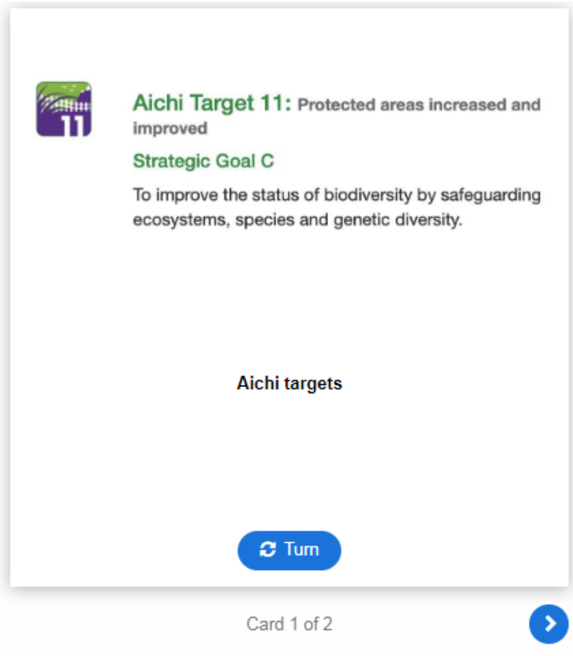
Watch this video

David Attenborough had this to say about it:

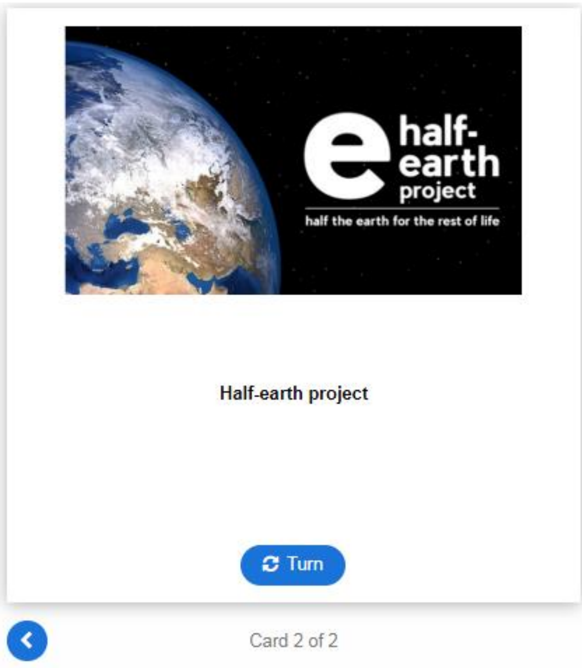
https://youtube.com/clip/UgkxSYw36atweAWm77tgZ6uu21g2ubfib8ZI?si=dMtfHgkY6j-2efi0

Read this

There are already some projects that aim to protect our ocean, each one with a different perspective on healthy ocean. Which percentage of the oceans would you want to protect to achieve healthy oceans? Here are two different takes this topic:



Aichi Target 11
The 10% goal as one of the 20 Aichi targets agreed in 2010 implementing the Convention on Biological Diversity (@UNBiodiversity)



e health-earth project
The 50% goal is the "half-earth project" by the E.O. Wilson biodiversity foundation (@EOWilsonFndtn)

3.8 Lesson 3: What is a healthy society?

In this lesson, you will learn what a healthy society means.

This lesson will help meet the following course Learning Outcome:

- Define a healthy society

A "healthy society" refers to a community or social group that is characterized by the well-being and high quality of life of its members. Key factors include:

- Physical and Mental Health
- Economic Stability

- Social Cohesion and Inclusion
- Education and Empowerment
- Sustainable Environment
- Good Governance

Read this

A healthy ocean plays a crucial role in sustaining a healthy society in various ways, highlighting the connectivity between the environment and human well-being.

- **Climate Regulation:** Oceans play a vital role in regulating the climate by transporting heat from the equator towards the poles, which affects weather patterns globally. This regulation helps mitigating extreme weather conditions which can have direct impacts on agriculture, housing, and overall livelihoods.
- **Biodiversity and Food Security:** Oceans provide a substantial amount of the world's protein intake through seafood, supporting billions of people. This biodiversity is also a potential source of new medicines and biotechnological advancements, which can lead to improvements in health and disease treatment.
- **Carbon Sequestration and Coastal Protection:** Coastal ecosystems like mangroves, seagrasses, and salt marshes are highly efficient at storing carbon dioxide, mitigating the effects of climate change. These habitats also protect shorelines from erosion and reduce the impact of storms on coastal communities, thus safeguarding human populations and infrastructures.
- **Economic Benefits:** The ocean economy is vast, encompassing traditional sectors such as fishing and emerging sectors like biotechnology and renewable energy. Sustainable management of ocean resources supports millions of jobs worldwide and drives economic activity, contributing to global prosperity.

"Our ocean provides countless benefits to our planet and all the creatures that live here"

https://oceanservice.noaa.gov/facts/why-care-about-ocean.html.

Following this topic, what do you think would be the right percentage of protection to achieve good ocean health? 10%? 50%? How about 30% that is what the draft Post-2020 Global Biodiversity Framework suggests…

To read more on this take, see https://campaignfornature.org/science-page.

To thrive both physically and mentally and to maintain a stable society, humans need:

- Good health via clean air, water, soil;
- Equal rights and equal chances;
- An economy that puts all beings at the centre of economic policy;
- Sustainable development.

3.9 Lesson 4: Wrap up – Healthy seas for healthy human societies

Read this

We cannot have healthy societies without healthy oceans. We need to maintain ocean health where it still exists and work towards it in places where we don't have it anymore. Reaching the good environmental status of our seas should be the goal.

It's also important to remember that the "good status" is not a pristine one. It is one that still allows human use but only to a degree where it does not sacrifice the health of the ocean. It balances human uses and needs with ocean conservation.

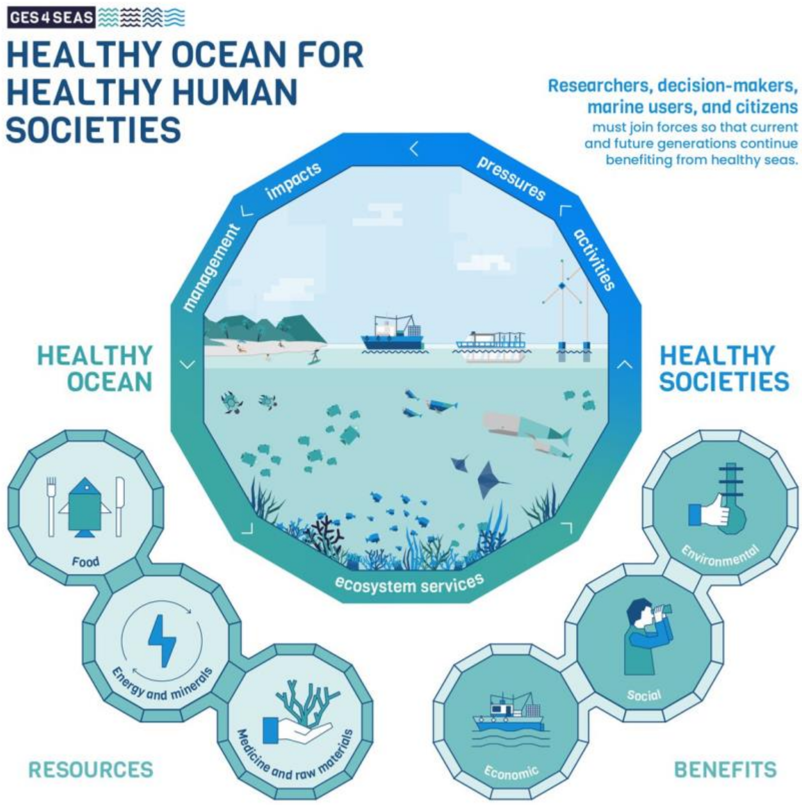
We should strive for this balance in situations where ocean health is compromised because of human activities. This can be done through Ecosystem-Based Management (EBM) – which will be the topic of **Module 5**.

As a recap, here are some key benefits the oceans provide us:

- **Coastal protection** – healthy seas and coastal ecosystems (e.g., mangroves and reefs). can better protect communities from extreme events. A high level of protection also implies altering landscapes and cutting off lagunes, building dikes and land reclamation. It’s crucial to have well-balanced management, as it often requires a compromise between ocean and human needs.
- **Food** – As food security is essential to society, the balance here tends more towards fishing than conservation. Excellent fisheries management is key here! Here's the @Europarl_en take https://europarl.europa.eu/factsheets/en/sheet/115/eu-fisheries-management.
- **Climate regulation** – climate and ocean are too tightly connected so there’s minimal margin for unbalances. Unhealthy oceans result in even faster climate change and unhealthy society.

Humans are deeply connected to the ocean. From cultural heritage to economic prosperity, from climate regulation to health, the impact of the ocean on our world and daily lives is undeniable. We understand the steps needed to address ocean health issues. What's left is to take action and achieve the right balance.

Here's everything in a nutshell with some of the examples of human uses and benefits from the sea and a (hopefully) healthy sea in the centre of all our work!



Check your understanding

[Multiple choice]

1. Why is a healthy ocean crucial for human societies?

a) They are essential for transportation only.
b) They are mainly used for recreation.
c) They support biodiversity, regulate climate, and provide resources.
d) They provide all of our drinking water.

2. What does maintaining the "good status" of our seas involve?

a) Allowing sustainable use that does not harm ocean health
b) Leaving the seas untouched and unused
c) Prohibiting all human activities
d) Encouraging industrial development

3. Which of the following is NOT a benefit provided by a healthy ocean?

a) Unlimited resources for industrial exploitation
b) Climate regulation and carbon sequestration
c) Supporting marine biodiversity and food supply
d) Coastal protection through ecosystems like mangroves

Correct answers: 1. c); 2. a); 3. a)

3.10 Final considerations

In this module, you learned that healthy seas are essential for human well-being. Oceans provide food, regulate climate, protect coastlines, support biodiversity, and contribute to economic and social development. We explored what makes both a healthy ocean and a healthy society, and why are they extremely interconnected.

3.11 Additional resources – relevant lesson plans and activities

If you want to learn more about what constitutes a healthy sea, here we provide some additional resources with relevant lesson plans and activities.

- **Examples of Blue Schools regarding Healthy and Clean Ocean**

The concept of a European Blue School evolved from the marine education expertise gathered from consultations with teachers and educators across Europe. It acknowledges the variety of cultures and school communities from the 27 EU Member States and champions the concept of open schooling.

This Handbook includes a wealth of useful resources and best practice to inspire you to find what connects you and your school to the ocean. It has built in flexibility to encourage and support teachers across all disciplines to bring the ocean to their classrooms, whether through biology, physics, chemistry, technology, mathematics, history, literature, or the arts.

You can find some inspiring projects on pages 64 through 77, specifically related to the health of the ocean (https://maritime-forum.ec.europa.eu/document/download/0e460a07-428c-4b0d-a4b4-2d82b999b6ee_en?filename=Handbook%20for%20Teachers%20-%20European%20Blue%20Schools_0.pdf).

- **MED EDUC Educational Resources (lessons plans)**

The MED EDUC project proposes the creation of a series of European level educational resources for middle and high schools. These resources concern the discovery and valorization of the coastal and marine environment in the Mediterranean. The project is mainly aimed at students, teachers and educators, offering them both educational tools focused on specific issues of environmental protection in the Mediterranean Sea (pollution and waste, mass tourism, overfishing, loss of biodiversity, coastal erosion, etc.).

Here are some relevant lesson plans in the context of healthy seas.

- **Waste and pollution** – https://mededuc.eu/en/resource-center/pedagogical-guide/13-waste-and-pollution.html

- **Sea water quality** – https://mededuc.eu/en/resource-center/pedagogical-guide/16-sea-water-quality.html
- **Coastline artificialisation** – https://mededuc.eu/en/resource-center/pedagogical-guide/26-coastline-artificialization.html
- **Energy: production and resources** – https://mededuc.eu/en/resource-center/pedagogical-guide/27-energy-production-and-resources.html
- **Maritime economy** – https://mededuc.eu/en/resource-center/pedagogical-guide/9-maritime-economy.html
- **Cultural heritage** – https://mededuc.eu/en/resource-center/pedagogical-guide/29-cultural-heritage.html

- **Ocean Literacy for all: a toolkit. IOC Manuals and Guides (lesson plans)**

This toolkit provides educators and learners worldwide the innovative tools, methods, and resources to understand the complex ocean processes and functions and, as well, to alert them on the most urgent ocean issues. It also presents the essential scientific principles and information needed to understand the cause-effect relationship between individual and collective behaviour and the impacts that threaten the ocean health.

Some particularly relevant sections within the topic of ocean health are:

- The role of international legislation to protect the high seas (pp. 99-100)
- Exploring the energy potential of the ocean (pp. 101-102)
- Let's go fishing (pp. 111-113)
- Integrated Multi-Trophic Aquaculture – IMTA (pp. 114-116)
- Eat the right fish (pp. 123-124)

- **Practical ocean literacy for all: ecology and exploration**

This last resource (https://www.scienceinschool.org/article/2023/practical-ocean-literacy-ecology-and-exploration/) is from the project *Science in School*, which aims to support teachers in the delivery of their STEM curricula by connecting them to inspiring, cutting-edge science and technology, in order to foster positive attitudes towards the science that shapes our lives, and attract students to careers in these fields.

This issue in particular, *Practical ocean literacy for all: ecology and exploration*, covers all ocean literacy principles and provides practical experiences for students to learn about these principles through hands-on exercises.

Check your understanding

[True or False]
More than 90% of traded goods are transported by sea.
Correct answer: True

[Multiple choice]

1. Which of the following is NOT a benefit provided by healthy oceans?
a) Coastal protection
b) Unlimited resources for industrial exploitation
c) Food security
d) Climate regulation

2. Maintaining the "good status" of our seas means:
a) Leaving the ocean untouched
b) Allowing sustainable human use without harming ocean health
c) Maximizing industrial activities
d) Prohibiting all human activities

3. Which of the following coastal ecosystems mentioned in this first module provides benefits to humans.
a) kelp forests, freshwater lakes, grasslands
b) saltmarshes, Savanna, lakes and ponds
c) kelp forests, mangroves, saltmarshes
d) mangroves, caves, deserts

4. What is a key feature of a healthy society, as described in the module?
a) Economic stability
b) Social cohesion
c) Good governance
d) All of the above

Correct answers: 1. b); 2. b); 3. c); 4. d)

4. Module 2 | Pressures in the marine environment: 1 + 1 is not always 2

4.1 Introduction to M2

Due to the current intensity of human activities, the health of our seas is under many different pressures. These pressures can act individually, or in combination with other pressures, forming what we call cumulative pressures. These interactions can produce additive, synergistic or antagonistic effects, all of which can generate significant impacts on marine life and habitats. Throughout this module, we will explore the science behind cumulative pressures, why they create challenges for the sustainable management of our seas, and what we can do to mitigate these effects.

4.2 Learning Outcomes

By the end of this Module, you should be able to:

- Understand the concept of cumulative pressures
- Identify cumulative pressures and why they matter
- Understand how the different pressures can interact with each other
- Recognize the effects of cumulative pressures and their interactions
- Understand that climate change can magnify the effects of cumulative pressures
- Recognize that the effects of local pressures can expand beyond that area
- Understand there are tools available to identify and map cumulative pressures and their impacts

4.3 How to proceed

Complete the **activities** as they appear in each Lesson.

To succeed in this Module, you need to successfully complete the following Lessons:

- **Lesson 1:** What are cumulative pressures?
- **Lesson 2:** Types of interactions between pressures
- **Lesson 3:** Climate change and cumulative pressures
- **Lesson 4:** Challenges and tools

4.4 Lesson 1: What are cumulative pressures?

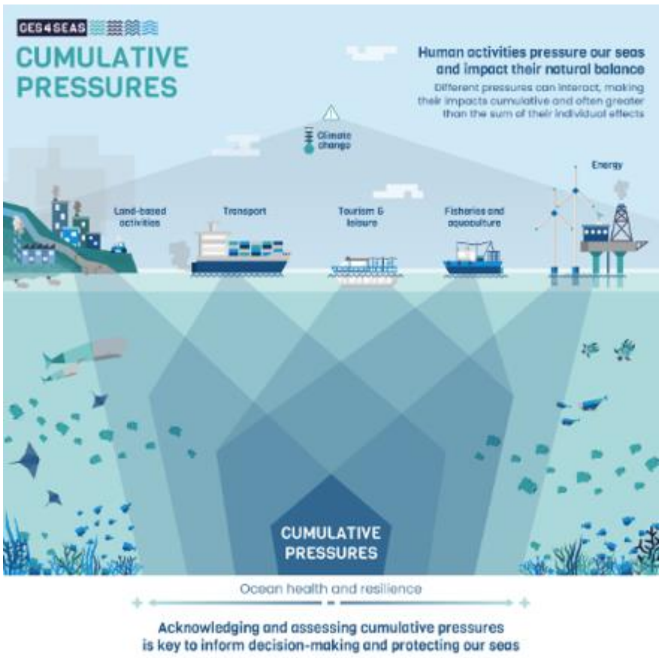
In this lesson, you will learn what cumulative pressures are and why the phrase "1 + 1 is not always equal 2" is used in this context.

The Lesson will cover the following learning outcomes:

- Understand the concept of cumulative pressures
- Identify cumulative pressures and why they matter

Read this

Cumulative pressures refer to the combined effects of different environmental stressors – such as ocean warming, coastal pollution, and habitat destruction – acting simultaneously on marine ecosystems. The compound effect of these stressors is often greater than the sum of their individual effects, hence the phrase "1 + 1 is not always equal 2". Consequently, cumulative pressures can result in significant negative impacts to marine biodiversity and habitats.

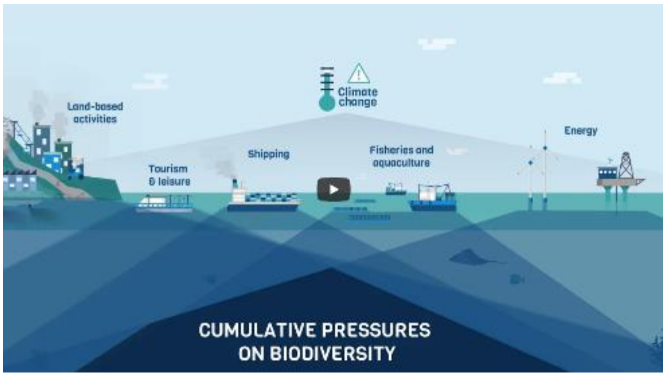


Examples of cumulative pressures from human activities on biodiversity.

Examples of cumulative pressures from the GES4SEAS Ocean Cube (watch the cube video here: https://www.youtube.com/watch?v=E7qFN2AxIdY).

Watch this video

To better understand this concept, watch this short video (https://www.youtube.com/watch?v=TRarrJGQK20) explaining what cumulative pressures are in more detail and what actions we can take to prevent their negative impact on biodiversity.



Why should we care about cumulative pressures?

Read this

In marine ecosystems, even small disruptions can have far-reaching consequences. If these are not adequately managed, they can compromise the resilience and health of marine ecosystems, with negative impacts across biodiversity, ecosystem services, and human communities. Therefore, ocean managers and policymakers need to evaluate which human activities are generating harmful pressures and at what level.

The Mediterranean Sea is a good example of how cumulative pressures have impacted an entire region. Located between Africa, Asia, and Europe, this semi-enclosed sea is one of the most biodiverse regions of our globe and has sustained human populations for millennia. However, with increasing human activities over recent decades, such as overfishing, intensive tourism, maritime traffic, and coastal urbanisation, pressures on the Mediterranean marine ecosystem have intensified. The consequences include depleted fish stocks, coastal erosion, widespread marine litter, habitat fragmentation, and the introduction of invasive alien species – all of which acting with climate change as background.

Watch this video

To better understand how climate change is impacting the Mediterranean Sea, increasing the pressures of other human activities, watch this video:

https://www.youtube.com/watch?v=ifQsKUFcf48

Read this

A study from 2008 (https://johnfbruno.web.unc.edu/wp-content/uploads/sites/1927/2011/11/Halpern-et-al-2008.pdf) mapped the human impacts on marine ecosystems at a global scale and provided a foundational framework for assessing how different pressures interact across marine environments.

In the European Union (EU), and within the Marine Strategy Framework Directive (MSFD), member states are meant to assess the environmental status of marine waters, for which they need to collect information on indicators of different pressures (e.g., marine litter, invasive species, eutrophication, etc.). The MSFD mandates the implementation of a Programme of Measures (PoMs) as means to improve and achieve the so-called "Good Environmental Status (GES)". Thus, the assessments would allow identifying the most suited PoMs to improve the environmental status of marine waters.

In 2022, the 17 member states (MSs) of the EU reported 2046 PoMs, most of which already implemented (39.2%) or being implemented (23.5%) in the coastal and territorial waters or Economic Exclusive Zone of each MS. The MS within the Baltic and Greater North seas reported the most PoMs (38.7% and 31.2%, respectively) but the MS within the Western and Central Mediterranean Sea, Ionian, Adriatic, and Aegean-Levantine seas reported a total of 807 PoMs altogether. Although all 30 pressures to be addressed in the PoMs were covered, the top five targeted pressures were, in order of importance: 1) the input of other substabces; 2) the extraction, mortality/injury of wild species; 3) the input of litter; 4) the disturbance of species; and 5) the input of nutrients. Explore this report (https://op.europa.eu/s/z7eq) to know more about the contribution of PoMs in achieving GES in the EU.

Check your understanding

[True or False]

1. *The MSFD was established by the United Nations to implement PoMs for reducing pressures on marine ecosystems.*
2. PoMs under the MSFD aim to achieve GES in marine waters by reducing pressures through regulatory, technical, and conservation measures.
3. The MSFD requires MSs to implement PoMs that primarily focus on economic growth in marine sectors.

Correct answers: 1. False [It was established by the European Union]; 2. True; 3. False [It focuses on reducing pressures on marine ecosystems]

4.5 Lesson 2: Types of interactions between pressures

In this lesson, you will learn how the different pressures can interact with each other and which effects can we expect from those interactions.

The Lesson will cover the following learning outcomes:

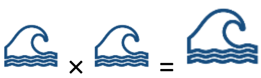
- Identify cumulative pressures and why they matter
- Understand how the different pressures can interact with each other
- Recognize the effects of cumulative pressures and their interactions

Read this

As we have mentioned in the previous lesson, the different pressures in the marine environment can act individually, or in combination with each other. These interactions can produce **additive**, **synergistic**, or **antagonistic** effects, all of which can lead to negative impacts on marine life and habitats.

- **Additive effects** – Additive effects occur when the combined impact of multiple pressures is equal to the sum of their individual effects (1 + 1 = 2). This type of interaction can be compared to two small waves merging to create a single, larger wave.

- **Synergistic effects** – Synergistic effects result in a combined impact that is greater than the sum of individual pressures (1 + 1 > 2). In this case, pressures do not just accumulate – they interact in a way that magnifies their impact, much like two small waves merging into a giant wave.



- **Antagonistic effects** – Antagonistic effects occur when the combined impact of multiple pressures is less than the sum of their individual effects (1 + 1 < 2). In this case, one pressure may reduce or even cancel out the effects of another. This interaction can be pictured as two waves colliding in such a way that they cancel each other out, leading to a smaller wave or no wave at all.

The challenges of managing the cumulative effect of multiple pressures are even greater when synergist, antagonistic, and additive effects occur simultaneously. Knowing the nature of these interactions allows understanding how marine communities will resist and respond to the cumulative pressures.

Coral reefs, for example, are often impacted by several co-occurring pressures, including nutrient and sediment overloads, both of which may aid in the development of long algal turfs that cover coral reefs, particularly if herbivore grazing is small or absent, preventing coral recovery. A recent study (https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2745.12914) has shown that these three pressures have additive, synergistic, and antagonistic interactions between them, pushing the coral reef towards a degraded state with long algal turfs. Moreover, all three types of interactions were common and occurred in equal frequency, but when interactions broke down the reef was able to recover to coral dominance.

Check your understanding

[Multiple choice]

1. When do additive effects occur in marine ecosystems?

a) When pressures cancel each other out.
b) When the combined impact of pressures equals the sum of their individual effects.
c) When pressures interact to magnify their impacts.
d) When pressures reduce each other's effects.

2. Which scenario best represents synergistic effects?

a) Two small waves merge to create a wave larger than expected.
b) Two waves collide and cancel each other out.
c) Two small waves merge to create a wave exactly equal to their combined size.
d) Two pressures reduce each other's overall impact.

3. What happens during antagonistic effects?

a) Pressures combine to create a wave equal to the sum of their impacts.
b) Pressures interact to amplify their overall impact.
c) Pressures reduce or cancel each other's effects, resulting in a smaller impact.
d) Pressures have no interaction at all.

Correct answers: 1. b); 2. a); 3. c)

4.6 Lesson 3: Climate change and cumulative pressures

In this lesson, you will learn how climate change interacts with the different pressures, amplifying their effects.

The Lesson will cover the following learning outcomes:

- Recognize the effects of cumulative pressures
- Understand that climate change can magnify the effects of cumulative pressures

Read this

Climate change can amplify the effects of certain human pressures. For example, the warming ocean caused by climate change can facilitate the spread of non-indigenous species, who may outcompete native species for resources.

A recent GES4SEAS study (https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2023.1271755/full) looked at the Levantine Basin in the Mediterranean as a hotspot for both climate change and biological invasions, showing how tropical non-indigenous species are more resilient to a warming ocean than native species. This threatens local marine life through increased predation, and habitat modification and degradation.

The Red Sea lionfish Pterois miles and the urchin Diadema setosum meet again as alien spcies on the reefs of the Israeli coast (photo: G. Ra'anan). @GES4SEAS study, Frontiers in Marine Science, https://doi.org/10.3389/fmars.2023.1271755.

The southeastern Mediterranean, specifically the Levantine Basin, is the most invaded region of the global ocean due to rapid warming and bioinvasions. Alien species dominate, particularly Mollusca, following native species collapse driven primarily by warming, as evidenced by studies on species like the purple sea urchin, fish, and molluscs. Alien species are more resilient to warming than native species, creating a new ecosystem where they dominate. Marine Protected Areas (MPAs) alone may be insufficient to address these issues, requiring a reassessment of conservation goals and indicators for Good Environmental Status (GES) to account for the shift in ecosystem dynamics.

Watch this video

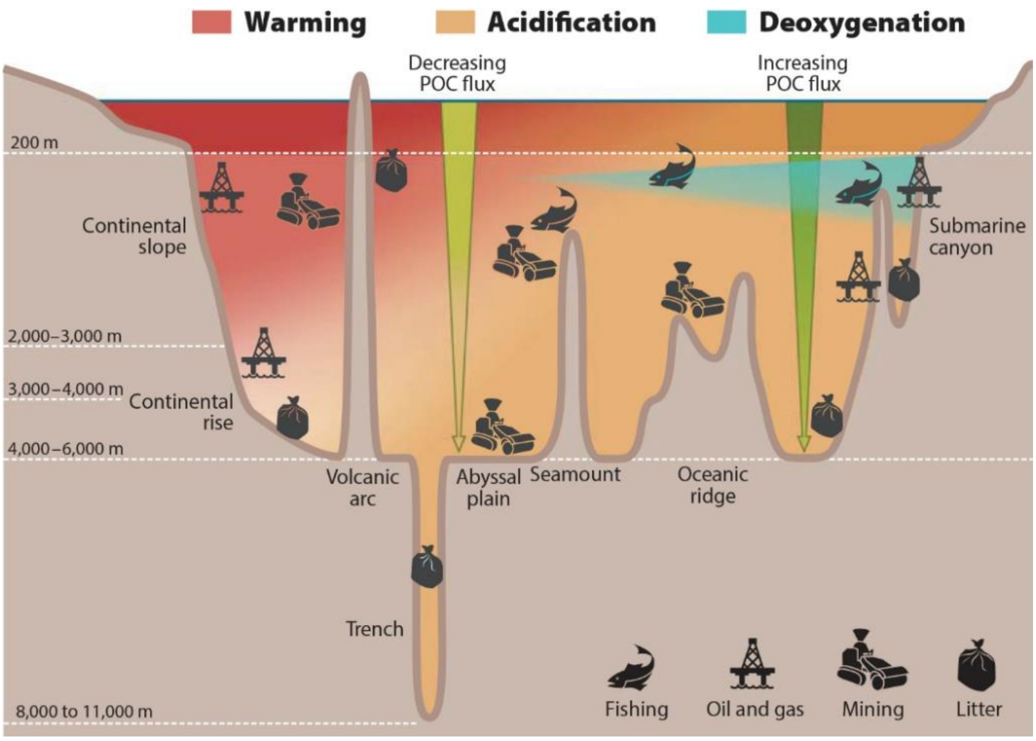
Watch this video (https://www.youtube.com/watch?v=PW92qJtANME) to learn more about how climate warming is impacting the Mediterranean Sea and its ecosystems.

Read this

Here you can find other examples of how pressures and climate change interact:

- Changes in water circulation and nutrient supply in the Strait of Gibraltar may have antagonistic or synergistic effects on Mediterranean nutrient concentrations and primary productivity. https://bg.copernicus.org/articles/16/135/2019/
- While in the North Atlantic and North Pacific the distribution range of some fish species is expanding, some tropical regions are facing huge declines in catches. https://www.msc.org/what-we-are-doing/oceans-at-risk/climate-change-and-fishing
- Climate change in combination with different human stressors are impacting global pinguin distribution. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.17143
- The interactions between climate change and human pressures can also be observed in the deep ocean, where the footprint of our activities keeps steadily increasing. https://doi.org/10.5670/oceanog.2019.224

The image below illustrates the different types of human activities at different depths along with the effect it exerts on that area, such as warming, acidification and deoxygenation.



Climate related changes in temperature, pH, and oxygenation are superimposed on disturbance from human resource extraction and debris accumulation. (@ Levin 2019, https://doi.org/10.5670/oceanog.2019.224, from Levin and LeBris 2015, https://www.science.org/doi/10.1126/science.aad0126).

4.7 Lesson 4: Challenges and tools

In this lesson, you will learn that although pressures exerted in one location may have repercussions in a much extensive area in the marine environment, there are means available to manage these pressures.

The Lesson will cover the following learning outcomes:

- Recognize that the effects of local pressures can expand beyond that area
- Understand there are tools available to identify and map cumulative pressures and their impacts

Read this

One of the most distinct features of our ocean is its interconnectedness, as all marine ecosystems are linked together. This means that impacts in one region often have repercussions way beyond it, which is why it is so hard to stop pressures from exerting their negative effects on marine life.

Despite this, there are actionable solutions available for managing marine resources and pressures sustainably. For an inspiring perspective, explore the Food and Agriculture Organization of the United Nations website for more information on its “Towards Blue Transformation” (https://www.fao.org/interactive/state-of-fisheries-aquaculture/2022/en/) initiative. The infographics and reflections provide great insights about what is needed to move towards a more sustainable use of marine resources.

Additionally, scientists have also been developing multiple methods (https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2016.00153/full) to improve the assessment of the effects of cumulative pressures and their impacts in the marine environment. Substantial knowledge was recently gained on the best practices to conduct a Cumulative Effects Assessment (CEA) of human activities in the marine environment.

4.0 HOW TO CONDUCT A CEA

There are several different methods for performing CEA. In this chapter we summarise the main steps (see Figure 1) and present some of the available tools.

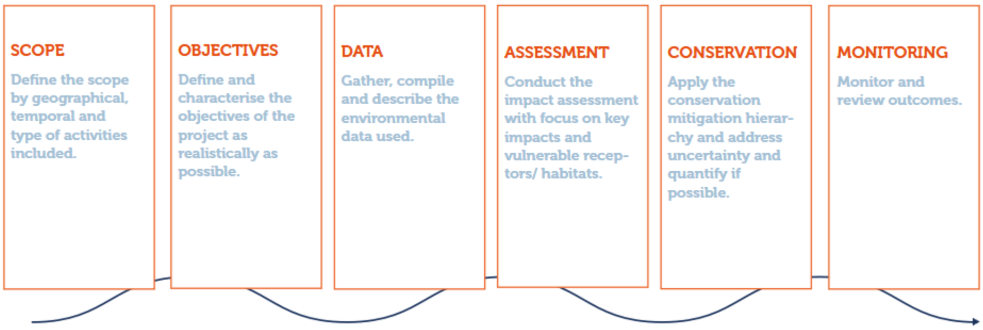


Figure 1. The workflow of a Cumulative Effects Assessment (Milner-Gulland et al., 2021).

A global example of a cumulative impact assessment of human activities is included in the Ocean Health Index (https://oceanhealthindex.org/resources/data/cumulative-human-impacts/), where the cumulative impact of human activities on global oceans was mapped from 2003 to 2013. It was found that our impact is increasing for most of the ocean (59%), and that this increase has been due to climate change, fishing, land-based pollution, and shipping.

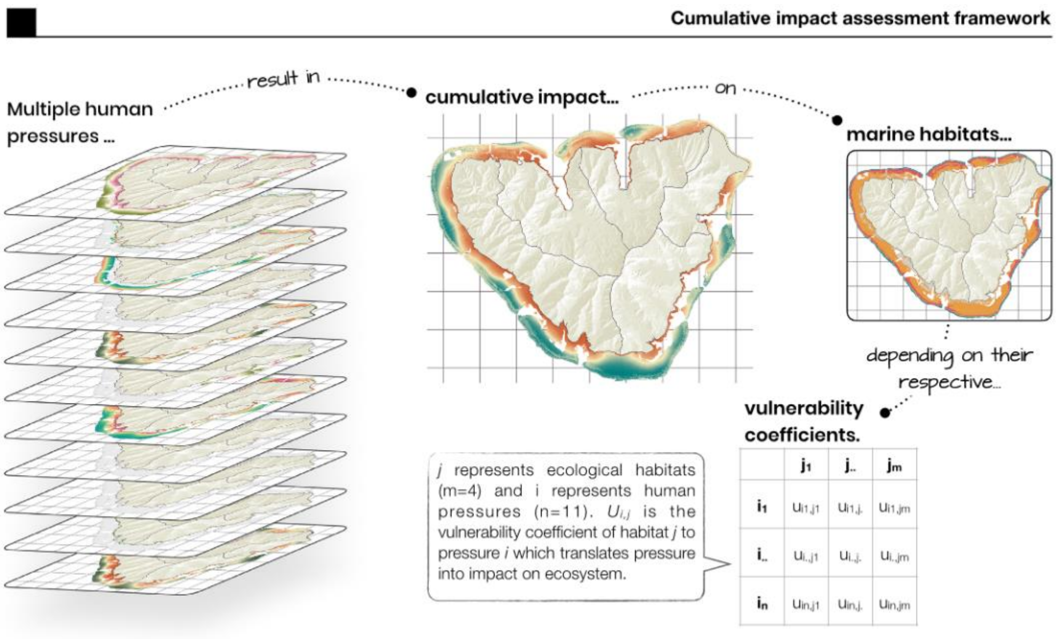
The **Ocean Health Index (OHI)** is a framework for assessing ocean health based on the sustainable provisioning of benefits and services people expect from a healthy ocean, such as food, cultural and social value, and jobs.

The basic philosophy of the Ocean Health Index is that it measures how well ocean systems are sustainably providing people with the benefits and services they need and desire from marine systems. The global OHI measures the status of these key societal 'goals': artisanal fishing opportunity, biodiversity, carbon storage, clean waters, coastal livelihoods and economies, coastal protection, food provision, natural products, sense of place, tourism and recreation.

A plethora of CEA tools are available for use at regional and global scales. Some examples are:

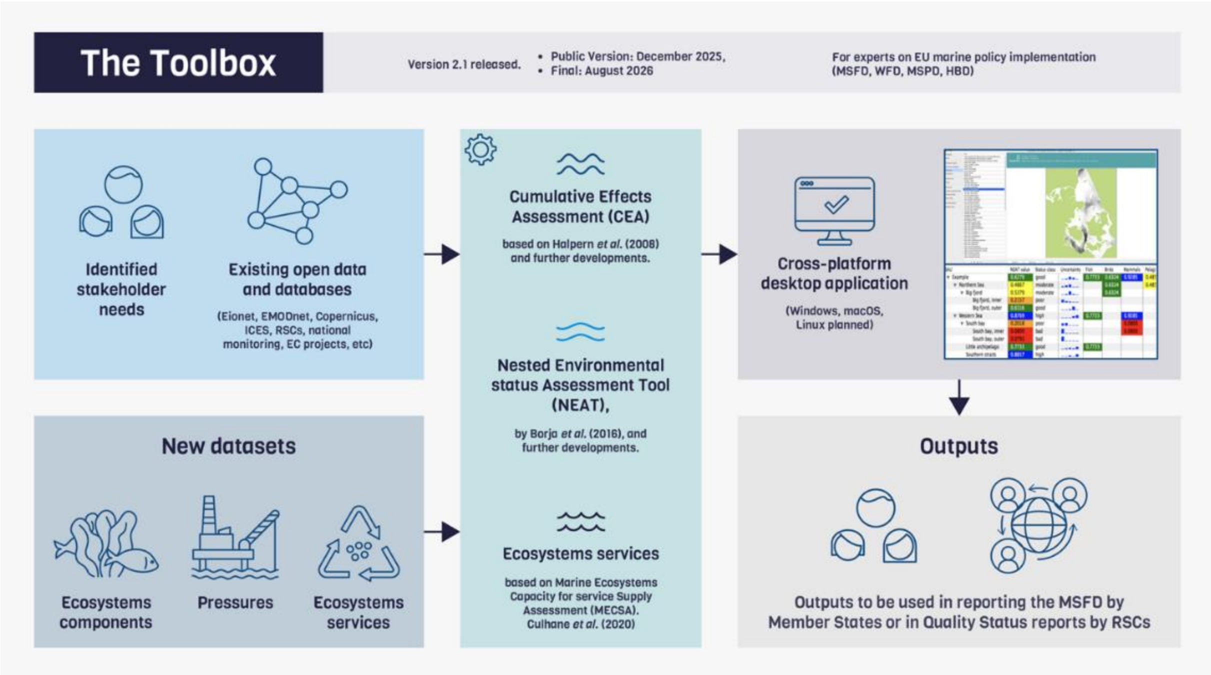
- Spatial Pressure and Impact assessment tool (https://maps.helcom.fi/website/bsii/) – used at a regional level in the Baltic Sea;
- Adriplan Cumulative impact tool (https://maritime-spatial-planning.ec.europa.eu/practices/adriplan-cumulative-impact-tool) – used at a regional level in the Adriatic Sea and the Eastern Mediterranean;
- WIO Symphony (https://www.nairobiconvention.org/wio-symphony/) – developed by countries of the Western Indian Ocean, together with the Nairobi Convention Secretariat and Swedish partner.

However, at small local scales, cumulative impact assessments are also very useful to inform marine spatial planning. This was evidenced in a study in Moorea's coral reef, French Polynesia, by GES4SEAS colleagues to inform the ongoing revision of the island-wide marine spatial management plan (https://doi.org/10.1016/j.scitotenv.2021.147339).



Schematic representation of the cumulative impact assessment framework used in Loiseau et al. 2021.

GES4SEAS has also been at the forefront of CEA tools, developing new technology for the purpose of managing cumulative pressures. These efforts will result in a toolbox that will support Regional Sea Conventions, Member States, stakeholders, and researchers in evaluating the cumulative effects of various stressors on marine ecosystems. It will also operationalise integrative and holistic solutions through a scientific framework (ecosystem-based management) for analysing, assessing, and mapping cumulative pressures, GES, and ecosystem services.



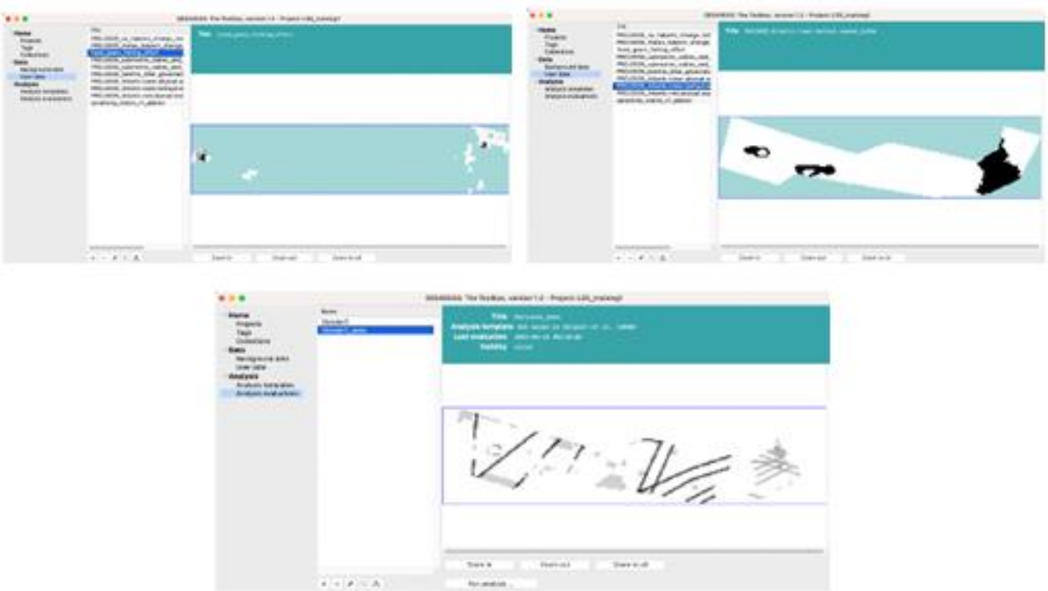
The development of the GES4SEAS toolbox.

The development of this toolbox requires a lot of tests performed at 11 learning sites (LSs) of the GES4SEAS project, which are comprised of different types of marine ecosystems across European seas, plus one LS in the Pacific Ocean. An example of this testing is presented below.

Learning site example: In the Atlantic-Mediterranean transition at 500-5000 m depth is the GES4SEAS deep sea learning site. Despite its a great diversity of habitats (from mud volcanos to cold water corals), it is still amongst the least addressed under MSFD assessments. GES4SEAS scientists have been exploring this site and have captured mussels living around mud volcanoes by the Luso underwater vehicle and methane bubbles in a mud volcano in the Gulf of Cadiz.

GES4SEAS deep learning site images: photos by EMEPC https://www.emepc.pt

This type of field work helped developing the GES4SEAS toolbox. Here is a sneak peek into GES4SEAS toolbox version 1.2 (currently, version 2.1 already available), tested with data from learning site in deep sea Atlantic-Mediterranean transition. These are visualisations of pressure and habitat layers integrated into a final cumulative effects map CEA.



An example of toolbox testing at GES4SEAS learning site in deep-sea.

Ultimately, understanding the mechanisms and impacts of cumulative pressures and what tools we have at hand to assess and manage them is key for efficient ecosystem-based management and achieving GES of our seas. The GES4SEAS toolbox has been developed for this purpose in collaboration with the project's stakeholders, who bring different expertise of scientific methods, approaches and tools.

Furthermore, to help co-develop, guide, and validate project outcomes, such as the GES4SEAS toolbox, GES4SEAS established its Practitioners' Advisory Board at the start of the project, which includes stakeholders with complementary roles in marine policy. Working together, scientists and stakeholders are creating sustainable solutions to help resolve some of the issues we have discussed in this lesson and reach the GES of our seas.

Check your understanding

[Word Association]

Match the pressure to its outcome in marine ecosystems.

Pressure	Outcomes
1. Overfishing	A. Habitat fragmentation
2. Coastal Urbanization	B. Decline in native species populations
3. Invasive Species	C. Depleted fish stocks

Correct answers: A – 3; B – 1; C – 2

[Multiple choice]

1. Why is it important to understand cumulative pressures in marine ecosystems?

a) They only occur in a few regions, making them easier to manage.
b) They can lead to impacts greater than the sum of individual pressures.
c) They only affect marine biodiversity and not human societies.
d) They are not influenced by human activities like tourism or fishing.

2. Which of the following is NOT a consequence of cumulative pressures in the Mediterranean Sea?

a) Depleted fish stocks
b) Coastal erosion
c) Increased water salinity
d) Habitat fragmentation

3. How does climate change interact with other pressures in marine ecosystems?

a) It only has additive effects, increasing pressures proportionally.
b) It amplifies certain pressures, such as facilitating the spread of invasive species.
c) It cancels out the impact of human activities like pollution.
d) It reduces the resilience of invasive species compared to native species.

Correct answers: 1. b); 2. c); 3. b)

[True or False]

1. Coastal urbanization and maritime traffic are examples of human activities that contribute to cumulative pressures in marine ecosystems.
2. The Mediterranean Sea is one of the least biodiverse marine regions in the world, making it less affected by cumulative pressures.
3. The Ocean Health Index is used to assess the cumulative impact of human activities on the ocean.

Correct answer: 1. True; 2. False [The Mediterranean is highly biodiverse and heavily impacted by cumulative pressures]; 3. True

4.8 Final considerations

As we have seen, the interactions between pressures are rarely straightforward – sometimes they amplify one another, sometimes they cancel each other out, and often, their combined effects are unpredictable. This complexity brings many challenges to the management of marine ecosystems, which GES4SEAS is committed to overcome through the development of new and advanced technology.

Equally important is the adaptability management measures that are implemented. They must be flexible enough to respond to the unpredictable nature of the effects of cumulative pressures. To achieve this, we must adopt a dynamic approach to marine management – one that continuously integrates new data, cultivates collaboration, and encourages informed decision-making.

Ultimately, solving the challenge of cumulative pressures goes beyond protecting marine life; it is about securing the long-term well-being of human societies that rely on healthy oceans for food, economic activities, and cultural value. Sustainable ocean management is a foundational aspect of securing our future.

4.9 Additional resources – relevant lesson plans and activities

If you want to learn more about cumulative pressures, here are some additional resources and lesson plans.

- **Blue Schools Projects regarding pressures in the marine environment, with focus on food from the ocean**

The concept of a European Blue School evolved from the marine education expertise gathered from consultations with teachers and educators across Europe. It acknowledges the variety of cultures and school communities from the 27 EU Member States and champions the concept of open schooling.

The Handbook for Teachers “A Wave of European Blue Schools” (https://maritime-forum.ec.europa.eu/document/download/0e460a07-428c-4b0d-a4b4-2d82b999b6ee_en?filename=Handbook%20for%20Teachers%20-%20European%20Blue%20Schools_0.pdf) includes a wealth of useful resources and best practice to inspire you to find what connects you and your school to the ocean. It has built in flexibility to encourage and support teachers across all disciplines to bring the ocean to their classrooms, whether through biology, physics, chemistry, technology, mathematics, history, literature, or the arts.

You can find some inspiring projects on pages 53 through 63 related to pressures in the marine environment.

- **MED EDUC Educational Resources (lesson plans)**

The MED EDUC project proposes the creation of a series of European level educational resources for middle and high schools. These resources concern the discovery and valorisation of the coastal and marine environment in the Mediterranean. The project is mainly aimed at students, teachers and educators, offering them both educational tools focused on specific issues of environmental protection in the Mediterranean Sea (pollution and waste, mass tourism, overfishing, loss of biodiversity, coastal erosion, etc.).

Here are some relevant lesson plans in the context of pressures in the marine environment.

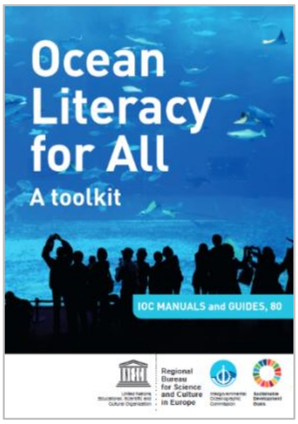
- Natural Hazard in the Mediterranean Basin – https://mededuc.eu/en/resource-center/pedagogical-guide/15-natural-hazard.html
- Climate Change – https://mededuc.eu/en/resource-center/pedagogical-guide/30-climate-change.html

- **Ocean Literacy for all: a toolkit. IOC Manuals and Guides (lesson plans)**

This toolkit

(https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000260721&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_2d3dfb02-da9b-410a-9386-dd31047e6ef0%3F_%3D260721eng.pdf&locale=en&multi=true&ark=/ark:/48223/)

provides educators and learners worldwide the innovative tools, methods, and resources to understand the complex ocean processes and functions and, as well, to alert them on the most urgent ocean issues. It also presents the essential scientific principles and information needed to understand the cause-effect relationship between individual and collective behaviour and the impacts that threaten ocean health.



Some particularly relevant sections within the topic of marine pressures are:

- How does ocean acidification occur? (pp. 108-110)
- Watershed activity using anadromous fish cherry salmon to understand land - ocean connection (pp. 120-122)
- The sea: water that... sustains us! (pp. 128-132)
- Let's go fishing (pp. 111-113)
- Integrated Multi-Trophic Aquaculture – IMTA (pp. 114-116)
- Eat the right fish (pp. 123-124)

- **Practical ocean literacy for all: ecology and exploration**

This resource from project *Science in School*, aims to support teachers in the delivery of their STEM curricula by connecting them to inspiring, cutting-edge science and technology, to foster positive attitudes towards the science that shapes our lives, and attract students to careers in these fields.

This issue in particular, "Practical ocean literacy for all: ecology and exploration" (https://www.scienceinschool.org/article/2023/practical-ocean-literacy-ecology-and-exploration/), covers all ocean literacy principles and provides practical experiences for students to learn about these principles through hands-on exercises. To further explore the topic of pressures in the marine environment, see Activity 3.

Science in School
The European journal for science teachers

- **BlueMinds4Teachers**

BlueMinds4Teachers (https://www.emseanet.eu/node/546) is an educational toolkit on the ocean literacy principles for teachers. The project aims to strengthen the competence of teachers and other marine educators of all levels in Ocean Literacy (OL) by providing an online training course with three sessions of approximately 2 hours each.

Within the topic of marine pressures, there are several lesson plans you can access:

- Lesson plan – Principle 3: Traces of tropical marine species (Lessepsian migrants) in the Mediterranean Sea (pp. 19-27)
- Lesson plan – Principle 6: Hydroelectric power. How environmentally friendly is it? (pp. 43-55)

- **Ocean Wise**

Ocean Wise offers free online courses about different aspects of our ocean to arm students with the tools needed to conserve it. You can learn more about the courses here: https://ocean.org/learn-explore/education/ocean-literacy/. Below we suggest some of the most relevant courses related to pressures in the marine environment.

- The ocean and human connection – https://ocean.org/education/the-ocean-and-human-connection/
- Weather and climate – https://ocean.org/education/weather-climate/
- The ocean and humans are connected – https://ocean.org/education/the-ocean-and-humans-are-connected/
- Clams and ocean acidification – https://ocean.org/education/clams-and-ocean-acidification/
- Global Weather and Climate – https://ocean.org/education/global-weather-and-climate/

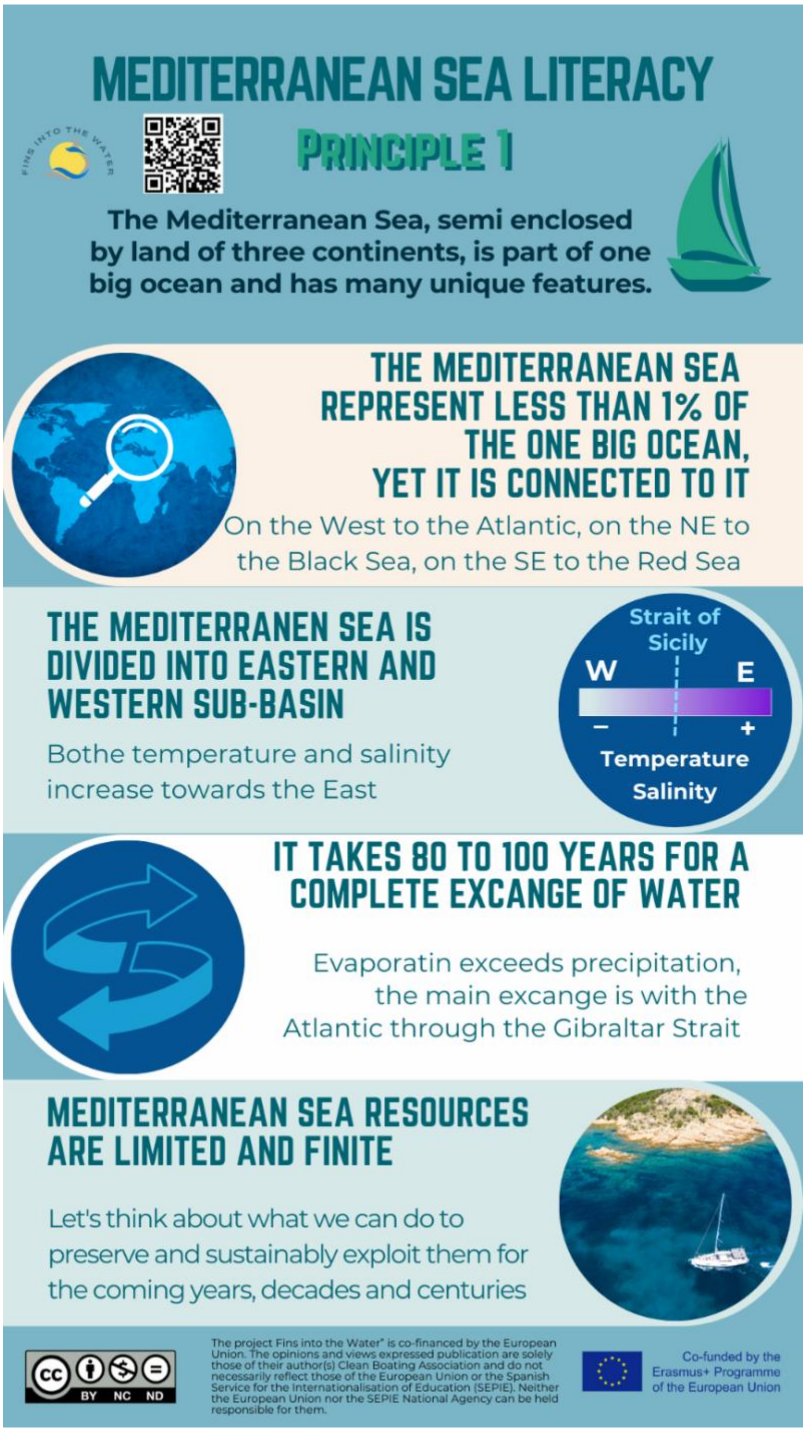
OCEAN WISE

- **Fins into the Water**

Building on the Mediterranean Sea Literacy Principles, the project partners of Fins into the Water developed an open-source library, translations of the Mediterranean Sea Literacy Brochure, a

Resource Map with more than 150 resources and visual elements principally for leisure centres and any other maritime tourism stakeholders in the Mediterranean region.

You can learn about how you can access these resources here: https://www.emseanet.eu/fins-water-library.



5. Module 3 | Good environmental status and how it can affect your health and life

5.1 Introduction to M3

In our first educational module, we explored the definition of a healthy sea. In our second educational module, we talked about the impacts of cumulative pressures in the ocean. Now, in this third module, we are going to cover the concept of Good Environmental Status (GES) and its ecological, societal and economic benefits, using the Black Sea as an example.

5.2 Learning Outcomes

By the end of this Module, you should be able to:

- Understand the concept of GES
- Understand the importance of achieving and maintaining GES
- Understand the consequences of not achieving GES
- Identify the tools available for evaluating GES
- Recognize the uniqueness of the Black Sea and the importance of GES in this ecosystem

5.3 How to proceed

Complete the **activities** as they appear in each Lesson.

To succeed in this Module, you need to successfully complete the following Lessons:

- **Lesson 1:** Why the Black Sea?
- **Lesson 2:** What is GES?
- **Lesson 3:** Why do we need to achieve and maintain GES?
- **Lesson 4:** What is we don't reach GES?
- **Lesson 5:** Tools for evaluating GES in practice

5.4 Lesson 1: Why the Black Sea?

In this lesson, you will learn about the uniqueness of the Black Sea and why it was selected as an example to illustrate the concept of GES.

The lesson will cover the following learning outcomes:

- Recognize the uniqueness of the Black Sea and the importance of GES in this ecosystem

Read this

The Black Sea is a marginal mediterranean sea lying between Europe and Asia. Despite its harsh environmental conditions compared to other seas, it supports a great variety of underwater life. The Black Sea is also known for its rich heritage, abundant natural resources and unique habitats. With a mixture of saline and freshwater, it has several distinct environmental zones and habitats, ranging from shallow coastal zones to deep, anoxic basins. This sea's history and culture is also of great value, with a vast legacy of maritime traditions and communities. Given the importance of the Black Sea for marine and terrestrial life, achieving and maintaining the GES of the Black Sea should be a top priority for decision and policy makers.

Some of the unique features of the Black Sea.

If you'd like to know more about the Black Sea, you can read the small book "*Secrets of the Black Sea*" available here: https://emblasproject.org/wp-content/uploads/2020/08/Secrets-of-the-Black-Sea.pdf.

5.5 Lesson 2: What is GES?

In this lesson, you will learn how GES is defined and how it can be achieved.

The Lesson will cover the following learning outcomes:

- Understand the concept of GES
- Understand the importance of achieving and maintaining GES

Read this

The environmental status of an ecosystem is determined by its structure and functions. An ecosystem's structure is characterised by the organisation of both living components (such as fish, plants and microorganisms) and non-living (such as sunlight availability, salinity and temperature). On the other hand, the functions of an ecosystem refer to capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly.

Achieving GES implies that despite the presence of human activities, the ecosystem's structure and functions are maintained at levels that ensure their continuity and integrity, with the capacity to deliver services and benefits for future generations. To achieve such levels, scientists and decision-makers must know how to interpret and integrate information on ecosystem components, descriptors, and habitats and how to identify the cascading effects into the ecosystem services. Although a challenge, this work is key to achieve GES.

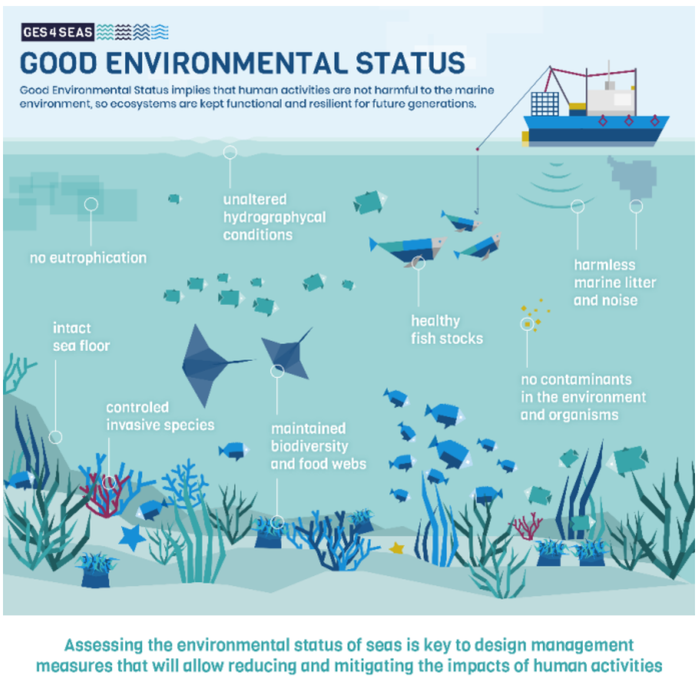


Illustration of an ecosystem where GES is achieved.

Check your understanding

[Multiple choice question]

What does Good Environmental Status (GES) aim to achieve?

1. Complete elimination of human activities in marine environments
2. An ocean free from all harmful organisms
3. Ecosystems that remain functional and resilient despite human activities
4. Replacement of all invasive species with native species

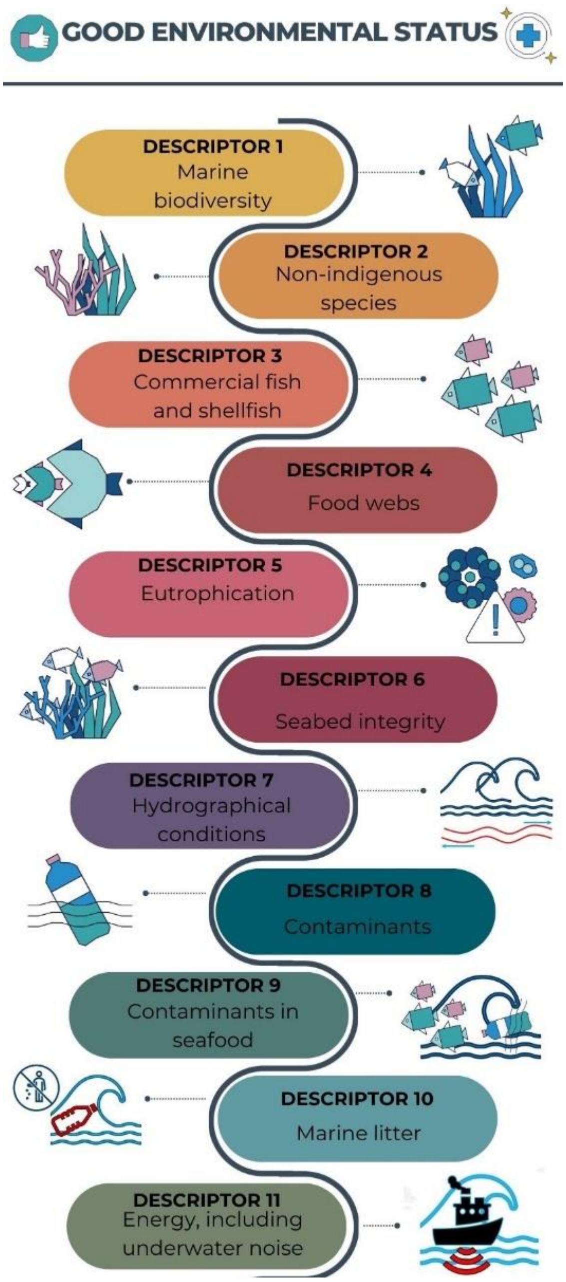
Correct answer: 3

Read this

According to the Marine Strategy Framework Directive (MSFD), GES is defined through 11 descriptors (listed below). These describe the state of the marine environment, such as conserving biodiversity or food webs. They also describe anthropogenic pressures on the marine environment, including commercial fisheries, or pollutants, like marine litter and contaminants, or the input of energy. The statuses of these descriptors indicate how far a marine ecosystem is from achieving GES.

1. **Marine biodiversity** – *Biological diversity is maintained.*
2. **Non-indigenous species** – *Non-indigenous species introduced by human activities are at levels that don't negatively impact the ecosystems.*
3. **Commercial fish and shellfish** – *Populations of commercial fish and shellfish are within safe biological limits.*
4. **Food webs** – *All elements of the marine food webs occur at normal abundance and diversity.*
5. **Eutrophication** – *Human-induced eutrophication is minimised.*
6. **Seabed integrity** – *Seabed integrity is at a level where the structure and functions of the ecosystems are safeguarded.*
7. **Hydrographical conditions** – *Permanent alteration of hydrographical conditions does not negatively affect marine ecosystems.*
8. **Contaminants** – *Concentrations of contaminants don't lead to pollution effects.*
9. **Contaminants in seafood** – *Contaminants in fish and other seafood for human consumption do not exceed the established safety levels.*
10. **Marine litter** – *Properties and quantities of marine litter do not cause harm to the coastal and marine environments.*
11. **Energy, including underwater noise** – *Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.*

Launched at the end of 2024, "The Blue Manifesto: A Roadmap for a Healthy Ocean by 2030" (https://www.oceanweek.eu/blue-manifesto-launch) advocates for an ambitious Ocean Deal that places the ocean at the heart of European Union (EU) decision-making in the new legislative period, and it is endorsed by more than 100 organisations. In the context of the GES4SEAS project, this manifesto is very relevant as it aligns with our research and advocacy goals.



The Blue Manifesto Roadmap.

Check your understanding

[Multiple choice questions]

1. What is the goal of the descriptor related to "non-indigenous species"?

a) To eliminate all non-indigenous species from marine environments
b) To maintain indigenous species at levels that do not negatively impact ecosystems
c) To encourage the introduction of non-indigenous species to improve biodiversity
d) To prioritize non-indigenous species over native species
Correct answer: b

2. How does the descriptor related to "marine litter" contribute to GES?

a) By reducing marine litter to levels that do not harm coastal and marine environments
b) By increasing the recycling of marine litter within ecosystems
c) By promoting the accumulation of marine litter in deep-sea areas
d) By encouraging the use of litter to restore marine habitats
Correct answer: a

5.6 Lesson 3: Why do we need to achieve and maintain GES?

In this lesson, you will learn that maintaining GES is not only important for marine ecosystems – it directly or indirectly impacts human societies at several levels.

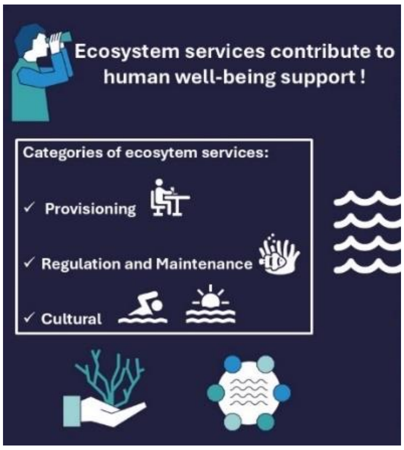
The Lesson will cover the following learning outcomes:

- Understand the importance of achieving and maintaining GES

Read this

The environmental status of our seas directly impacts the health of our societies because the services provided by marine ecosystems directly support human well-being.

The services provided by marine ecosystems cascade into goods and benefits that add value to our lives. There are primarily three categories of ecosystem services provided by the ocean: provisioning, regulation and maintenance, and cultural.



The three categories of ecosystem services provided by the ocean.

Provisioning services include tangible resources such as seafood, medicinal compounds, and raw materials. Regulation and maintenance include carbon sequestration, water purification, and coastal protection. Cultural services include the non-material benefits, such as recreational activities, tourism, and educational opportunities. Ultimately, a decline in one service can lead to the inability to provide certain benefits to a community. This is why achieving and maintaining GES is so important for our well-being.

Examples of ecosystem services in each category.

5.7 Lesson 4: What if we don't reach GES?

In this lesson, you will learn which factors may compromise GES, using examples from the Black Sea.

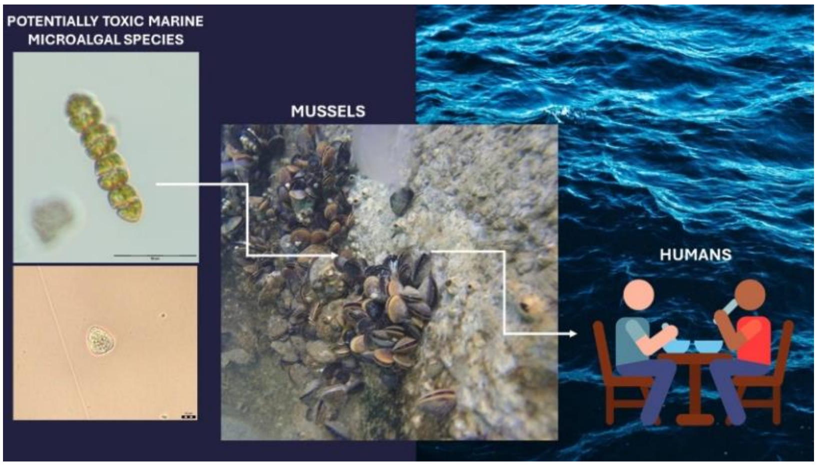
The Lesson will cover the following learning outcomes:

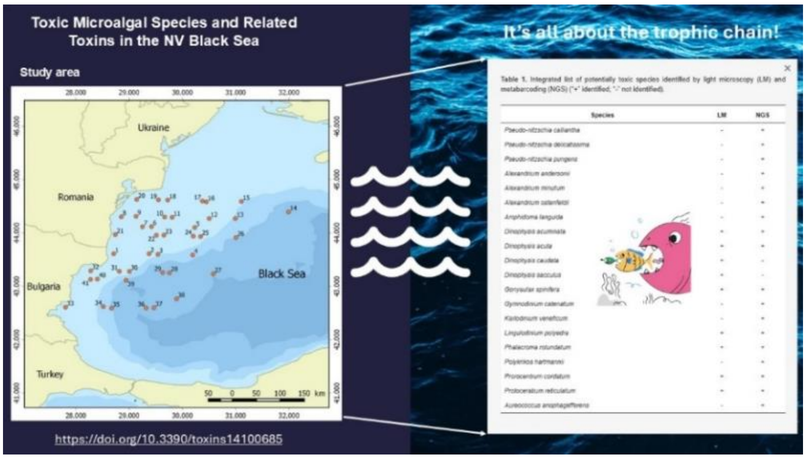
- Understand the consequences of not achieving GES
- Recognize the uniqueness of the Black Sea and the importance of GES in this ecosystem

Read this

Failing to reach GES would compromise the mentioned ecosystem services and benefits. So, which factors may compromise GES?

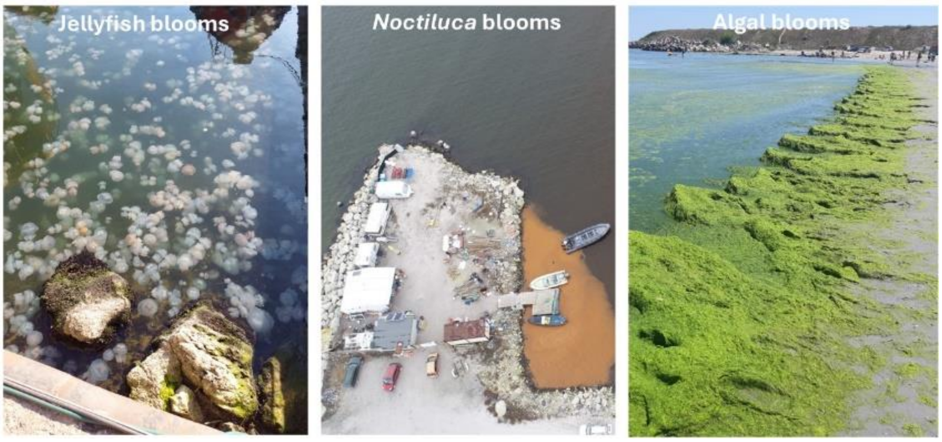
- **Potentially toxic plankton species** commonly occur in the Black Sea, and, despite the low levels of toxins and toxicity, chronic exposure could pose a danger to human health. Find out more at https://doi.org/10.3390/toxins14100685. Toxic microalgae may also compromise water quality and, if consumed by other marine may contaminate the food web and ultimately humans, thereby affecting ecosystem and human health.



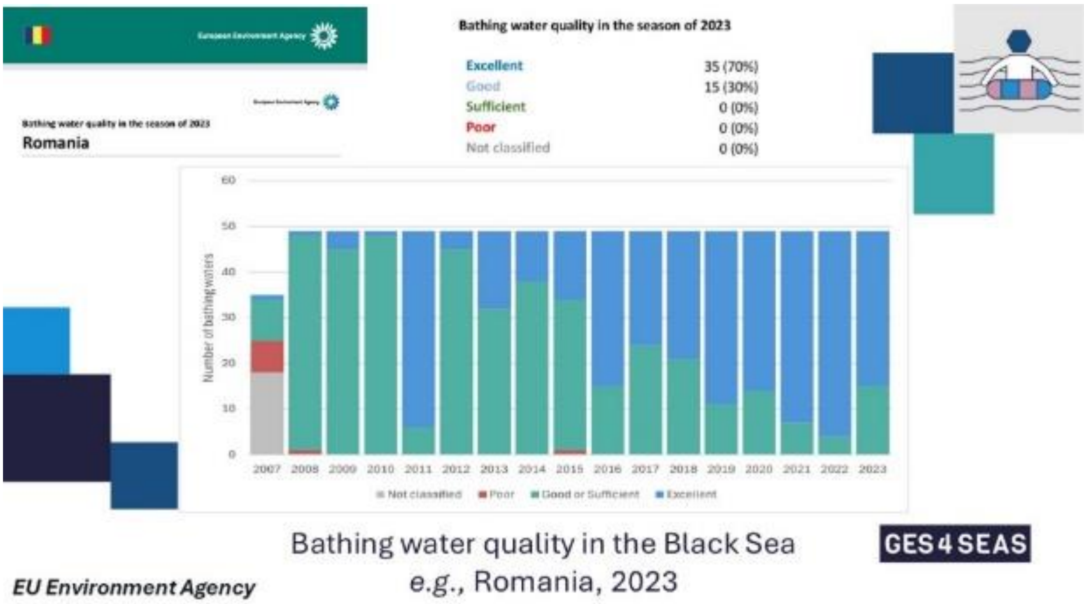


- **Algal and jellyfish blooms** occur in the Black Sea due to eutrophication and high-water temperatures. Apparently harmless, jellyfish may cause skin irritation and cause problems in fisheries, and algal blooms hinder tourism activities. These blooms can become tipping points for the Black Sea. As so, it is best not to reach such blooms as the consequences on both human and marine life are difficult to manage.

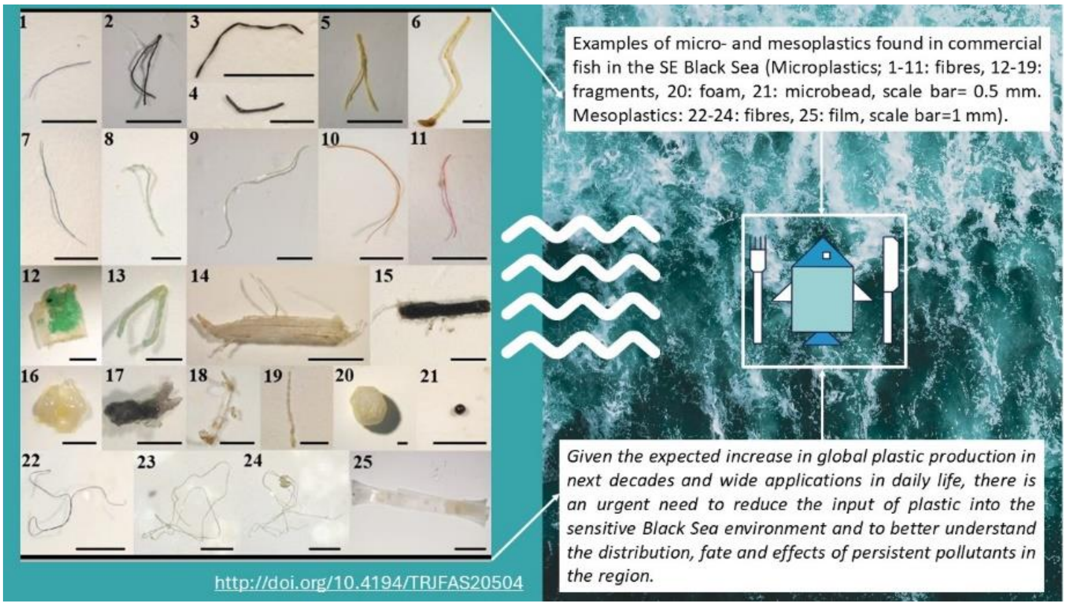
So, we have these problems in the Black Sea...now think first about touristic activities to understand more easily the influence of these phenomena on our lives !



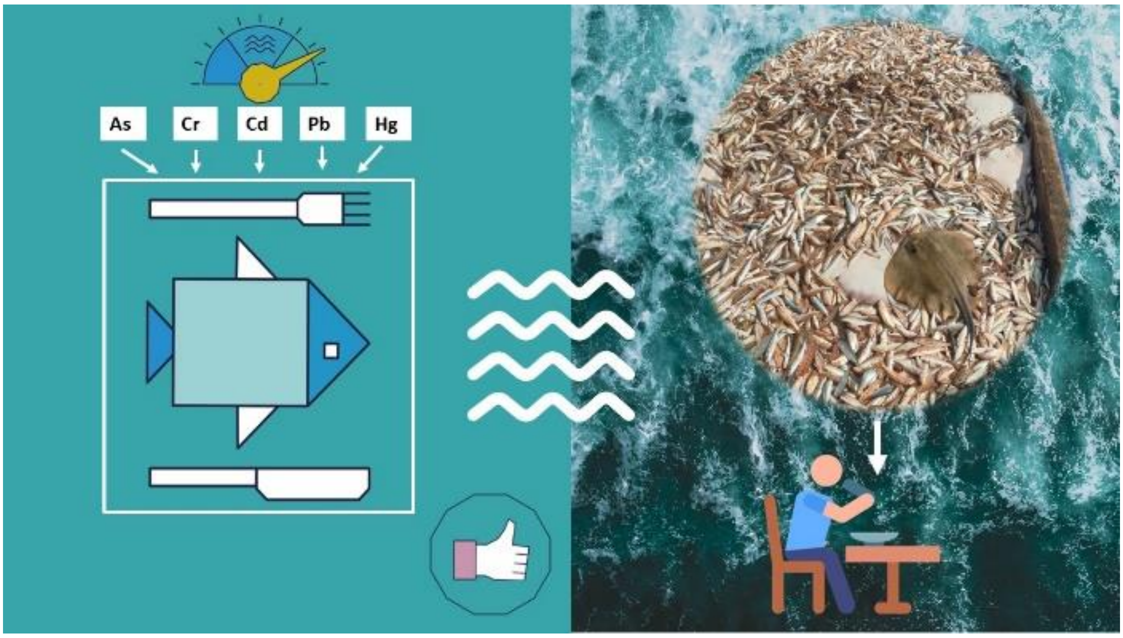
- **Pollution** is another issue, of which the consequences are difficult to estimate. For instance, contaminants may contribute to increase harmful populations of disease-causing agents. Examples include waterborne infectious diseases, skin and digestive problems, and exposure to bacteria like *Escherichia coli* and intestinal *enterococci*. Bathing water quality in the Black Sea has significantly improved over the past few decades due to EU policies and actions by Member States. Despite this, contamination of surface and groundwater remains substantial and may be exacerbated by the changing climate.



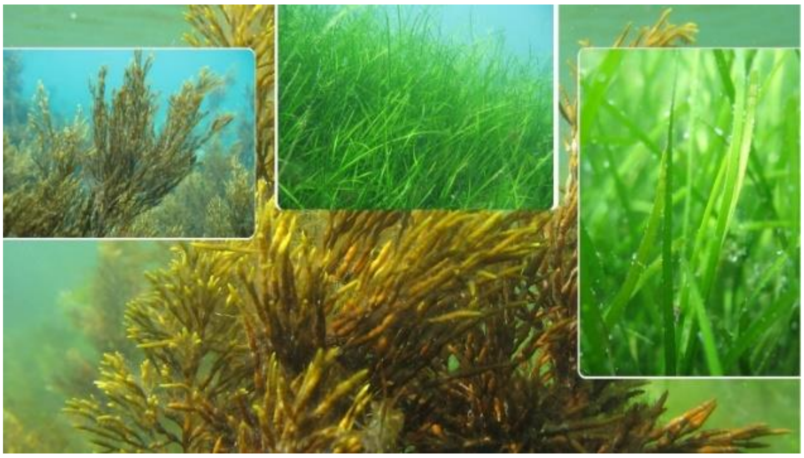
- Among pollutants, **macro- to microplastics** are a matter of concern not only as part of marine litter but also because they accumulate in food webs. Does this mean that commercial fish from the Black Sea are contaminated with plastics? Indeed. Moreover, the presence of plastic in fish has potential adverse effects on the Black Sea ecosystem and human health. For more information, read http://doi.org/10.4194/TRJFAS20504.



- What about **toxic and trace metals**? Although some fish species in the Black Sea exhibit high concentrations of toxic and trace elements, these are within acceptable thresholds for safe fish consumption. You can find more information at https://doi.org/10.1016/j.emcon.2023.100295.



- The **loss of key species** is another factor that may compromise GES. Did you know that some marine plants of the Black Sea are threatened, such as the brown algae *Cystoseira* spp.? To prevent the loss of these are other key species, we need ecological restoration to continue.



Check your understanding

[Multiple choice questions]

1. What is a potential consequence of chronic exposure to toxins produced by toxic plankton in the Black Sea?

a) Enhanced marine biodiversity
b) Danger to human health
c) Improved water quality
d) Decreased jellyfish populations

Correct answer: b

2. What environmental factors contribute to algal and jellyfish blooms in the Black Sea?

a) Overfishing and habitat destruction
b) Eutrophication and high-water temperatures
c) Increased tourism and plastic pollution
d) Rising levels of contaminants in seafood

Correct answer: b

3. What is a key concern about microplastics in the Black Sea?

a) They degrade quickly and leave no impact.
b) They accumulate in food webs, potentially affecting both marine ecosystems and human health.
c) They reduce algal blooms and improve water quality

Correct answer: b

4. How has bathing water quality in the Black Sea improved in recent decades?

a) Overfishing and habitat destruction
b) Eutrophication and high-water temperatures
c) Increased tourism and plastic pollution
d) Rising levels of contaminants in seafood

Correct answer: b

5.8 Lesson 5: Tools in practice

In this lesson, you will learn about the tools available for assessing GES and about the tool used in GES4SEAS.

The Lesson will cover the following learning outcomes:

- Identify the tools available for evaluating GES

Read this

Some initiatives worldwide are intending to assess the status of marine waters in an integrative way, such as the Marine Strategy Framework (MSFD) and the Ocean Health Index, by incorporating multiple metrics, indicators and ecosystem components. Within the GES4SEAS project, the Nested Environmental status Assessment Tool (NEAT) is an integrative tool used to assess the environmental status of marine ecosystems under the MSFD that identifies environmental issues in need of management.

NEAT is a free and integrative tool designed to evaluate the environmental status of marine areas, such as the Black Sea, using the MSFD descriptors. It aggregates diverse indicators across multiple spatial scales and ecosystem components that produce a clear evaluation of environmental health.

When attempting to assess the environmental status of marine ecosystems in an integrative way, marine managers often encounter some challenges. These include a lack of validated and consistent indicators across regions, difficulty in aggregating data from diverse ecosystem components and habitats and the complexity of integrating multiple metrics into a single cohesive assessment.

NEAT addresses these issues through an ecosystem-based approach that aggregates data from various indicators and spatial units, integrating data into a single score. This enables managers to identify key environmental issues needing intervention and develop targeted, evidence-based management strategies.

To know more, read the article: https://doi.org/10.3389/fmars.2019.00019.

5.9 Additional resources – relevant lesson plans and activities

If you want to learn more about GES, here are some additional resources and lesson plans.

- **Blue Schools Projects regarding GES, with focus on biodiversity.**

The concept of a European Blue School evolved from the marine education expertise gathered from consultations with teachers and educators across Europe. It acknowledges the variety of cultures and school communities from the 27 EU Member States and champions the concept of open schooling.

The Handbook for Teachers "A Wave of European Blue Schools" (https://maritime-forum.ec.europa.eu/document/download/0e460a07-428c-4b0d-a4b4-2d82b999b6ee_en?filename=Handbook%20for%20Teachers%20-%20European%20Blue%20Schools_0.pdf) includes a wealth of useful resources and best practice to inspire you to find what connects you and your school to the ocean. It has built in flexibility to encourage and support teachers across all disciplines to bring the ocean to their classrooms, whether through biology, physics, chemistry, technology, mathematics, history, literature, or the arts.

You can find some inspiring projects related to GES on pages 78 through 89.

- **MED EDUC Educational Resources (lesson plans)**

The MED EDUC project proposes the creation of a series of European level educational resources for middle and high schools. These resources concern the discovery and valorisation of the coastal and marine environment in the Mediterranean. The project is mainly aimed at students, teachers and educators, offering them both educational tools focused on specific issues of environmental protection in the Mediterranean Sea (pollution and waste, mass tourism, overfishing, loss of biodiversity, coastal erosion, etc.).

Here are some relevant lesson plans in the context of GES.

- *Biodiversity* – https://mededuc.eu/en/resource-center/pedagogical-guide/12-biodiversity.html
- *Politics and Governance* – https://mededuc.eu/en/resource-center/pedagogical-guide/28-politics-and-governance.html

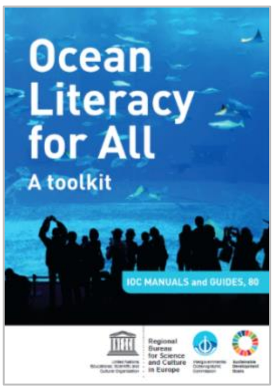
- **Ocean Literacy for all: a toolkit. IOC Manuals and Guides (lesson plans)**

This toolkit

(https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000260721&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_2d3dfb02-da9b-410a-9386-dd31047e6ef0%3F_%3D260721eng.pdf&locale=en&multi=true&ark=/ark:/48223/) provides educators and learners worldwide the innovative tools, methods, and resources to understand the complex ocean processes and functions and, as well, to alert them on the most urgent ocean issues. It also presents the essential scientific principles and information needed to understand the cause-effect relationship between individual and collective behaviour and the impacts that threaten ocean health.

Some particularly relevant sections within the topic of GES are:

- The waves? (pp. 97-98)
- Ocean currents and ocean drifters (pp. 103-104)
- Know, think, act (pp. 133-135)



- **BlueMinds4Teachers**

BlueMinds4Teachers (https://www.emseanet.eu/node/546) is an educational toolkit on the ocean literacy principles for teachers. The project aims to strengthen the competence of teachers and other marine educators of all levels in Ocean Literacy (OL) by providing an online training course with three sessions of approximately 2 hours each.

Within the topic of GES, there are several lessons plans you can access:

- Lesson plan – Principle 1: Let’s discover the ocean floor (pp. 6-10)
- Lesson plan – Principle 2: From the deep sea to the mountains and back: Discover the long trips of the rocks! (pp. 11-17)
- Lesson plan-Principle 4: Secret life of a water droplet (pp. 29-35)
- Lesson plan-Principle 5: Marine food web (pp. 37-42)
- Lesson plan-Principle 7: Explore the ocean with the “Adopt a float” educational program (pp. 57-66)

- **Ocean Wise**

Ocean Wise offers free online courses about different aspects of our ocean to arm students with the tools needed to conserve it. You can learn more about the courses here: https://ocean.org/learn-explore/education/ocean-literacy/.

Below we suggest some of the most relevant courses related to pressures in the marine environment:

- The ocean support biodiversity – https://ocean.org/education/the-ocean-supports-diversity/
- The ocean is diverse – https://ocean.org/education/the-ocean-is-diverse/

OCEAN WISE

6. Module 4 | Tipping Points: Small changes that trigger big shifts

6.1 Introduction to M4

Have you ever leaned back on a chair, balancing just on two legs? At first, it feels stable, you can rock a little without falling. But lean too far, and suddenly you tip over. No matter how quickly you try to correct yourself, getting back up isn't as simple as just leaning the other way.

Marine ecosystems work in a similar way. They can withstand pressures such as fishing, pollution, or habitat disturbance up to a point. But once those pressures push the system beyond a critical limit, it may suddenly shift into a new state – one that is very different from before. These moments are called tipping points, and crossing them makes recovery extremely difficult, sometimes even impossible.

In this module, we will explore how small changes can lead to big shifts. We will look at the mechanisms behind tipping points, how they differ from gradual changes, and why ecosystems are sometimes pushed past the point of no return. You will learn how scientists detect these critical thresholds, why this is often a challenge, and why prevention is far more effective than restoration once a tipping point has been crossed.

By the end of this module, you will understand that tipping points have profound consequences for human societies that depend on a healthy Ocean. Recognising and avoiding these thresholds is essential for sustainable management of our seas.

6.2 Learning Outcomes

By the end of this Module, you should be able to:

- Define what a tipping point is and their implications for marine ecosystems and societies.
- Recognise the mechanisms behind tipping points and the different ways ecosystems can shift.
- Describe how scientists detect tipping points and why it is challenging.
- Explain why preventing tipping points is more effective than trying to reverse them, and what measures can help.

6.3 How to proceed

Complete the **activities** as they appear in each Lesson.

To succeed in this Module, you need to complete the following lessons:

- **Lesson 1:** What are tipping points?
- **Lesson 2:** Types of tipping points – regime shifts and bifurcations
- **Lesson 3:** Detecting tipping points in the real world
- **Lesson 4:** Prevention and management – avoiding the point of no return
- **Lesson 5:** Wrap-up – Living with thresholds

6.4 Lesson 1: What are tipping points?

In this lesson, you will learn what tipping points are and why they matter for marine ecosystems and societies.

By the end of this lesson, you should be able to:

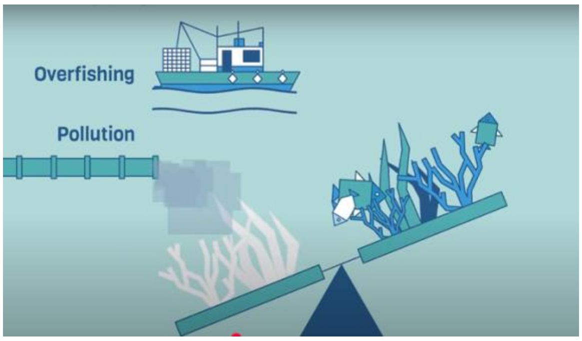
- Explain what a tipping point is in the context of ecosystems.
- Distinguish between gradual ecological change and sudden state shifts.
- Describe the role of resilience in keeping ecosystems stable and what happens when resilience is exceeded.

Read this

Ecosystems are often resilient, meaning they can cope with pressures such as fishing, pollution, or habitat loss and still return to their previous state. This capacity to recover keeps them functioning despite disturbances. But resilience has its limits. When pressures build up and accumulate over time, even a small additional stress can cause the system to shift abruptly into a new state. This moment is called a tipping point.

Unlike gradual changes, tipping points are thresholds. Once crossed, ecosystems may shift into a new state that is very different from the original one, often with reduced biodiversity and altered functioning. Recovering from such a shift can be extremely difficult — and sometimes impossible — because the system reorganises around new conditions.

Think of balancing on a beam. As long as you stay close to the centre, small movements don’t matter — you can correct yourself. But move too far, and a tiny extra step can send you falling off. In the same way, ecosystems can remain stable under small disturbances until that last added pressure causes them to “tip.”

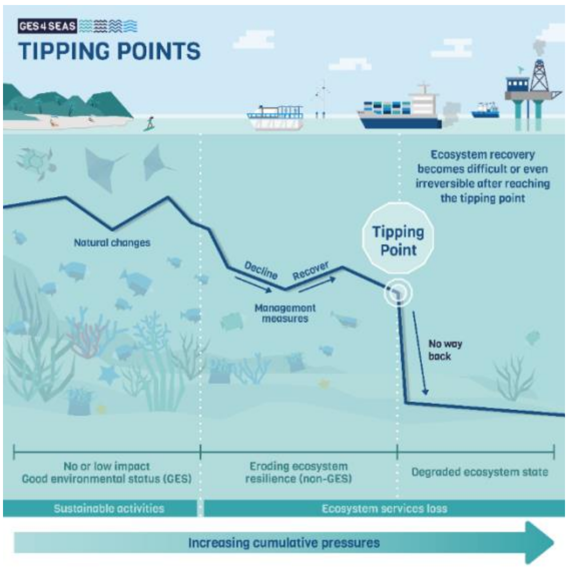


Representation of cumulative pressures shifting the balance of an ecosystem.

To understand tipping points, we first need to grasp how human activities create pressures on marine ecosystems. In a previous module, you learned that we depend on the Ocean, but our activities also affect it. Fishing, pollution, coastal construction, and climate change all add stress to marine systems. Each pressure alone may seem small, but their combined effect can push ecosystems toward instability.

Some pressures act strongly, such as industrial fishing or nutrient pollution, while others, like recreational boating, seem minor but still add to the total impact. When these pressures accumulate, their effects are no longer isolated — they interact, amplifying the strain on marine life.

Imagine how different activities are — from coastal development to maritime traffic and oil drilling — combined to impact the ocean. Together, they can reduce an ecosystem's ability to recover, bringing it closer to the point where a small change can cause a major shift.



How increasing cumulative pressures can push ecosystems beyond a tipping point.

Watch this video

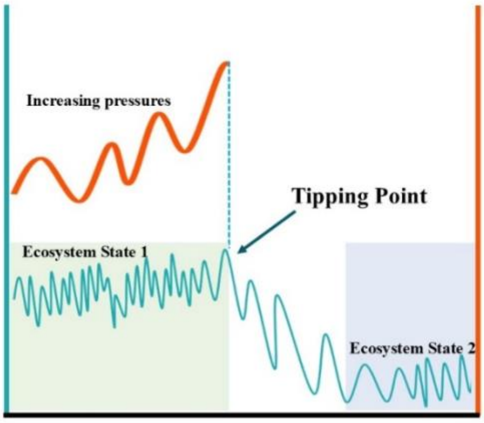
To better understand how these cumulative pressures can lead to tipping points, watch this video: https://www.youtube.com/watch?v=TRarrJGQK20

Read this

The impacts of human activities are not always immediate, they build over time. For example, trawling can reduce fish populations and disturb the seafloor, leading to biodiversity loss. If the pressure stops early enough, the ecosystem can recover; fish populations grow back and habitats regenerate. This ability to recover is what we call resilience.

But there's a limit. When an ecosystem faces too many pressures — from overfishing, pollution, habitat destruction, or climate change — it becomes harder to regain balance. Beyond a certain point, even small disturbances can trigger sudden and lasting change.

At some point, just a tiny bit more pressure is enough to push the system past its tipping point, causing it to shift abruptly and irreversibly. Once resilience is lost, the ecosystem collapses into a new state that can no longer sustain the same biodiversity or functions.



Increasing pressures can cause an ecosystem to lose resilience and cross a tipping point, shifting from one stable state to another.

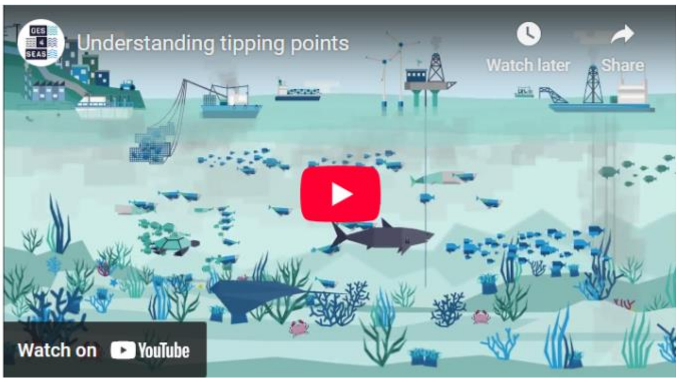
Resilience is the ability of an ecosystem to absorb disturbances and still maintain its basic structure and function. Healthy ecosystems, like diverse coral reefs or seagrass meadows, can recover from short-term stress and continue to provide essential services.

However, ecosystems can only tolerate so much stress before they reach a tipping point. When this happens, the system moves from a resilient state to a collapsed one. In a collapsed state, feedback loops maintain degradation. For instance, algae overgrowth preventing corals from regrowing.

When coral reefs suffer from prolonged bleaching and pollution, they may shift from coral-dominated ecosystems to algae-dominated ones, with reduced biodiversity. This transition from resilience to collapse is one of the defining features of tipping points. Once crossed, the system cannot easily return to what it was.

Watch this video

To better understand the concepts explored on this lesson, watch this video (https://www.youtube.com/watch?v=Y8h0jivDFuA) explaining how human activities like overfishing and pollution can push ecosystems towards tipping points, and why it is so important to avoid crossing these thresholds.



Check your understanding

[Multiple choice questions]

1. What happens when an ecosystem crosses a tipping point?
a) It quickly returns to its original state once pressures are reduced.
b) It shifts to a new state that may be very different and hard to reverse.
c) It experiences only temporary fluctuations in species abundance.
d) It becomes completely unaffected by further pressures.

Correct answer: b

2. Which of the following best describes *ecosystem resilience*?
a) The ability of an ecosystem to absorb disturbances and maintain its structure and function.
b) The capacity of an ecosystem to prevent any change from occurring.
c) The rate at which an ecosystem collapses after a disturbance.
d) The process by which ecosystems become less diverse over time.
Correct answer: a

[True or False]
Minor human pressures, such as small-scale fishing or low levels of pollution, have limited impact on marine ecosystems and cannot lead to major changes.
Correct answer: False [even small pressures can accumulate over time, interacting with others to weaken ecosystem resilience and potentially drive large-scale shifts]

6.5 Lesson 2: Types of tipping points – regime shifts and bifurcations

In this lesson, you will learn about the different types of tipping points and the mechanisms behind them. Specifically, we will explore how ecosystems can shift from one stable state to another, sometimes through sudden, dramatic changes.

By the end of this lesson, you should be able to:

- Explain the difference between phase transitions and regime shifts.
- Identify the three main bifurcations (hysteresis/fold, pitchfork, and transcritical) and how they drive ecosystem shifts.
- Use real-world examples to show how these tipping points unfold in nature.

Read this

Imagine an ecosystem as a tightrope walker, balancing delicately. As pressure builds — from overfishing, pollution, or habitat destruction — the ecosystem can hold steady, adjusting and maintaining balance. But once it reaches a tipping point, a sudden shift happens. The ecosystem falls, shifting from one stable state to another, often with drastically different biodiversity and functionality.

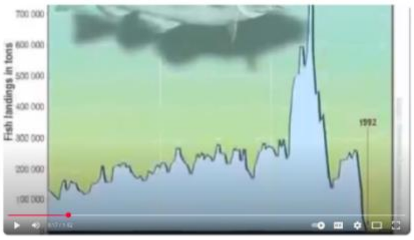
This shift can happen in two main ways: a phase transition or a regime shift.

- **A phase transition** happens when an ecosystem smoothly moves from one state to another. Think of it like changing lanes on a road, a gradual but noticeable change.
- **A regime shift**, on the other hand, is like slamming on the brakes. A sharp, sudden change that is often irreversible. For example, coral reefs can shift from a coral-dominated state to an algae-dominated state, and once the shift occurs, it's very difficult to go back.

Watch this video

Learn more about regime shifts in the following video:

https://www.youtube.com/watch?v=Cf0oQaEd7NM



Regime shifts occur when ecosystems undergo sudden and often irreversible changes in their structure and functioning. Such shifts are usually triggered by a combination of external shocks, like storms or fires, and long-term pressures that gradually weaken the system's stability. Once a regime shift happens, the ecosystem settles into a new state that is difficult to reverse.

Read this

But what makes tipping points so unpredictable? The answer lies in bifurcations.

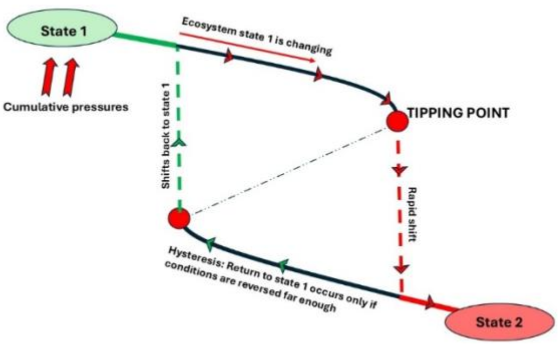
A bifurcation is a point where the ecosystem can split into different stable states, much like a fork in the road. The ecosystem could settle into one state or another, depending on how the pressures are applied.

Let's explore three key types of bifurcations that help explain how tipping points happen:

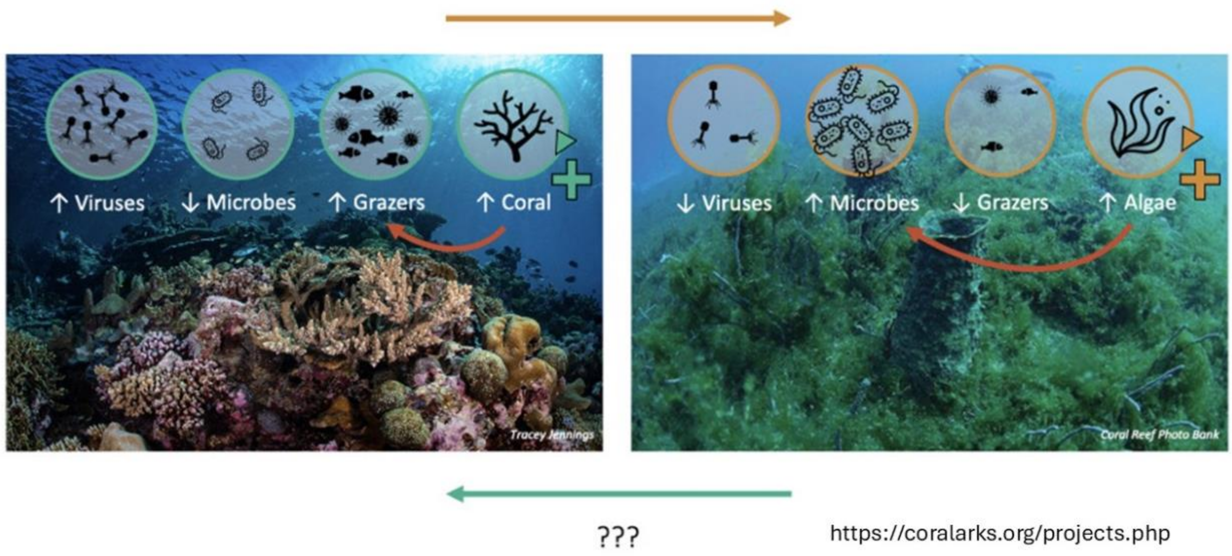
1. Hysteresis/Fold bifurcation: the point of no return

Imagine a rubber band stretched so far that it won't return to its original shape, no matter how hard you try. That's a hysteresis shift.

When pressures push an ecosystem past a tipping point, it may shift suddenly. But getting back to the original state requires much more than just reducing those pressures.



For example, when pollution increases nutrient levels, algae can grow much faster than corals. This disrupts the natural balance of the reef: microbes and viruses increase, while the fish and invertebrates that normally graze on algae decline. As a result, the ecosystem shifts from a coral-dominated state to an algae-dominated one. Even if pollution later decreases, the new state tends to persist because the conditions and interactions within the ecosystem have changed. Restoring corals then requires much more than simply cleaning the water.

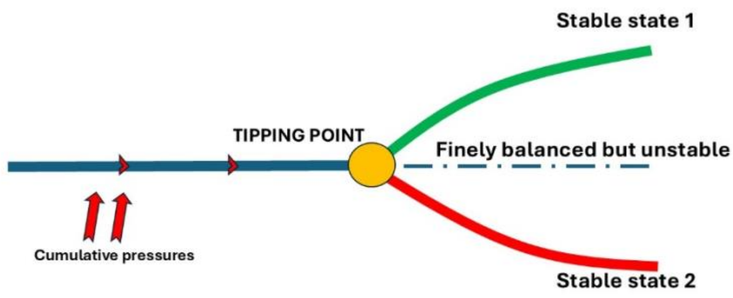


From corals to algae – a tipping point that makes the ecosystem unrecognisable.

This example shows how a tipping point can fundamentally alter an ecosystem. Pollution increases nutrients and triggers a chain reaction: microbial activity rises, while the number of grazers that normally keep algae under control decreases, and corals lose their ability to compete. These shifts create a self-reinforcing loop that locks the reef into an algae-dominated state. Even when pollution is reduced, the altered balance between microbes, grazers, and primary producers prevents corals from re-establishing — showing how deeply a tipping point can transform an ecosystem.

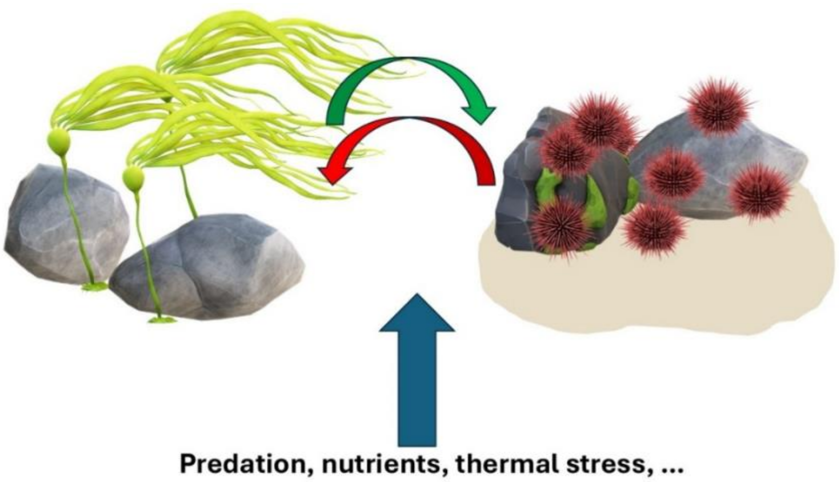
2. Pitchfork bifurcation: the crossroads of change

Think of the ecosystem as a road that splits into two paths. The system is at a crossroads, where it could shift one way or another depending on small changes in the environment. This is a pitchfork bifurcation.



An ecosystem can follow different paths once it reaches a tipping point.

For example, a kelp forest can either stay stable, or it could be dominated by urchins, depending on changes in stressors like predation. If urchin populations grow too large, they may overgraze the kelp, creating a barren ecosystem. Alternatively, if predators keep the urchin population in check, the kelp remains dominant. A small shift in pressure can tip the system in either direction.



Predation, nutrient enrichment, and warming waters, cause a shift from a healthy kelp forest to an urchin-dominated barren state. The ecosystem reaches a tipping point.

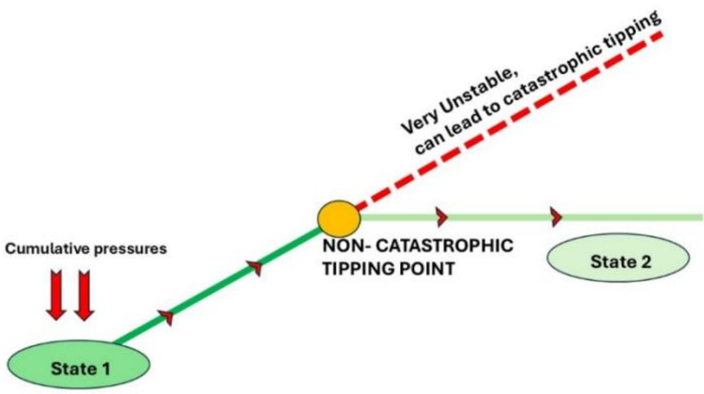
Watch this video

Learn more about the delicate equilibrium between kelp and sea urchins in the following video: https://www.youtube.com/watch?v=PSBCFCMTk8I

This example shows how several pressures can combine to push an ecosystem past its tipping point. Warmer waters, the loss of sea star predators, and an explosion of purple sea urchins have devastated kelp forests along the California and Oregon coasts. What was once a complex, life-rich ecosystem has shifted to an almost barren state. The story also highlights the potential of local action — from divers and scientists to Indigenous communities — working together to find solutions. Turning urchins into a resource and restoring kelp through nature-based methods are examples of how people can help guide ecosystems back toward balance.

3. Transcritical bifurcation: the smooth transition

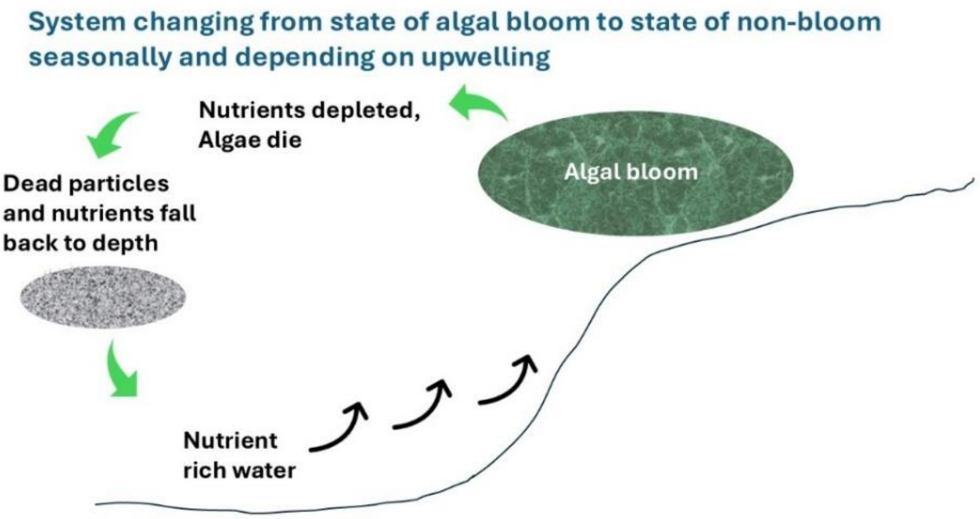
Not all tipping points are dramatic. Some ecosystems transition smoothly into a new stable state — this is a transcritical bifurcation.



Transcritical bifurcation, when the ecosystem responds gradually to increasing pressures.

As shown in the figure, the system passes a non-catastrophic tipping point where change begins smoothly and remains reversible for a time. If pressures are reduced, the ecosystem can return to its original state. But if pressures persist, the system becomes increasingly unstable and may eventually tip into a new state. Although this transition appears continuous, it can still lead to significant and lasting changes in ecosystem structure and function.

A good example of this is algal blooms that happen during upwelling events, when nutrient-rich water from the deep ocean rises. The bloom is stable for a while, but when the nutrients are depleted, the system can return to its original state. It’s not catastrophic — just a temporary shift that eventually self-corrects.



Reversible transition in marine ecosystems, where nutrient-rich waters rising from the deep ocean trigger an algal bloom.

This process is a natural example of a reversible transition. When nutrient-rich waters rise from the deep ocean, they fuel rapid algal growth near the surface. As the algae consume these nutrients, the water gradually becomes depleted, and the bloom collapses. The dead algal material then sinks, carrying nutrients back to deeper layers where they accumulate until the next upwelling event. This continuous cycle shows how ecosystems can experience temporary shifts driven by environmental conditions yet return to their original state once those conditions stabilise — a typical feature of non-catastrophic tipping points.

Check your understanding

[Multiple choice questions]

1. What distinguishes a regime shift from a phase transition?

a) A regime shift is gradual, while a phase transition is sudden and reversible.

b) A regime shift is a sudden, often irreversible change, while a phase transition occurs smoothly and can be reversed.
c) A phase transition always results in loss of biodiversity, while a regime shift does not.
d) Both describe the same process but in different ecosystems.
Correct answer: b

2. In a hysteresis (fold) bifurcation, what happens when pressures are reduced after a tipping point has been crossed?
a) The ecosystem immediately returns to its original state.
b) The system stabilizes in a temporary state before recovering.
c) A much greater reduction in pressures is required for recovery, and it may not fully return to the original state.
d) The system alternates continuously between states.
Correct answer: c

[True or False]
In a transcritical bifurcation, ecosystems change gradually and can return to their original state if pressures are reduced in time.
Correct answer: True

6.6 Lesson 3: Detecting tipping points in the real world

In this lesson, you will learn how scientists detect tipping points in marine ecosystems, and why this is often challenging due to multiple interacting pressures.

By the end of this lesson, you should be able to:

- Identify the monitoring indicators used to detect tipping points in ecosystems.
- Explain why detecting tipping points is challenging when multiple pressures act together.
- Describe how scientists use case studies to help detect and understand tipping points.

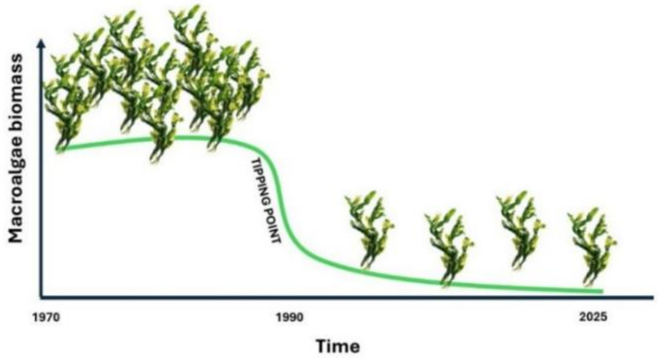
Read this

Detecting tipping points is crucial, but it is not always straightforward. Scientists use different monitoring indicators to track changes in ecosystems that could signal an impending tipping point. These indicators help us understand when an ecosystem is moving toward a critical threshold.

1. Detection along timelines

One of the most basic methods for detecting tipping points is observing how ecosystems change over time. By monitoring long-term trends, scientists can spot gradual declines or sudden changes that signal a loss of stability.

For example, if the biomass of macroalgae in a region drops sharply from one year to the next and remains low, it may indicate that the ecosystem has crossed a tipping point. Such a persistent change suggests a shift from a healthy, algae-rich system to a degraded state where biomass remains low and recovery becomes difficult even if conditions improve



Temporal shift in ecosystem state, showing how macroalgae biomass declines over time past the tipping-point.

2. Detection with increasing pressure

Ecosystems can withstand a degree of pressure, such as pollution or fishing, but when these pressures accumulate, they begin to erode the system's resilience. Monitoring how these pressures change over time helps scientists identify when an ecosystem is approaching its limits.

For example, increasing fishing pressure can gradually deplete fish populations. Once a critical threshold is crossed, the system may shift abruptly, the ecosystem can no longer support the same biomass, and recovery becomes slow or even impossible without significant intervention.

Tipping point driven by increasing fishing pressure.

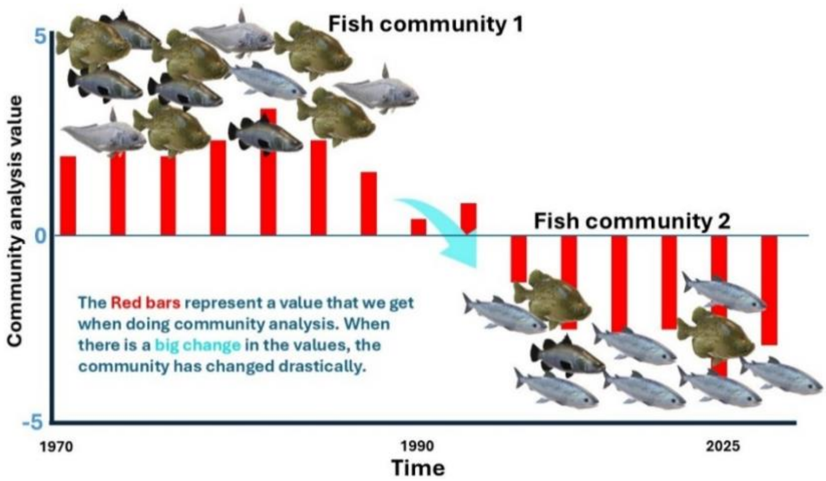
3. Graphs and statistics to track changes

Graphs and statistical models are key tools for detecting tipping points. They help scientists visualise how ecosystems change over time and identify patterns that may reveal when a system is losing stability. As pressures and species interactions become more complex, interpreting these trends requires increasingly advanced approaches.

For example, tracking species populations can reveal early warning signs of instability. A steady decline in one species might suggest that the ecosystem is nearing a tipping point. But when several species and pressures interact, the signals become harder to isolate, demanding more detailed and sophisticated analysis to understand when — and how — the shift might occur.

4. Community-level statistics

In ecosystems where many species interact, changes rarely happen in isolation. Scientists use community-level statistics to understand how shifts in one species can influence others. A change in the composition of species. For example, some declining while others increase can be an early warning sign that the ecosystem is losing balance and approaching a tipping point.



Community level analysis following several species of fish simultaneously.

This type of analysis helps reveal patterns that might not be visible when looking at species individually. In this example, the red bars show how the composition of a fish community changes over time. A sudden shift in the values indicates that one community has been replaced by another, meaning the ecosystem has reorganised into a new state. By tracking the interactions between species, scientists can detect when the system is changing, helping to predict when it might reach a tipping point.

When multiple pressures act together, things get even more complicated

When multiple pressures act on many species at once, detecting tipping points becomes far more challenging. In these situations, scientists use advanced statistical analyses and multivariate models to understand how different pressures interact and when tipping points are likely to occur.

Let's take a closer look at a real-world example to understand how multiple pressures can interact and lead to tipping points:

The Baltic Sea

Over the years, this ecosystem has been exposed to many pressures, leading to significant challenges and changes.

Map of the Baltic sea region

Source: [Gabriel Ziegler](), Wikipedia.

In the Baltic Sea, overfishing and nutrient pollution from agricultural runoff have caused drastic shifts in the ecosystem. These pressures act together, making it difficult to pinpoint exactly when the tipping point occurs. But understanding these changes is crucial for managing the health of the sea and preventing further damage.

Watch this video

To learn more about the issue of hypoxia in the Baltic Sea, watch this video (https://www.youtube.com/watch?v=P6qpvoi4HmA) highlighting the key findings of a study which examined a 1500-year record of coastal hypoxia in the northern Baltic Sea and reveals the severe deoxygenation that has occurred over the 20th century.

Further reading: https://www.egu.eu/news/414/new-study-oxygen-loss-in-the-coastal-baltic-sea-is-unprecedentedly-severe/

Check your understanding

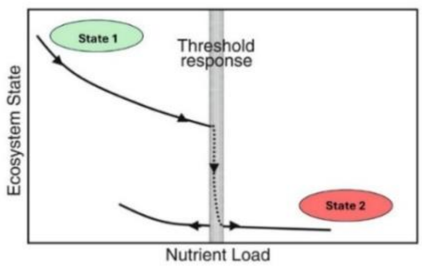
[Multiple choice questions]

1. How does a Regime shift differ from a Phase transition?
   a) They are the same
   b) Regime shifts are sudden and sharp
   c) Phase transition are often smooth changes
   d) Both two and three

Correct answer: d

2. What is the peculiarity of this type of shift?
   a) Generally, it is easy to change from one state to another.
   b) Changing from one state to another requires reduction of nutrients
   c) Reducing the nutrients to the threshold will change the system back to state 1

Correct answer: b



3. How easy is it to detect tipping points?

a) Always easy
b) Often it can be very complex.
c) We cannot detect them

Correct answer: b

4. What happens if hypoxia persists?

a) Biological and chemical processes change drastically.
b) Many organisms disappear
c) A tipping point can be reached where the ecosystem changes severely
d) All three above

Correct answer: d

6.7 Lesson 4: Prevention and management – avoiding the point of no return

In this lesson, you will learn why preventing tipping points is far more effective than trying to reverse damage once they have been crossed, and what strategies can help mitigate or avoid these irreversible shifts.

By the end of this lesson, you should be able to:

- Explain why restoration becomes more difficult after tipping points are passed.
- Identify key tools and strategies for ecosystem management, including protection, restoration, and adaptive management.
- Recognize the role of policy measures such as Natura 2000 and the Nature Restoration Law.
- Describe the role of ecosystem-based management (EBM) in preventing tipping points.

Read this

Once an ecosystem has crossed a tipping point, it becomes extremely difficult to return it to its original state. While some recovery may be possible, it often requires significant effort and time. Even then, the ecosystem may not return to the healthy state it once was in.

Restoration becomes particularly challenging once a tipping point has been crossed. For example, after ecosystems like coral reefs or kelp forests are pushed past their tipping points, it can take decades or longer to restore them to their previous state. And in some cases, they may never fully recover.

While restoration is crucial, prevention of tipping points is always the best option. The goal is to prevent ecosystems from reaching their tipping points in the first place, before the damage becomes irreversible.

Protection and restoration: Two key approaches

To prevent ecosystems from reaching tipping points, there are two main approaches: protection and restoration. Both have their strengths and limitations.

Protection

Marine Protected Areas (MPAs) are one of the main tools used to protect ecosystems. These areas are designated as no-take zones, where human activities like fishing, mining, or development are restricted to allow the ecosystem to thrive without disturbance. MPAs provide safe havens for marine species, giving ecosystems the space to function normally.

Watch this video

Learn more about MPAs on this animated video: https://www.youtube.com/watch?v=1czxb4u9eUo

MPAs are not only about conservation, they are also about balance. As shown in the video, these areas bring together scientists, fishers, policymakers, and other stakeholders to decide which regions should be protected and how. When well-managed, MPAs allow marine life to recover, habitats to regenerate, and the benefits to extend beyond their borders, supporting local fisheries and coastal communities. They also contribute to climate action by helping the ocean store more carbon and maintain its resilience.

Challenge: While MPAs are essential for protecting specific areas, it is not always feasible to protect every part of the ecosystem. There are limits to how many areas can be designated for protection, especially in regions with high human impact or competing needs, like shipping lanes or tourism.

Restoration

Restoration involves actively rebuilding ecosystems that have been degraded by human activities. This can include activities like replanting seagrass, restoring coral reefs, or reintroducing species that have been lost. Although restoration can help ecosystems recover, it often takes long periods of time to achieve meaningful results. Even with significant investment, some ecosystems may not fully return to their original state.

Watch this video

Learn more about restoration of seagrass meadows on this video: https://www.youtube.com/watch?v=i41xIHpp00I

Seagrass meadows are being restored in many parts of the world because they are among the most threatened marine habitats. Coastal development, pollution, and rising ocean temperatures have caused large-scale declines in these vital ecosystems. Restoration projects like the one shown in the video focus on re-establishing lost meadows without further harming existing ones. By collecting and cultivating naturally detached seedlings, scientists can grow new plants that are later reintroduced into damaged areas. As these meadows recover, they once again provide food and shelter for marine life, store carbon, and help stabilise coastal environments.

Challenge: Restoration is a slow process, and it requires massive resources, long-term commitment, and careful monitoring. Even when ecosystems are restored, the original biodiversity or ecosystem functions might not be fully regained.

Check your understanding

In this exercise, you will take the role of a decision-maker responsible for managing an estuary under pressure. The future of this ecosystem depends on the choices you make.

Read the scenario carefully and consider the environmental, social, and economic factors involved. Then, decide which actions you think would lead to the most sustainable outcome.

Hint: There is no easy solution — every choice comes with trade-offs. Your decisions could determine whether the estuary recovers or continues to decline.

Today, you are the leader responsible for managing an estuary under pressure. Your choices could determine whether the ecosystem recovers or continues to decline.

Read the scenario carefully and consider the environmental, social, and economic factors involved before deciding on the best way forward.

Let's suppose we have an estuary — an area where a river meets the sea. The estuary contains seagrass meadows, oyster reefs, and mangrove habitats. These habitats are vital for biodiversity and also support fisheries by producing large numbers of fish and crustaceans. In addition, the estuary plays an important role in cargo shipping.

Over the last ten years, fish and crustacean populations have declined sharply. The government asks scientists why this has happened.

Their analyses suggest that:

1. The system has become polluted by agricultural nutrients and other pollutants entering from the river.
2. The ecosystem has crossed a tipping point.
3. The estuary's condition will continue to worsen in the future if no action is taken.

The government now faces a difficult task: to restore the estuary's health — bringing back fish, crustaceans, and healthy habitats — while ensuring that shipping, fisheries, and agriculture can continue to operate without causing an economic collapse.

In your opinion, what should they do?
Answer: There is no single correct answer to this scenario. Different solutions may apply depending on local conditions, priorities, and environmental regulations. However, once an ecosystem has crossed a tipping point, recovery becomes extremely complex and uncertain.
Key takeaway: *It is always better to prevent ecosystems from reaching tipping points in the first place.*

6.8 Lesson 5: Wrap up – living with thresholds

In this lesson, you will learn how societies can adapt to a world where ecological thresholds exist, and why understanding and respecting these limits is key to protecting marine ecosystems.

By the end of this lesson, you should be able to:

- Summarise the main concepts of tipping points and ecosystem resilience.
- Recognise that thresholds are a natural part of complex ecosystems.
- Explain why adaptive management and flexibility are essential to long-term sustainability.
- Reflect on the role of science, policy, and citizens in living within environmental limits.

Read this

Throughout this module, we have explored how cumulative pressures can push ecosystems beyond their limits, triggering tipping points that lead to new, often degraded, states. We've seen that once a tipping point is crossed, recovery can be extremely difficult. This is why early detection, prevention, and adaptive management are essential.

But what happens when thresholds cannot be avoided?

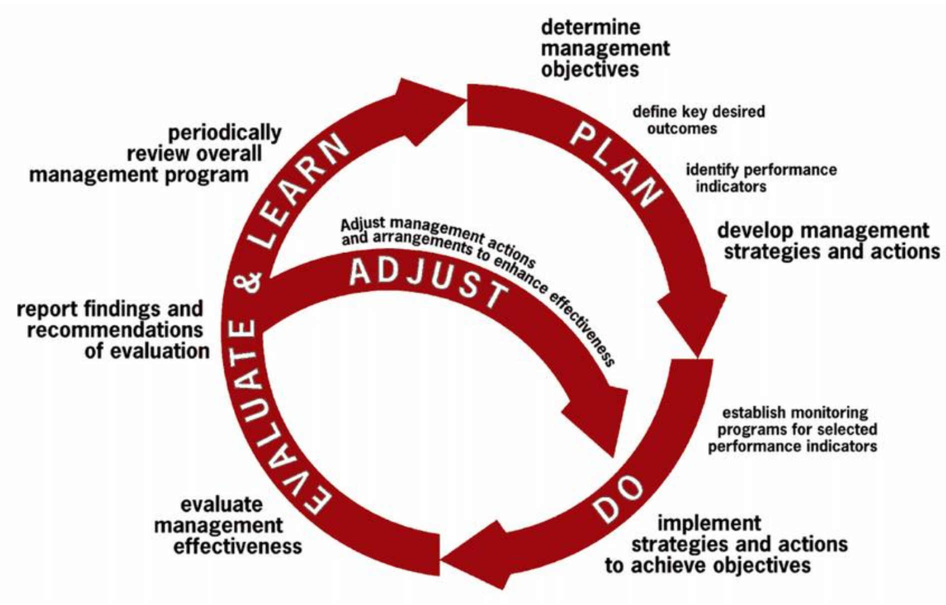
Ecosystems are dynamic — they change, adapt, and reorganise. Some shifts are natural, while others are driven by human pressures. Learning to live with thresholds means recognising that change is part of the system and that our management approaches must be flexible enough to respond.

Instead of focusing solely on preventing change, we must also focus on building resilience — creating conditions that allow ecosystems to recover, reorganise, and continue providing essential services even after disturbances occur.

Adaptive management offers a way forward. It is a learning-based approach that treats management actions as experiments — monitoring outcomes, learning from results, and adjusting decisions as new information becomes available.

For example, fisheries management can use adaptive measures to respond to shifting fish stocks under climate change. If a species declines in one area but increases in another, management strategies can be revised to prevent overexploitation while maintaining livelihoods.

The same principle applies to coastal management, pollution control, and restoration. By embracing uncertainty and planning for flexibility, we can make our responses more robust in the face of change.



The adaptative management circle. Source: Jones, G. (2005). Is the management plan achieving its objectives? in Worboys, G. Lockwood, M. and De Lacy, T. Protected Area Management. Principles and Practice. Oxford University Press.

Living with thresholds also requires cooperation between science, policy, and society. Scientists provide data and tools to identify risks; policymakers create frameworks to act on this knowledge; and citizens contribute through education, sustainable consumption, and public engagement.

The concept of tipping points reminds us that every action counts. Reducing pressures, restoring ecosystems, and improving our understanding of natural limits all contribute to keeping ecosystems within safe boundaries.

Ultimately, avoiding collapse is not just a scientific challenge — it is a societal one.

Listening

Listen to this episode of the *World Ocean Radio* podcast (https://www.youtube.com/watch?v=Y_jlWDvTd8E) As you listen, think about how the speaker describes "resilience" in marine ecosystems. How does this connect to what you have learned about tipping points and the loss of ecosystem stability?

This podcast highlights how ecological thresholds are deeply connected to social and economic resilience. When marine ecosystems lose their capacity to recover, the consequences extend to communities, industries, and economies that depend on them — reinforcing the need for prevention, adaptation, and sustainable management.

Check your understanding

Think about a marine or coastal ecosystem you know — perhaps one near your community or country.

- What types of pressures might be pushing it toward a tipping point?
- Are there management strategies or community actions that could help reduce those pressures?
- How could you, as a teacher, student, or citizen, contribute to building awareness or resilience?

6.9 Final considerations

Throughout this module, you have learned that tipping points represent critical thresholds beyond which ecosystems can change rapidly and sometimes, irreversibly. These shifts are often driven by the accumulation of multiple pressures — from pollution and overfishing to habitat loss and climate change — that together push ecosystems beyond their limits.

We explored how different types of tipping points, from sudden regime shifts to gradual transitions, can transform marine ecosystems. You saw that these changes are not always dramatic at first, but once the tipping point is crossed, the system's structure and functioning can become entirely different. Detecting early warning signs and understanding the mechanisms behind these shifts are key steps in anticipating and preventing them.

You also learned that protection, restoration, and policy measures all play a vital role in maintaining ecosystem health. Tools such as Marine Protected Areas, the MSFD, and the Nature Restoration Regulation to detect, prevent and manage tipping points.

Indeed, while protection and restoration are crucial strategies, prevention is always the best option. Once a tipping point has been crossed, the ecosystem may not be able to recover. It is therefore essential to focus on maintaining ecosystem health before it's too late.

Finally, you learned that not all changes can be prevented — and that managing marine ecosystems also means learning to live with natural variability and uncertainty. Adaptive management and resilience-building allow societies to respond to change, recover from shocks, and make decisions that remain effective in a dynamic world. By embracing flexibility, collaboration, and continuous learning, we can ensure that management practices evolve alongside ecosystems themselves.

In the end, avoiding tipping points is not just about saving ecosystems — it is about securing the future of the ocean services that support our societies, economies, and well-being. Understanding where these thresholds lie, and acting before we reach them, is one of the most effective ways to protect our seas for generations to come.

6.10 Additional resources – relevant lesson plans and activities

If you want to learn more about tipping points, here are some additional resources and lesson plans.

- ### MED EDUC Educational Resources

The MED EDUC project proposes the creation of a series of European level educational resources for middle and high schools. These resources concern the discovery and valorisation of the coastal and marine environment in the Mediterranean. The project is mainly aimed at students, teachers and educators, offering them both educational tools focused on specific issues of environmental protection in the Mediterranean Sea (pollution and waste, mass tourism, overfishing, loss of biodiversity, coastal erosion, etc.).

Here are some relevant lesson plans in the context of tipping points and the lessons included on this module in the marine environment.

- Melting ice and rising sea level: https://mededuc.eu/en/resource-center/pedagogical-guide/30-climate-change/79-melting-ice-and-rising-sea-level.html
- Exploring marine food webs: https://mededuc.eu/en/resource-center/pedagogical-guide/12-biodiversity/73-exploring-marine-food-webs-in-mediterranean.html
- Explore a marine protected area: https://mededuc.eu/en/resource-center/pedagogical-guide/12-biodiversity/15-explore-a-marine-protected-area.html
- Politics and government in our daily life: https://mededuc.eu/en/resource-center/pedagogical-guide/28-politics-and-governance/61-politics-and-government-in-our-daily-life.html

- ### The European Space Agency (ESA)

The European Space Agency (ESA) provides a range of educational resources designed to help understand the science behind climate change and its impacts on the planet. These materials help learners connect real satellite observations with the mechanisms driving climate change, encouraging curiosity and a deeper understanding of how small changes can lead to large, lasting shifts in the global environment.

Here are some relevant resources to introduce students to the concept of tipping points in the Earth system:

Understanding Climate Tipping Points – https://www.esa.int/Applications/Observing_the_Earth/Space_for_our_climate/Understanding_climate_tipping_points

- **Ocean Literacy for all: a toolkit. IOC Manuals and Guides**

This toolkit

(https://unesdoc.unesco.org/in/documentViewer.xhtml?v=2.1.196&id=p::usmarcdef_0000260721&file=/in/rest/annotationSVC/DownloadWatermarkedAttachment/attach_import_2d3dfb02-da9b-410a-9386-dd31047e6ef0%3F_%3D260721eng.pdf&locale=en&multi=true&ark=/ark:/48223/) provides educators and learners worldwide the innovative tools, methods, and resources to understand the complex ocean processes and functions and, as well, to alert them on the most urgent ocean issues. It also presents the essential scientific principles and information needed to understand the cause-effect relationship between individual and collective behaviour and the impacts that threaten ocean health.

Some particularly relevant sections within the topic of marine pressures are:

- The ocean supports a great diversity of life and ecosystems (pp. 46-48)
- The role of international legislation to protect the high seas (pp. 99-100)
- How does ocean acidification occur? (pp. 108-110)

- **Activity on modelling marine stressors and tipping points**

The marine ecosystem stressor game (https://www.sciencelearn.org.nz/resources/2582-modelling-marine-stressors-and-tipping-points) uses wooden blocks that represent marine stressors and as as stressors build up, the marine ecosystem reaches a tipping point.

- **Blue Schools Projects regarding GES**

The concept of a European Blue School evolved from the marine education expertise gathered from consultations with teachers and educators across Europe. It acknowledges the variety of cultures and school communities from the 27 EU Member States and champions the concept of open schooling. The Handbook for Teachers "A Wave of European Blue Schools" (https://maritime-forum.ec.europa.eu/document/download/0e460a07-428c-4b0d-a4b4-2d82b999b6ee_en?filename=Handbook%20for%20Teachers%20-%20European%20Blue%20Schools_0.pdf) includes a wealth of useful resources and best practice to inspire you to find what connects you and your school to the ocean. It has built in flexibility to encourage and support teachers across all disciplines to bring the ocean to their classrooms, whether through biology, physics, chemistry, technology, mathematics, history, literature, or the arts.

You can find some inspiring projects related to GES on:

- *STEM4Sea Can you build a dike with recycled materials to protect the coast from flooding?* · p. 59 Kids Save Ocean Giving students a voice to change environmental policy · p 69
- *Bonus MICROPOLL Assessing pollution in the Baltic Sea coast together with scientists* · p. 71
- *Aire marine éducative de Port-Vendres: Children manage a marine area* · p. 76
- *Biodiesel from algae Too many algae on the beach? Students find a solution* · p. 77
- *Nya arter Studying marine invasive species together with scientists* · p. 84
- *Marine Wildlife Champions Discovering how our actions can have an impact on the seas and ocean* · p. 85

7. Module 5 | Ecosystem-Based Management: Managing the Whole or the Hole

7.1 Introduction to M5

Imagine trying to fix a car engine by adjusting just one component at a time. You might improve one part but unknowingly cause problems elsewhere, because you did not consider how the rest of the engine works. Managing the ocean often happens in a similar way. Fisheries, shipping, energy, tourism, and conservation are frequently addressed separately, even though they all interact within the same shared space. A similar pattern appears when we look at species, they are often managed independently, through separate management programmes, even when it is clear that organisms do not understand of borders and the high complexity of linkages in the ocean food web.

Marine ecosystems are not made up of isolated parts. They are interconnected systems where species, habitats, and human activities influence one another. Actions taken in one place can have effects that spread across the system, sometimes in unexpected ways. Managing these systems effectively requires looking beyond individual activities, pressures and/or ecosystem components and understanding how the whole system functions together.

In this module, you will explore Ecosystem-Based Management (EBM) — an approach designed to address this challenge. You will learn what EBM is, why it is needed, and how it differs from traditional sector-by-sector, single-pressure or species-by-species management. You will also explore how competing uses of the marine environment are managed, how decisions involve trade-offs, and how EBM is applied in real policy and management contexts.

By the end of this module, you will understand why seeing the big picture (the whole) is essential for protecting marine ecosystems while supporting the human activities that depend on them.

7.2 Learning Outcomes

By the end of this module, you should be able to:

- Explain what Ecosystem-Based Management (EBM) is and why it is needed for marine management.
- Distinguish EBM from traditional sector-by-sector, single-pressure, or single-species management approaches.
- Recognise how multiple human activities interact and create trade-offs within marine ecosystems.

- Describe Ecosystem-Based Management as a cyclical and adaptive management process supported by policy.
- Explain the key principle that EBM focuses on managing human activities, not ecosystems themselves.

7.3 How to proceed

Complete the **activities** as they appear in each Lesson.

To successfully complete this Module, you should work through the following Lessons in order:

- **Lesson 1:** What is Ecosystem-Based Management?
- **Lesson 2:** Why Ecosystem-Based Management is needed
- **Lesson 3:** Is EBM just a concept? Policy and governance context
- **Lesson 4:** EBM across sectors: managing trade-offs
- **Lesson 5:** Ecosystem-Based Management as a cyclical and adaptive process
- **Lesson 6:** Tools for Ecosystem-Based Management
- **Lesson 7:** What can Ecosystem-Based Management really manage?

7.4 Lesson 1: What is Ecosystem-Based Management?

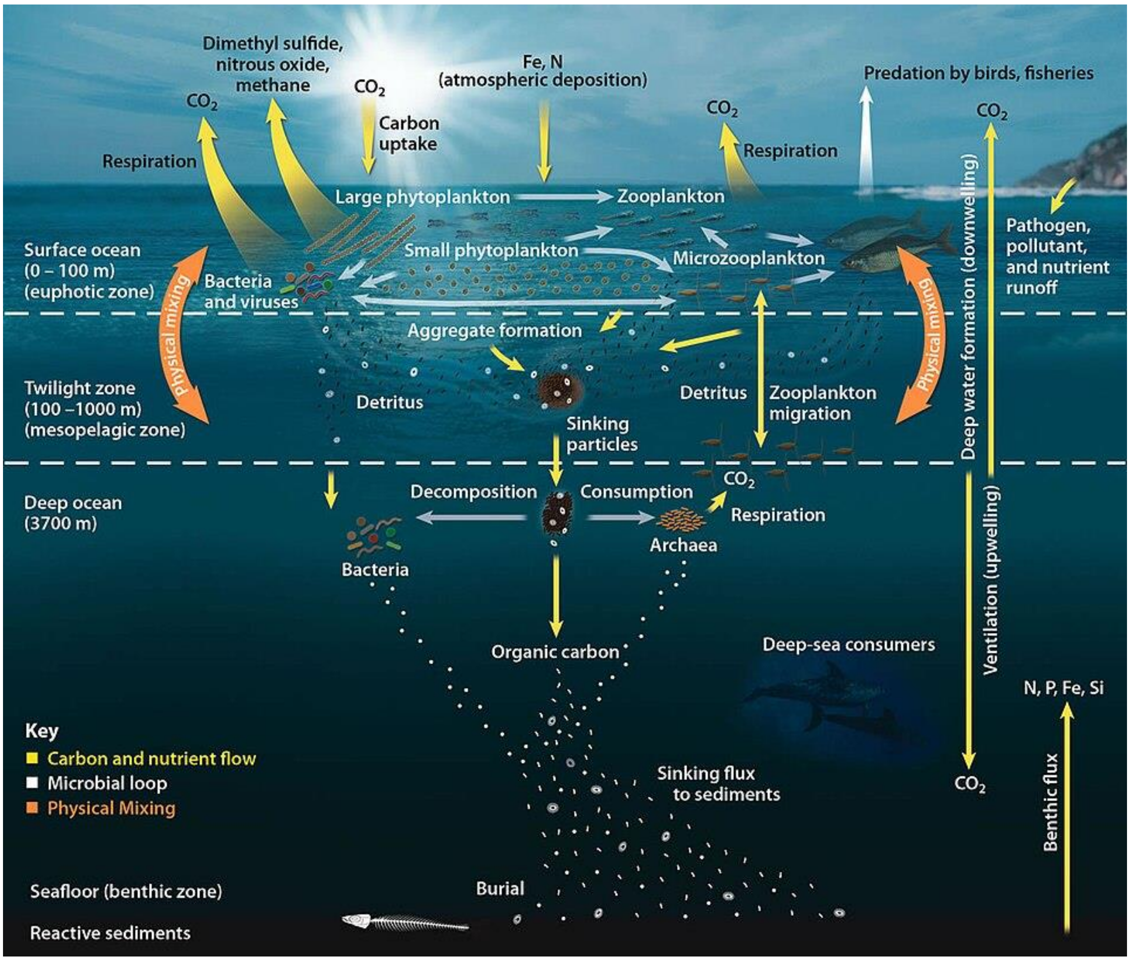
In this lesson, you will learn what Ecosystem-Based Management (EBM) is and how it differs from traditional approaches to marine management.

By the end of this lesson, you should be able to:

- Explain what Ecosystem-Based Management is in the context of marine ecosystems.
- Describe how EBM differs from traditional sector-by-sector, single-pressures and/or single-species management approaches.
- Recognise the importance of considering ecological, social, and human dimensions together when managing marine environments.

Read this

The ocean is a vast, interconnected web. Every part of that web is linked, from microscopic plankton to large predators, from coastal habitats to offshore waters, and from natural processes to human activities. When one part of the web is disturbed, the effects can spread in a cascade mode through the web, and far beyond the original point of impact.

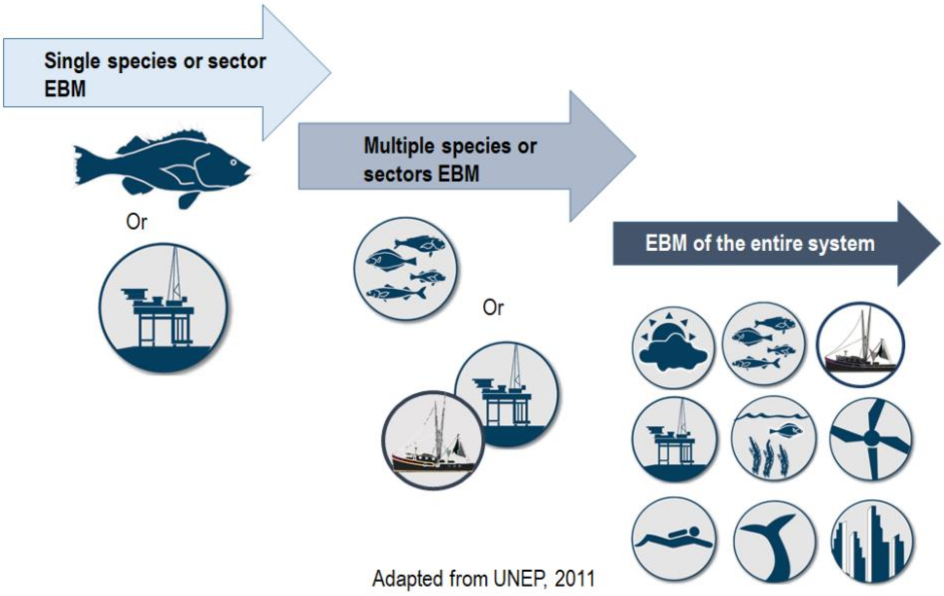


Marine ecosystems are deeply interconnected. Alterations in biological, chemical, and or physical processes in one area can cascade through food web and affect distant parts of the ocean | © U.S. Department of Energy.

For a long time, marine management has focused on individual parts of the system. Fisheries are managed separately from shipping, conservation is treated independently from energy production, and pollution is often addressed without considering its interaction with other pressures. Similarly, species, have also been managed independently, having specific single-species management programs for some of the commercially exploited or protected species. While these sector-by-sector approaches or focusing the management on single-species can be effective in specific cases, they often fail to capture how ecosystems function, requiring more holistic approaches that consider species and human interactions.

Ecosystem-Based Management (EBM) starts from a different premise. Instead of managing one species, pressure, or activity at a time, EBM looks at the ecosystem, including humans as part of that system. Its goal is to maintain healthy, resilient and functioning ecosystems while allowing sustainable human use of marine resources.

Without an ecosystem-based perspective, management can suffer from “tunnel vision”. Actions taken to solve one problem may unintentionally create new ones elsewhere. For example, protecting a single fish species without considering its habitat, food sources, or fishing methods can shift pressure onto other species or ecosystem components and cause economic impacts in the fishing sector.



Continuum of Ecosystem-Based Management

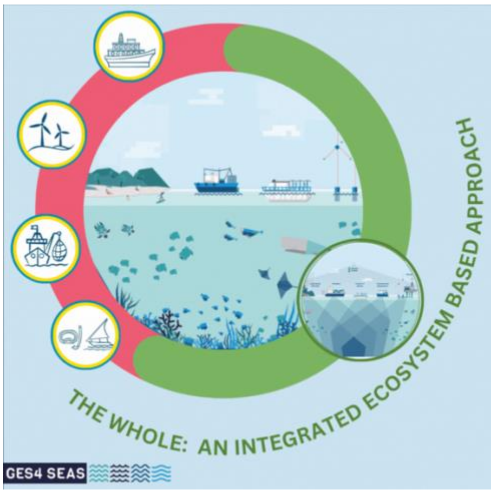
Source: https://www.integratedecosystemassessment.noaa.gov/about-iea/ecosystem-based-management.

A key principle of EBM is recognising that people are not separate from the ecosystem. Human well-being, maritime economies, and marine ecosystems are tightly linked. The fish we eat, the coasts we enjoy, and the waters we use for transport and energy all depend on functioning ecosystems.

Fishing nets in the beach.

EBM therefore explicitly includes social, economic, and cultural dimensions alongside ecological ones. Good management is not only about protecting nature, but about finding balanced solutions that support both ecosystem health and human needs.

To understand EBM, it is useful to think again of the ecosystem as a web. Human activities pull on different strands of that web. Some pressures stretch it slightly; others weaken it more severely. If too many strands are pulled at once, or pulled too hard, the structure of the web can fail. EBM is a 'big picture' approach that respects all these links to make wiser decisions.



'Managing the whole' so as not to leave a dangerous 'hole' in marine management.

Watch this video

To better understand the idea behind EBM and why it is needed, watch this short video explaining why EBM offers a smarter way forward:

https://www.youtube.com/watch?v=EsS3YvEWHEg

Check your understanding

[Multiple choice]

1. What is the main focus of Ecosystem-Based Management?
a) Managing individual species independently
b) Managing single human activities one at a time
c) Managing the ecosystem as a whole, including human activities
d) Preventing all human use of the ocean

Correct answer: c)

[True or False]

Ecosystem-Based Management recognises humans as part of the marine ecosystem.

Correct answer: True

7.5 Lesson 2: Why Ecosystem-Based Management is needed

In this lesson, you will learn why traditional approaches to marine management are often insufficient, and why Ecosystem-Based Management is necessary to address the combined effects of human activities on marine ecosystems.

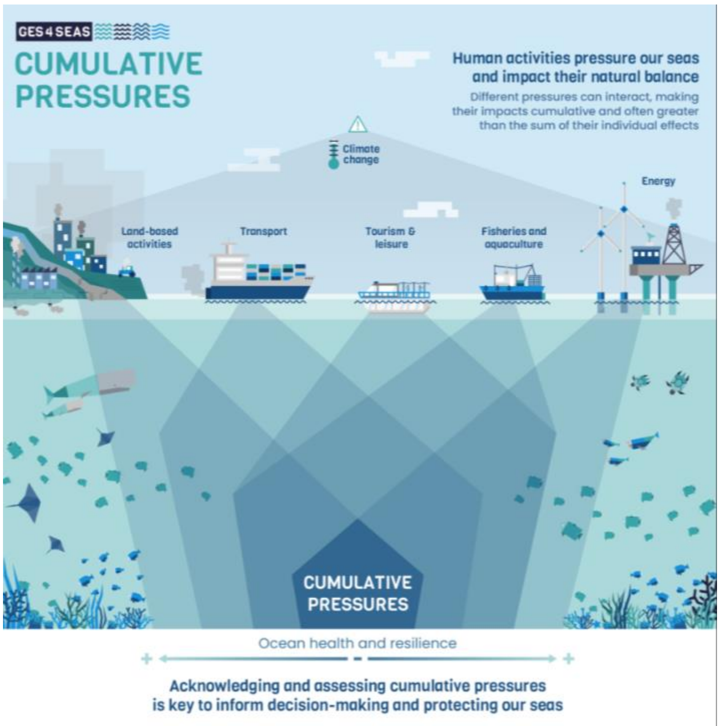
By the end of this lesson, you should be able to:

- Explain why managing single pressures or sectors in isolation can lead to unintended consequences.
- Describe how multiple human pressures interact to affect marine ecosystems.
- Recognise the link between cumulative pressures, ecosystem degradation, and the need for Ecosystem-Based Management.

Read this

Marine ecosystems function as interconnected systems influenced by multiple human activities. The challenge lies not in recognising these connections, but in how pressures on marine ecosystems are managed in practice. Activities such as fishing, shipping, coastal development, tourism or even conservation, and pressures such as pollution or climate change, all act simultaneously, often in the same places and over long periods.

When the different pressures coming from different human activities accumulate, their combined effects can differ substantially from the effects of each pressure considered on its own.



Human activities overlap in space and time, creating cumulative pressures that shape ocean health and resilience.

When pressures are addressed through separate sectoral frameworks, their interactions are often overlooked. Measures may successfully reduce one impact while leaving others unchanged or even increasing them elsewhere in the system.

A clear example of why Ecosystem-Based Management is needed can be seen in the increasing occurrence of jellyfish blooms in some marine regions.

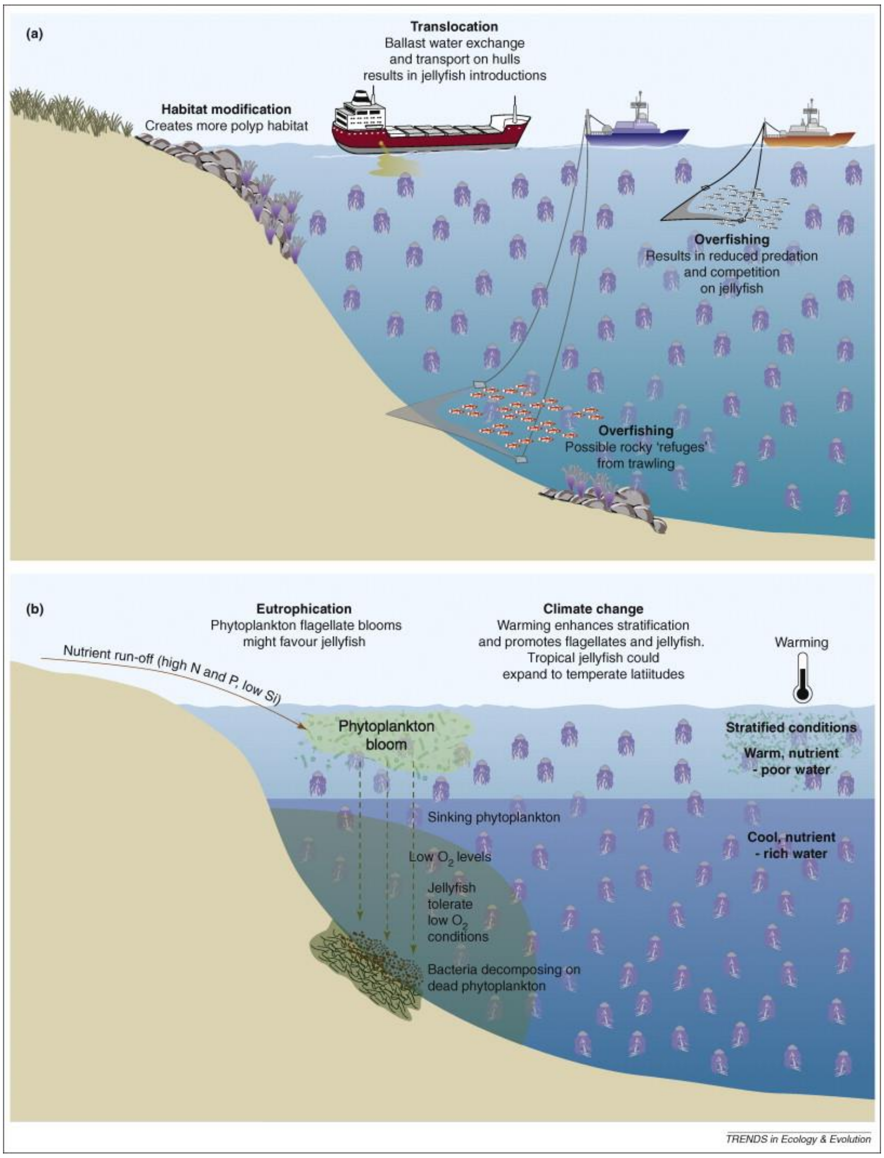
A Jellyfish bloom. Source: Envato.

Jellyfish blooms are often treated as an isolated problem, leading to responses that focus only on the jellyfish themselves. However, these blooms are usually a symptom of broader ecosystem imbalance, rather than a single cause.

Research has shown that jellyfish blooms are often associated with the combined effects of:

- overfishing, which removes predators and competitors,
- nutrient enrichment and changes in water quality, and
- climate-driven changes in temperature and circulation.

These changes can create conditions that favour jellyfish outbreaks.



How human activities, nutrient pollution, and climate change can create conditions that favour jellyfish outbreaks Source: https://www.cell.com/AJHG/fulltext/S0169-5347(09)00088-3. The jellyfish joyride: causes, consequences and management responses to a more gelatinous future. *Richardson, Anthony J. et al. Trends in Ecology & Evolution, Volume 24, Issue 6, 312 – 322.*

Managing any one of those pressures (for example, overfishing or nutrient enrichment) in isolation is unlikely to prevent blooms from occurring. Ecosystem-Based Management is needed because it allows these interacting pressures to be considered together, helping to address underlying causes rather than responding only to visible symptoms.

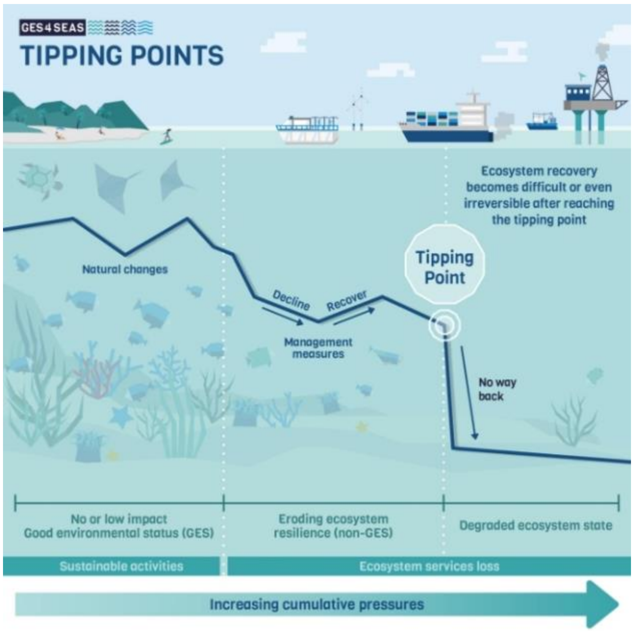
Watch this video

Watch this short cartoon to learn more about jellyfish blooms.

https://www.youtube.com/watch?v=rIMWFak0leU

Read this

Another reason Ecosystem-Based Management is needed is that ecosystems do not respond linearly to increasing pressure. As multiple pressures accumulate, ecosystems can gradually lose resilience, becoming more sensitive to disturbance. When resilience is reduced, ecosystems may approach what is known as "tipping points".



How increasing cumulative pressures can push marine ecosystems towards a tipping point, beyond which recovery becomes difficult or even impossible.

In such situations, even small additional pressures can trigger abrupt and sometimes irreversible change. Managing pressures one at a time makes it difficult to recognise when these thresholds are being approached. A system-wide perspective is therefore essential to identify where combined pressures increase the risk of crossing a tipping point.

Check your understanding

[Multiple choice]

Why is managing pressures in isolation often insufficient in marine ecosystems?

a) Because ecosystems respond only to climate change

b) Because pressures interact and accumulate across the system

c) Because sectoral policies are always ineffective

d) Because human activities should be excluded from the ocean

Correct answer: b)

[True or False]

Jellyfish blooms are typically the result of a single pressure and can be managed by addressing that pressure alone.

Correct answer: false

7.6 Lesson 3: Is EBM just a concept? Policy and governance context

In this lesson, you will explore how Ecosystem-Based Management is translated into real-world policy and governance, and why it functions as a guiding logic for decision-making rather than a standalone management tool.

By the end of this lesson, you should be able to:

- Explain how Ecosystem-Based Management is embedded in marine policy and governance.
- Identify key European and international frameworks that apply Ecosystem-Based Management principles.
- Understand EBM as a governance approach that connects science, policy, and management across sectors and scales.

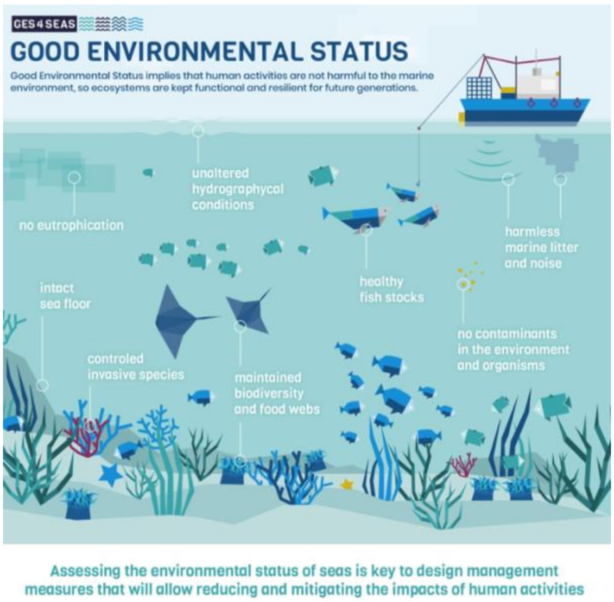
Read this

By now, you have seen why managing marine ecosystems requires looking beyond single pressures, sectors or species and isolated decisions. But this raises an important question: is Ecosystem-Based Management just a scientific idea, or is it actually used in real-world decision-making?

The answer is clear. Ecosystem-Based Management is already embedded in marine governance, shaping how seas are assessed, planned, and managed at European and international levels.

Rather than operating as a stand-alone concept, EBM provides a common logic that connects science, policy, and management across sectors and scales.

In the European Union, Ecosystem-Based Management is a core principle of the Marine Strategy Framework Directive (MSFD). The MSFD is the EU's main environmental policy for protecting marine ecosystems, with the objective of achieving Good Environmental Status (GES).



Good Environmental Status (GES) describes a condition in which human activities do not compromise the structure, functioning, and resilience of marine ecosystems.

Under the MSFD, Member States are required to:

- assess the condition of marine ecosystems,
- identify pressures and their impacts,
- define environmental targets, and
- design Programmes of Measures to reduce risks to ecosystem health.

This structure reflects Ecosystem-Based Management in practice: decisions are based on ecosystem status, multiple pressures are considered together, and measures are designed to protect the functioning of the whole system.

Watch this video

To learn more about the MSFD, watch this short video explaining how Good Environmental Status is achieved through an ecosystem-based approach that integrates environmental protection, sustainable use, and coordinated management across sectors and regions.

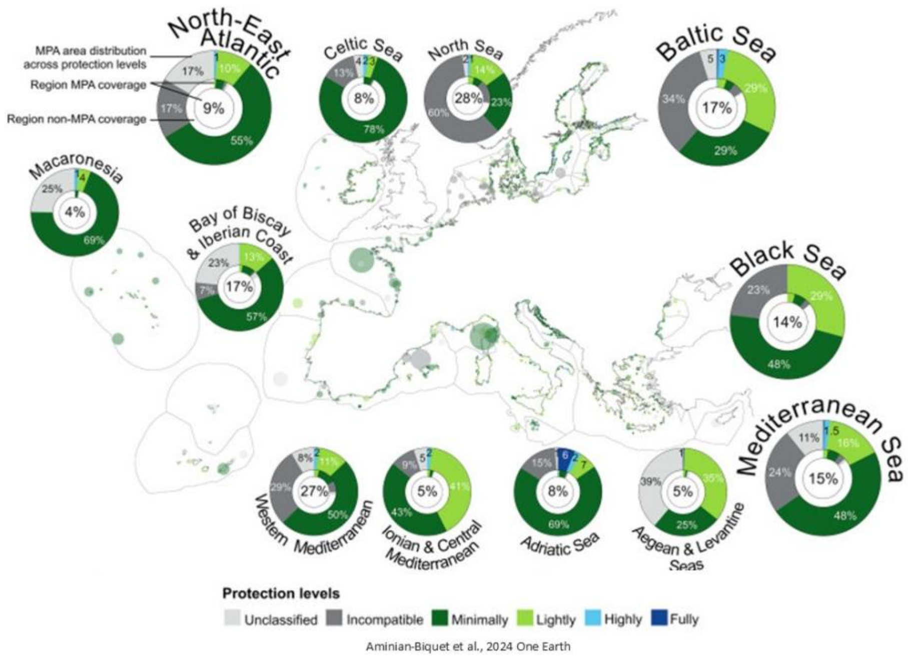
https://www.youtube.com/watch?v=itNo5jycW1M

Read this

Similarly to the MSFD, the Marine Spatial Planning Directive requires member states to develop marine spatial plans based on scientific data and stakeholder engagement, as means to ensure the sustainable development of human activities, minimizing conflicts between users and interests, as well as impacts on the environment.

Once ecosystem status and pressures are assessed under the MSFD, management action is required where risks to ecosystem functioning are identified. In practice, this action is delivered through a combination of protection and restoration measures, applied at different levels and with different objectives.

One example is the Natura 2000 network, a Europe-wide system to establish a network of protected areas across Europe. It aims to conserve biodiversity by creating safe zones for species and habitats that are at risk. While Natura 2000 is an important step forward, it can be difficult to implement in areas with significant human activity. Learn more about Natura 2000: https://www.eea.europa.eu/themes/biodiversity/natura-2000/the-natura-2000-protected-areas-network



Different protection levels of the European seas.

Building on this effort, the Nature Restoration Law aims to boost restoration initiatives across Europe. It focuses on restoring ecosystems and their natural functions, with the goal of improving biodiversity and helping ecosystems recover from the damage caused by human activities.

Learn more about the Nature Restoration Law: https://environment.ec.europa.eu/news/nature-restoration-law-enters-force-2024-08-15_en

In the management of fisheries, the management of species have historically been based on single species. On most recent years, EBM approaches to species is being promoted both in Europe and elsewhere. For example, ICES uses tools and models for multi-species assessment and management, such as Ecopath with Ecosim. The Marine Stewardship Council is revising certification standards for mixed- multi-species management. In the US, the Fisheries department of NOAA is developing multi-species models to support decision-making processes, especially in the North Atlantic. This approaches, although far more complex, and difficult to obtain a clear understanding of the processes, are fully required for the sustainable future of fishing resources.

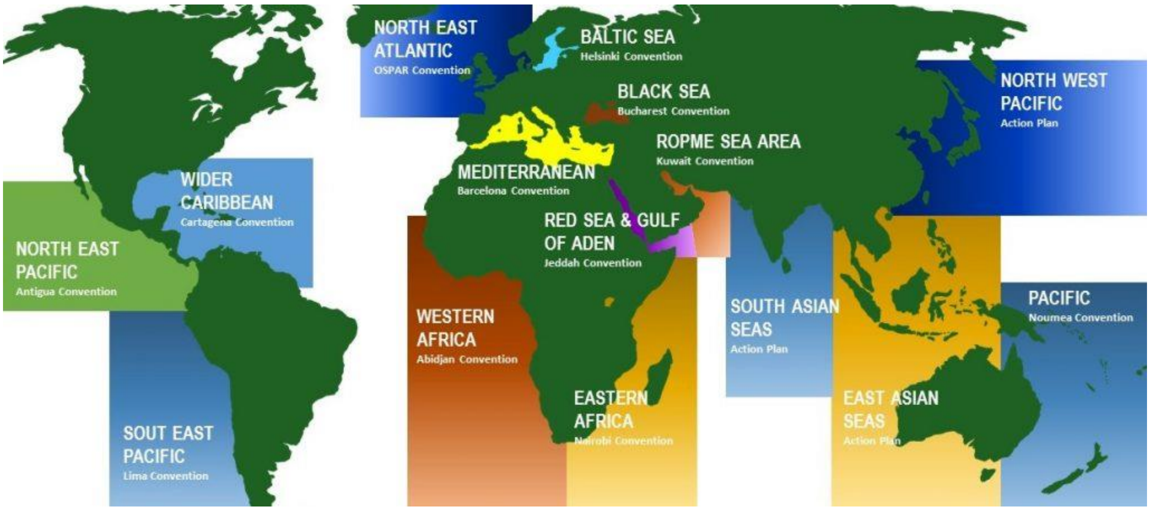
Read this

Ecosystem-Based Management is not limited to the EU. It is also embedded in international marine governance, recognising that marine ecosystems extend beyond national borders and require coordinated action. A multitude of organisations govern the high seas, but few mechanisms exist to facilitate communication or coordinate activities among them

This map illustrates all international governance bodies with a high seas mandate, except those with global coverage — i.e., the International Whaling Commission (IWC), International Maritime Organization (IMO), and International Seabed Authority (ISA). These organizations collectively cover virtually all high seas areas and overlap in many places.

At the global level, the Convention on Biological Diversity promotes ecosystem-based approaches to conservation and sustainable use. At the regional level, this principle is put into practice through Regional Seas Conventions, which coordinate management across countries sharing the same marine regions.

Marine governance is therefore organised at the scale of shared sea basins rather than national borders. Frameworks such as the United Nations Environment Programme's Regional Seas Programme support this approach by facilitating cooperation, joint assessment, and coordinated management across jurisdictions. Together, these arrangements reinforce a core principle of Ecosystem-Based Management: effective marine management depends on cooperation across countries, sectors, and governance levels.



Cartographic representation of the United Nations Environment Programme (UNEP) Regional Seas Programme.

Check your understanding

[Matching exercise]

Match each policy or framework with its main role:

- Marine Strategy Framework Directive (MSFD)
- Convention on Biological Diversity
- Regional Seas Conventions

a) Coordinates marine management across countries sharing the same sea

b) Promotes ecosystem-based approaches to conservation and sustainable use

c) Provides the EU framework for achieving Good Environmental Status

Correct matches:

- MSFD ⟶ c
- CBD ⟶ b
- Regional Seas Conventions ⟶ a

7.7 Lesson 4: EBM across sectors: managing trade-offs

In this lesson, you will explore how Ecosystem-Based Management addresses situations where multiple human activities compete for the same marine space and resources. You will learn why trade-offs are unavoidable in marine management, and how EBM helps make these trade-offs explicit and manageable.

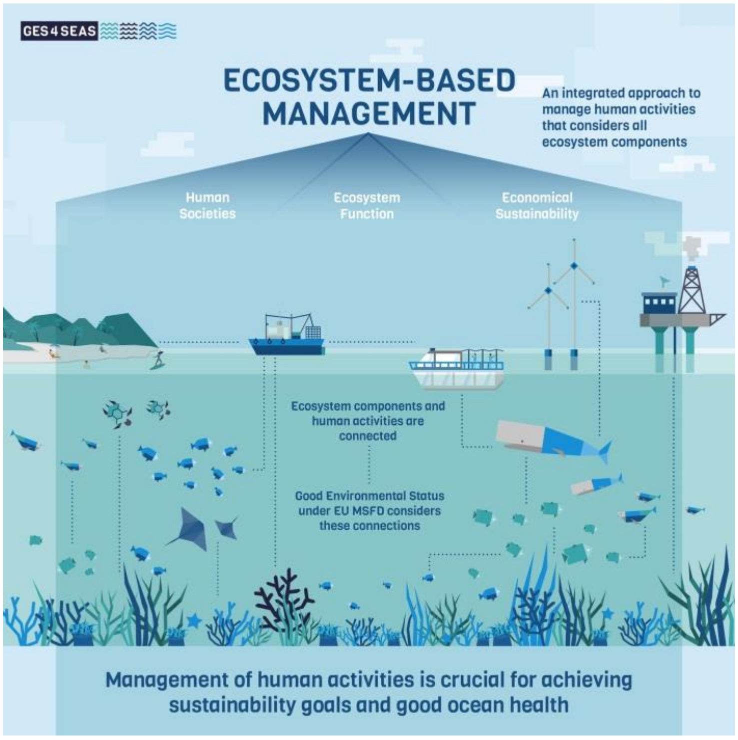
By the end of this lesson, you should be able to:

- Explain why trade-offs arise when multiple sectors operate in the same marine areas.
- Recognise trade-offs as an inherent feature of marine management rather than a failure of governance.

- Understand how Ecosystem-Based Management supports informed and transparent decision-making across sectors.

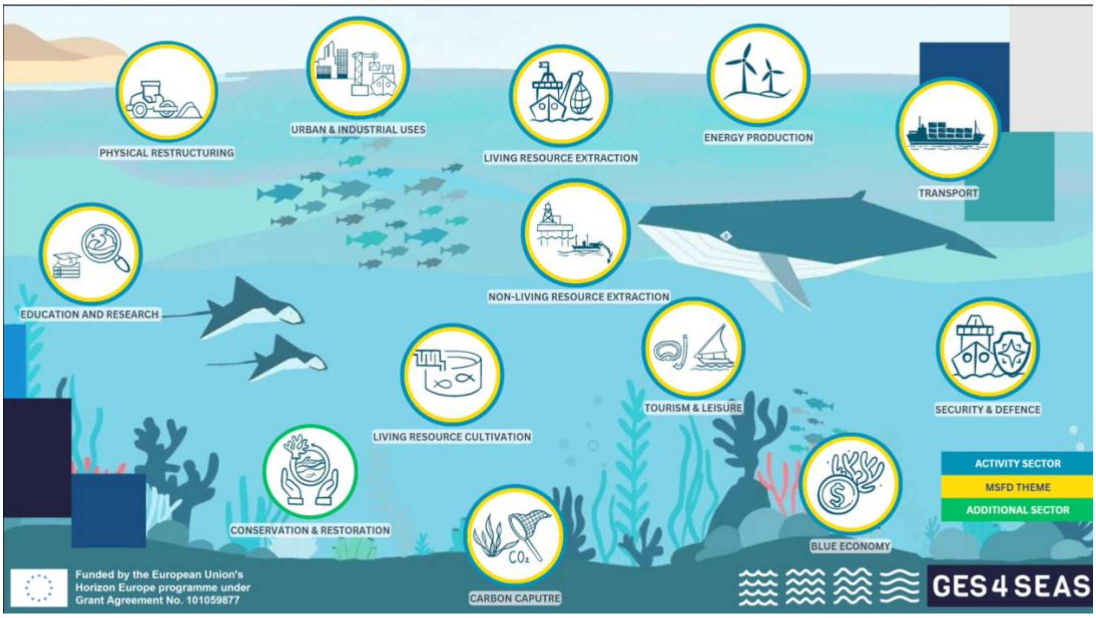
Read this

Governance based on Ecosystem-Based Management must deal with competing demands for marine space and resources. Fisheries, offshore energy, shipping, tourism, aquaculture, and bioprospecting, among others, operate simultaneously, often in overlapping areas. EBM does not remove these conflicts. Instead, it provides a way to make trade-offs visible and manageable.



Ecosystem-Based Management brings together human uses, ecosystem functioning, and sustainability objectives when managing shared marine space.

In regions such as the Atlantic, managing trade-offs is particularly challenging due to the concentration of activities. Traditional sectors such as fisheries and aquaculture operate alongside emerging uses like offshore renewable energy, while shipping lanes, tourism, and conservation areas add further layers of complexity. For example, offshore wind farms can support climate goals but may overlap with fishing grounds; shipping routes are essential for trade but can increase underwater noise and pollution; and tourism can bring economic benefits while placing pressure on sensitive coastal habitats.



Multiple human activities can overlap in the same marine area, creating cumulative pressures and trade-offs that must be considered together under an Ecosystem-Based Management approach.

A key principle of Ecosystem-Based Management is that no single sector should undermine the functioning of the ecosystem. This requires moving beyond sectoral priorities and considering cumulative impacts and ecosystem limits.

Because these limits exist, decisions about marine use inevitably involve trade-offs. Ecosystem-Based Management helps decision-makers identify these trade-offs and where they are acceptable, where pressures need to be reduced, and where certain activities may be incompatible with ecosystem protection objectives.

These decisions about marine use, regional development, or energy security, may have profound impact on livelihood and our cultural values, and must therefore balance ecological, social, and economic considerations.

Check your understanding

[Multiple choice]
Question 1:
What is the role of Ecosystem-Based Management when dealing with multiple marine sectors?
a) To prioritise one sector over all others
b) To eliminate all conflicts between marine uses

c) To manage trade-offs while respecting ecosystem limits
d) To prevent economic activities at sea
Correct answer: c)

[Reflection question]
Think about a marine region you are familiar with. Which two sectors are most likely to come into conflict, and what trade-offs would need to be considered under an Ecosystem-Based Management approach?

7.8 Lesson 5: Ecosystem-Based Management as a cyclical and adaptive process

In this lesson, you will learn how Ecosystem-Based Management works in practice as a cyclical and adaptive process. You will explore the main steps of this process and understand why continuous assessment, monitoring, and adjustment are essential for managing marine ecosystems under changing conditions.

By the end of this lesson, you should be able to:

- Describe Ecosystem-Based Management as a cyclical and adaptive management process.
- Identify the main steps of the Ecosystem-Based Management cycle.
- Explain why monitoring and feedback are essential for adjusting management measures over time.

Read this

Ecosystem-Based Management is not a one-off decision or a fixed management plan. Marine ecosystems change over time, pressures and ecosystem components evolve, and new information becomes available. For this reason, EBM is designed as a cyclical and adaptive process, rather than a linear sequence of actions.

Instead of assuming that one decision will solve a problem permanently, EBM treats management as a continuous process of learning, adjustment, and improvement.

The NOAA Integrated Ecosystem Assessment (IEA) approach, a multi-step process that permits evaluation of cross-sector trade-offs.

The EBM cycle begins with **assessing ecosystem status and pressures**. This involves collecting and analysing information on ecosystem components, human activities, and the pressures they generate, to understand where ecosystems are under stress and what is driving change.

This step reflects a key insight of Ecosystem-Based Management: ecosystem condition is shaped by multiple pressures acting together, not by single pressures in isolation, and by the interaction between species themselves.

Based on these assessments, the next step is to **identify risks and vulnerabilities**. This means determining where ecosystems are most sensitive, which components may be approaching critical thresholds, how changes in one ecosystem component may be affecting others and where cumulative pressures increase the likelihood of degradation.

Identifying risk helps prioritise action. Not all pressures can be addressed everywhere at once, so EBM supports responses that are targeted and proportionate to the level of risk.

Once risks are identified, decision-makers **design and evaluate management measures**, often referred to as Programmes of Measures. These measures aim to reduce pressures, prevent further degradation, or support ecosystem functioning.

Before implementation, measures are assessed for their potential environmental, social, and economic effects. This helps ensure that actions reduce risk without creating new problems or unacceptable trade-offs.

After **measures are implemented**, their **effectiveness is monitored and evaluated**. Monitoring provides evidence of whether actions are working and whether ecosystem conditions are improving, remaining stable, or continuing to decline.

If measures are not achieving their objectives, Ecosystem-Based Management requires adjustment. This feedback closes the management loop and allows the cycle to begin again, informed by new knowledge and experience.

Check your understanding

[Multiple choice]
Which statement best describes how Ecosystem-Based Management works in practice
a) Management measures are designed once and remain fixed over time.
b) Ecosystem-Based Management focuses mainly on monitoring environmental change.
c) Ecosystem-Based Management is a cyclical process in which assessment, action, and learning continuously inform each other.
d) Ecosystem-Based Management aims to eliminate uncertainty by collecting more data.
Correct answer: c)

[True or False]
In Ecosystem-Based Management, monitoring results can lead to changes in management measures if objectives are not being met.
Correct answer: True

7.9 Lesson 6: Tools for Ecosystem-Based Management

In this lesson, you will explore how different tools support Ecosystem-Based Management at different stages of the decision-making process. You will learn why no single tool can address all management challenges, and how combining tools helps translate EBM from concept into practice.

By the end of this lesson, you should be able to:

- Explain why Ecosystem-Based Management relies on a combination of tools or “toolboxes” rather than single tools.
- Distinguish between different types of tools used at different stages of the EBM process.
- Understand how combining tools supports informed and transparent management decision

Read this

Ecosystem-Based Management relies on information, analysis, and decision-making across complex systems. No single method or model can answer all management questions. Different questions require different tools.

EBM therefore works with toolboxes, not single tools. Each tool supports a specific step of the management process, from understanding pressures to evaluating management options.

A useful way to think about EBM tools is to imagine a cube, where each side represents a different management challenge. Solving one side does not automatically solve the others. Each requires a different approach.

The GES4SEAS Ocean Cube is a visual tool used to illustrate how different pressures, management challenges, and assessment tools interact in Ecosystem-Based Management.

In Ecosystem-Based Management:

- some tools help identify where pressures overlap,
- others assess ecosystem status,
- others support decision-making and trade-offs, and
- others evaluate management effectiveness.

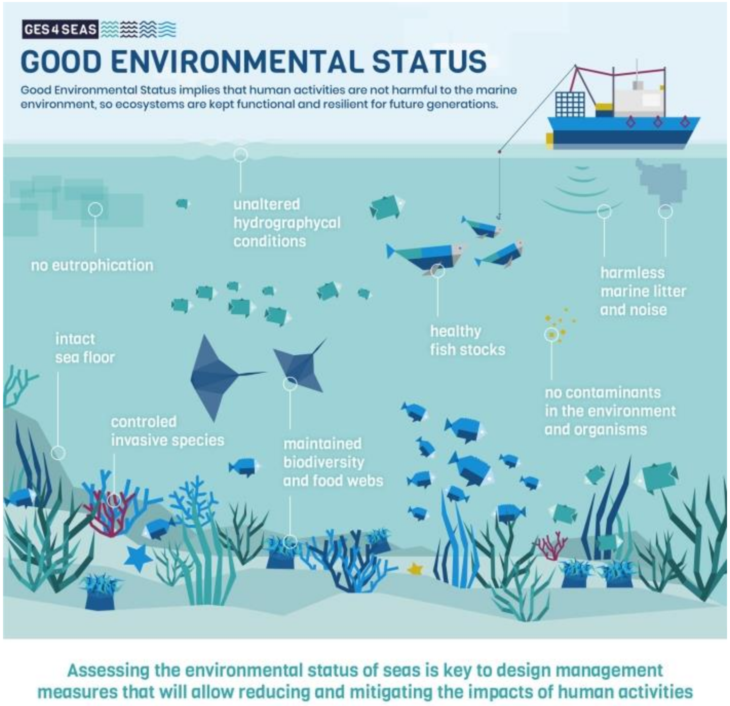
Using the wrong tool for the wrong question can lead to misleading conclusions or ineffective decisions.

One important group of tools focuses on cumulative effects. These tools help identify areas where multiple pressures act together and where ecosystems may be most vulnerable.

Cumulative Effects Assessment (CEA) tools combine information on human activities, pressures, and ecosystem sensitivity to highlight hotspots of concern. They are particularly useful in the early stages of EBM, when identifying risk and prioritising action.

Other tools focus on assessing ecosystem status. These tools help answer a fundamental management question: what is the condition of the ecosystem as a whole?

Ecosystem status assessment tools integrate information across ecosystem components and indicators. They support comparisons across areas and help track progress toward environmental objectives such as Good Environmental Status.



Assessing ecosystem status requires integrating multiple indicators to understand the condition of the ecosystem as a whole.

Once risks are identified and ecosystem status is understood, **decision-support tools** help explore management options. These tools are used to compare scenarios, assess environmental, social and economic trade-offs, and evaluate the potential outcomes of adopting different measures.

Decision-support tools do not make decisions. Instead, they provide structured information to support transparent and informed choices, particularly when environmental, social, and economic objectives need to be balanced.

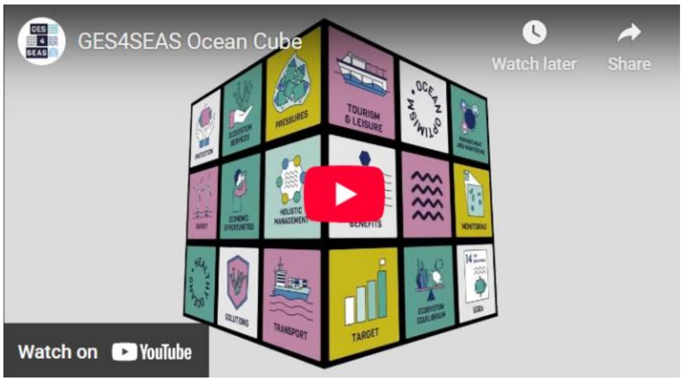
In practice, Ecosystem-Based Management depends on combining tools. Outputs from one tool often serve as inputs for another. This is why testing, adapting, and integrating tools is a key part of operationalising EBM.

Within initiatives such as GES4SEAS, tools are tested and combined across different regions and learning sites. For example, GES4SEAS project has developed Tikta, which is a tool that allows exploring Cumulative Effects Assessment and environmental status assessments, which will support decision making processes. By developing this and other tools tested in different regions and environmental contexts once can ensure that the tools are robust, context-sensitive, and useful for real management decisions.

Watch this video

Achieving a good environmental status of our ocean encompasses a lot of factors and is as complex as solving a Rubik cube. Watch this short video introducing the GES4SEAS Ocean Cube, which illustrates why multiple tools are needed to support Ecosystem-Based Management.

https://www.youtube.com/watch?v=E7qFN2AxIdY



Check your understanding

[Matching exercise]

Match each tool type with its main purpose:

- Cumulative Effects Assessment (CEA)
- Ecosystem Status Assessment Tools (e.g. NEAT)
- Decision-support Tools

a) Exploring management options and trade-offs
b) Identifying areas where multiple pressures overlap
c) Assessing the overall condition of ecosystems

Correct matches:
CEA → b); Status Assessment Tools → c); Decision-support Tools → a)

7.10 Lesson 7: What can Ecosystem-Based Management really manage?

In this lesson, you will clarify what Ecosystem-Based Management can and cannot manage, and how distinguishing between controllable and uncontrollable pressures helps set realistic and effective management goals.

By the end of this lesson, you should be able to:

- Explain why Ecosystem-Based Management manages human activities rather than ecosystems directly.
- Distinguish between endogenic and exogenic pressures.
- Understand how managing controllable pressures helps build ecosystem resilience under environmental change.

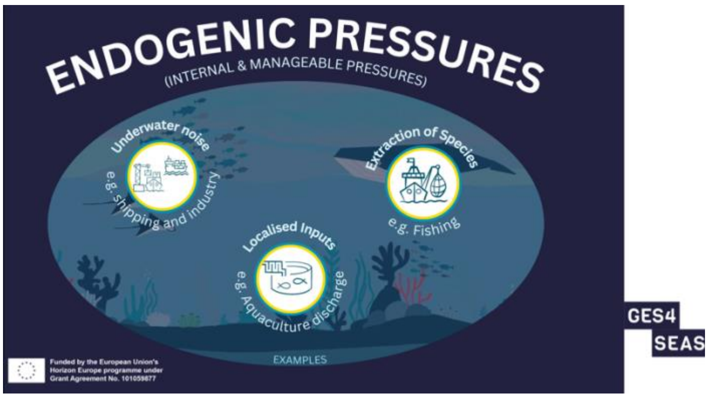
Read this

By this point, Ecosystem-Based Management may sound like a powerful way to control complex marine systems. This leads to important clarification: ecosystems themselves cannot be managed. What Ecosystem-Based Management actually manages are human activities and the pressures they create.

Marine ecosystems respond to natural variability, long-term environmental change, and human influence. While management cannot control natural processes, it can influence how human activities interact with ecosystems.

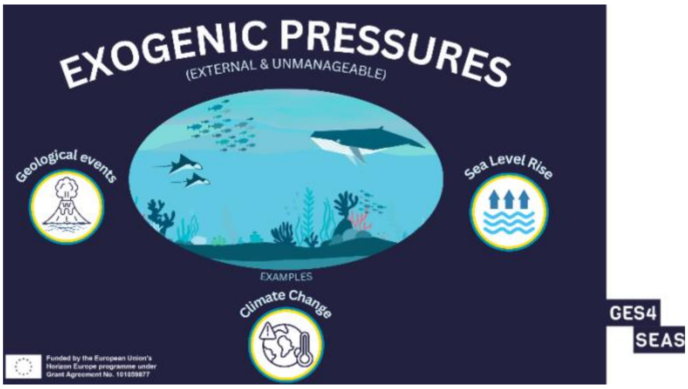
A useful distinction in Ecosystem-Based Management is between endogenic and exogenic pressures.

- **Endogenic pressures** are generated by human activities that can be managed at regional or local scales.



Examples of endogenic pressures include fishing intensity, nutrient inputs from rivers, underwater noise from shipping, or physical disturbance of habitats.

- **Exogenic pressures** originate outside the management area or beyond direct control.



Examples of exogenic pressures include large-scale climate change, ocean warming, acidification, and changes in global circulation patterns.

This distinction helps clarify what Ecosystem-Based Management can realistically influence.

Ecosystem-Based Management focuses on rigorously managing endogenic pressures. By reducing pressures that can be controlled, EBM aims to maintain or enhance ecosystem resilience.

This is particularly important in the context of climate change. While climate-driven pressures cannot be managed locally, reducing controllable pressures can increase the capacity of ecosystems to cope with unavoidable change.

Confusing what can and cannot be managed can lead to unrealistic expectations. Ecosystem-Based Management does not promise to prevent all ecosystem change or eliminate environmental risk. Instead, it provides a structured way to:

- reduce avoidable pressures,
- avoid unnecessary risk, and
- prevent human activities from pushing ecosystems beyond their limits.

Recognising these limits is essential for effective and credible management.

Check your understanding

[Classification exercise]

Classify the following pressures as endogenic or exogenic:

- Nutrient pollution from agriculture
- Ocean warming due to climate change
- Underwater noise from shipping
- Changes in global ocean circulation

Correct answers:

- Nutrient pollution from agriculture → Endogenic
- Ocean warming due to climate change → Exogenic
- Underwater noise from shipping → Endogenic
- Changes in global ocean circulation → Exogenic

7.11 Final considerations

Throughout this module, you have explored Ecosystem-Based Management as a way of addressing how marine ecosystems and human activities interact. You learned that effective marine management cannot focus on single pressures or sectors in isolation nor on single-species, but must consider cumulative effects, ecosystem limits, the complex relationships between the different elements of the ocean web and the connections between environmental, social, and economic systems.

You saw that Ecosystem-Based Management is not a fixed recipe, but an adaptive approach that brings together science, policy, and decision-making. By assessing risks, managing trade-offs, and adjusting actions over time, EBM helps avoid decisions that could push ecosystems beyond critical limits.

A key message of this module is that trade-offs are unavoidable. Marine space and resources are shared, and Ecosystem-Based Management does not aim to eliminate conflicts, but to make choices explicit, transparent, and informed by ecosystem functioning.

Finally, this module clarified that Ecosystem-Based Management has the focus on ecosystems but does not manage them directly. It manages human activities and the pressures they create. By focusing on what can be controlled, EBM supports ecosystem resilience and helps marine systems cope with ongoing environmental change.

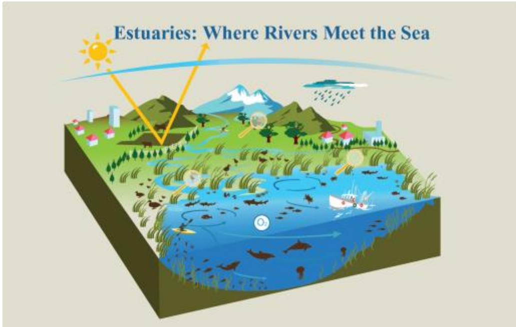
In the end, Ecosystem-Based Management is about managing our choices to ensure that marine ecosystems can continue to function and support society over the long term.

Check your understanding

In this exercise, you will take the role of a decision-maker responsible for managing an estuary under pressure. The future of this ecosystem depends on the choices you make.

Read the scenario carefully and consider the environmental, social, and economic factors involved. Then, decide which actions you think would lead to the most sustainable outcome.

Hint: There is no easy solution — every choice comes with trade-offs. Your decisions could determine whether the estuary recovers or continues to decline.



Let's suppose we have an estuary — an area where a river meets the sea. The estuary contains seagrass meadows, oyster reefs, and mangrove habitats. These habitats are vital for biodiversity and also support fisheries by producing large numbers of fish and crustaceans. In addition, the estuary plays an important role in cargo shipping.

Over the last ten years, fish and crustacean populations have declined sharply. The government asks scientists why this has happened.

Their analyses suggest that:

1. The system has become polluted by agricultural nutrients and other pollutants entering from the river.
2. The ecosystem is exposed to several human pressures that lead to overgrowing green algae, reduction of exploited fish, and waters that are not suitable for bathing.
3. The estuary's condition will continue to worsen in the future if no action is taken.

The government now faces a difficult task: to restore the estuary's health — bringing back fish, crustaceans, and healthy habitats — while ensuring that shipping, fisheries, and agriculture can continue to operate without causing an economic collapse.

In your opinion, what should they do?

Answer: There is no single correct answer to this scenario. Different solutions may apply depending on local conditions, priorities, and environmental regulations. Once an ecosystem is exposed to multiple pressures that affect its quality, recovery becomes extremely complex given the diversity of actors involved in the management and in the restoration processes.

Key takeaway: *It is always better to prevent ecosystems from reaching bad environmental status in the first place.*

7.12 Additional resources – relevant lesson plans and activities

If you want to learn more about ecosystem-based management, here are some additional resources and lesson plans.

- **MED EDUC Educational Resources**

The MED EDUC project proposes the creation of a series of European level educational resources for middle and high schools. These resources concern the discovery and valorisation of the coastal and marine environment in the Mediterranean. The project is mainly aimed at students, teachers and educators, offering them both educational tools focused on specific issues of environmental protection in the Mediterranean Sea (pollution and waste, mass tourism, overfishing, loss of biodiversity, coastal erosion, etc.).

Here are some relevant lesson plans in the context of ecosystem-based management and the lessons included on this module in the marine environment:

- Politics and government in our daily life: https://mededuc.eu/en/resource-center/pedagogical-guide/28-politics-and-governance/61-politics-and-government-in-our-daily-life.html
- Exploring marine food webs: https://mededuc.eu/en/resource-center/pedagogical-guide/12-biodiversity/73-exploring-marine-food-webs-in-mediterranean.html
- Coastline artificialization: https://www.mededuc.eu/en/resource-center/pedagogical-reference/10-coastline-artificialization.html

- **Activity on environmental thinking and planning with ecosystem-based management (EBM)**

A marine EBM learning activity that encourages students to explore EBM principles in local ecosystems, including collaborative decision-making and multi-stakeholder involvement. https://www.sciencelearn.org.nz/resources/2505-environmental-thinking-and-planning-with-ecosystem-based-management-ebm

- **InTeGrate EBM Teaching Unit – Marine Protected Areas**

Part of an ocean sustainability teaching module that includes exercises on pressures, marine reserve design, and integrated decision-making — useful as a hands-on classroom activity linked to EBM concepts. https://octogroup.org/news/ebm-toolbox-teaching-marine-protected-area-design-and-/

Welcome to the Science Learning Hub
Pokapū Akoranga Pūtaiao
Explore our New Zealand science education resources

Activity: Environmental thinking and planning with ecosystem-based management (EBM)

EBM – is a holistic and inclusive approach for managing an ecosystem. In this activity, students use EBM principles as a framework to consider how a local area of significance could be managed. Alternatively, it can form the basis for planning a local environmental project.

https://www.sciencelearn.org.nz/resources/2505-environmental-thinking-and-planning-with-ecosystem-based-management-ebm

- **Ecosystem-based Management Simulation**

Students will work in groups of 2 to complete the ecosystem-based management simulation. Students play the role of a fishery manager, and must make best decisions to preserve the ecological health of the environment, while taking into account economic interests of fishers. It is useful to go over the first couple of questions together as a class to make sure students understand what is being asked of them.

https://earthref.org/ERDA/2112/

file:///C:/Users/laptop/Downloads/lesson5-ebmactivity.pdf

Marine Protected Areas Lesson Plan

https://www.coris.noaa.gov/activities/resourceCD/resources/protect_this_lp.pdf

As several links are not working in this very interesting lesson plan, please find below the site of NOAA for more information on the issues of the lesson plan

https://marineprotectedareas.noaa.gov/resources/education/

8. Module 6 |Ocean optimism: rewriting the narrative of our seas

8.1 Introduction to M6

Imagine walking into a room where every clock is set to a different time, and all of them are counting down to zero. For a long time, this is how we have talked about the ocean: a series of countdowns toward collapse, from overfishing and pollution to climate change. It is easy to feel that the "mirror" of our marine world is permanently shattered. But if we only look at the cracks, we miss the hands that are already at work repairing them.

It is undeniable that pollution, overfishing, biodiversity loss, habitat degradation, and climate change dominate the narrative, and that these challenges are real and urgent. But they are not the whole story. Around the world, there are also inspiring examples of marine ecosystems recovering, species returning, habitats being restored, and communities taking action to protect the sea.

In this module, we will explore the idea of ocean optimism. You will discover how science, policy, restoration, and collective action can lead to positive change in the marine environment. Through real examples from different parts of the world, we will look at how good management practices, protection measures, and social engagement are helping to restore ocean health and create hope for the future.

By the end of this module, you will understand that while the ocean faces serious pressures, recovery is possible. Recognising these success stories is important not only to inform society, but also to inspire action and help change the way we communicate about the ocean.

8.2 Learning Outcomes

By the end of this module, you should be able to:

- Define what is ocean optimism;
- Recognise why hope and positive stories matter in ocean communication;
- Identify examples of marine recovery and restoration;
- Understand how science, policy, and collective action can support positive change in the ocean;
- Recognise the role of ocean literacy and education in building a more hopeful and engaged society.

8.3 How to proceed

Complete the **activities** as they appear in each Lesson.

To successfully complete this Module, you should work through the following Lessons in order:

- **Lesson 1:** What is ocean optimism?
- **Lesson 2:** Seeing is believing: success stories of recovery
- **Lesson 3:** What makes recovery happen?
- **Lesson 4:** Science, restoration and the ocean we want
- **Lesson 5:** Ocean literacy and the future of our seas

8.4 Lesson 1: What is ocean optimism?

In this lesson, you will learn what ocean optimism is and why it matters in the way we understand and communicate about the ocean.

By the end of this lesson, you should be able to:

- Define what ocean optimism means in the context of marine conservation and communication.
- Explain why it is important to balance stories of ocean crisis with evidence-based stories of hope and recovery.
- Recognise how positive narratives can inspire engagement and action to protect the ocean.

Read this

What kind of news do you usually hear about the ocean?

Most of the time, the message is negative. We hear about pollution, overfishing, biodiversity loss, habitat destruction, climate change, and declining marine life. These problems are real, urgent, and important. They deserve public attention because they affect ecosystems, economies, food security, and human well-being. However, this is only part of the story, and how we speak about the ocean dictates how we act.

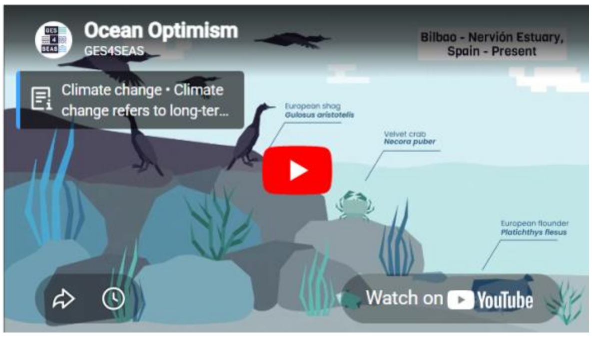
When the ocean is presented only through crisis, it can make people feel that the damage is too great, that solutions are too difficult, or that individual and collective action will not make a difference. If people are exposed only to decline and collapse, they may stop engaging with the issue altogether. *Doom and gloom* narratives lead to apathy.

News outlets tend to choose the crisis side instead of presenting success stories, creating a partial vision of what is really happening.

Ocean optimism focuses on highlighting solutions and successes. By documenting what works, whether it's a species coming back from the brink or a bay being cleaned of industrial waste, we create a roadmap for others to follow.

Watch this video

To better understand the idea behind ocean optimism, watch the GES4SEAS video and pay attention to how it presents both the challenges facing the ocean and the examples of positive change:



https://www.youtube.com/watch?v=OzxeC3u1b2k&t=1s

Read this

Ocean optimism is a way of communicating about the marine environment that includes evidence-based stories of progress, recovery, and solutions.

It does not mean pretending the problems do not exist. It does not mean replacing science with wishful thinking. And it does not mean assuming the ocean will recover on its own.

Instead, ocean optimism means recognising that while the ocean is under pressure, there are also real examples of recovery and real opportunities to act. It is about building a more balanced narrative: one that informs people about environmental problems, while also showing that good decisions, better management, and social action can lead to improvement.

In this sense, ocean optimism is not naïve. It is grounded in science, management, and observed change.

Bridging marine science and action for a healthier future.

Check your understanding

[Multiple choice]

1. What is ocean optimism?

a) A way of ignoring marine problems and focusing only on positive stories
b) A way of communicating about the ocean that includes evidence-based stories of progress, recovery, and solutions
c) The belief that the ocean will recover naturally without human action
d) A communication strategy based mainly on emotion rather than science

Correct answver: b)

2. Why is it important to balance stories of ocean crisis with stories of hope and recovery?

a) Because marine problems are no longer urgent
b) Because negative stories about the ocean are usually inaccurate
c) Because only positive stories can motivate people to care about the ocean

d) Because balanced communication can help people stay engaged and recognise that change is possible

Correct answer: d)

[True or False]

Ocean optimism is grounded in science, management, and observed change.

Correct answer: True

8.5 Lesson 2: Seeing is believing: success stories of recovery

In this lesson, you will learn that marine recovery is possible and explore real examples from around the world showing how ecosystems, species, and coastal areas can improve when pressures are reduced and the right actions are taken.

By the end of this lesson, you should be able to:

- Identify examples of recovery and restoration in marine ecosystems.
- Explain how protection, better management, and restoration actions can lead to positive change in the ocean.
- Recognise that evidence of recovery can help support a more hopeful and balanced narrative about the future of the ocean.

Read this

If ocean optimism is to be taken seriously, it needs to be supported by evidence.

That evidence exists. Around the world, there are places where marine life has begun to return, habitats have improved, and damaged coastal systems have shown signs of recovery. These changes did not happen overnight. But they show that the future of the ocean is not fixed. When pressures are reduced and action is sustained over time, recovery can begin, and it can take many forms.

Recovery can sometimes be seen in a place that was once heavily degraded and slowly bounces back. Also, in the return of a species that had long since been gone. Or in the slow improvement of a habitat that had been declining for decades. Fact is, if we give it space and time, it happens.

Read this

One example of recovery at the scale of a whole place comes from the Nerbioi **estuary** in Bilbao, northern Spain.

For many years, this estuary was heavily affected by mining, industrial activity, and urban discharges. Water quality worsened, habitats were damaged, and the estuary lost much of its ecological value. Like many coastal areas under intense human pressure, it became a symbol of decline.

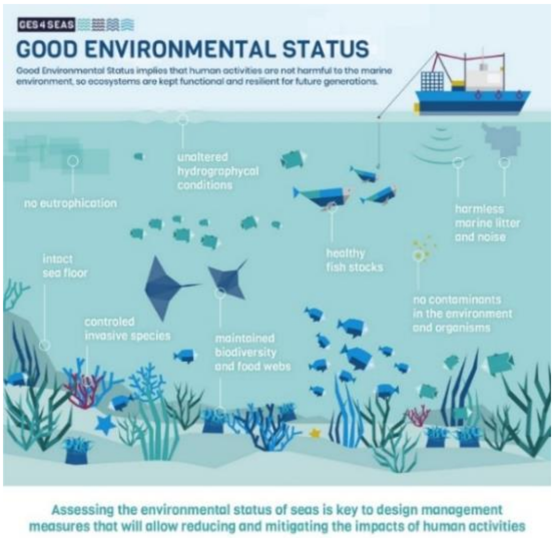
Bilbao during the 1980's vs Present. Source: https://www.mascontext.com/issues/30-31-bilbao/bilbaos-strategic-evolutionthe-metamorphosis-of-the-industrial-city/.

But that story did not end there.

Change was coming, and it began with a bold commitment to reverse decades of industrial neglect. In 1979, the Integrated Sanitation Plan for Greater Bilbao was launched—one of the most ambitious environmental projects in Spain's history. By investing in a massive network of sewers and the advanced Galindo wastewater treatment plant, the region moved from simply managing waste to actively restoring the river's health. Moreover, the industrial crisis in the 70s and 80s forced the closure of many of the companies located along the estuary's margins, which greatly reduced the volume of polluting discharges that had been released without control in previous decades.

The environmental recovery of the Nerbio river estuary and on its current ecosystem. Source: Itsas Museum, Bilbao (Source: https://www.itsasmuseum.eus/en/learn/schools/upper-secondary/).

These decisive actions made recovery possible. First, anoxic conditions changed with the increase of oxygen concentrations in the water, and nowadays, most of the estuary's ecosystem components, including phytoplankton, benthic invertebrate communities, and fish, have achieved good ecological status. This transformation proves that even ecosystems, shaped by long periods of extreme degradation, can thrive again when the root pressures are removed through sustained investment and engineering.



Good environmental status is achieved when human activities are not harmful to the environment.

As the ecological health of the water improved, the changes became visible to the community, and the estuary regained its social and recreational value. Activities that were once unthinkable, such as recreational fishing and bathing, have returned to the two margins of the estuary and to the heart of the city. The Nerbioi estuary is no longer just an industrial artery; it is a living example of how "ocean optimism" translates into a better quality of life for coastal societies.

Watch this video

Hear what the locals have to say about an estuary that was destroyed by heavy industry and the impact of seeing it flourishing, once again breathing life into the city:

https://www.youtube.com/watch?v=RpsSRn5SXgw

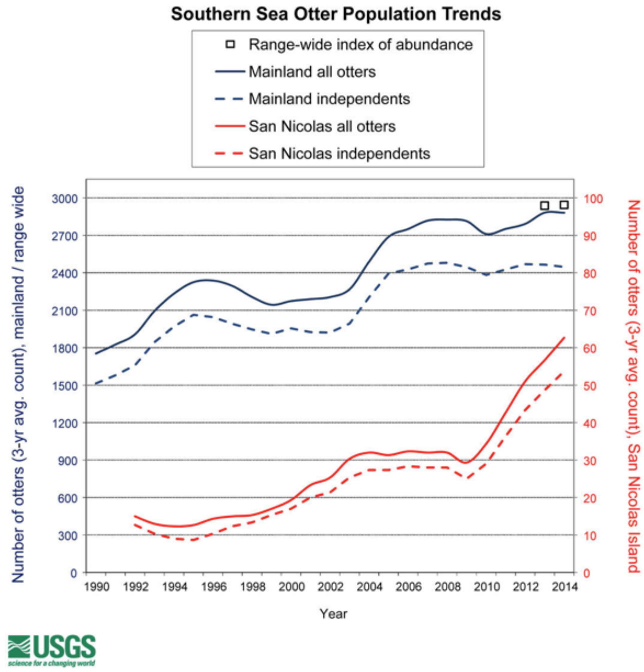
Read this

Not all recovery stories are the same, of course. They can also begin with the protection of a single species and its effects spreading outwards through the ecosystem.

A well-known example is the **sea otter in the North Pacific**. During the eighteenth and nineteenth centuries, sea otters were heavily hunted for their fur, and in California they were eventually thought to be extinct. The North Pacific Fur Seal Convention of 1911 was put in place for protecting this sea otters and other fur seals, and it is in fact considered the first "conservation" treaty implemented on marine species.

Skins of sea otters. Unalaska, Alaska. Gulf of Maine Cod Project, NOAA National Marine Sanctuaries.

Then, in 1914, an isolated population of around 50 individuals was discovered. From that point on, already existing protection through laws and treaties allowed the species to slowly make a comeback.



Protected by laws and treaties, Sea Otters have slowly recovered, as shown in this graphic. Source: https://www.usgs.gov/media/images/trends-population-index-reported-usgs-southern-sea-otters.

This recovery was important not only for the species itself, but also for the wider ecosystem. Sea otters feed on sea urchins, which in turn graze on kelp. When sea otters disappear, sea urchin populations usually grow uncontrolled, and kelp forests decline. When otters return, this balance shifts again. Studies have shown that, in some areas, kelp beds increased as sea otters recovered, while shoreline erosion was also reduced.

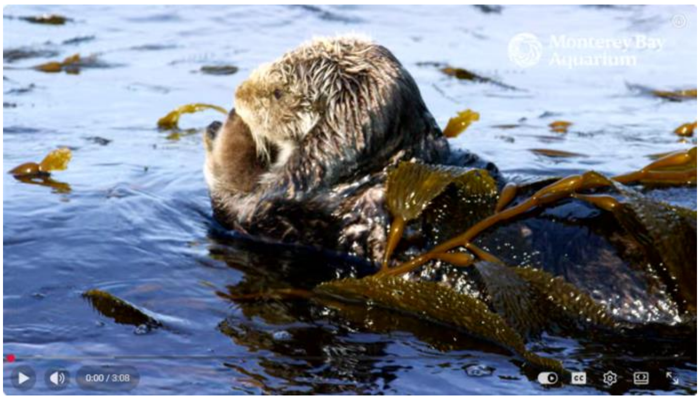
An underwater kelp forest.

This example reminds us that nature does not heal in fragments, as it is a complex system in which changes in one component influence the rest. Recovery is like a stone cast into a pool, sending ripples of renewal far beyond its own shores. Bringing back a single species can help restore ecological relationships that support the whole system.

Watch this video

Dive into the world of sea otters with a senior research biologist at Monterey Bay Aquarium, as she uncovers the crucial role these marine mammals play in kelp forest ecosystems:

https://www.youtube.com/watch?v=5pGdwqCRcDQ



Read this

The blueprint for a healthier ocean is increasingly being drawn at the water's edge, led by local communities, just as it did in Baja California, Mexico.

When extreme hypoxia (low oxygen levels) and marine heatwaves struck the coast of Baja California, the biological foundation of the region began to crumble. **Kelp forests** are foundational ecosystem engineers; their collapse triggered a trophic cascade, leading to the immediate decline of high-value species like abalone and red sea urchin. For local fishing communities, this wasn't just an environmental shift, it was an economic emergency.

However, they did not surrender. Recognizing that their livelihoods depended on the ecological resilience of the seabed, they organized into cooperatives to take direct conservation action:

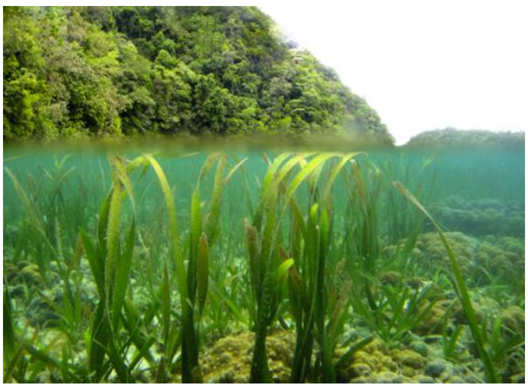
- Voluntary Marine Protected Areas (MPAs): Establishing "no-take" zones, a sanctuary for biological recruitment and with spillover effect, to allow depleted stocks to recover.

- Kelp forests monitoring: Partnering with scientists to track water temperature and canopy density, providing the data needed to manage the fishery adaptively.
- Active restoration projects: Engaging in reforesting the seafloor to kickstart the recovery of these vital carbon sinks and nurseries.

A group of citizen scientists-divers known as the Sirenas de Natividad was founded in 2019; this all-women team is made up of five homemakers, all wives and daughters of fishers, who are monitoring fishery resources and the volunteer-run marine reserves. Credits: Elba Lopez.

Participatory studies have shown that, as a result of the communities taking action, depleted species and ecosystems recovered, helping support thriving ecosystems and fisheries. By helping the ecosystem recover, these communities helped all those whose livelihoods depend on healthy seas. Recovery was not only ecological. It also strengthened the relationship between healthy marine ecosystems and coastal well-being.

This kind of example shows that recovery does not always begin through large-scale policy alone. It can also emerge from local stewardship, cooperation, and long-term commitment. Similar patterns can be seen in other places, such as Palau, where coastal ecosystems including **mangroves and seagrasses** have also benefited from community-led care and management.



A lush underwater meadow of seagrass growing in shallow coastal waters, with a forested mangrove coastline visible above the surface. Credits: Alan Friedlander.

Read this

Some of the most profound signs of hope emerge from the very habitats we once thought were in permanent decline.

This is the story of **Europe's seagrass meadows**. Mirroring the losses seen in places like Palau, Europe witnessed the disappearance of nearly one-third of its seagrass area between 1869 and 2016. Driven by disease, coastal development, and plummeting water quality, these losses reached a breaking point during the 1970s and 1980s, standing as a stark symbol of a coastline under siege.

Yet, in a remarkable reversal, the rate of loss began to slow, and by the 2000s, the trend finally turned. Fast-growing species began to reclaim their territory, and the net loss of these vital meadows started to reverse.

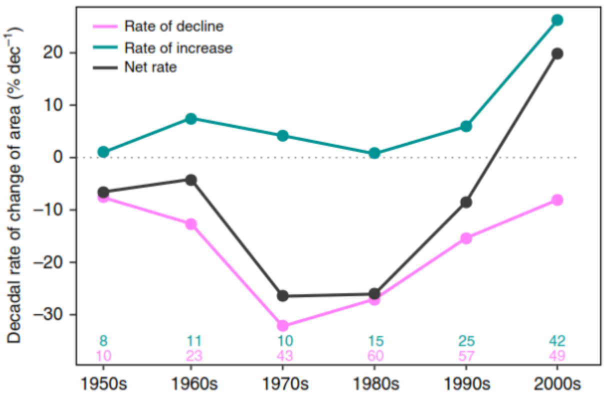


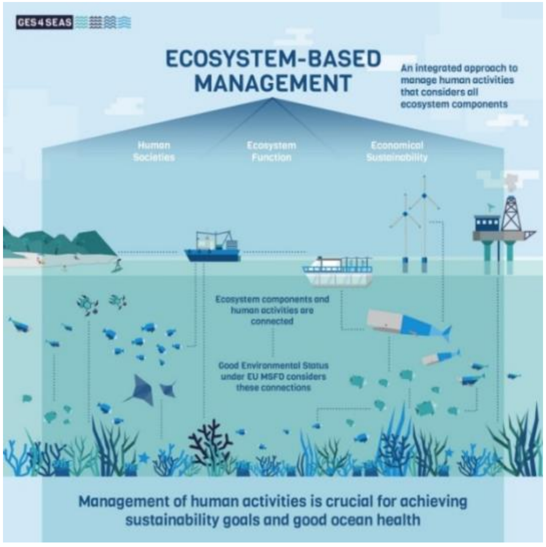
Fig. 3 Decadal rate of change of area of European seagrasses (1950s-2000s). Decadal analysis includes time series >8 years. Number of sites per decade and trajectory are given at the bottom of the plot

Source: https://www.nature.com/articles/s41467-019-11340-4.

Much like the recovery of the Bilbao estuary, these underwater meadows showed that decades of degradation do not have to be a permanent sentence. Recovery is possible when the meadow has not reached a tipping point (point of no return) and the root causes of decline are addressed through decisive, science-based management:

- Active habitat restoration: Giving nature the space and structure to heal.
- Seagrass transplanting: Directly reintroducing life to barren seafloors.
- Reduction of eutrophication: Cleaning the water column to let the sunlight reach the seabed once again.

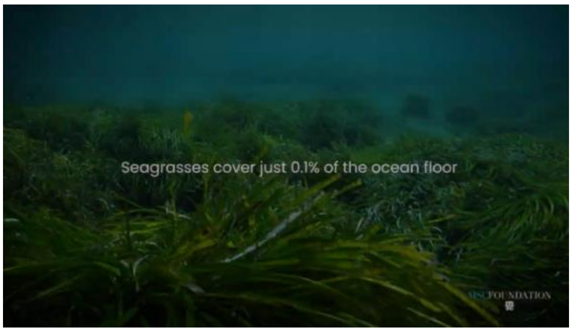
Seagrasses are among the most influential habitats of our ocean. They act as massive carbon sinks, stabilize the shifting sands of the seafloor, and serve as the essential nurseries for a vast array of marine life. Their recovery is a testament to the fact that when we reduce the pressure and implement sound, ecosystem-based management, we give the ocean the chance to respond. It is a living reminder that rebuilding marine life is not just a dream, it is a tangible reality happening right now beneath the waves.



Ecosystem-Based Management brings together human uses, ecosystem functioning, and sustainability objectives when managing shared marine space.

Watch this video

Learn how seagrass meadows are recovering in Formentera, Spain, through science-based monitoring and active restoration:
https://www.youtube.com/watch?v=9IIJoSQ3vHs



Read this

These stories, though separated by geography and species, share a singular, resilient pattern. Whether it is the cleansing of a long-polluted estuary, the return of a keystone species to rebalance the scales, a community rising to guard its local reefs, or a silent meadow reclaiming the seafloor, the message is the same and clear.

Marine recovery is rarely a single, sudden event, nor does it follow a rigid, one-size-fits-all model. Instead, it is a deliberate process that begins when we choose to change our relationship with the sea. It starts when pressures are lifted, ecosystems are granted the luxury of time, and human communities remain steadfast in their commitment to protection, restoration, and adaptive management.

This is why these examples of "ocean optimism" are so vital. They do not claim that our oceans are safe, nor they do pretend that the path to recovery is easy or guaranteed. Instead, they offer something far more transformative: evidence. They prove that positive change is not a theoretical hope, but a measurable reality. By observing, supporting, and learning from these successful paradigms, we move past the paralyzing narrative of inevitable decline. We see that when we provide the spark of management and the space for nature to respond, the ocean possesses an incredible, quiet power to heal itself.

Check your understanding

[Multiple choice]

1. What do the examples in this lesson have in common?
a) They show that marine recovery always happens quickly
b) They show that recovery can begin when pressures are reduced and action is sustained over time
c) They show that only species can recover, not ecosystems or habitats
d) They show that recovery happens without human involvement
Correct answer: b)

2. Why is the recovery of sea otters an important example in this lesson?
a) Because it shows that protecting a species can also influence the wider ecosystem
b) Because it shows that kelp forests recover without any changes in marine life
c) Because it proves that all marine mammals are now fully recovered
d) Because it is mainly an example about tourism
Correct answer: a)

[True or False]
The examples in this lesson suggest that marine recovery can happen in different ways but often depends on reducing pressures and maintaining long-term action.
Correct answer: True

8.6 Lesson 3: What makes recovery happen

In this lesson, you will look beyond the success stories to understand what makes marine recovery possible, and how protection, restoration, governance, and long-term commitment help create lasting change.

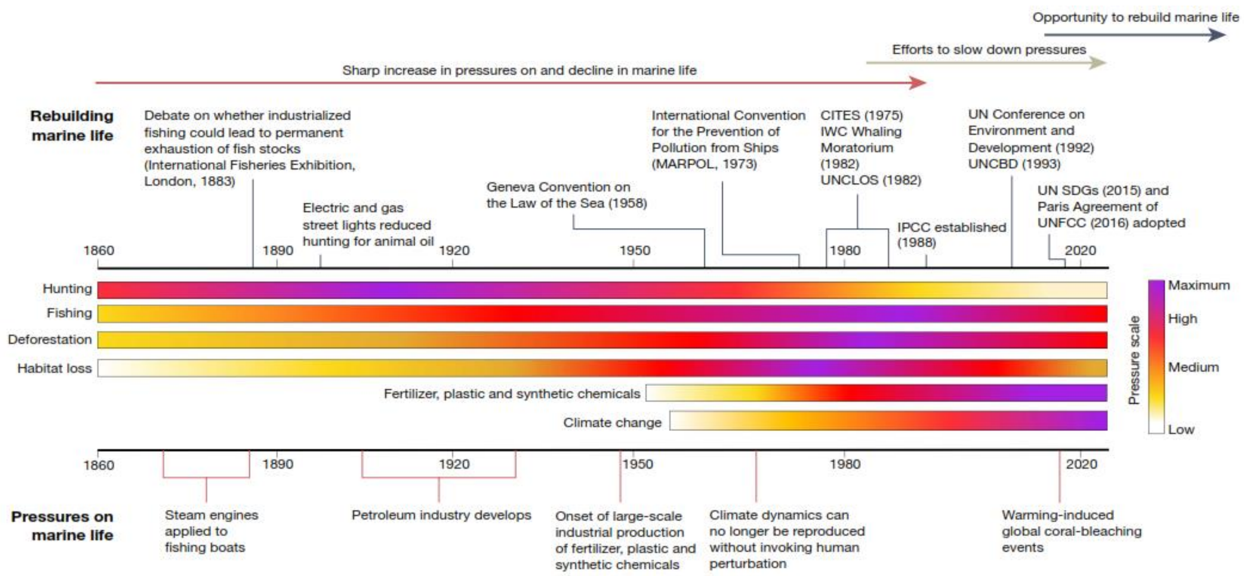
By the end of this lesson, you should be able to:

- Identify the main factors that can support marine recovery.
- Explain how protection, restoration, and better governance can help ecosystems recover.
- Recognise that ocean optimism is built not only on hope, but also on sustained action and engagement.

Read this

The lessons explored previously all point toward a single, powerful truth: recovery is possible of the species, habitat or ecosystem has not reached its tipping point. Yet, this raises a fundamental question: What does actually drive this transformation?

Marine ecosystems are not healed simply because we wish them to. Recovery is a deliberate process that begins when the pressures of human impact are lifted, providing ecosystems with the essential space and time to respond. Scientific evidence suggests that if we mitigate major pressures, including the threat of climate change, we could achieve a substantial restoration of marine abundance, structure, and function by 2050. Recovery, therefore, is never accidental; it is the direct result of sustained decisions and long-term collective effort.

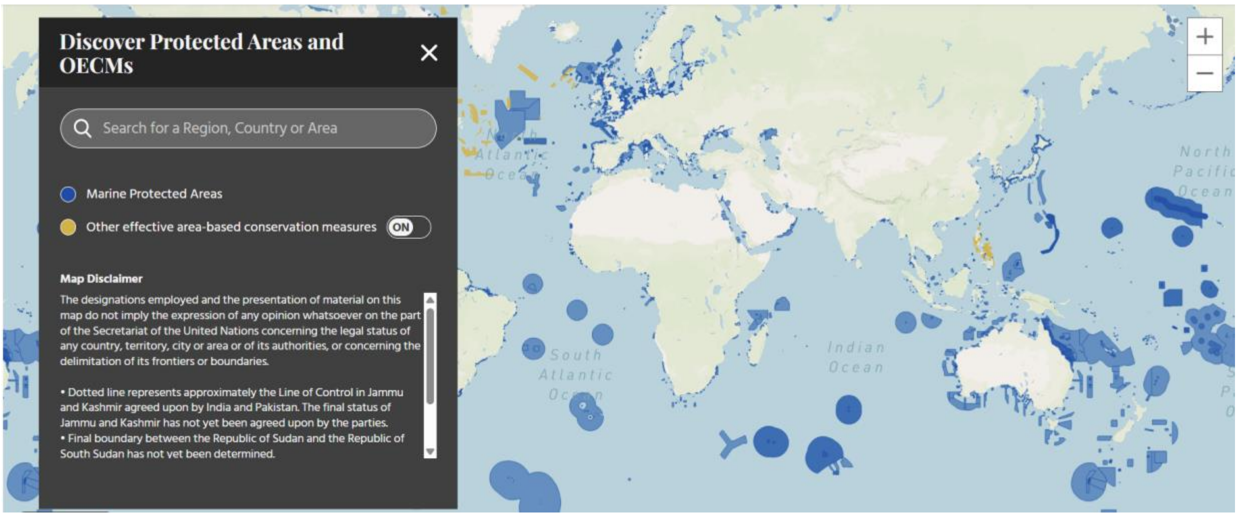


Global pressures on marine life. Source: https://www.nature.com/articles/s41586-020-2146-7.

This is one of the key ideas behind ocean optimism. Hope for the future of the ocean is not based on wishful thinking. It is based on the scientific idea that positive change can happen when action is taken and sustained over time.

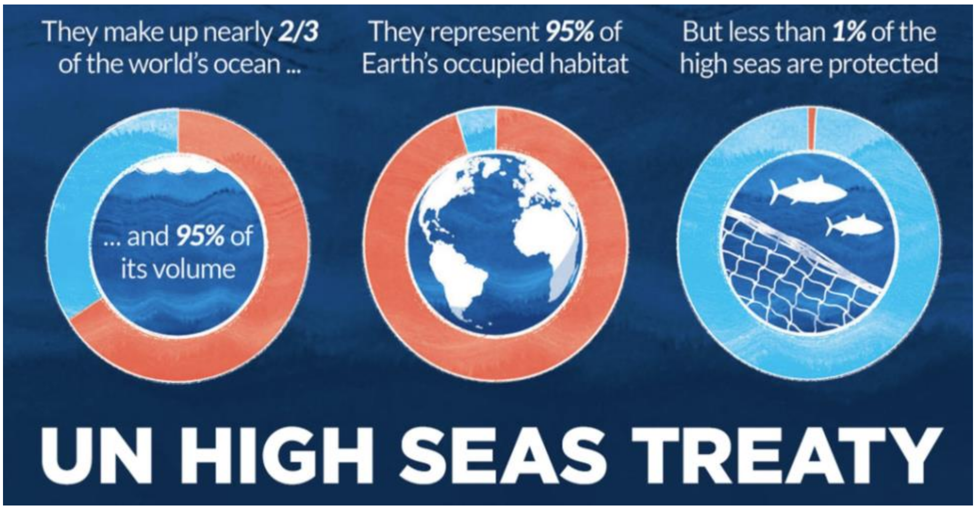
The most effective tool in this effort is **protection**.

When we shield marine ecosystems from their most damaging stressors, we preserve their biological integrity and functional resilience. This can take many forms: safeguarding a single vulnerable species, restricting harmful activities in sensitive zones, early detecting and removing invasive species or establishing Marine Protected Areas (MPAs) to conserve entire habitats. Because many ecosystems face a "perfect storm" of simultaneous pressures, reducing even a few of these stressors creates the vital window of opportunity for life to return.



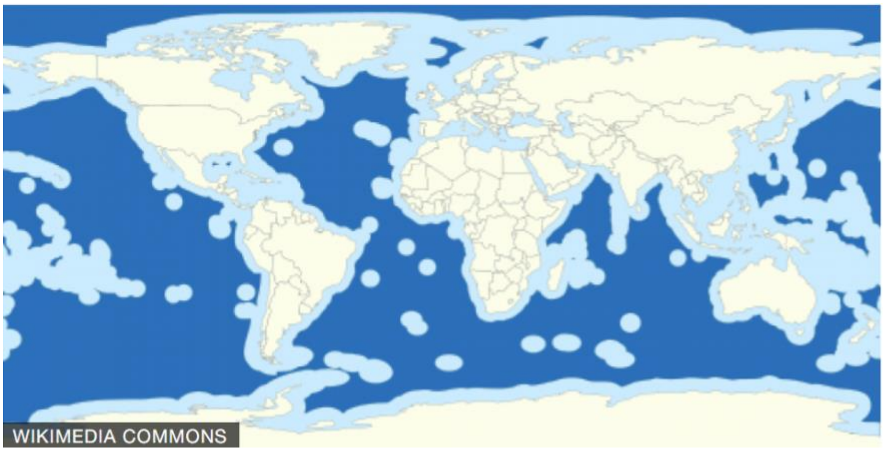
You can discover the MPAs in the world, using this link of Protected Planet, where 16,805 MPAs are presented *https://www.protectedplanet.net/en/thematic-areas/marine-protected-areas.*

The efforts to protect marine ecosystems are now moving beyond our coastlines and into the vast expanse of the open ocean. A landmark step in this journey is the **High Seas Treaty** (the Biodiversity Beyond National Jurisdiction Agreement).



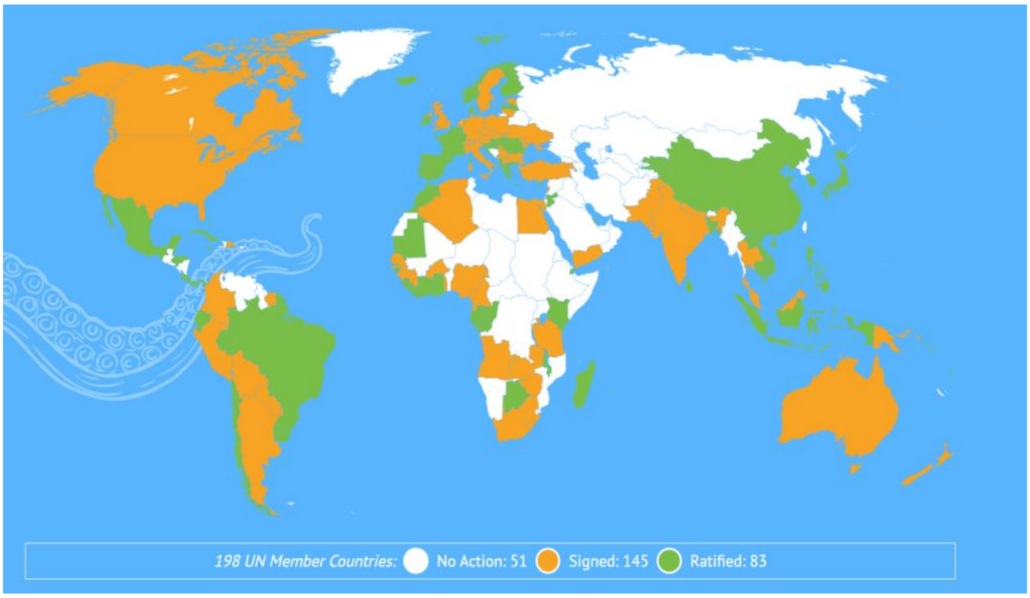
Bridging the protection gap: The High Seas Treaty aims to safeguard the 95% of Earth's occupied habitat that remains largely unprotected.

This legally binding United Nations treaty governs the waters beyond national border regions or Exclusive Economic Zone (EEZ) (> 200 miles), which cover two-thirds of the ocean's surface and represent more than 90% of Earth's living habitat. For generations, these waters were a "wild west," difficult to govern and largely unprotected. The treaty establishes a framework for inclusive ocean governance, recognizing that we must address climate change, biodiversity loss, and pollution as a single, connected crisis (see for instance the "One Ocean" projection: https://oceanservice.noaa.gov/facts/howmanyoceans.html.)



Mapping the boundary between national coastal waters (light blue) and the vast High Seas (dark blue) that cover the majority of our planet.

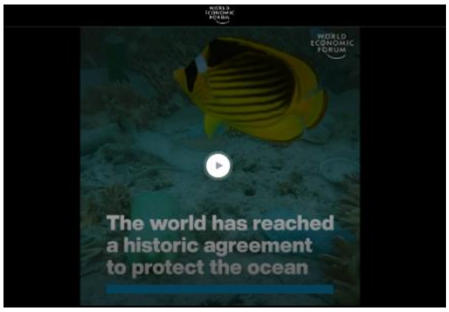
While 81 nations have already ratified the agreement, the path forward requires global unity; several major economies, including the US, India, the UK, and Russia, have yet to join. This progress is critical because the health of the ocean is not confined by maps. Recovery depends on how humanity governs the sea as a shared, global system. When protection expands and our responsibilities become clear, the horizon for long-term recovery grows stronger.



Treaty ratification map.
You can visit the website and track progress: https://highseasalliance.org/treaty-ratification/map/.

Watch this video

Learn more about the High Seas Treaty and how it works: https://www.weforum.org/videos/the-world-has-reached-a-historic-agreement-to-protect-the-ocean/

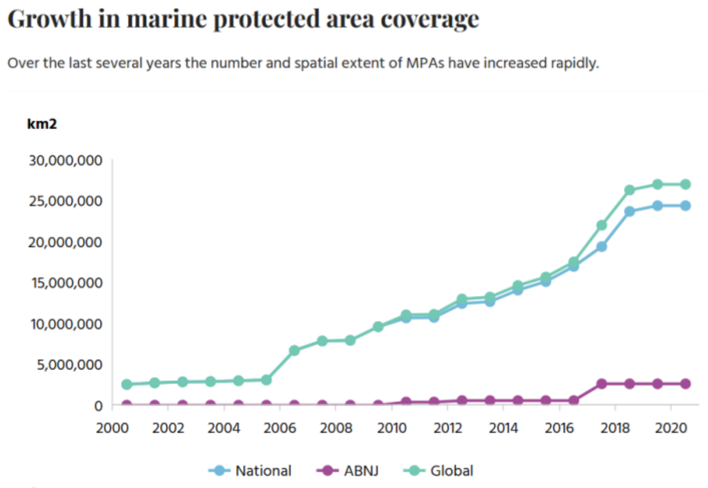


Read this

Protection, however, is only one piece of the puzzle. Across the globe, many ecosystems have already crossed a threshold of damage where simply lifting pressures is no longer enough. Habitats have been erased, populations decimated, and the delicate ecological threads that bind them together have been snapped. In these wounded landscapes, active **restoration** becomes the essential next step.

One of the most visible examples is the global ambition to **protect 30% of the ocean by 2030**. This target does not guarantee recovery on its own, but it provides direction. It helps turn concern into measurable ambition, and ambition into accountability. It also sends an important signal: that protecting the ocean at scale is not an unrealistic aspiration, but a shared objective.

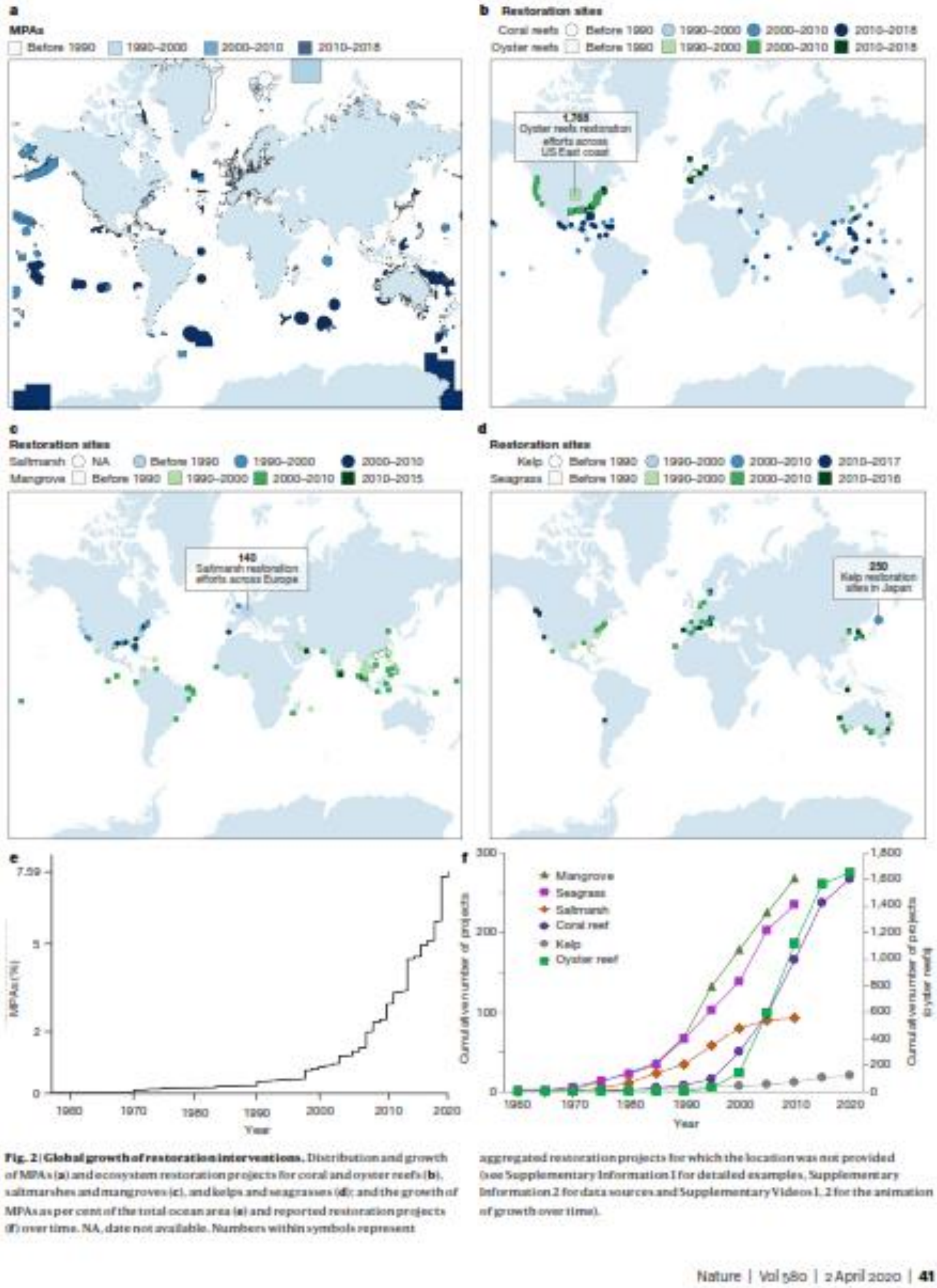
Progress is still uneven and much remains to be done. But the expansion of marine protected areas (MPAs) in recent years shows that change is possible when goals are defined and supported by action.



We are still far from the objective of 30% but in recent years the increase in the areas protected is impressive, and we have near 3 times the surface protected 10 years ago. Source: https://www.protectedplanet.net/en/thematic-areas/marine-protected-areas.

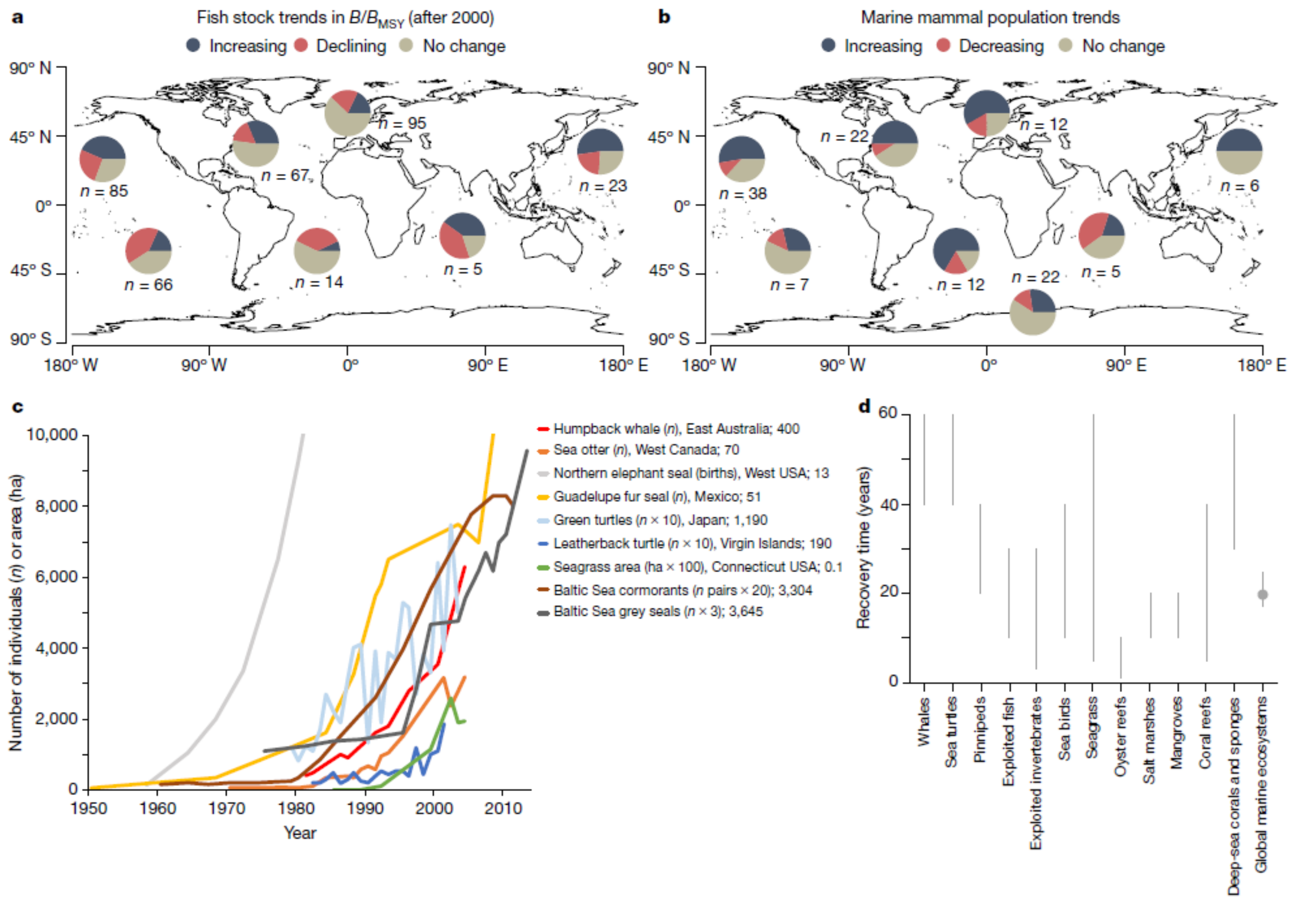
Restoration implies actively helping ecosystems to recover. It is the replanting of seagrasses, the rebuilding of oyster and coral reefs, and the careful reintroduction of species to fragmented and degraded habitats. While these interventions are often slow, costly and demanding, they are the vital catalysts that help an ecosystem regain the functions necessary to support both biodiversity and human society.

The global surge in restoration projects is perhaps the most convincing evidence that marine recovery has moved from a hopeful concept to a practical reality. We are seeing an unprecedented rise in efforts to restore salt marshes, mangroves, kelp forests, and seagrass meadows, often within the safety of Marine Protected Areas (MPAs). This shift reflects a maturing understanding of the ocean: recovery requires active, sustained investment, not just protection on paper.



Global growth of restoration interventions, in MPAs, coral and oyster reefs, saltmarshes and mangroves, and kelps and seagrasses. Source: https://www.nature.com/articles/s41586-020-2146-7.

These trends show that when management is adequately undertaken, marine populations exhibit remarkable resilience. We are no longer just imagining a healthier ocean; people in every corner of the world are already building it.



Recovery trends of marine populations, such as assessed fish stocks and marine mammals, with many examples of hope, if management is adequately undertaken. Source: https://www.nature.com/articles/s41586-020-2146-7.

Read this

Recovery also rests upon a foundation that is less visible than a returning species but just as critical: **governance**.

Protection and restoration do not exist in a vacuum; they require the scaffolding of policies, laws, and international cooperation. Without robust systems to set priorities and coordinate action, even the most well-intentioned projects risk being short-termed or isolated.

This is why recovery so often depends on frameworks that bridge the gap between science and policy. In Europe, this trajectory is visible in ambitious environmental legislation and restoration targets. The lesson here is clear: recovery becomes a reality not through a single "silver bullet" policy, but through durable, long-term commitments that outlast temporary projects.

Another reason recovery can happen is that societies are beginning to define clearer goals for the ocean.

Taken together, these examples show that recovery is usually built on several foundations at once.

It needs protection, so ecosystems have space to recover.

- It needs restoration, so damaged habitats and populations can be actively supported.
- It needs governance, so action is coordinated and maintained.
- And it needs time, because marine recovery is rarely immediate.

This is what lies behind many of the success stories explored in this module. Recovery is not magic. It is the result of human choices, long-term effort, and a willingness to give the ocean a chance to respond.

Check your understanding

[Multiple choice]

1. What helps make marine recovery possible?

a) Waiting for ecosystems to recover on their own
b) Protection, restoration, governance, and long-term commitment
c) Communication alone
d) Protecting only one species at a time

Correct answer: b)

2. Why is the High Seas Treaty important?

a) Because it focuses only on coastal tourism
b) Because it creates a stronger framework for governing and protecting ocean areas beyond national waters
c) Because it replaces all national marine policies
d) Because it applies only to fishing

Correct answer: b)

[True or False]

Marine recovery is usually supported by a combination of reduced pressures, active measures, and long-term commitment.

Correct answer: True

8.7 Lesson 4: Science, ocean recovery, and the ocean we want

In this lesson, you will explore how science helps make marine recovery possible, and how scientific knowledge can guide protection, restoration, and action for the future of the ocean.

By the end of this lesson, you should be able to:

- Explain why science is essential for marine protection and restoration.
- Identify examples of scientific action that support ocean recovery.
- Recognise how science helps shape a more informed and hopeful vision for the future of the ocean.

Read this

Behind every story of marine recovery, there is often another story running quietly in the background: the story of science.

Science helps us understand what is changing in the ocean, identifying where biodiversity is declining, which ecosystems are most vulnerable, and which interventions are most likely to succeed. Without it, we might sense that something is wrong, but we would struggle to understand why. We might hope for improvement, but we would lack the metrics to prove that recovery is actually taking place. This is why ocean optimism is built on more than just positive anecdotes; it is built on scientific evidence. Hope gains its true strength when it is anchored in knowledge.

Science acts as a vital tool in the recovery process through three primary functions:

- Identification: It diagnoses the state of ecosystems and the specific pressures driving their degradation.
- Monitoring: It tracks progress over time. Because recovery is often slow and uneven, careful scientific observation is the only way to detect the subtle signs of both impacts and life returning.
- Guidance: It directs our efforts by showing which habitats are most critical to restore and which management measures are most likely to yield results.

In this way, science does not sit outside marine recovery. It is one of the tools that makes recovery possible.

Marine ecological restoration in soft and hard-bottom shallow-water habitats following established and standardised protocols. Upper panels: a nursery for brown macroalgae to aid in restoring hard bottoms at shallow depths (left panel) and the transplant of habitat-forming species (e.g., gorgonians) for hard-bottom restoration in the Western Mediterranean Sea (right panel). Lower panels: transplant of the endemic Mediterranean seagrass (Posidonia oceanica) (left); cultivation of pillow corals (e.g., Cladocora caespitosa) on hard bottoms (central); rearing of deep-water corals for subsequent transplanting into a defaunated deep-sea habitats (right). Source: https://doi.org/10.1038/s41467-025-57254-2.

Today, this knowledge combines diverse scientific disciplines. Researchers map the seabed to reveal hidden habitats, use environmental DNA (eDNA) to detect species from mere traces of genetic material, and rely on satellites to observe vast oceanic patterns. They study "blue carbon" systems—like mangroves, salt marshes, and seagrasses—to understand how coastal health supports both climate regulation and biodiversity. Each approach reveals a different chapter of the ocean’s story, building a clear picture of risk, change, and opportunity.

This relationship between science and action is captured well in the idea of **“the science we need for the ocean we want.”**

The **UN Decade of Ocean Science for Sustainable Development**, which runs from 2021 to 2030, was built around this phrase. Its message is simple: a healthy, resilient ocean requires scientific guidance to get us there.

The central message of the UN Decade of Ocean Science for Sustainable Development.

This initiative connects research to a broader social purpose. It is not science for its own sake, but science that fuels protection, sustainable management, and better decision-making. By connecting researchers, policymakers, and communities, it fosters a shared vision for the future of our waters.

Watch this video

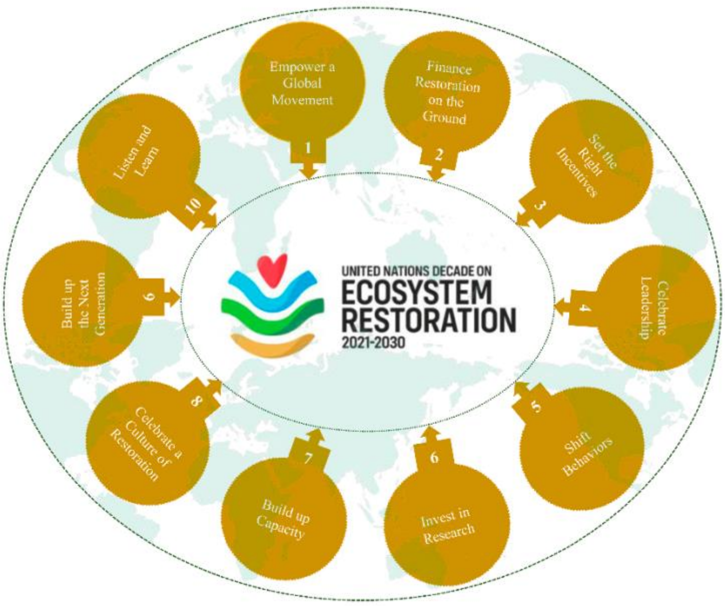
Watch the following video to learn more about the United Nations Decade of Ocean Science for Sustainable Development: https://www.youtube.com/watch?v=EO2Un-6nIS4

Curious about the details? Visit https://oceandecade.org/decade-actions/ and find the actions connected to the UN Decade of the Oceans 2021-2023, including mapping the seabed, eDNA expeditions, satellite observations, blue carbon studies, and more.

Read this

Marine recovery is also part of a wider movement to restore nature.

The **UN Decade on Ecosystem Restoration**, also running from 2021 to 2030, aims to prevent, halt, and reverse the loss of nature across the planet, an ambition reflected in Europe's own restoration targets.



Ten-point action plan for restoring the vitality of the global ecosystem during the UN Decade on Ecosystem Restoration (2021–2030). Source: https://doi.org/10.3390/land10020201.

These initiatives show that restoring the ocean is now recognized as a fundamental response to biodiversity loss and climate change. Recovery is becoming the cornerstone of how societies imagine a healthier future.

Learn more about the UN Decade on Ecosystem Restoration: https://www.decadeonrestoration.org/

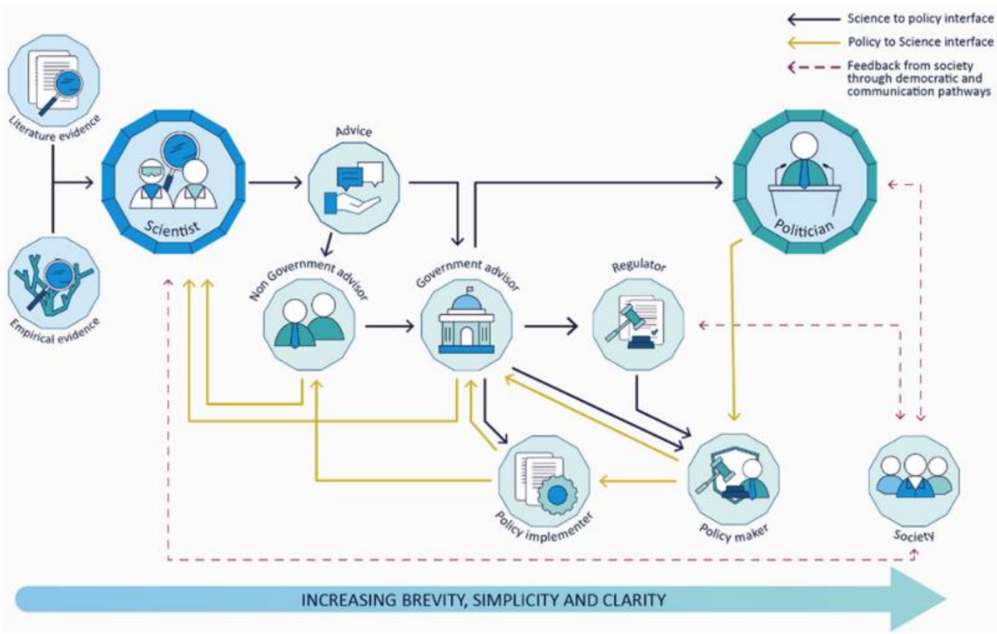
Science is especially important because marine recovery is not always straightforward.

Ecosystems do not all respond in the same way. Some rebound quickly, while others require centuries or the careful restoration of complex ecological relationships. This inherent complexity means that recovery cannot be guided by optimism alone; it demands constant observation and learning.

This is the power of the alliance between science and ocean optimism. Science keeps hope grounded, distinguishing real progress from empty promises. It shows us where our hope is justified and where more work remains.

Seen in this light, science does more than describe the ocean. It helps shape what is possible.

- It tells us where the damage is.
- It helps identify what can be restored.
- It shows when recovery is beginning.
- And it helps societies act with greater clarity and purpose.



A map of how evidence moves from the lab to the legislative floor, ensuring that ocean recovery is guided by data and supported by society.

Check your understanding

[Multiple choice]

1. Why is science important for marine recovery?
a) Because it replaces the need for policy and action
b) Because it helps understand change, guide action, and monitor recovery
c) Because it only applies to deep-sea ecosystems
d) Because recovery always happens automatically once data are collected
Correct answer: b)

2. What is the main idea behind the phrase "the ocean we want"?
a) The ocean should be left entirely untouched
b) A healthy ocean depends on the science needed to guide protection, restoration, and management
c) Science is less important than communication
d) Ocean recovery depends mainly on individual choices
Correct answer: b)

[True or False]
Science helps make ocean optimism more credible because it provides evidence of what is changing and what is working.
Correct answer: True

8.8 Lesson 5: Ocean literacy and the future of our seas

In this lesson, you will bring together the main ideas of the module and reflect on why ocean optimism matters for the future of the ocean and for society.

By the end of this lesson, you should be able to:

- Summarise the main ideas explored throughout the module.
- Explain why ocean literacy, hope, and action are closely connected.
- Recognise the role of education in building a more informed and engaged relationship with the ocean.

Read this

Throughout this module, one message has resonated above all: the future of the ocean is not fixed.

The sea faces serious and urgent pressures. Pollution, biodiversity loss, habitat degradation, overexploitation, and climate change continue to challenge marine ecosystems across the globe. These problems cannot be ignored. But they are not the whole story. As we have seen, the narrative is also defined by recovery: by species returning, habitats improving, restoration efforts accelerating, and scientific and political initiatives supporting long-term action.

This is the essence of ocean optimism. It does not replace concern with comfort; instead, it balances concern with the evidence that positive change is possible.

By now, it should be clear that ocean optimism is built on a framework of connected elements:

- **knowledge** that helps us understand the ocean,
- **protection** that reduces the weight of human pressure,
- **restoration** that actively helps ecosystems recover,
- **governance** that ensures action is sustained over time,
- and **communication** that keeps society engaged and informed.

When these elements align, hope becomes more than a sentiment. It becomes a way of understanding the future that is grounded in action.

This is where ocean literacy becomes especially important.

Ocean literacy helps people understand the ocean's influence on us and our influence on the ocean. It connects scientific understanding with everyday choices, social responsibility, and long-term care. In this sense, ocean literacy is not only about knowledge. It is also about relationships and making inform-decisions that are responsible with the ocean.

It helps us see the ocean not as a distant expanse, but as a system deeply connected to our climate, food, culture, and life on Earth.

For teachers, this is especially relevant. Education is not only about providing information; it is about shaping how students relate to the world. As Jacques Yves Cousteau once famously said:

"We only protect what we love,
we only love what we understand,
and we only understand what we are taught."

If the ocean is always presented as a distant ecosystem and a place beyond repair, students may struggle to imagine themselves as part of the solution. First, they need to feel connected with the ocean and feel that are part of this ecosystem. Then, if they learn that ecosystems can recover, that communities can make a difference, and that science can guide action, they are far more likely to feel involved and responsible.

Teachers help shape how younger generations perceive environmental change. They create the space for scientific thinking, ethical reflection, and practical engagement—turning concern into curiosity, and curiosity into action. In this way, education does not sit at the edge of ocean recovery; it is an active part of it.

Initiatives like the **Network of European Blue Schools** demonstrate how education can bring the ocean into everyday learning. This approach encourages schools to connect marine themes with various subjects and the realities of local communities, reflecting the idea that learning should not be confined to a single discipline. These initiative supports teachers across Europe in bringing the ocean into the classroom in flexible and meaningful ways.

Learn more about ocean literacy:

https://cdn.oceanservice.noaa.gov/oceanserviceprod/education/literacy/ocean-literacy-english.pdf

The Network of European Blue Schools is promoting the inclusion of the ocean in school curricula, enabling schools to obtain the European Blue School Certification. To date, more than 500 schools have already been certified. More info: https://maritime-forum.ec.europa.eu/theme/ocean-literacy-and-blue-skills/ocean-literacy/network-european-blue-schools_en

The growth of ocean literacy, alongside progress in science, restoration, and protection, provides a reason to move forward. There is still much to be done — recovery remains uneven and pressures remain intense — but there are also immense knowledge and momentum.

This is the wider meaning of ocean optimism. It is a way of seeing the future of the ocean not as something already decided, but as a horizon still open to learn about, care, change and consider as our collective responsibility.

Watch this video

Ocean literacy is defined as the understanding of our influence on the ocean and the ocean's influence on us. Learn more on the following video: https://www.youtube.com/watch?v=8eTFvLe4biY

More resources about ocean literacy: https://www.marine-ed.org/ocean-literacy/overview

Check your understanding

[Multiple choice]

1. Which of the following best describes the core framework of "Ocean Optimism"?
a) Assuming the ocean will naturally recover without human intervention.
b) Replacing scientific concerns with comfortable, positive stories.
c) A synergy of knowledge, protection, restoration, governance, and communication.
d) Ignoring industrial pressures to focus exclusively on local education.
Correct answer: c)

2. Why is the role of teachers and education vital for marine recovery?
a) Because it turns environmental concern into curiosity and actionable engagement.
b) Because scientific data is only useful if it is taught in universities.
c) Because education is the only foundation required for an ecosystem to heal.
d) Because students should only be taught about the ocean's beauty, not its challenges.
Correct answer: a)

[True or False]
The concept of "30×30" and the Network of European Blue Schools are examples of how clear goals and structured frameworks help turn ambition into measurable action.
Correct answer: True

9. Conclusion

As stated at the beginning of this deliverable, the aim of the GES4SEAS educational modules is to translate the project's scientific knowledge, tools and key messages into accessible, flexible and classroom-ready resources for teachers, marine educators and learners. The modules were designed to support ocean literacy by helping audiences understand why healthy seas matter, how human pressures affect marine ecosystems, and how science-based management can contribute to maintaining or restoring Good Environmental Status. Across the six modules, the educational pathway follows a clear storyline. It starts by showing the strong links between healthy seas and healthy human societies, then introduces the complexity of cumulative pressures and explains why their combined effects are not always easy to predict. The modules then move towards the concept of Good Environmental Status, using the Black Sea as an example to connect environmental condition with human health and wellbeing. This is followed by an exploration of tipping points, highlighting how small changes can trigger major ecosystem shifts if pressures are not properly managed. The pathway then introduces Ecosystem-Based Management as a practical and adaptive approach to balance human uses with the conservation of marine ecosystems. Finally, the sequence closes with ocean optimism, shifting the narrative from degradation alone towards recovery, solutions and collective responsibility. In this way, the modules do not simply present isolated topics, but guide learners from understanding the value of the ocean, to recognising threats, exploring management responses, and identifying reasons for informed and hopeful action. To ensure the long-term use and legacy of these materials, the modules will be made available through the GES4SEAS website and hosted or disseminated through established ocean-literacy platforms and networks, including the OceanTeacher Global Academy of IOC-UNESCO, EuroGOOS, REEDUCAMAR and the Network of European Blue Schools. This will help ensure that the resources remain findable, freely accessible and useful beyond the lifetime of the project, reaching educators and learners across different geographical and educational contexts. Ultimately, the ambition is that the scientific work carried out in GES4SEAS can be taken up by teachers and educators as a practical support for bringing marine science into classrooms and learning spaces. By making this knowledge understandable and engaging, the project hopes to contribute to citizens, and especially younger generations, developing a stronger science-based understanding of the ocean. Such knowledge is essential not only to appreciate the importance of marine ecosystems, but also to question information critically, recognise the consequences of human activities, and feel empowered to act proactively in favour of healthier seas and more sustainable societies.

2026