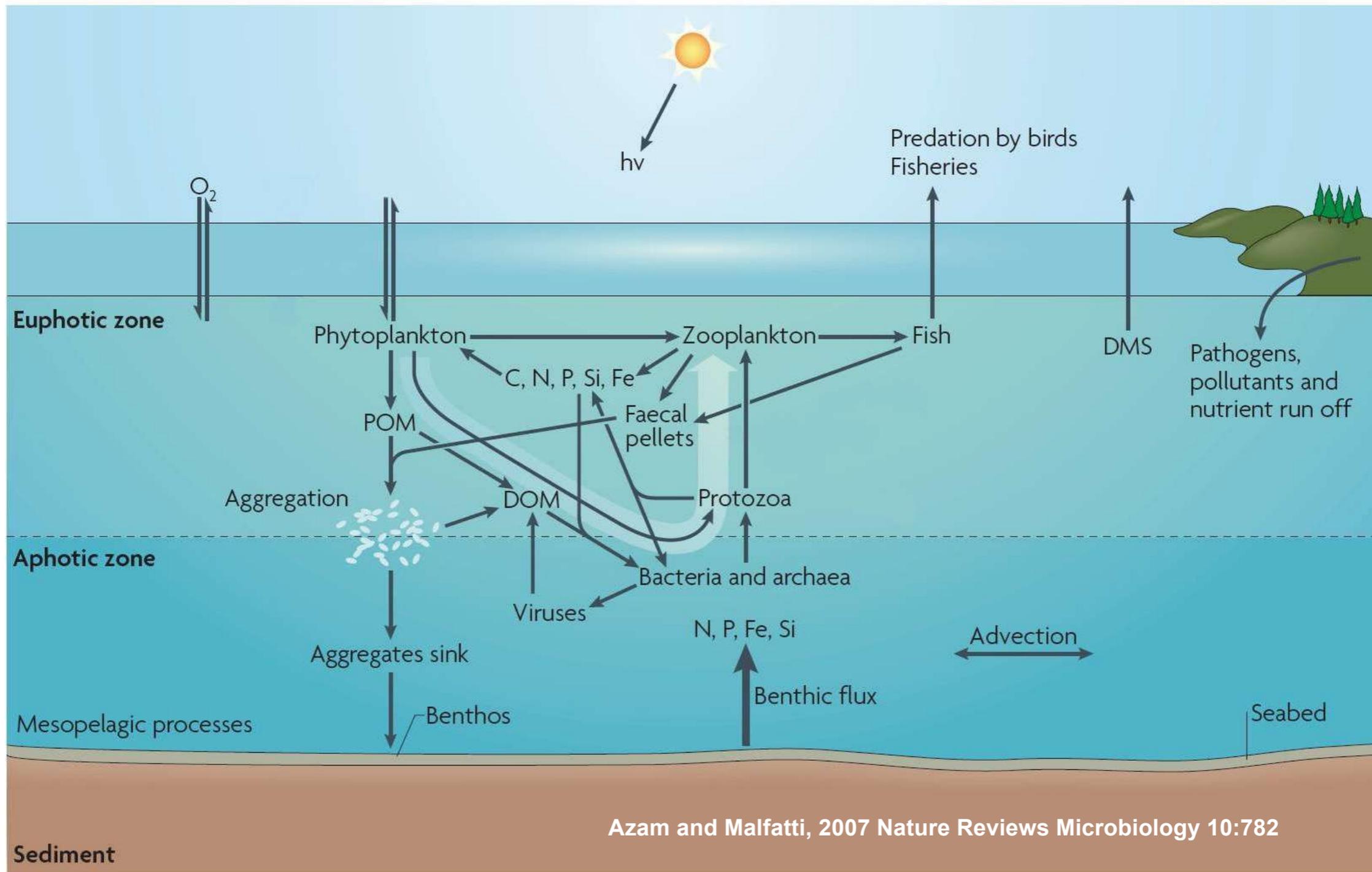


L06b:

Marine Microbes and Society

Microbial fingerprint on planet Earth and Human Society



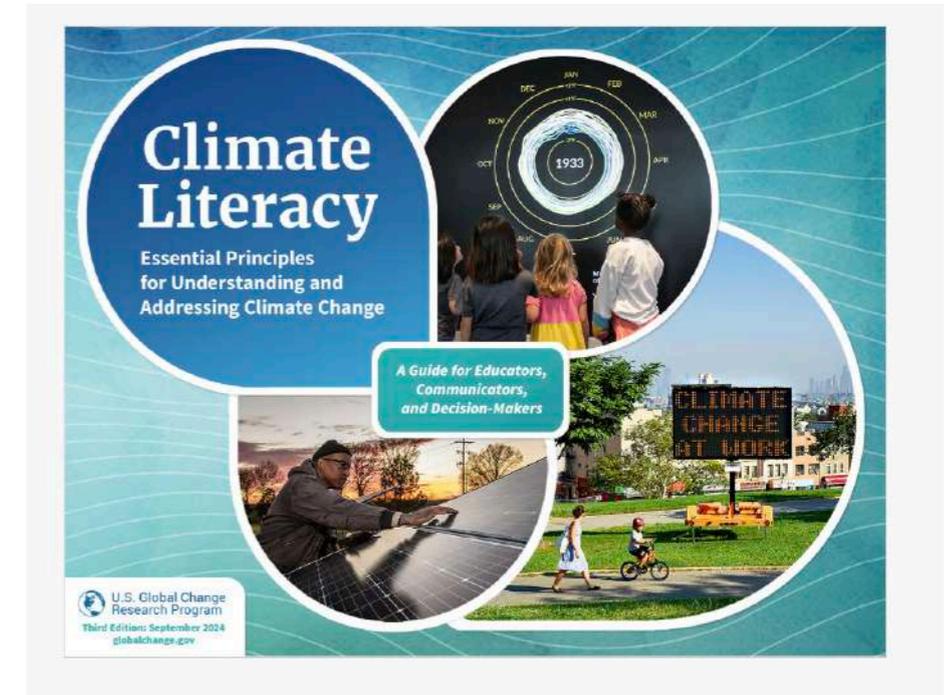
Climate

Climate Literacy

Essential Principles for Understanding and Addressing Climate Change

A Guide for Educators, Communicators, and Decision-Makers

Third Edition: September 2024



A climate-literate person:

- understands the essential principles of Earth's climate system and the options to address human-caused climate change, which are summarized in this guide;
- recognizes credible information about climate change and knows where to find it;
- communicates about climate change in accurate and effective ways; and
- is able to make informed decisions related to climate change.

Climate Literacy Essential Principles

1

HOW WE KNOW

Scientists understand the climate system through interdisciplinary observations and modeling.

3

CAUSES

Burning fossil fuels and other human activities are causing the planet to warm.

5

EQUITY

Climate justice is possible if climate actions are equitable.

7

MITIGATION

Reducing emissions of greenhouse gases from human activities to net zero by 2050 can help limit global warming and climate change impacts.

2

CLIMATE CHANGE

Greenhouse gases shape Earth's climate.

4

IMPACTS

Rapid warming and other large-scale climate changes threaten human and ecological systems.

6

ADAPTATION

Humans can adapt social, built, and natural environments to better withstand the impacts of climate change.

8

HOPE AND URGENCY

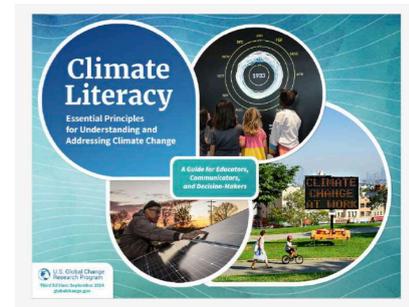
A livable and sustainable future for all is possible with rapid, just, and transformational climate action.

Climate Literacy

Essential Principles for Understanding and Addressing Climate Change

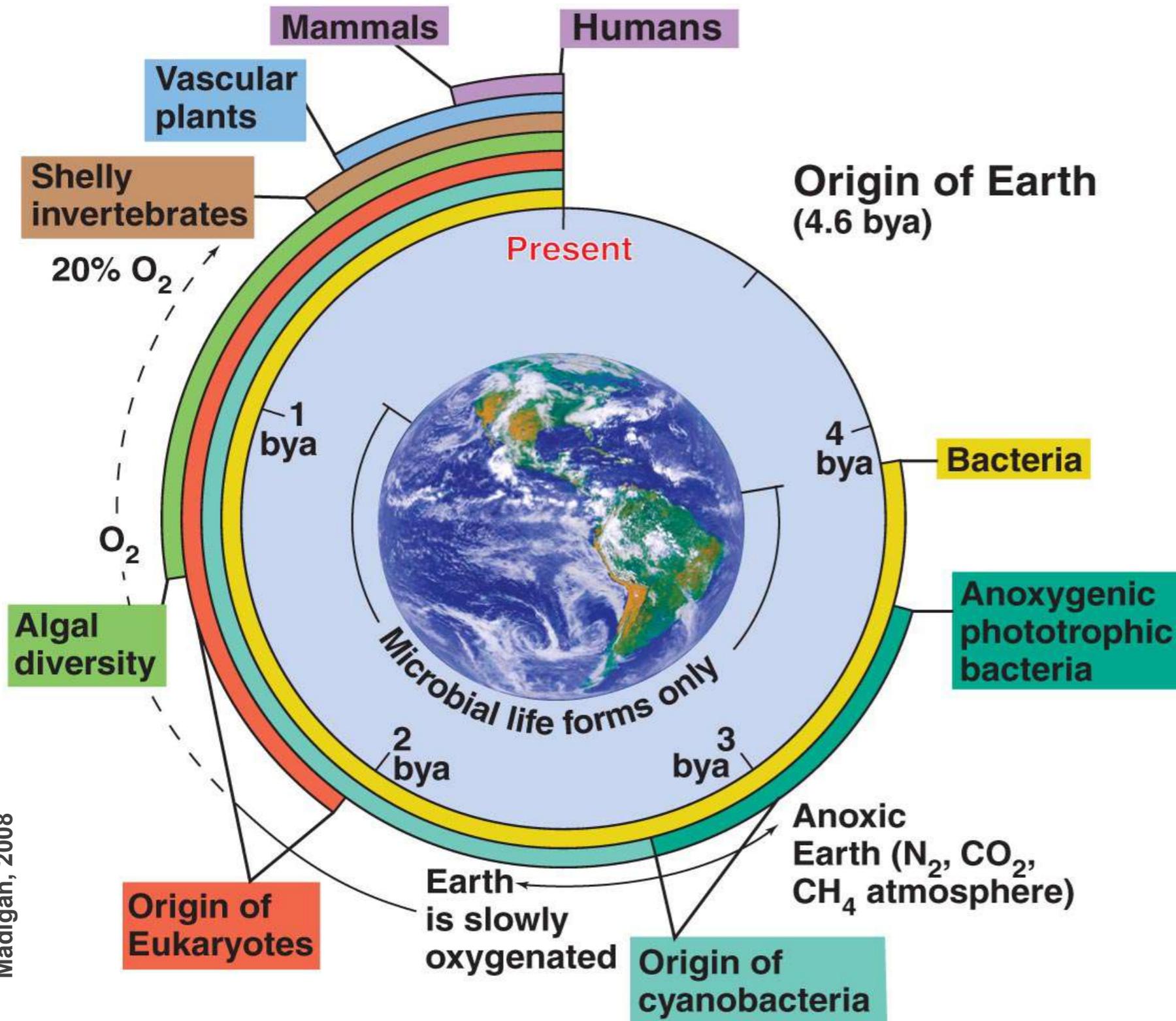
A Guide for Educators, Communicators, and Decision-Makers

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Microbes and Society: how to integrate Microbes in Ocean planet management?

Microbes and Ecosystem Services



- Bacteria and Archaea have invented biogeochemistry on Earth
- We are in the Anthropocene (no more Holocene)
- The baseline and the old knowledge have changed

Ecosystem & Ecosystem services

Ecosystems consist of organisms, their environments, and all of the **interactions among the organisms and environments**

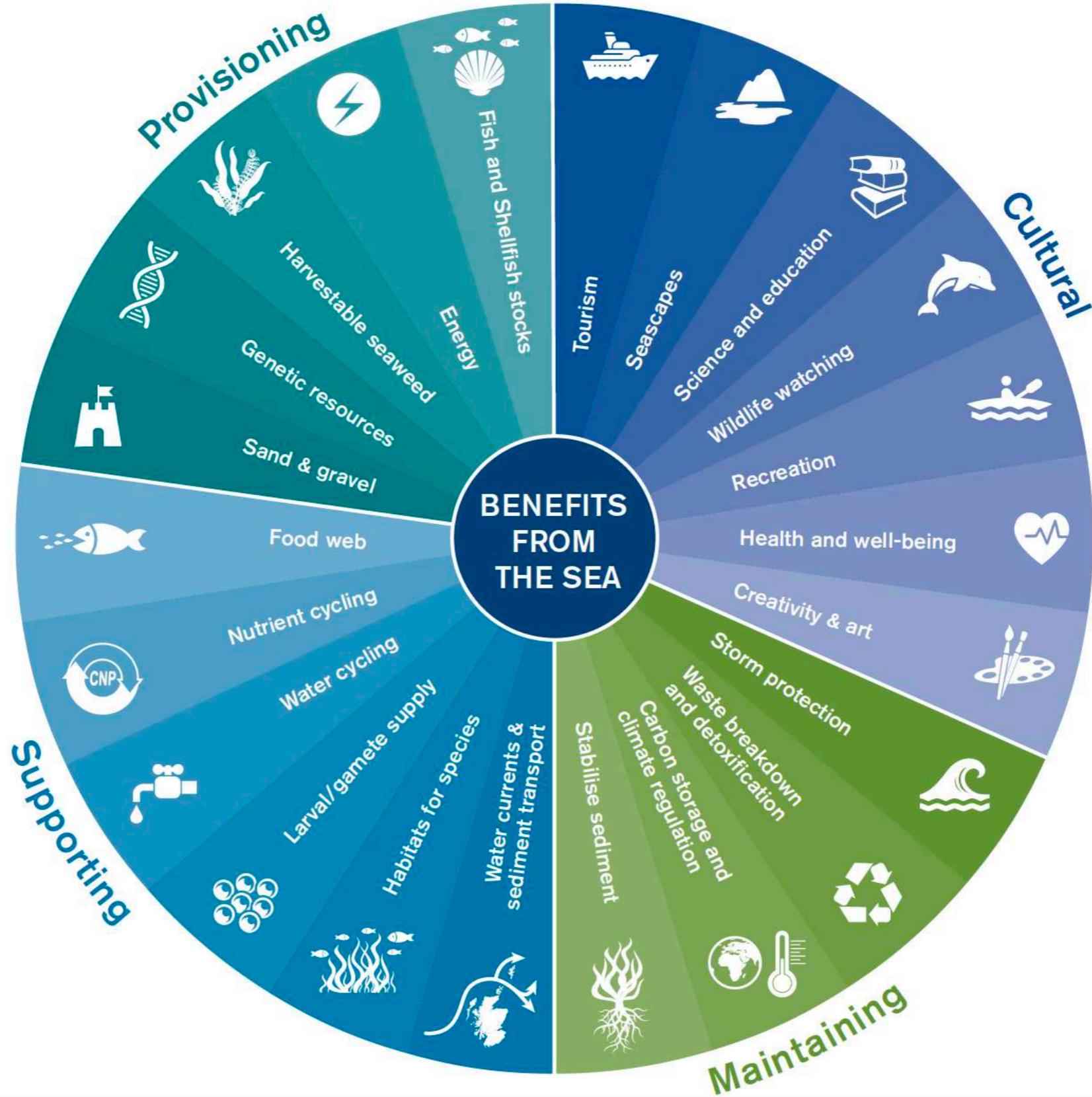
The organisms are members of populations and communities and are adapted to habitats → species richness and abundance

Ecosystem services: outputs, conditions, or processes of natural systems that directly or indirectly benefit humans or enhance social welfare

<https://www.millenniumassessment.org/en/index.html>



source: *Final Recommendations of the Interagency Ocean Policy Taskforce, 2010*



<https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy-and-cop15/ecosystem-approach/ecosystem-services-natures-benefits>

Marine and coastal ecosystems produce various services, including:

- Provisioning services: fisheries, building materials;
- Supporting services: life-cycle maintenance for both fauna and local, element and nutrient cycling;
- Regulating services: carbon sequestration and storage, erosion prevention, waste-water treatment, moderation of extreme events;
- Cultural services: tourism, recreational, aesthetic, and spiritual benefits.

<https://ocean-climate.org/en/marine-and-coastal-ecosystem-services/>

<https://www.millenniumassessment.org/en/index.html>

Microbes drive ecosystem services

Table 1 | Major groups of microbes and ecosystem services they provide.

Microbial group	Process	Ecosystem service	Ecosystem service category
Heterotrophic bacteria/ archaea	Organic matter breakdown, mineralization	Decomposition, nutrient recycling, climate regulation, water purification	Supporting and regulating
Photoautotrophic bacteria	Photosynthesis	Primary production, carbon sequestration	Supporting and regulating
Chemo(litho)autotrophic	Specific elemental transformations (e.g., NH_4^+ , S_2^- , Fe_2^+ , CH_4 oxidation)	Nutrient recycling, climate regulation, water purification	Supporting and regulating
Unicellular phytoplankton	Photosynthesis	Primary production, carbon sequestration	Supporting and regulating
Archaea	Specific elemental transformation (e.g., metals, CH_4 formation, NH_4^+ oxidation), often in extreme habitats.	Nutrient recycling, climate regulation, carbon sequestration	Supporting and regulating
Protozoa	Mineralization of other microbes	Decomposition, nutrient recycling, soil formation	Supporting
Fungi	Organic matter breakdown and mineralization	Decomposition, nutrient recycling, soil formation, primary production (i.e., mycorrhizal fungi)	Supporting
Viruses	Lysis of hosts	Nutrient recycling	Supporting
All	Production of metabolites (e.g., antibiotics, polymers), degradation of xenobiotics, genetic transformation, and rearrangement	Production of precursors to industrial and pharmaceutical products	Provisional
All	Huge diversity, versatility, environmental and biotechnological applications	Educational purposes, getting students interested in science	Cultural

*The last column depicts the ecosystem service category as was defined in the Millennium Ecosystem Assessment (2005).
Modified from Ducklow, 2008.*

Microbial life provides ecosystem services

Unique goal of microbial life: survival, maintenance, generation of ATP (energy storage), reducing power, growth of new cells

Decomposition, nutrient recycling, climate regulation, water purification

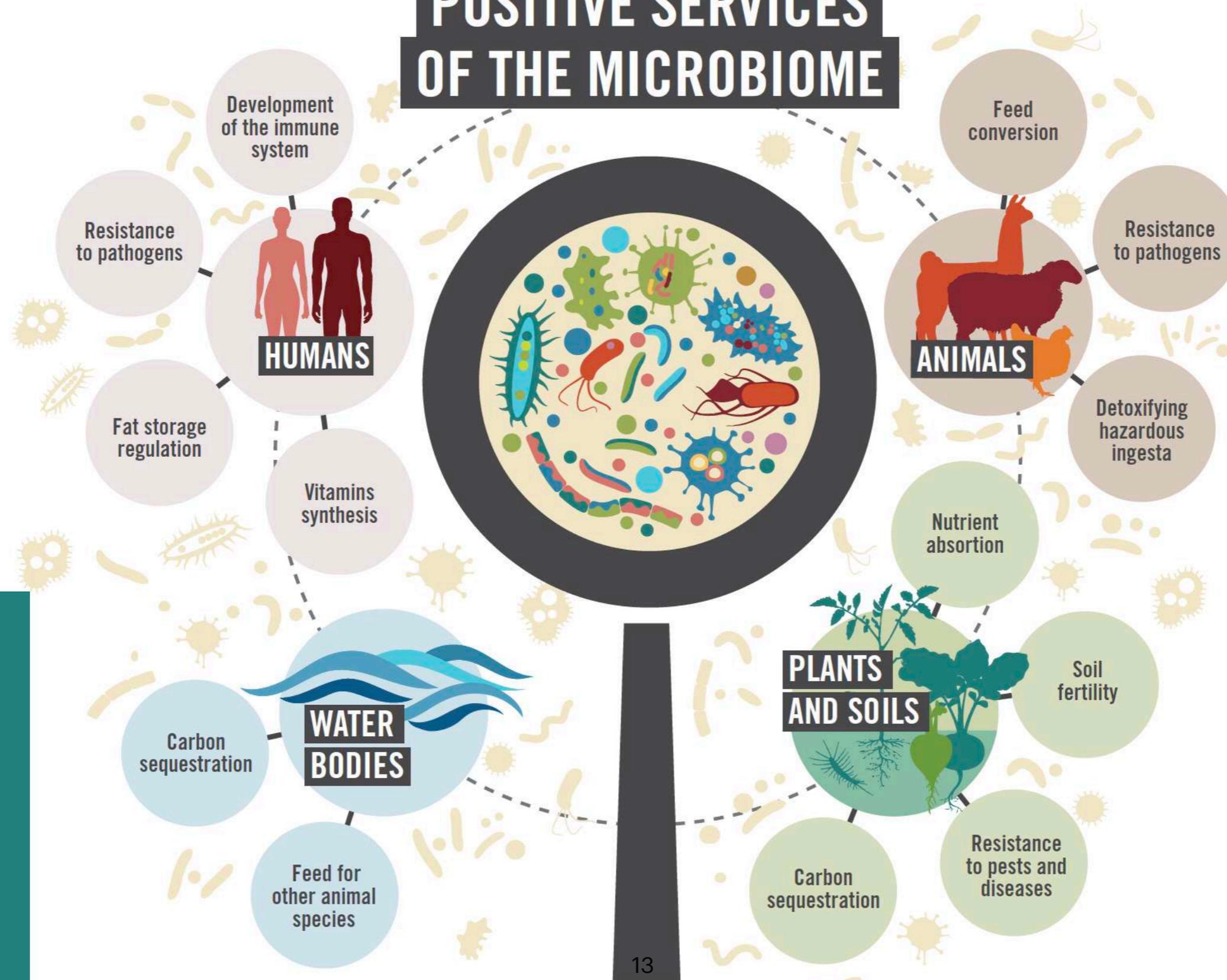
Primary production, carbon sequestration

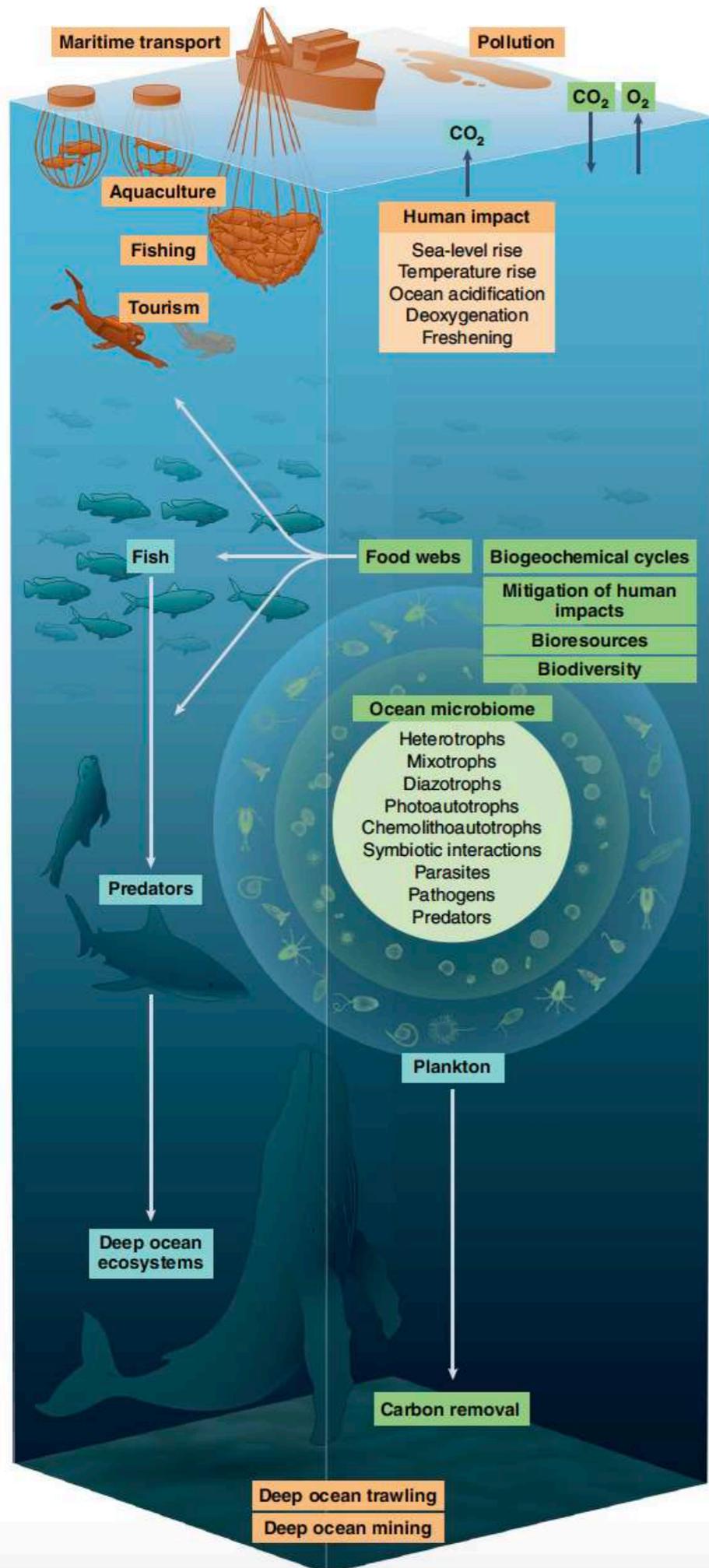
Nutrient recycling, climate regulation, water purification

..... in an ecosystem context

Microbial functions on Earth Ecosystems

POSITIVE SERVICES OF THE MICROBIOME





Roles of the ocean microbiome

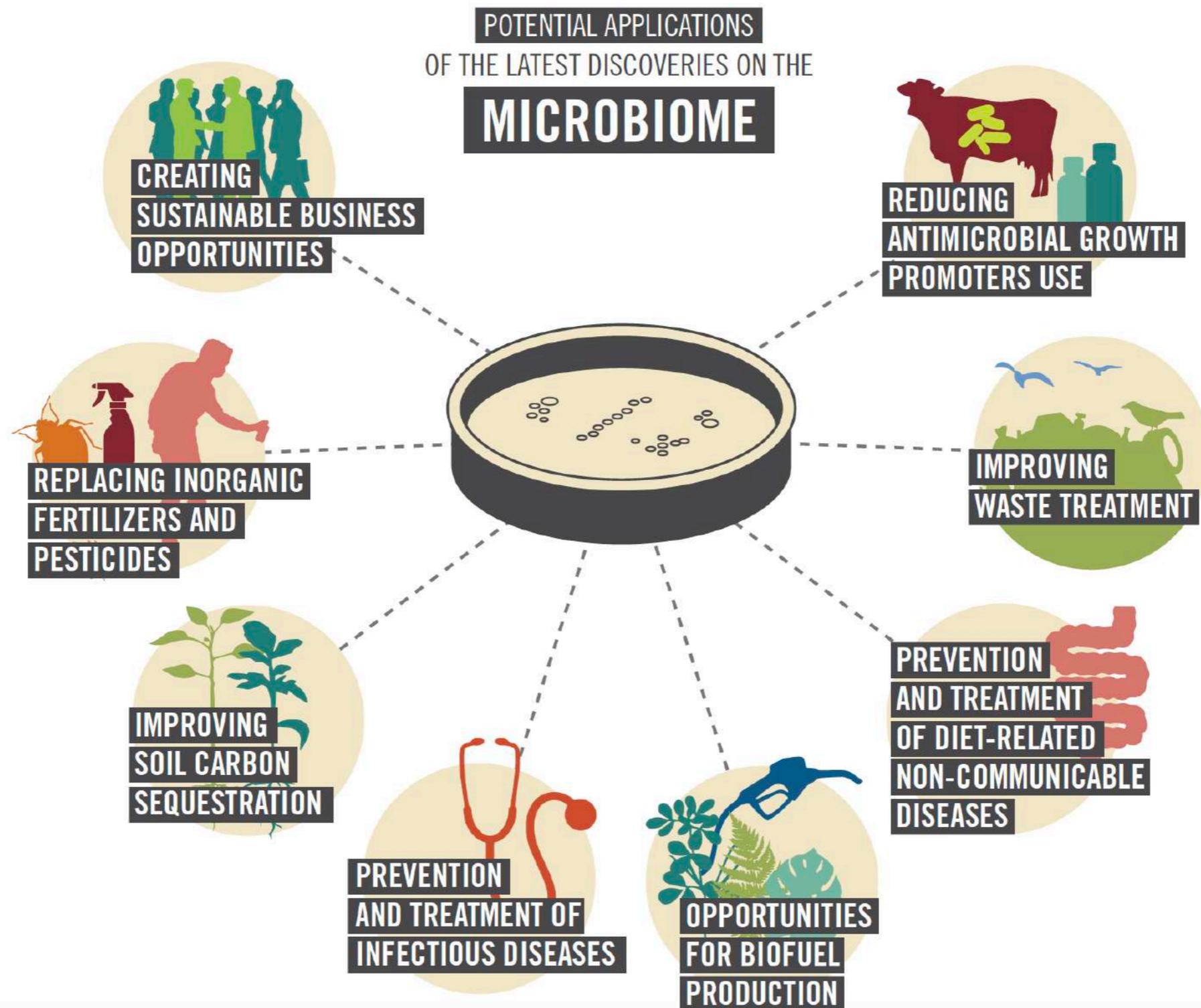
The ocean microbiome (centre) is composed of a range of prokaryotes, eukaryotic microbes and viruses, which have a **range of different lifestyles driving microbial interactions**

The essential ecosystem services they provide, such as **biogeochemical cycling** (e.g. CO₂ capture, O₂ generation and carbon removal), **mitigation of human activities, bioresources, biodiversity and resources for the entire ocean food web**, are shown in green

Humans impact ocean functioning thus microbial functioning in the ocean

Other aspects of the ocean environment are indicated in blue, and interconnections between different components are shown with arrows

Integrated One Health microbial impact



The Keeling Curve

HISTORY

MEASUREMENT NOTES

VIDEOS

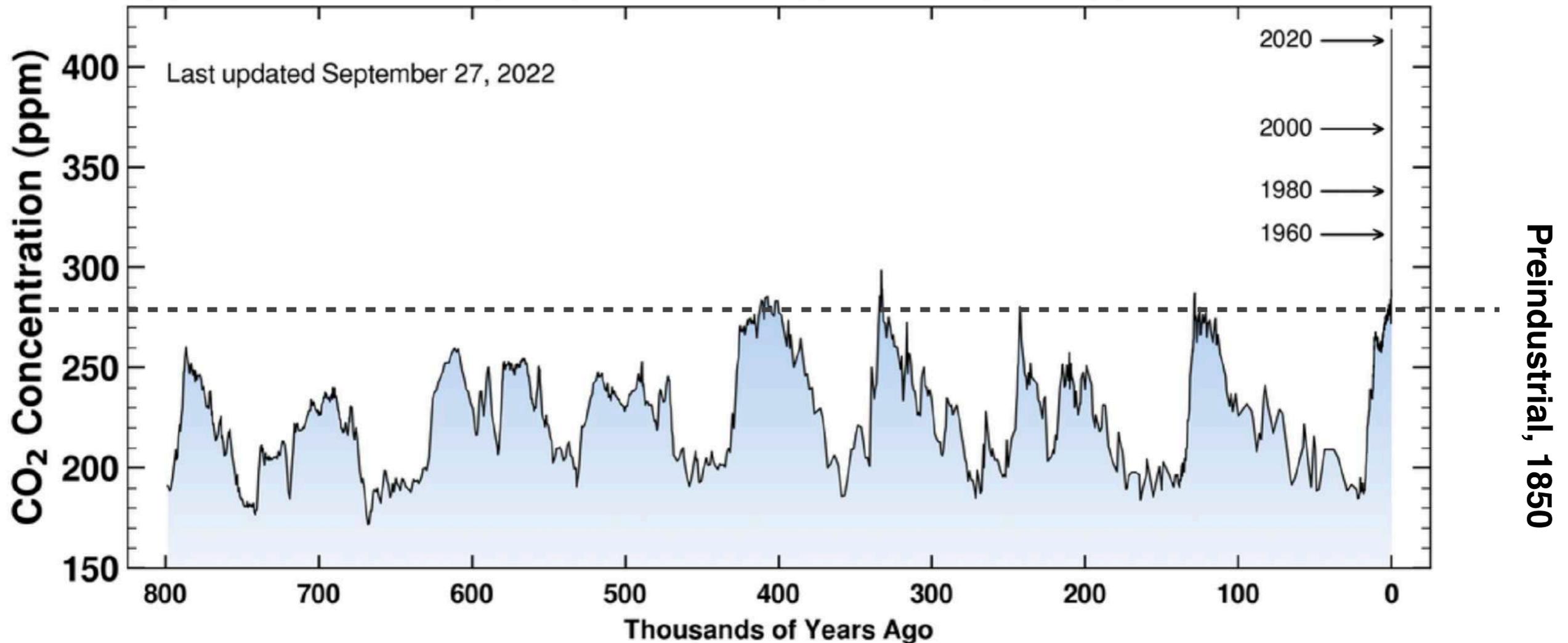
OTHER CLIMATE INDICATORS



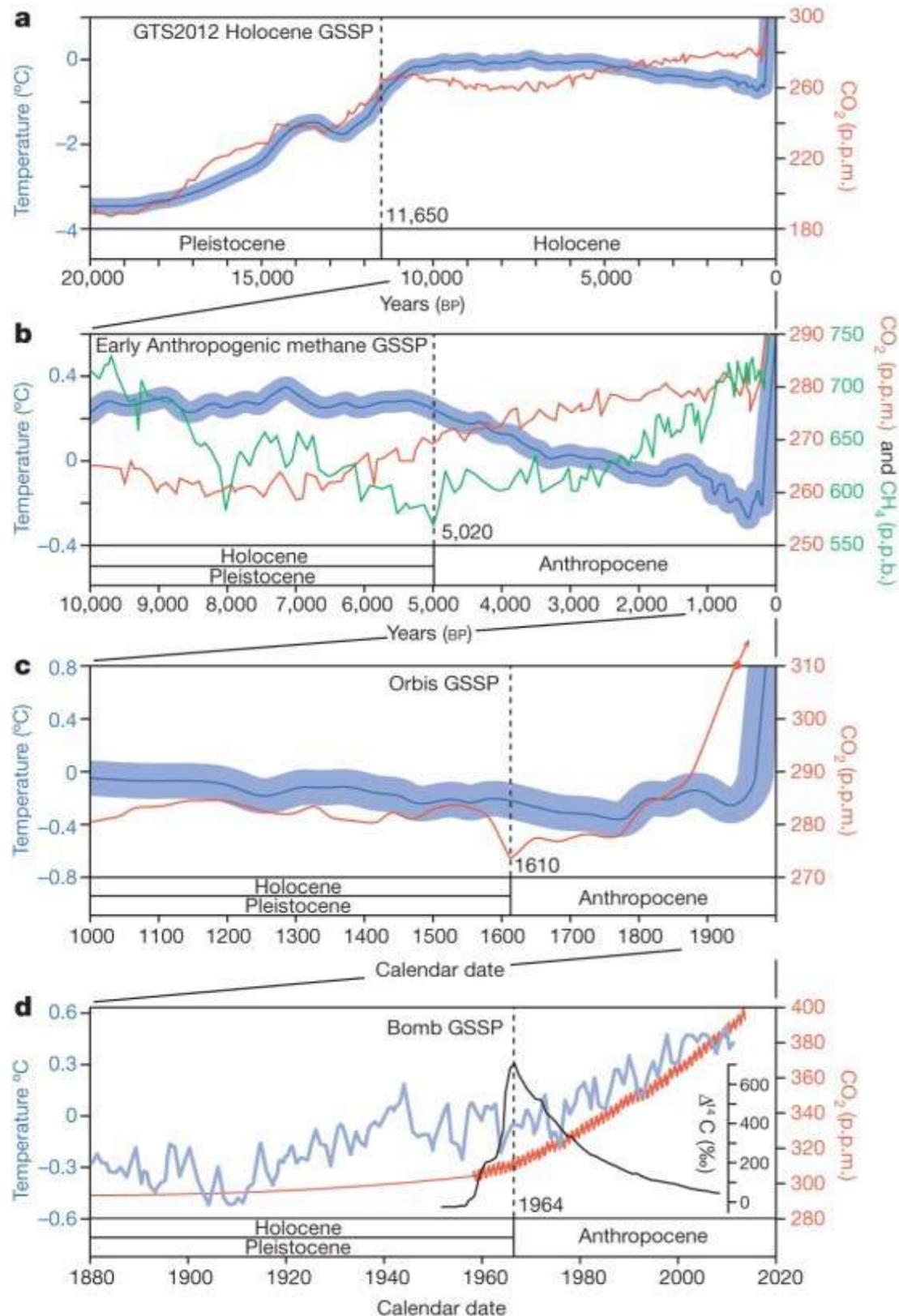
The Keeling Curve is a daily record of global atmospheric carbon dioxide concentration maintained by Scripps Institution of Oceanography at UC San Diego

*Latest CO₂ reading: **414.77 ppm**

Ice-core data before 1958. Mauna Loa Data after 1958.



Defining the beginning of the Anthropocene



Human dominated geological epoch:

- *Proposed beginning: 1610 and 1964*
- *Great acceleration in socio-economic trends:*
- *Population*
- *Energy use*
- *Water use*
- *Fertilizer consumption*
- *Transportation*

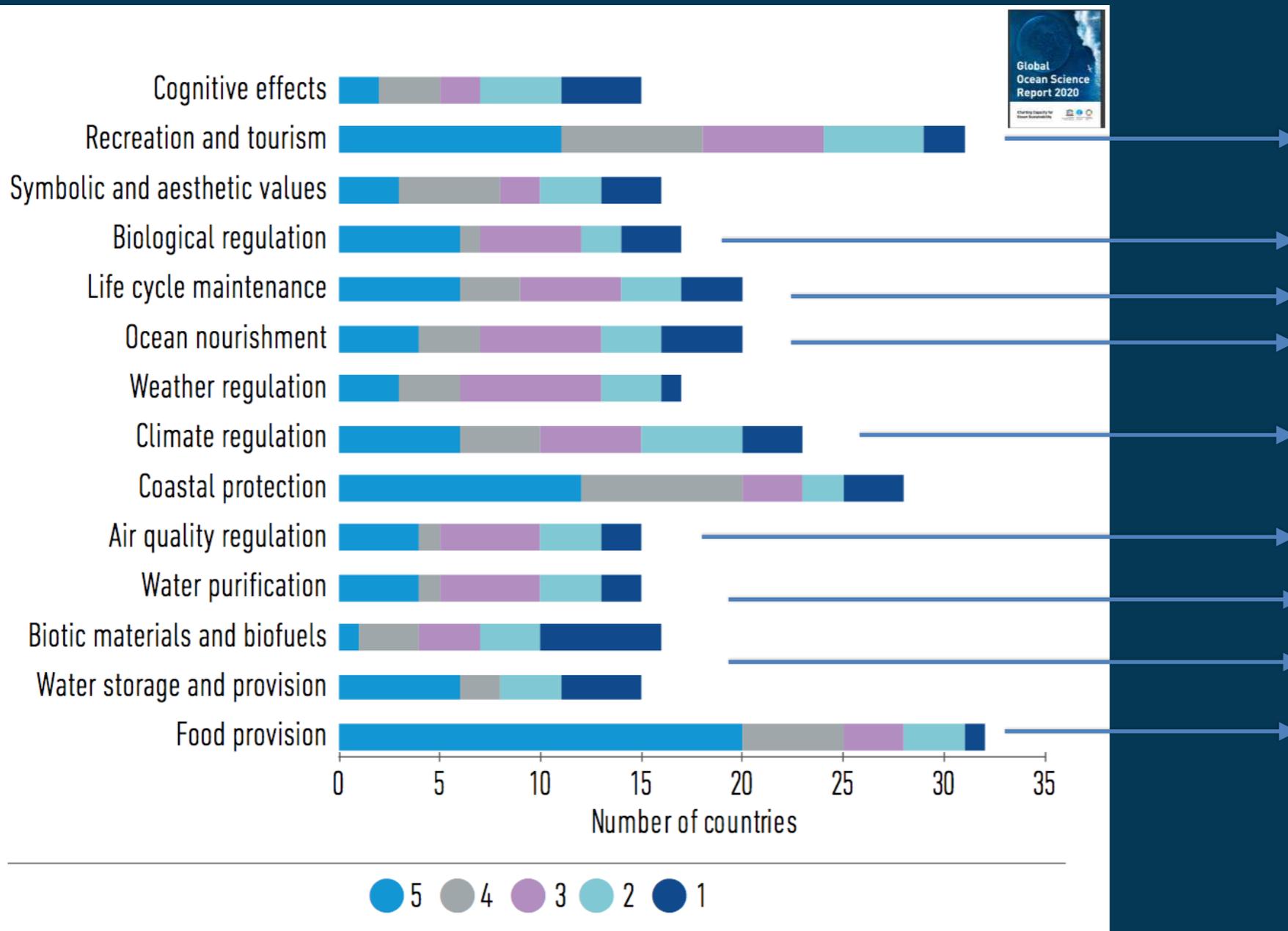
Great acceleration in earth system trends:

- *Nitrous oxide*
- *Methane*
- *Marine fish capture*
- *Aquaculture*
- *Tropical forest loss*
- *New sedimentation fluxes (cement, plastic, petrol-derived entities, pharmaceuticals)*

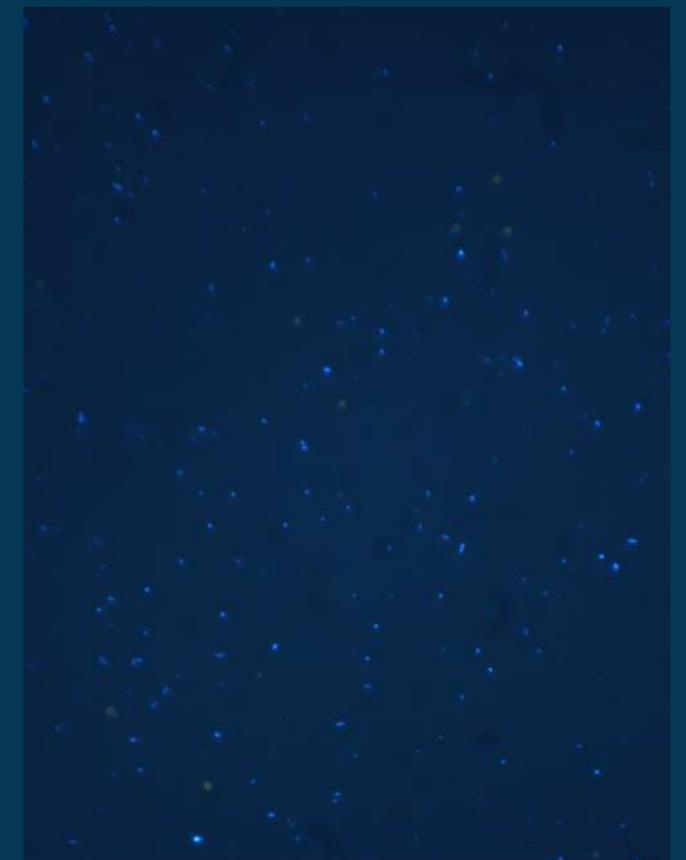
www.anthropocene.info



Ocean services



Marine microbes



<https://en.unesco.org/gosr>

Figure 6.4. Importance attributed by countries to the different ocean services (5 high importance — 1 low importance).

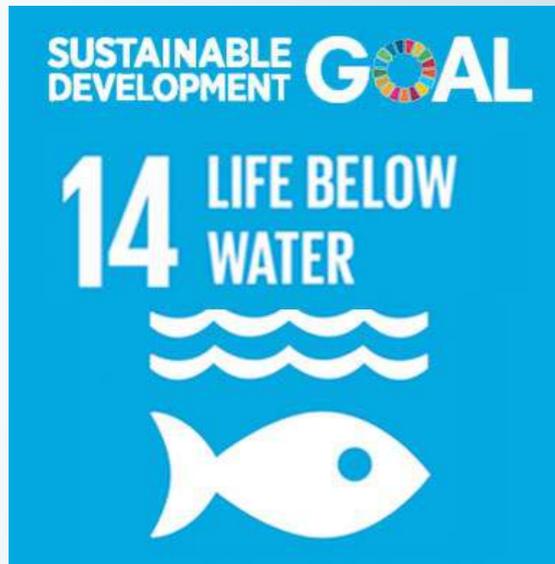
Source: Data based on the GOSR2020 questionnaire.

The 17 UN Sustainable Development Goals are a call for action by all to promote prosperity while protecting the planet

<https://www.un.org/sustainabledevelopment/>



SDG 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development



Conserve and sustainably use the oceans, seas and marine resources for sustainable development

<https://www.globalgoals.org/14-life-below-water>

EU Directive 2008/56/CE on marine strategy (MSFD) and the Good Environmental Status (GES)



**2021
2030** United Nations Decade
of Ocean Science
for Sustainable Development



The Science We Need For The Ocean We Want

SDG 14: Life below Water

TARGET 14-1



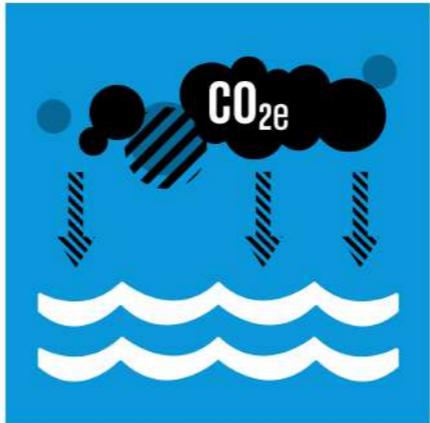
REDUCE MARINE POLLUTION

TARGET 14-2



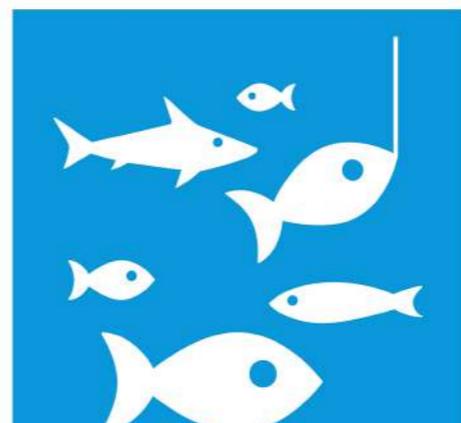
PROTECT AND RESTORE ECOSYSTEMS

TARGET 14-3



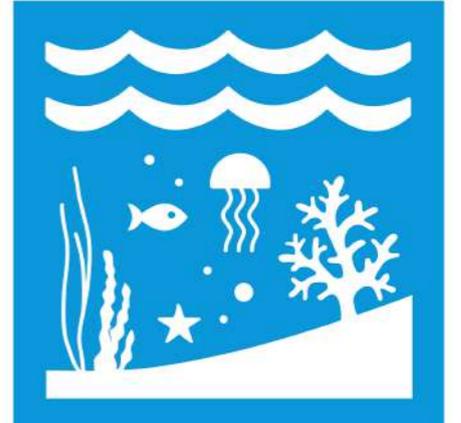
REDUCE OCEAN ACIDIFICATION

TARGET 14-4



SUSTAINABLE FISHING

TARGET 14-5



CONSERVE COASTAL AND MARINE AREAS

TARGET 14-6



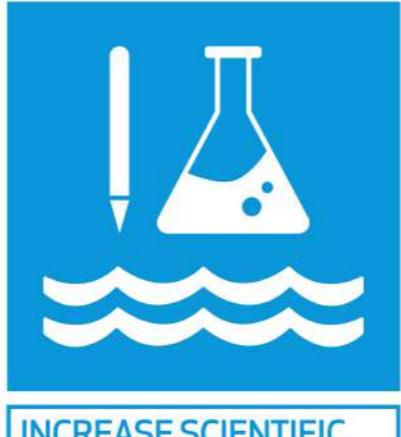
END SUBSIDIES CONTRIBUTING TO OVERFISHING

TARGET 14-7



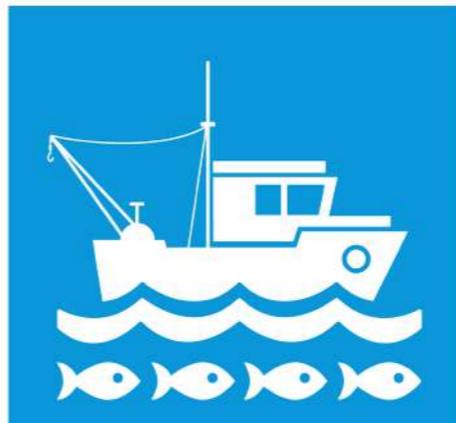
INCREASE THE ECONOMIC BENEFITS FROM SUSTAINABLE USE OF MARINE RESOURCES

TARGET 14-A



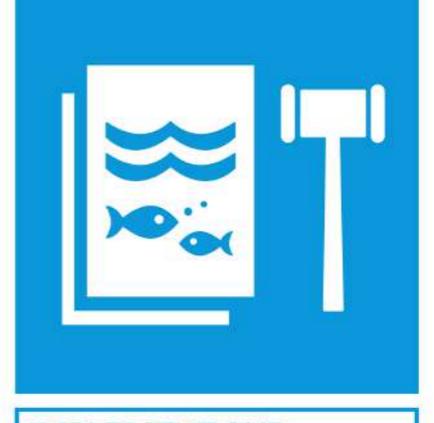
INCREASE SCIENTIFIC KNOWLEDGE, RESEARCH AND TECHNOLOGY FOR OCEAN HEALTH

TARGET 14-B



SUPPORT SMALL SCALE FISHERS

TARGET 14-C



IMPLEMENT AND ENFORCE INTERNATIONAL SEA LAW

EU Directive 2008/56/CE on marine strategy and the Good Environmental Status (GES)



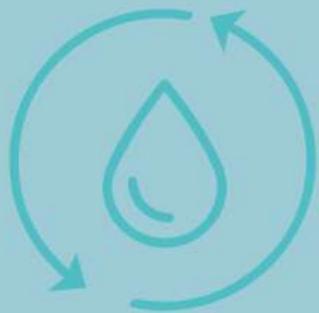
EU Directive 2008/56/CE on marine strategy and the Good Environmental Status (GES)

- **Descriptor 1.** Biodiversity is maintained
- **Descriptor 2.** Non-indigenous species do not adversely alter the ecosystem
- **Descriptor 3.** The population of commercial fish species is healthy
- **Descriptor 4.** Elements of food webs ensure long-term abundance and reproduction
- **Descriptor 5.** Eutrophication is minimised
- **Descriptor 6.** The sea floor integrity ensures functioning of the ecosystem
- **Descriptor 7.** Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
- **Descriptor 8.** Concentrations of contaminants give no effects
- **Descriptor 9.** Contaminants in seafood are below safe levels
- **Descriptor 10.** Marine litter does not cause harm
- **Descriptor 11.** Introduction of energy (including underwater noise) does not adversely affect the ecosystem



2021
2030

United Nations Decade
of Ocean Science
for Sustainable Development



A clean ocean where sources of pollution are identified and removed



A healthy and resilient ocean where marine ecosystems are mapped and protected



A predicted ocean where society has the capacity to understand current and future ocean conditions

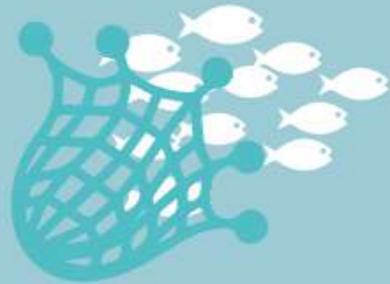


A safe ocean where people are protected from ocean hazards



2021
2030

United Nations Decade
of Ocean Science
for Sustainable Development



**A sustainably harvested
and productive ocean**
ensuring the provision of
food supply



A transparent ocean
with open access to
data, information and
technologies



**An inspiring and
engaging ocean**
where society understands
and values the ocean

Summary of the main challenge of each Ocean Decade outcome and the scientific solutions identified

TABLE 1 | Summary of the main challenge of each OD outcome and the scientific solutions identified.

OUTCOME	MAIN CHALLENGE	SCIENTIFIC SOLUTIONS
1. A clean ocean	Elimination of pollution from wastewater, hydrocarbons and plastic.	<ul style="list-style-type: none"> • City wastewater treatment mediated by micro/macro-organisms. • <i>In situ</i> bioremediation of coastal and oceanic sites. • Use of OGMs for high performance bioremediation.
2. A healthy ocean	Protection of marine resources and biodiversity.	<ul style="list-style-type: none"> • Implementation of autonomous observatories. • Use of non-invasive investigation techniques.
3. A productive ocean	Extraction of marine resources and food production under regulation.	<ul style="list-style-type: none"> • Application of sustainable fisheries management. • Improvement of sustainable aquaculture procedures. • Identification of new edible species.
4. A predicted ocean	Detection of ocean changing conditions.	<ul style="list-style-type: none"> • Technological development (sensors and platforms). • Integration of chemical and genetic analysis in risk evaluation.
5. A safe ocean	Identification and prevention of ocean hazards.	<ul style="list-style-type: none"> • Application of risk reduction strategies. • Expansion of Maritime Spatial Planning principles. • Development of early warning systems.
6. An accessible ocean	Sharing of relevant information with all entities and stakeholders.	<ul style="list-style-type: none"> • Implementation of global data portals. • Encourage data sharing. • Support Open Science.
7. An inspiring ocean	Scientific dissemination to the general public.	<ul style="list-style-type: none"> • Creation of new public infrastructures of science dissemination. • Encourage Citizen Science. • Promotion of science contents through social media-based tools.

EU- level: Mission Starfish 2030



Figure 6. Mission Starfish 2030 ©European Union, 2020

EU- level: Mission Starfish 2030



Figure 6. Mission Starfish 2030 ©European Union, 2020

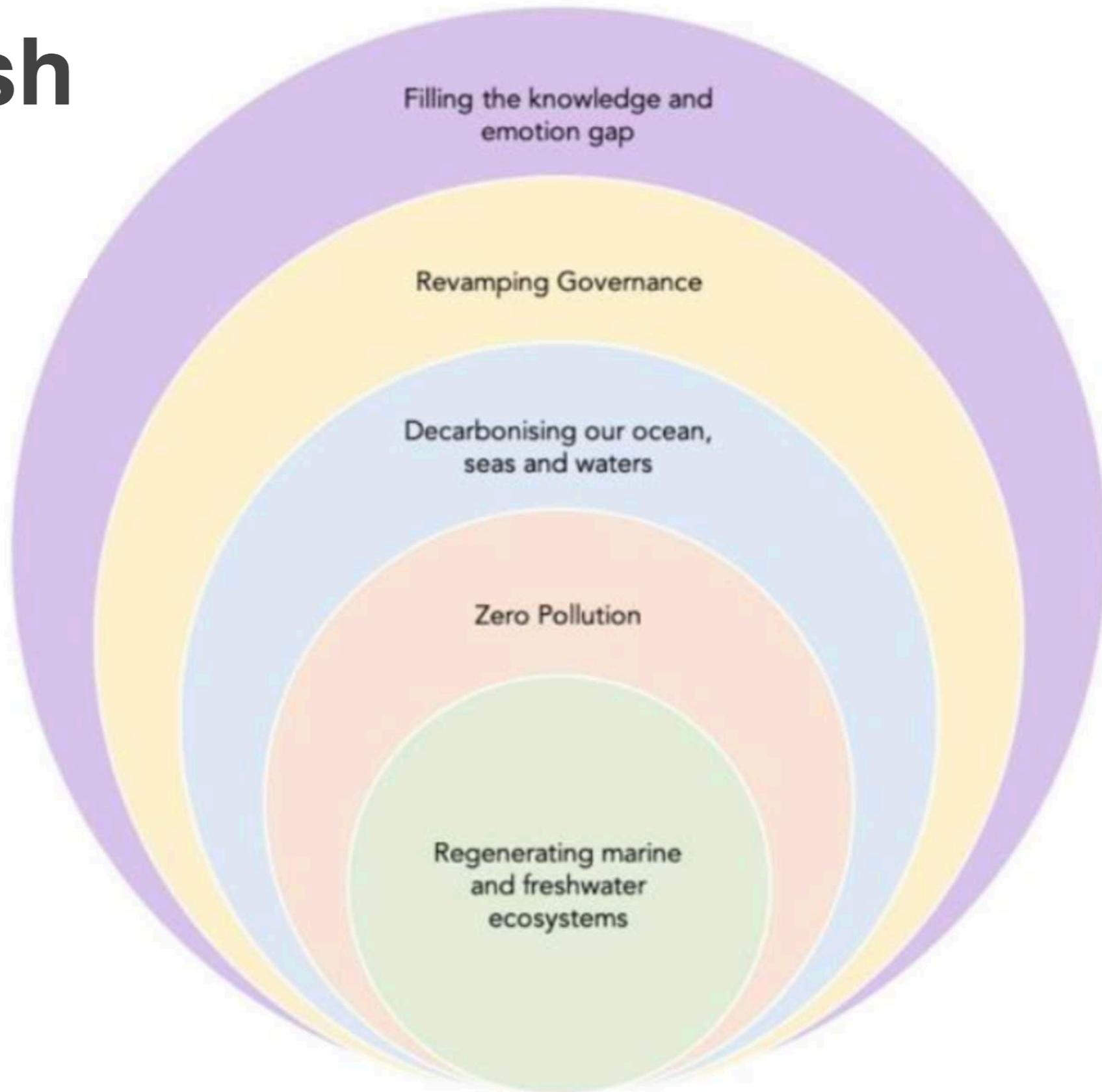
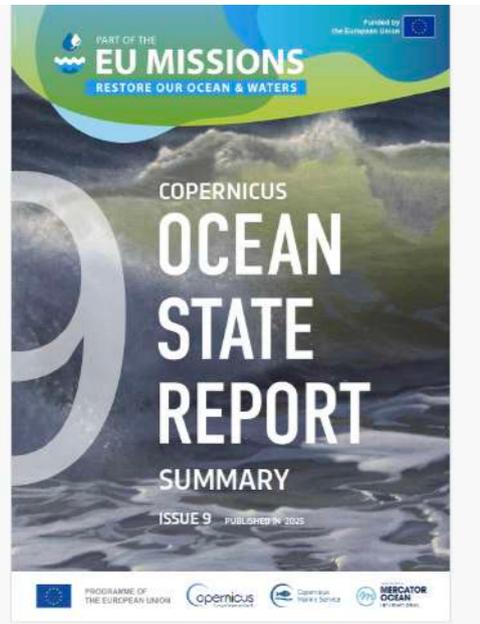
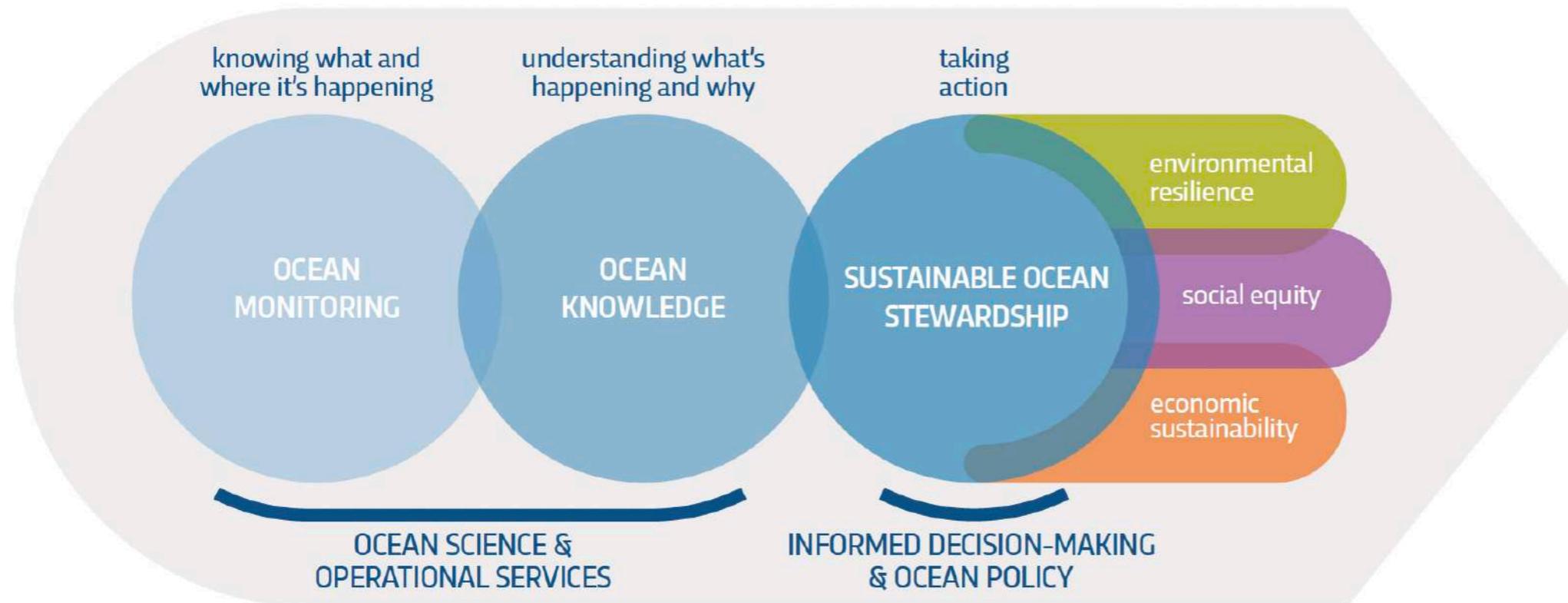


Figure 7. Five mutually supportive objectives

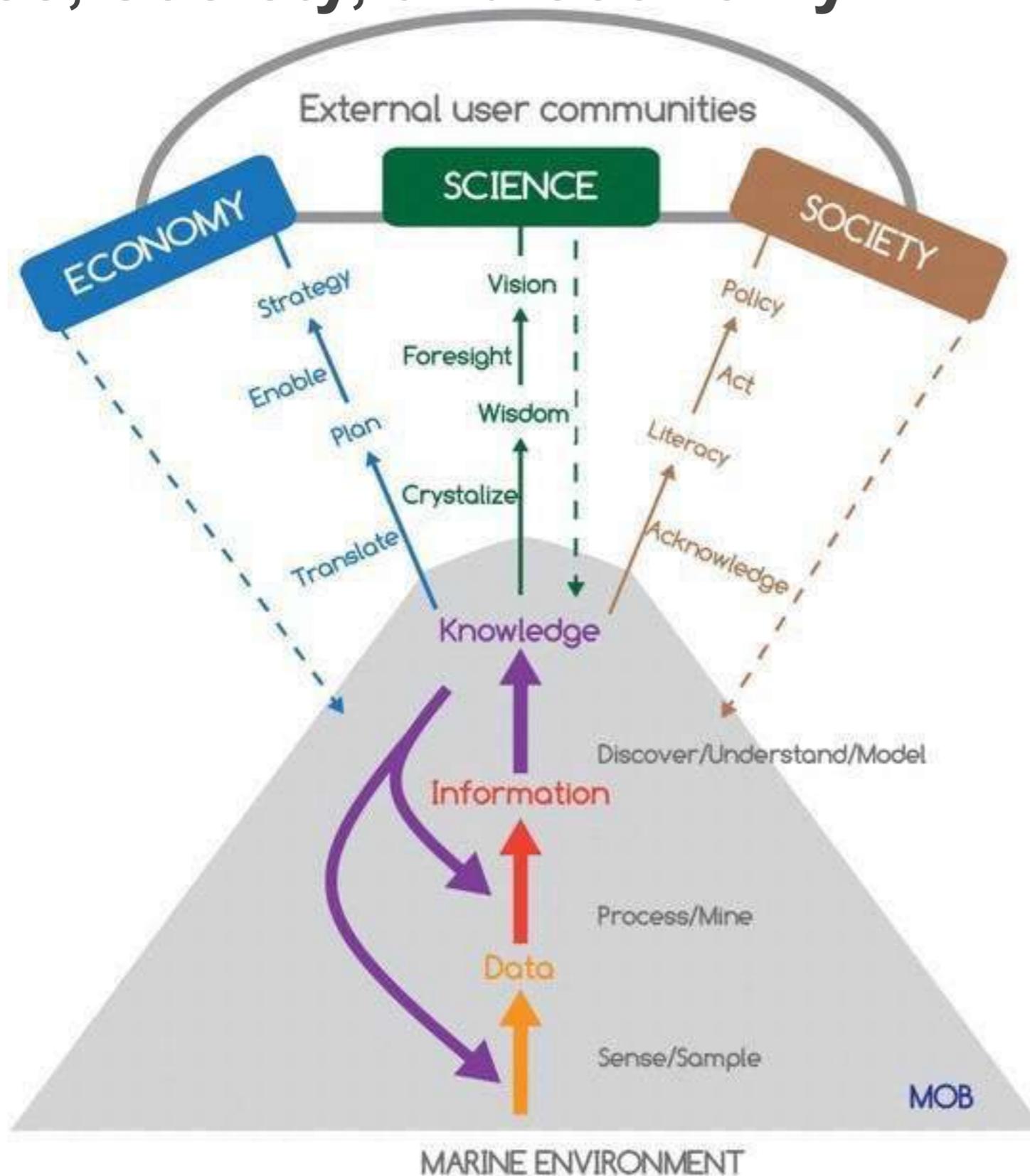


A PATHWAY TO ACTION



MOB-based hierarchy of understanding for science, society, and economy

Marine OBservatory structure (MOB)



WHY?

Science-based governance of the ocean

Our goal: a vibrant ocean ecosystem

This knowledge will help us design the most effective ways to **restore marine and coastal habitats, support a sustainable blue economy and adapt to a changing climate.**

Mitigating and adapting to climate change

Supporting a sustainable blue economy

Restoring marine and coastal habitats

Boosting biodiversity

**#MissionOcean
#EUMissions**

**EU
MISSIONS**

RESTORE OUR OCEAN & WATERS BY 2030

Research and
Innovation

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