Impacts of Ocean Acidification

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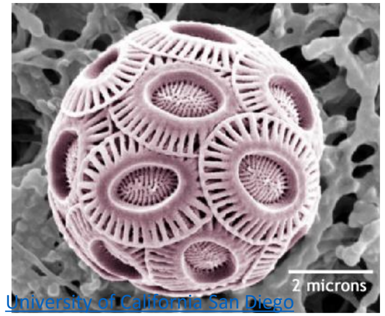
Image by Kristen Krumhardt



University of California San Diego

What is Ocean Acidification?

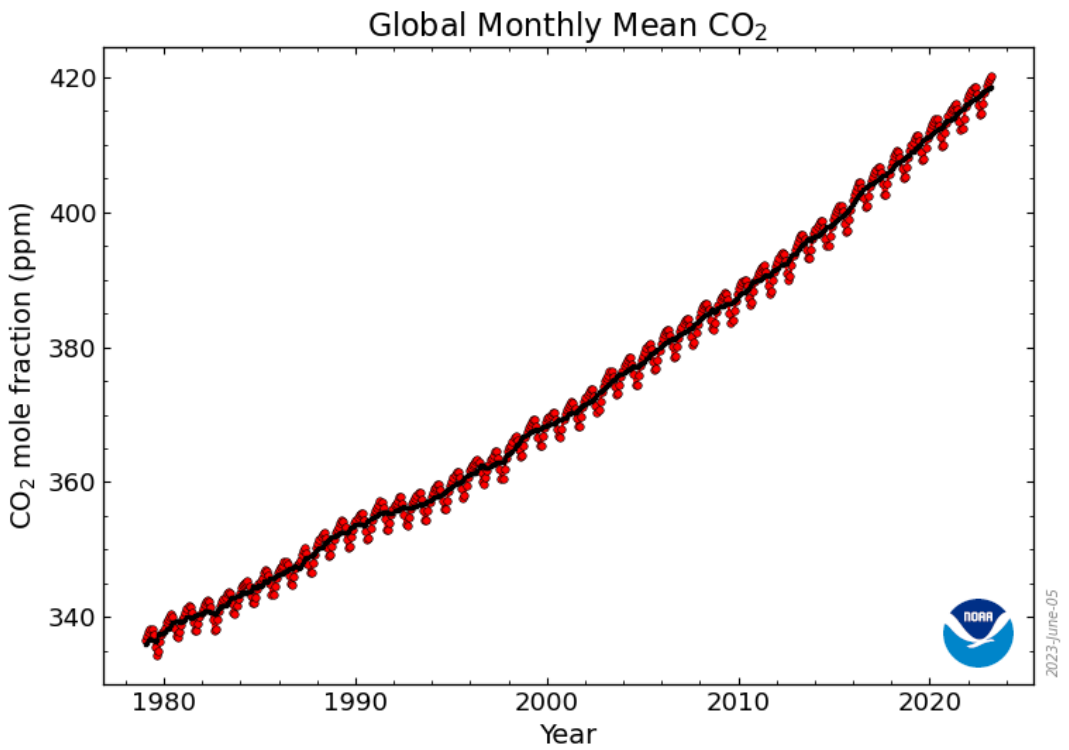
Man-made climate change, combustion of fossil fuels → increase of carbon dioxide CO_2 in the atmosphere

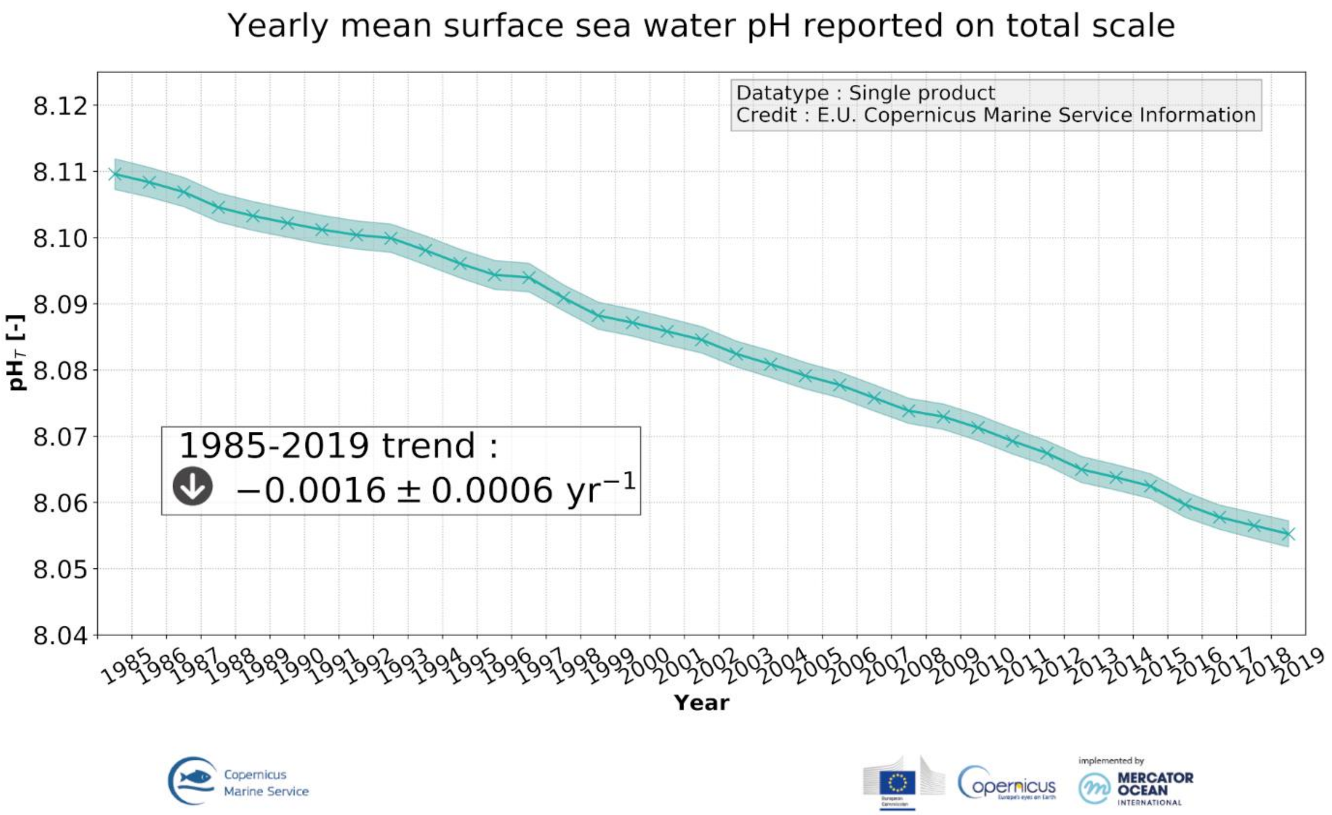
↑ pCO_2 atmosphere → ↑ pCO_2 seawater

Example: mineral water bottle

‘The ocean has absorbed about 30% of the emitted anthropogenic carbon causing ocean acidification since pre-industrial times.’
[IPCC, 2019]

Increase of carbon dioxide concentration → Decrease in pH





Data is important!

Ocean Acidification Data: Weaves to be tied on European and global scale

→ FAIR (**F**indable, **A**ccessible, **I**nteroperable and **R**eusable) Ocean Acidification dataset

→ Including the parameters related to Ocean Acidification: **pH, Total Alkalinity (TA), Total Dissolved Inorganic Carbon (DIC) and partial pressure of CO_2 (pCO_2)**

→ Standard **metadata** and common vocabularies (BODC Parameter Usage Vocabulary)

→ **Aim:** → **using common metadata and vocabularies to harmonize world-wide ocean acidification databases**

→ **Metadata template has been created within the UNESCO Working Group SDG 14.3.1.**

SOCAT · SURFACE OCEAN CO_2 ATLAS ·

INTERNATIONAL OCEAN CARBON COORDINATION PROJECT IOCCP

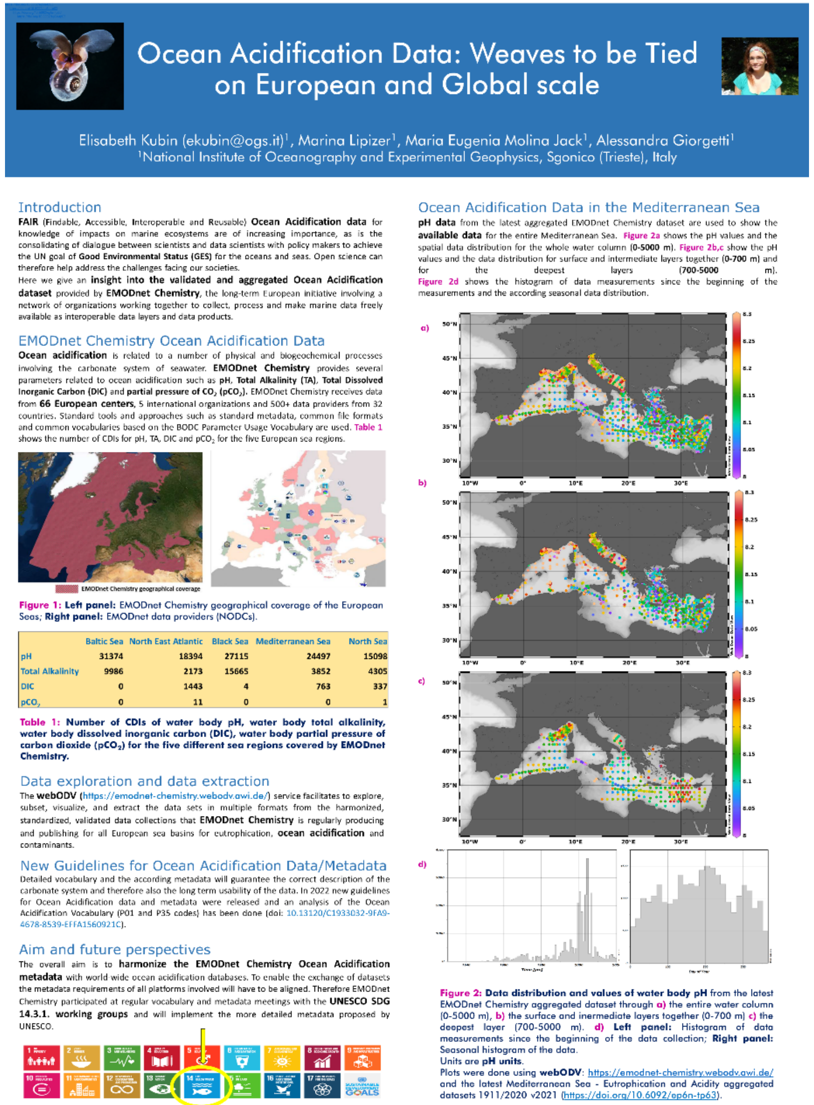
UNESCO unesco

EMODnet European Marine Observation and Data Network

5th World Ocean Climate Conference, Bergen, Norway

→ ***Presentation***:

'Ocean Acidification Data: Weaves to be Tied on European and Global scale'



Ocean Acidification Data: Weaves to be Tied on European and Global scale

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Introduction

FAIR (Findable, Accessible, Interoperable and Reusable) **Ocean Acidification data** for knowledge of impacts on marine ecosystems are of increasing importance, as is the consolidating of dialogue between scientists and data scientists with policy makers to achieve the UN goal of **Good Environmental Status (GES)** for the oceans and seas. Open science can therefore help address the challenges facing our societies.

Here we give an **insight into the validated and aggregated Ocean Acidification dataset** provided by **EMODnet Chemistry**, the long-term European initiative involving a network of organizations working together to collect, process and make marine data freely available as interoperable data layers and data products.

EMODnet Chemistry Ocean Acidification Data

Ocean acidification is related to a number of physical and biogeochemical processes involving the carbonate system of seawater. **EMODnet Chemistry** provides several parameters related to ocean acidification such as **pH**, **Total Alkalinity (TA)**, **Total Dissolved Inorganic Carbon (DIC)** and **partial pressure of CO_2 (pCO_2)**. EMODnet Chemistry receives data from **66 European centers**, 5 international organizations and 500+ data providers from 32 countries. Standard tools and approaches such as standard metadata, common file formats and common vocabularies based on the BODC Parameter Usage Vocabulary are used. Table 1 shows the number of CDIs for pH, TA, DIC and pCO_2 for the five European sea regions.

EMODnet Chemistry geographical coverage

Figure 1: Left panel: EMODnet Chemistry geographical coverage of the European Seas; **Right panel:** EMODnet data providers (NODCs).

	Baltic Sea	North East Atlantic	Black Sea	Mediterranean Sea	North Sea
pH	31374	18394	27115	24497	15098
Total Alkalinity	9986	2173	15665	3852	4305
DIC	0	1443	4	763	337
pCO_2	0	11	0	0	1

Table 1: Number of CDIs of water body pH, water body total alkalinity, water body dissolved inorganic carbon (DIC), water body partial pressure of carbon dioxide (pCO_2) for the five different sea regions covered by EMODnet Chemistry.

Data exploration and data extraction

The **webODV** (https://emodnet-chemistry.webodv.awi.de/) service facilitates to explore, subset, visualize, and extract the data sets in multiple formats from the harmonized, standardized, validated data collections that **EMODnet Chemistry** is regularly producing and publishing for all European sea basins for eutrophication, **ocean acidification** and contaminants.

New Guidelines for Ocean Acidification Data/Metadata

Detailed vocabulary and the according metadata will guarantee the correct description of the carbonate system and therefore also the long term usability of the data. In 2022 new guidelines for Ocean Acidification data and metadata were released and an analysis of the Ocean Acidification Vocabulary (P01 and P35 codes) has been done (doi: 10.13120/C1933032-9FA9-4678-8539-EFFA1560921C).

Aim and future perspectives

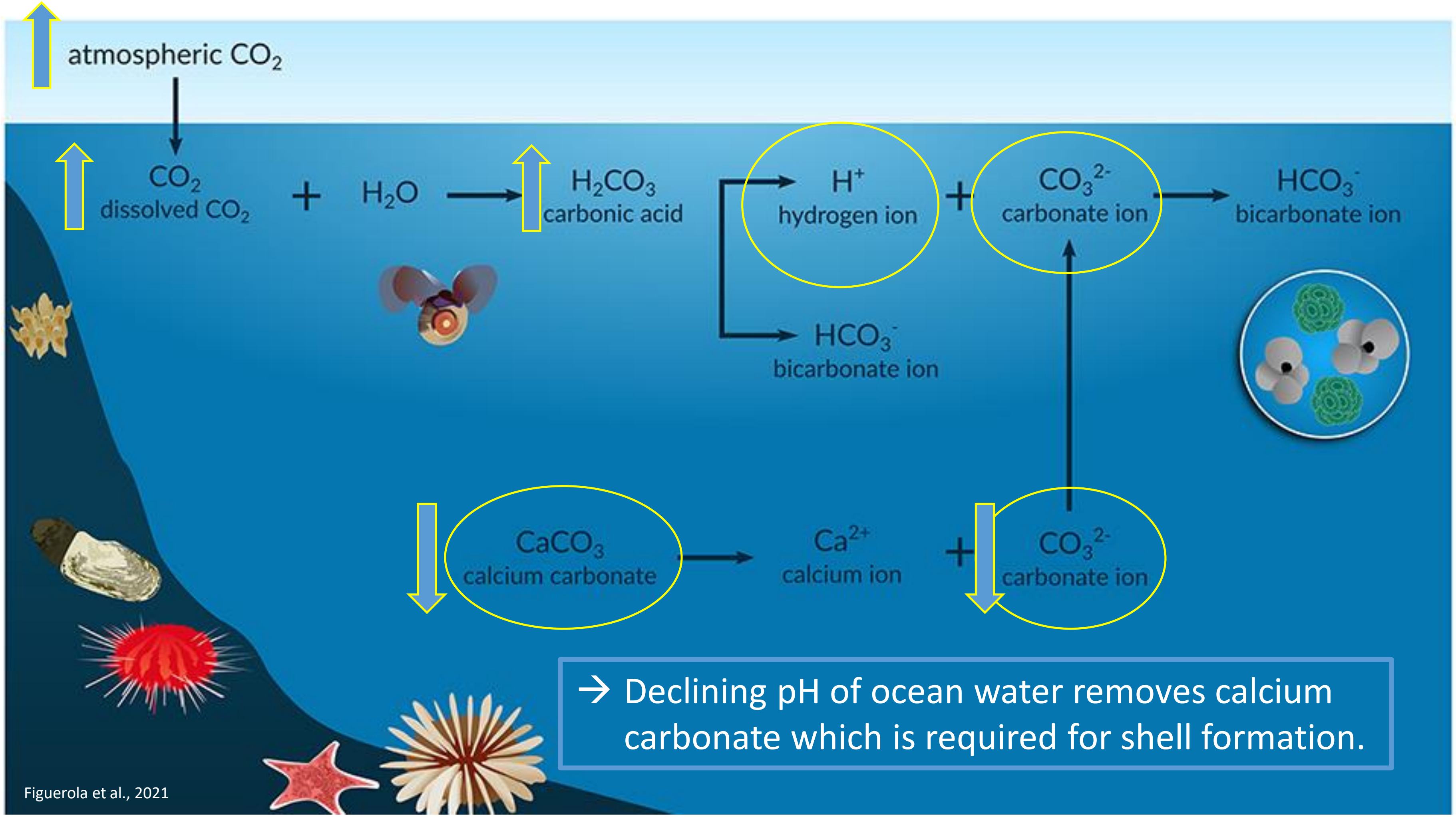
The overall aim is to **harmonize the EMODnet Chemistry Ocean Acidification metadata** with world-wide ocean acidification databases. To enable the exchange of datasets the metadata requirements of all platforms involved will have to be aligned. Therefore EMODnet Chemistry participated at regular vocabulary and metadata meetings with the **UNESCO SDG 14.3.1. working groups** and will implement the more detailed metadata proposed by UNESCO.

Ocean Acidification Data in the Mediterranean Sea

pH data from the latest aggregated EMODnet Chemistry dataset are used to show the **available data** for the entire Mediterranean Sea. Figure 2a shows the pH values and the spatial data distribution for the whole water column (**0-5000 m**). Figure 2b,c show the pH values and the data distribution for surface and intermediate layers together (**0-700 m**) and for the deepest layers (**700-5000 m**). Figure 2d shows the histogram of data measurements since the beginning of the measurements and the according seasonal data distribution.

Figure 2: Data distribution and values of water body pH from the latest EMODnet Chemistry aggregated dataset through **a)** the entire water column (0-5000 m), **b)** the surface and inermediate layers together (0-700 m) **c)** the deepest layer (700-5000 m). **d) Left panel:** Histogram of data measurements since the beginning of the data collection; **Right panel:** Seasonal histogram of the data.
Units are **pH units**.
Plots were done using **webODV**: https://emodnet-chemistry.webodv.awi.de/ and the latest Mediterranean Sea - Eutrophication and Acidity aggregated datasets 1911/2020 v2021 (https://doi.org/10.6092/ep6n-tp63).

Chemical reactions to the increased partial pressure of CO_2



→ states of $CaCO_3$: Aragonite, Calcite, Mg-calcite

Some facts

→ Since the beginning of industrialization the average pH of seawater has fallen from about **8.2 to 8.1**, i.e. about a 30 % increase in aciditiy on pH's logarithmic scale.

→ This corresponds to a **decrease of 30 % in carbonate concentration [CO_3^{2-}]**.

→ Projection for the year **2100**: decrease of **~ 0.3 pH units**, corresponding to a **decrease of 50 % in [CO_3^{2-}].**

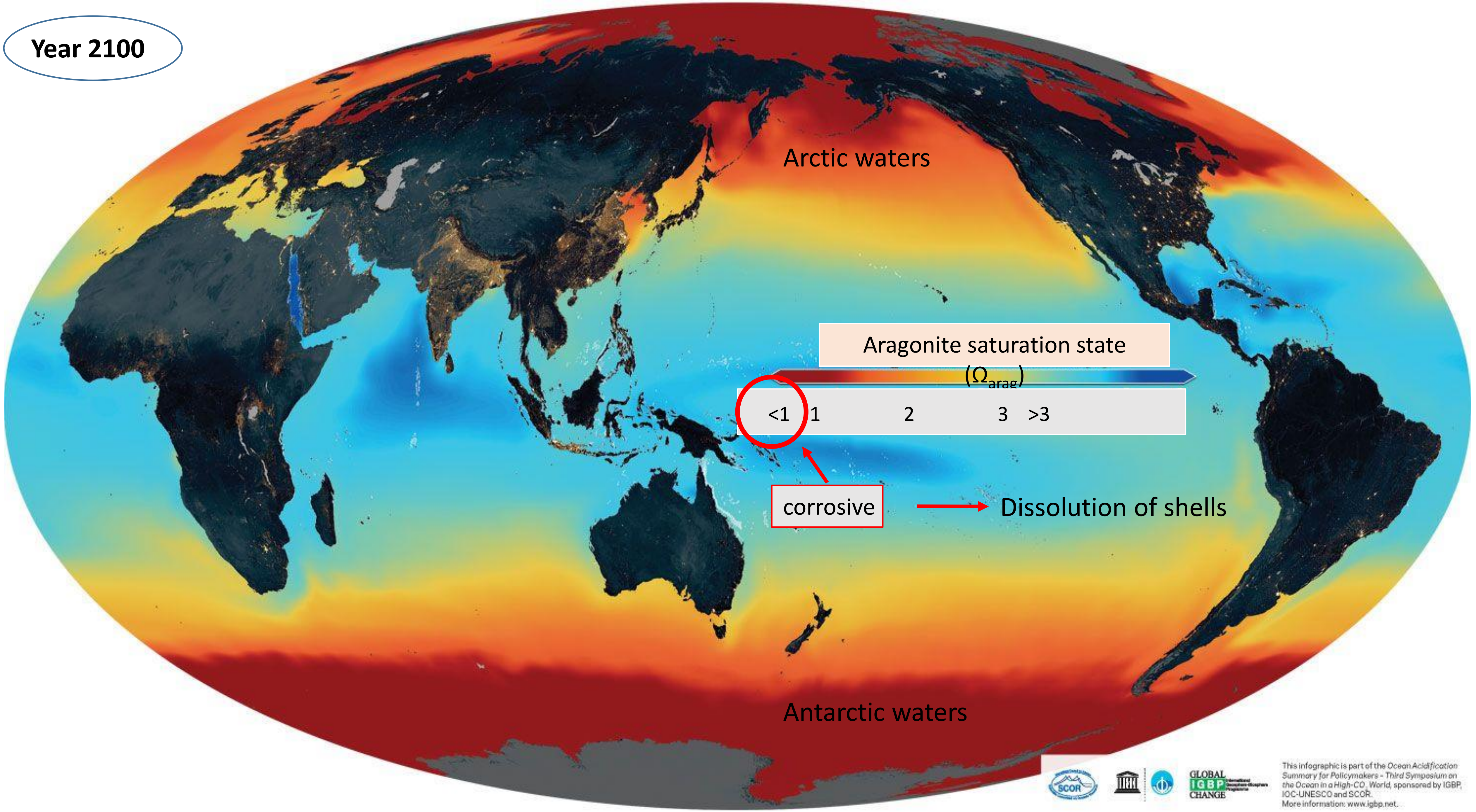
→ Colder waters will show undersaturation states earlier than warmer waters due to the physical fact that colder waters can hold more CO_2 → especially the polar areas

‘These pH changes are very likely to cause ~20% of the surface ocean, specifically the Arctic and Southern Oceans, as well as the northern Pacific and northwestern Atlantic Oceans, to experience year-round corrosive conditions for aragonite by 2100.’

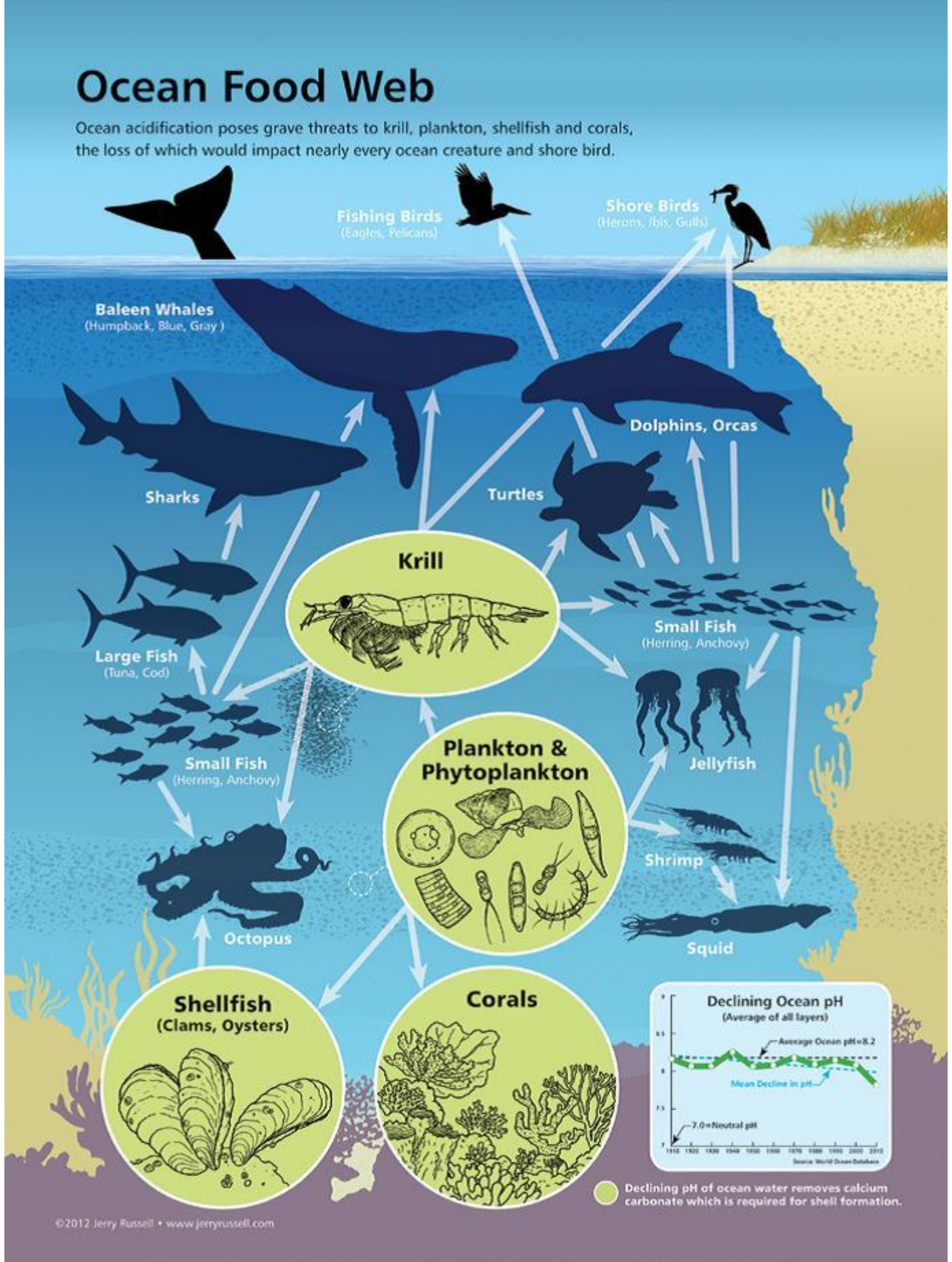
[IPCC, 2019]

Image by Andrew McDonnell.

Year 2100


Arctic waters
Aragonite saturation state
(Ω_{arag})
<1 1 2 3 >3
corrosive
Dissolution of shells
Antarctic waters
SCOR
GLOBAL IGBP CHANGE
This infographic is part of the Ocean Acidification Summary for Policymakers - Third Symposium on the Ocean in a High-CO$_2$ World, sponsored by IGBP, IOC-UNESCO and SCOR.
More information: www.igbp.net.

What does this actually mean for marine organisms and the functioning of the ecosystem ?



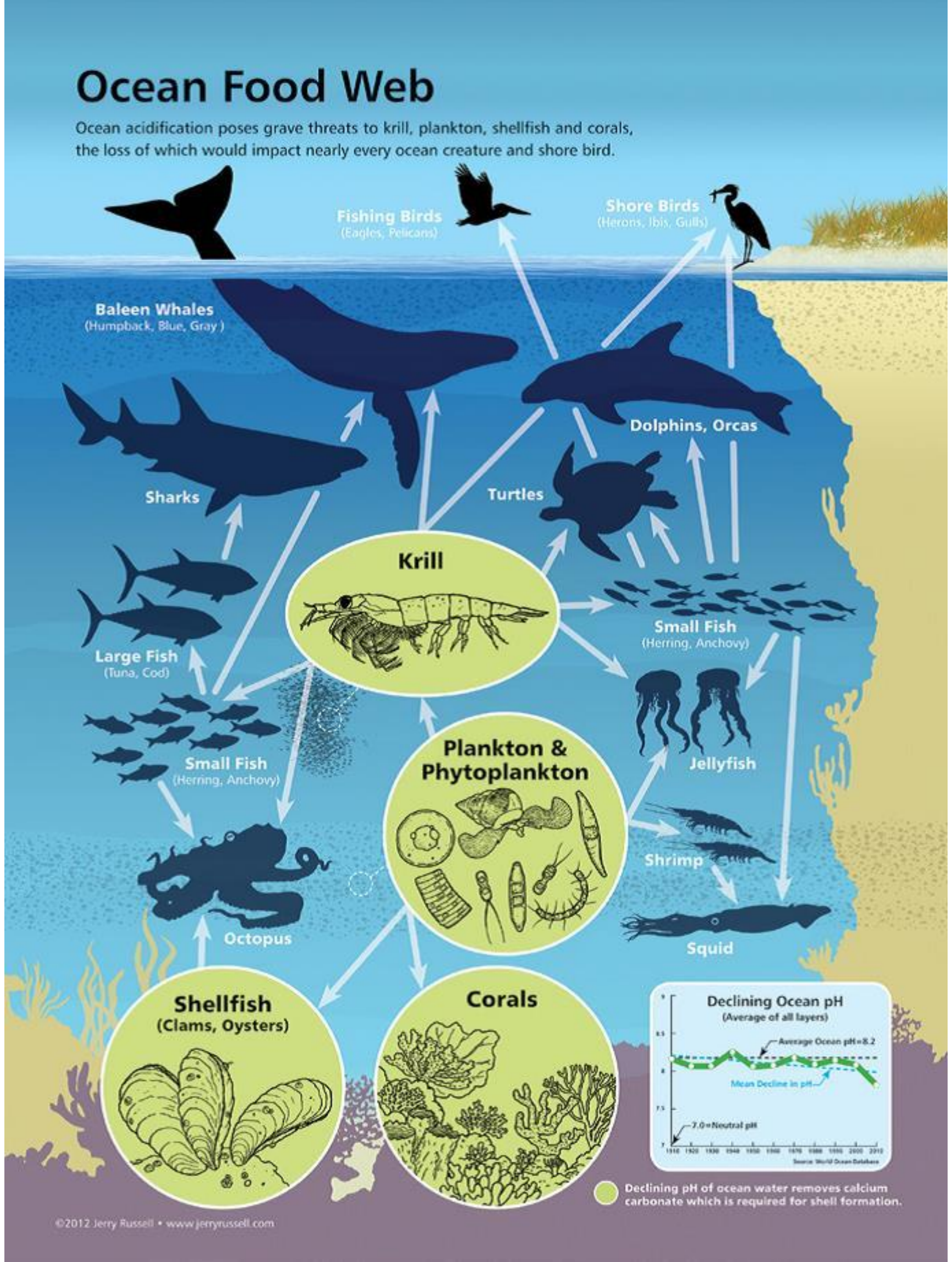
- Food chains are shifted by a decreasing pH value.
- Many edible fish such as haddock, halibut, flounder and cod feed mainly on molluscs.
- Also shellfish have problems to build their shells.
- The smallest plants and animals determine the state of the food web.


Krill feeds mainly on phytoplankton
© Tenedos/Getty

Blue whale, Mt. Maunganui, New Zealand
Photo: Kim Westerskov

Blue whale, south of Karewa Island, New Zealand
Photo: Kim Westerskov

Different types of marine calcifying organisms will respond in very different ways.



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Corals

→ As aragonite producers, **corals are very sensitive to ocean acidification**.
→ Since the Southern Ocean will be the most rapidly affected by aragonite, the cold-water corals will be the first to be affected.
→ By the end of the century, 70 % (**!**) of the current coral habitat could no longer be suitable.

Molluscs

→ Studies on the **edible mussel (Mytilus edulis)** and the **Pacific oyster (Crassostreagigas)** show that their calcification rate decreases at elevated pCO_2. This was also demonstrated for the larvae of the two species.
→ Since the two species mentioned above are important for coastal ecosystems and account for a large part of global aquaculture, ocean acidification has and will have a major **impact on coastal biodiversity** and will also lead to **economic damage**.

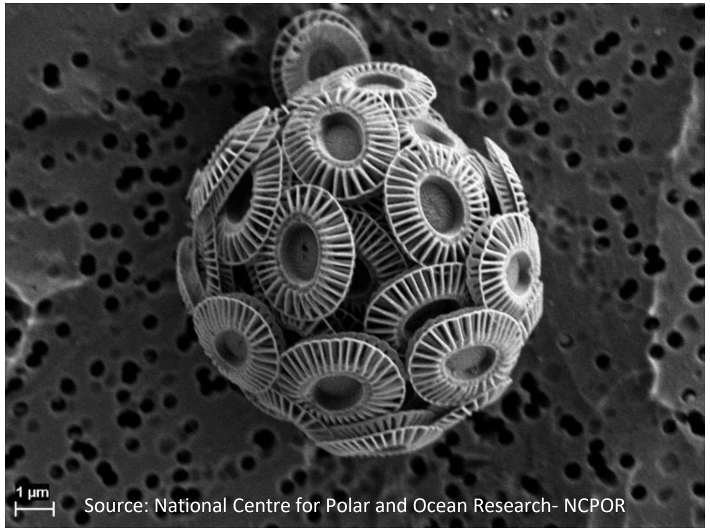
Echinodermata

→ Their skeleton consists of Mg-calcite. As Mg calcite is more easily soluble than aragonite, Echinodermata react **very sensitive** to ocean acidification.
→ At reduced pH value, the **larvae** (starfish Ophiothrix fragilis) became **smaller**, **anomalies** and asymmetries in the skeletal structure and generally altered body proportions were observed.

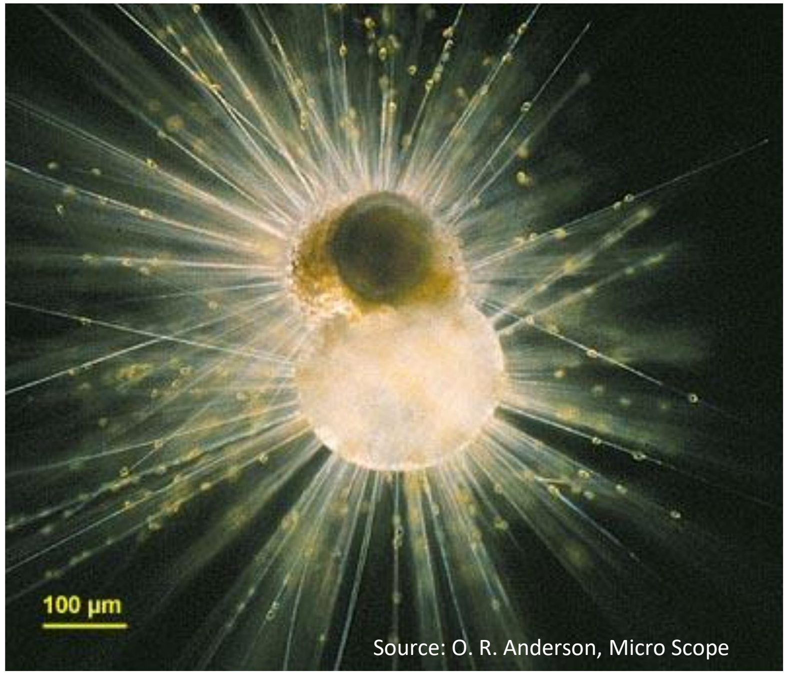
The largest producers of calcium carbonate ($CaCO_3$) are:

- the **coccolithophores**,
- the **foraminifera** and
- the **thecosomata** (sea butterflies, pteropods).

Coccolithophores



Foraminifera



Thecosomata (sea butterfly)

The largest producers of calcium carbonate ($CaCO_3$) are:

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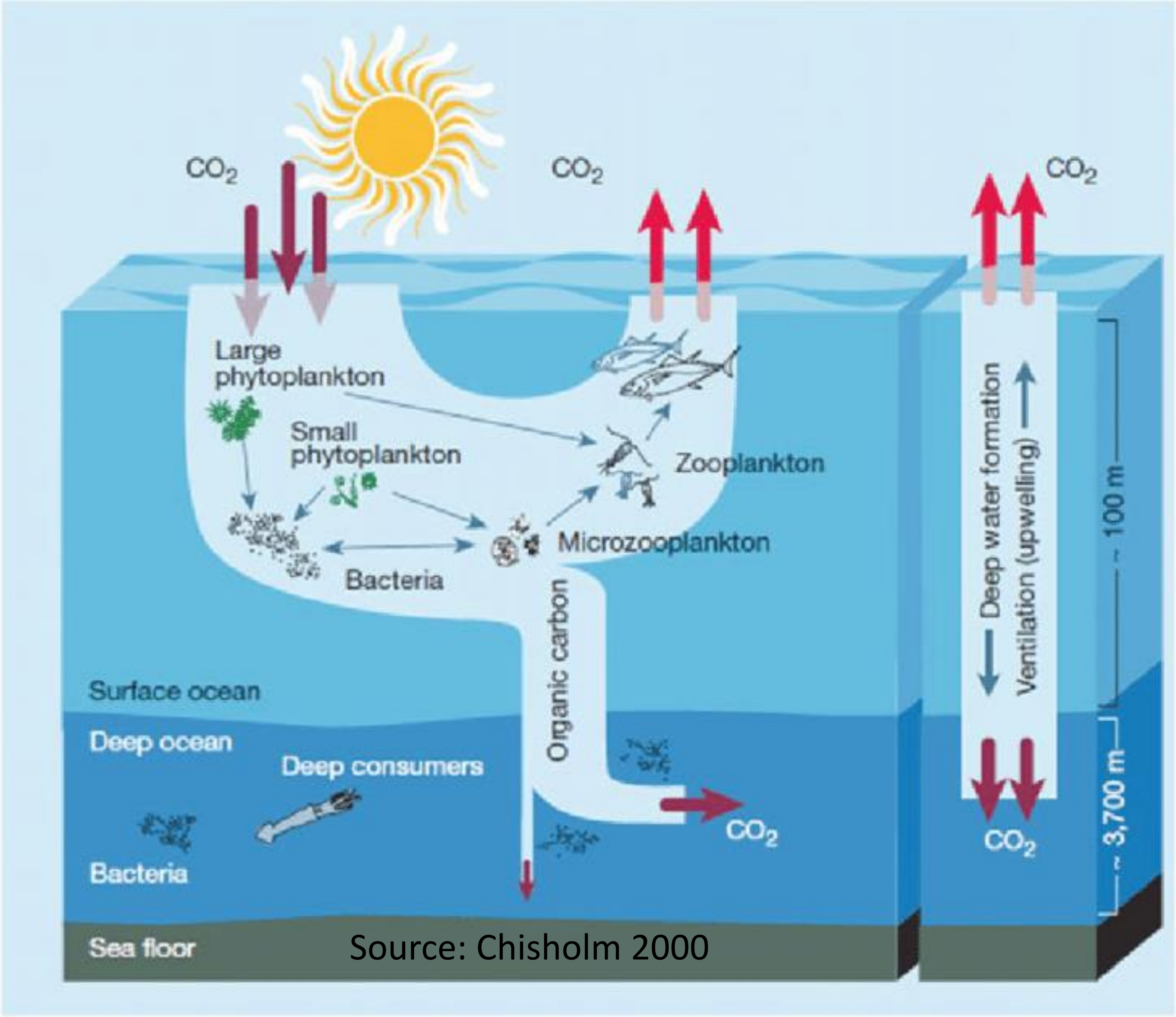
- the **foraminifera** and
- the **thecosomata** (sea butterflies, pteropods).

These three calcifiers are responsible for almost the entire transport of $CaCO_3$ from the ocean surface into the deep sea → biological pump.

Foraminifera and coccolithophores form their shells from **calcite**, **thecosomata** from **aragonite,** which is about 50% more soluble in seawater than calcite.

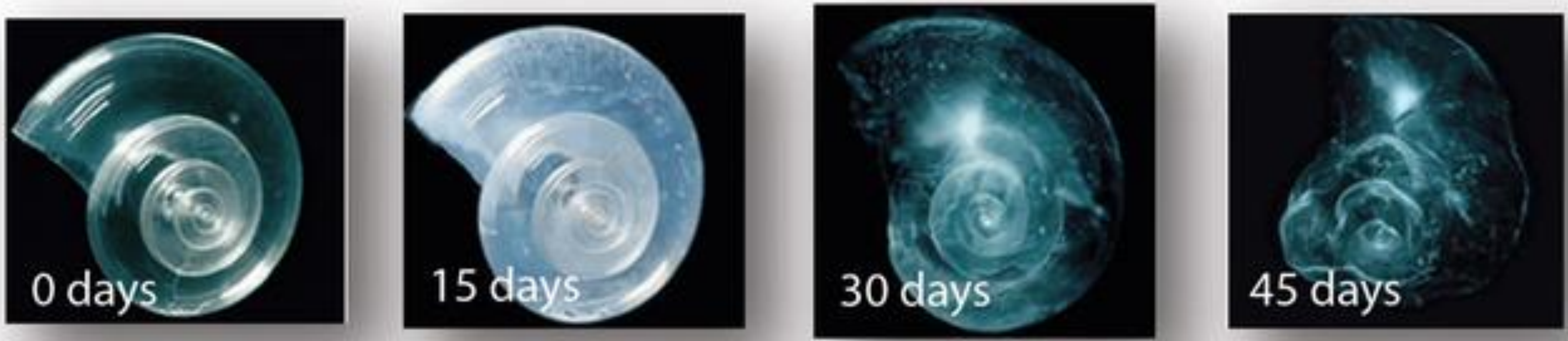


Source: Chisholm 2000

Pteropods: Sea butterflies (Limacina helicina)

→ important source of food for **juvenile Pacific salmon**

→ In a lab experiment, a sea butterfly (pteropod) shell placed in seawater with increased acidity slowly dissolves over 45 days.



(Source: David Littschwager/National Geographic Society)

Solutions ?

Technical Solutions ?

→ fertilization

→ CO_2 removal

→ ……

→ Dangers: side effects, may increase ocean acidification [IPCC, 2019]

→ Does not try to solve the cause of the problem, tries to solve only the symptom.

Change in life philosophy ?

→ Respect for the earth and the oceans

→ Interconnectedness of all living and non-living things

→ Collaboration instead of competition

→ Connection with nature; learning from indigenous people

→ Go to the root of the problem: Decrease CO_2 emissions

The IPCC Special Report (2019) also states that reducing the general risks by limiting warming to 1.5ºC above pre-industrial levels would require ***transformative systemic change, integrated with sustainable development***.

- We need to **change our paradigm of ‘eternal growth’ on a finite planet and to replace it** with the paradigm of true sustainability (not just blue- or greenwashing) and circular economy.
- Establish a **living stewardship of the earth**: to treat the earth and the ocean with respect and to recognise the interconnectedness of all life forms, between the living and the ‘non-living’.

The solution to pollution, mass mortalities and climate change cannot (only) be of technological nature, but
requires a profound change in our life philosophy and our attitude towards all life on earth.

If you want to travel happily, travel light and with little luggage. This also applies to the journey of life.

[Antoine de Saint-Exupery]


.... Together

.... Interconnectedness

Thank you for your attention !

... Shift of consciousness

... 7 generation contract

For questions/ideas/discussions please write to:

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