Cold-water corals

Hidden beauties of the deep – yet impacted by climate change

Janina V. Büscher

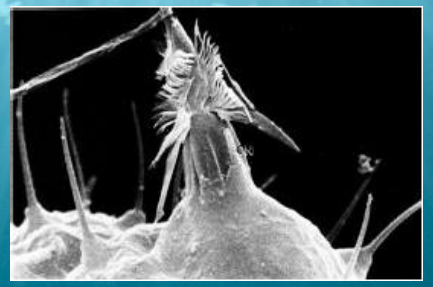
GeoTopics 2026

Ulster University

Corals

Phylum: Cnidaria

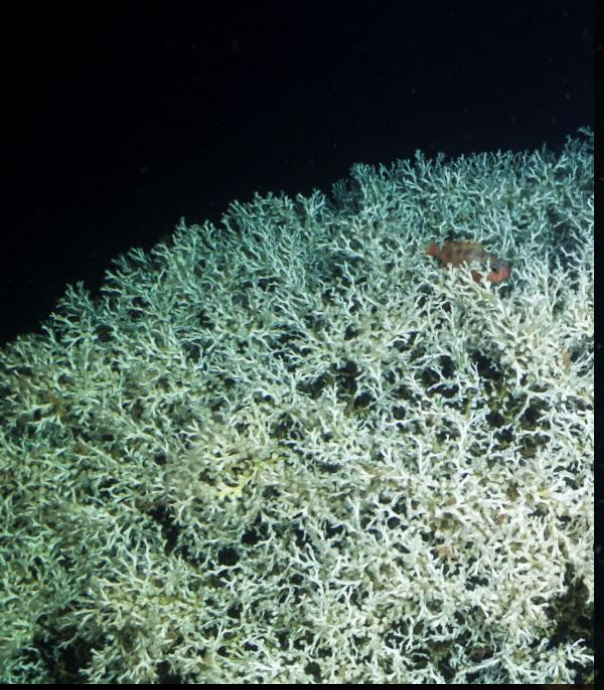
→ stinging cells (cnidocytes)

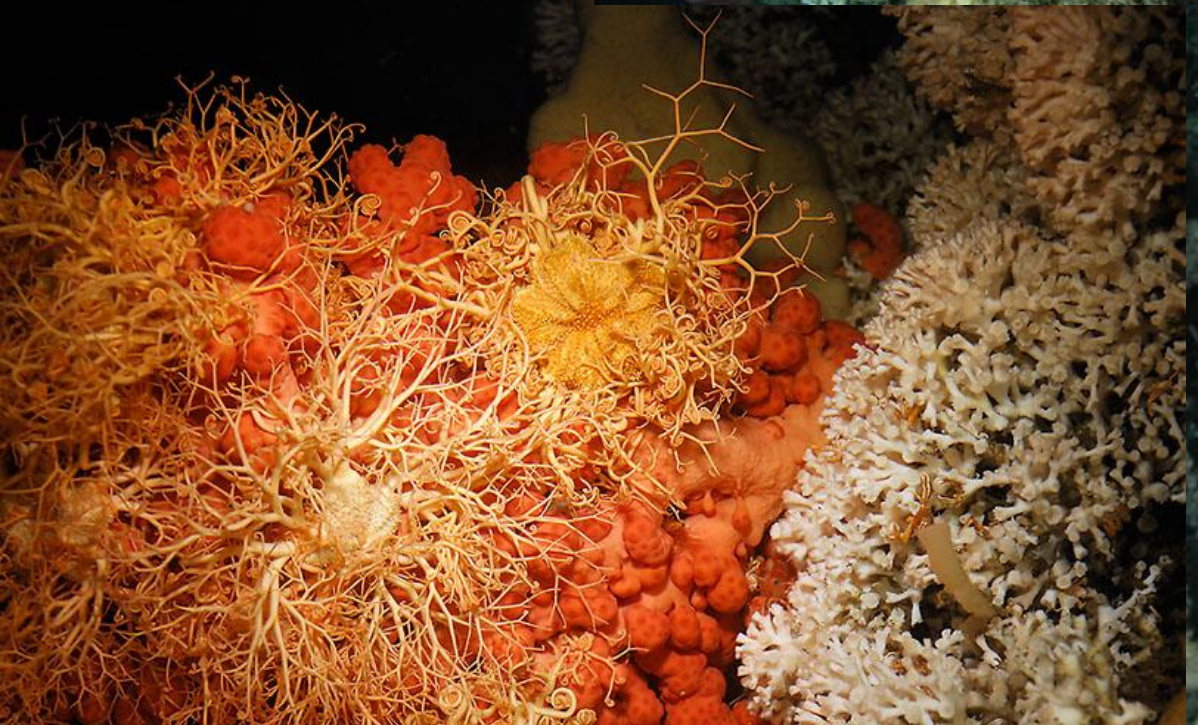


Subphylum: Anthozoa (“flower animals”)

- Octocorallia (soft corals)
- Hexacorallia (stony corals)

- sessile (attached to seabed/hard structure)
- colonial or solitary → polyps are individuals
- warm-water vs. cold-water corals
- zooxanthellate vs. azooxanthellate
- filter feeders (plankton, nutrients, trace elements)
- hermatypic (reef-builders) or ahermatypic




Cold-water coral distribution

- More than half of all coral species in water depths > 50 m

Source: UNEP/GRID-Arendal Maps & Graphics Library

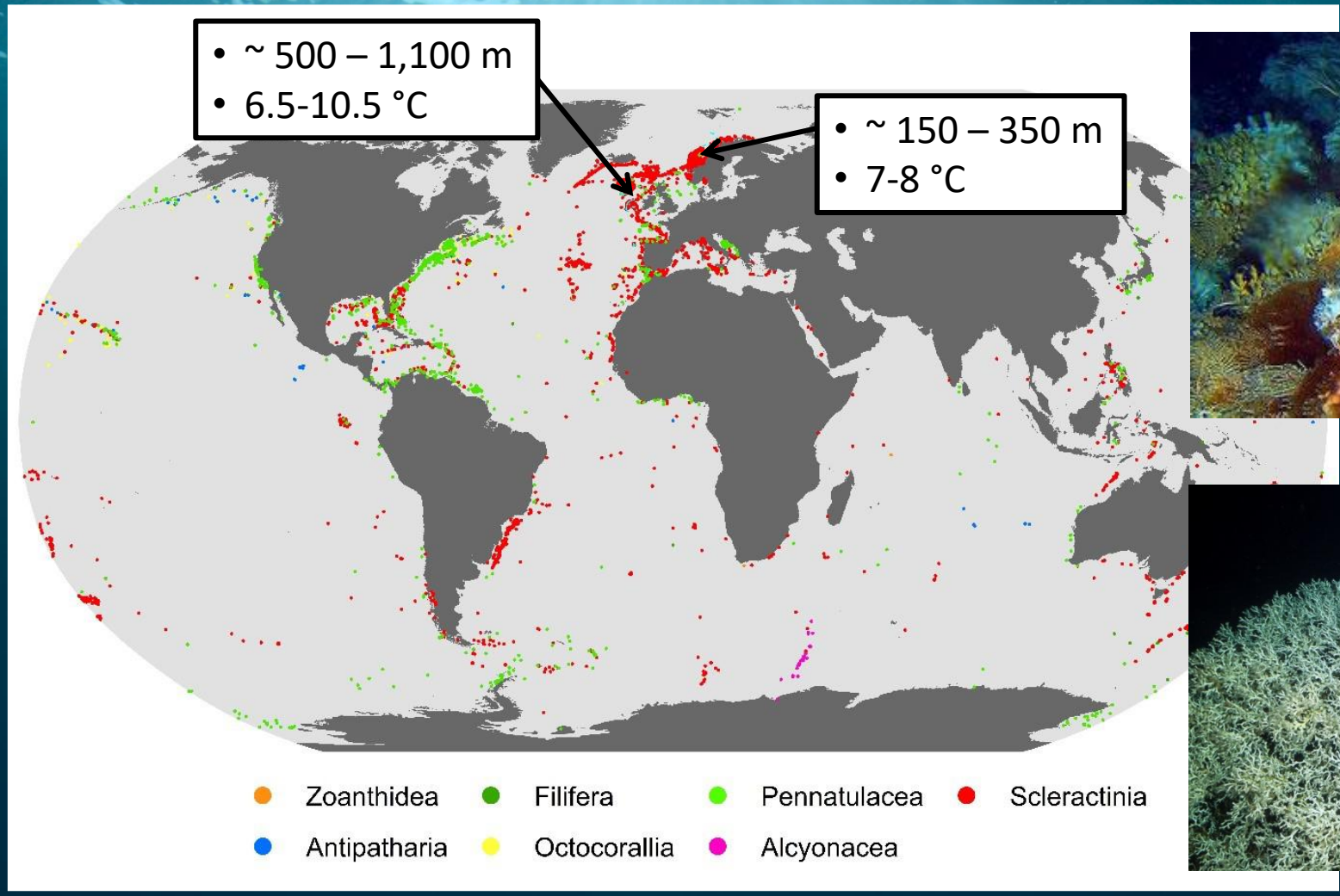
Cold-water corals Warm-water corals

Cold-water coral distribution

- More than half of all coral species in water depths > 50 m
- ‘Coral gardens’ to large deep-water framework reefs

  → 17 framework forming species (Scleractinia)

- 39 to > 3,000 m
- 4 to 14°C
- Salinity ~ 35 to 38

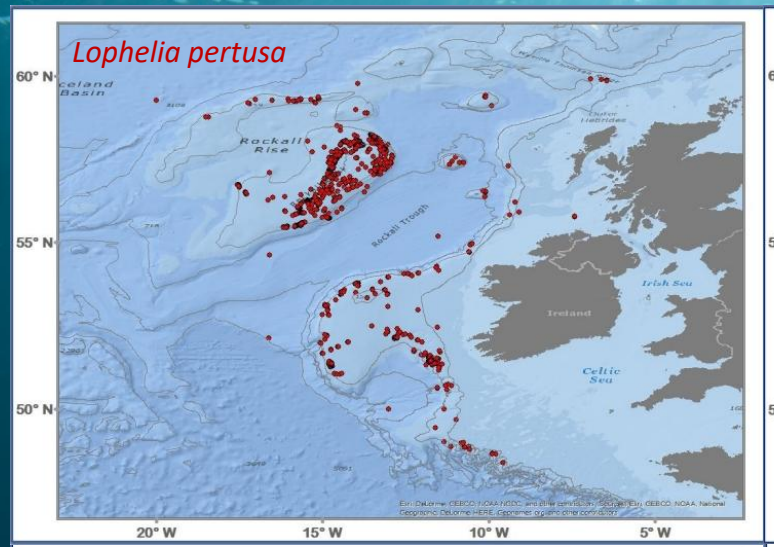


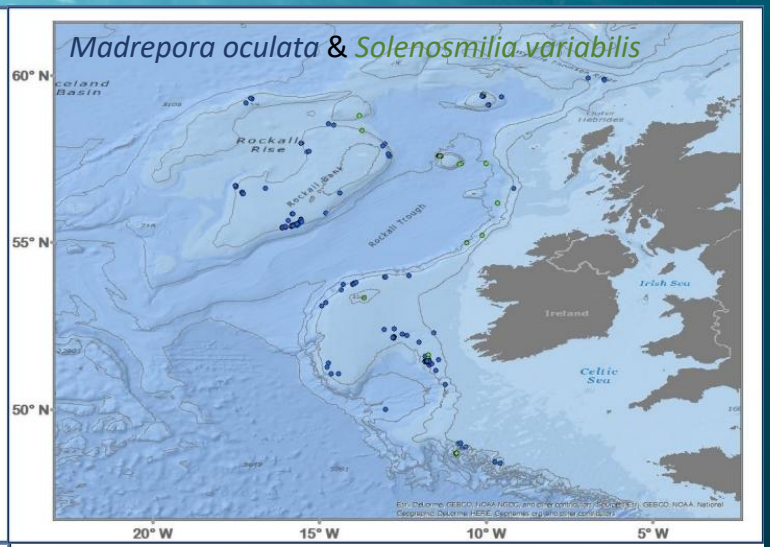
Freiwald *et al.* (2021), UNEP-WCMC dataset version 5.1

A. Lindner, NOAA Fisheries

JAGO-Team, GEOMAR

Cold-water coral distribution around Ireland





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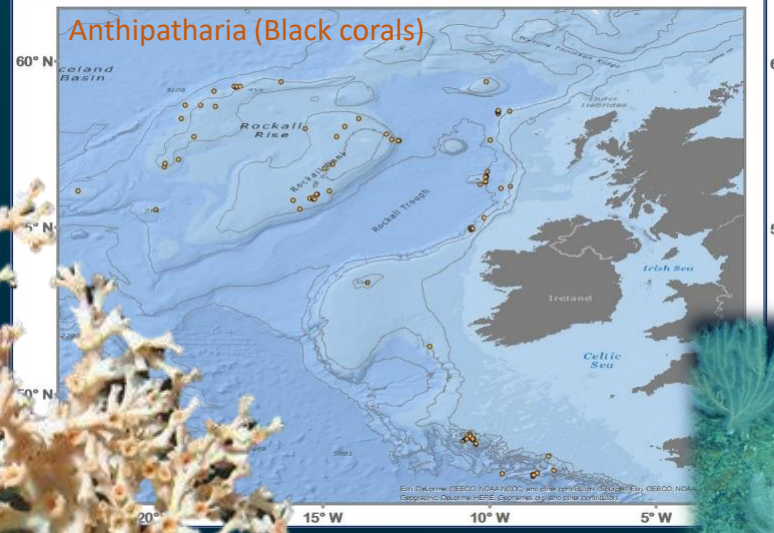

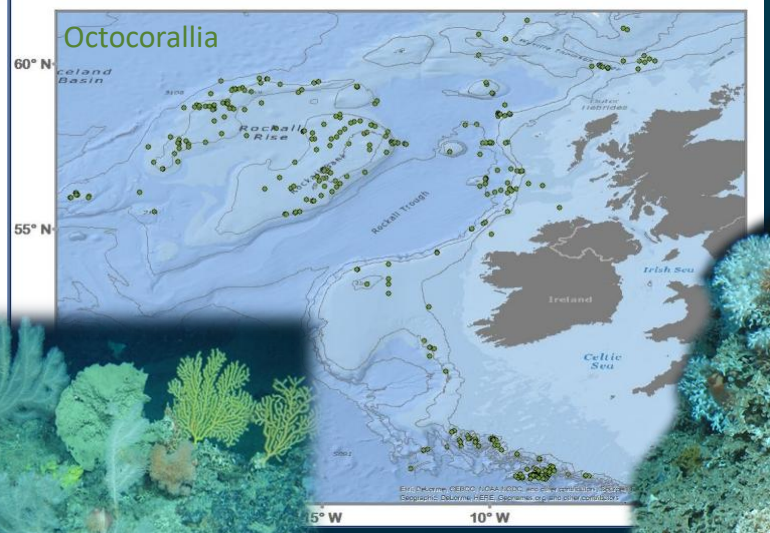

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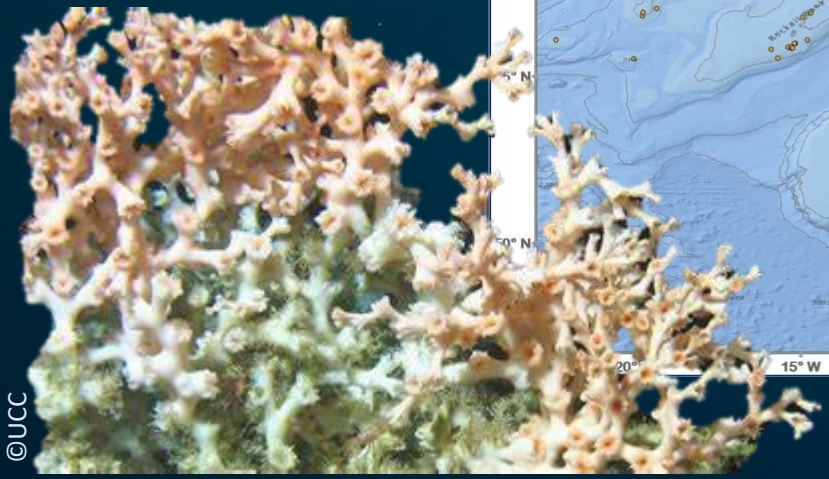
Forde *et al.* (2024). *Reef habitat in Irish Offshore Waters – A synthesis of current knowledge*. Irish Wildlife Manuals, No. 152. NPWS, Ireland.



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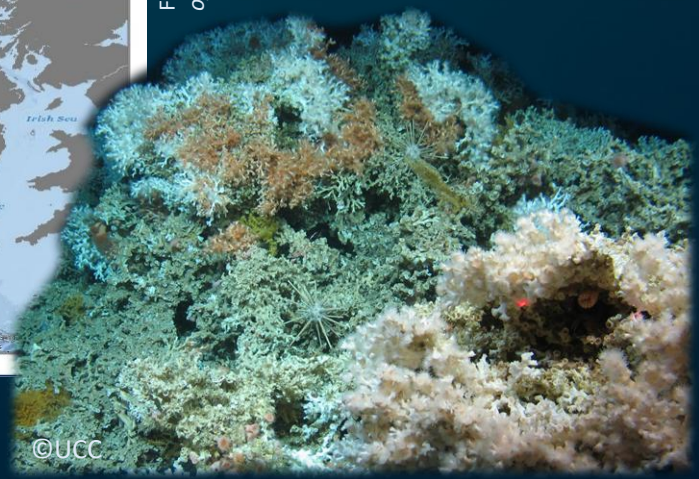

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Cold-water coral distribution

- ‘Coral gardens’ to large deep-water framework reefs

  → 17 framework forming species (Scleractinia)

- 39 to > 3,000 m
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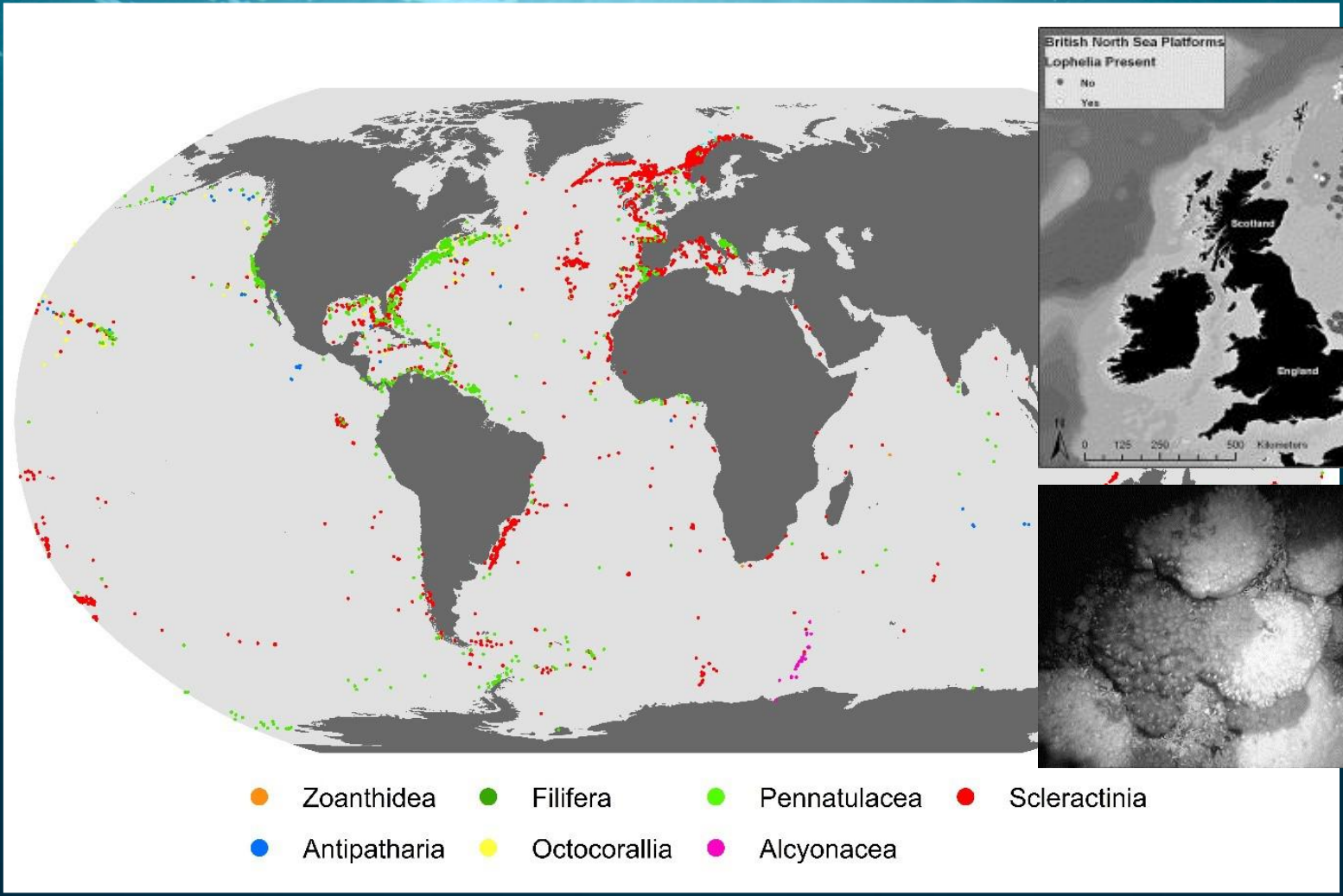
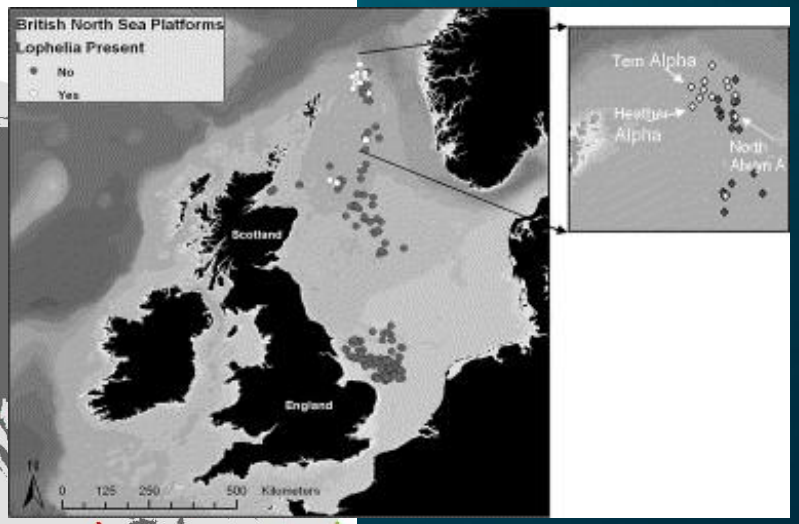
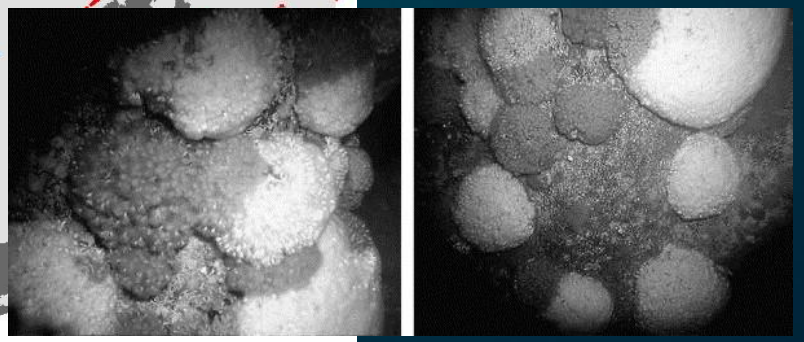
- Salinity ~ 35 to 38







Gass & Roberts, 2006
Marine Pollution Bulletin

Freiwald *et al.* (2021), UNEP-WCMC dataset version 5.1

Cold-water coral habitats

- **Live coral zone**
  - densest accumulation of live corals (~ 20 generations)
  - diverse fauna (primarily mobile species)
- **Dead coral framework**
  - highest species richness
  - very diverse fauna (many permanent species)
- **Coral rubble**
  - most degraded state
  - diverse fauna (permanent and mobile species)

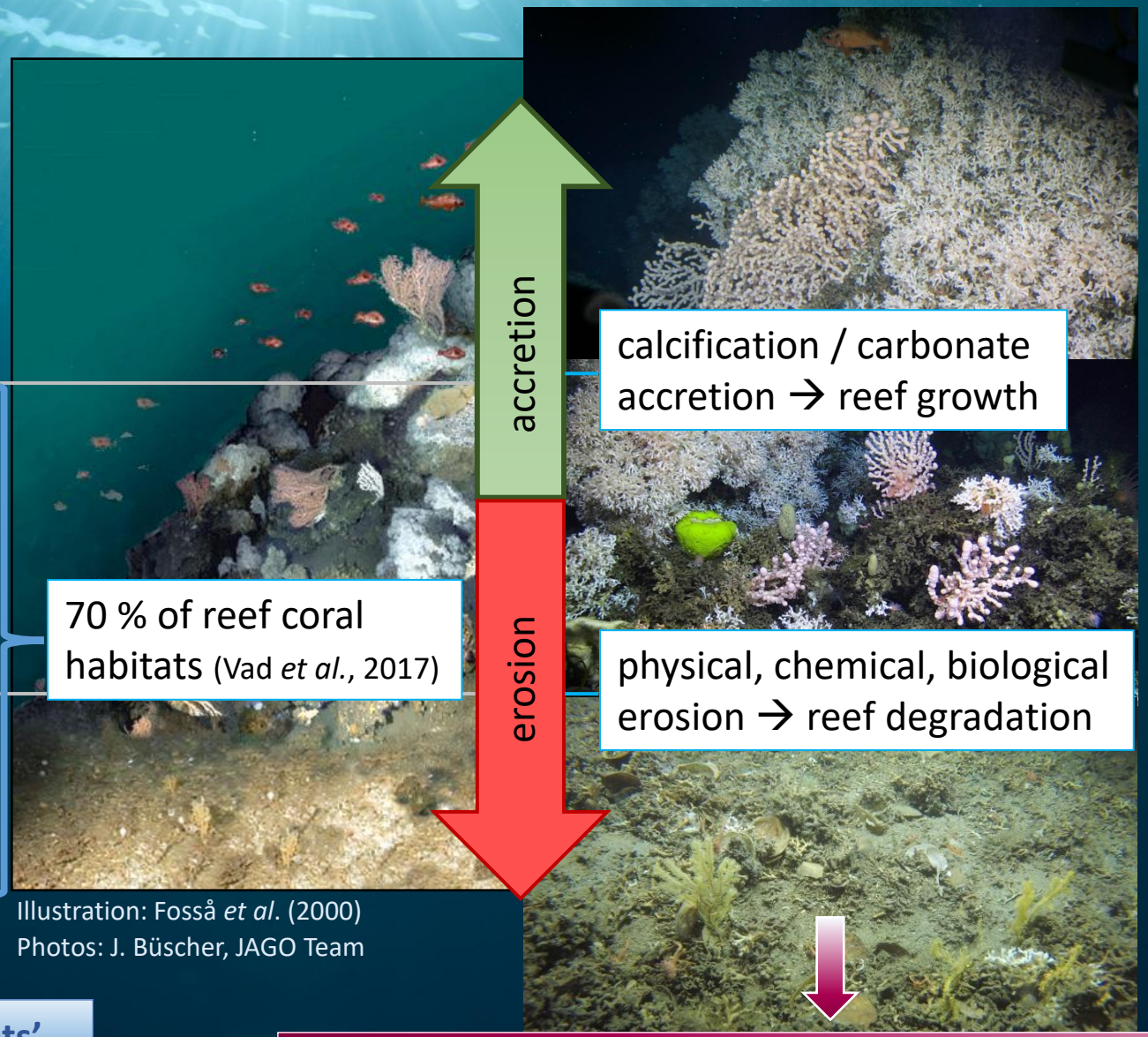


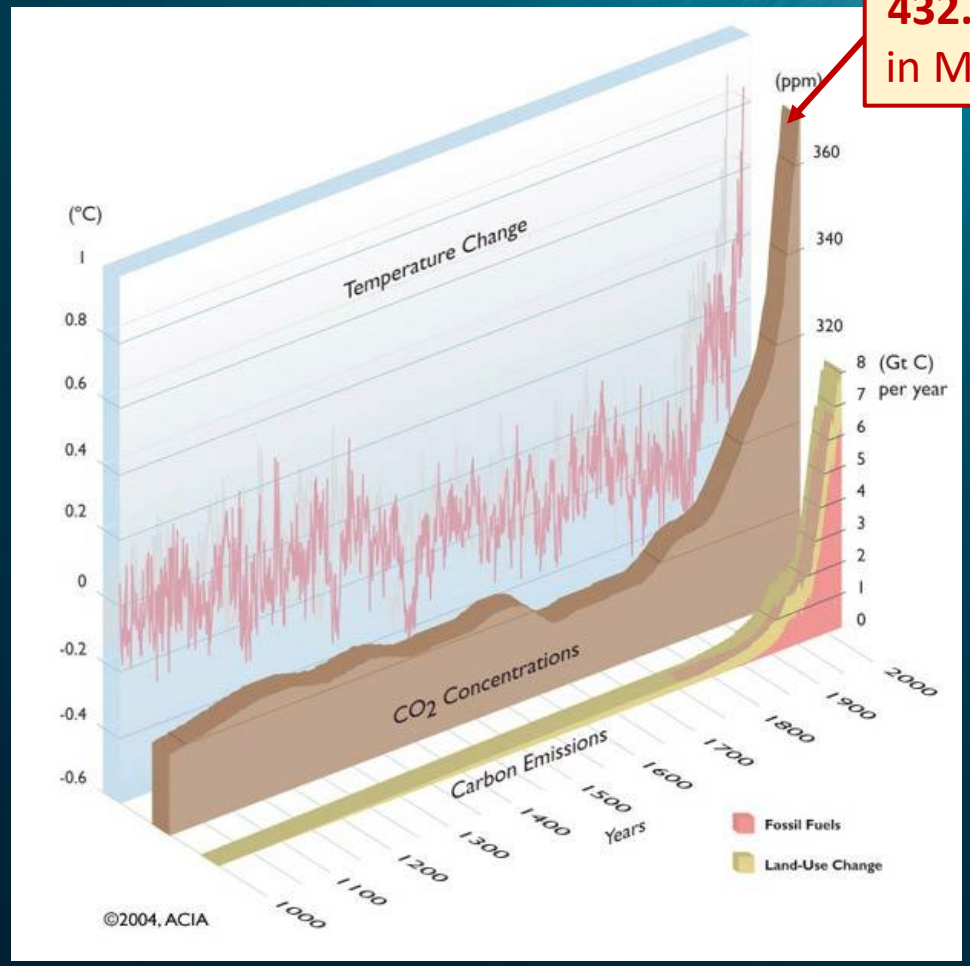
Illustration: Fosså *et al*. (2000)
Photos: J. Büscher, JAGO Team

- **'biodiversity hotspots'**

70% of known CWCs in undersaturated conditions by 2100

Ocean as sink for anthropogenic CO_2

- One of the major gases taken up by the ocean is CO_2
- CO_2 is a greenhouse gas – influences Earth's climate



432.34 ppm in May 2026

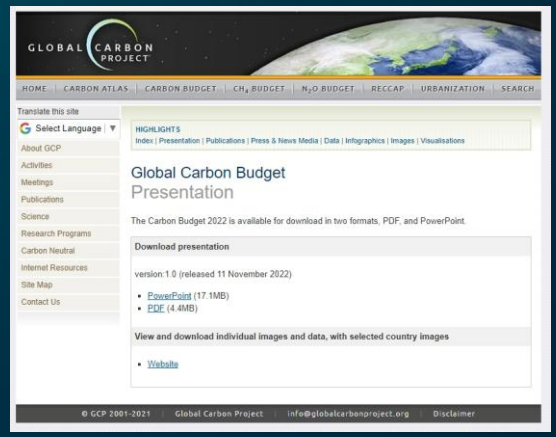
51% above pre-industrial levels!

10.1 ± 0.5 GtC yr^{-1} (36.8 ± 1.8 $GtCO_2$ yr^{-1})

1.1 ± 0.7 GtC yr^{-1} (4.1 ± 2.6 $GtCO_2$ yr^{-1})

2014-2024

Global Carbon Project



https://essd.copernicus.org/preprints/essd-2024-519/

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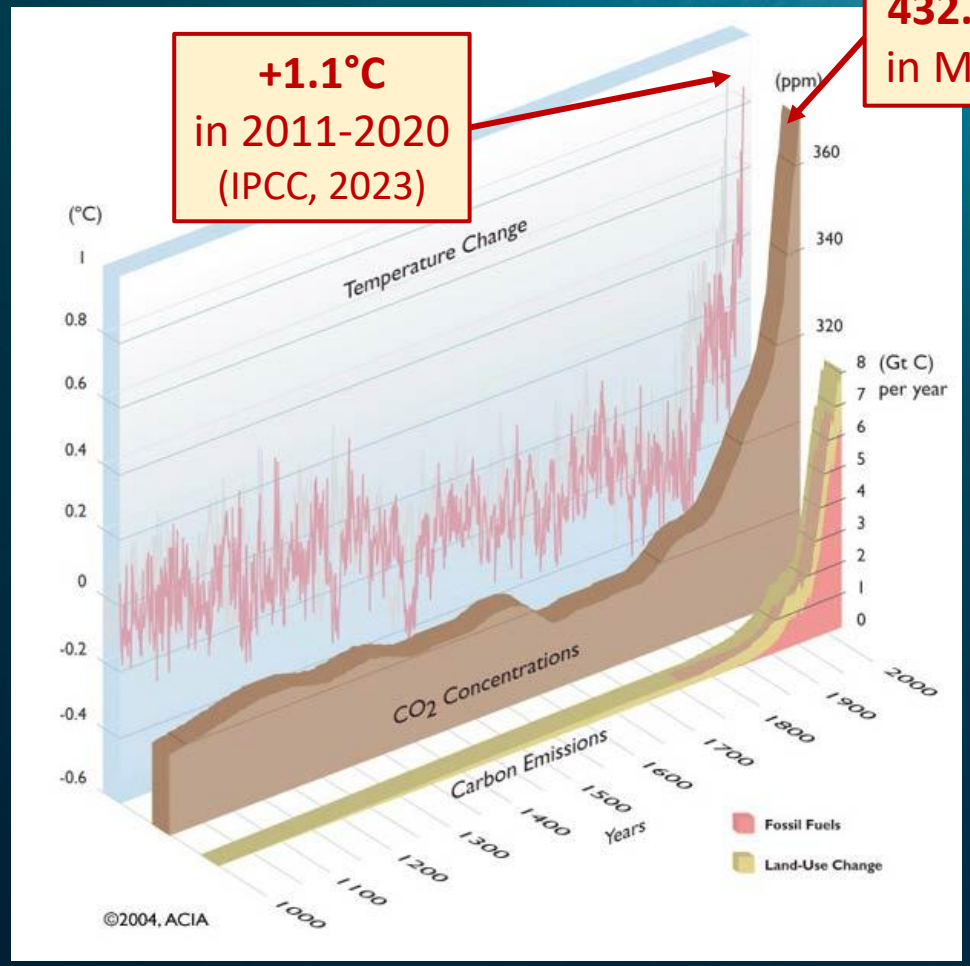


51% above pre-industrial levels!

46.0%

5.2±0.02 Gt C yr^{-1}

28.3%

3.2 ±0.9 Gt C yr^{-1}

25.7%

2.9±0.4 Gt C yr^{-1}

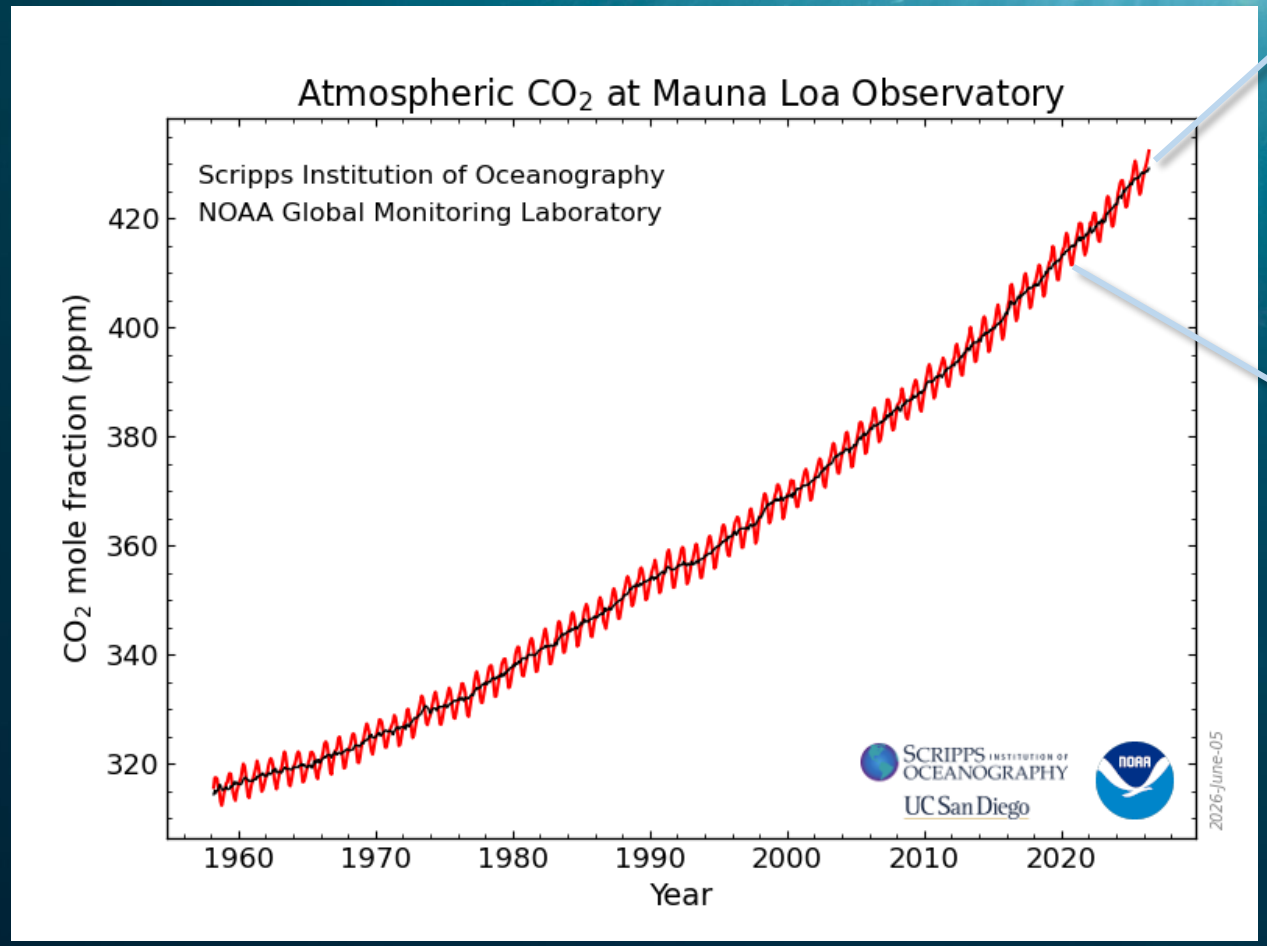
2014-2024

Global Carbon Project

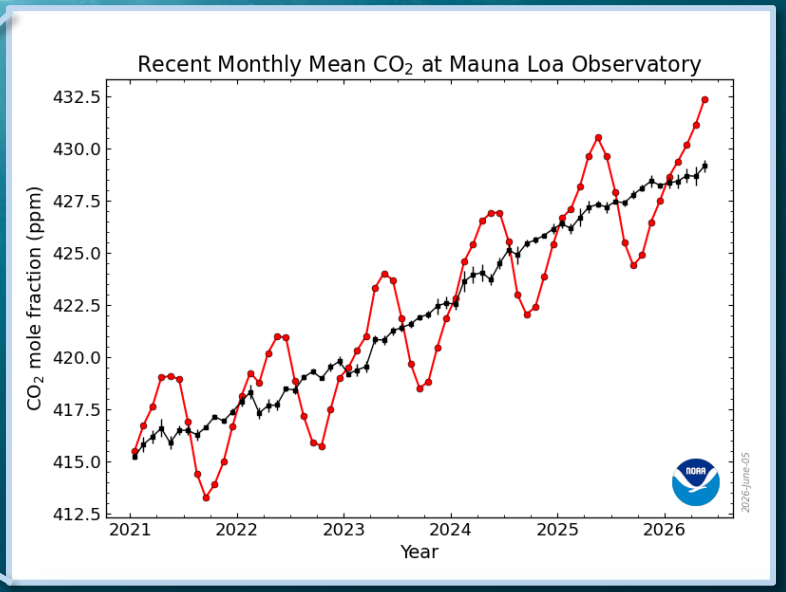
https://essd.copernicus.org/preprints/essd-2024-519/

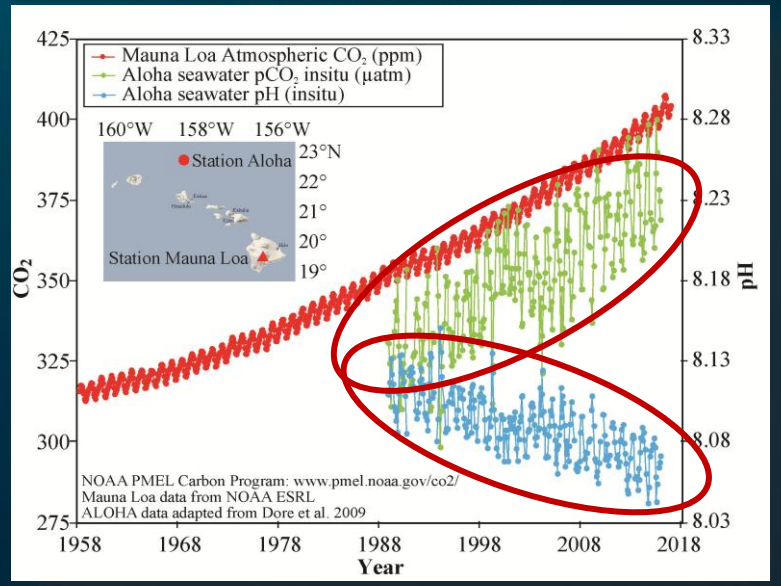
https://www.ipcc.ch/

Ocean as sink for anthropogenic CO_2



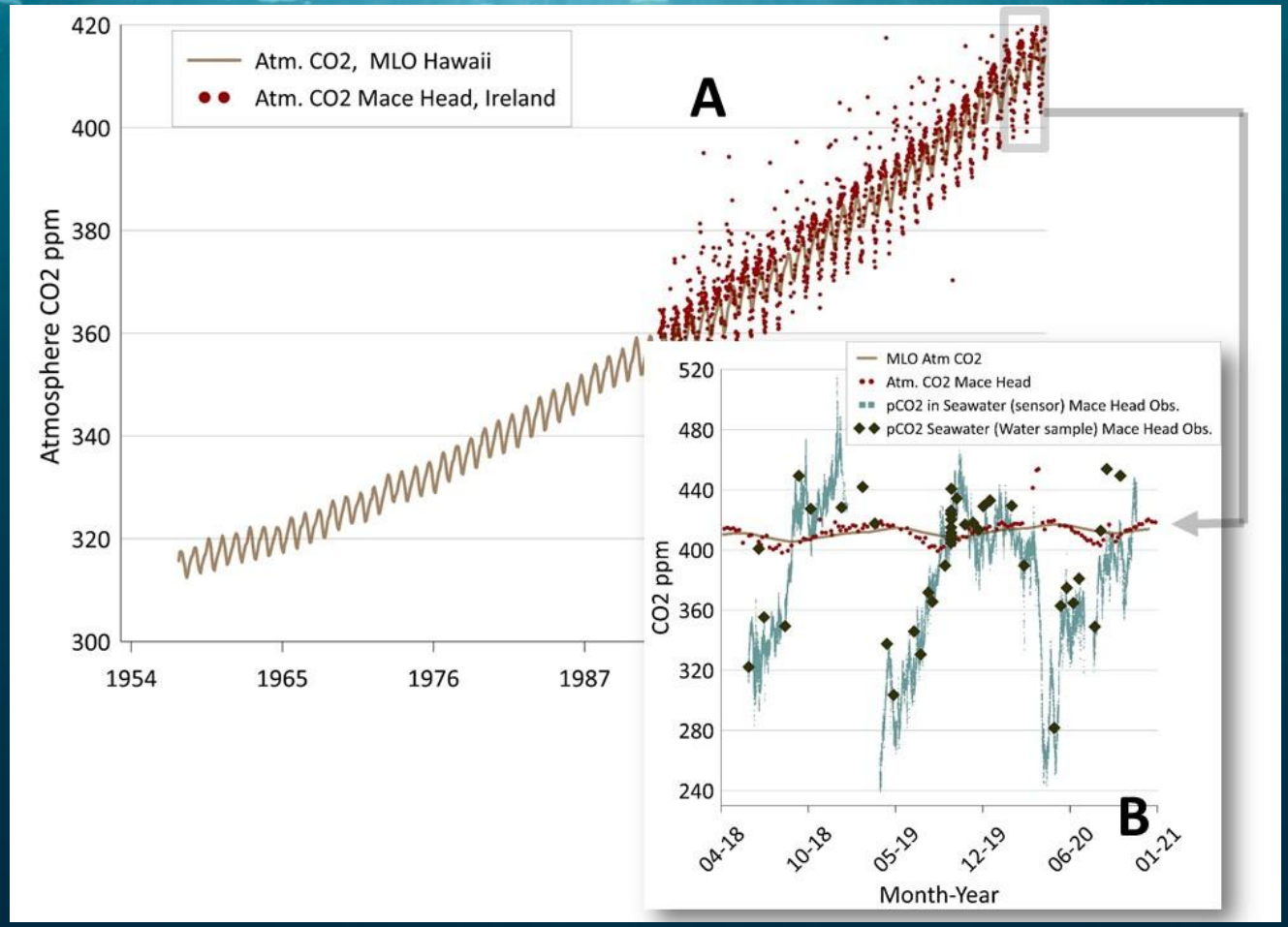
https://gml.noaa.gov/ccgg/trends/mlo.html





Ocean as sink for anthropogenic CO_2

CO_2 Time Series at Mace Head in the North Atlantic in comparison

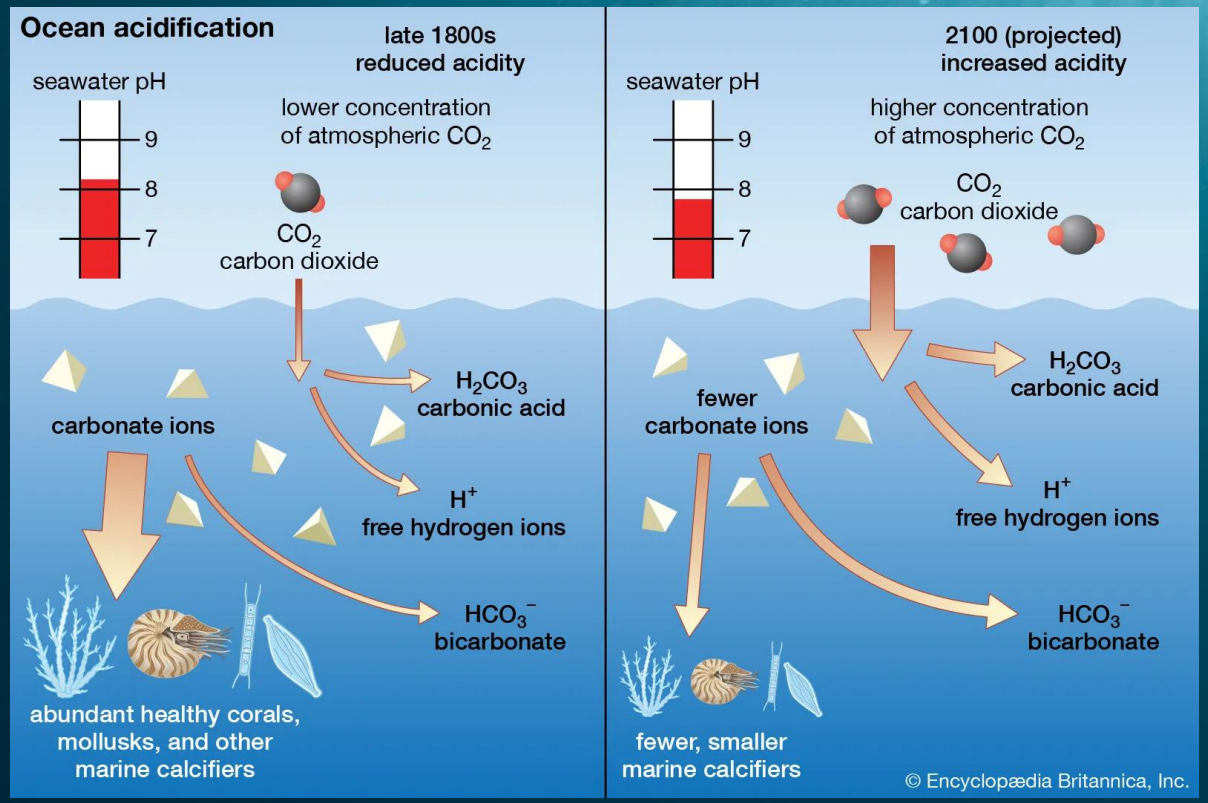


Büscher et al. Chapter 4 – Ocean Chemistry *In: Nolan, G., Cusack, C., Fitzhenry, D. (Eds.) (2023). Irish Ocean Climate & Ecosystem Status Report. Marine Institute, Galway, Ireland, pp 192.*

https://www.marine.ie/site-area/areas-activity/oceanography/irish-ocean-and-climate-status-report

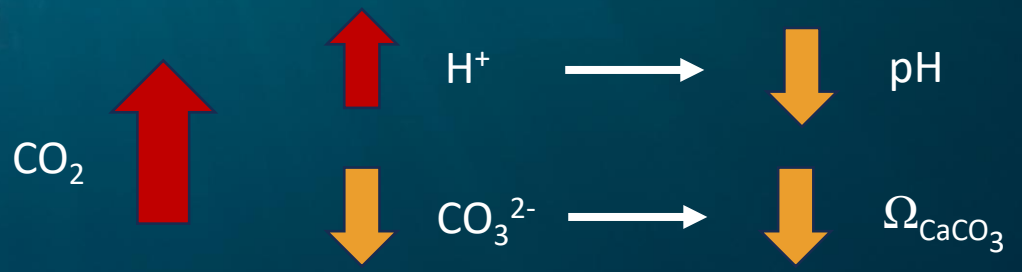
Ocean acidification

'The other CO_2 problem'



$$CO_2\,(aq) + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

Carbonic acid — Bicarbonate — Carbonate



Ocean acidification refers to a reduction in the pH and carbonate ion concentration of the ocean over an extended period of time, caused primarily by uptake of CO_2 from the atmosphere

Calcium Carbonate ($CaCO_3$)

Saturation State

$$\Omega_{phase} = \frac{[Ca^{2+}] * [CO_3^{2-}]}{K^*_{sp,\,phase}}$$

$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3$ Carbonate **precipitation** $\Omega_{CaCO_3} > 1$

$CaCO_3 \longrightarrow Ca^{2+} + CO_3^{2-}$ Carbonate **dissolution** $\Omega_{CaCO_3} < 1$

- Calcium carbonate crystallises in three anhydrous polymorphs:
  - **calcite** – thermodynamically most stable
  - **aragonite** – slightly less stable
  - **vaterite** – least stable

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Calcium Carbonate ($CaCO_3$)

´What happens to calcium carbonate shells/skeletons under ocean acidification?'

Second Year

$CaCO_3 \longrightarrow Ca^{2+} + CO_3^{2-}$

Carbonate dissolution

OA & Warming effects on *L. pertusa*

Lab Experiment (LOUISE II)

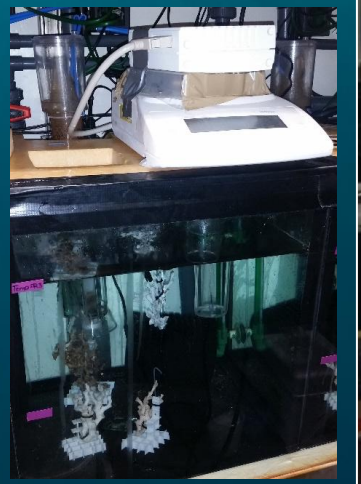
- 7 intervals of gradual temperature and pCO_2 manipulation

13 months

8 – 15 °C

400 – 1800 µatm

	controls	manipulated replicates
T1: Warming	C1 C2 C3	R1 R2 R3 R4 R5 R6 R7
		+ 1°C every 6 weeks
T2: Acidification	C1 C2 C3	R1 R2 R3 R4 R5 R6 R7
		+ 200 µatm every 6 weeks
T3: Combined	C1 C2 C3	R1 R2 R3 R4 R5 R6 R7
		+ 1°C and + 200 µatm every 6 weeks



- **calcification rates,**
- **respiration rates, &**
- **mortality of live corals**

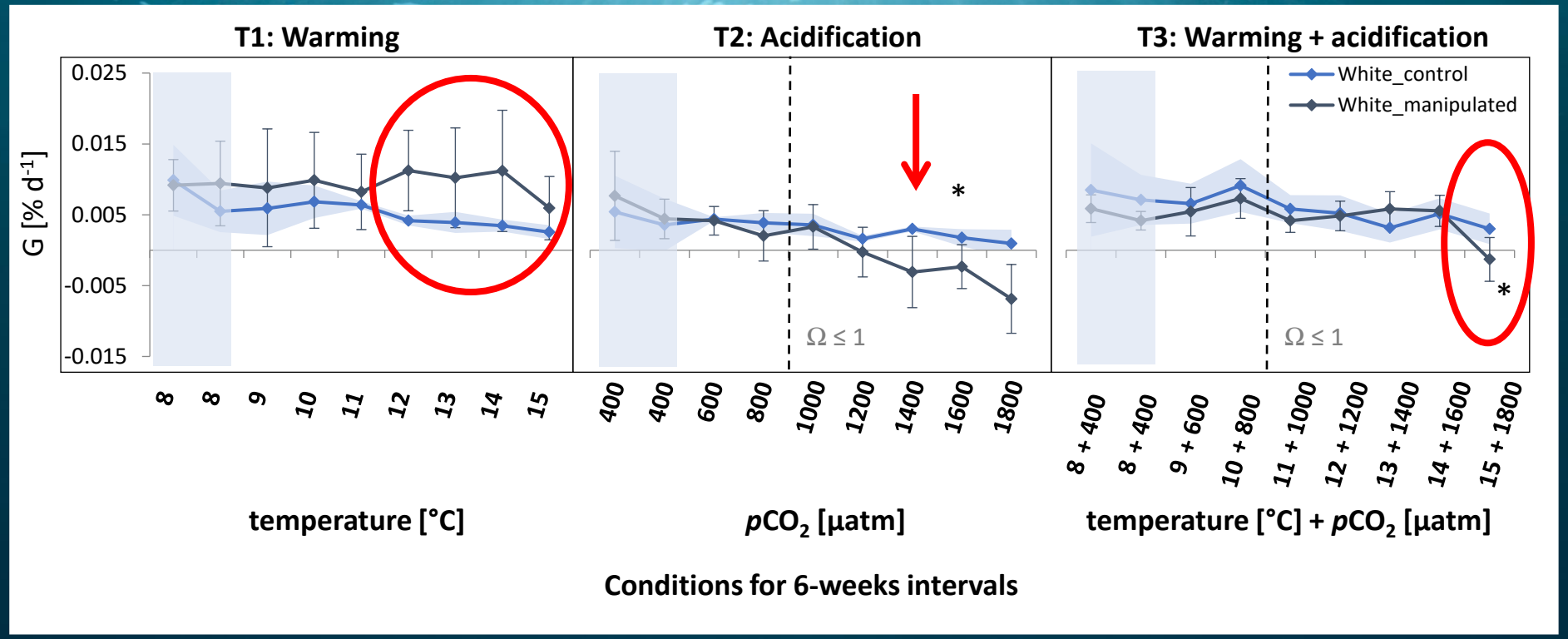
} live *L. pertusa*

- **bioerosion/dissolution**

} naturally eroded dead coral framework

Thresholds & optima under gradually increasing temperature and pCO_2 conditions

OA & Warming effects on *L. pertusa*



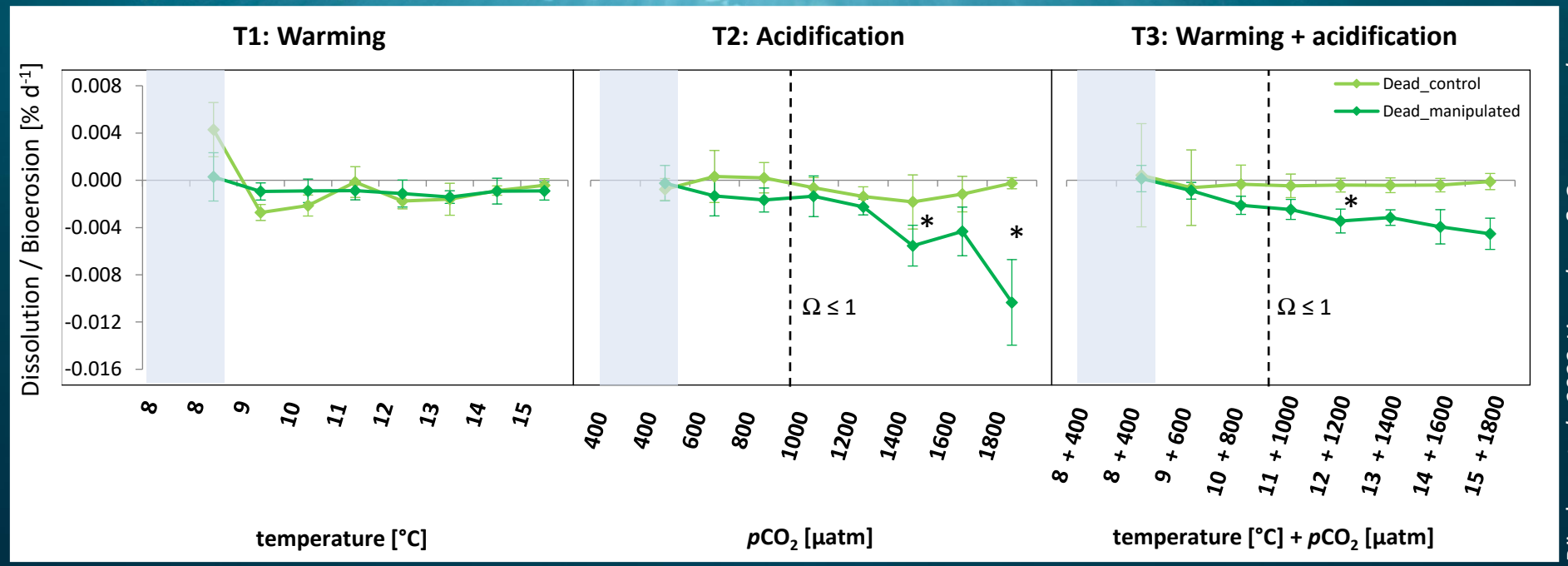
Büscher *et al.*, 2022 *Limnology & Oceanography*

- slightly increasing growth with temperature
- decreased growth under elevated pCO_2
- breakdown in growth rates from 14-15°C

  → effect amplified by ↑ CO_2

➡ Live corals can counteract the effect of OA under warmer conditions, but likely at a cost (energy imbalance)

OA & Warming effects on *L. pertusa*



Büscher *et al.*, 2022 *Limnology & Oceanography*

- no effect
- significantly increasing dissolution/bioerosion
- significantly increasing dissolution/bioerosion
- promoted by warming at lower pCO_2 levels than under acidification alone

→ dead/eroded coral parts significantly impacted by OA!

OA & Warming effects on *L. pertusa*

Laboratory:

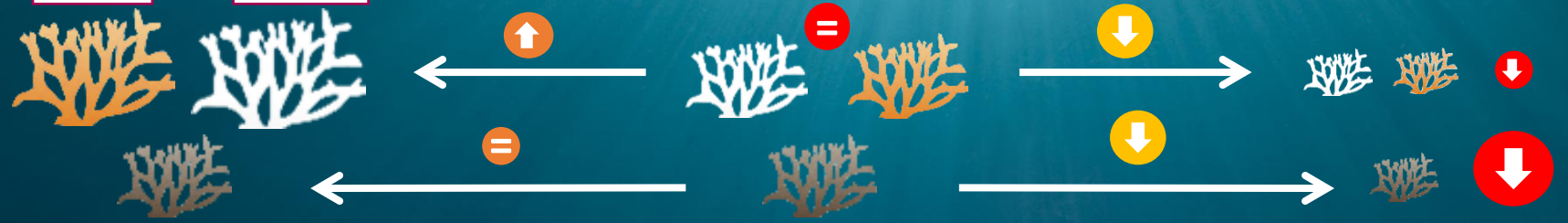
14-15°C

9-13°C | 12-14°C

Warming

Growth (Calcification)

Acidification



Degradation (Bioerosion/Dissolution)

Acidification **Warming** **Combined acidification + warming**

Increase
Decrease
No effect

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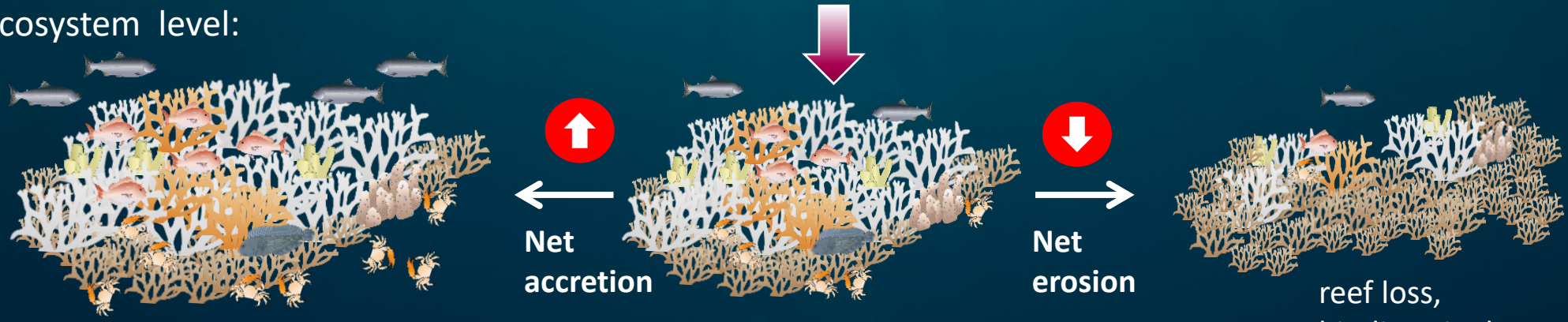
Ecosystem level:



Net accretion

Net erosion

reef production, biodiversity increase

reef loss, biodiversity loss

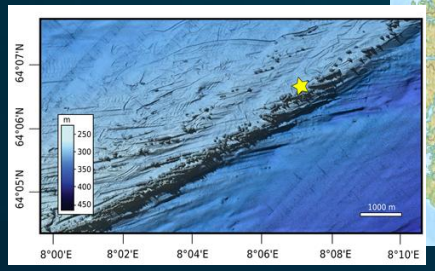
Current reef state under natural variability

1st Year Infographics

Environmental conditions

Monitor environmental conditions in a fjord compared to an offshore reef habitat

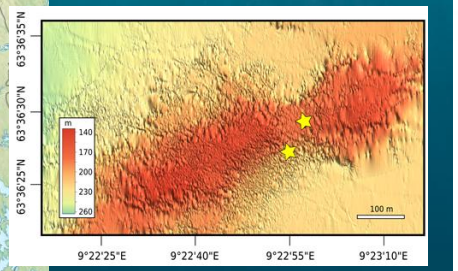
- Sula Reef Complex
  - offshore
  - 300 m
  - stable environment



- Temp.: ~ 7.5°C
- Sal: 35.1
- Flow speed: ~ 8 cm s^{-1}

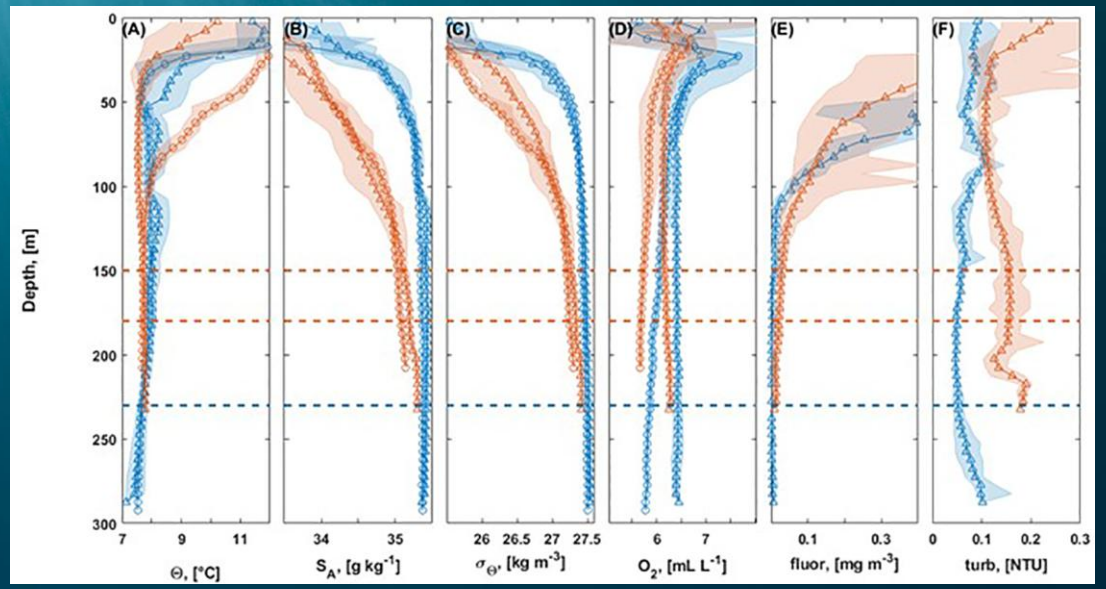
- Offshore reefs bathed in Atlantic Water

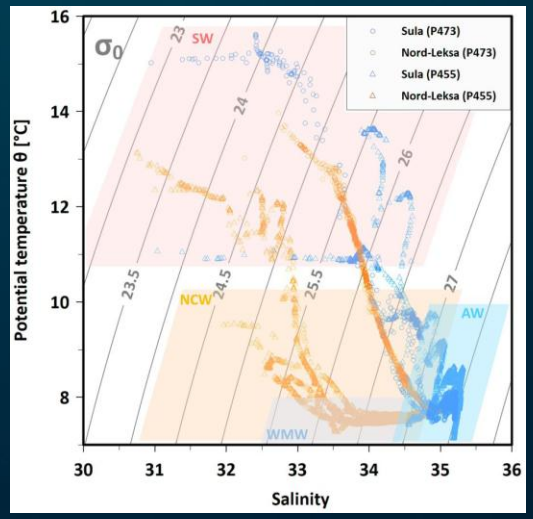
- Leksa Reef
  - inshore
  - ~ 150 – 200 m
  - currents and tides



- Temp.: ~ 7.9°C
- Sal: 34.8
- Flow speed: ~ 20 cm s^{-1}

- Inshore reefs influenced more by Norwegian Coastal Water





Büscher & Juva *et al.*, 2024 *Frontiers in Marine Science*

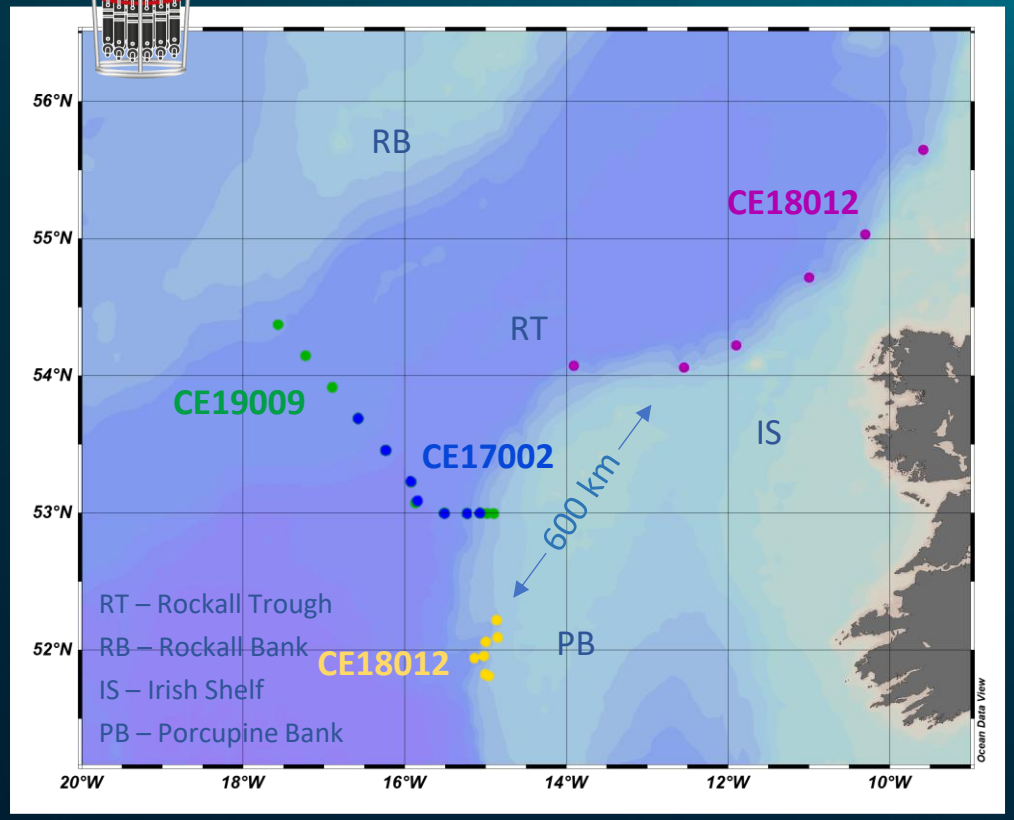
Environmental conditions

Monitor environmental north and south along the Irish continental shelf edge

CE18011 – August, 8th 2018

CE18012 – August, 13th–16th 2018

→ compare water masses north and south of the eastern flank of the Rockall Trough

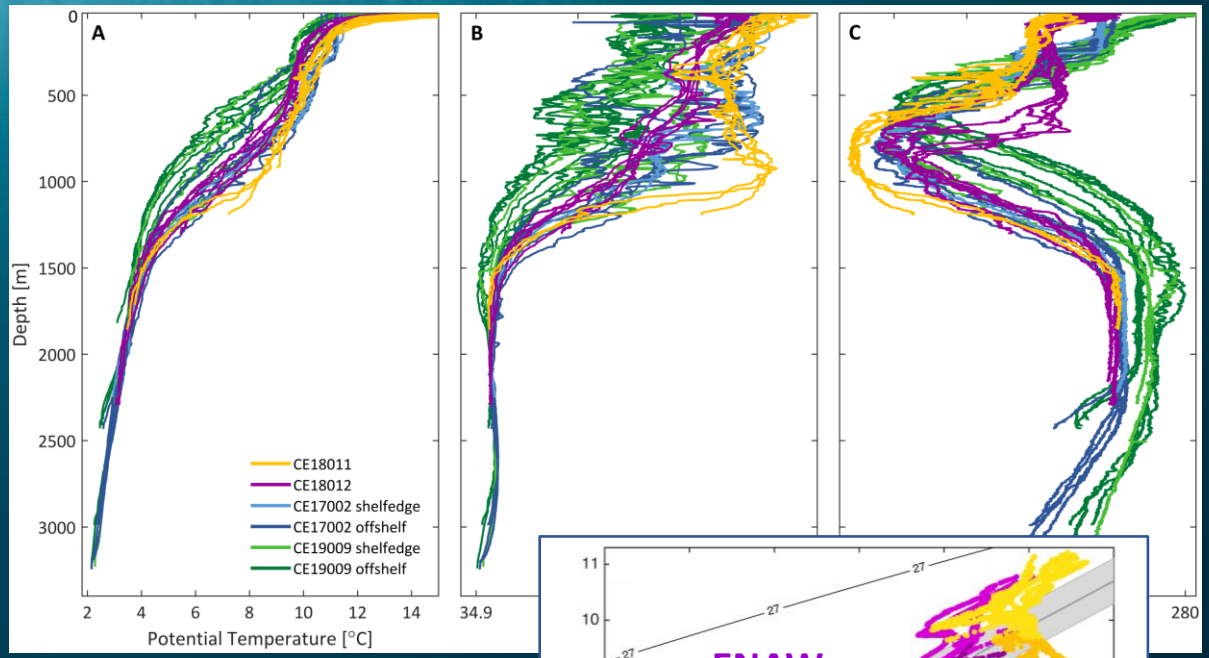


2018 – southern canyons

2018 – northern canyons

Feb 2017 – across RT

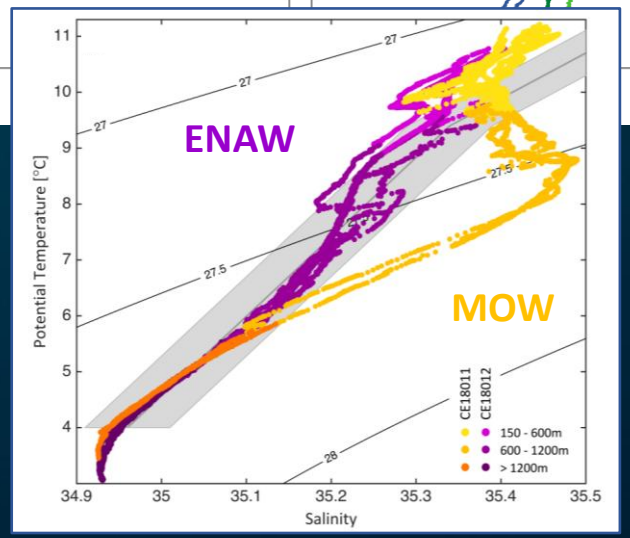
May 2019 – across RT



CE17002 – February 2017

CE19009 – May 2019

→ *'Ocean Climate Section'* surveys of the *Marine Institute* in Ireland



Büscher *et al.*, in prep. (unpublished data)

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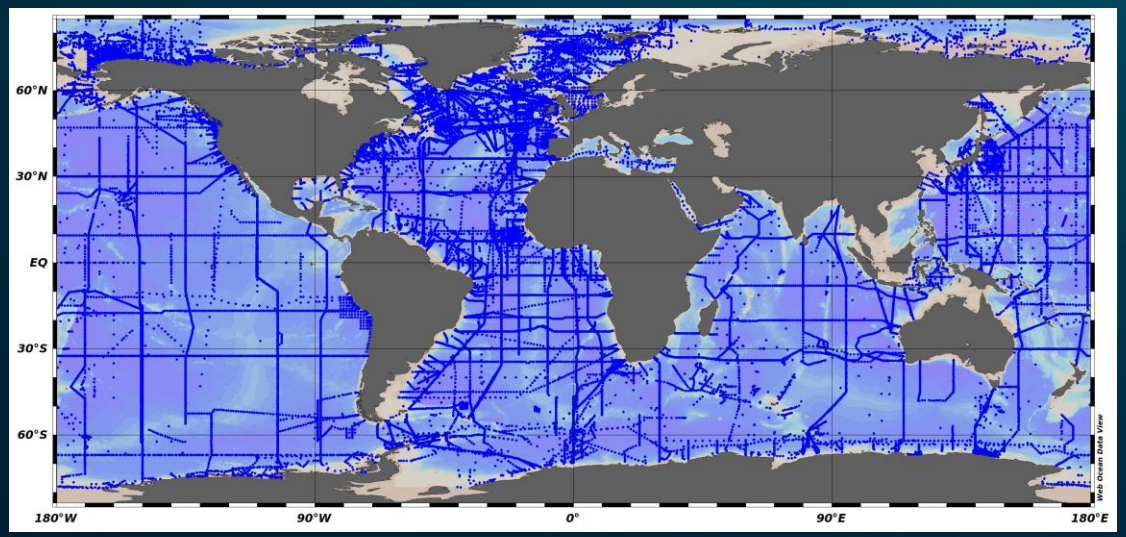
Plotting oceanographic data using global datasets

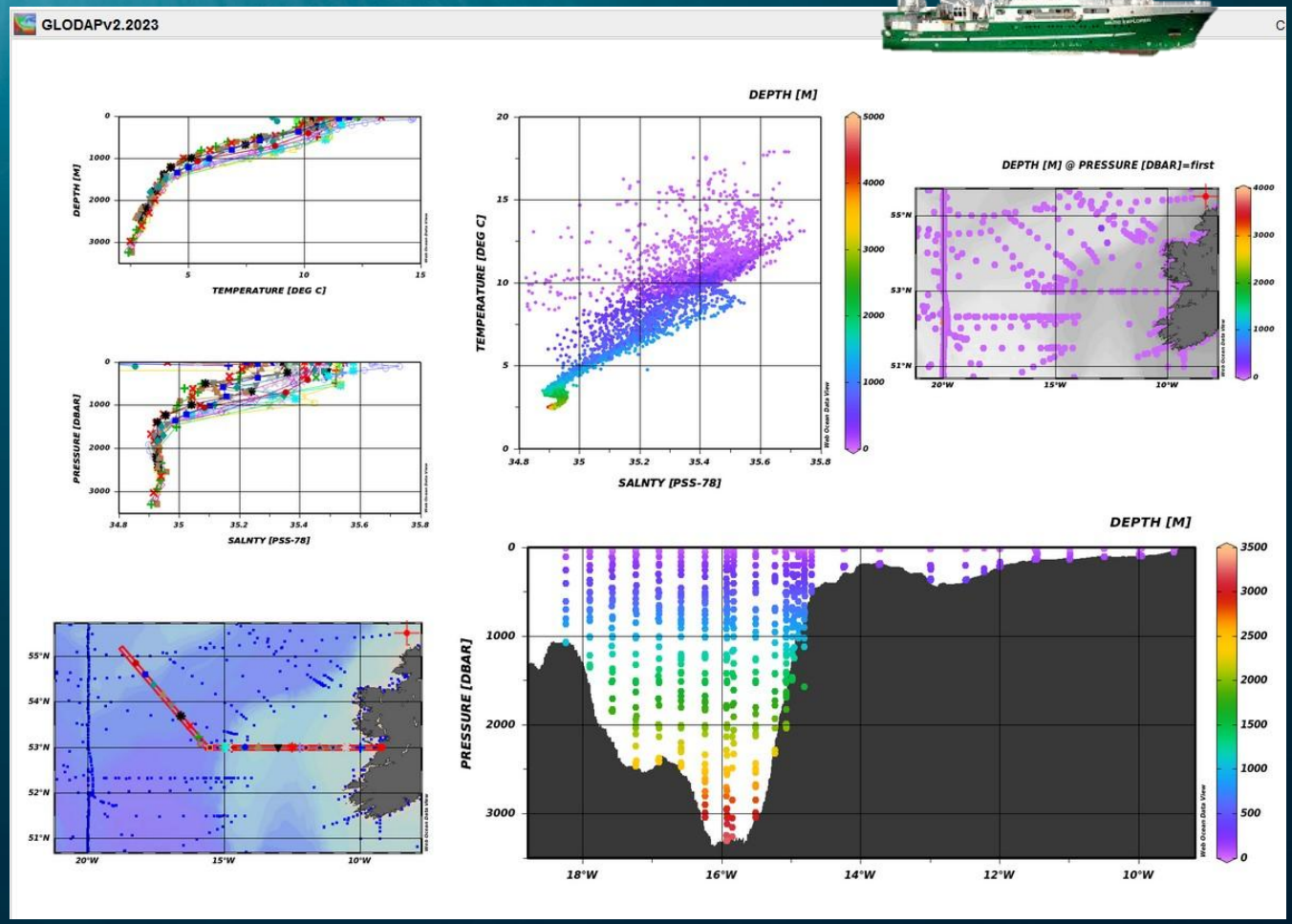
Ocean Data View

https://odv.awi.de

Final Year

GLODAPv2.2023





Cold-water coral ecosystems as case study for

- Abiotic conditions control distribution of marine species
- Effects of ocean change (ocean acidification & warming) on benthic marine ecosystems
- Aragonite saturation horizon and the effects of calcium carbonate dissolution (protective shells and skeletons)

webODV Explore

https://explore.webodv.awi.de/

https://www.geomar.de/en/discover/ocean-and-climate/climate-change-in-the-ocean/ocean-acidification

https://storymaps.arcgis.com/stories/11db7a539c3e4cbf80e703c31f04ef7c


Thank you!
Go raibh míle maith agat!
Dankeschön!
© Solvin Zankl

Any questions?