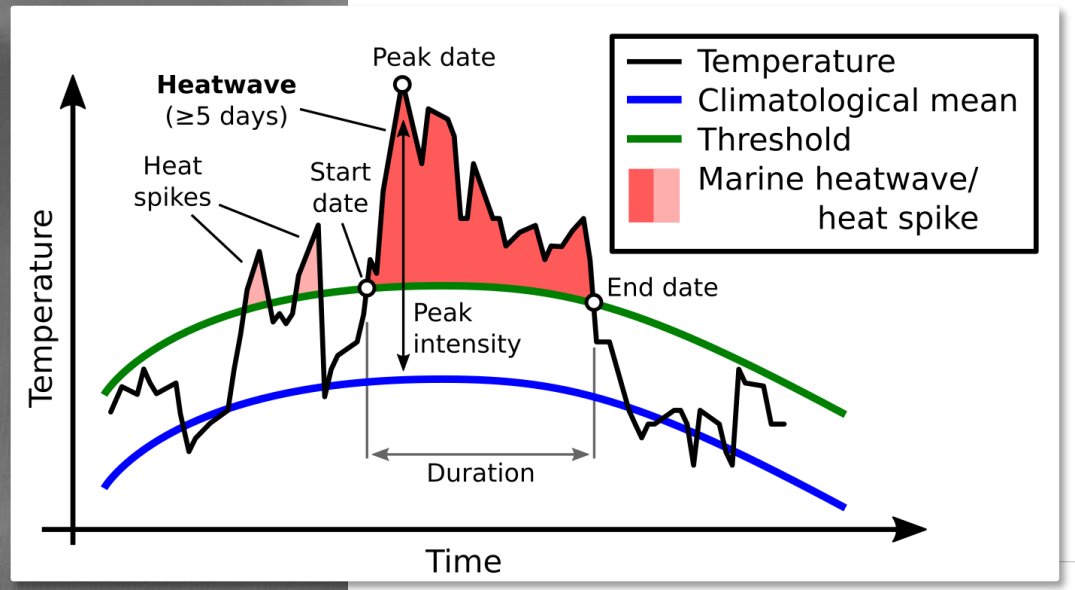
Impact of Marine Heatwaves in the coastal ocean

- an open question -

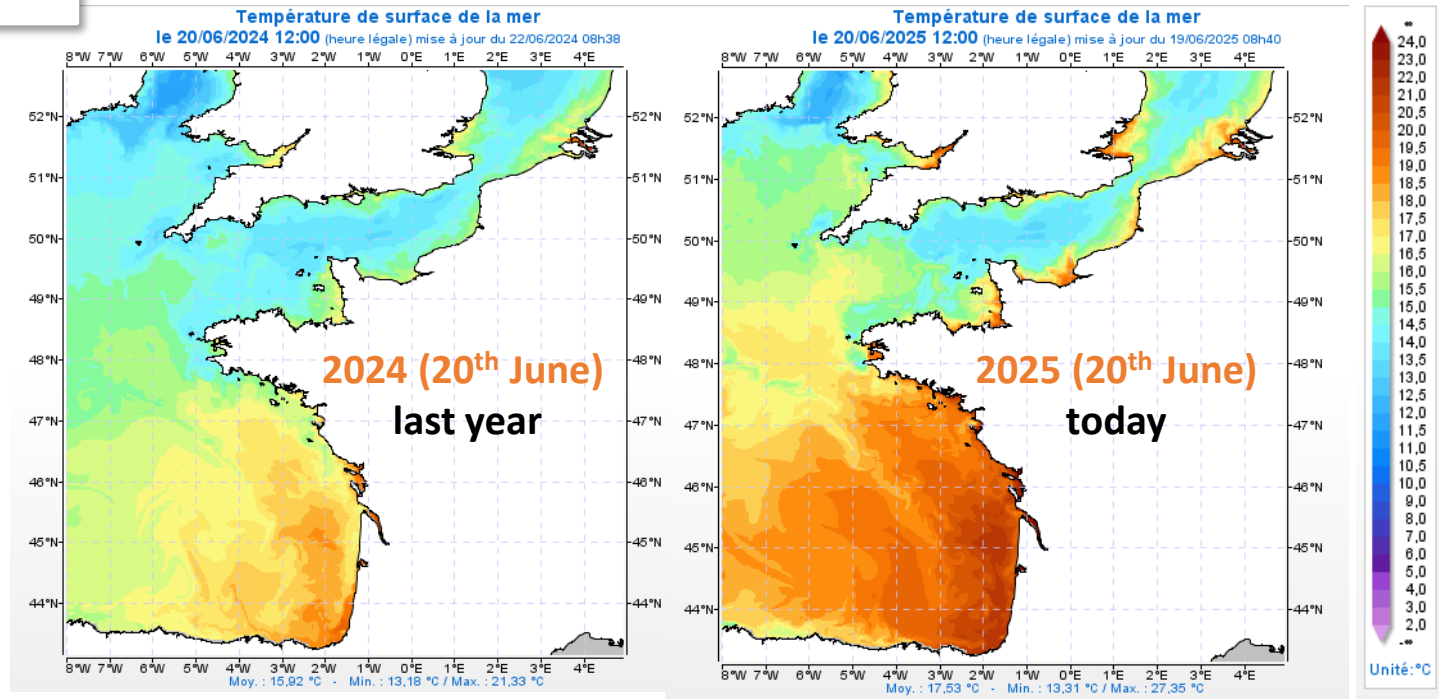
Guillaume **Charria**, Amélie **Simon**, Nathaniel **Bensoussan**, Ivane **Pairaud**, Coline **Poppeschi**, Maud **Martinez Almoyna**, Anne **Gaymard**, Nicolas **Savoye**, Xavier **Couvelard**, Sébastien **Theetten**, Jean-François **Le Roux**

Marine Heatwaves (MHWs)



MHW = Sea Temperature larger than a threshold for more than 5 days *(Hobday et al., 2016)*

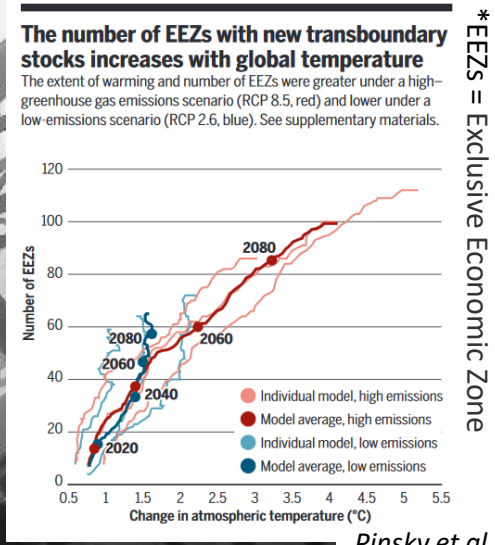
Threshold (percentile 90) calculated from SST time series



Context

Marine Heatwaves (MHWs) impacts

Oncoming changes will seriously challenge current **natural resource management** and **conservation efforts**.



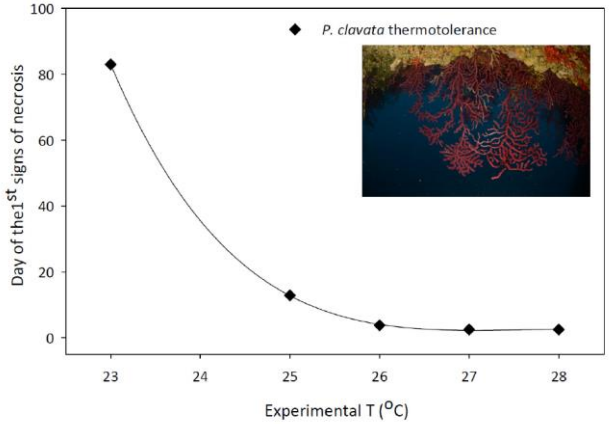
Pinsky et al. (2018) Science

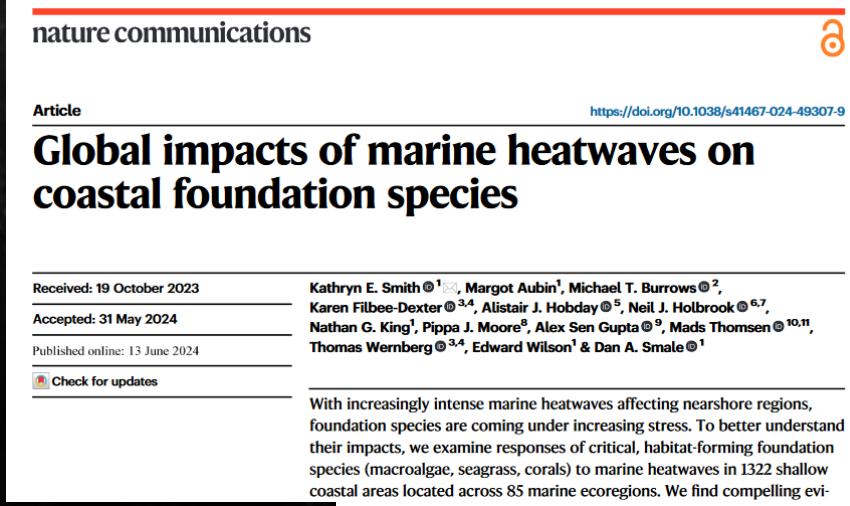
- **Geographic shifts**
- **Changes in phenology**
- **Bleaching/Mortality**

with cascading effects across ecosystems and ecosystem services

How the shifting spectrum of environmental variability will impact species, communities, and ecosystems broadly depends on **life history traits** and **adaptation capabilities**;

Thermotolerance response function for the Mediterranean soft coral *Paramuricea clavata*

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Global impacts of marine heatwaves on coastal foundation species

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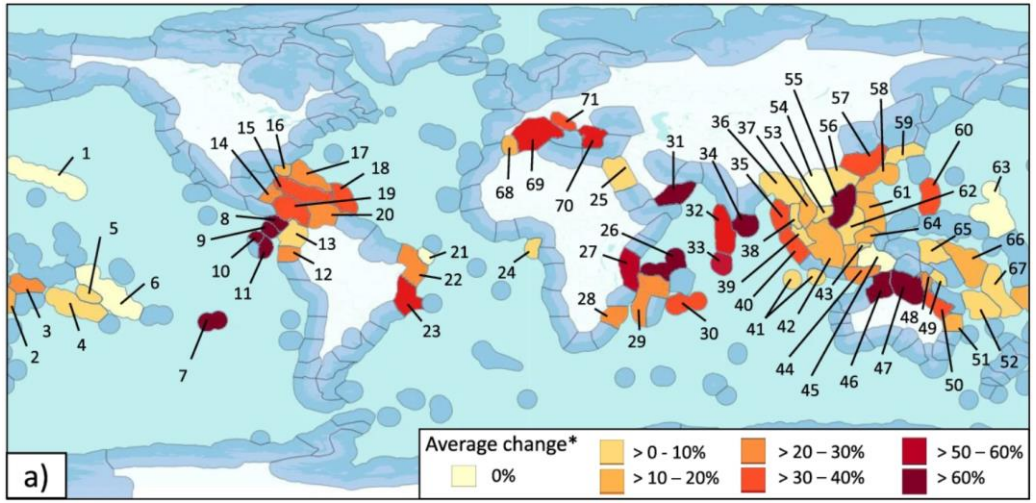
Kathryn E. Smith[1], Margot Aubin[1], Michael T. Burrows[2], Karen Filbee-Dexter[3,4], Alistair J. Hobday[5], Neil J. Holbrook[6,7], Nathan G. King[1], Pippa J. Moore[8], Alex Sen Gupta[9], Mads Thomsen[10,11], Thomas Wernberg[3,4], Edward Wilson[1] & Dan A. Smale[1]

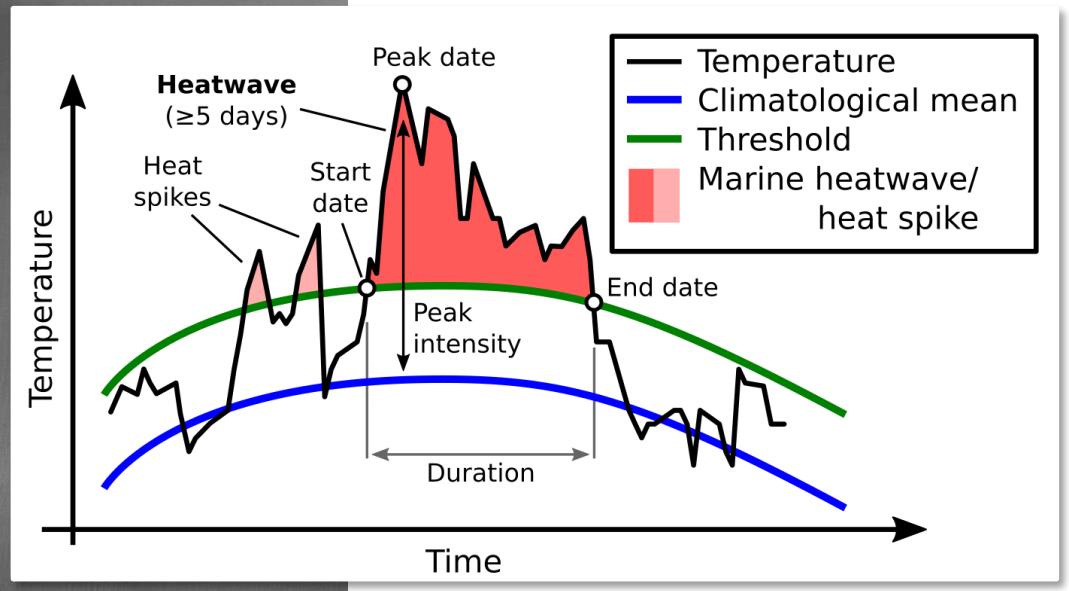
With increasingly intense marine heatwaves affecting nearshore regions, foundation species are coming under increasing stress. To better understand their impacts, we examine responses of critical, habitat-forming foundation species (macroalgae, seagrass, corals) to marine heatwaves in 1322 shallow coastal areas located across 85 marine ecoregions. We find compelling evi-

Occurrence of bleaching in Scleractinia hard corals and mass mortality events in Gorgonian soft corals following marine heatwaves by marine ecoregion



Smith et al. (2024) Nature

Marine Heatwaves (MHWs) – detection and features



MHW = Sea Temperature larger than a threshold for more than 5 days *(Hobday et al., 2016)*

Threshold (percentile 90) calculated from SST time series

An integrated indicator: **Activity** *(Simon et al., 2022)*

$$Activity = \sum_{EE \in Time\ Range} mean\ intensity_{EE} . duration_{EE \cap Time\ Range} . area_{EE}$$

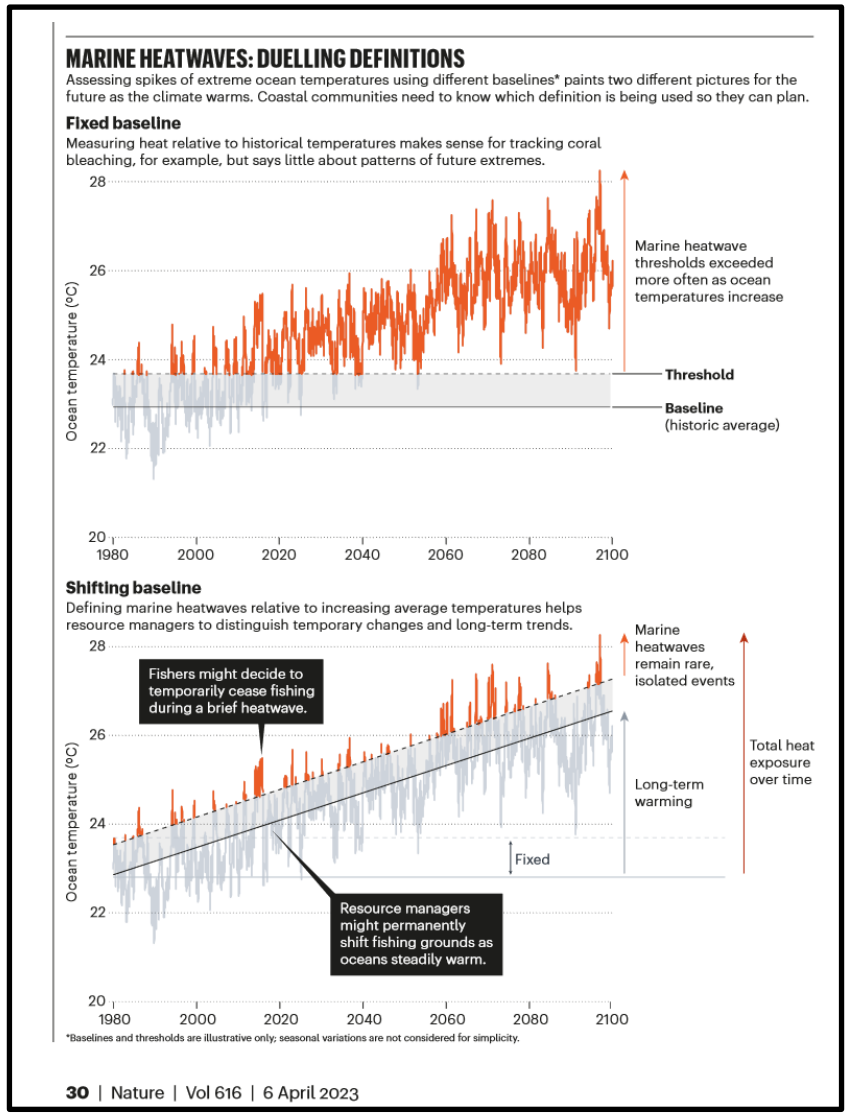
Mean temperature anomaly, w.r.t. the threshold, during the EE, in °C *(as defined in Hobday et al, 2016)*

Duration of the EE that remains under the considered period

Area affected by the discrete the EE

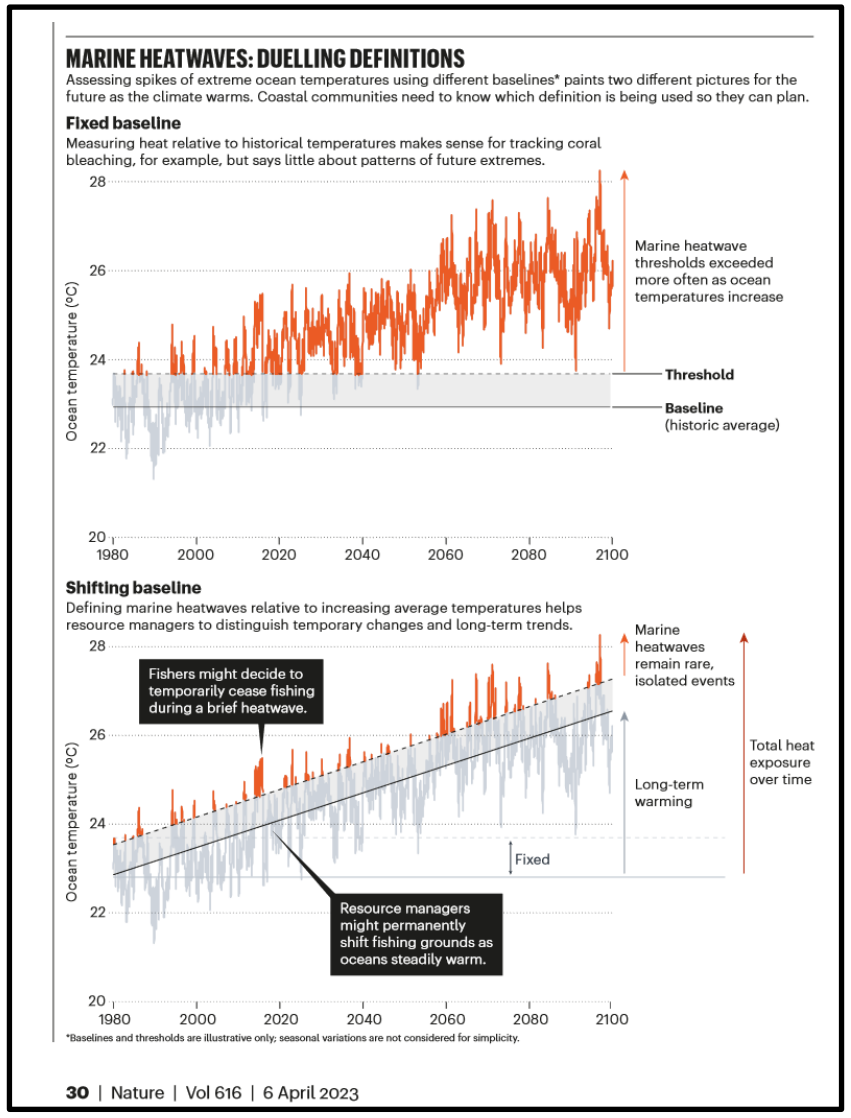
Method

Methods Different baselines convey different levels of changing risk for marine species.



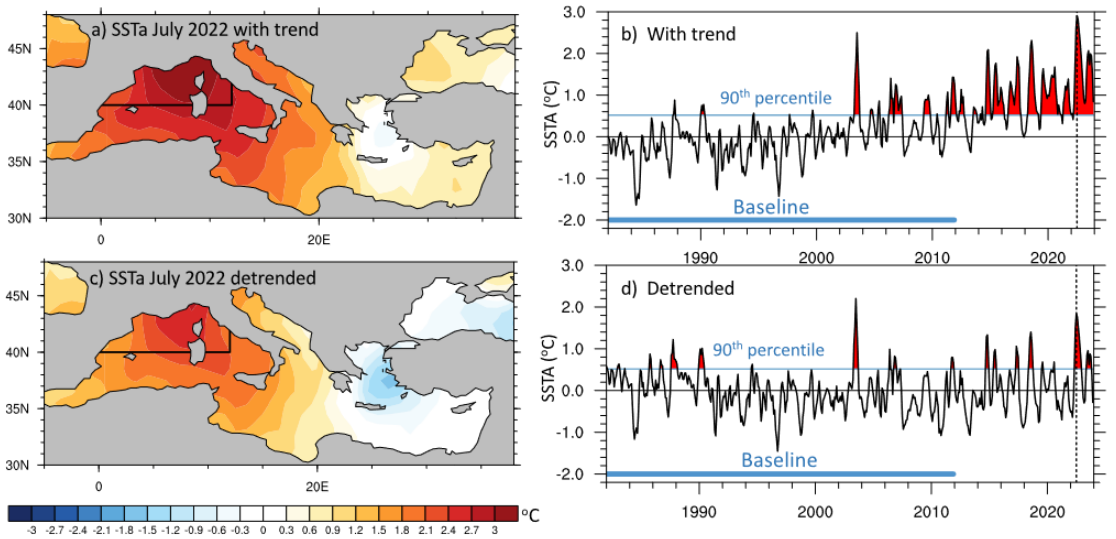
Amaya et al. (2023) Nature

Methods Different baselines convey different levels of changing risk for marine species.



Amaya et al. (2023) Nature

Both the fixed and detrended baseline methods have merits.



Capotondi et al. (2024) Commun. Earth Environ.

Methods

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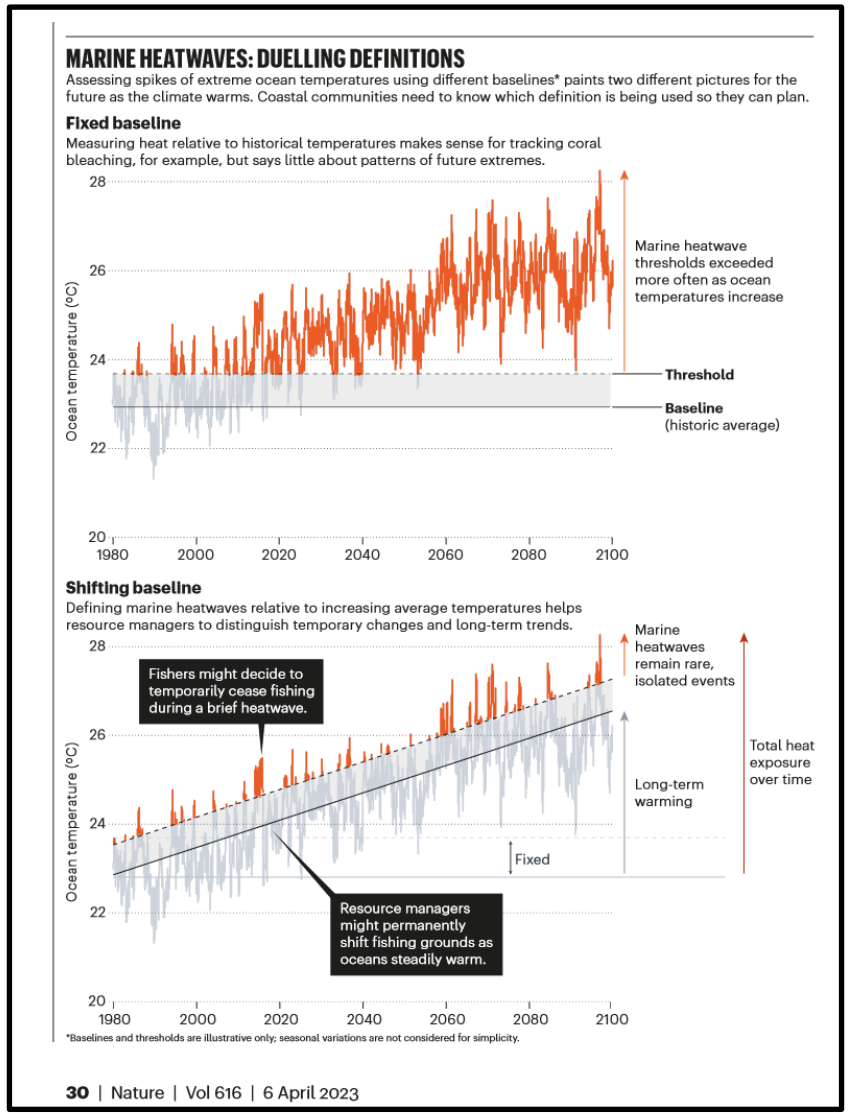

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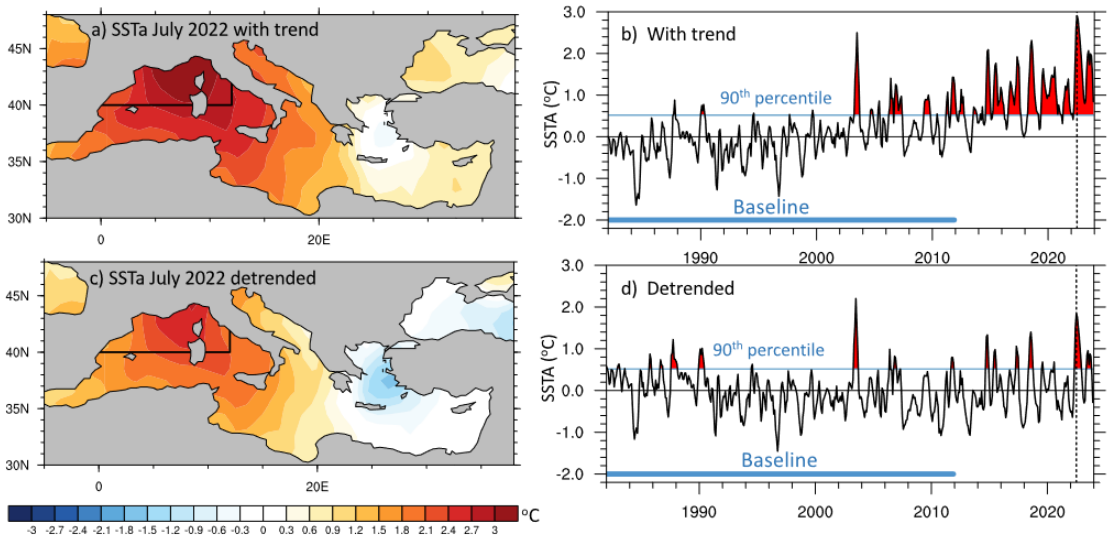
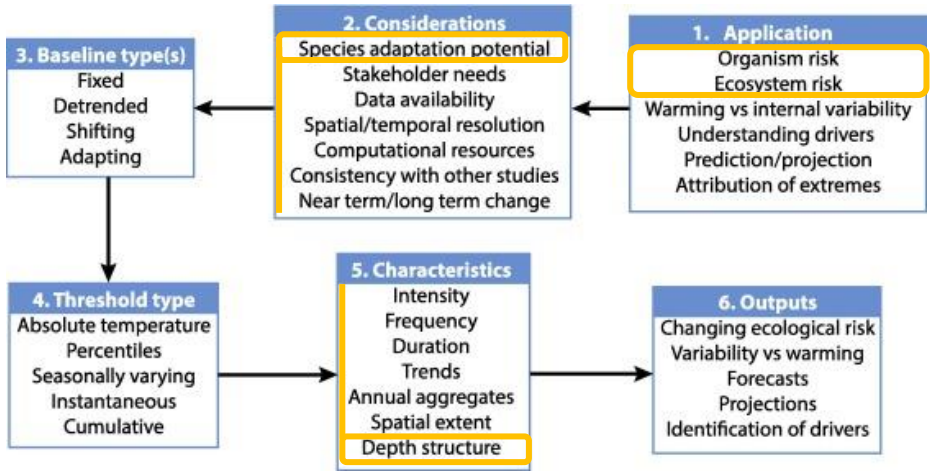
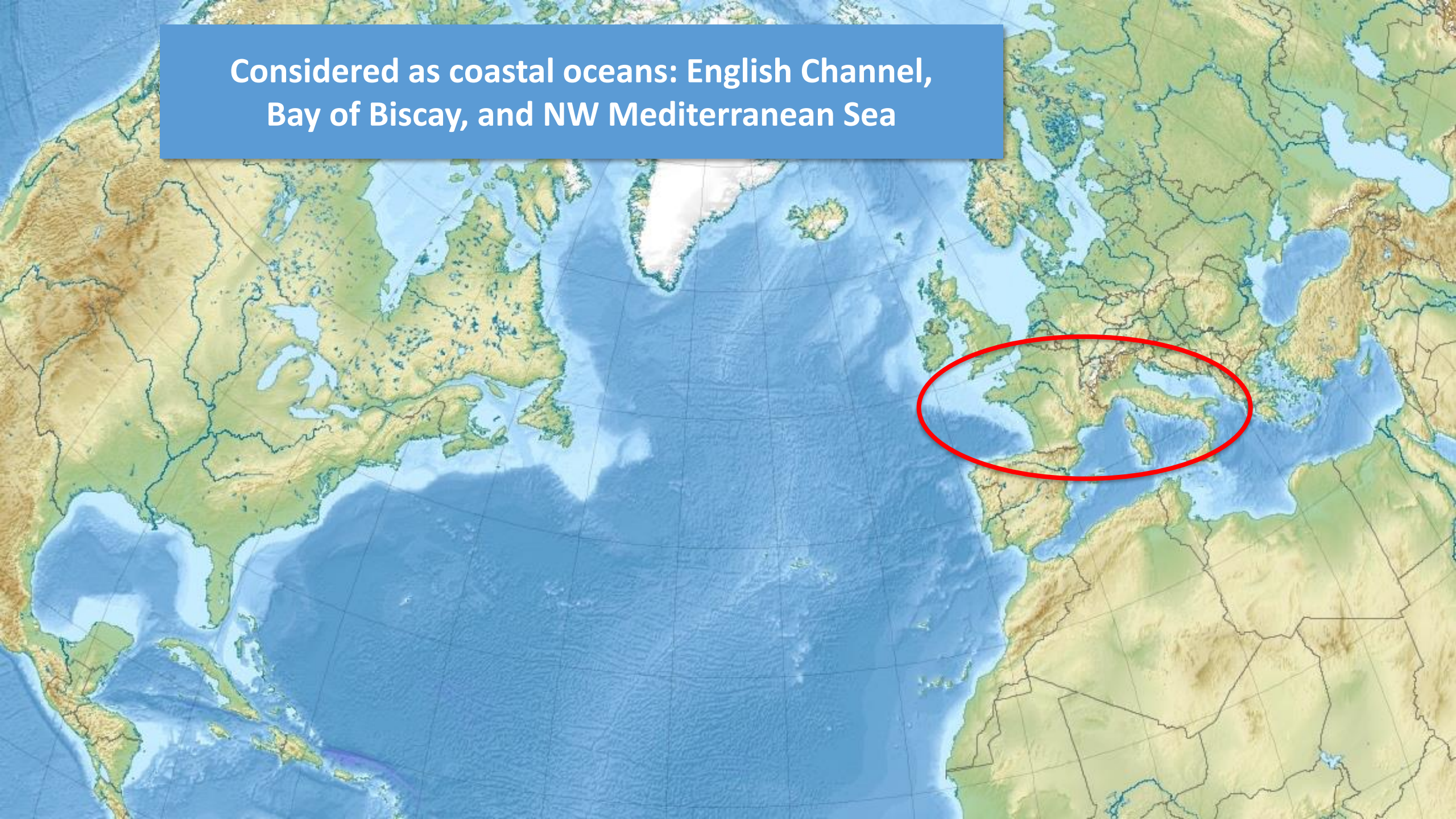


Capotondi et al. (2024) Commun. Earth Environ.

Ultimately, method depends on an **application**, assessing technical and stakeholder **considerations**, choosing a **baseline type** and reference period, deciding on the **type of threshold** and on the **metrics** needed to provide the necessary **outputs**.



Smith et al. (2025) Prog. Oceanogr.

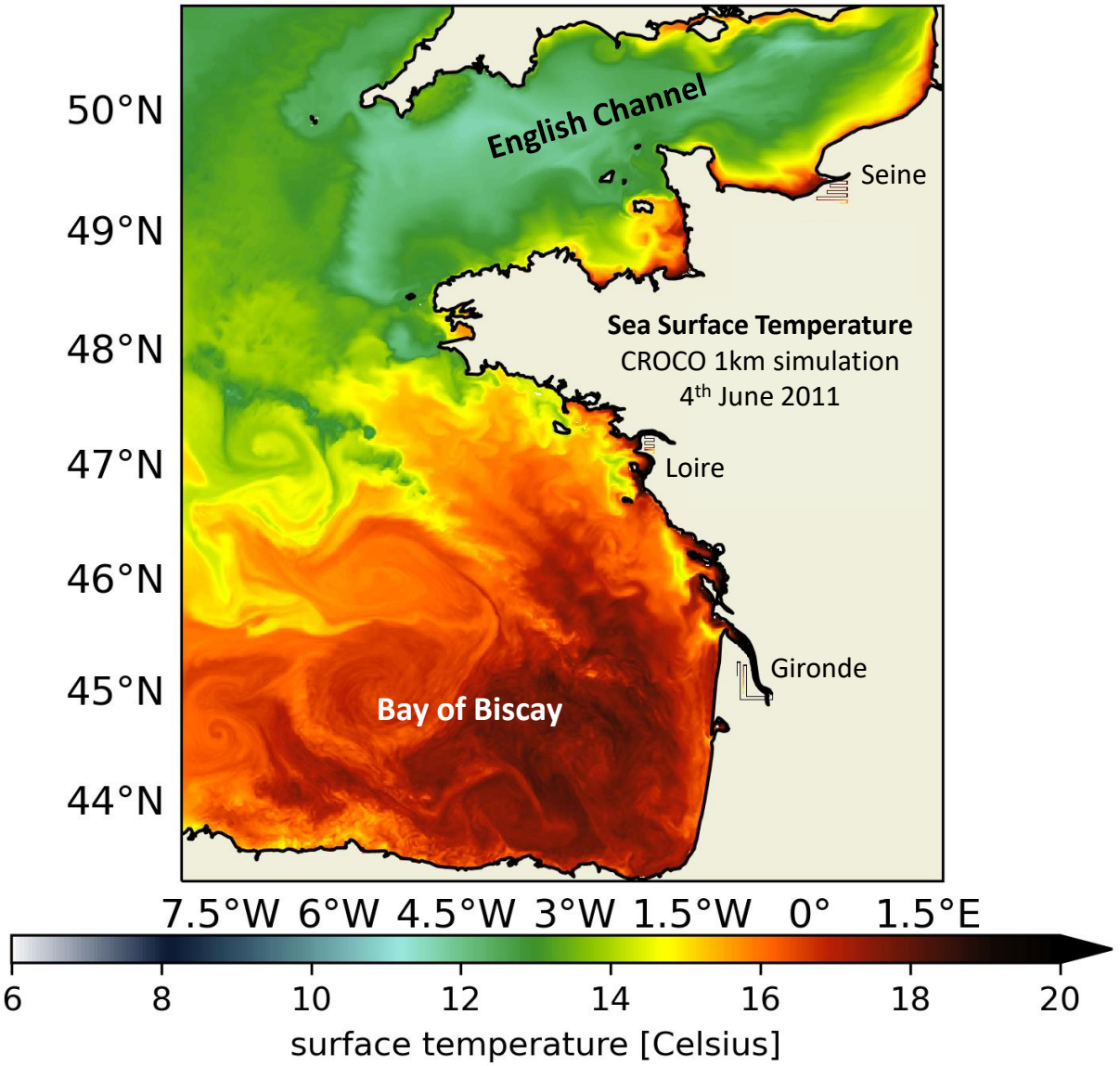

Considered as coastal oceans: English Channel,
Bay of Biscay, and NW Mediterranean Sea

Example of Bay of Biscay and English Channel

Contrasted dynamical systems – **macrotidal / mesotidal** dynamics

Extended Regions of Freshwater Influence – **3 main rivers** (Gironde, Loire, Seine)

Fine scale dynamics linked with ocean-atmosphere interactions



Marine Heatwaves (MHWs) in the Bay of Biscay and the English Channel

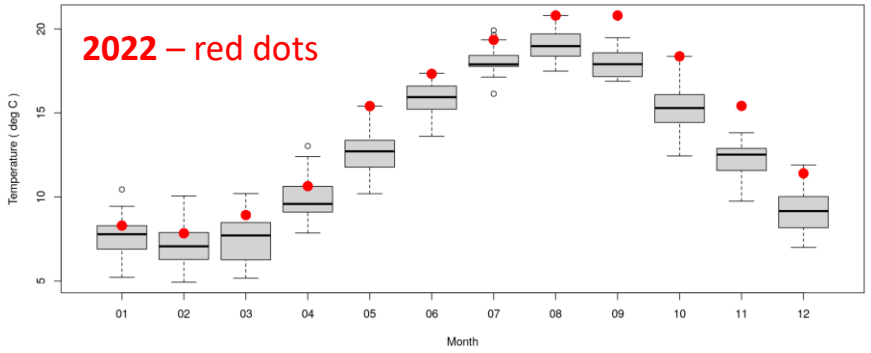
Observed an **increasing activity of surface Marine Heatwaves** in the region (increasing number and duration)
Simon *et al.*, 2023

However ...

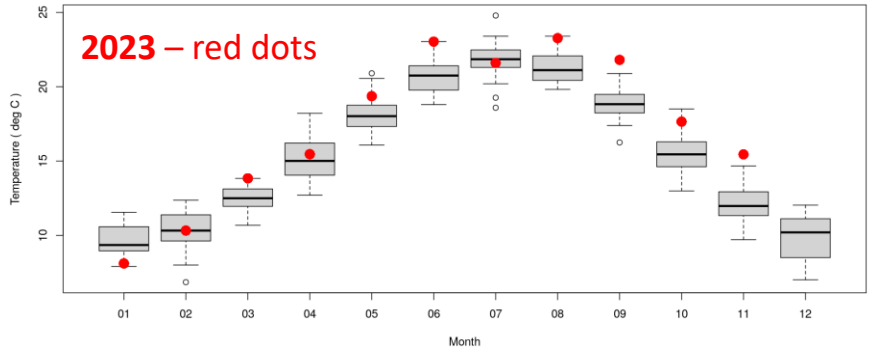
What are the **impacts in the water column** linked with the contrasted coastal dynamics ?
- crucial for living ecosystems –

And in **2022 and 2023 –** how was the MHW activity during those warm recent years ?

Wimereux – English Channel



Arcachon – Bay of Biscay



In situ temperature observations between 1997 and 2023 (SOMLIT netwok - https://www.somlit.fr/mysomlit/)

Context

MHWs detection – from which dataset ?

Remotely sensed and *in situ* observations

OISST product

Optimum Interpolation Sea Surface Temperature

Reynolds et al., 2007; Huang et al., 2020

Spatial resolution: 0.25°

Since 1982

Numerical simulations

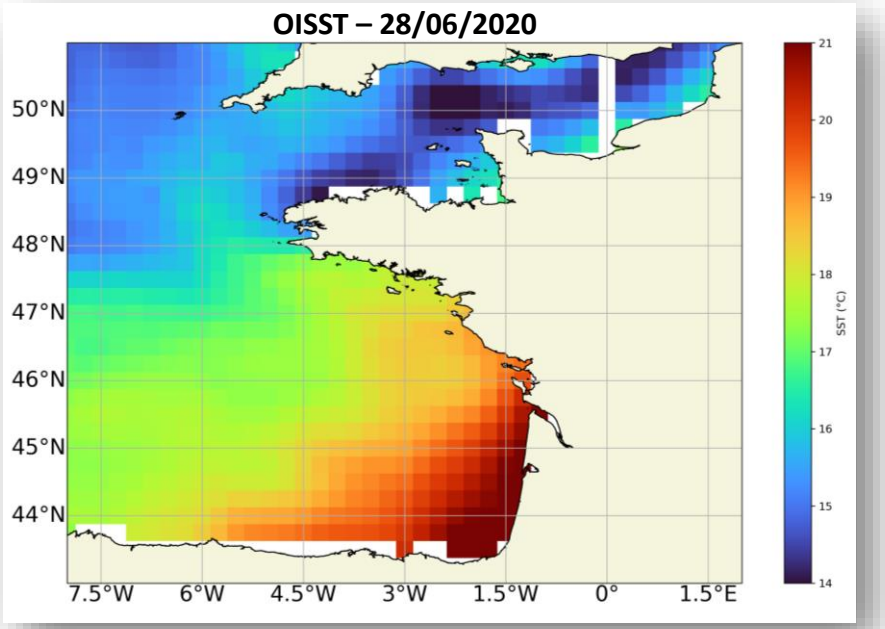
MARC simulation based on MARS3D model

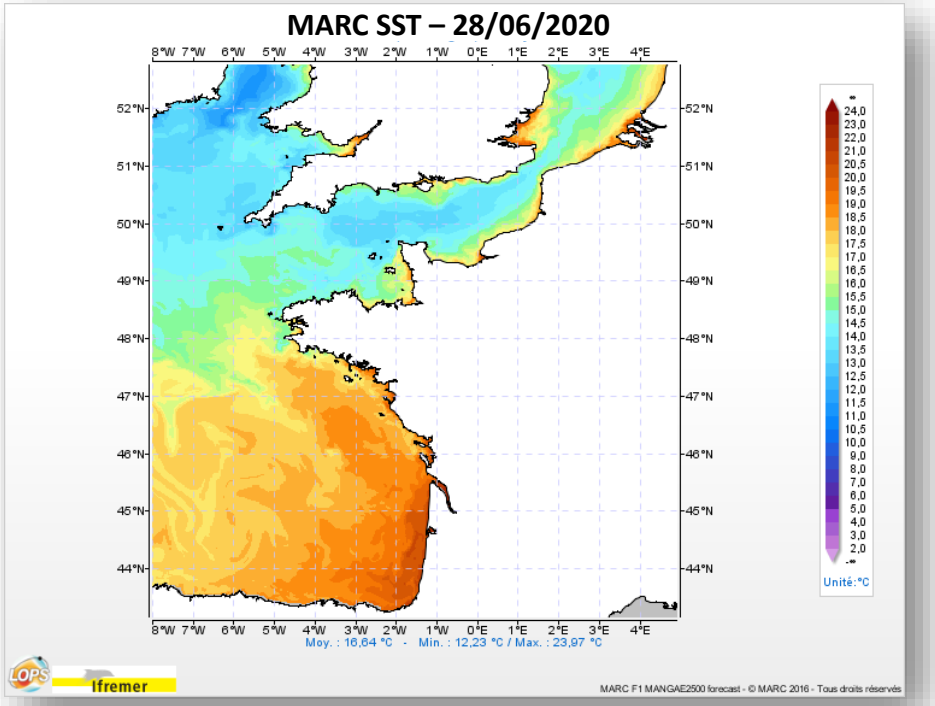
https://marc.ifremer.fr

Spatial resolution: 2.5 km

40 sigma vertical levels

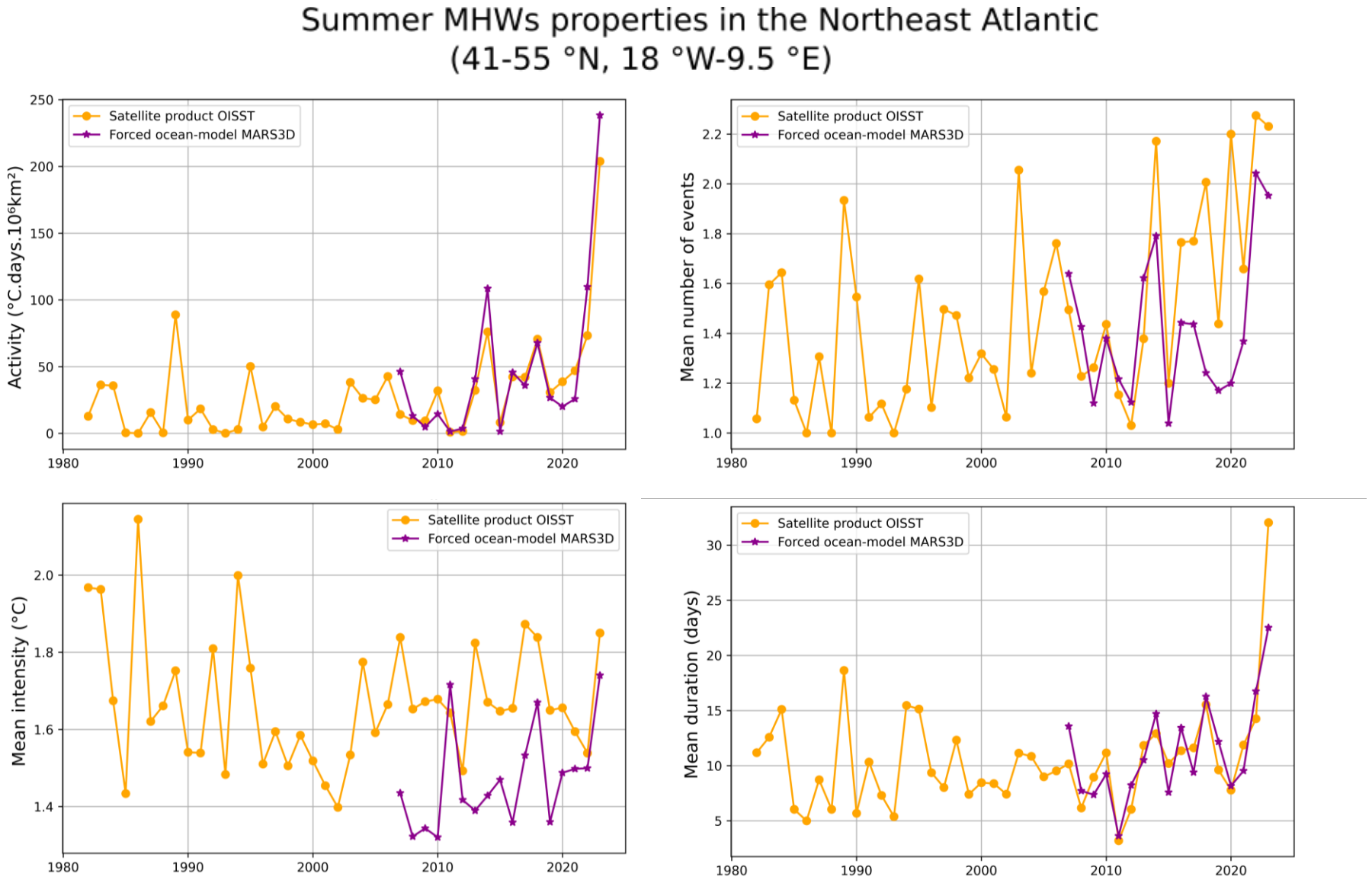
Since 2007





Datasets

At the surface ... Summer MHWs

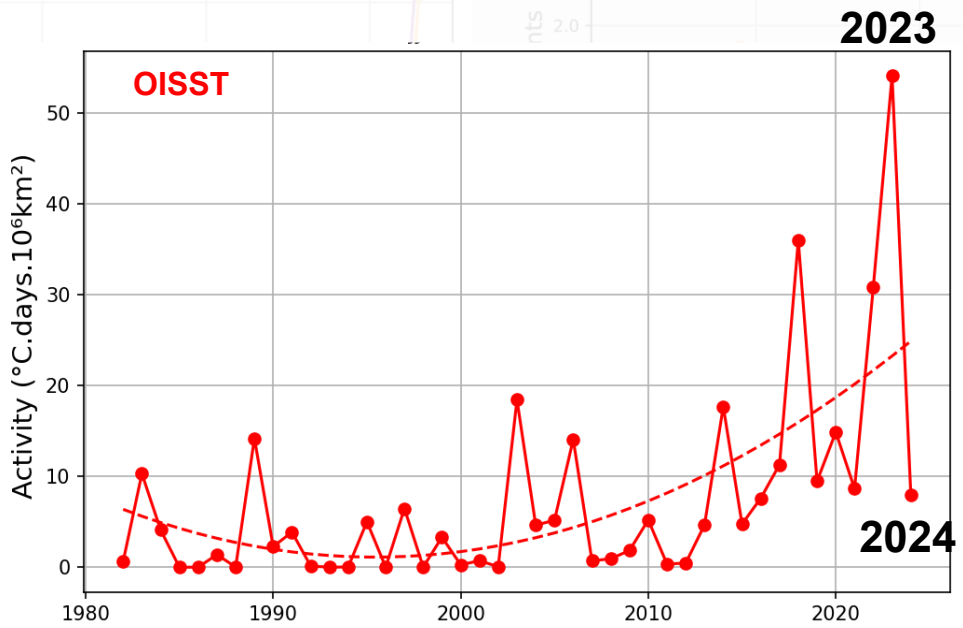


Results

At the surface ... Summer MHWs

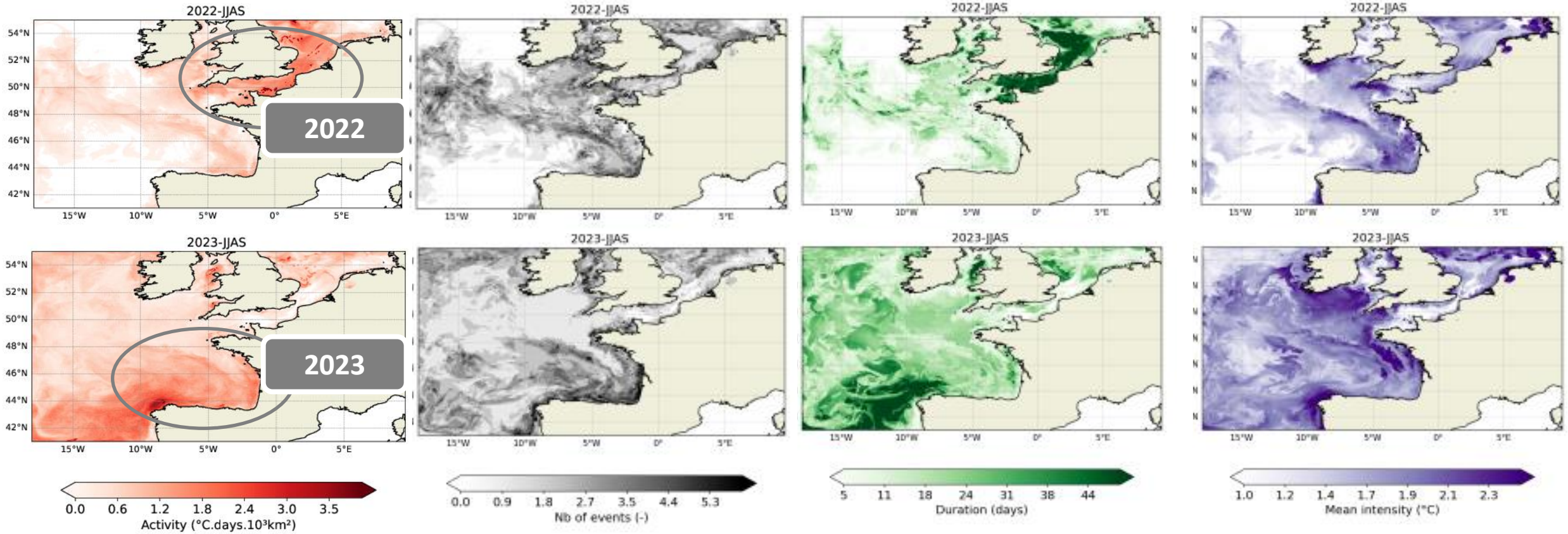
Results

Summer MHWs properties in the Northeast Atlantic
(41-55 °N, 18 °W-9.5 °E)



A contrasted spatial distribution – two singular years: 2022 and 2023

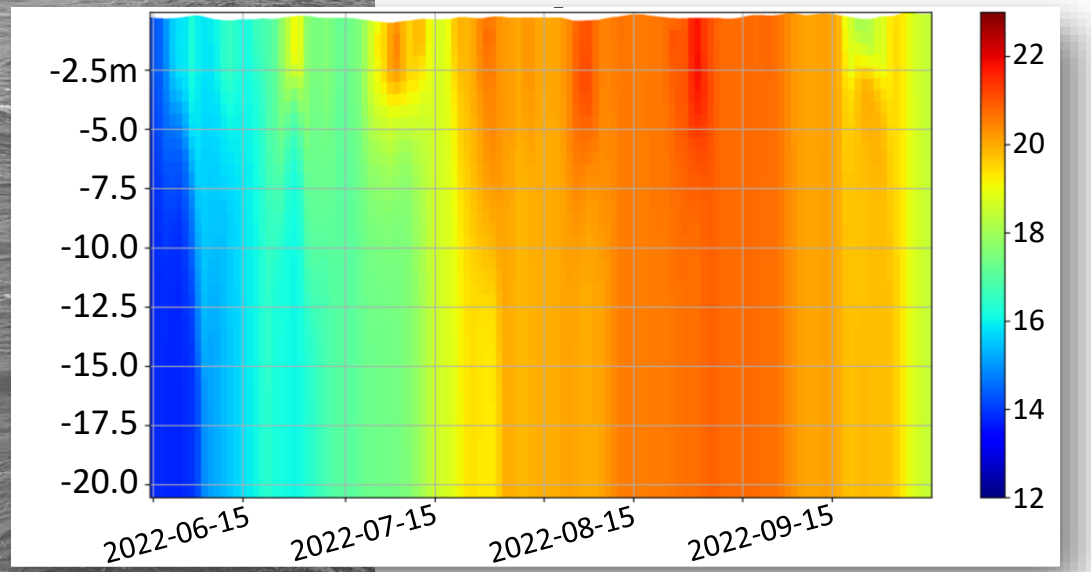
From model simulations ...

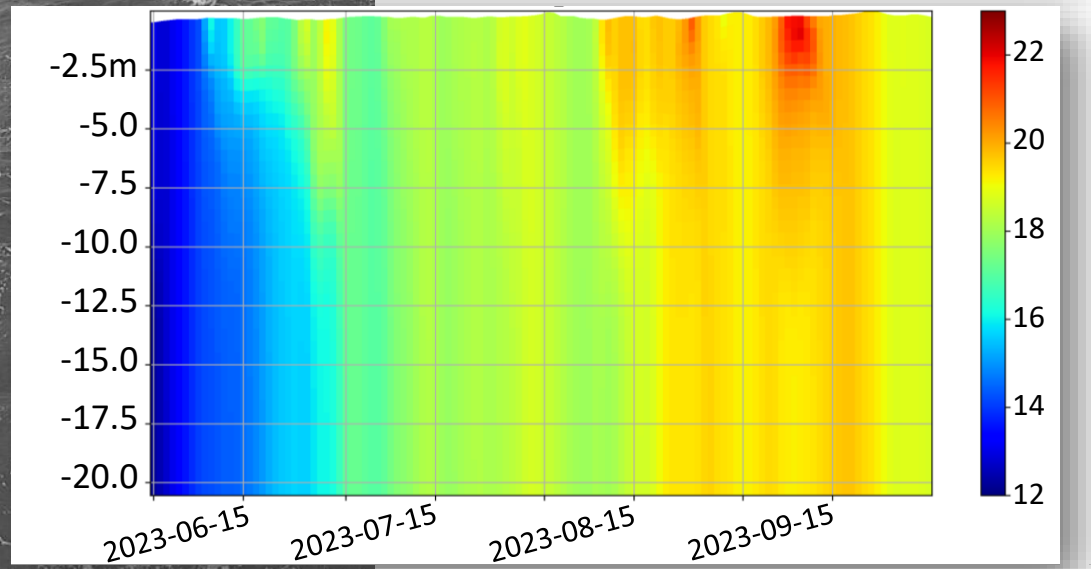


- 2022 – higher activity in the **English Channel**
- 2023 – higher activity in the **Bay of Biscay**

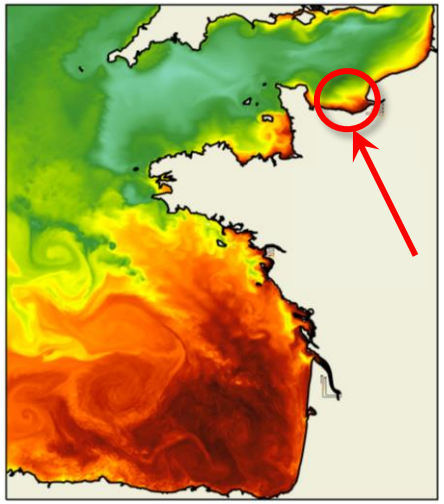
... but strong spatial variability linked with coastal processes (*e.g.* rivers, tides, bathymetry constraints)

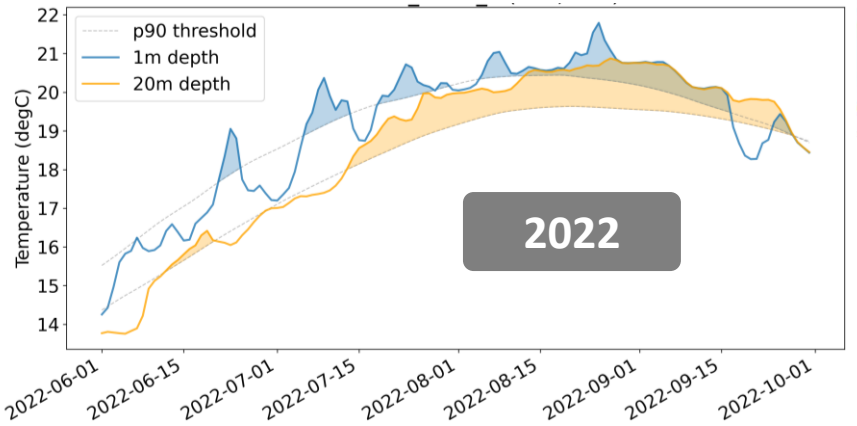
What about the temperature in the water column ?

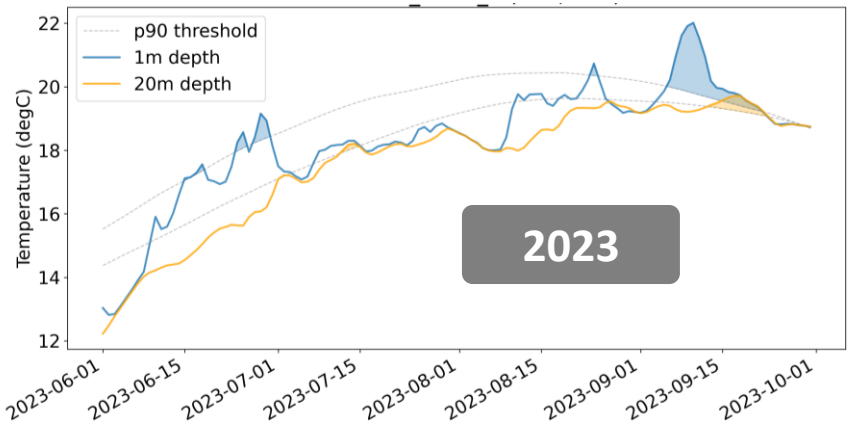




In the English Channel ...



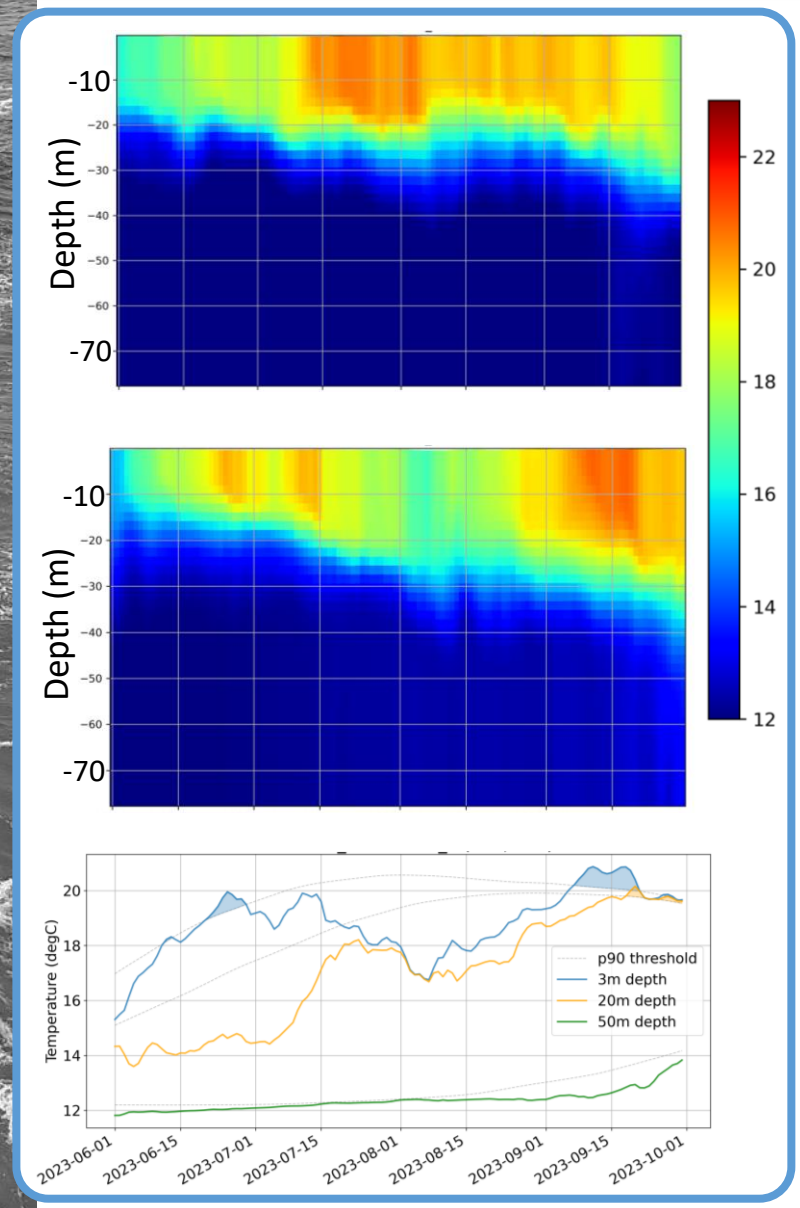


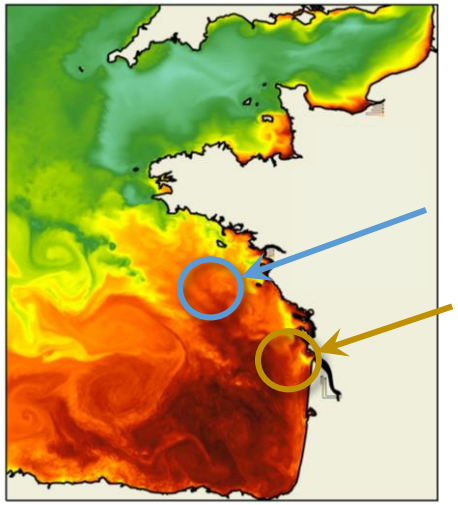


What about the temperature in the water column ?

2022

2023





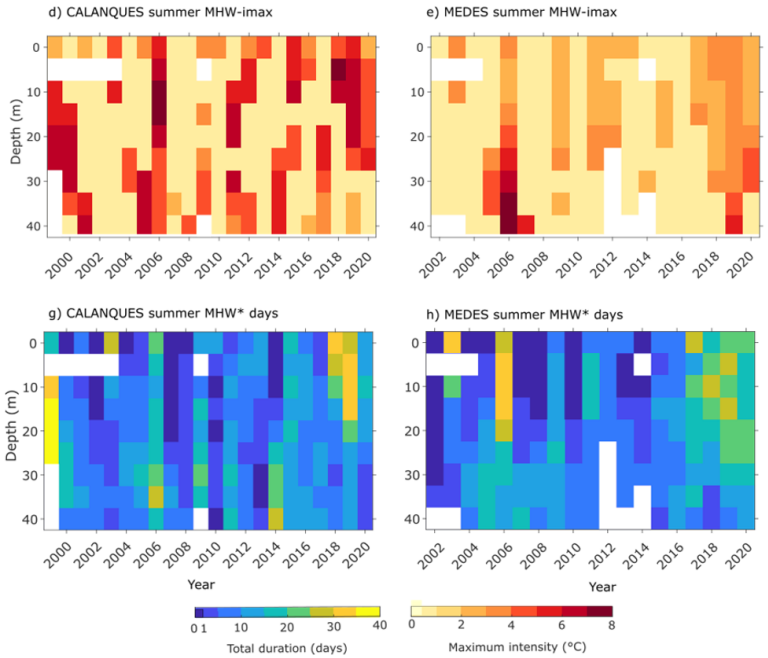
In the Bay of Biscay ...

Results

MesuRho station (COAST-HF network) – Rhône river plume

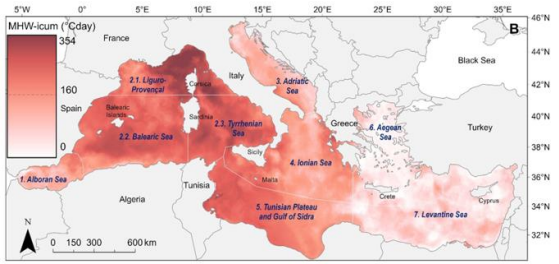
Marine Heatwaves in recent years

Surface (satellite) and subsurface (in situ) MHWs total duration and maximal intensity in summer



Bensoussan et al. (2022) LPS

Cumulated intensity MHW-icum



Vertical structure of Marine Heatwaves

Vertical structures of MHWs under coastal processes:

Assessing conditions at the depth of essential ecosystems

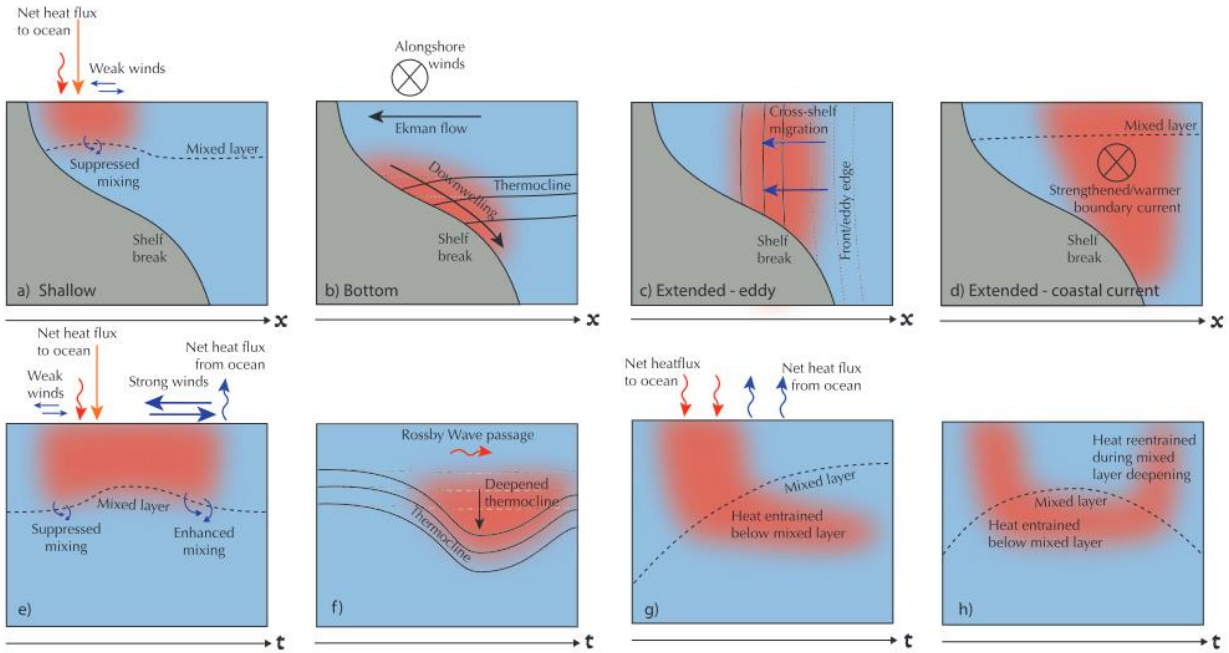
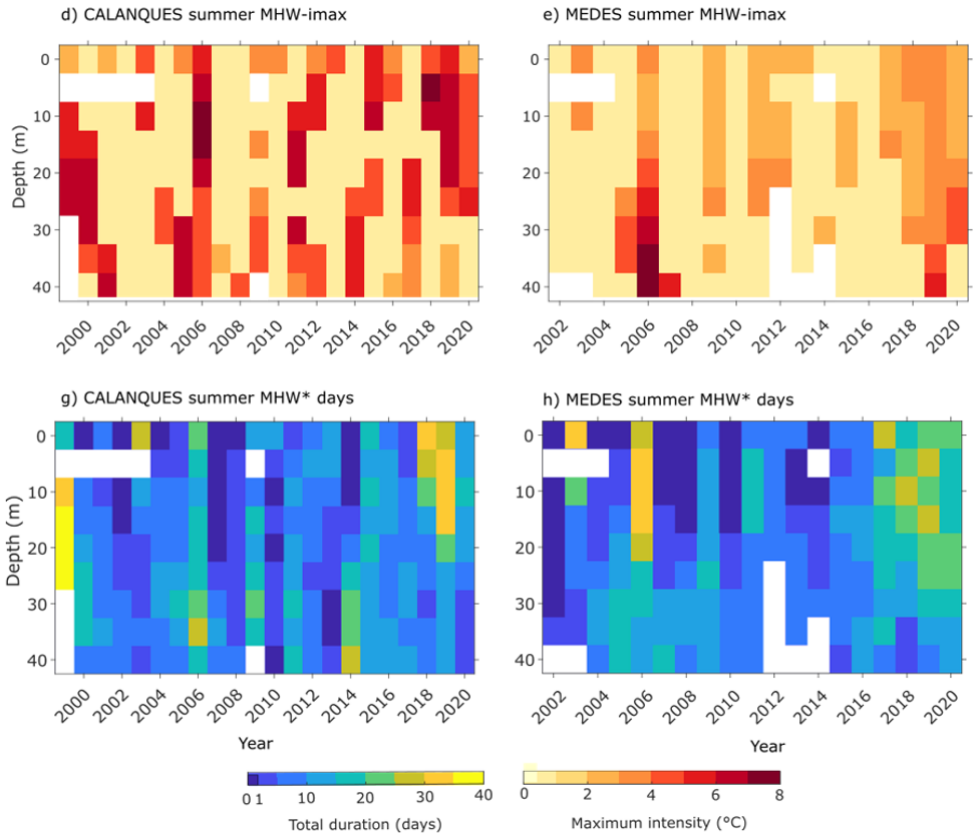


Fig. 2 | Vertical structures of MHWs. a–d Possible vertical structures of MHWs near the shelf, including: "shallow" MHWs which do not penetrate below the mixed layer (**a**); "Bottom" intensified events due to a downwelling thermocline near the bottom, resulting, for example, from alongshore winds, as illustrated for the Southern Hemisphere (**b**); "Extended" profiles from the surface to the bottom due to intrusion of warm eddies or western boundary meanders into the shelf (**c**) or due to warm alongshore advection (**d**). **e–h** Temporal evolution of subsurface MHWs associated with: changes in upper-ocean mixing for shallow events (**e**); propagation of oceanic Rossby waves causing variations in thermocline depth (**f**); persistence of deep anomalies with no surface signature due to mixed layer shoaling (**g**); and re-emergence of deep anomalies at the surface when the mixed layer deepens (**h**). The subsurface structure of MHWs depends on the processes involved in their formation, as well as the region's stratification and circulation.

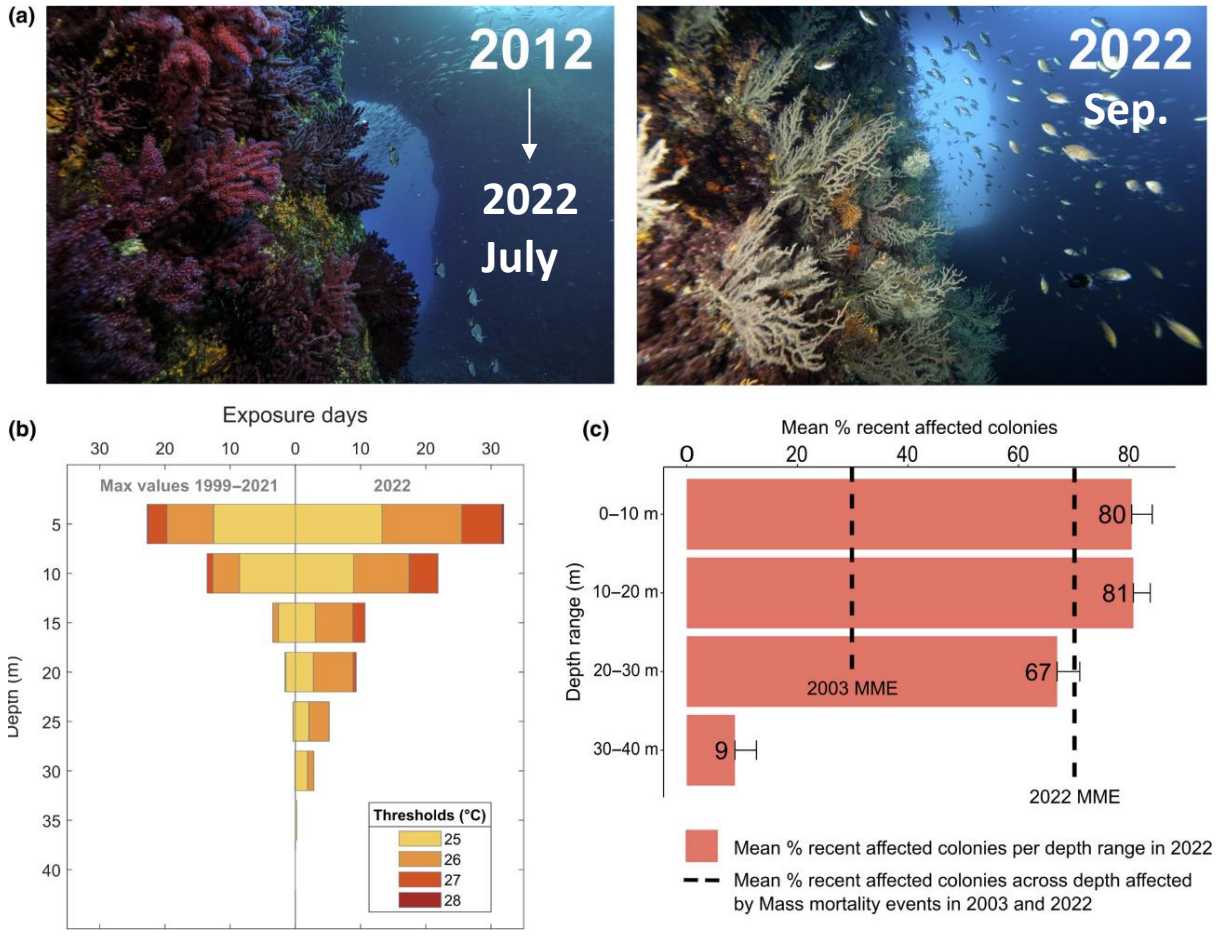
Capotondi et al. (2024)



Bensoussan et al. (2022) LPS

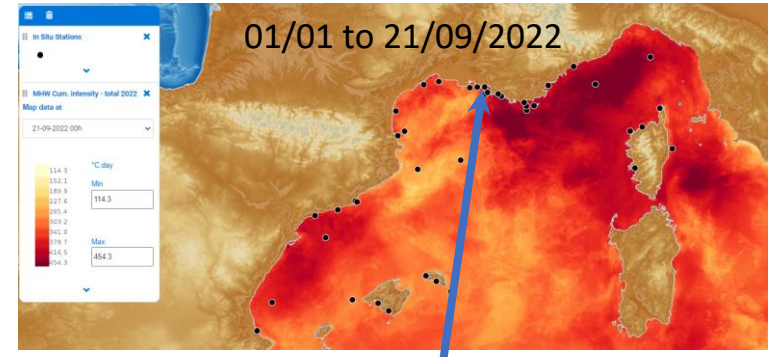
Example in 2022 …

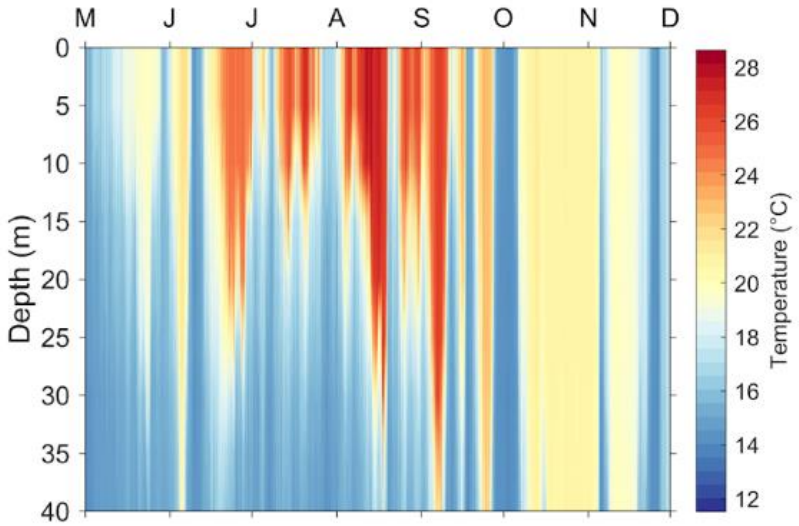
One of the strongest ever Mass Mortality Event in gorgonians: the role of sporadic wind driven up- and downwelling under persistent regional surface MHW



Estaque et al. (2023) Global Change Biology

Cumulative MHW stress (in °C.Day)



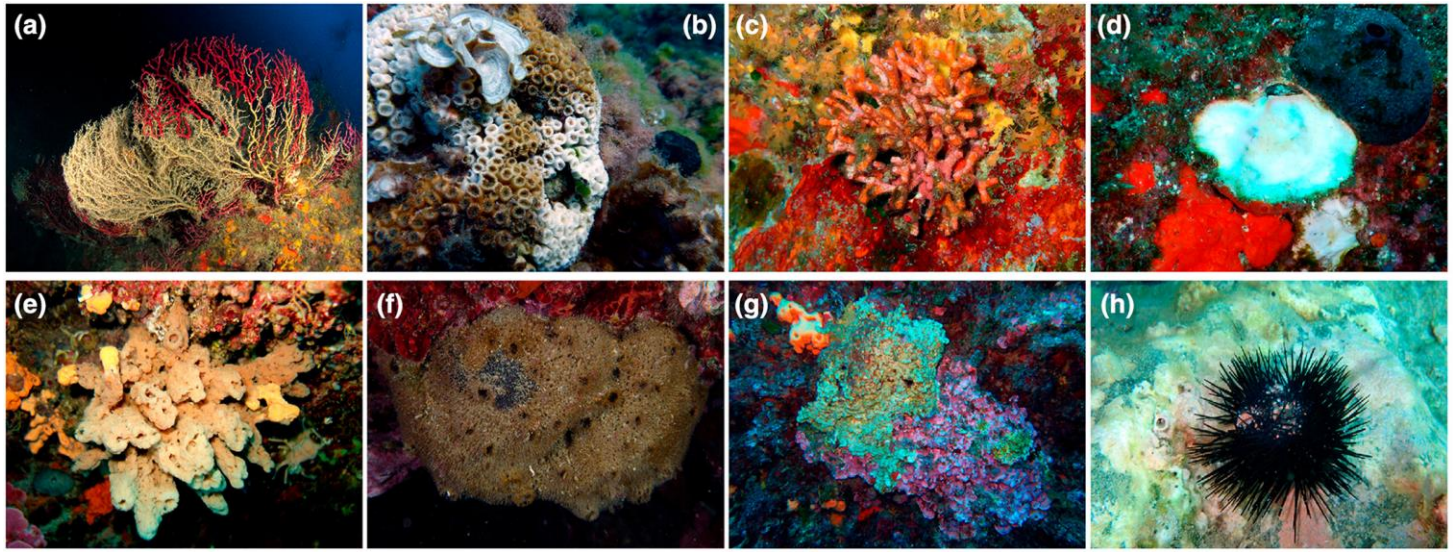


Concluding remarks

Needs to shift from Marine Heatwaves (MHWs) as a **surface temperature anomaly** to a **process** to be defined following the **impact of MHWs on benthic and pelagic ecosystems.**

Combining **complementary methodologies** is essential.

Dedicated to **drivers and impacts.**



Garrabou et al., 2022

Thank you for your attention ...

For any questions: guillaume.charria@ifremer.fr