Marine Heatwaves

Definitions across depths, methods, patterns & limitations

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Funded by the European Union

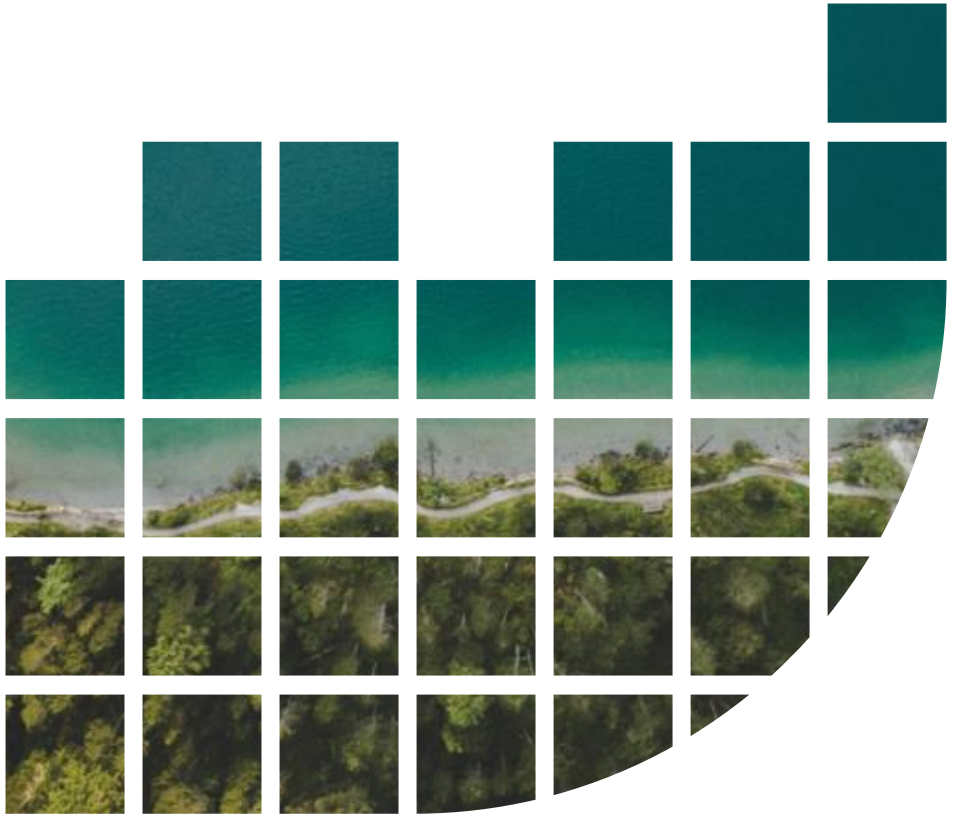
What Are Marine Heatwaves (MHWs) and Why They Matter

Definition

- Extreme climatic events.
- Prolonged periods of unusually warm ocean temperatures.
- Defined as ocean temperatures above a seasonal varying threshold for ≥5 consecutive days.

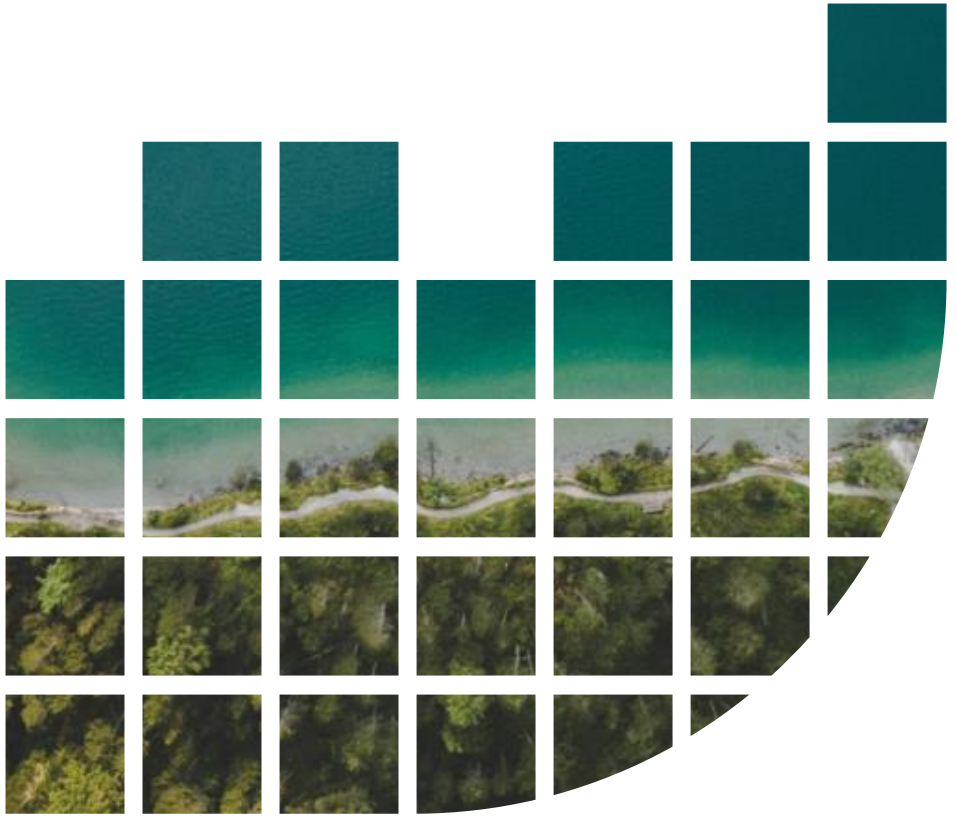
Impacts

- Mass mortality events of marine organisms
- Shifts in species distributions
- Loss of ecosystem functions
- Socioeconomic consequences



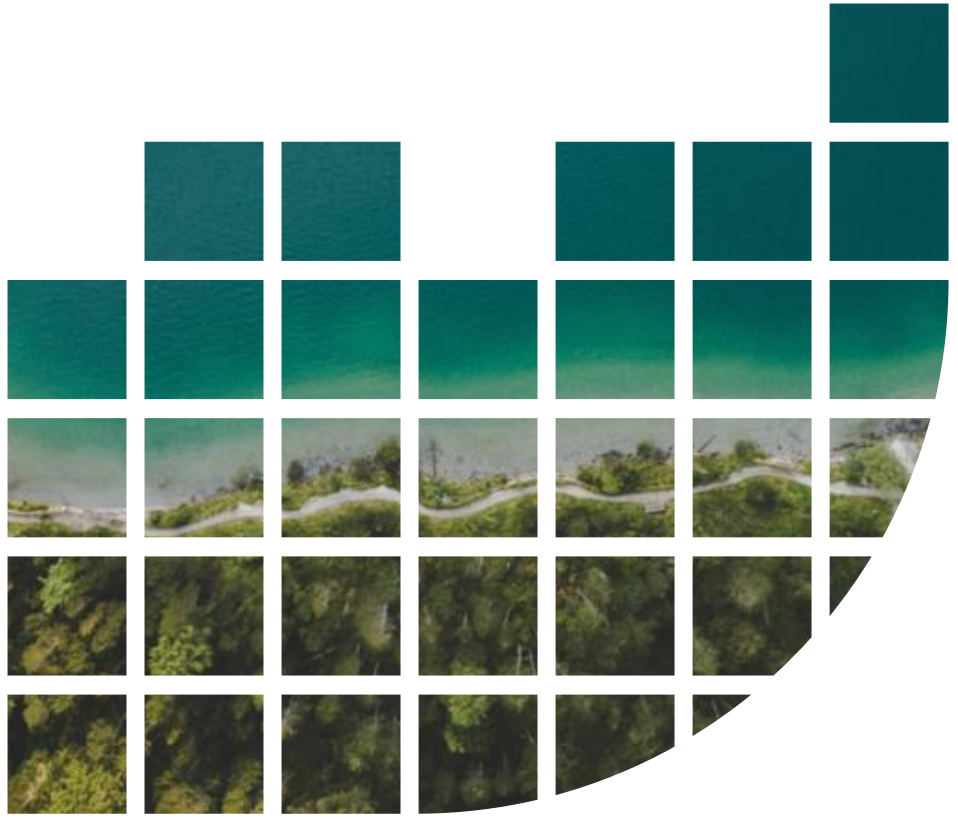
Why Study MHWs Across Depths

- Ocean warming is often studied at the surface (utilizing sea surface temperature).
- Excess heat penetrates deep into the water column, expanding MHWs vertically.
- Subsurface MHWs can occur without surface signals, yet still threaten ecosystems.
- Many marine species depend on different depth zones for breeding, feeding, and migration.
- Ignoring subsurface events leads to an incomplete understanding of MHW impacts on marine life.

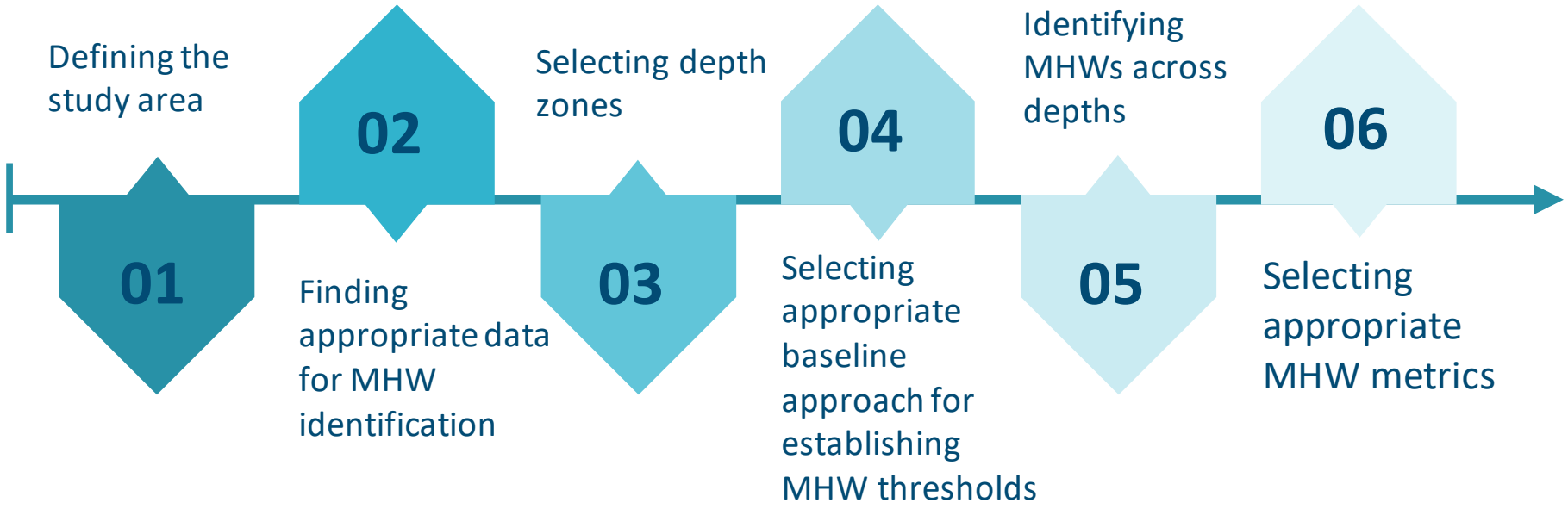


Why Integrate MHWs into EB-SCP

- New dimension to climate change considerations, towards the establishment of climate-smart MPAs.
- Enhances ecosystem resilience to climate change.
- Avoid prioritizing highly exposed areas that are less likely to withstand future extremes, ensuring protection across horizontal & vertical dimensions.
- Builds adaptive, future-proof MPA networks aligned with broader climate goals.

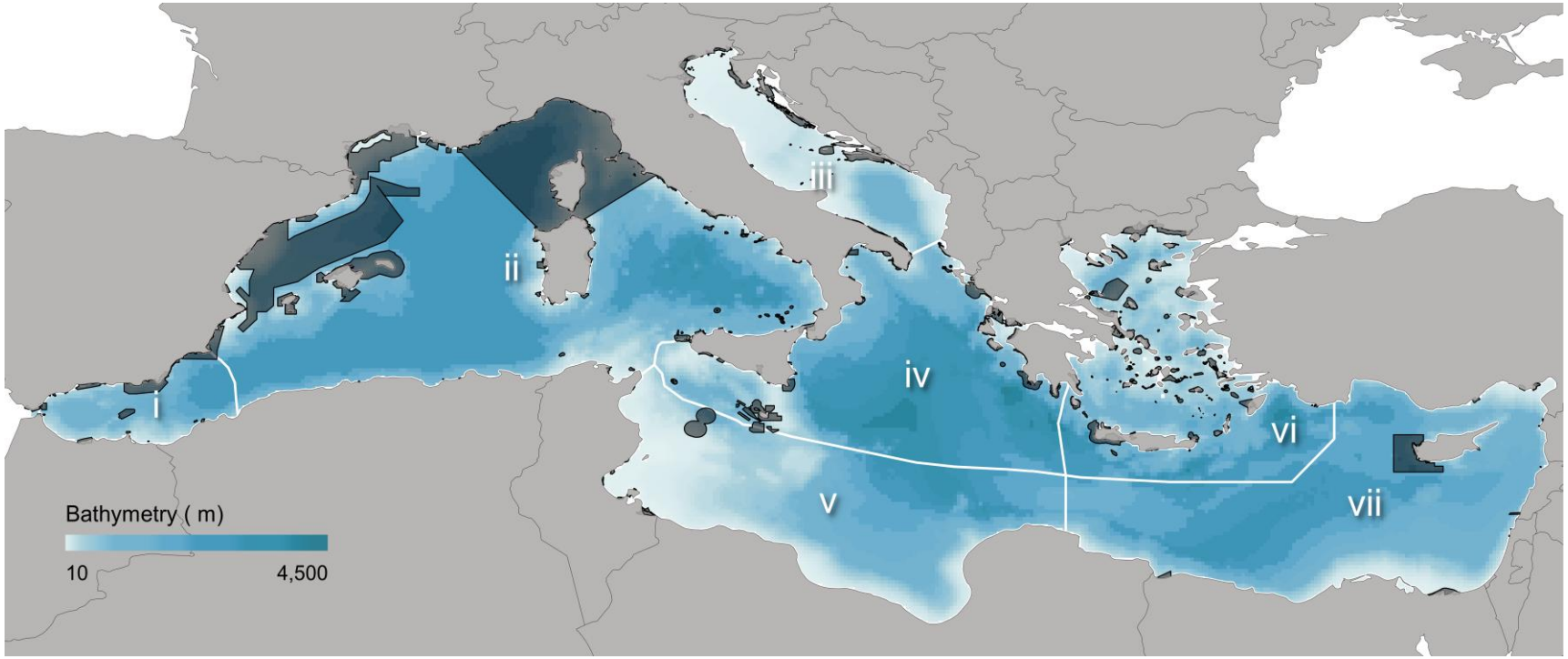


Methodological Framework



Applied in: Konsta, K., Doxa, A., Katsanevakis, S., Mazaris, A.D. Projected marine heatwaves over the Mediterranean Sea and the network of marine protected areas: a three-dimensional assessment. *Climatic Change* **178**, 17 (2025). https://doi.org/10.1007/s10584-025-03860-4

Study Area



The methodological framework was developed & applied in the Mediterranean Sea. The region includes a number of Planning Sites.

The Mediterranean Sea is characterized by high temperature variability, more frequent, prolonged & intense MHWs

Data for MHW Identification

Consistent identification of MHWs requires:

- Daily ocean temperature data
- Over a sufficiently long period to estimate climatology, ideally a minimum of 30 years.

The projection of future MHWs requires relevant daily temperature projections.

! **Limitation**: Future daily temperature projections across ocean depths for the global ocean currently do not exist. Regional datasets are very limited.

In our analysis we employed daily three-dimensional seawater temperature projections from the POLCOMS-ERSEM system, retrieved from the Copernicus Climate Change Service. This dataset, that covers 94 years, from 2006 to 2100 in a horizontal resolution of 0.1° (approximately 11 km) and a vertical extent of 43 depth levels, ranging from 0 to 5500 m below sea level, was the only one available for the Mediterranean Sea.

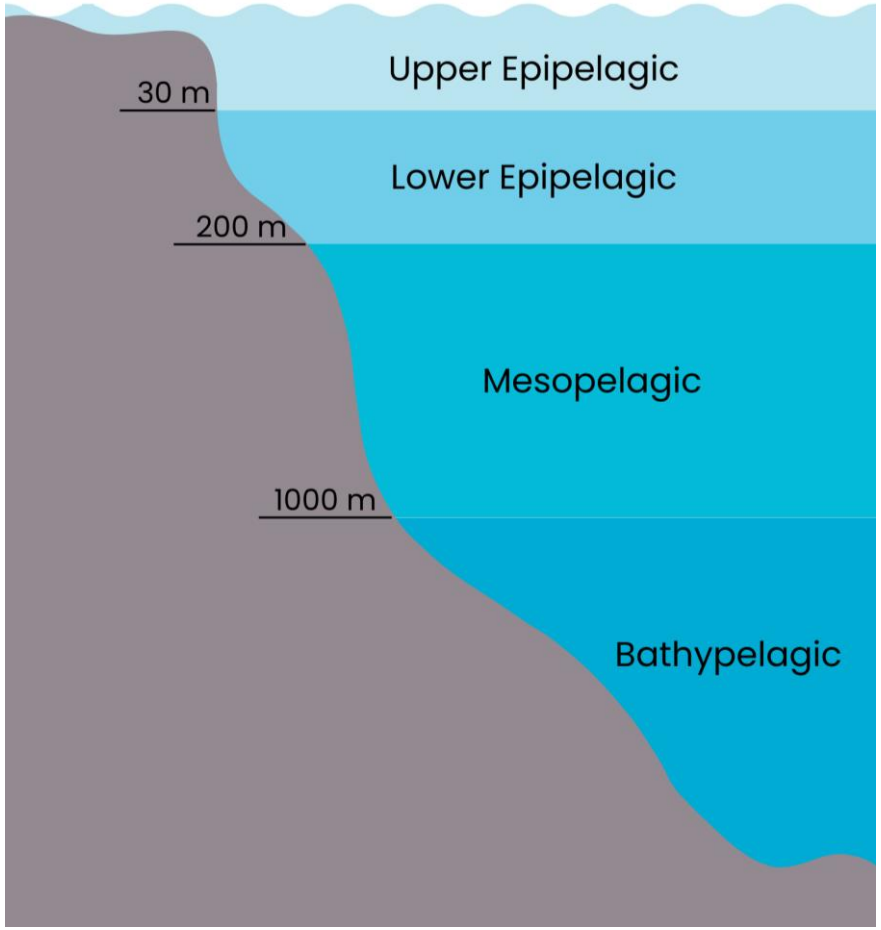
Selecting Depth Zones

We analyzed vertical temperature data down to 2000 m, covering the depth range of most marine ecosystems.

To represent the 3D structure of MHWs, we grouped depth layers into four ecologically relevant zones:

- Upper epipelagic (0–30 m) – 11 layers
- Lower epipelagic (30–200 m) – 11 layers
- Mesopelagic (200–1000 m) – 11 layers
- Bathypelagic (1000–2000 m) – 3 layers

The subdivision of the Epipelagic zone (0-200m) reflects qualitative similarities in MHW properties within subzones (Lower & Upper Epipelagic).



Baselines for MHW Threshold

MHWs are detected when daily temperatures exceed a climatological threshold for over 5 days. Thresholds are typically based on a 30-year baseline period.

The selection of the baseline period used to calculate the climatology could have an effect on the outputs generated regarding the MHW characteristics (i.e. frequency, intensity, duration).

Baseline Type	Definition	Strengths	Limitations
Fixed baseline	2006–2035 used for all future years	Conservative, suited for slower-adapting ecosystems	May underestimate adaptation capacity, incorporates long-term warming
Shifting baseline	Most recent 30 years preceding year of study	Captures adaptive capacity, focuses on short-term variability	More conservative, may underestimate effects on ecosystems

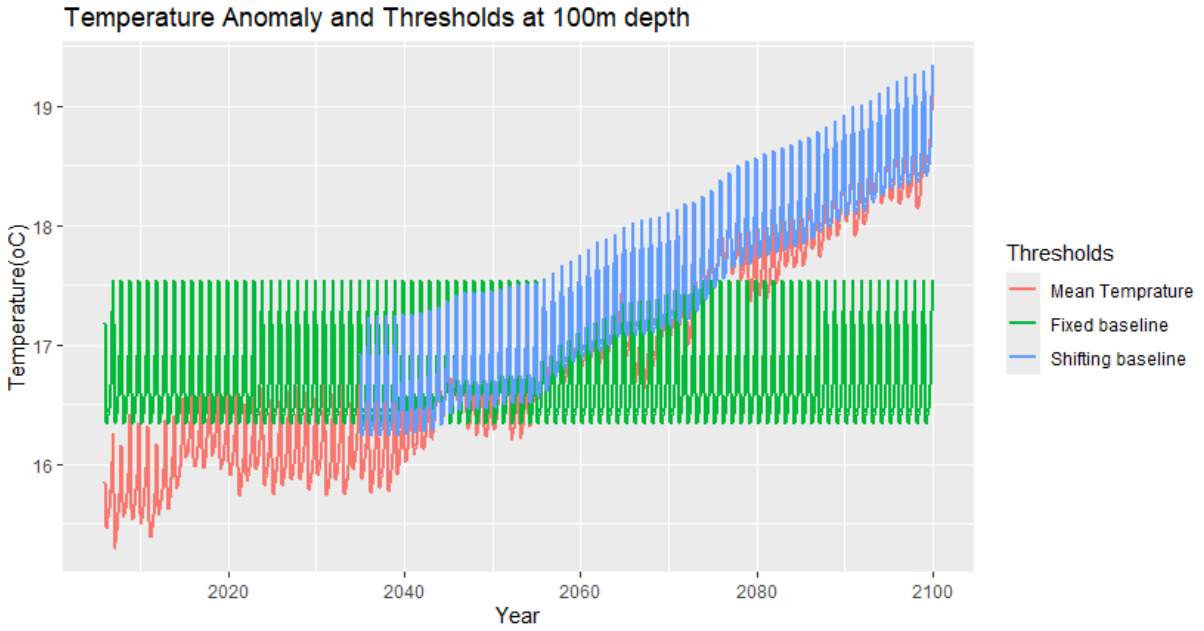
MHW Identification

The percentile choice also matters. Threshold is the local daily upper temperature percentile used to define “extreme” events.

Common choices:

- 90th percentile: captures many mild and short-lived events especially with a fixed baseline
- 99th percentile: only the most extreme events especially with a fixed baseline

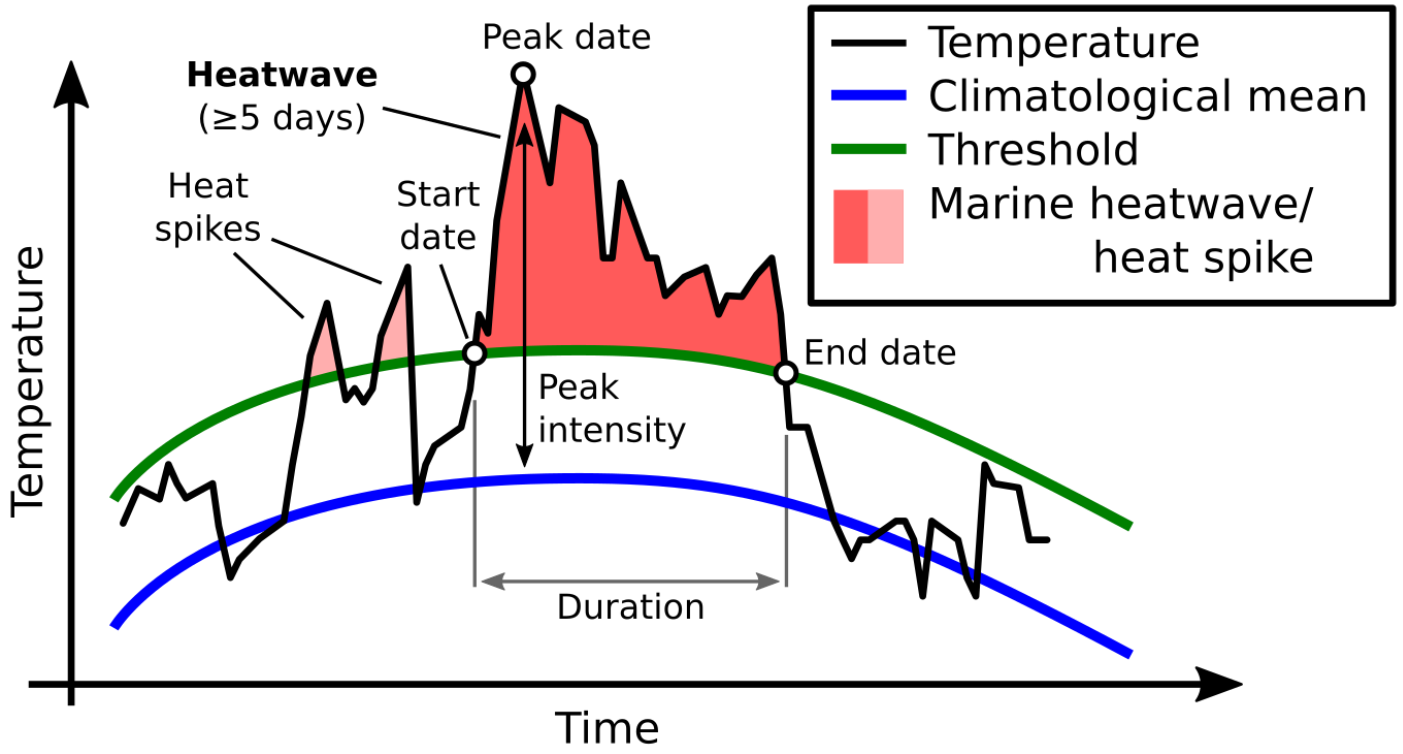
For this study, where we employed both a fixed and a shifting baseline, we used the 95th percentile to filters out mild/short-lived anomalies & ensure inclusion of ecologically relevant MHWs.



MHW Definition

Event definition:

- MHWs occur when daily temperatures exceed the local threshold for ≥5 consecutive days.
- Breaks shorter than 3 days are considered part of the same event.
- Thresholds are applied locally at each grid cell and depth.
- MHWs are averaged across depth zones.
- MHW annual duration (annual count of MHW days) & intensity (annual spatiotemporal mean temperature anomaly reached) are calculated

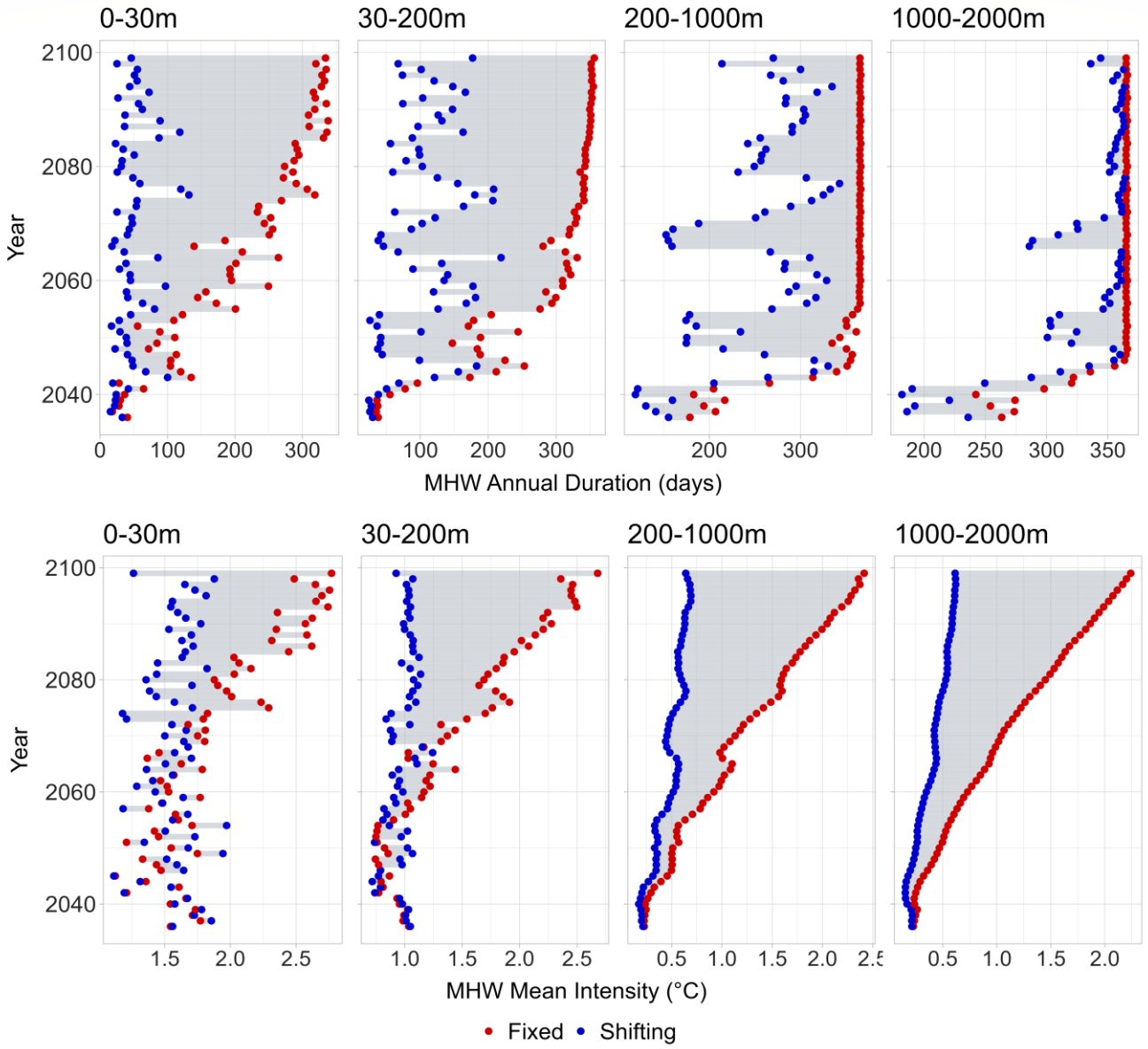


Source: https://www.marineheatwaves.org/

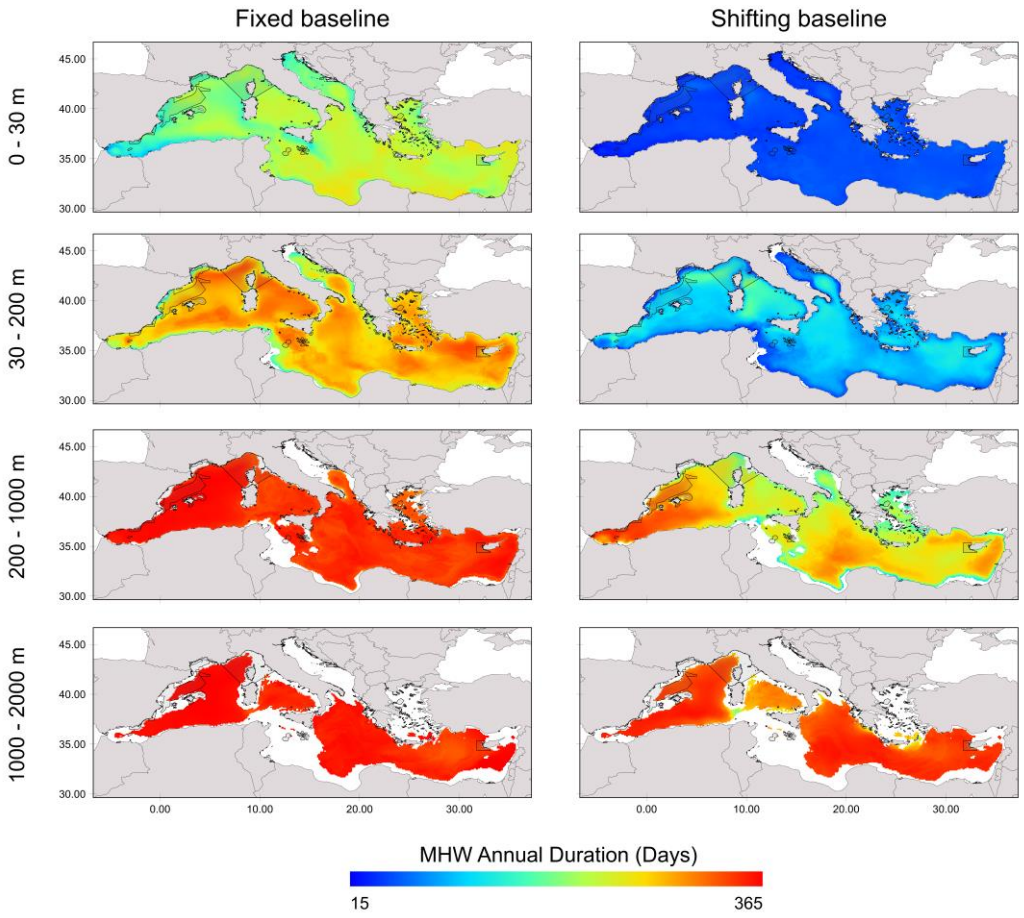
MHW Metrics

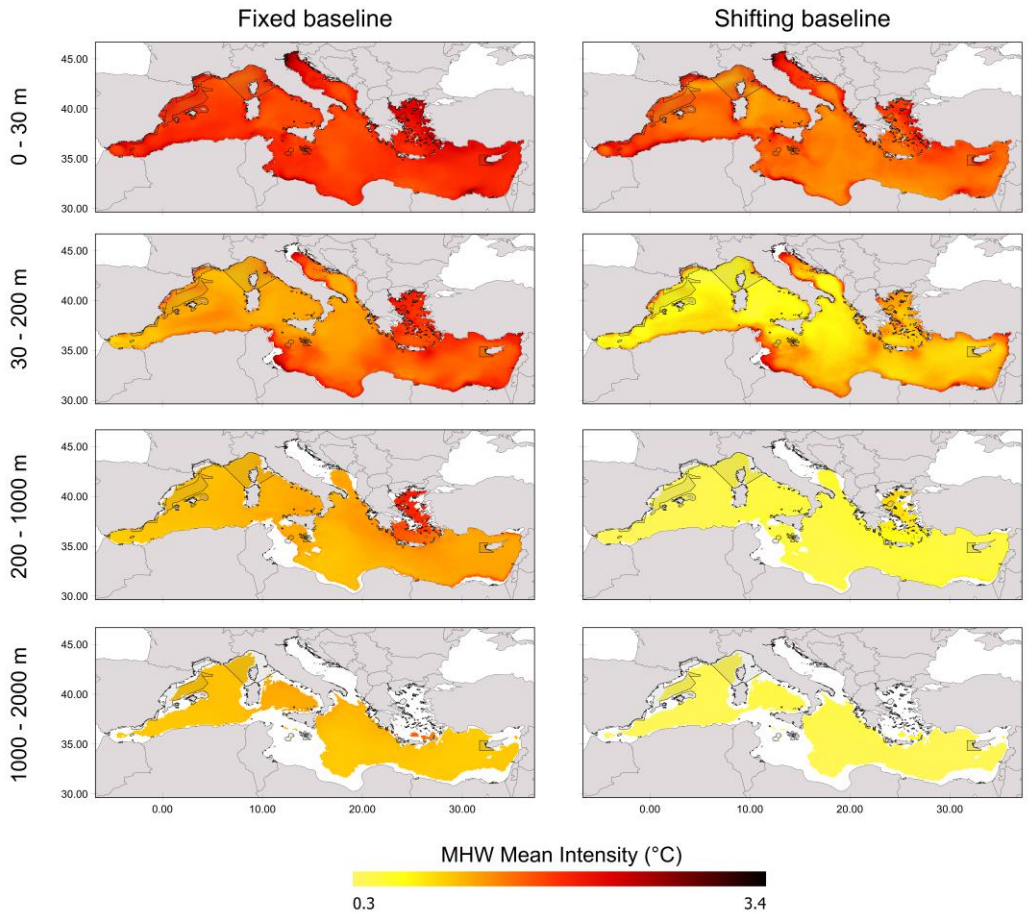
Observed patterns:

- MHWs are **longer but milder** as they extend deeper into the water column.
- There is a **grater increase** in MHW duration & intensity **with the fixed baseline** – saturation of events.
- Smoother increase in MHW intensity in deeper zones reflecting lower temperature variability.



MHW Metrics


Fixed baseline
Shifting baseline
0 - 30 m
30 - 200 m
200 - 1000 m
1000 - 2000 m
45.00
40.00
35.00
30.00
0.00
10.00
20.00
30.00
MHW Annual Duration (Days)
15
365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30 - 200 m
200 - 1000 m
1000 - 2000 m
45.00
40.00
35.00
30.00
0.00
10.00
20.00
30.00
MHW Mean Intensity (°C)
0.3
3.4

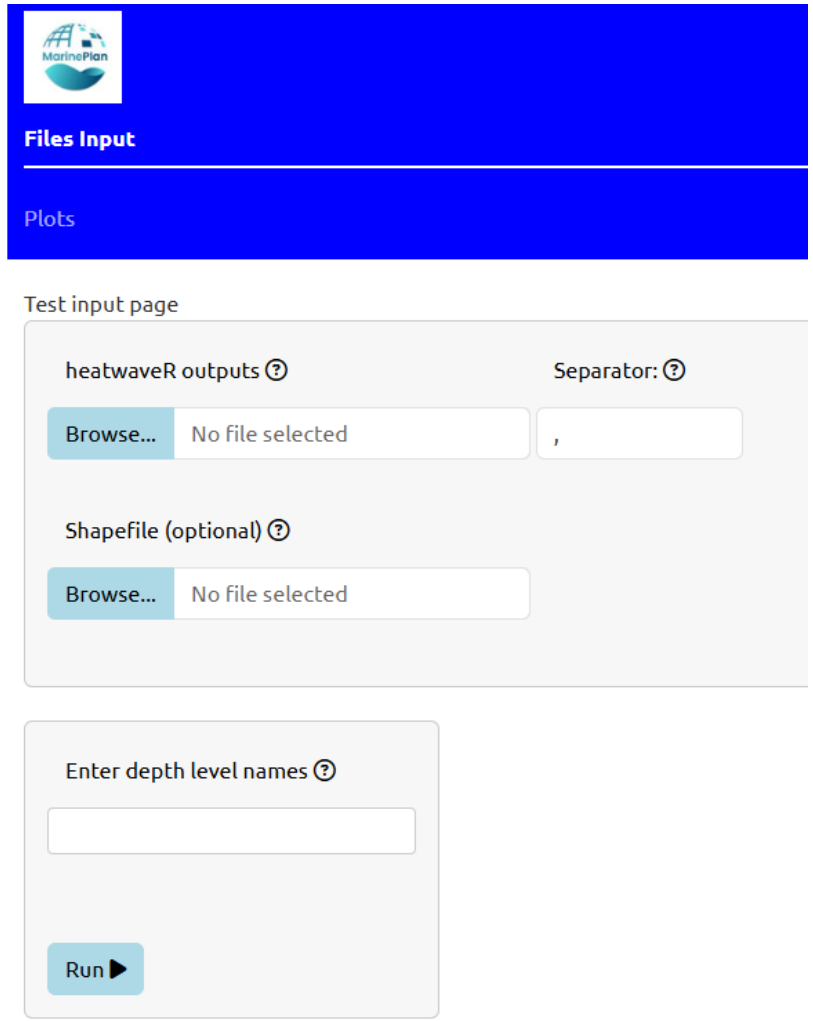
Use of MHW Outputs

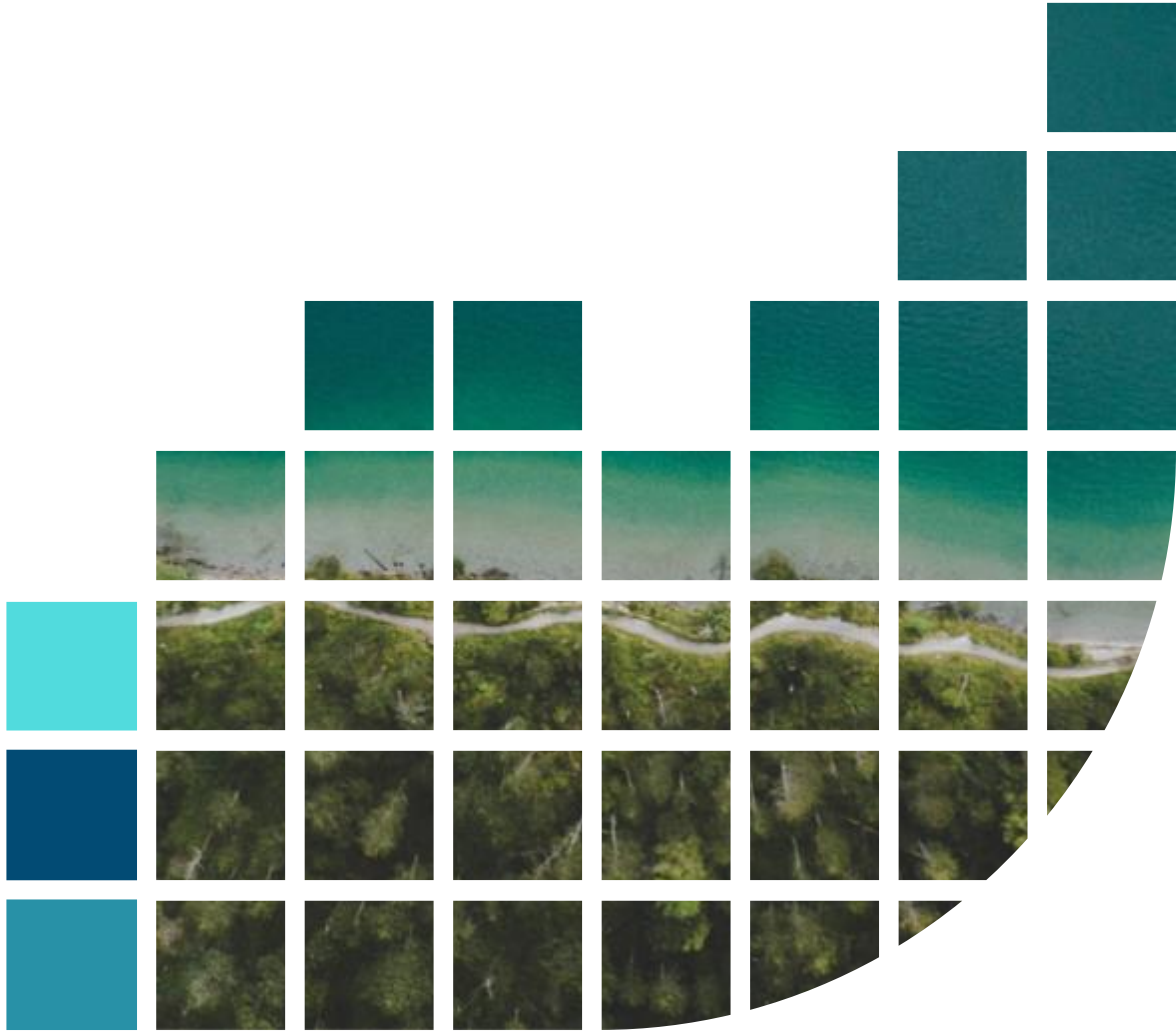
Marine heatwaves shiny app:
https://marineplanner.shinyapps.io/hws_shiny/

- Upload & process outputs (txt, csv, xlsx, Rds).
- Filter by depth, time range, and MHW metric.
- Extract site-specific metrics across user-defined areas (via shapefiles).

Relevance for EB-SCP:

- Integration of climate-driven extreme events into spatial planning.
- Site-level risk assessments for MPAs and other planning units.
- Comparison of adaptation strategies under fixed vs. shifting baselines.
- Subsurface insights essential for building resilient MPA networks





Thank you!

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