Marine Biological Association

13TH INTERNATIONAL TEMPERATE REEFS SYMPOSIUM
HOBART, UNIVERSITY OF TASMANIA

Broad-scale impacts of marine heatwaves on global kelp forests

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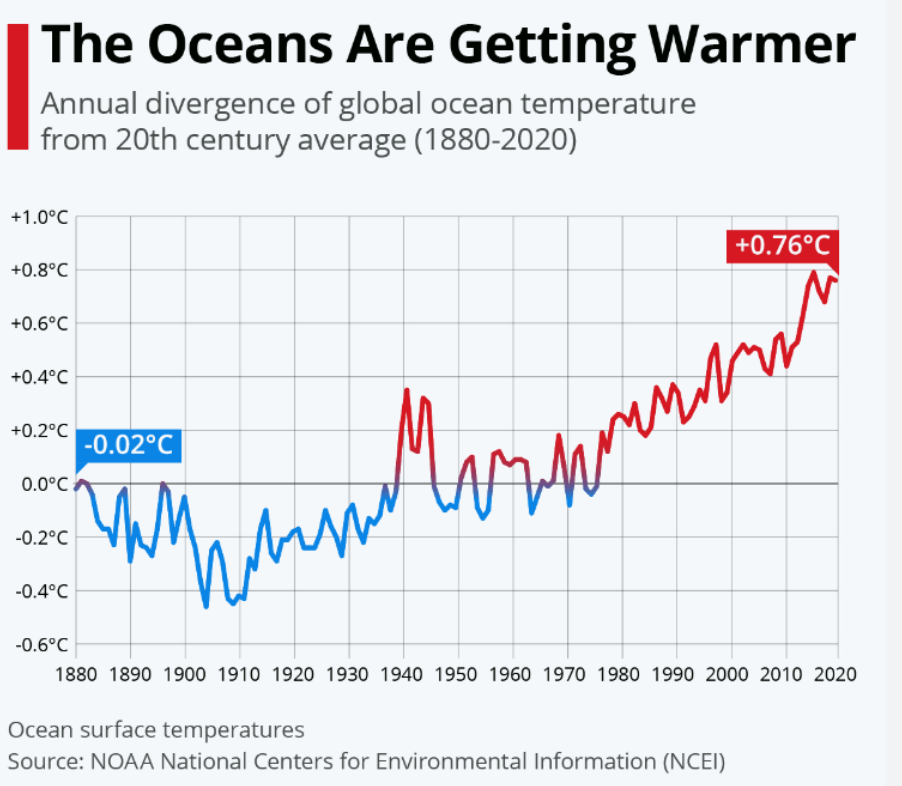
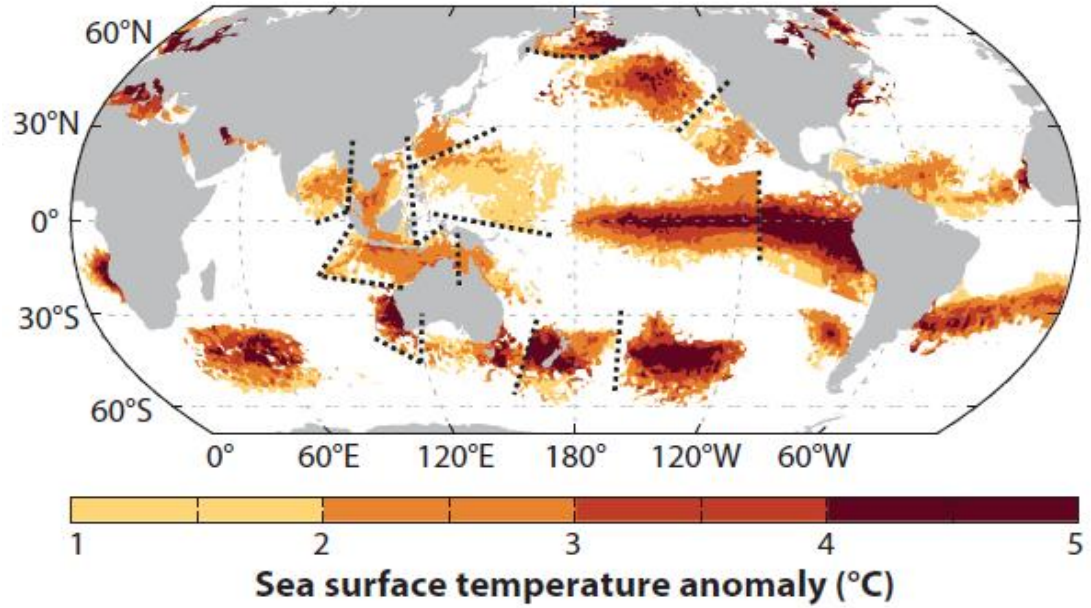
Benthic Ecosystems & Environmental Change
BEECH

Marine heatwaves

Discrete periods of anomalously warm water occurring in addition to background climate change

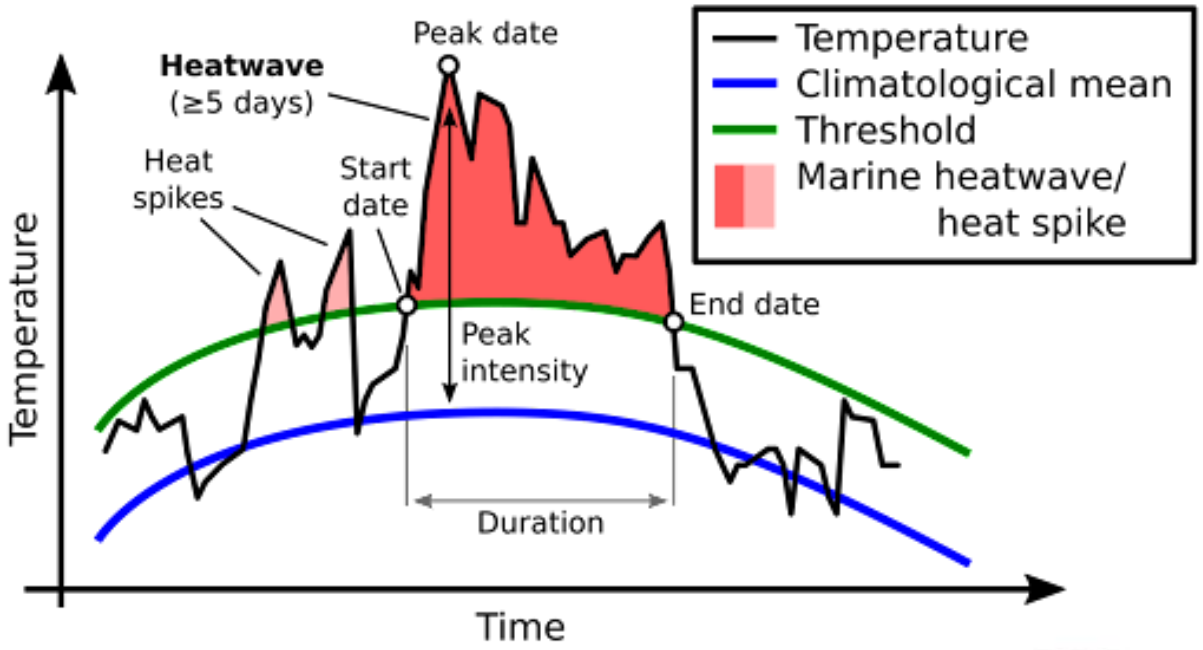


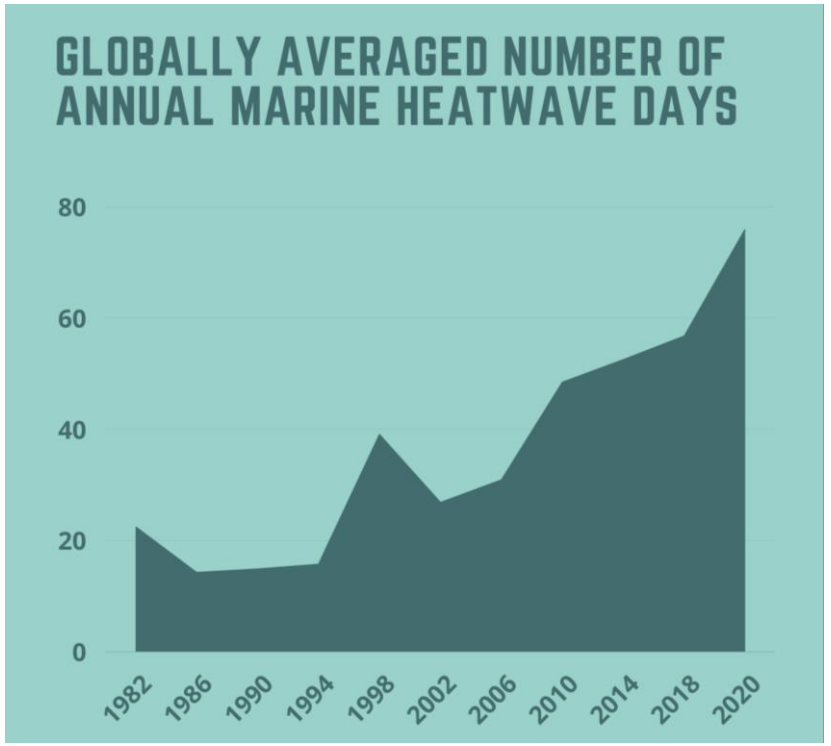


Smith et al. 2023. ARMS

Marine heatwave definition:

A period of five or more days where water temperatures are warmer than the 90th percentile based on a 30-year historical climatology for the time of year and location (Hobday et al. 2016)





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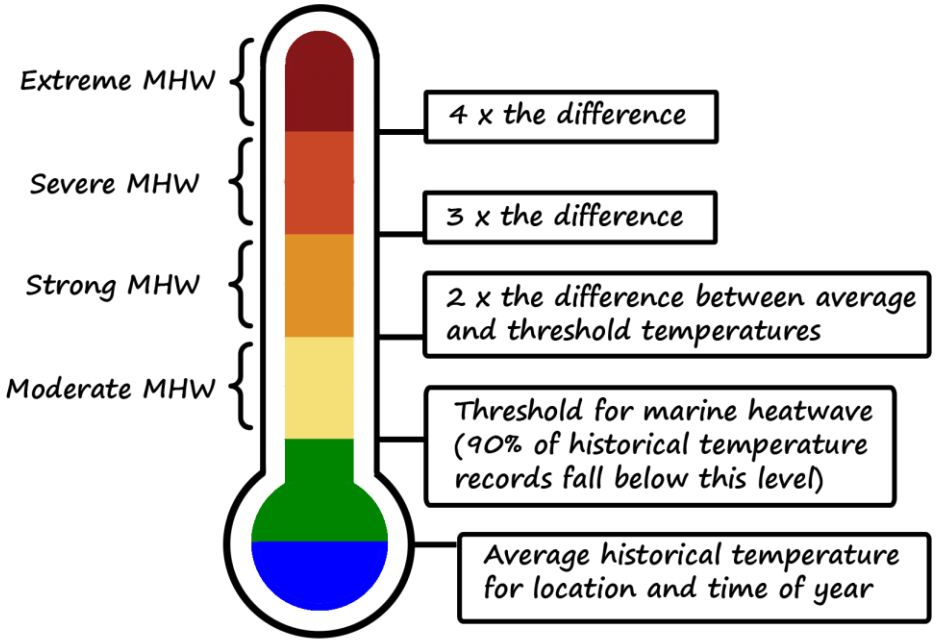
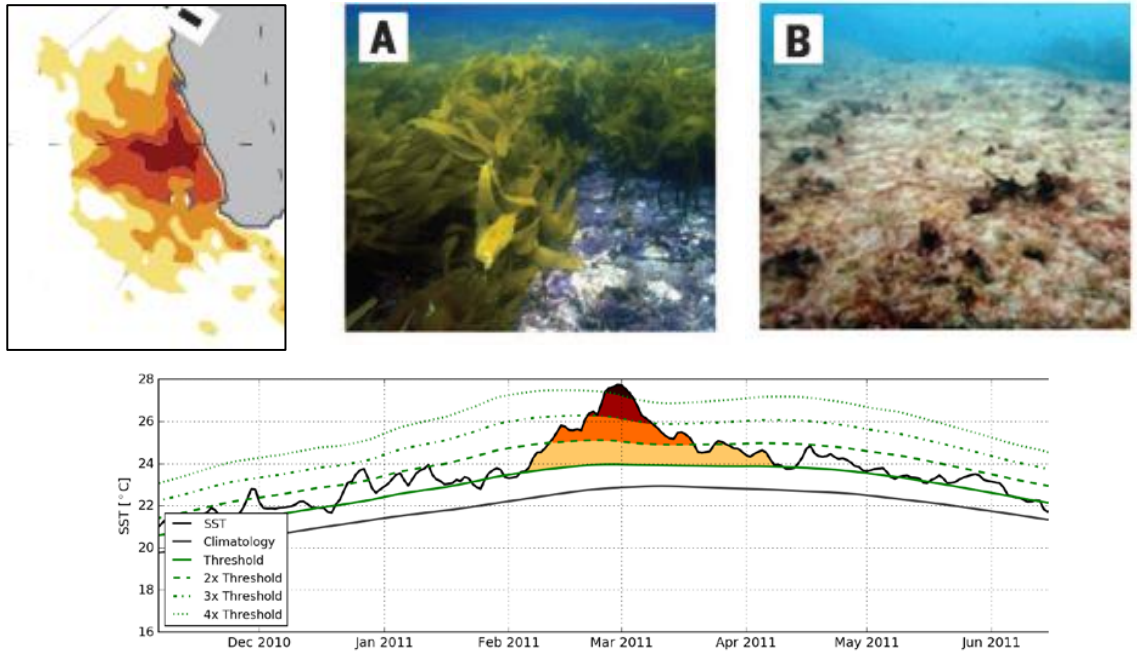
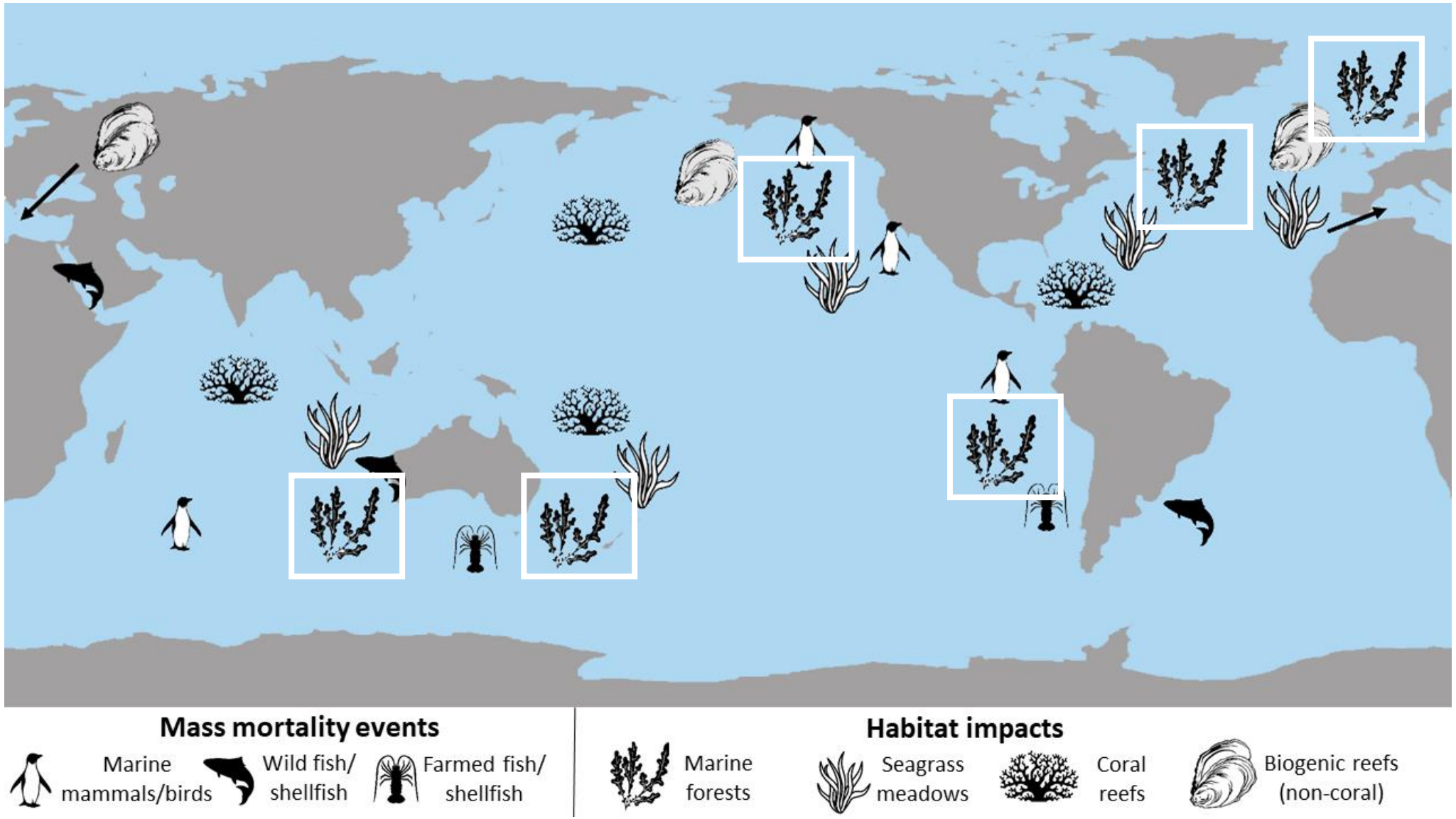
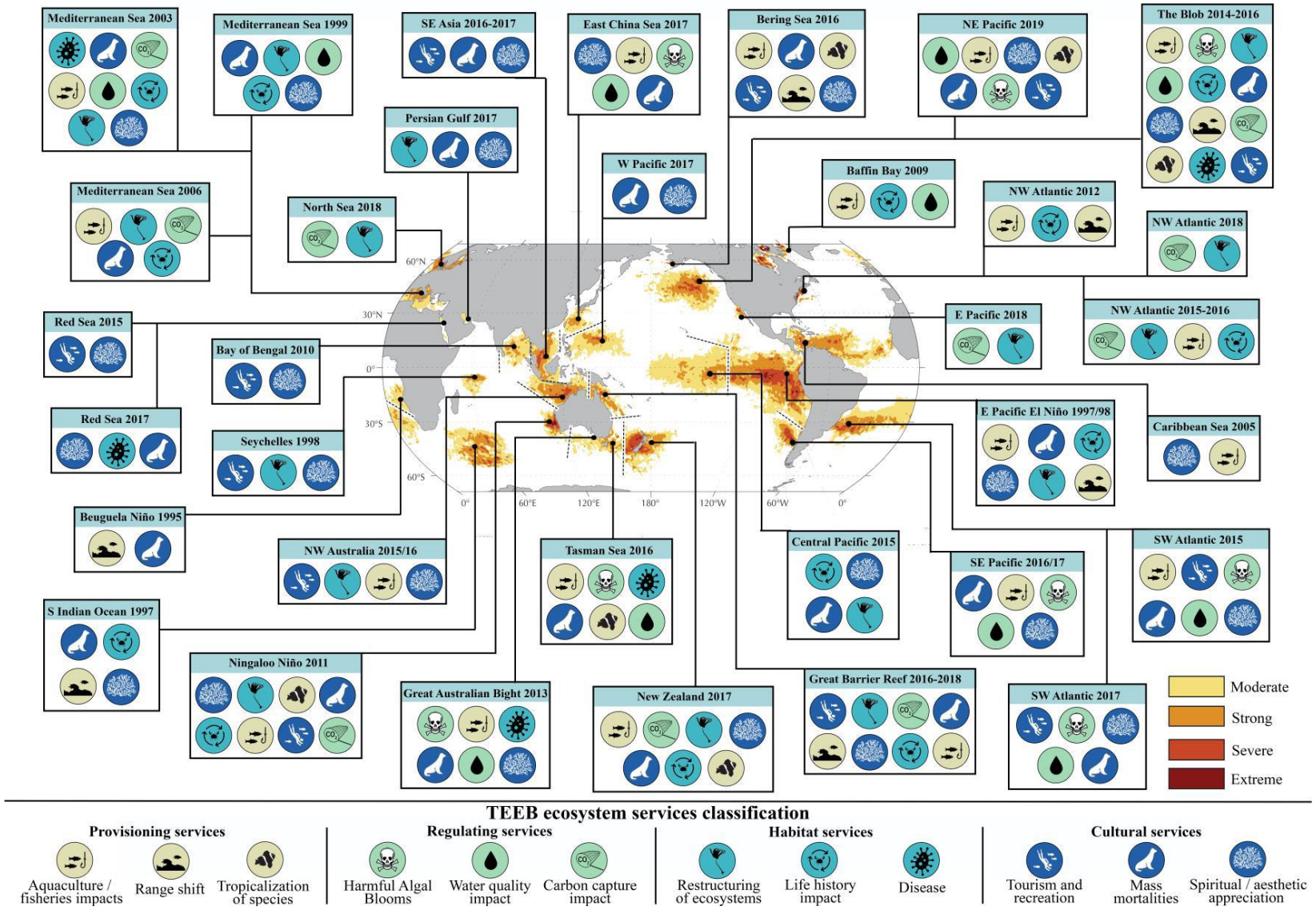




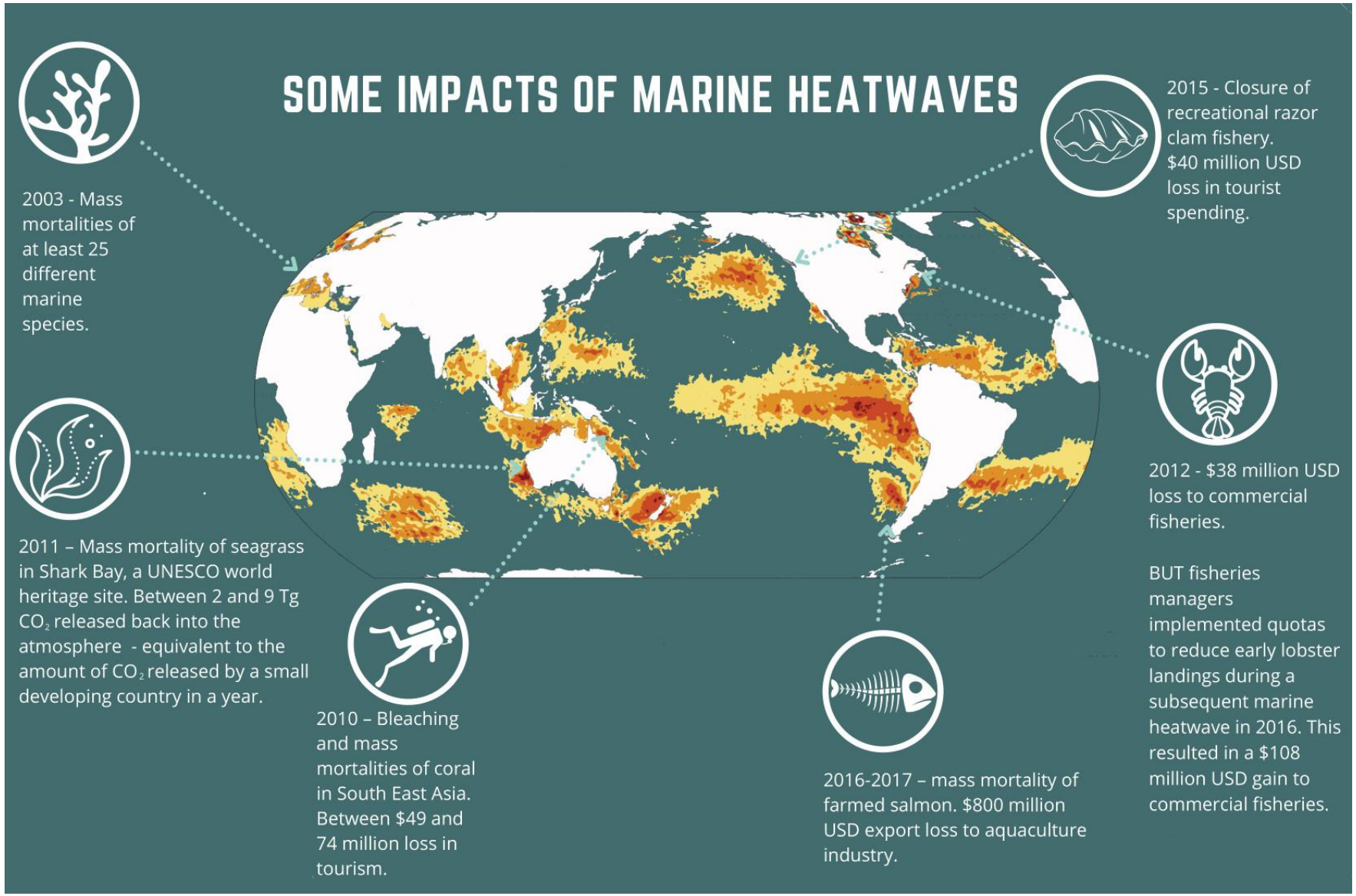
Wernberg et al. 2016. Science,
Hobday et al. 2018. Oceanography



Smith et al. Biological Impacts of Marine Heatwaves. *Annual Review of Marine Science* (2023).



Smith et al. Socioeconomic impacts of marine heatwaves: Global issues and opportunities. *Science* 374.6566 (2021)



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Key questions

- How are foundation species impacted by MHWs
- Which MHW characteristics are most closely related to change in foundation species?
- Do the most 'important' characteristics differ between different ecoregions?

Kelp forests | Seagrass beds | Reef-forming invertebrates | Coral reefs




Methods

Identify time-series datasets for kelp forest
- Density
- Biomass

Explore MHWs that have occurred in these areas
- Strong
- Summer

Cross-reference MHW events with time-series data

Compare kelp responses to MHW characteristics

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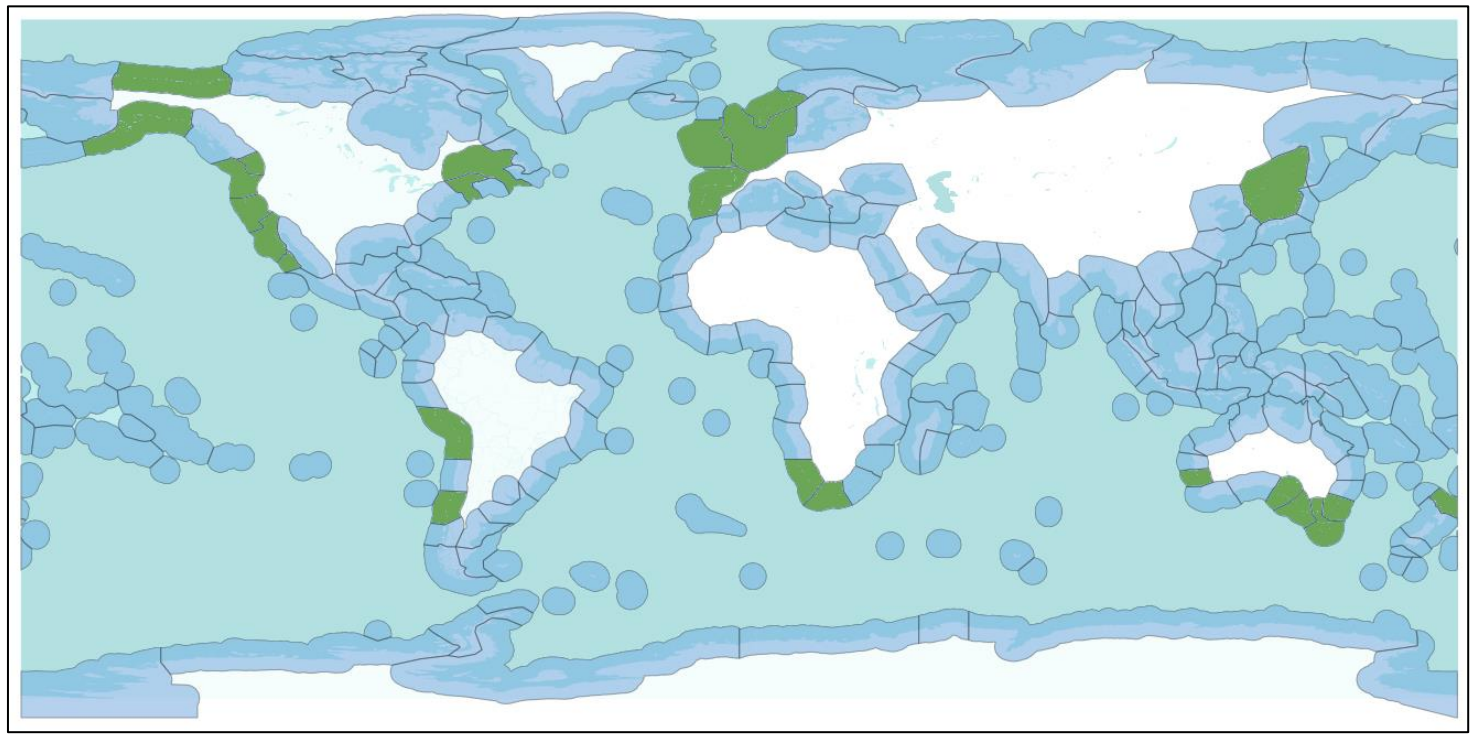
Results: all time-series data

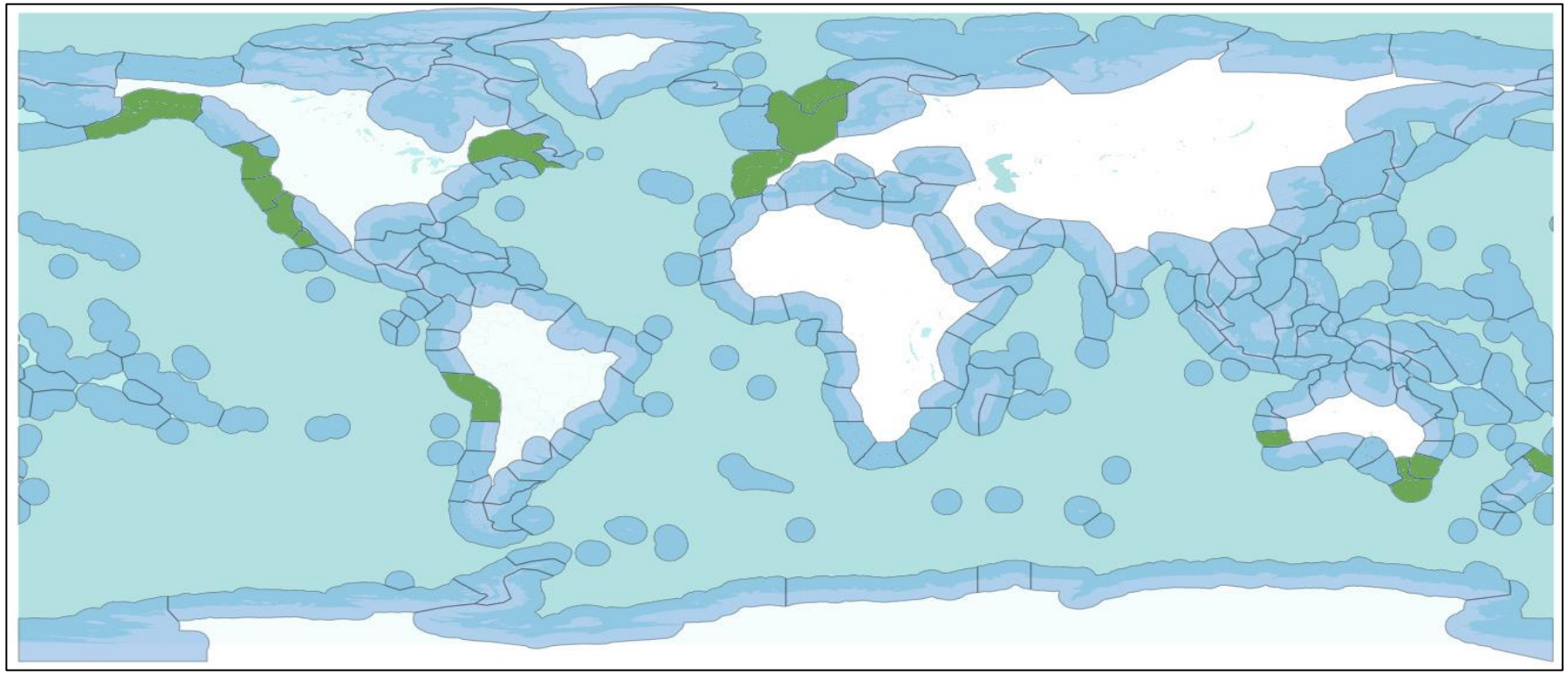
527 sites, 310 localised areas, 24 ecoregions



- TRB_KEEN kelp timeseries
  (Rassweiler et al. 2016)
- PISCO kelp forest community surveys
  (Carr et al. 2020)
- A2B kelp dataset
  (rodrigobeas@gmail.com)
- LTER Santa Barbara Channel
  (Reed & Miller 2022)
- Reef Life Survey/IMOS National Reef Monitoring Network
  (www.reeflifesurvey.com)
- Reef Check
  (www.reefcheck.org)

Results: time-series data with MHWs

185 sites, 97 localised areas, 14 ecoregions



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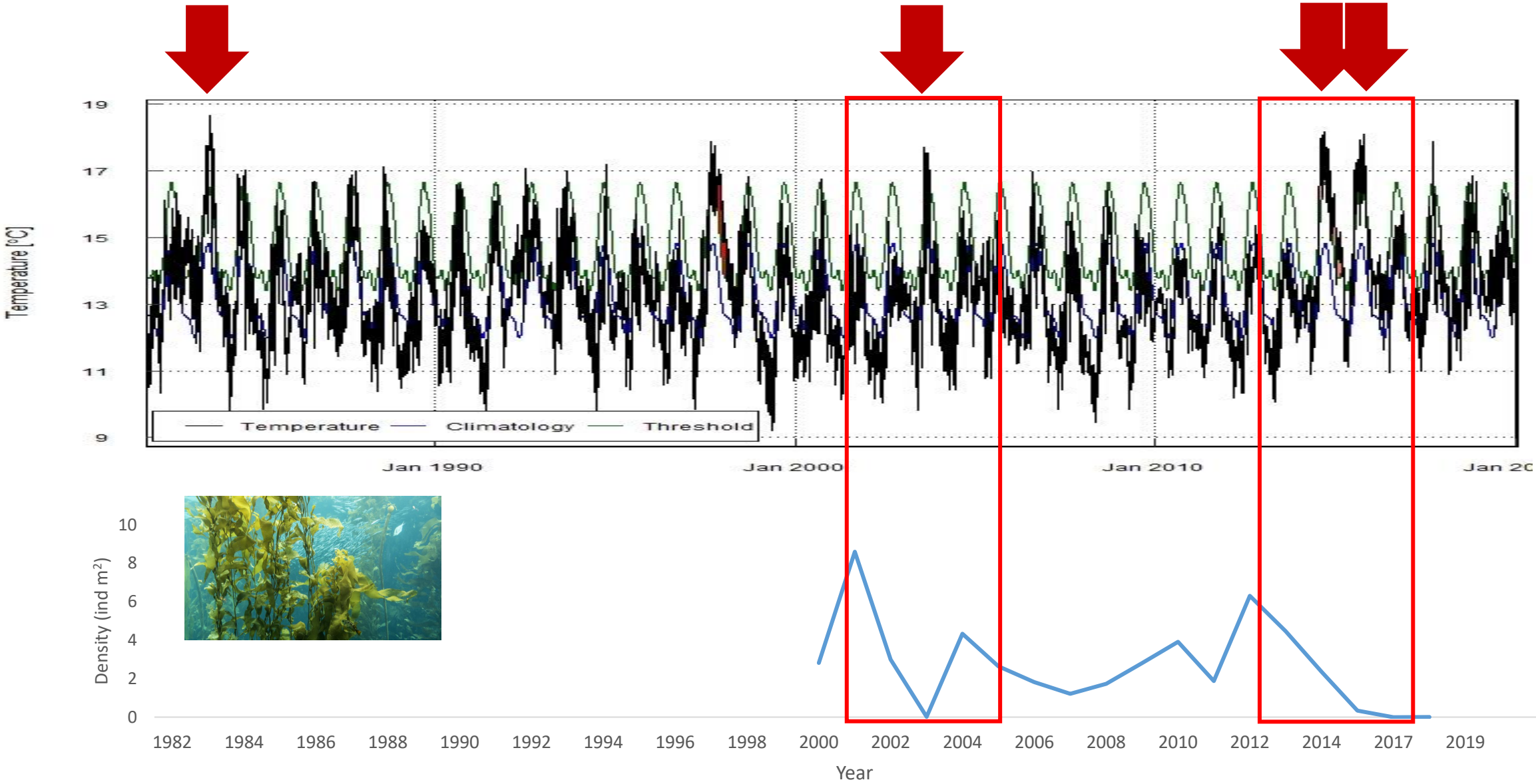
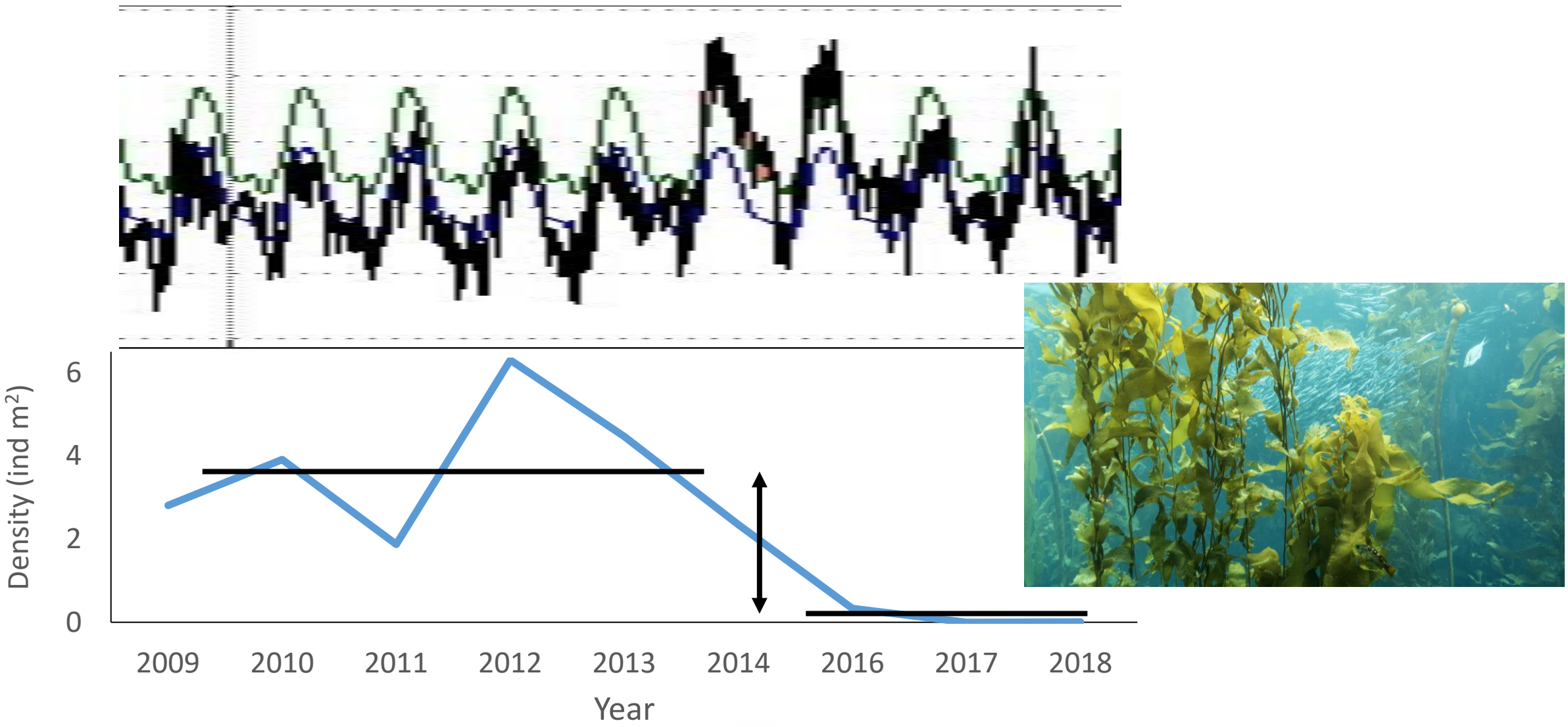


Data from PISCO kelp forest community surveys



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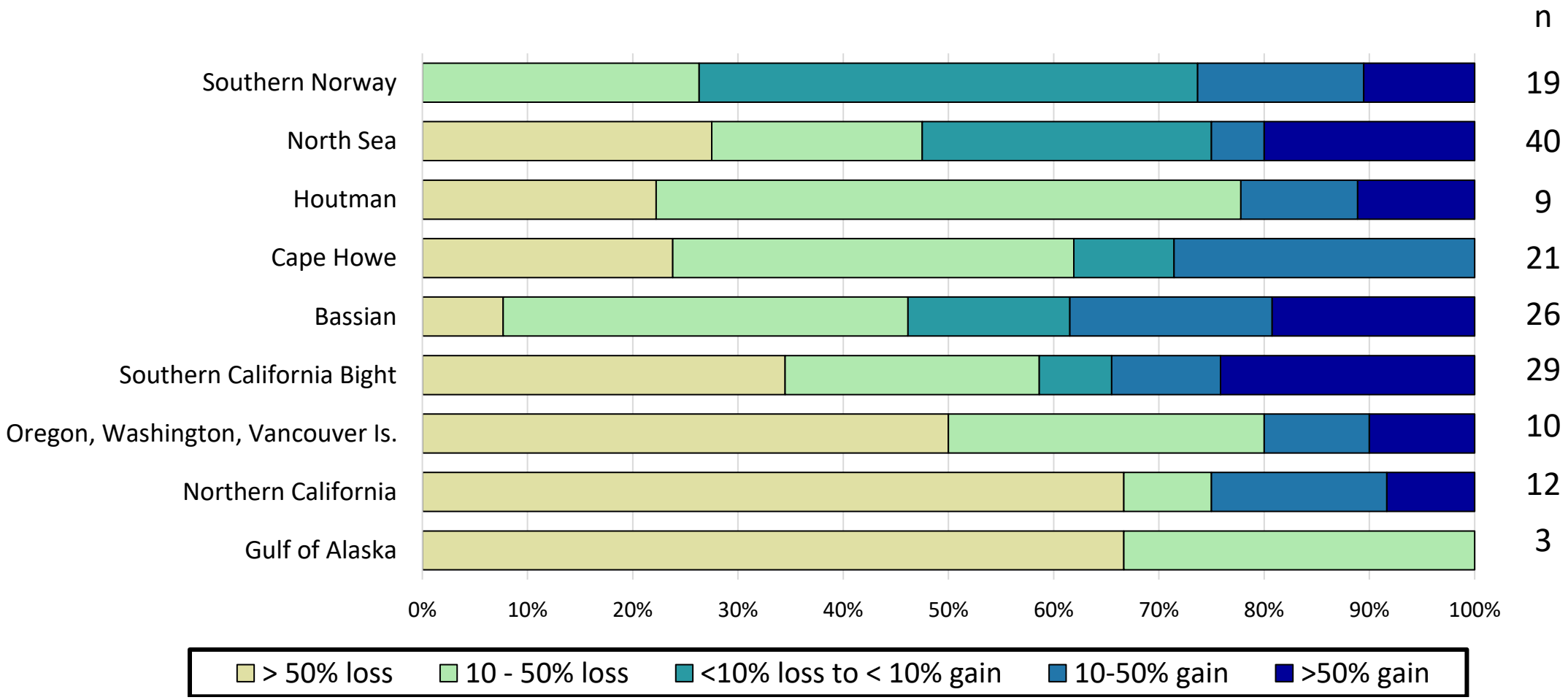
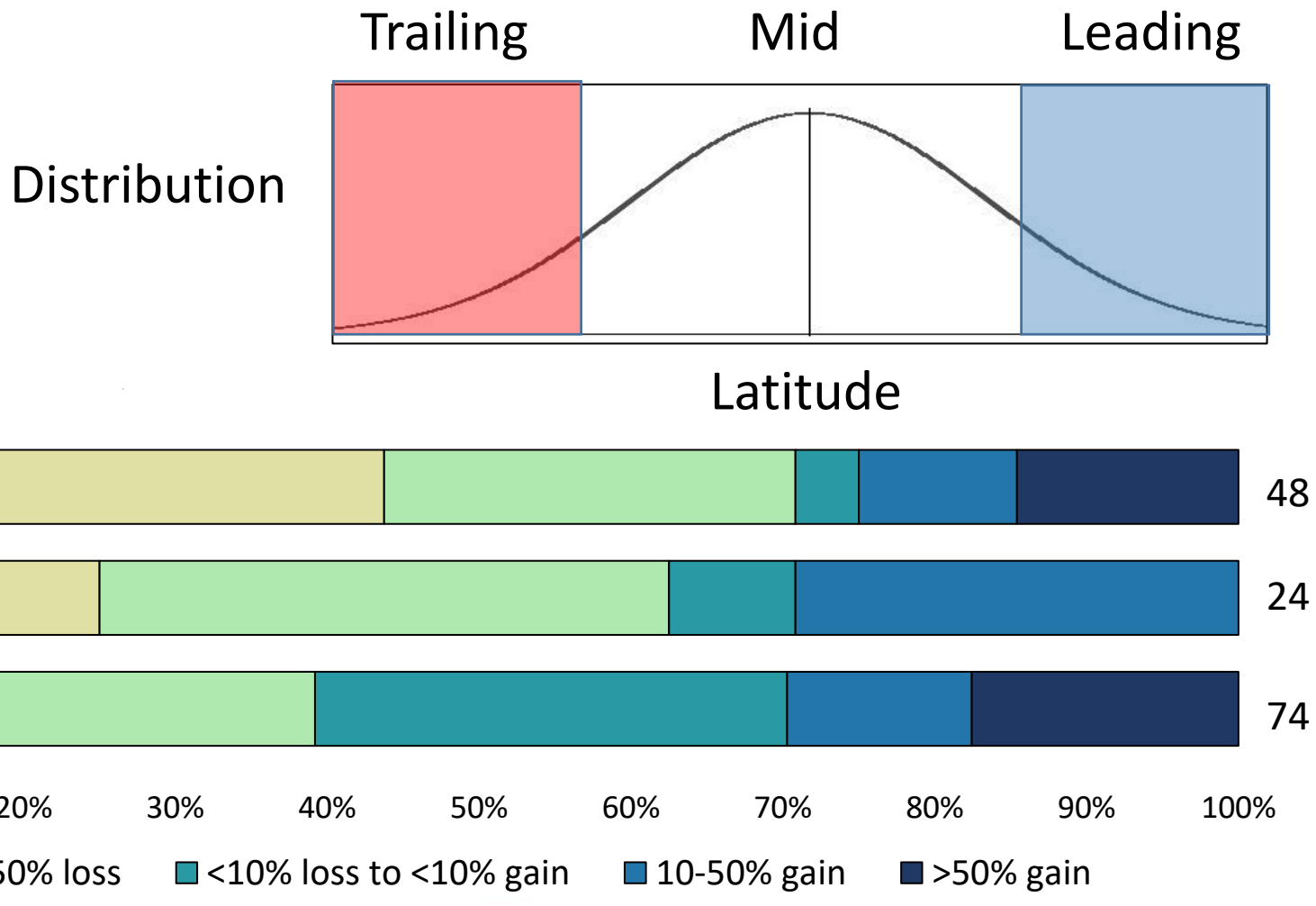
Results: by ecoregion

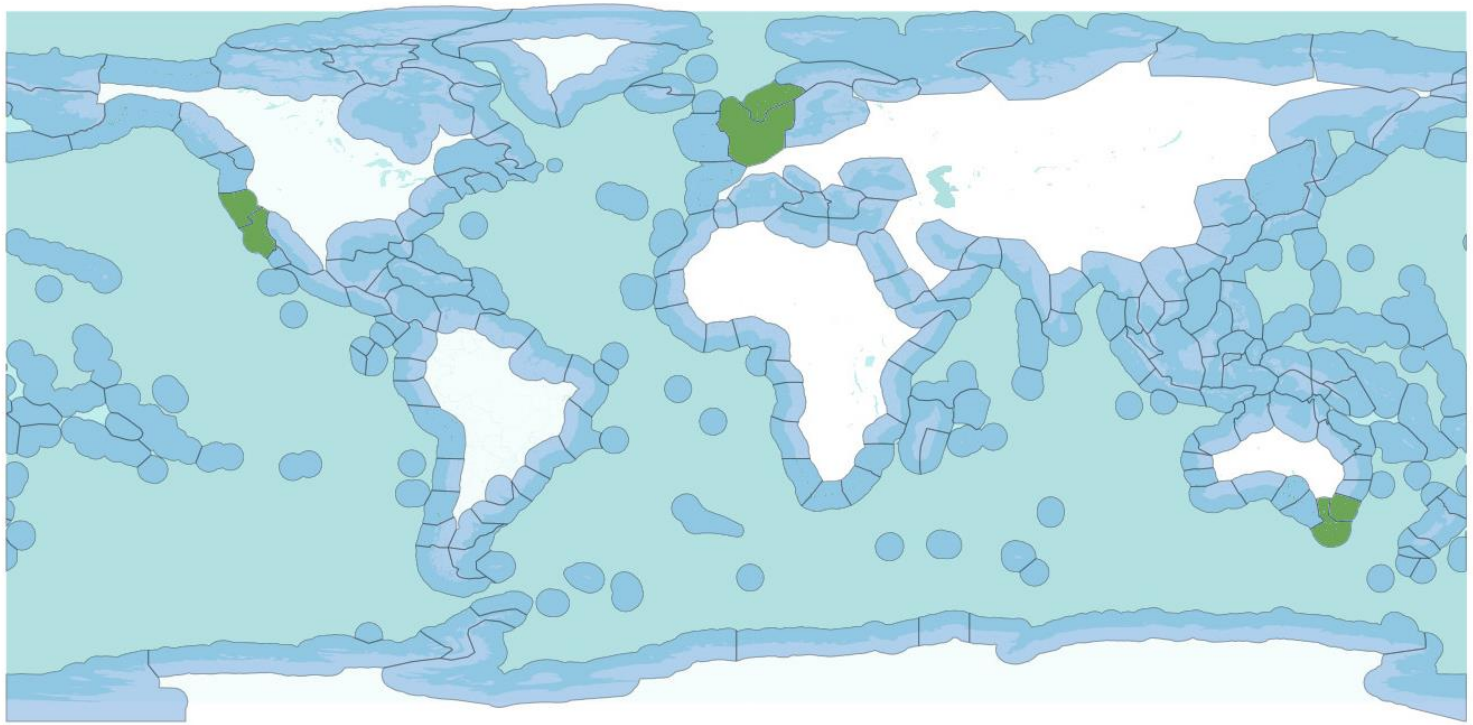


Results: by point in range



Results: MHW characteristics

Only used ecoregions with n>10 data points



157 sites

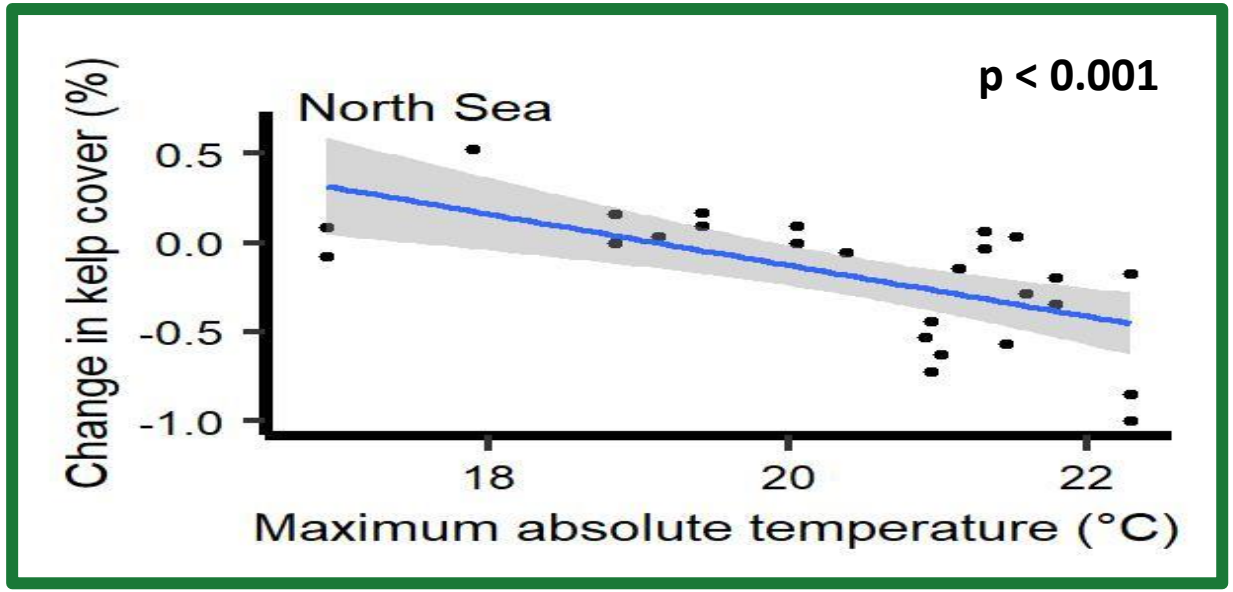
79 localised areas

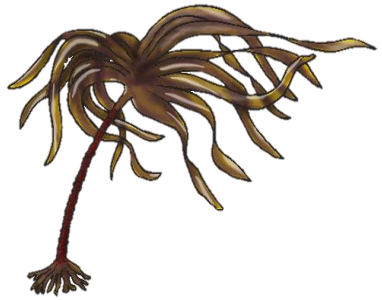
6 ecoregions

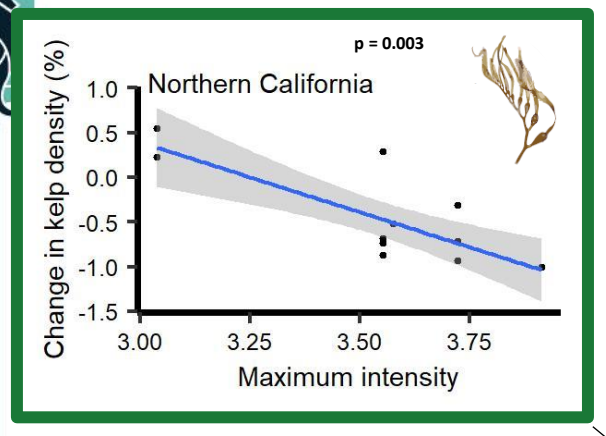
MHW characteristics
- Duration
- Max intensity
- Mean intensity
- Cumulative int.
- Max abs temp

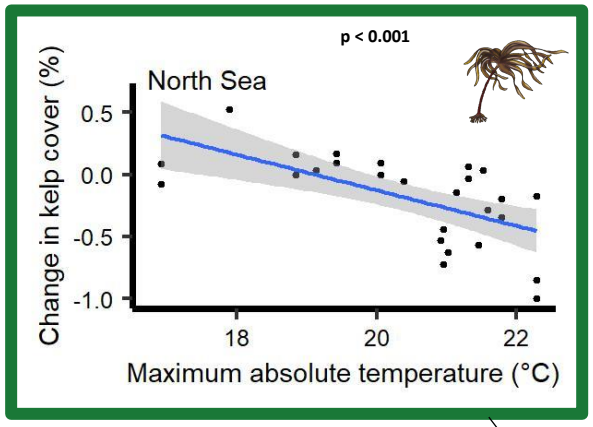
Results: GLMs

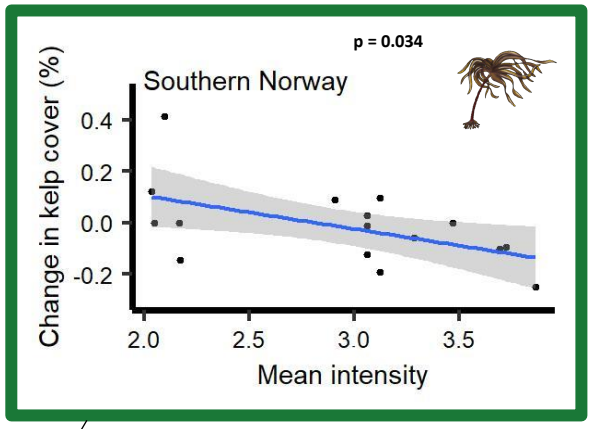
Group and ecoregion	Mean intensity			Max intensity			Cumulative intensity			Max absolute temp			Duration		
	p	df	AIC	p	df	AIC	p	df	AIC	p	df	AIC	p	df	AIC
Southern California Bight Macrocystis	0.053	24	22.30	**0.029**	24	21.15	**0.020**	24	20.45	**0.044**	24	21.96	**0.023**	24	20.70
Northern California Macrocystis	**0.019**	11	16.17	**0.003**	11	12.26	0.487	11	22.44	**0.006**	11	13.60	0.499	11	22.469
Southern Norway Laminaria	**0.034**	15	-14.66	**0.049**	15	-13.93	0.75	15	-9.48	0.147	15	-11.85	0.495	15	-9.91
North Sea Laminaria	**<0.001**	26	17.80	**<0.001**	26	18.10	**0.010**	26	23.10	**<0.001**	26	12.94	**0.007**	26	22.36
Cape Howe Ecklonia	0.270	20	12.10	0.625	20	13.21	0.083	20	10.07	0.178	18	9.40	**0.039**	20	8.65
Bassian Ecklonia	0.546	23	26.46	0.973	23	26.87	0.506	23	26.38	0.225	23	25.23	0.594	23	26.55

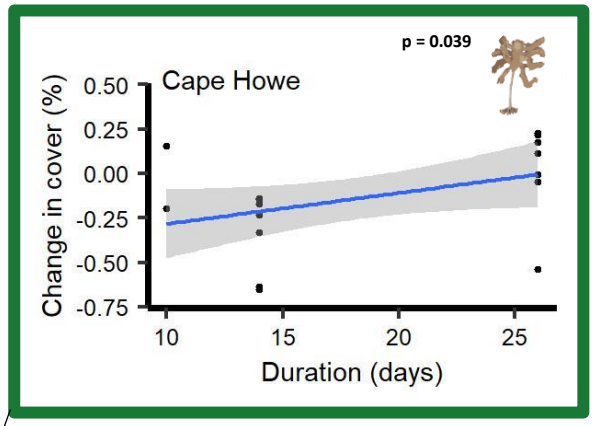


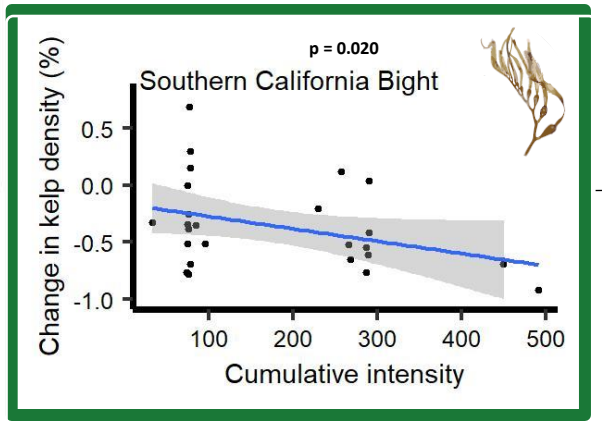


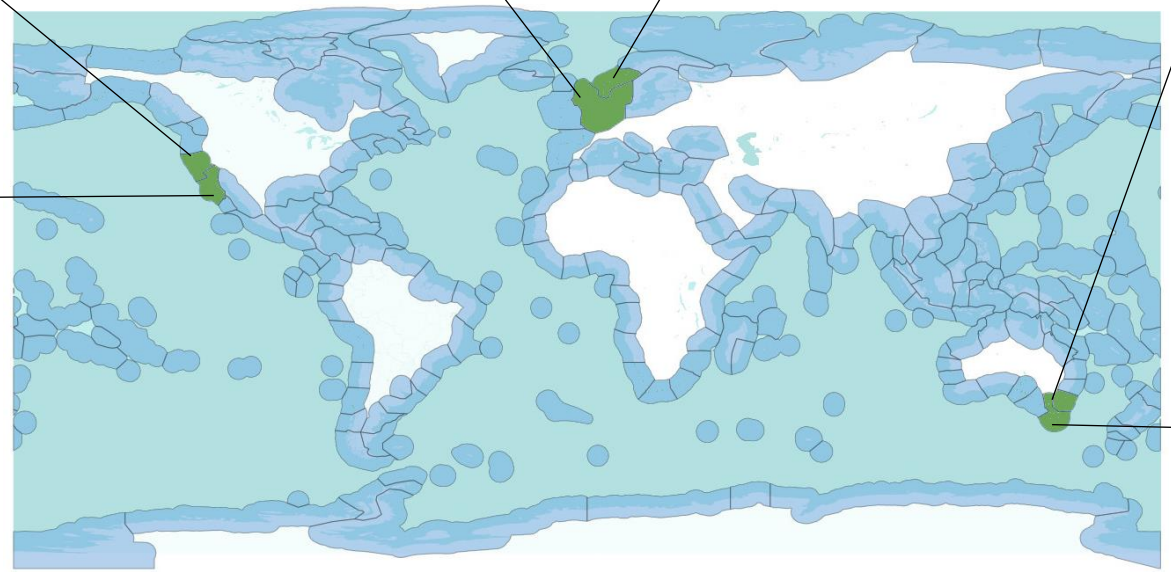

p = 0.003
Northern California
Change in kelp density (%)
1.0
0.5
0.0
-0.5
-1.0
-1.5
3.00
3.25
3.50
3.75
Maximum intensity

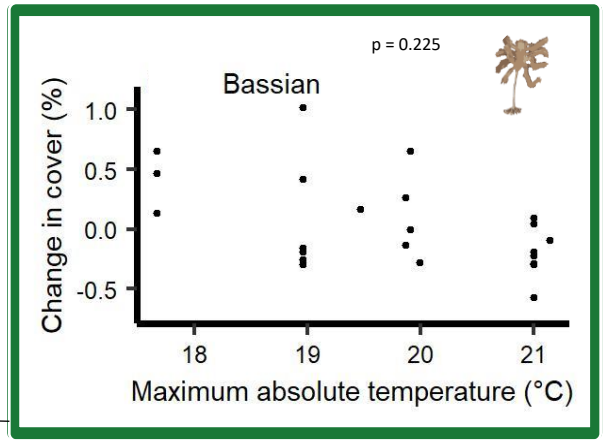

p < 0.001
North Sea
Change in kelp cover (%)
0.5
0.0
-0.5
-1.0
18
20
22
Maximum absolute temperature (°C)


p = 0.034
Southern Norway
Change in kelp cover (%)
0.4
0.2
0.0
-0.2
2.0
2.5
3.0
3.5
Mean intensity


p = 0.039
Cape Howe
Change in cover (%)
0.50
0.25
0.00
-0.25
-0.50
-0.75
10
15
20
25
Duration (days)


p = 0.020
Southern California Bight
Change in kelp density (%)
0.5
0.0
-0.5
-1.0
100
200
300
400
500
Cumulative intensity




p = 0.225
Bassian
Change in cover (%)
1.0
0.5
0.0
-0.5
18
19
20
21
Maximum absolute temperature (°C)

Conclusions

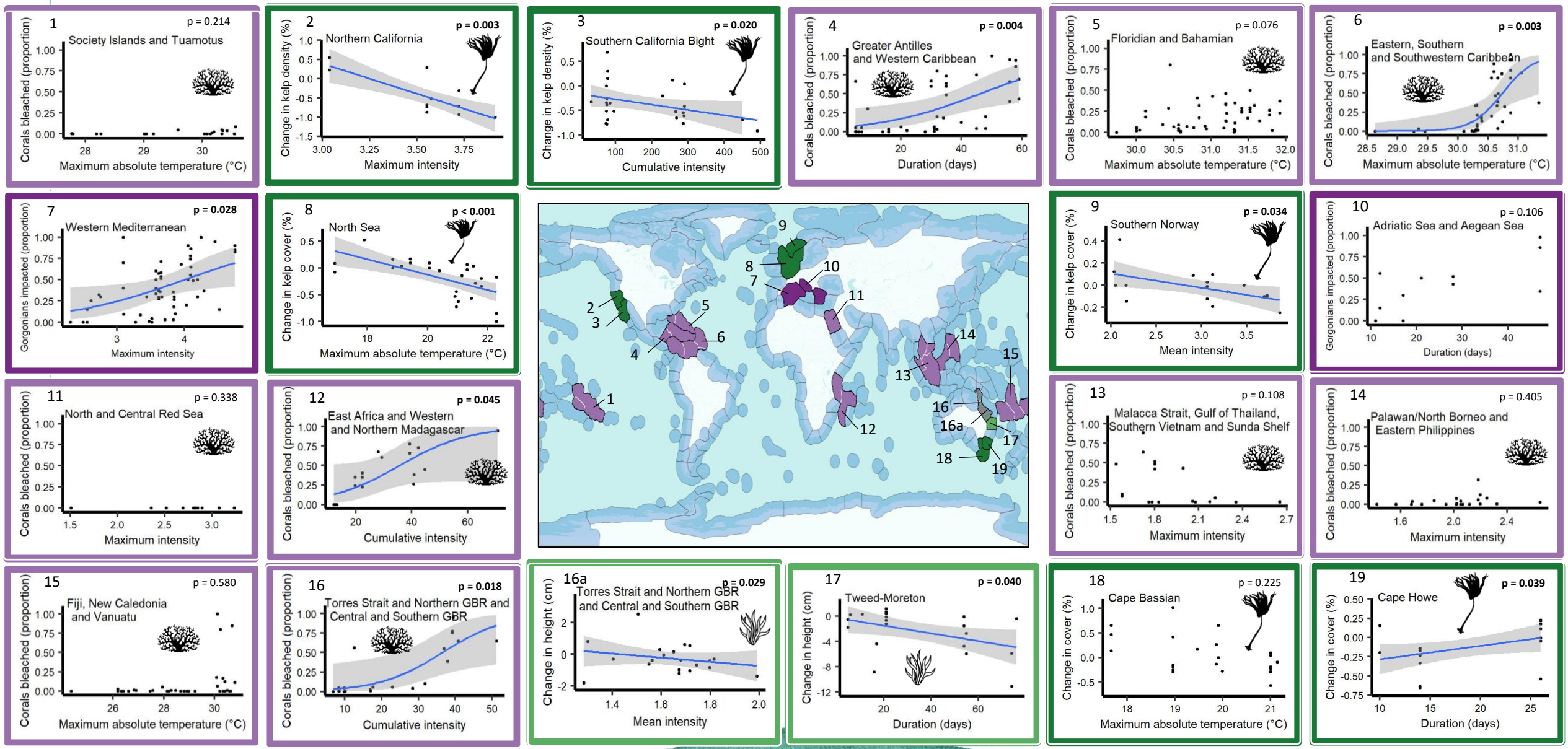
Building an understanding of the relationships between MHW characteristics and their impacts on foundation species

- Help guide management strategies

What next?

- Run lab experiments to support field observations

- Improve understanding of MHWs occurring simultaneously with other stressors


1
p = 0.214
Society Islands and Tuamotus
Corals bleached (proportion)
Maximum absolute temperature (°C)
2
p = 0.003
Northern California
Change in kelp density (%)
Maximum intensity
3
p = 0.020
Southern California Bight
Change in kelp density (%)
Cumulative intensity
4
p = 0.004
Greater Antilles and Western Caribbean
Corals bleached (proportion)
Duration (days)
5
p = 0.076
Floridian and Bahamian
Corals bleached (proportion)
Maximum absolute temperature (°C)
6
p = 0.003
Eastern, Southern and Southwestern Caribbean
Corals bleached (proportion)
Maximum absolute temperature (°C)
7
p = 0.028
Western Mediterranean
Gorgonians impacted (proportion)
Maximum intensity
8
p < 0.001
North Sea
Change in kelp cover (%)
Maximum absolute temperature (°C)
9
p = 0.034
Southern Norway
Change in kelp cover (%)
Mean intensity
10
p = 0.106
Adriatic Sea and Aegean Sea
Gorgonians impacted (proportion)
Duration (days)
11
p = 0.338
North and Central Red Sea
Corals bleached (proportion)
Maximum intensity
12
p = 0.045
East Africa and Western and Northern Madagascar
Corals bleached (proportion)
Cumulative intensity
13
p = 0.108
Malacca Strait, Gulf of Thailand, Southern Vietnam and Sunda Shelf
Corals bleached (proportion)
Maximum intensity
14
p = 0.405
Palawan/North Borneo and Eastern Philippines
Corals bleached (proportion)
Maximum intensity
15
p = 0.580
Fiji, New Caledonia and Vanuatu
Corals bleached (proportion)
Maximum absolute temperature (°C)
16
p = 0.018
Torres Strait and Northern GBR and Central and Southern GBR
Corals bleached (proportion)
Cumulative intensity
16a
p = 0.029
Torres Strait and Northern GBR and Central and Southern GBR
Change in height (cm)
Mean intensity
17
p = 0.040
Tweed-Moreton
Change in height (cm)
Duration (days)
18
p = 0.225
Cape Bassian
Change in cover (%)
Maximum absolute temperature (°C)
19
p = 0.039
Cape Howe
Change in cover (%)
Duration (days)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
16a
17
18
19

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