Marine heatwave response plans for ecosystems and fisheries

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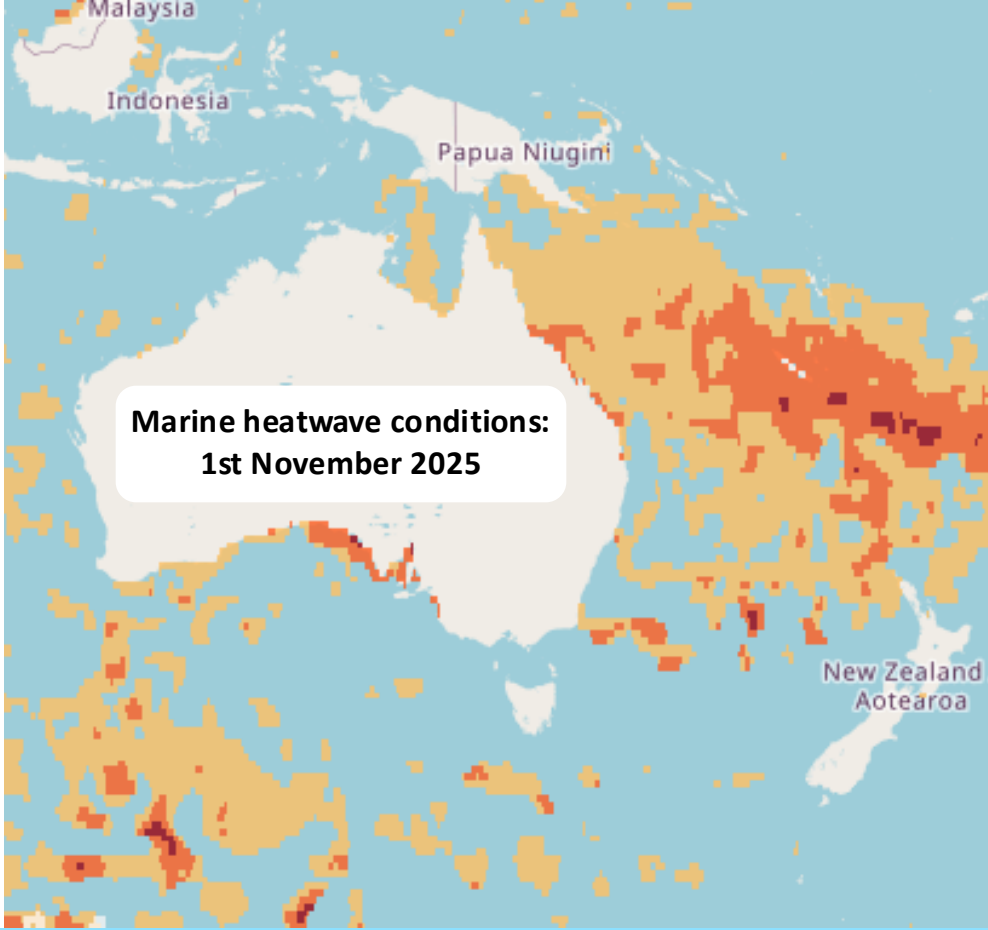

Response plans are a structured set of actions designed to address an actual or potential threat to something you want to protect.

They are **integrative >>>** information and actions in one stage feed into the next.

Towards marine heatwave response plans...

Assess risk

Plan responses

Act during an event

Learn and adjust

Action	Example
Obtain baseline data using long-term monitoring programs and historical studies (R, I) Revisit past marine heatwave effects in region of interest (I) Estimate risk, intensity and duration of marine heatwaves during El Niño in region of interest (R)	Marine heatwave historical analyses — for example www.marineheatwaves.org. In eastern Tasmania, an atlas of marine heatwaves can be used to revisit past events and understand the frequency, intensity, duration and impacts of past events(1).
Identify vulnerable ecological areas and populations using vulnerability assessment approaches (R)	Determine population susceptibility for different species (for example shallow or sessile). Measure thermal thresholds for species/populations survival. Knowledge from past events can inform expected impacts and improve responses, as occurred for lobster fisheries in Maine, USA(2).
Prioritize high-risk areas and populations for response using vulnerability mapping (R, I, P)	Based on mapping, aquaculture companies can prepare to shift populations to cooler parts of their lease sites, and fallow the warmer sites(7). Harvest before the forecast event.
Develop early warning systems based on ecosystem monitoring, ocean forecasting and available real-time information (R)	Develop skills in using existing ocean information websites, such as provided by observing programs — for example Australia's integrated marine observing system (IMOS) or www.marineheatwaves.org. Deploy monitoring equipment around area of activity, such as gliders.
Capture data relevant to expected impact and responses using a range of remote and in situ methods (R)	Undertake real time analysis or use existing resources (e.g. www.marineheatwaves.org). Undertake eDNA sampling, habitat surveys, fish surveys.
Adapt operations during the event via management strategies for human endeavours (I)	Alter timing of stocking or types of organisms (for example, source heat-tolerant species). Diversify activities. Move mobile activities to lower-risk areas (such as deeper waters). Reduce quotas or close fishery areas, change zones of operation based on real-time monitoring.
Assess recovery time post-event using data collected in the previous stages (I)	Implement or continue changes to harvesting, quotas, change industry operations and/or reduce other stressors until system recovers. Data repositories (such as www.imos.org.au) can be used to determine when environmental conditions have returned to pre-event levels.
Plan long term management responses, such as breeding programs for aquaculture species, or codify adaptive management approaches based on a range of plausible scenarios (R, I, M, P)	Consider the long-term risks from increasing frequency of extreme events and if system changes are needed using system models (for example ref. 7).

How can these actions be **linked and trigger** others?

It helps if we have a:

1. Defined spatial and temporal extent,

- New South Wales
- 'Marine heatwave season'

And,

2. Level of specificity (general or tailored for specific industries or ecosystems)

- A general plan
- An industry specific plan

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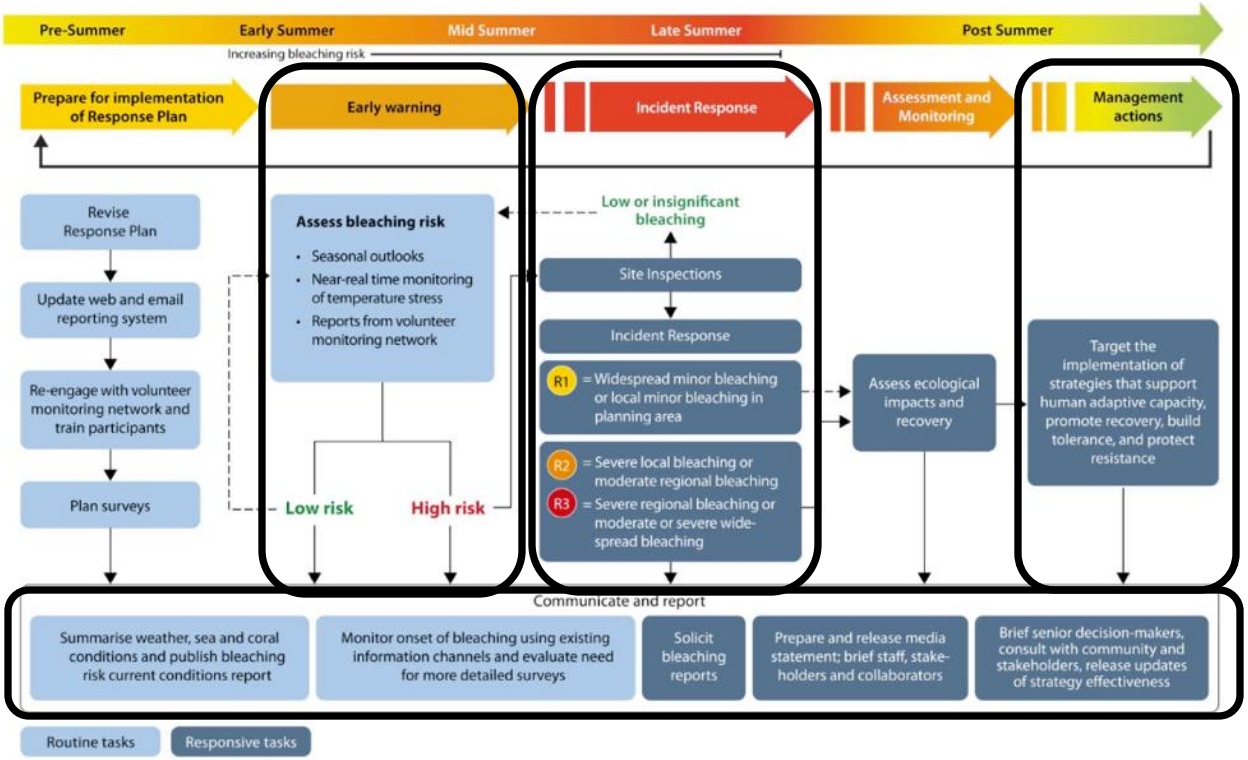
Supp info from Hobday *et al.* (2023) With the arrival of El Niño, prepare for stronger marine heatwaves. *Nature* 621, 38–41

Leveraging from coral bleaching response plans…



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Maynard *et al*. (2009) A Strategic Framework for Responding to Coral Bleaching Events in a Changing Climate. *Environmental Management* 44: 1–11.

The emerging need for marine heatwave response plans: A globally relevant example from New South Wales, Australia

Curtis Champion [a,b,*], Melinda A. Coleman [a,b,c]

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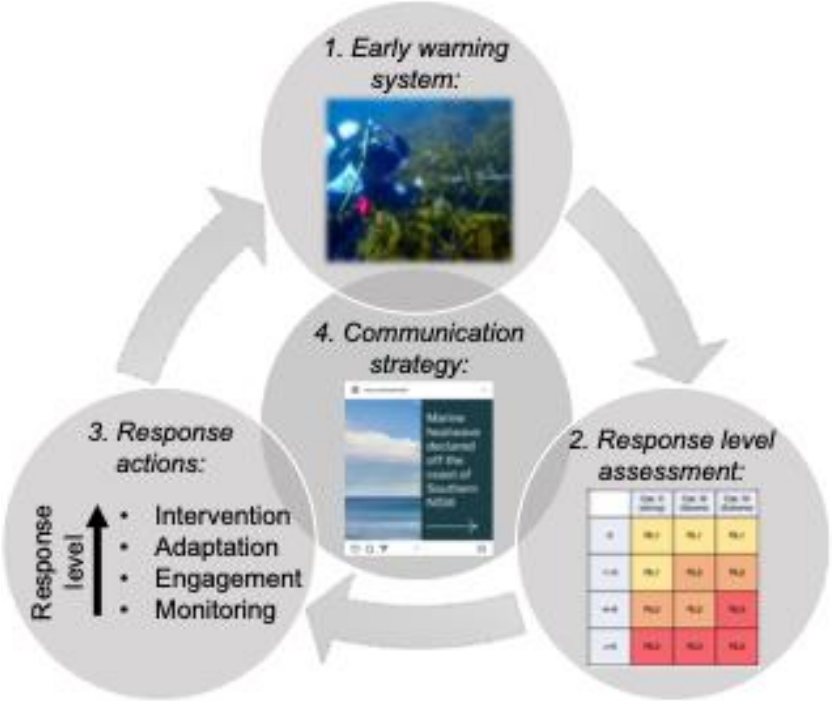

1. Early warning system

"MHW monitoring window": 1 December – 31 May

SST forecasts from ACCESS-S are reviewed on the first day of each month.

Anomalies > 1 °C initiate ~daily monitoring of the near real-time MHW tracker (weekly monitoring if < 1°C anomalies).

Onset of category 2 or greater MHW conditions for > 7 days initiates on-ground monitoring.

In NSW, includes replicated dive or video surveys untaken by trained research staff within areas experiencing MHW conditions and engagement with fishing, aquaculture and diving stakeholders to scope rapid biological indicators of thermal stress.

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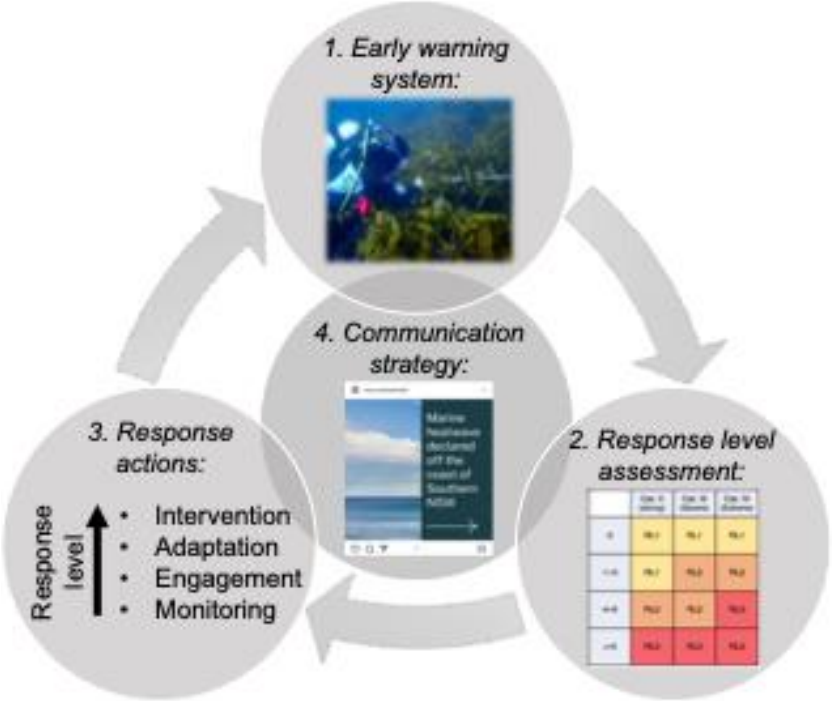

2. Response level assessment

Number of biological indicators of thermal stress identified	MHW category: Cat. II (strong)	Cat. III (Severe)	Cat. IV (Extreme)
0	RL1	RL1	RL1
1–3	RL1	RL2	RL2
4–6	RL2	RL2	RL3
> 6	RL3	RL3	RL3

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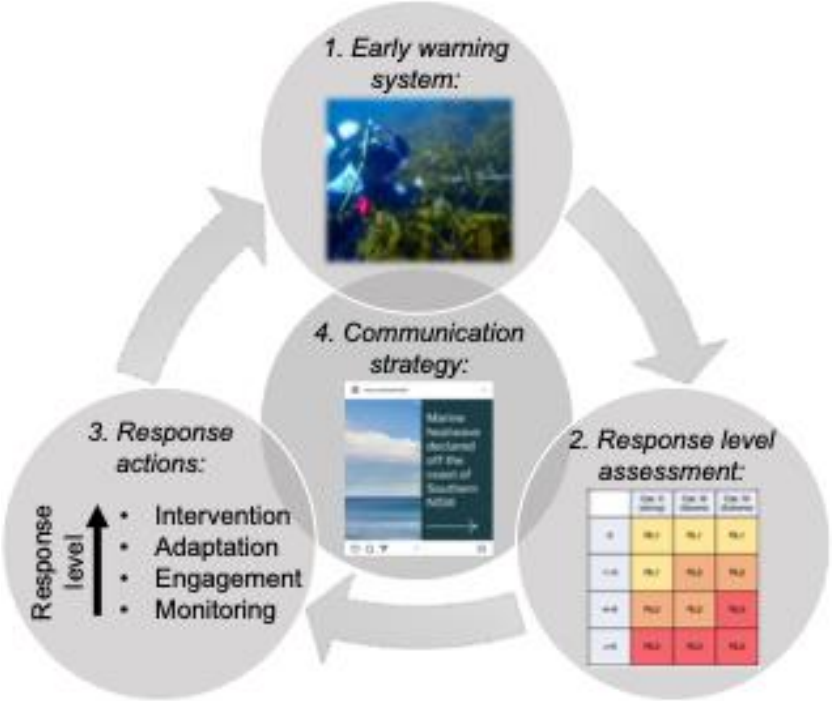

3. Response actions

Response actions	*Responsible sectors*
1. Undertake targeted research and monitoring to assess impacts during and following MHW conditions.	Research
2. Promote participation in marine citizen science programs (e.g. Redmap and Reef Life Survey) within areas experiencing MHW conditions to assess impacts.	Research, management
3. Cease restoration activities until thermal conditions have returned to suitable range.	Research, management
4. Undertaken rapid industry and cross sectoral engagement to identify and assess additional management and training options specific to affected areas and activities.	Management, Fisheries, Aquaculture
5. Engage with industry to promote adaptive harvest techniques and aquaculture system options.	Management, Fisheries, Aquaculture
6. Make assets available for emergency responses (e.g. starving animals or emergency translocation of threatened species) and alert groups to be ready to respond (e.g. volunteer groups, indigenous rangers).	Aquaculture, Non-government organisations
7. Temporarily cease harvest of aquaculture species until MHW conditions dissipate and species physiological condition is verified.	Aquaculture
8. Increase enforcement of fishing restrictions within areas experiencing MHW conditions, including bag and size limits and no-take marine protected areas.	Management
9. Redistribute fishing effort to areas outside of the MHW extent or thermal refugia within the MHW extent (e.g. regions of cooler water upwelling).	Fisheries, research
10. Temporarily amend size, possession or bag limits for impacted species.	Management
11. Apply spatial or temporal closures to provide additional stock and habitat protection.	Management
12. Artificial shading and cooling of aquaculture infrastructure (e.g. oyster leases).	Aquaculture
13. Undertake translocation programs to minimise impacts to threatened and other species (e.g. corals and kelp) that are sensitive to MHW impacts.	Research, management
14. Undertake stock enhancement and/or conservation breeding programs for vulnerable species for reintroduction following MHW conditions.	Research, management

RL1 RL2 RL3

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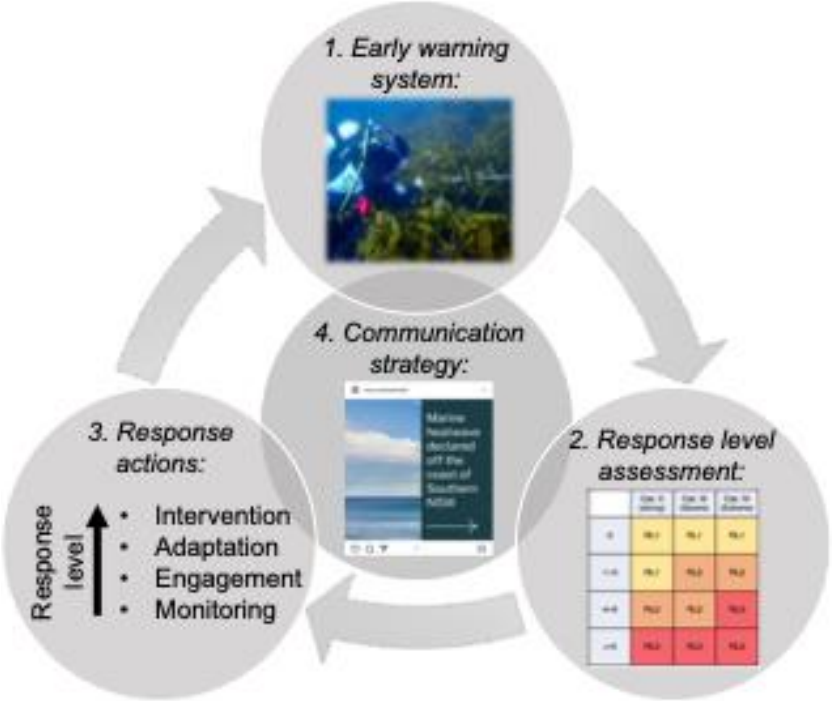


4. Communication strategy

NSW Government prepared for marine heatwaves

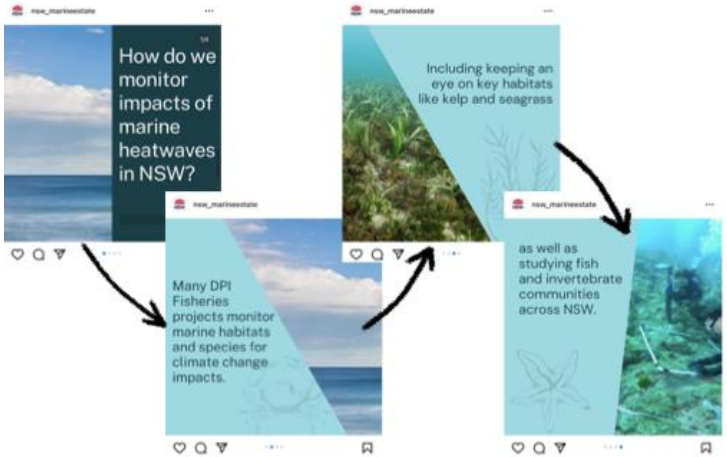
Minister for Agriculture and Western NSW - Media Release

8 Dec 2023

CSIRO has declared a marine heatwave for the NSW south coast and further Marine heatwaves are expected along the NSW coast, with sea temperatures forecast by the Bureau of Meteorology to be up to 2.5°C warmer than normal this summer.

The NSW Government in collaboration with key agencies and stakeholders has developed a response plan that includes:

- Early Warning System - monitoring to detect physical and biological impacts and the onset of heatwaves;
- Incident Response - establishing a structure to implement a response and coordinate the processes;
- Management Actions – activities that could be used to boost resilience and promote recovery; and,
- Communication Strategy - early and regular communication to ensure consistent, credible and accurate information is communicated about events, responses and recovery.



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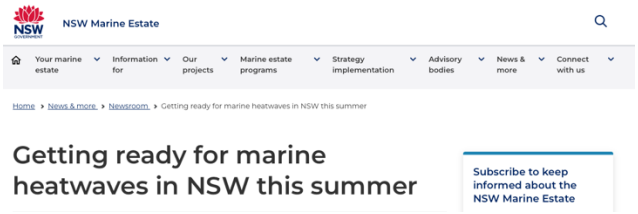
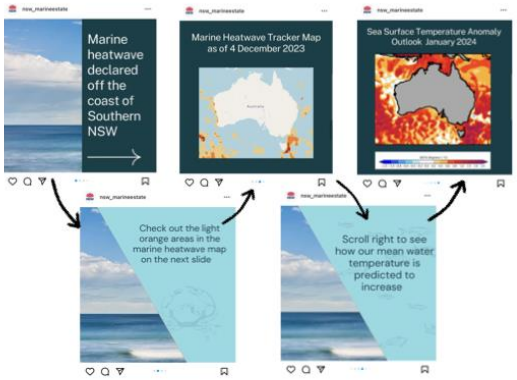
Enacting the plan...





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Reflected outside the marine heatwave monitoring window

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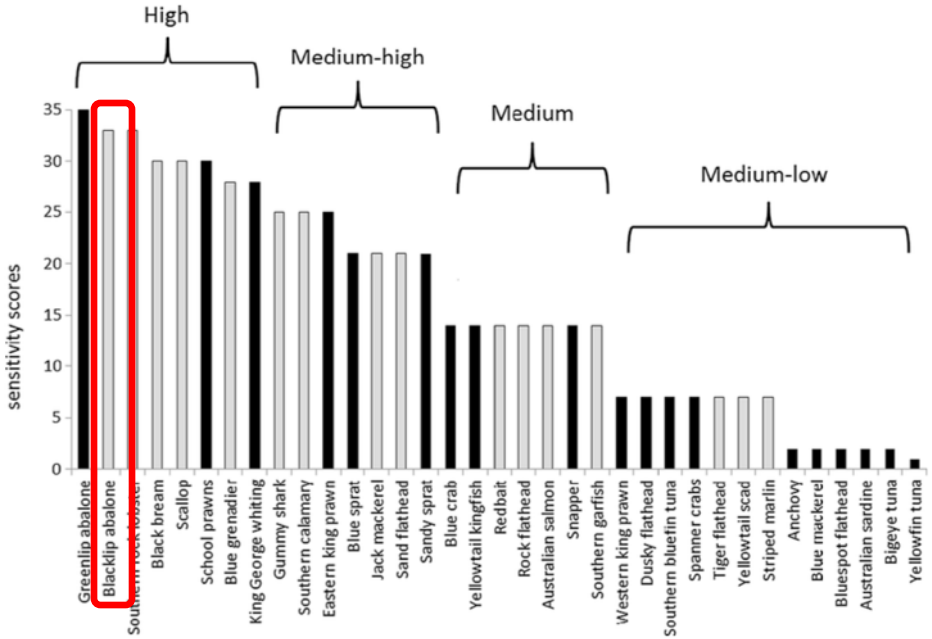
Industry-focused and co-developed response plans: NSW abalone industry



Pecl *et al*. (2014) Rapid assessment of fisheries species sensitivity to climate change. *Climate Change* 127: 505–520.

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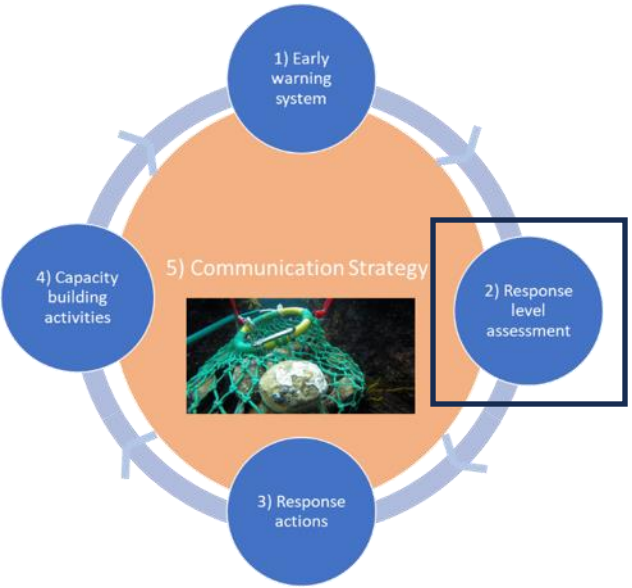

Indicators of thermal stress in abalone	Tier 1, 2 or 3 indicators
'Mushrooming' (i.e. individual rising from substrate).	1
Weak retention to substrate (can be associated with thermal stress and is associated with subsequent higher mortality if animals are removed under elevated thermal conditions).	1
Evidence of small-scale abalone mortality events (e.g. clusters of upturned shells).	1
Increased levels of mortality post-harvest.	1
Lack of meat bulging beneath the shell (indicative of heat-induced starvation).	2
Abscesses or cysts with associated bacterial infections.	2
Elevated levels of biofouling.	3
Early spawning.	3
Higher occurrence of 'shiny-back' individuals due to conspecifics grazing on top of each other due to lack of suitable food on the substratum. This can be an indication of starvation stress.	3
Signs of thermal stress among other organisms in areas experiencing marine heatwave conditions	3

Indicators of abalone thermal stress identified	Number of observed individuals displaying indicators of thermal stress			
		Up to 5%	Up to 30%	More than 30%
	Tier 3 indicator(s) evident	Low	Low	Medium
	Tier 2 indicator(s) evident	Low	Medium	High
	Tier 1 indicator(s) evident	Medium	High	High

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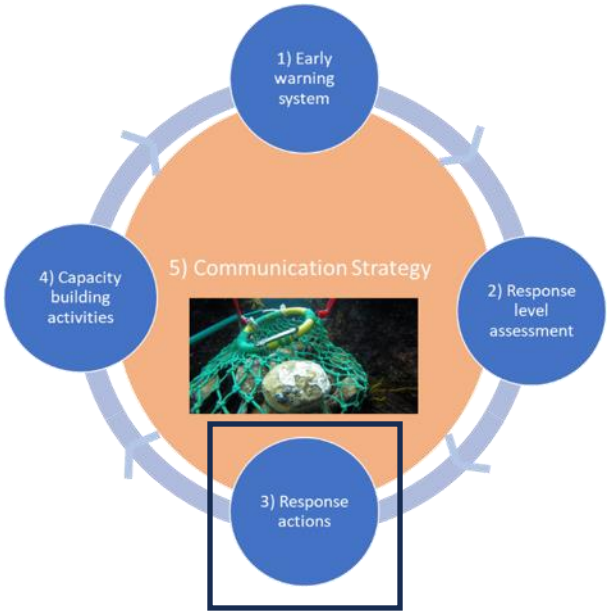
Coleman, Nimbs & Champion (*In press*) Industry-focused and co-developed marine heatwave response plans are needed for enhancing climate resilience: Application to a vulnerable abalone industry. *Climate Risk Management*.

Industry-focused and co-developed response plans: NSW abalone industry



Example response actions	Response level
Use of separators (corflute or damp course) in between abalone. Use of hessian sacks on top to keep harvested abalone cool.	Low
Rapid assessment of spatial extent of marine heatwave impacts to abalone on additional reefs after initial biological indicators are observed at a single site(s).	Low
Limit harvest to regions of the coast experiencing north-easterly wind-driven upwelling.	Medium
Further modifying on-vessel procedures. E.g., not using warm surface water for deck washing, hang individuals over the side of the vessel in deeper cooler water to limit stress and maximise the quality of the product, use of a small amount of ice to cool holding tubs.	Medium
Translocate healthy individuals from areas experiencing marine heatwave impacts to refuges (e.g. deeper or cooler reefs not experiencing marine heatwave conditions). Individuals that are not displaying signs of thermal stress should be used in emergency translocation efforts to enhance their survivability and minimise negative interactions with individuals present in areas they are translocated.	High
Cease fishing and push for harvest strategy to allow withholding portions of unused quota for future fishing years.	High

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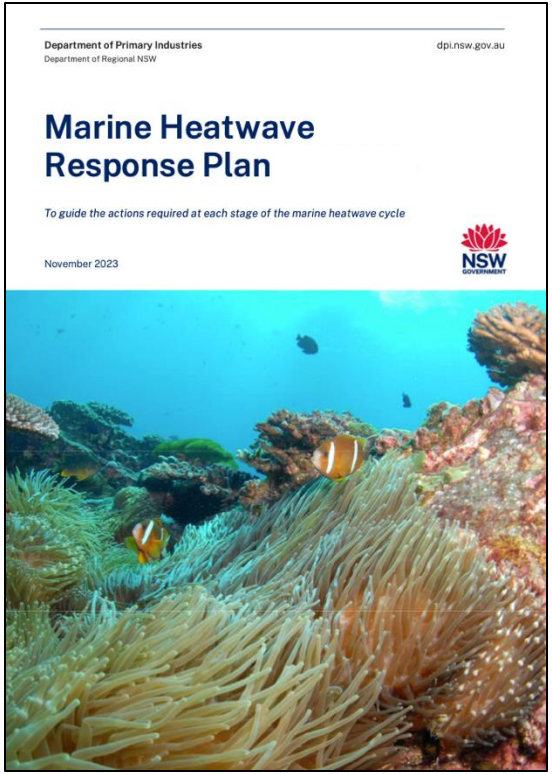
Finding homes for marine heatwave response plans



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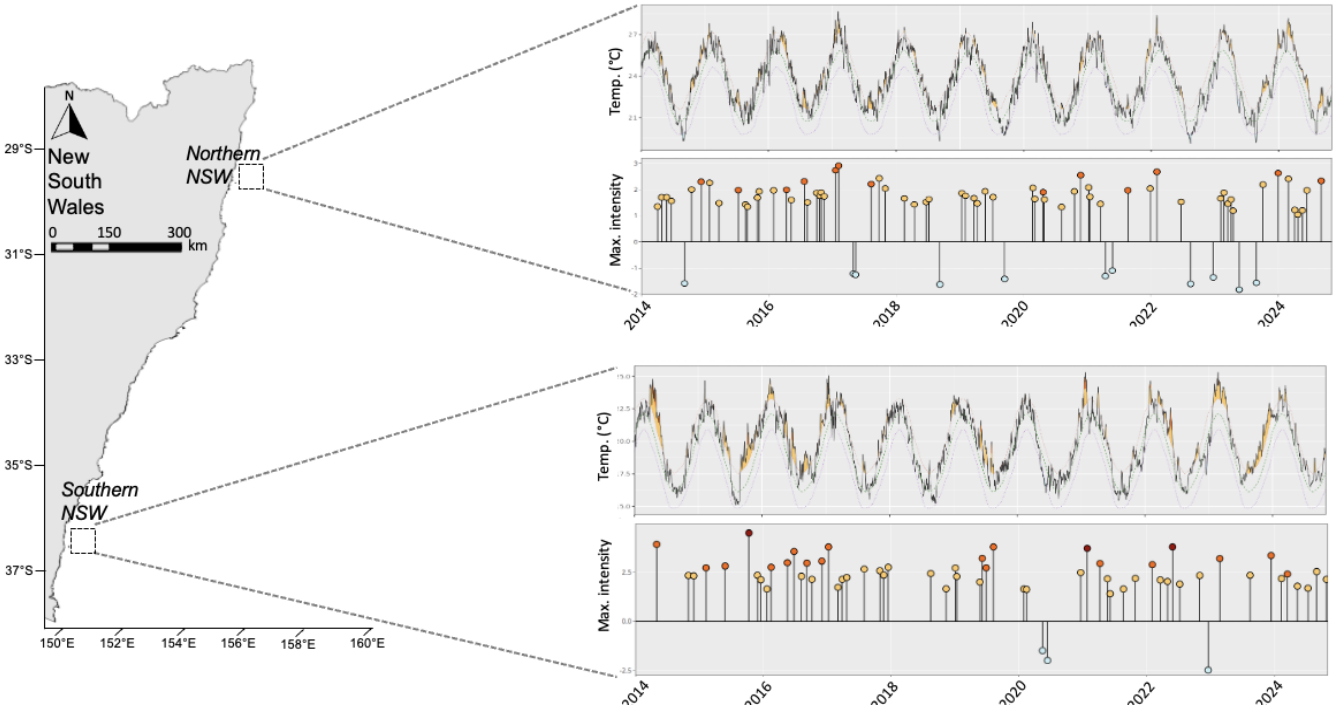
A decade of marine heatwaves in New South Wales



Data: Marine heatwave tracker (https://www.marineheatwaves.org/tracker.html)

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