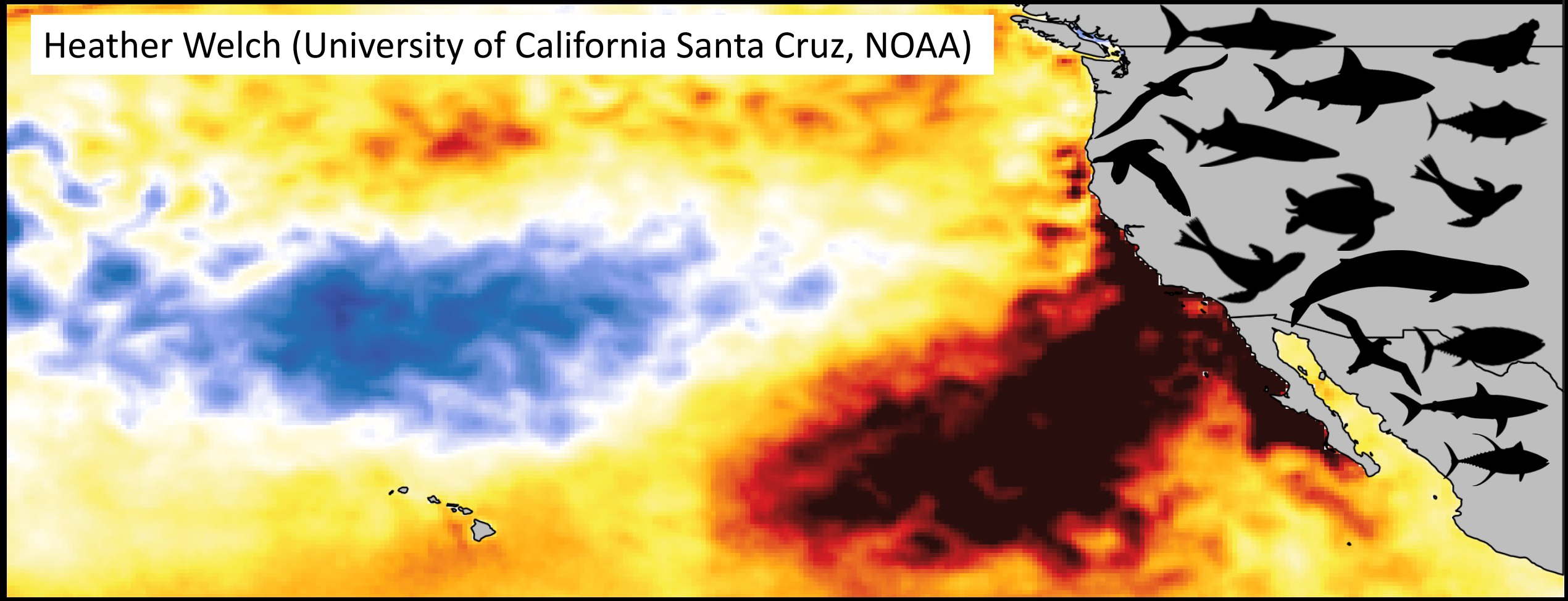
Impacts of marine heatwaves on top predator distributions are variable but predictable

Heather Welch (University of California Santa Cruz, NOAA)



Nature Communications 10.1038/s41467-023-40849-y

Welch, H., Savoca, M.S., Brodie, S, Jacox, M.G., Muhling, B.A., Clay, T.A., Cimino, M.A., Benson, S.R., Block, B.A., Conners, M.G., Costa, D.P., Jordan, F.D., Leising, A.W., Mikles, C.S., Palacios, D.M., Shaffer, S.A., Thorne, L.H., Watson, J.T., Holser, R.R., Dewitt, L., Bograd, S.J., Hazen, E.L

It’s been a hot summer – the ocean has been hot too

The Guardian

South-east Australia marine heatwave forecast to be literally off the scale

Patch of Tasman sea expected to warm over spring and summer to temperatures that risk significant losses to sea life.

1 week ago

Los Angeles Times

A marine heat wave off California helped fuel Hurricane Hilary. What'll it do next?

Off the California coast sits a marine heat wave that has persisted since 2014. Scientists aren't sure whether it's now permanent,...

1 week ago

BBC

There's a heatwave in the sea and scientists are worried

Could warmer ocean temperatures be a sign climate change has progressed further than we thought?

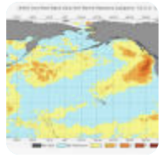
1 month ago

Oregon Live

Significant marine heatwave brewing off Oregon coast

The average ocean temperature around the world reached 70 degrees in 2023 – the highest ever.

4 weeks ago



The Guardian

Marine heatwave off north-east Australia sets off alarm over health of Great Barrier Reef

Experts fear for health of corals and other marine life as about 1m sq km of ocean experience prolonged elevated temperatures.

1 month ago

Environment America

A marine heat wave is taking a toll on the Pacific Northwest

Across our country our ocean's are facing a marine heat wave. We've all heard the news about how ocean water in Florida has eclipsed 100 degrees,...

3 days ago

ABC News

There is another marine heat wave in US waters, this time in the Gulf of Mexico

Yet another heat wave is warming waters off the U.S. coasts as oceans worldwide endure warmer-than normal temperatures, experts say.

2 weeks ago

UC Santa Barbara News

Multiple ecosystems in hot water after marine heatwave surges across the Pacific

Rising ocean temperatures are sweeping the seas, breaking records and creating problematic conditions for marine life. Unlike heatwaves on...

1 month ago

WPLN News

Marine heat waves affect Tennessee. Here's how.

Oceans are really stressed right now. In July, 44% of Earth's oceans were experiencing marine heat waves. That figure could increase to half...

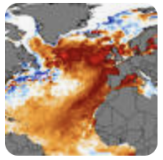
3 weeks ago

CNN

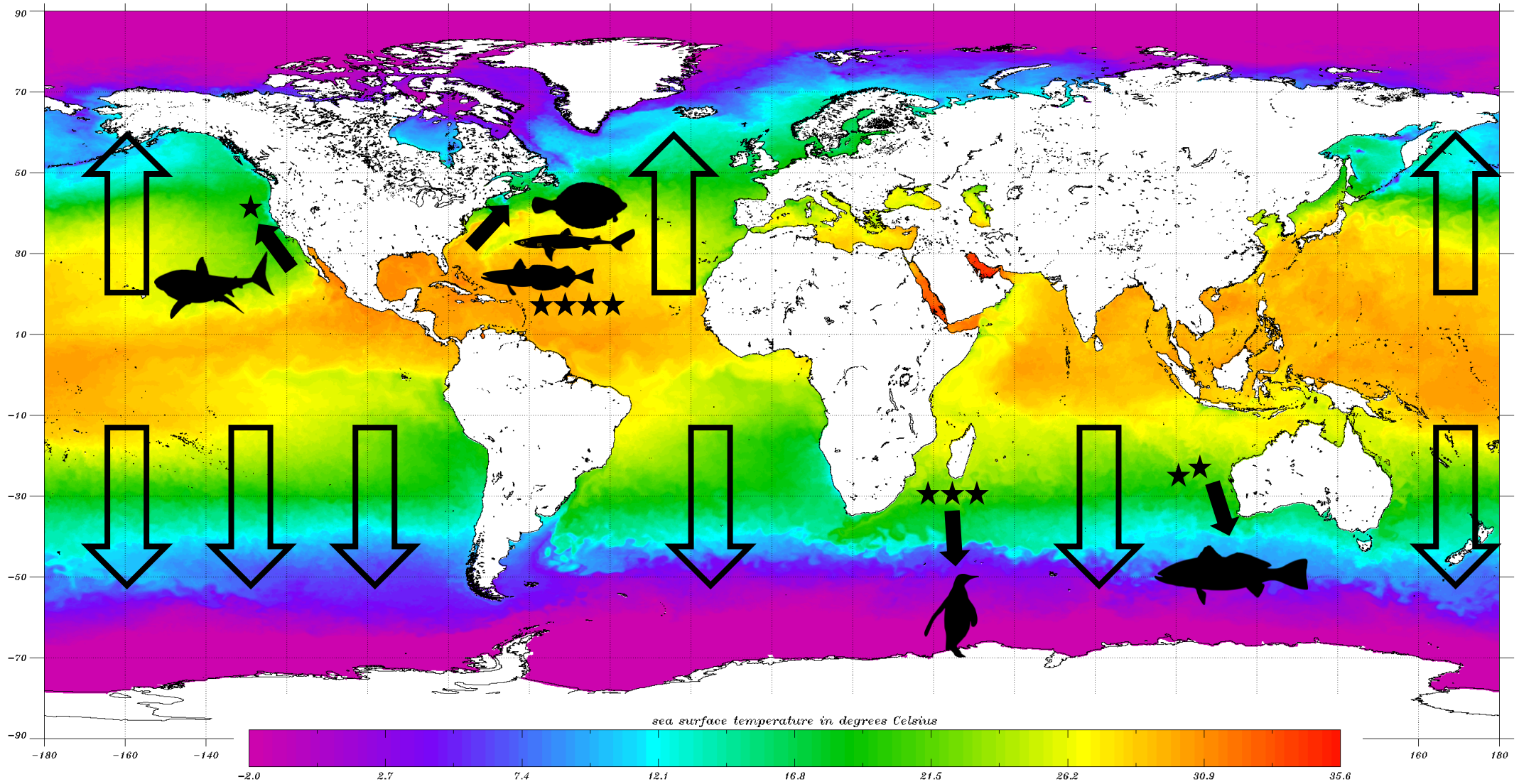
The North Atlantic is experiencing a 'totally unprecedented' marine heat wave

Temperatures in parts of the North Atlantic Ocean are soaring off the charts, with an “exceptional” marine heat wave happening off the...

Jun 20, 2023



Marine heatwaves will move species around



Colder

Warmer

★ Tanaka et al. "North Pacific warming shifts the juvenile range of a marine apex predator." *Scientific reports* 11.1 (2021).

★★ Smith et al. "Simmered then boiled: Multi-decadal poleward shift in distribution by a temperate fish accelerates during marine heatwave." *Frontiers in Marine Science* 6 (2019)

★★★ Bost et al. "Large-scale climatic anomalies affect marine predator foraging behaviour and demography." *Nature communications* 6.1 (2015)

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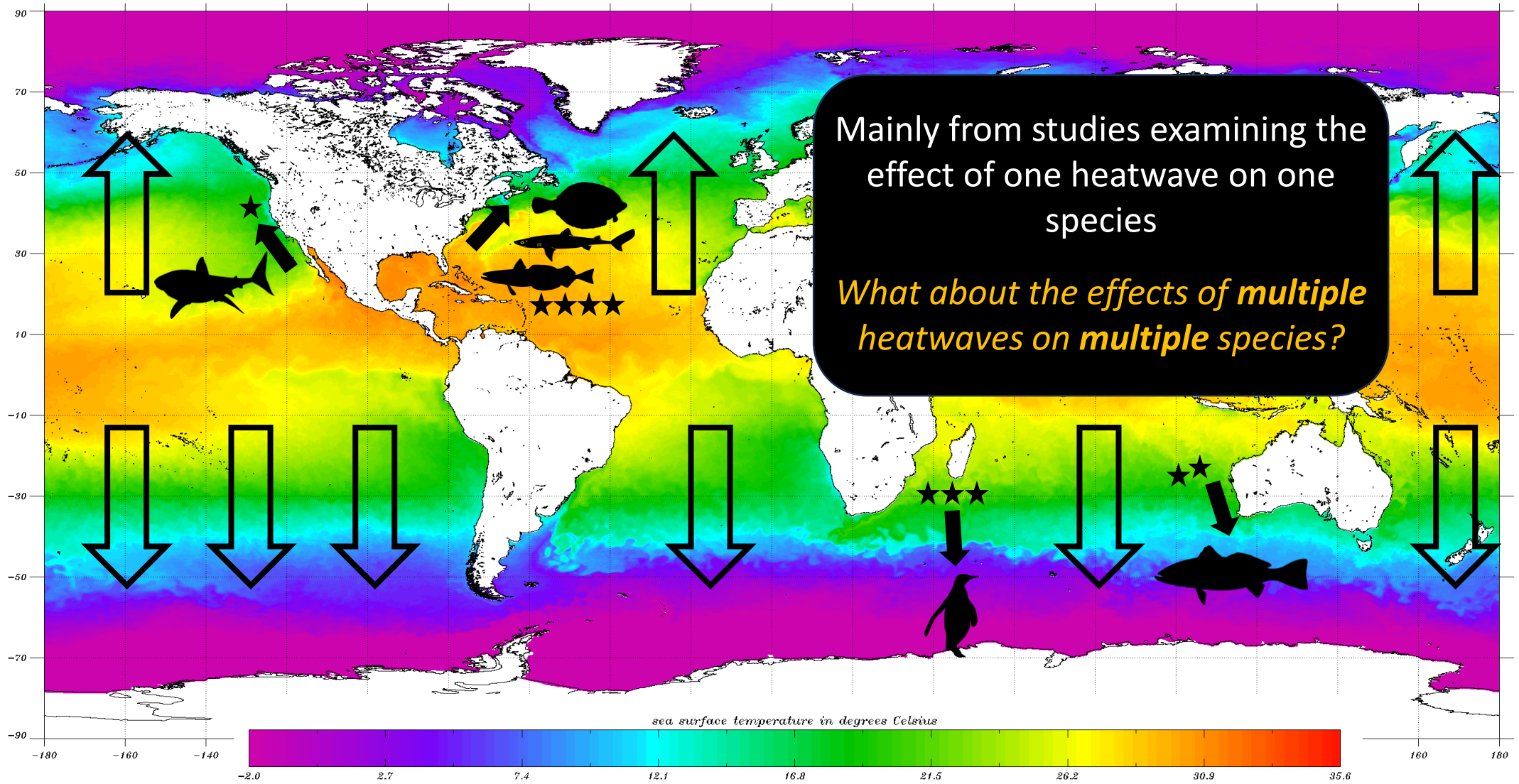

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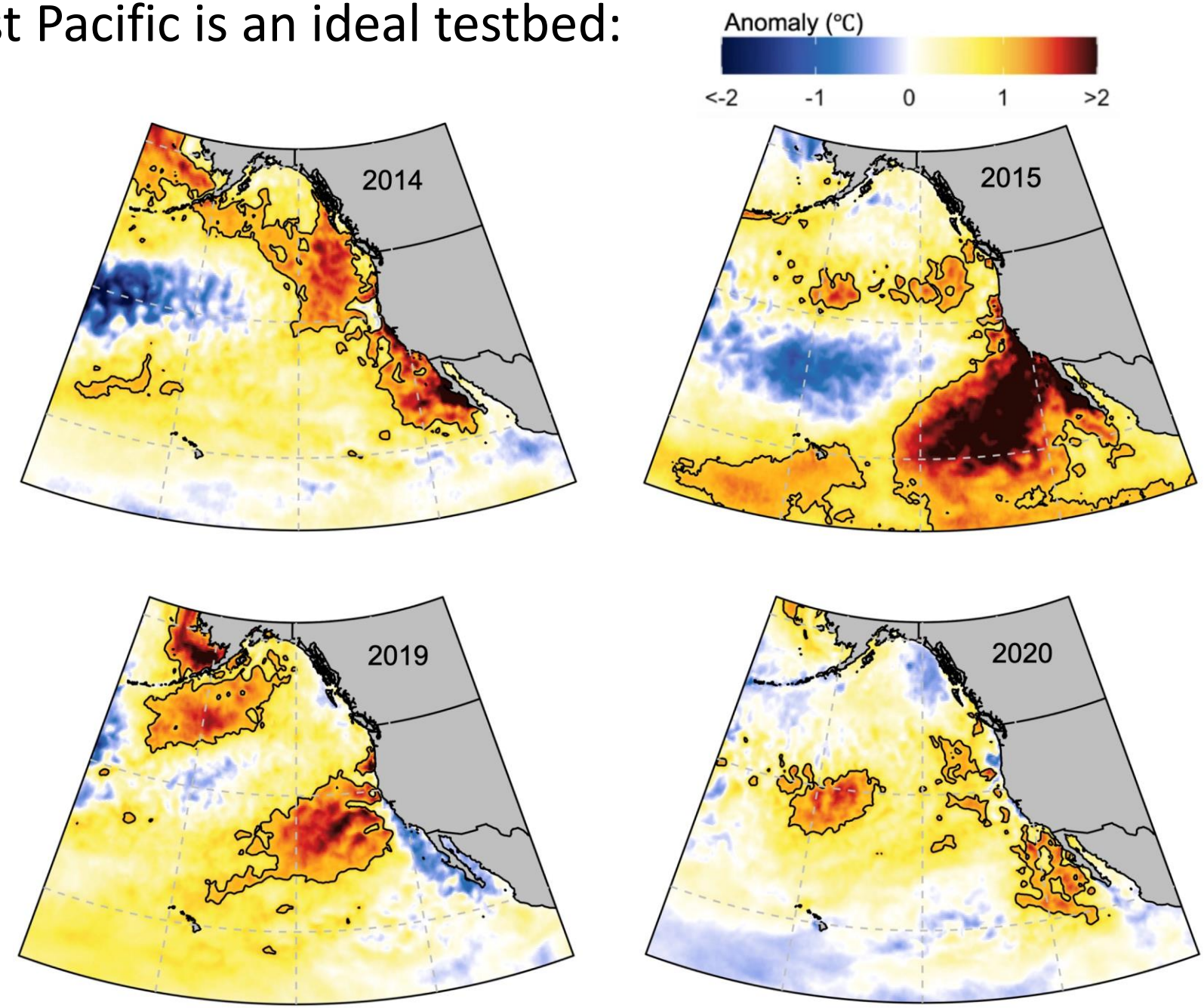
The northeast Pacific is an ideal testbed:

Lots of heatwaves



The northeast Pacific is an ideal testbed:

Lots of heatwaves, **and** lots of animal data

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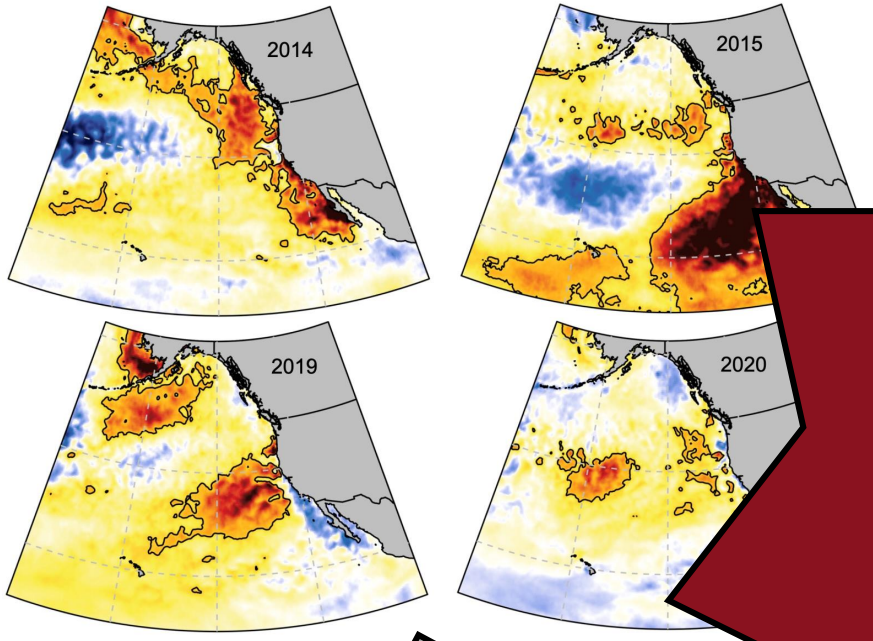
The northeast Pacific is an ideal testbed:

Lots of heatwaves, **and** lots of animal data

The northeast Pacific is an ideal testbed:

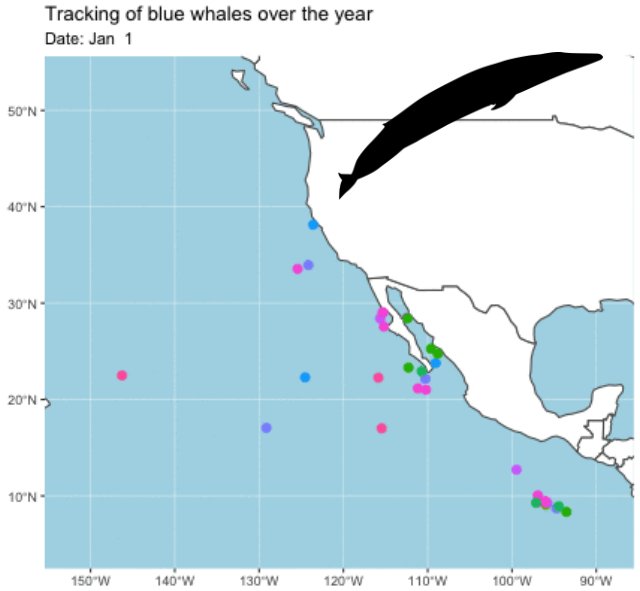
Four marine heatwaves



14 marine predators

Results are inferences from models as opposed to direct observations

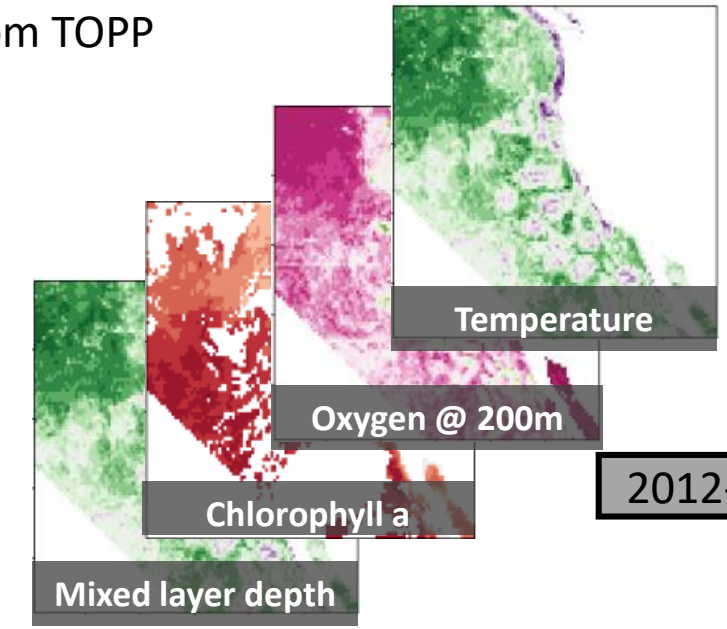
distrib
models



1. Predator tracking data from TOPP

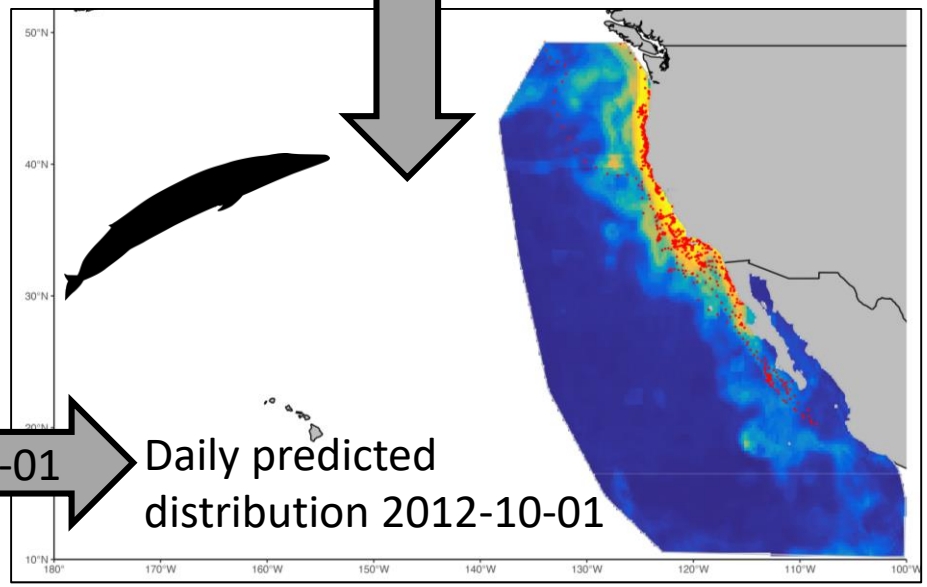
3. Boosted regression tree models

4. Novel validation dataset >1 M records From public, private, government sources

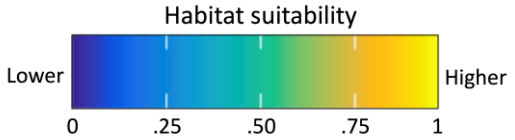


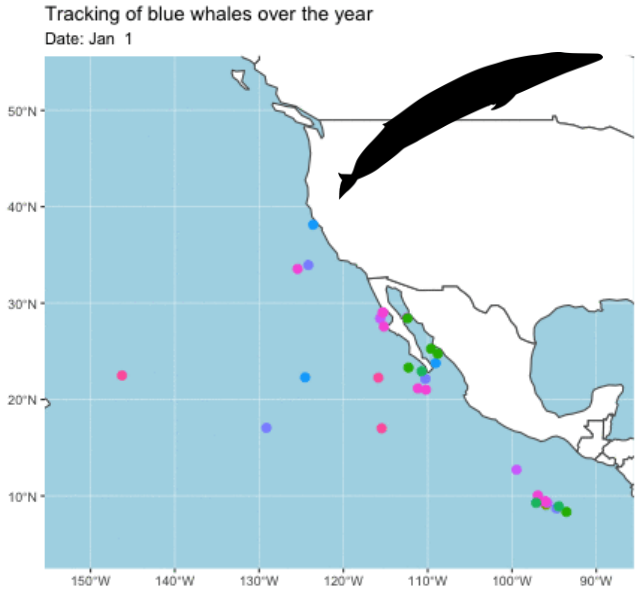
2. Environmental data from satellites / ocean models

2012-10-01



Daily predicted distribution 2012-10-01





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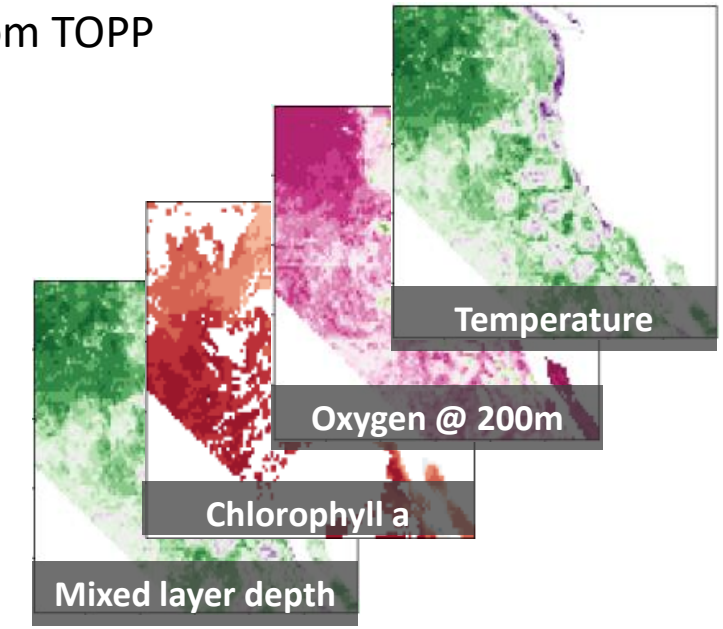
3. Boosted regression tree models

CSV

4. Novel validation dataset >1 M records From public, private, government sources



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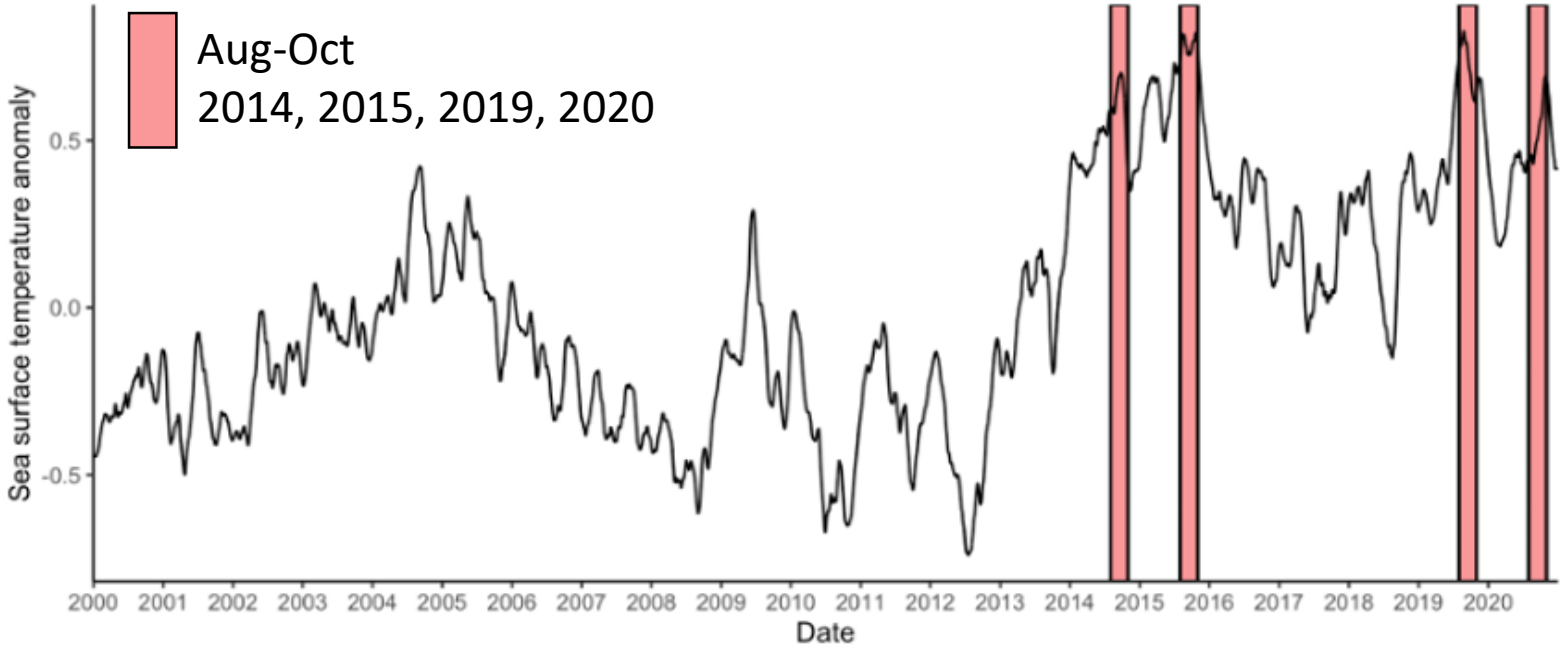

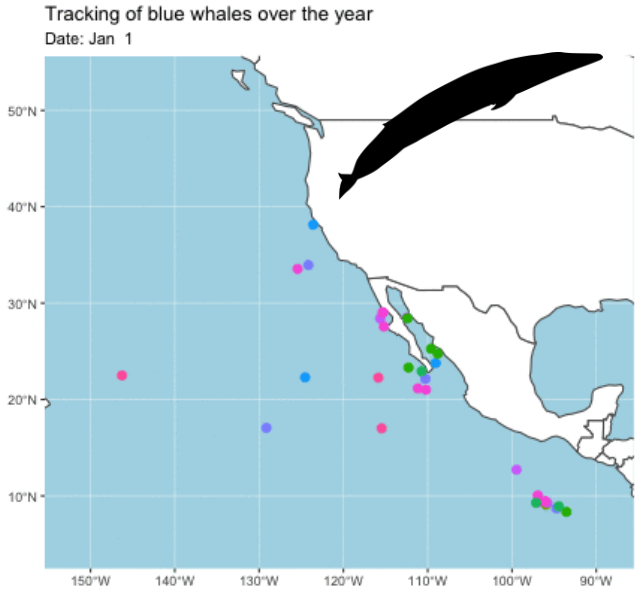

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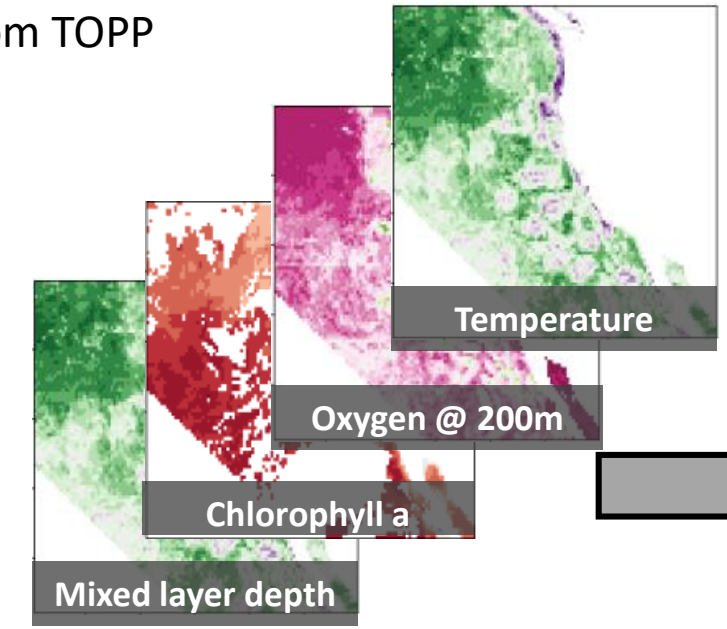
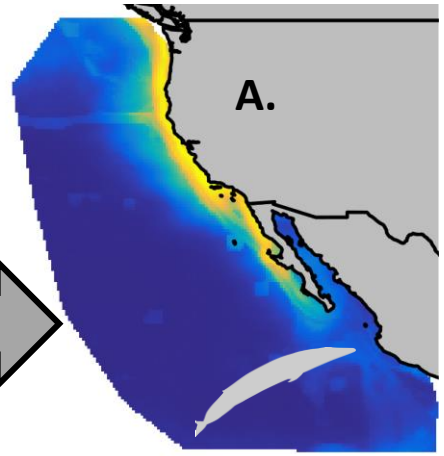
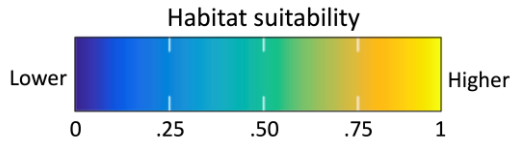
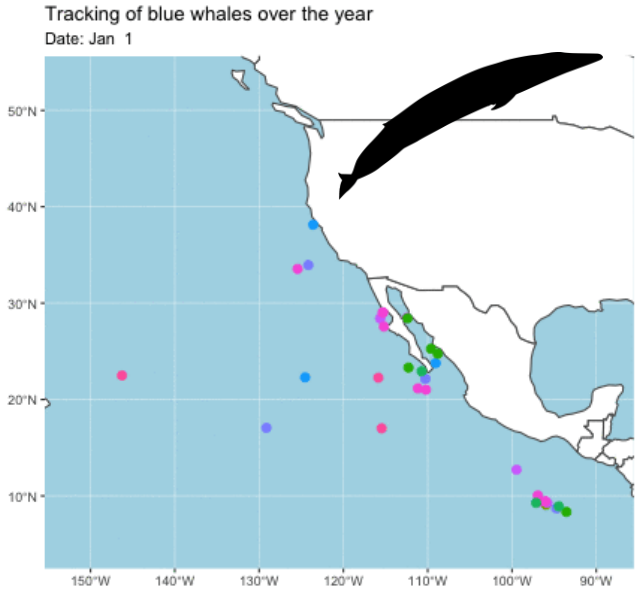


2. Environmental data from satellites / ocean models

5. Baseline and heatwave predicted distributions Aug-Oct 2000-2020.







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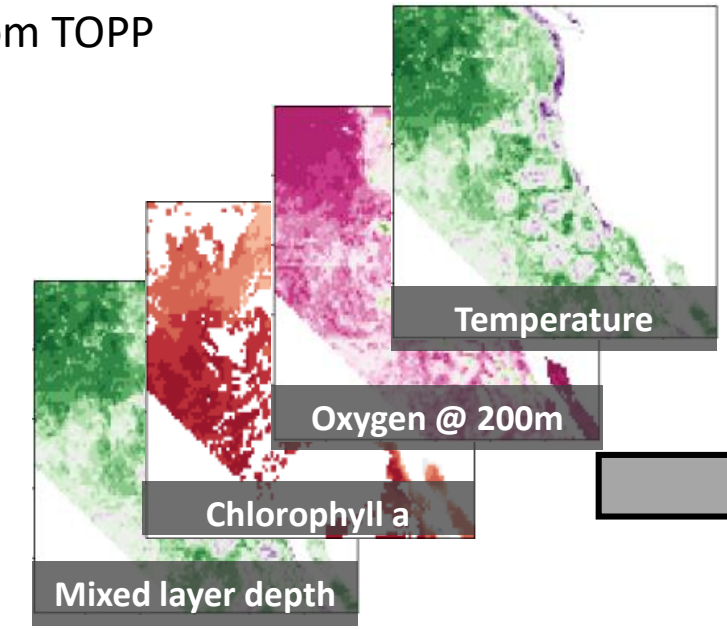

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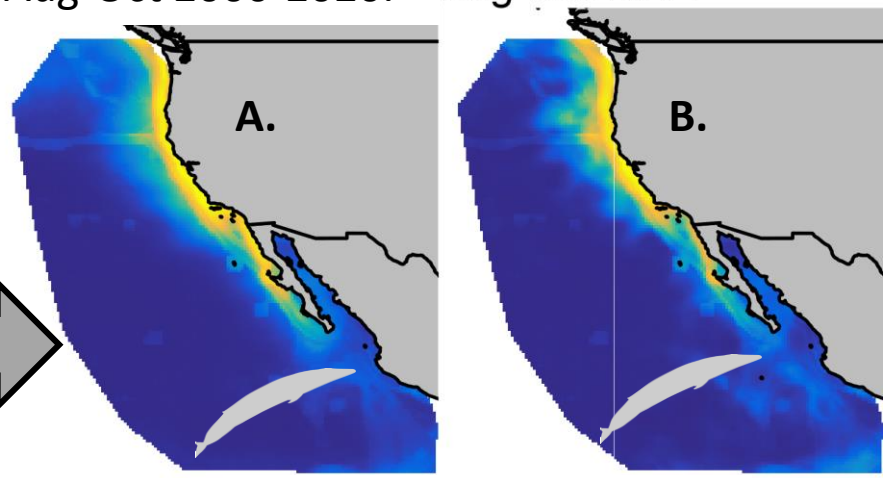
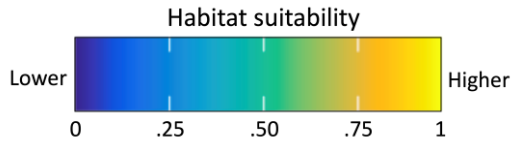
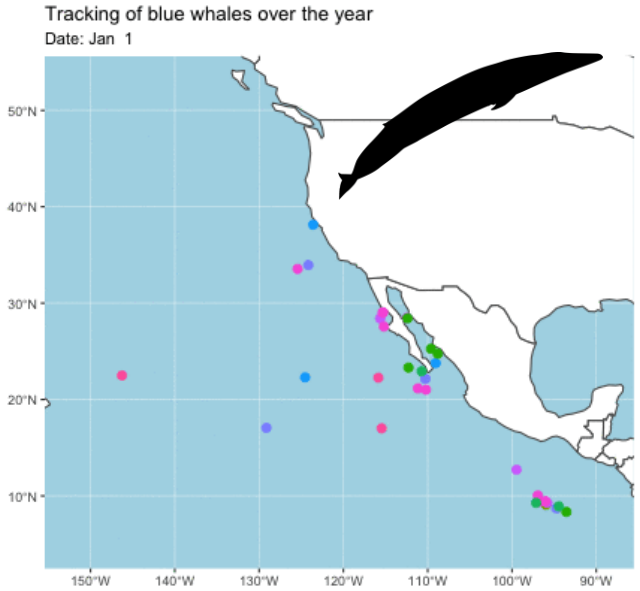
Aug-Oct 2000-2020. Aug-Oct 2014







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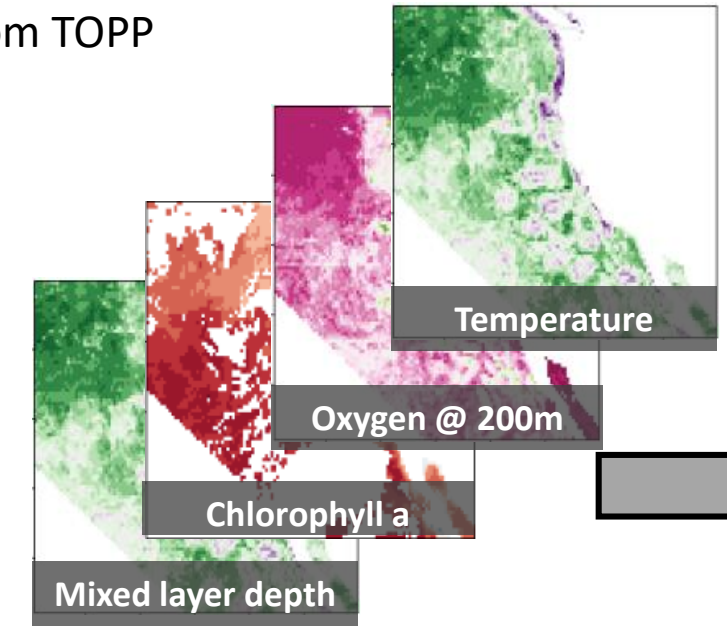

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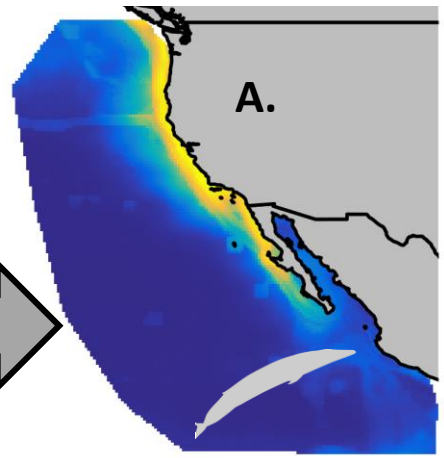
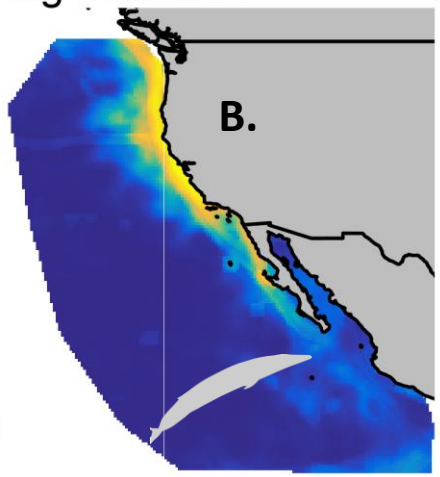
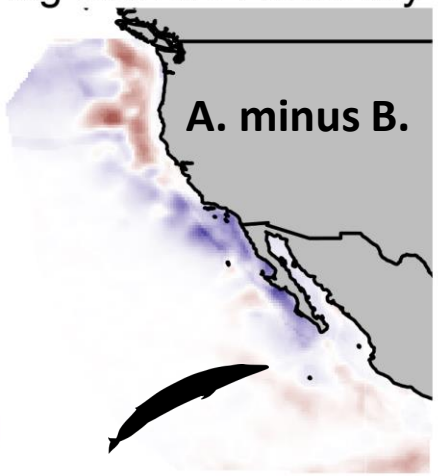
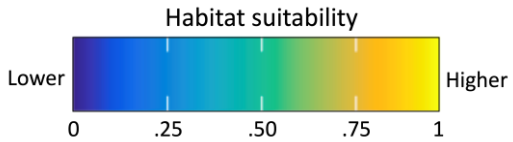


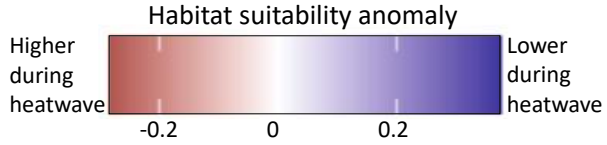
Aug-Oct 2014



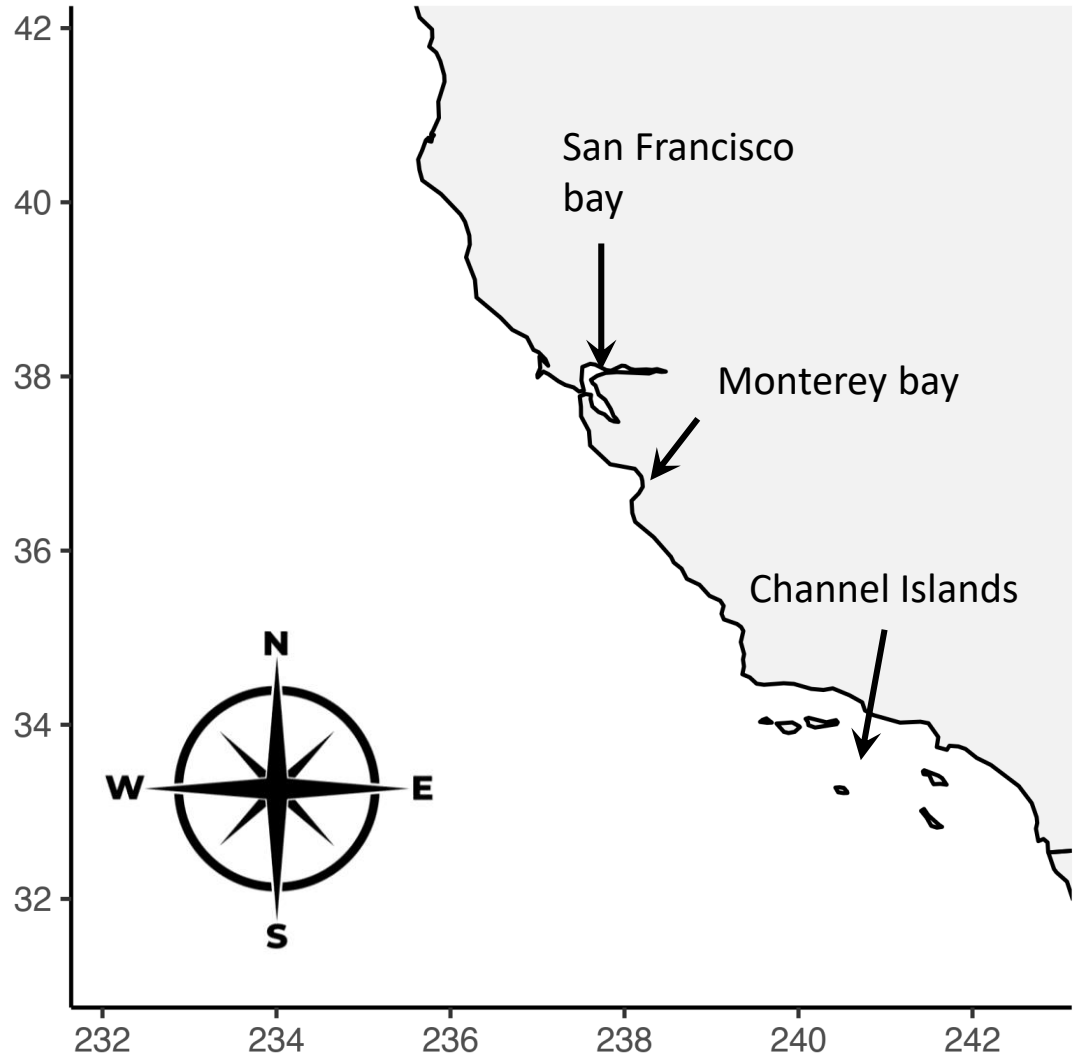
Aug-Oct 2014 anomaly







Marine heatwave impacts on species are surprisingly diverse



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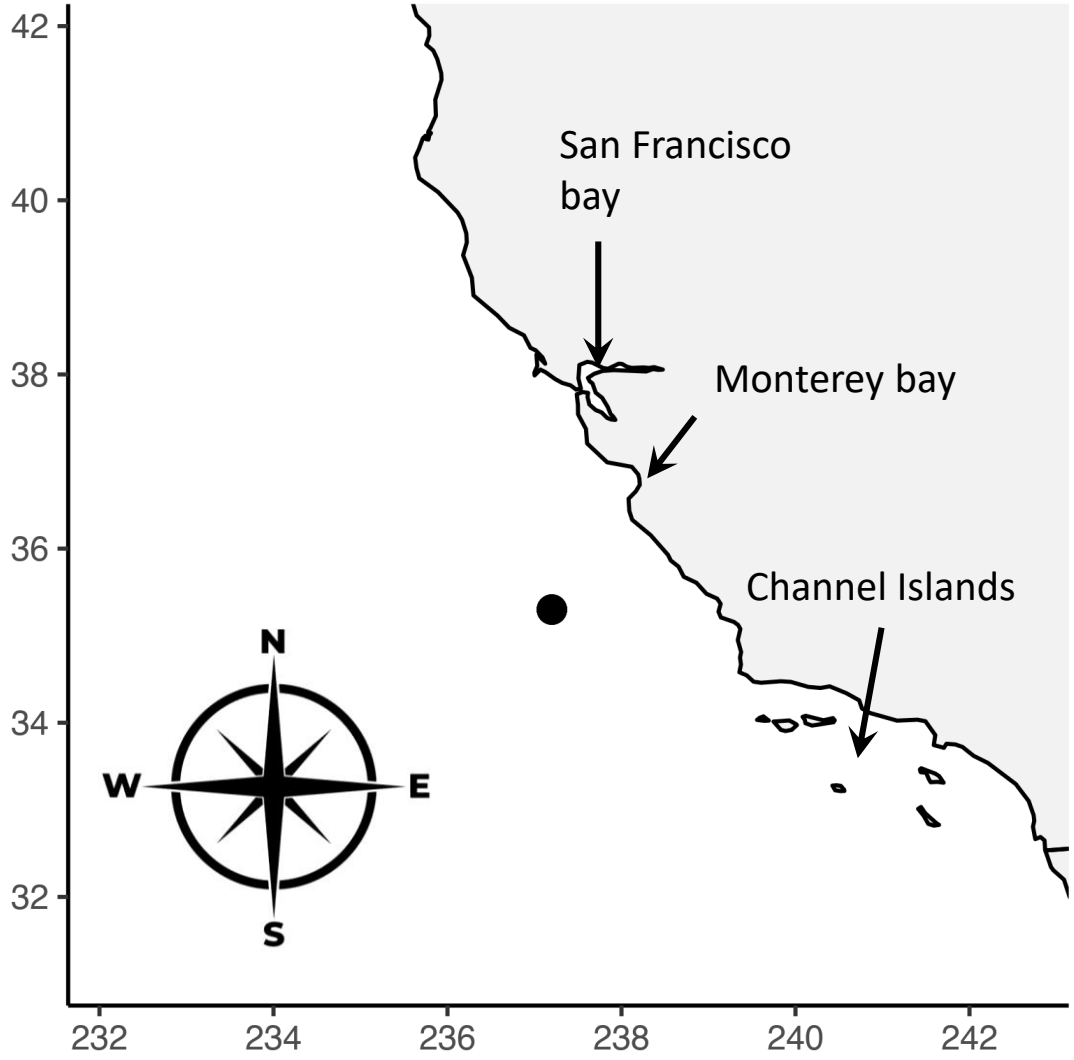
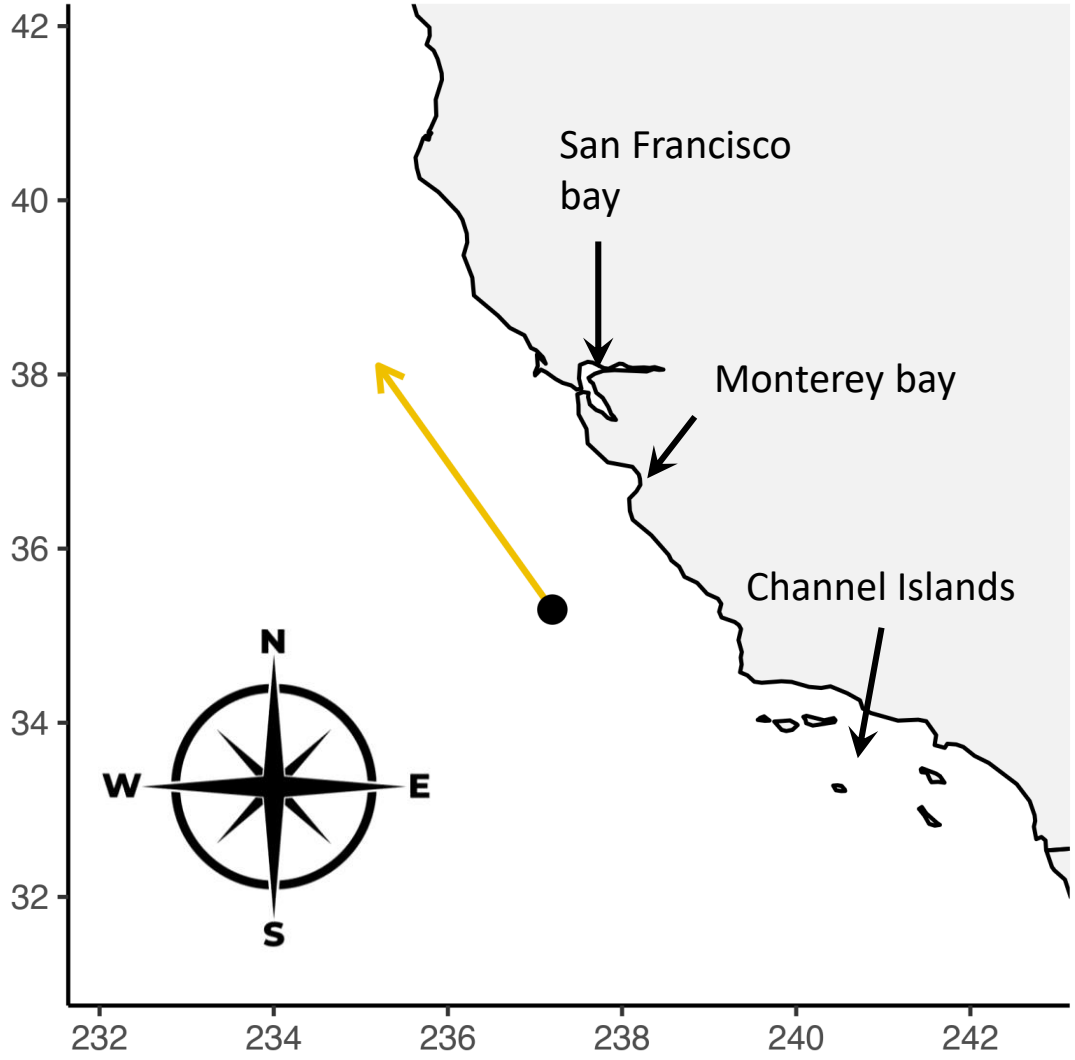


● Average location of habitat Aug-Oct 2000-2020

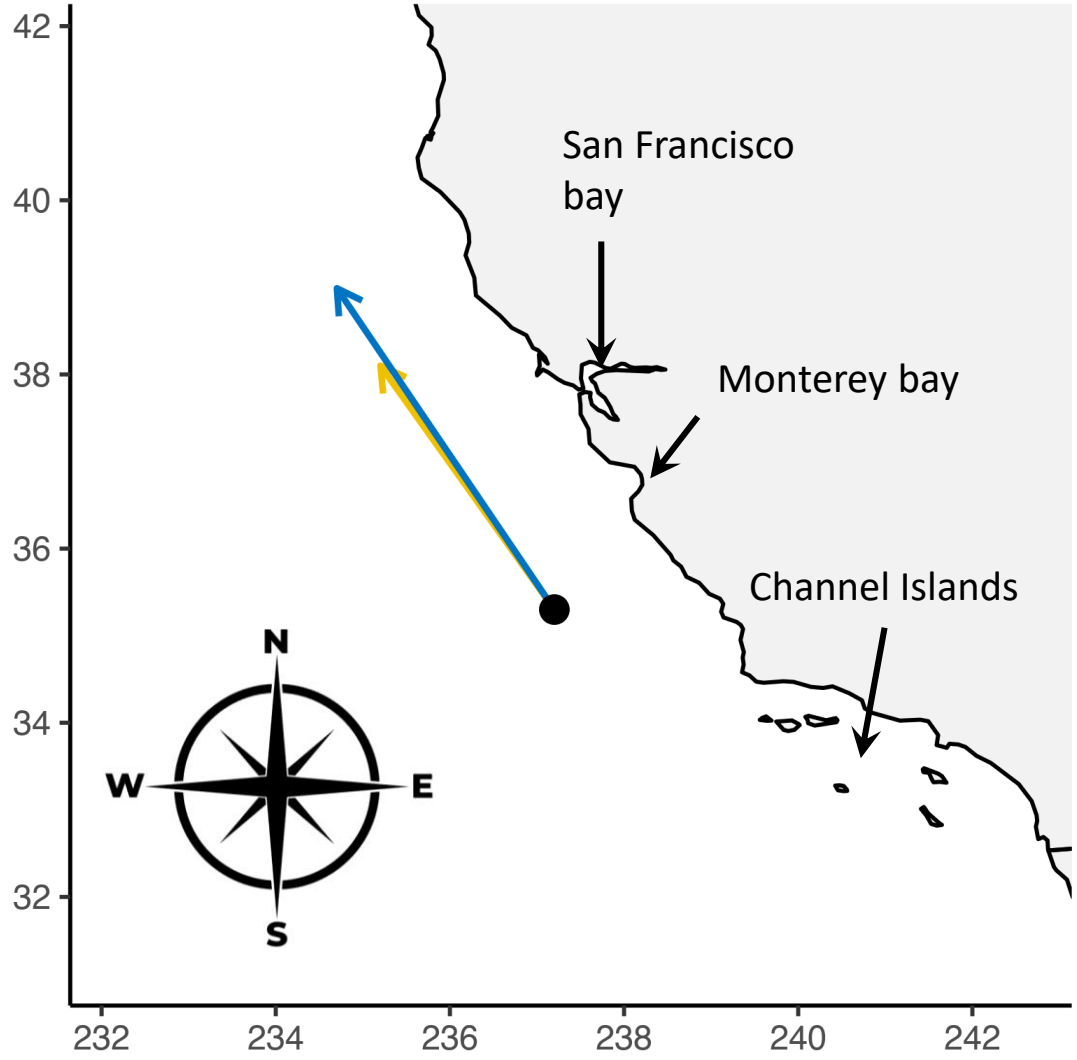
Marine heatwave impacts on species are surprisingly diverse



● Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the → 2014 heatwave

Marine heatwave impacts on species are surprisingly diverse



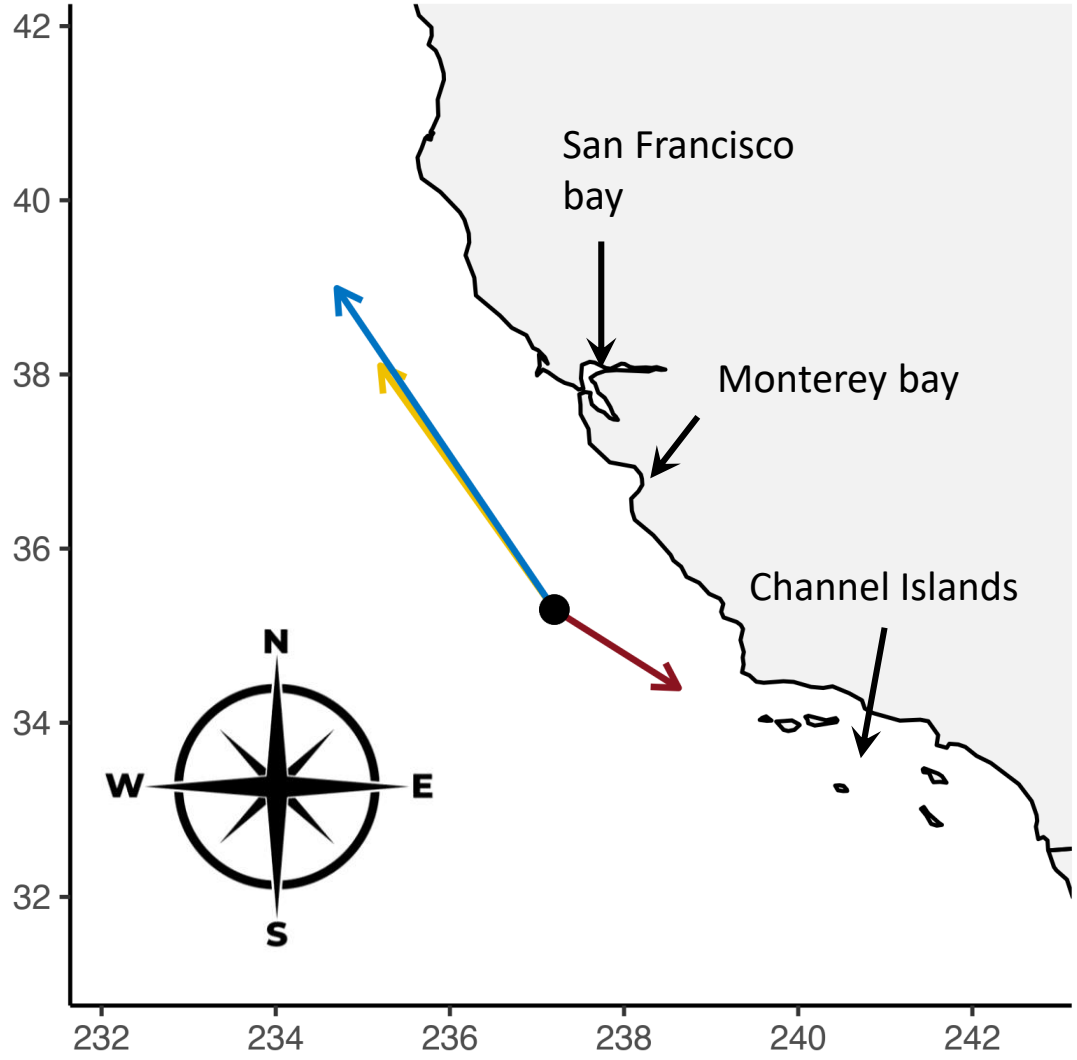
● Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the

→ 2014 heatwave

→ 2015 heatwave

Marine heatwave impacts on species are surprisingly diverse



● Average location of habitat Aug-Oct 2000-2020

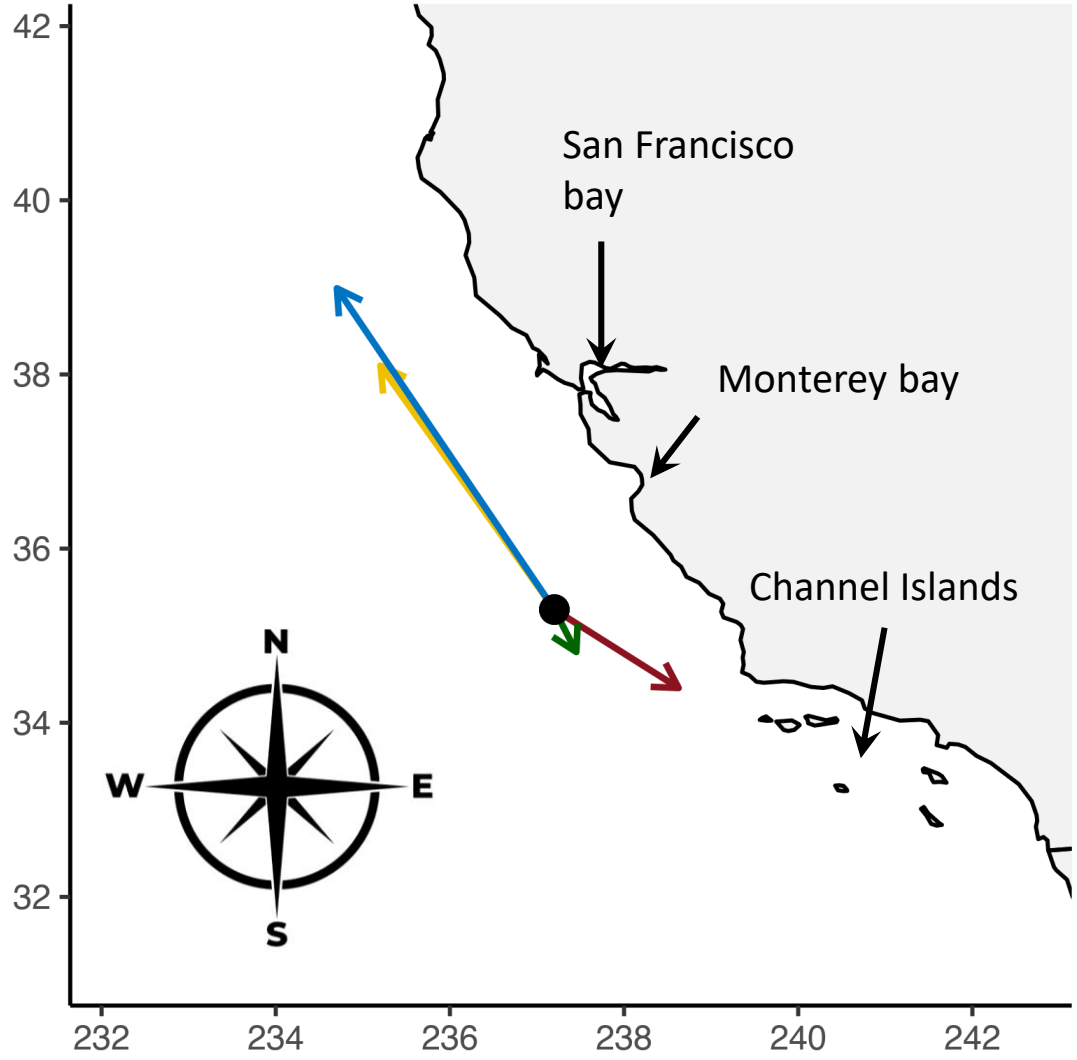
Displacement of habitat during the

→ 2014 heatwave

→ 2015 heatwave

→ 2019 heatwave

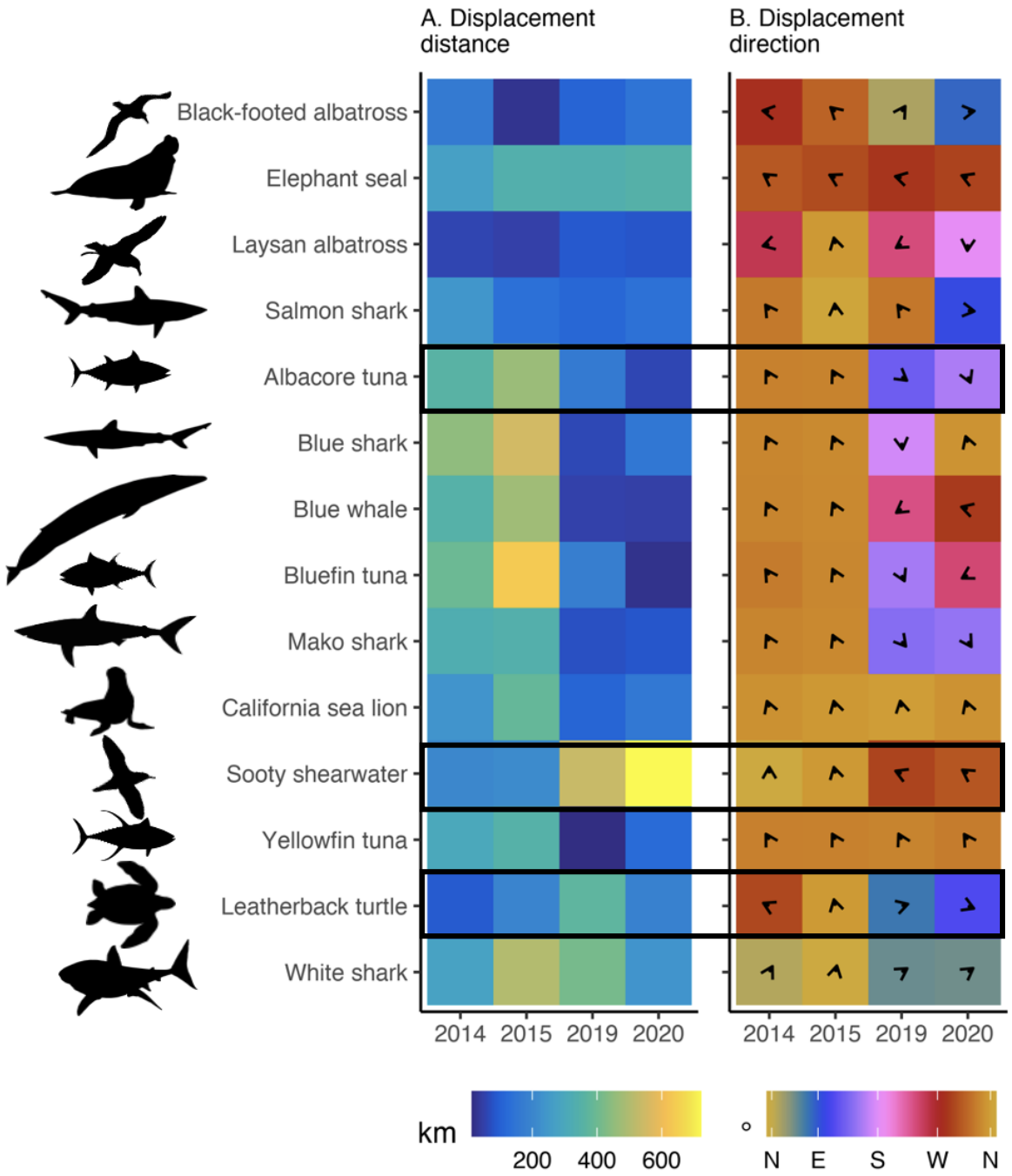
Marine heatwave impacts on species are surprisingly diverse



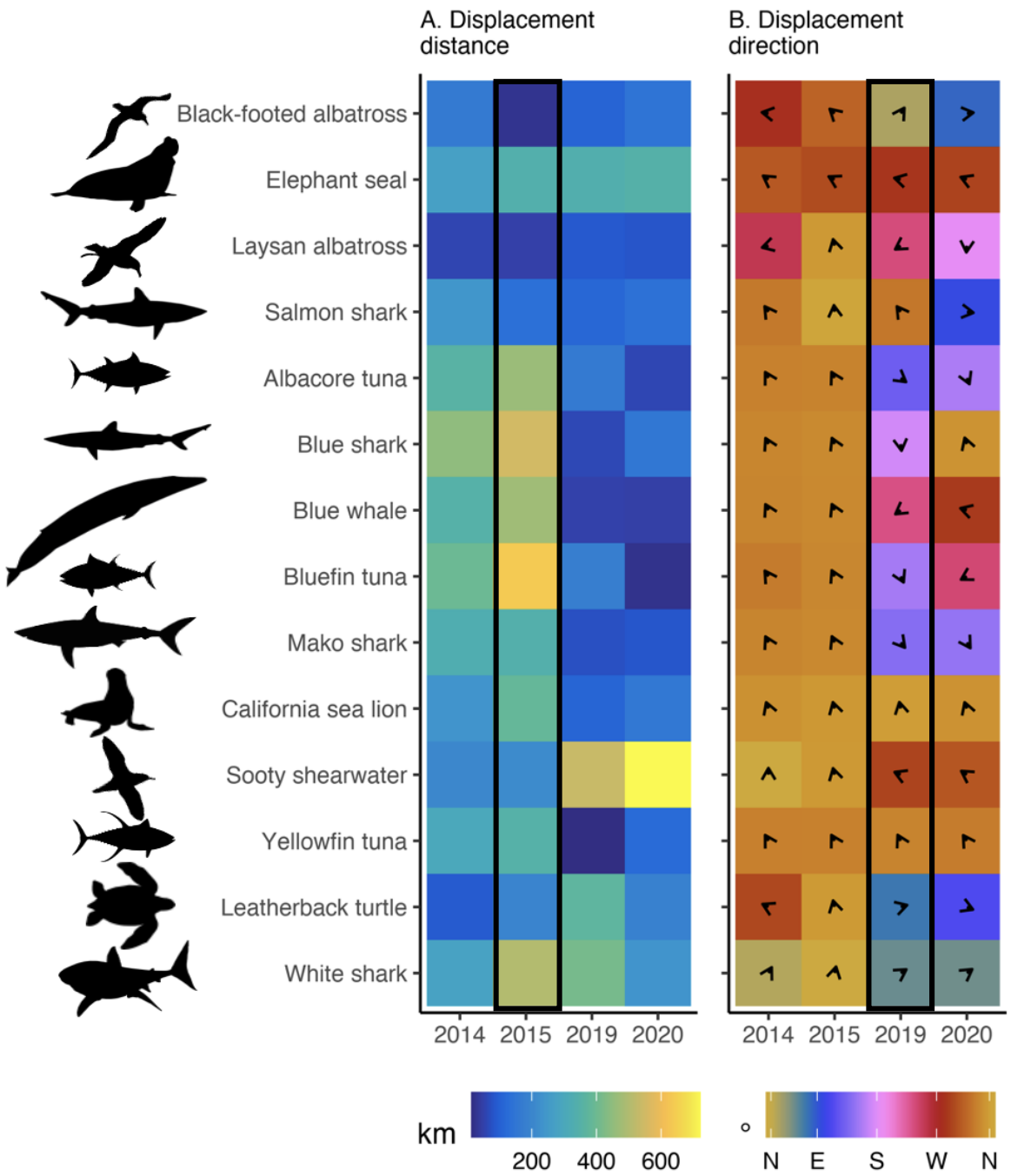
- Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the

- 2014 heatwave
- 2015 heatwave
- 2019 heatwave
- 2020 heatwave

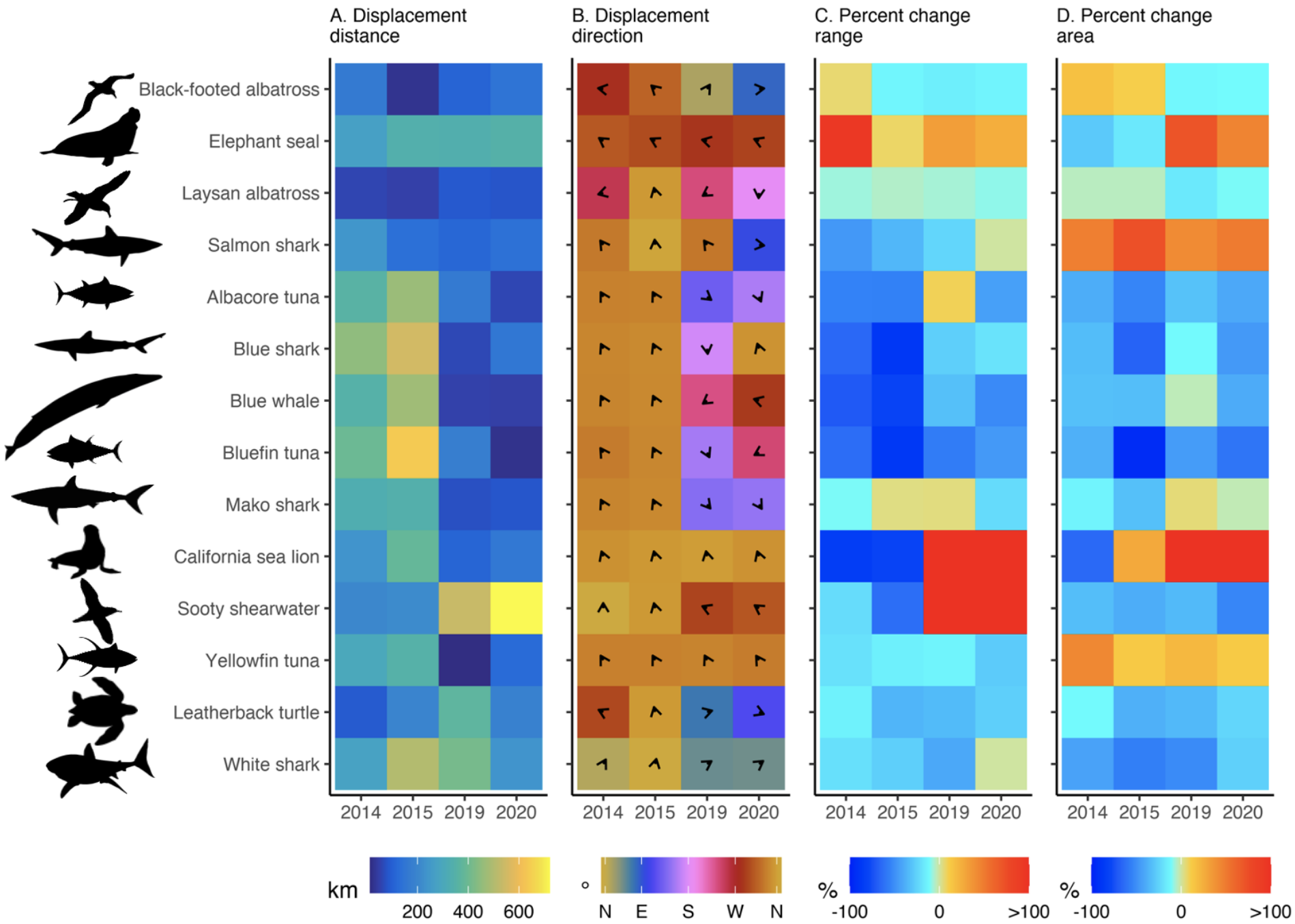


Variable impacts across heatwaves



Variable impacts across heatwaves

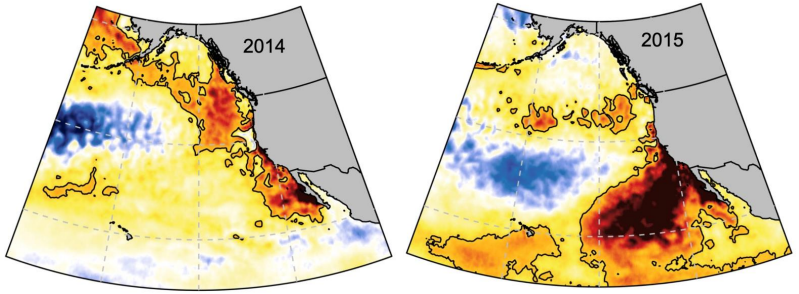
Variable impacts across species


A. Displacement distance
B. Displacement direction
C. Percent change range
D. Percent change area
Black-footed albatross
Elephant seal
Laysan albatross
Salmon shark
Albacore tuna
Blue shark
Blue whale
Bluefin tuna
Mako shark
California sea lion
Sooty shearwater
Yellowfin tuna
Leatherback turtle
White shark
2014 2015 2019 2020
km
200 400 600
°
N E S W N
%
-100 0 >100
%
-100 0 >100

Why do we see such a surprising diversity of impacts?

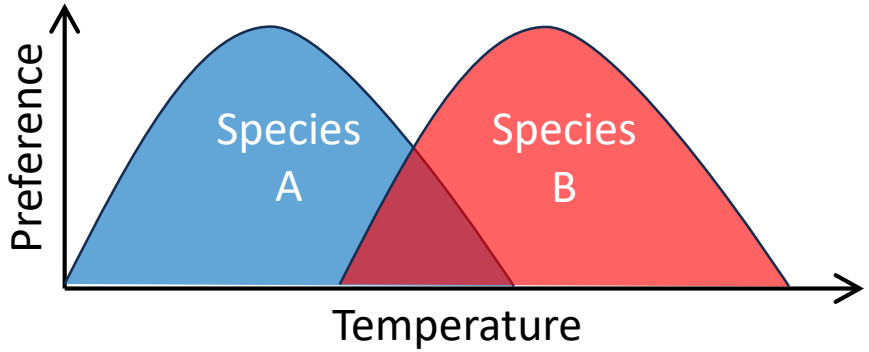
Physical

Heatwaves have different drivers, evolution, and characteristics



Ecological

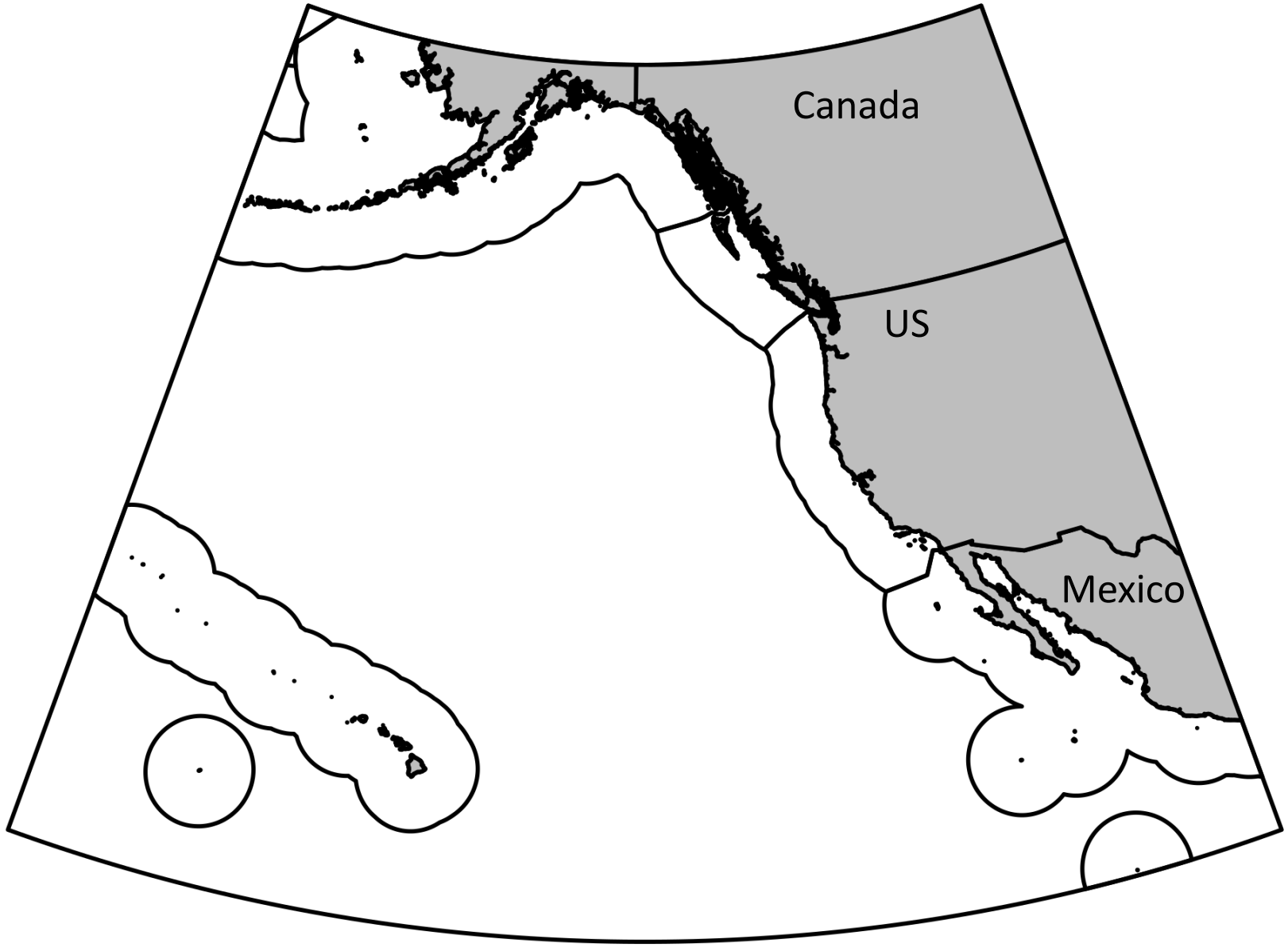
Species have different environmental preferences



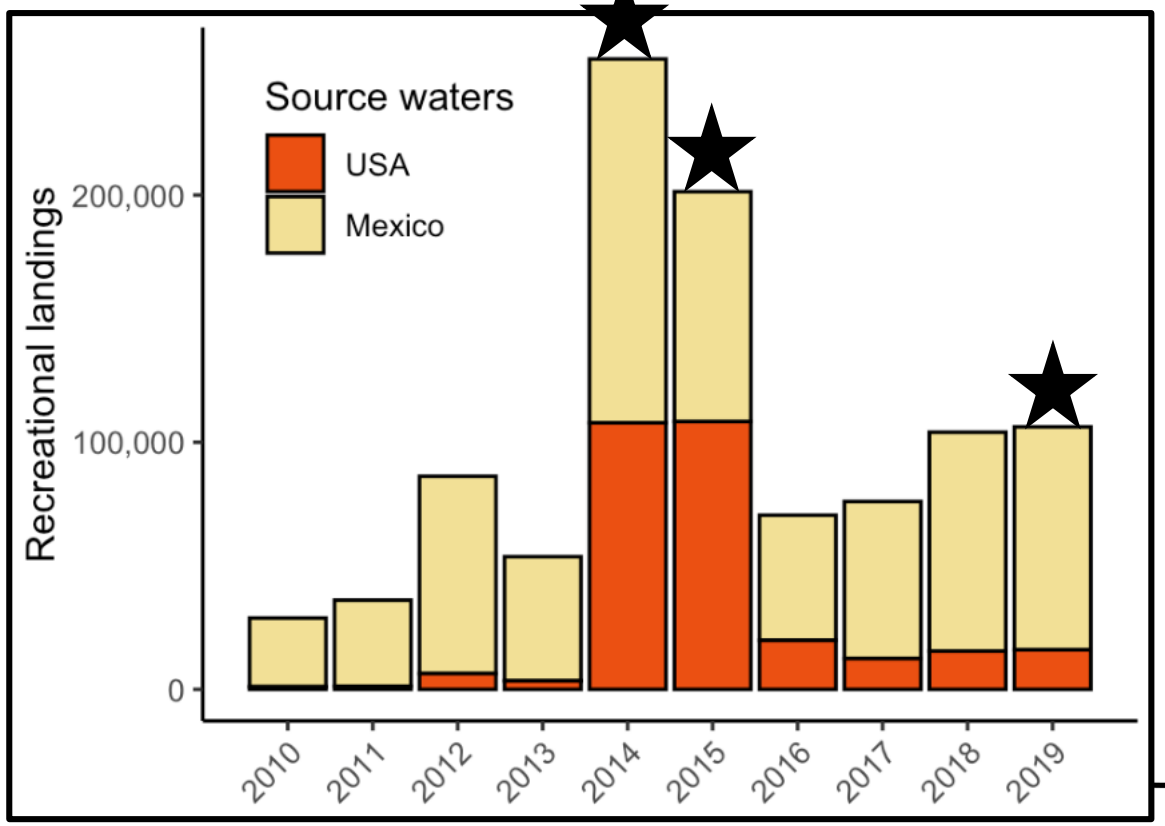
Scientific

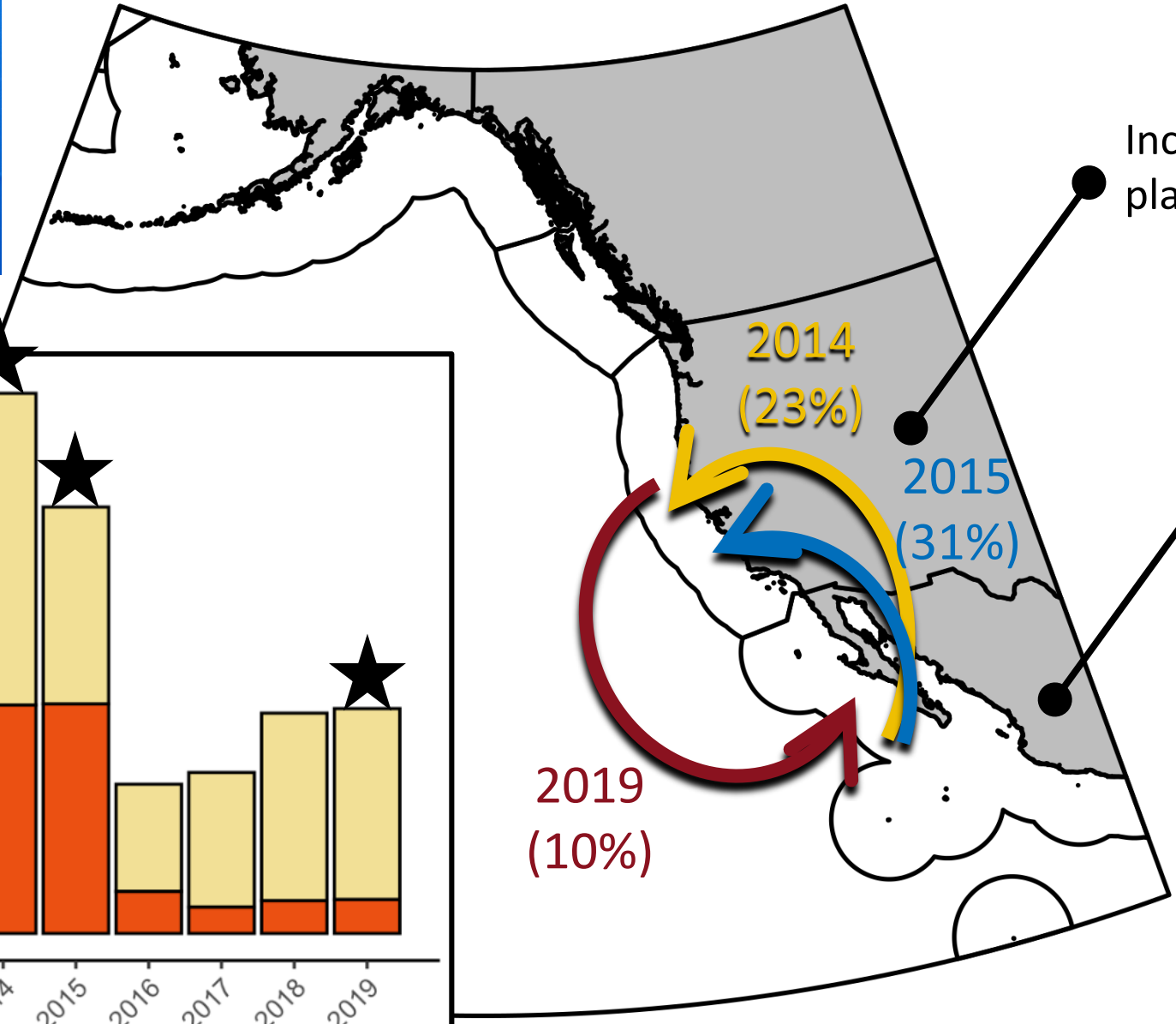
Large, negative impacts grab attention; small, positive impacts less so

Shifts across jurisdictional boundaries



Shifts across jurisdictional boundaries: new risks, rewards, and responsibilities



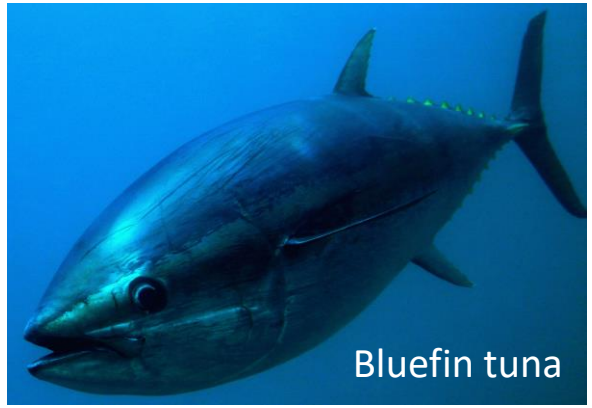


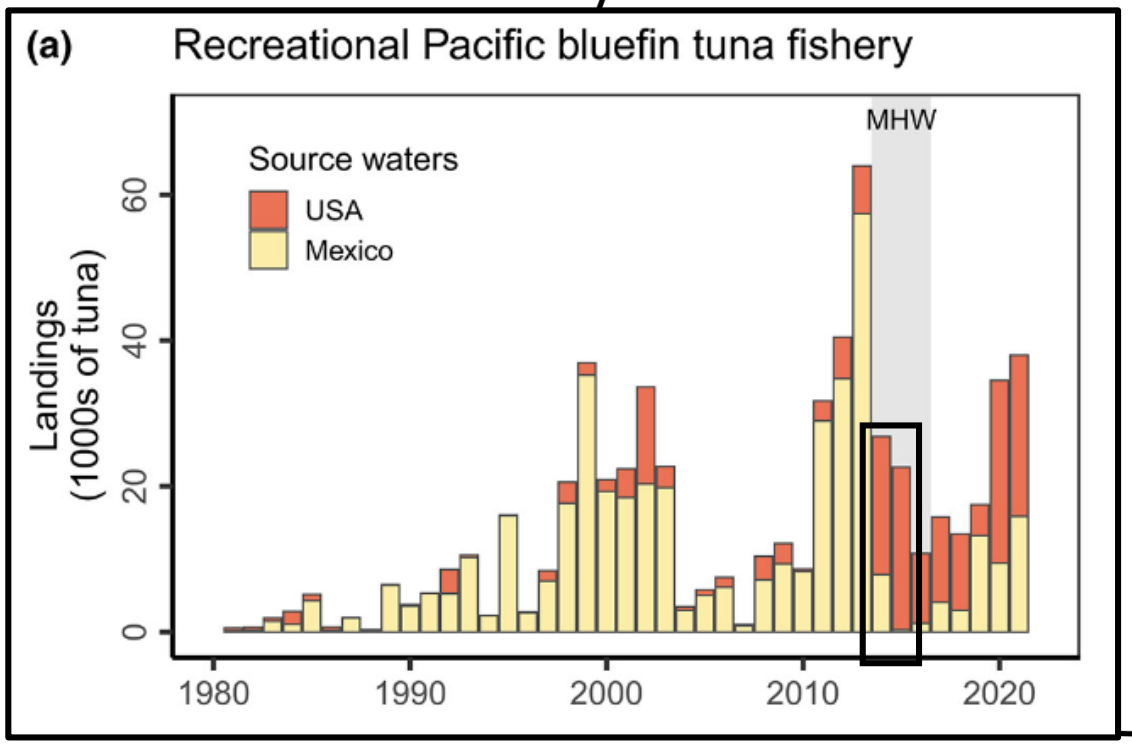
Increase processing plant capacity

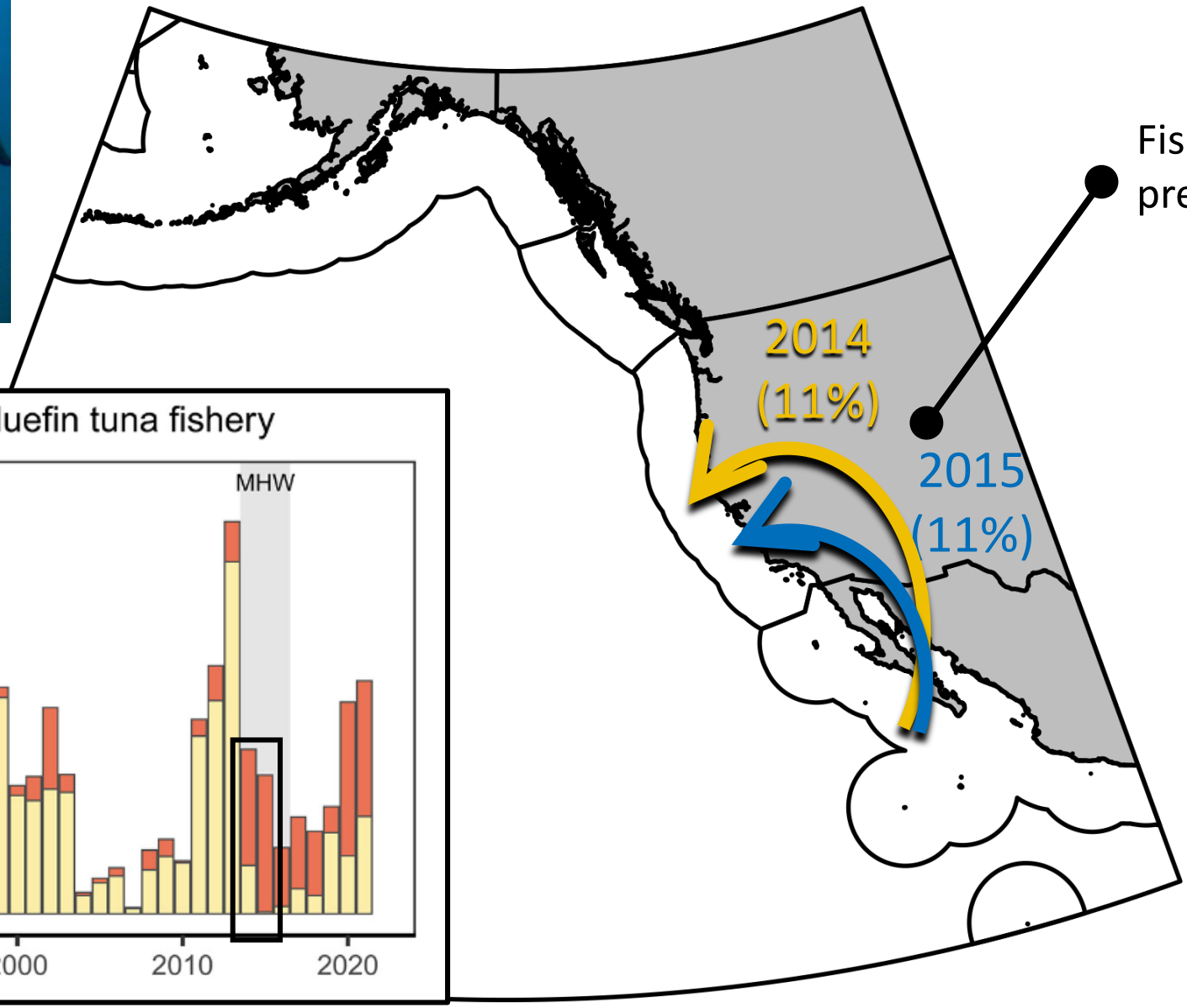
Compensate fishermen for lost revenue

Data from https://github.com/cfree14/wcfish

Shifts across jurisdictional boundaries: new risks, rewards, and responsibilities





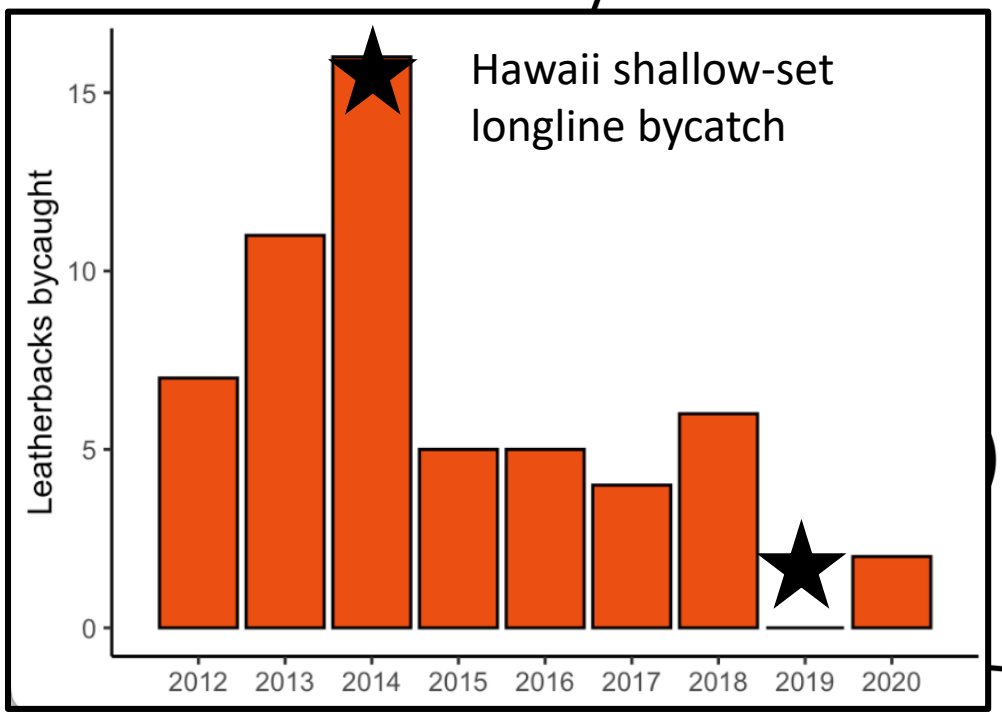


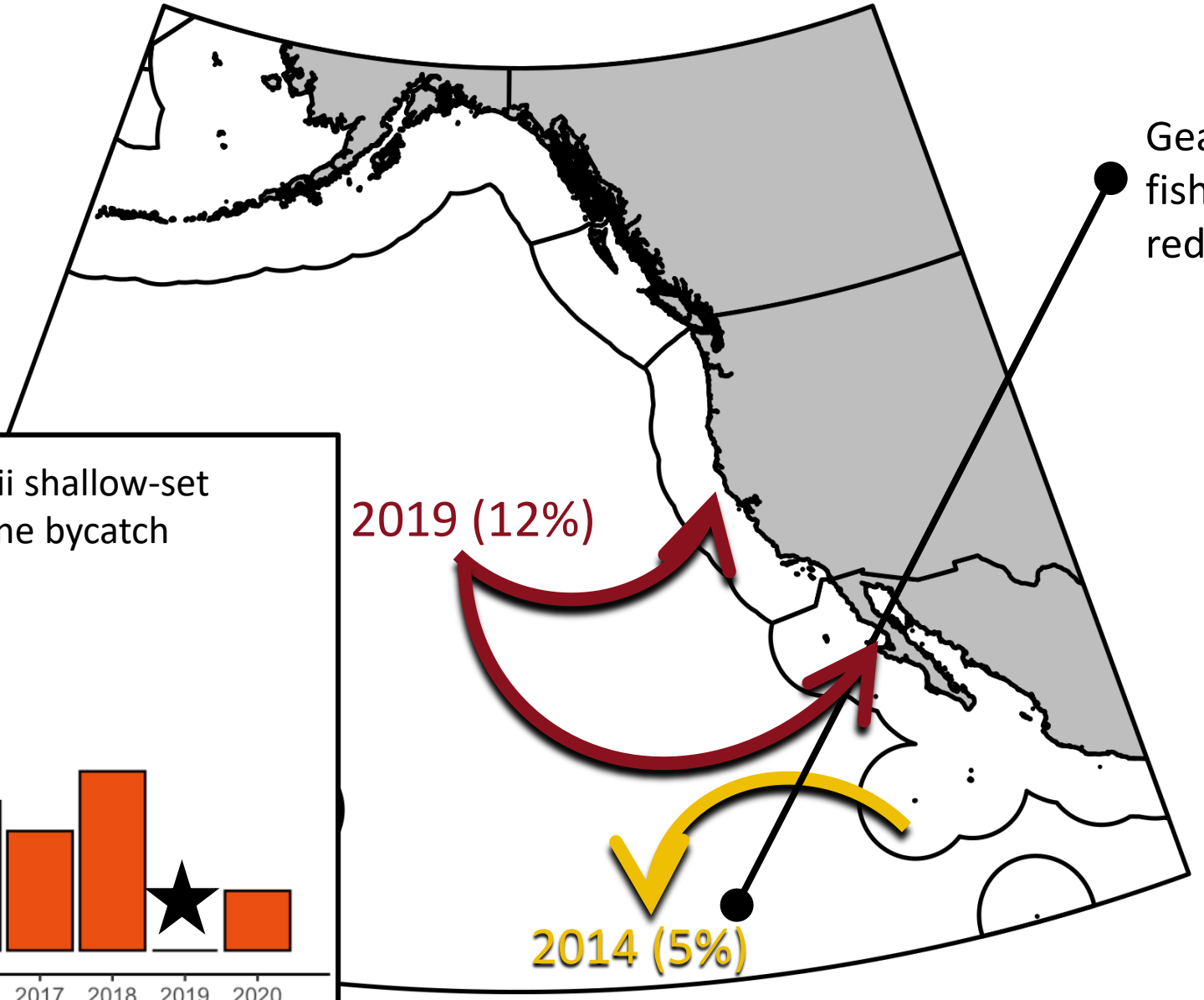
Fishery closure to prevent overfishing

Free, Christopher M., et al. "Impact of the 2014–2016 marine heatwave on US and Canada West Coast fisheries: Surprises and lessons from key case studies." *Fish and Fisheries* (2023).

Shifts across jurisdictional boundaries: new risks, rewards, and responsibilities

Leatherback turtle

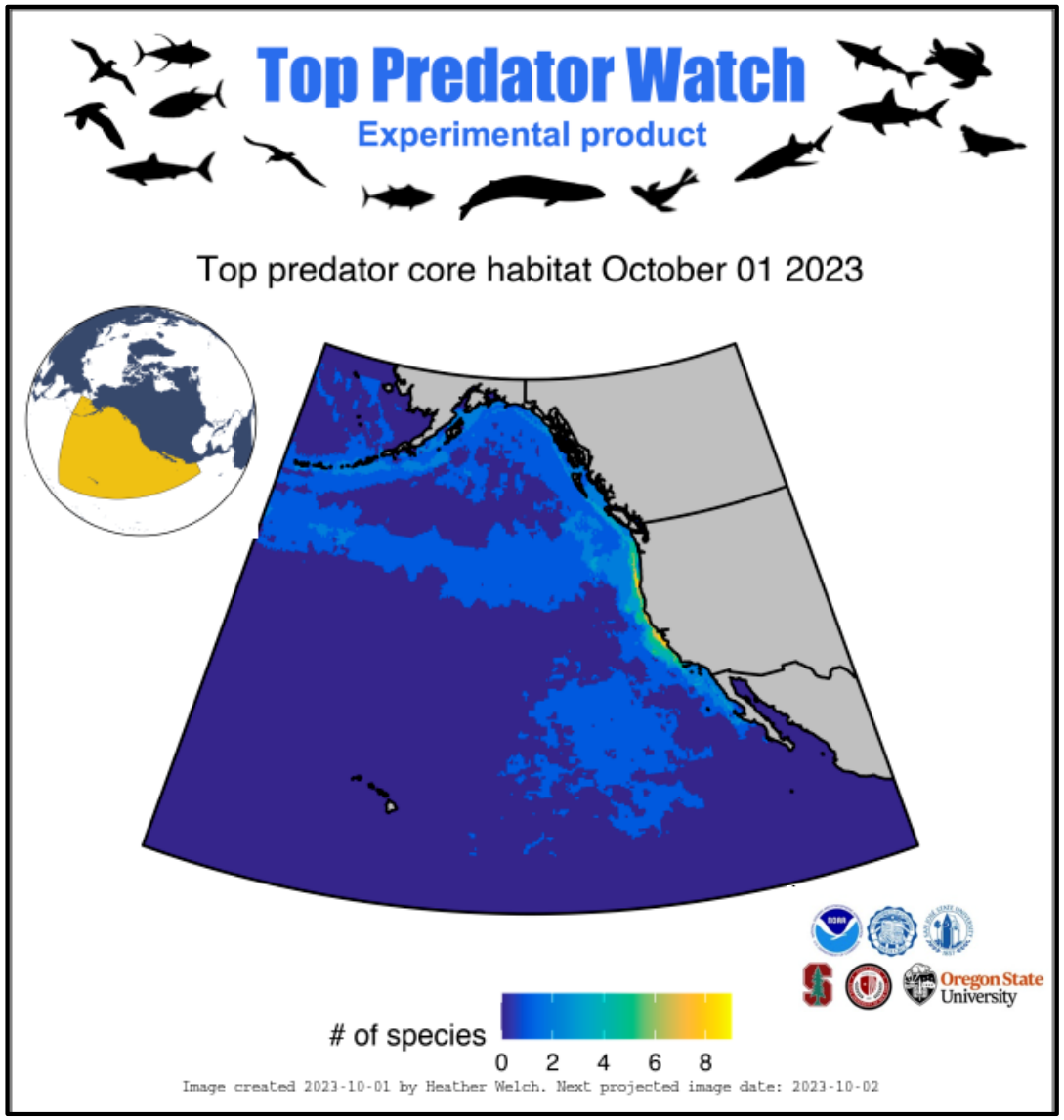




Gear modifications or fisheries closures to reduce bycatch

Data from: https://www.fisheries.noaa.gov/pacific-islands/bycatch/hawaii-shallow-set-longline-fishery-interactions-leatherback-sea-turtles

Real-time information



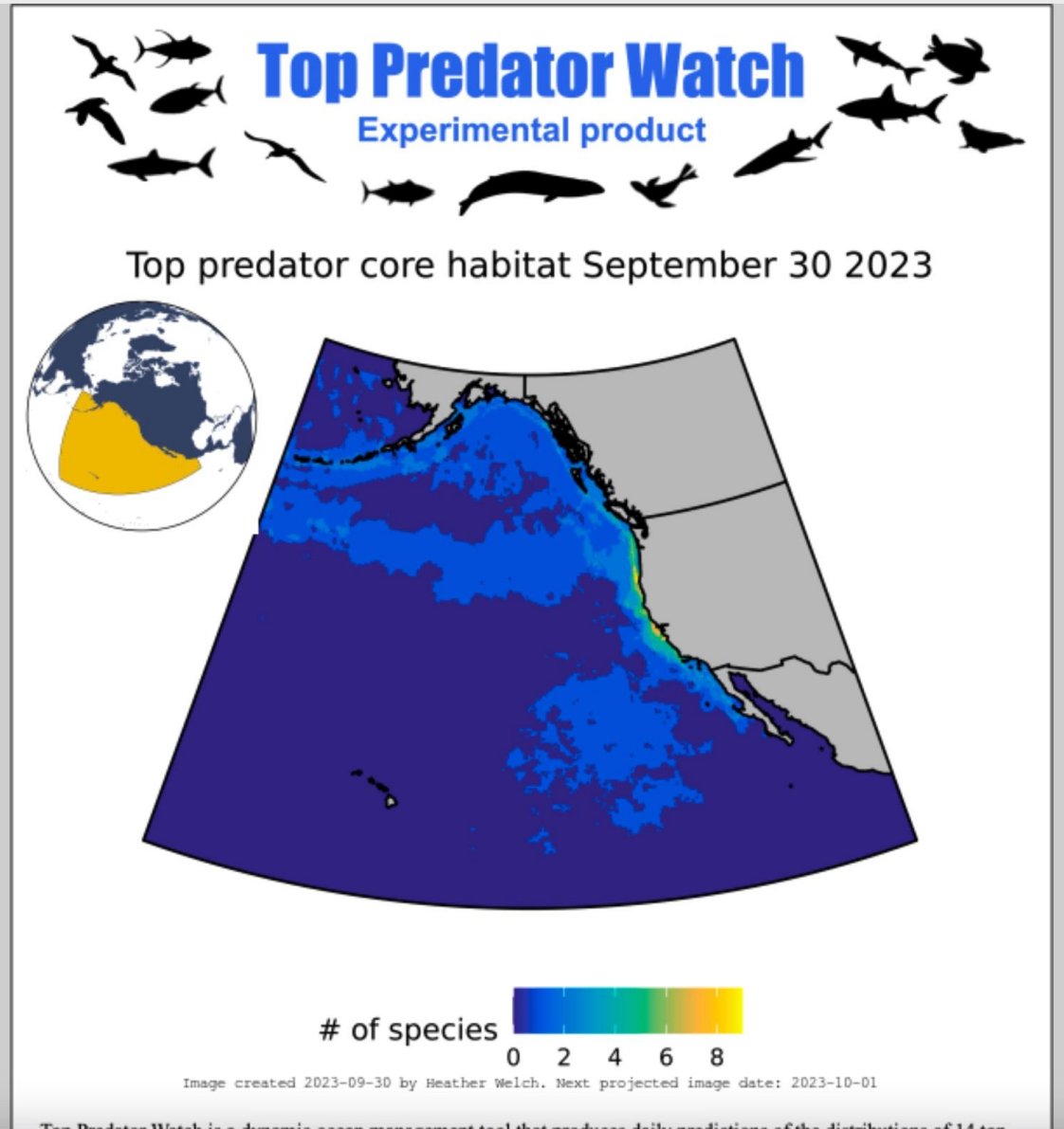
https://oceanview.pfeg.noaa.gov/top-predator-watch/

Top Predator Watch

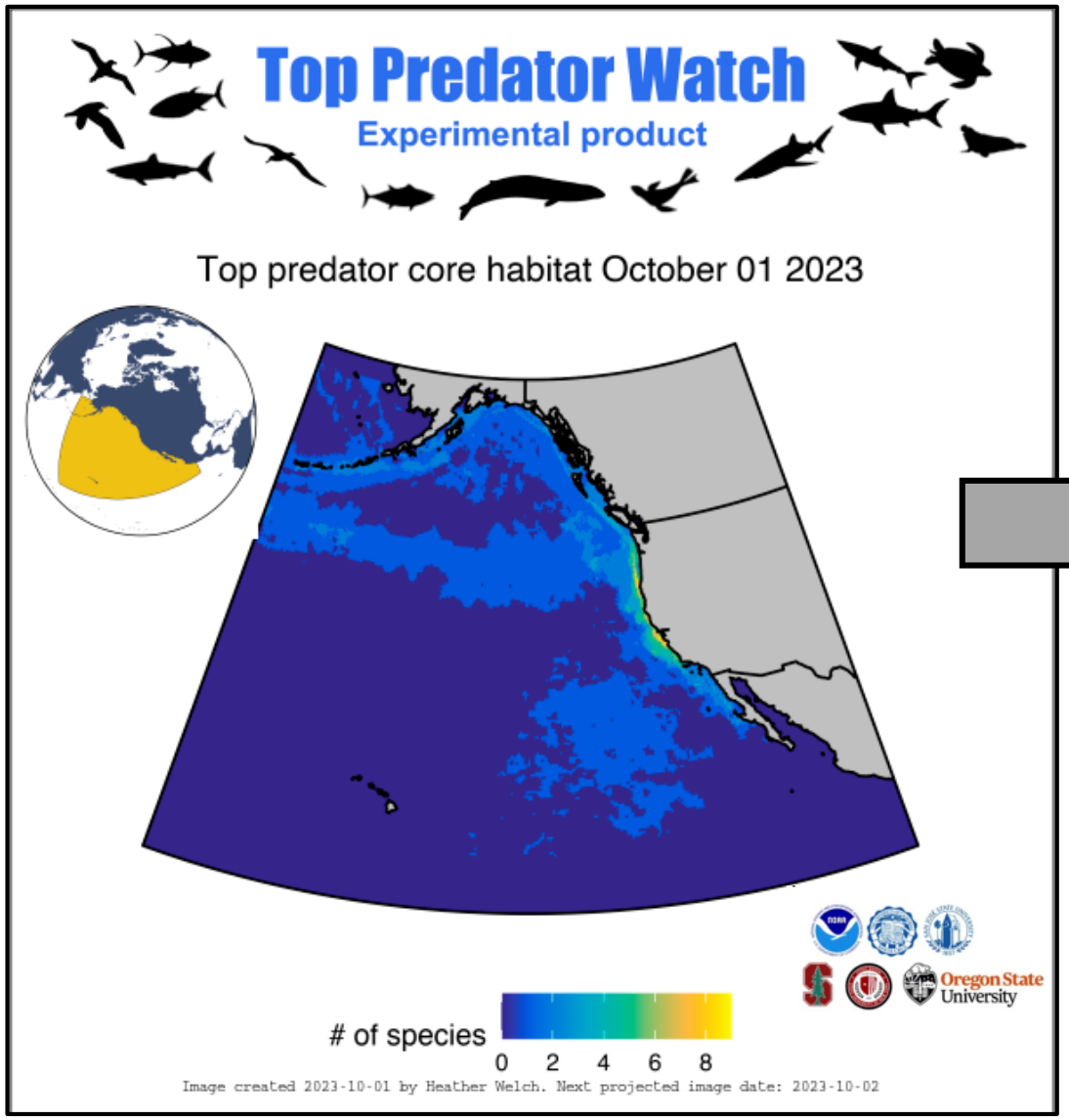
oceanview.pfeg.noaa.gov/top-predator-watch/

Update

Top Predator Watch Downloads

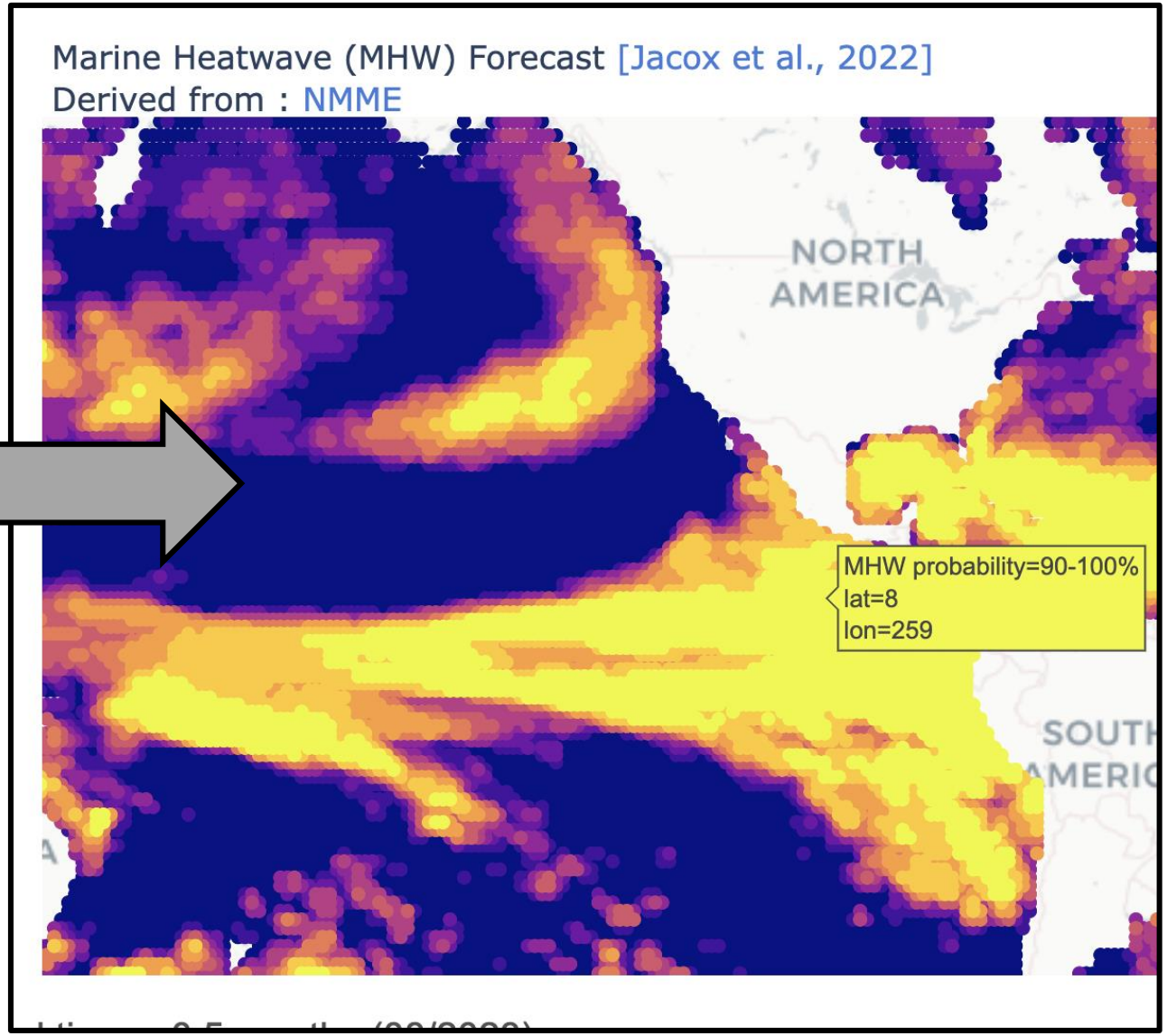


Real-time information



https://oceanview.pfeg.noaa.gov/top-predator-watch/

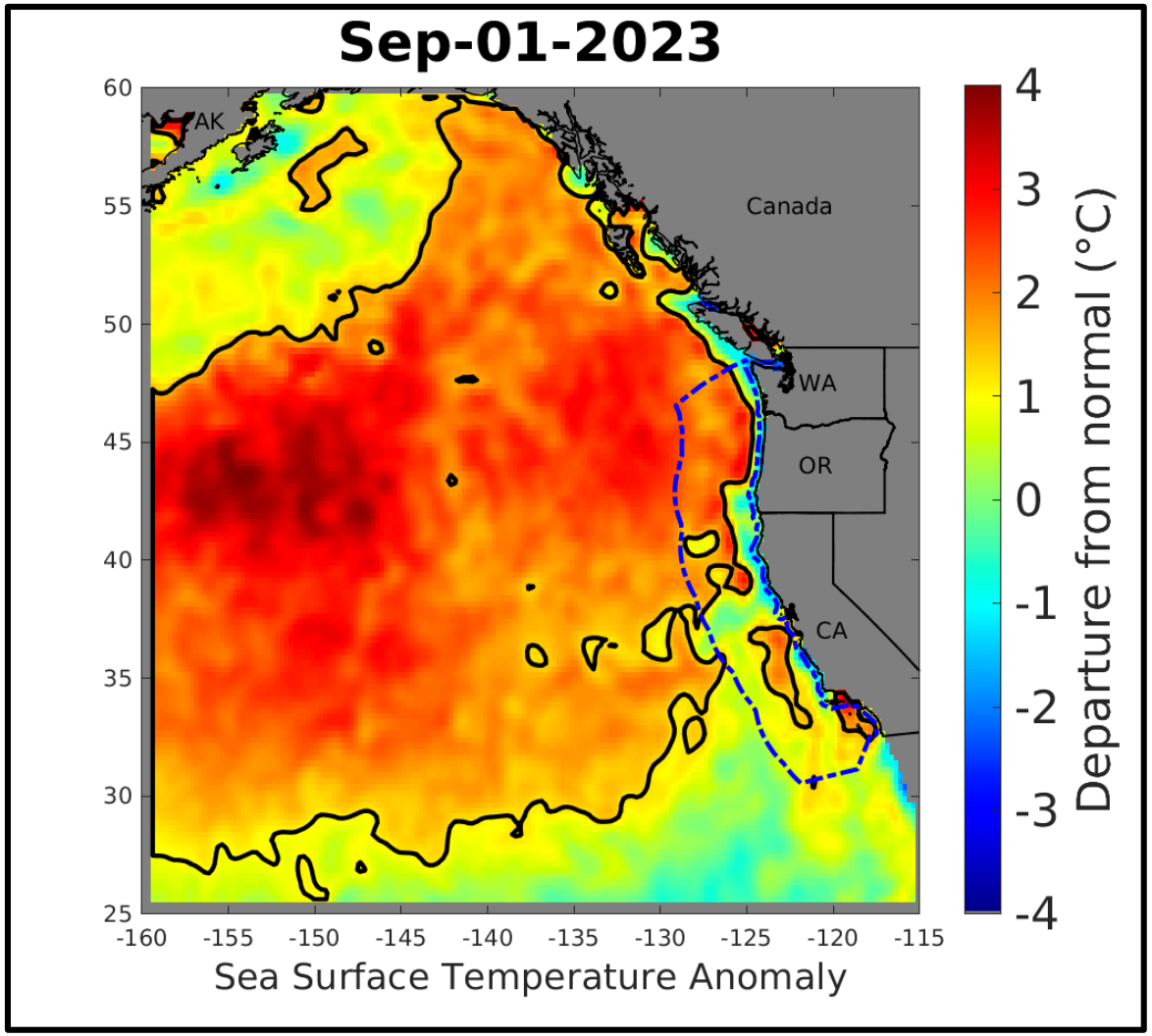
Forward-looking information



https://psl.noaa.gov/marine-heatwaves/#report

Current conditions in the northeast Pacific

Developing marine heatwave



https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker

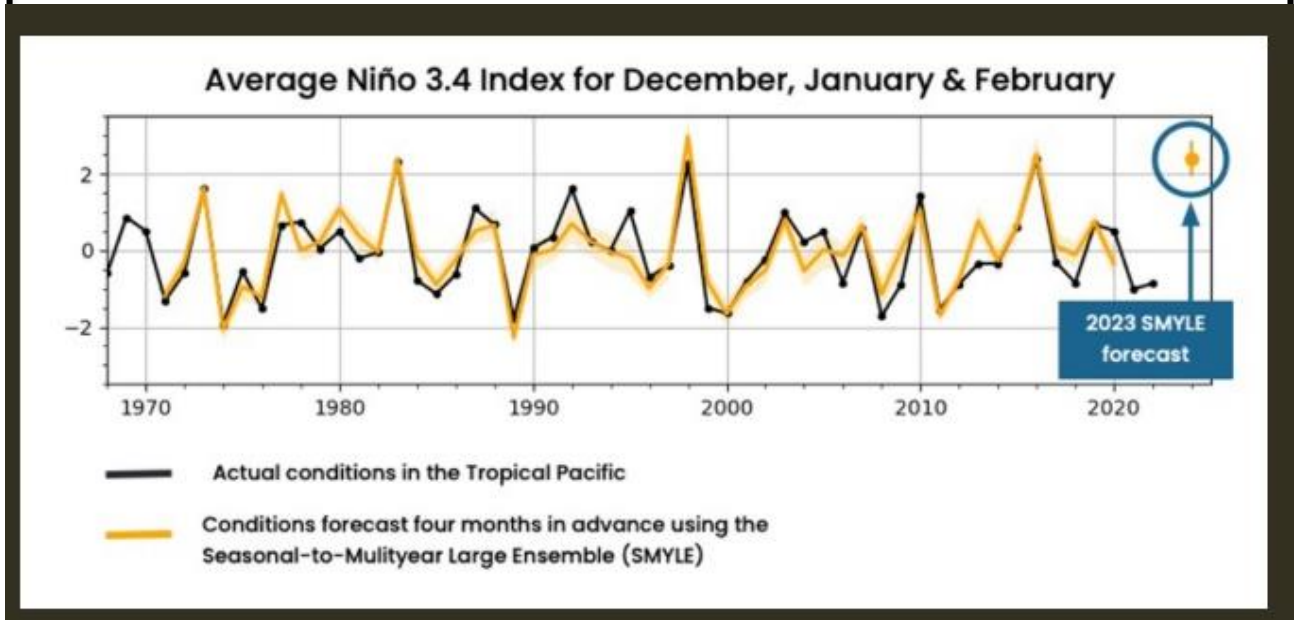
El Niño Advisory

EL NIÑO/SOUTHERN OSCILLATION (ENSO) DIAGNOSTIC DISCUSSION

issued by
CLIMATE PREDICTION CENTER/NCEP/NWS

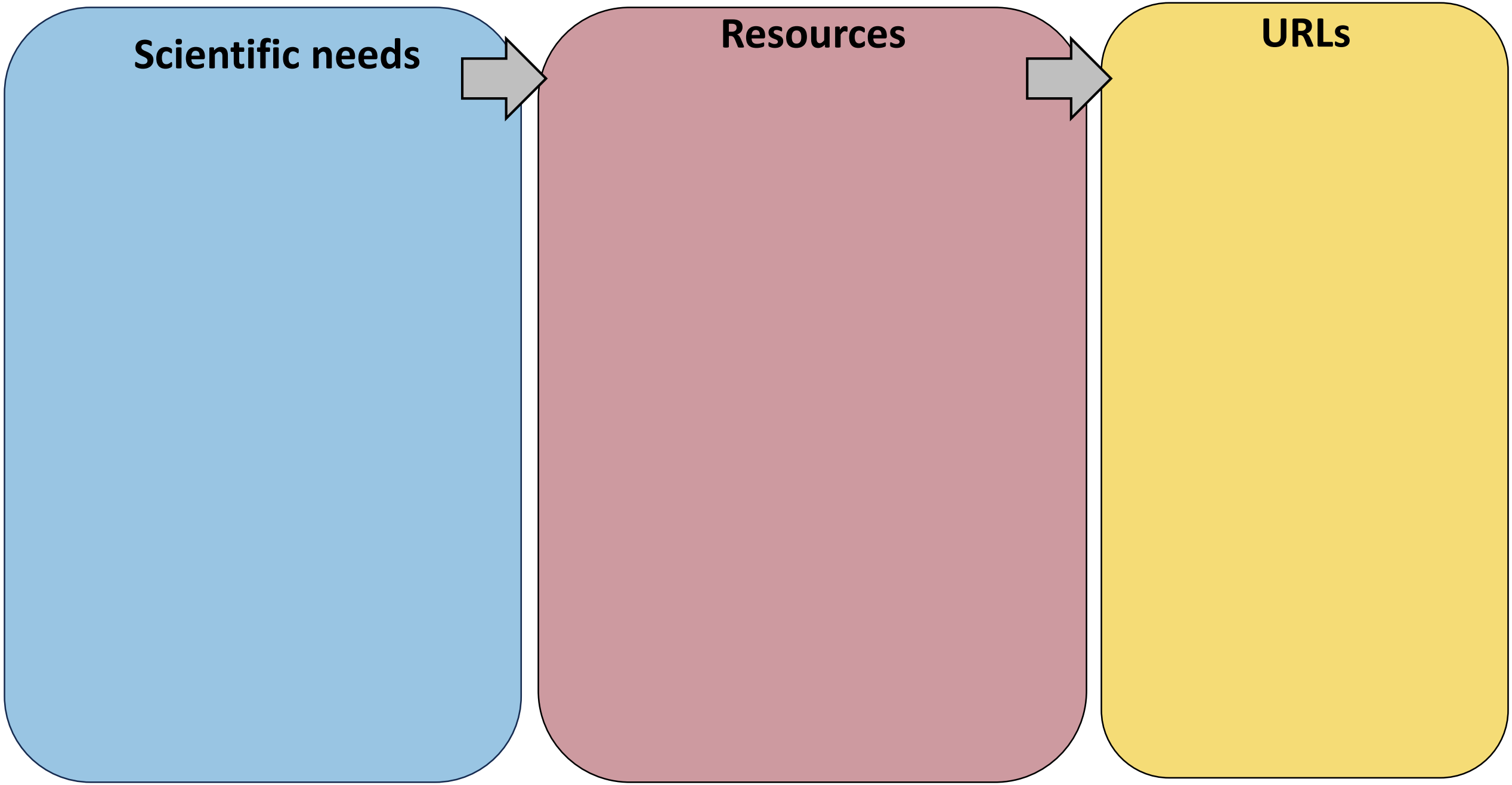
14 September 2023

ENSO Alert System Status: El Niño Advisory



Take home points

@Heather_M_Welch



Take home points

@Heather_M_Welch

Scientific needs

- Ecosystem-based investigations of heatwave impacts (multi-species, multi-heatwave)

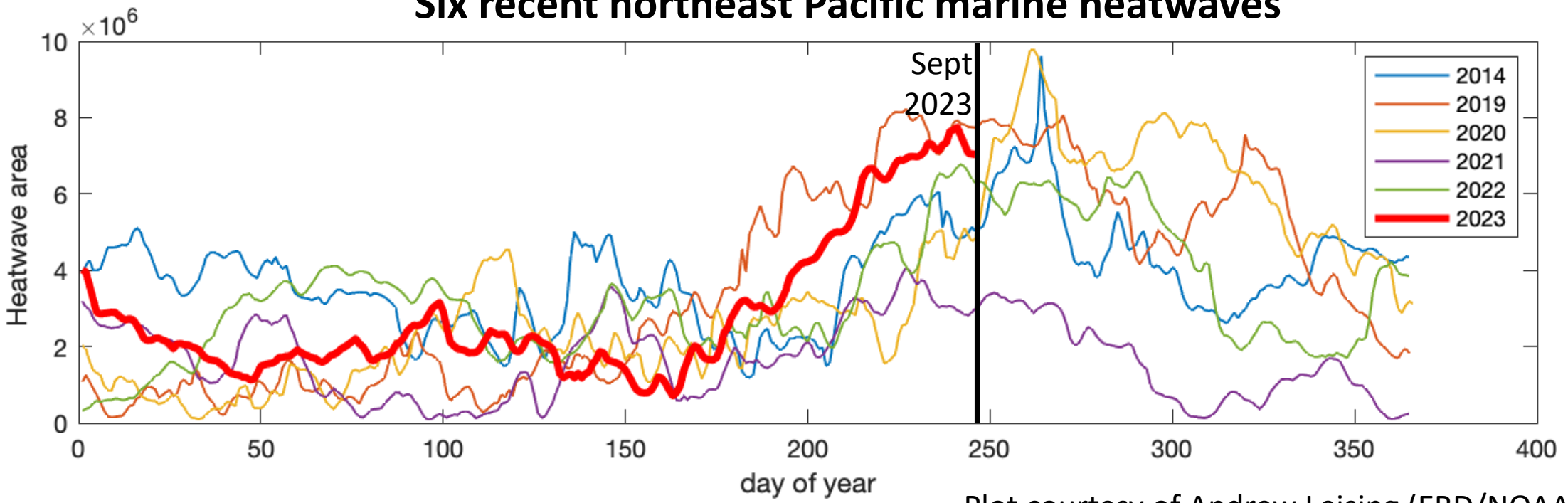
Resources

Heatwave data: Blob Tracker, Marine Heatwave Watch; **Species data:** Animal Telemetry Network, Seabird Tracking Database; NOAA trawl data

URLs

- *https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker;*
- *https://coralreefwatch.noaa.gov/product/marine_heatwave/;*
- *https://portal.atn.ioos.us/#;*
- *https://www.seabirdtracking.org/*
- *https://github.com/pfmc-assessments/nwfscSurvey*

Six recent northeast Pacific marine heatwaves



Plot courtesy of Andrew Leising (ERD/NOAA)

Take home points

@Heather_M_Welch

Scientific needs

- Ecosystem-based investigations of heatwave impacts (multi-species, multi-heatwave)
- Report on diverse and inconsistent heatwave impacts (common for physics, less common for ecology)

Resources

Heatwave data: Blob Tracker, Marine Heatwave Watch; **Species data:** Animal Telemetry Network, Seabird Tracking Database; NOAA trawl data

Welch et al. Impacts of MHW on top predator distributions are variable but predictable; **Fredston et al.** MHW are not a dominant driver of change in demersal fishes.

URLs

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- *https://coralreefwatch.noaa.gov/product/marine_heatwave/;*
- *https://portal.atn.ioos.us/#;*
- *https://www.seabirdtracking.org/*
- *https://github.com/pfmc-assessments/nwfscSurvey*

- *https://doi.org/10.1038/s41467-023-40849-y;*
- *https://doi.org/10.1038/s41586-023-06449-y*

Take home points

@Heather_M_Welch

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- Ecosystem-based investigations of heatwave impacts (multi-species, multi-heatwave)
- Report on diverse and inconsistent heatwave impacts (common for physics, less common for ecology)
- Ecological nowcasts (or better yet, forecasts) to inform climate ready management

Resources

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Nowcast: Top Predator Watch; **Forecast:** Southern Bluefin Tuna

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- *https://portal.atn.ioos.us/#;*
- *https://www.seabirdtracking.org/*
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- *https://doi.org/10.1038/s41467-023-40849-y;*
- *https://doi.org/10.1038/s41586-023-06449-y*
- *https://oceanview.pfeg.noaa.gov/top-predator-watch/;*
- *http://www.cmar.csiro.au/gab-forecasts/habitat-forecasts.html*

Take home points

@Heather_M_Welch

Scientific needs

- Ecosystem-based investigations of heatwave impacts (multi-species, multi-heatwave)
- Report on diverse and inconsistent heatwave impacts (common for physics, less common for ecology)
- Ecological nowcasts (or better yet, forecasts) to inform climate ready management
- Climate ready management tools that ingest nowcasts/forecasts to swiftly respond to diverse heatwave impacts

Resources

Heatwave data: Blob Tracker, Marine Heatwave Watch; **Species data:** Animal Telemetry Network, Seabird Tracking Database; NOAA trawl data

Welch et al. Impacts of MHW on top predator distributions are variable but predictable; **Fredston et al.** MHW are not a dominant driver of change in demersal fishes.

Nowcast: Top Predator Watch; **Forecast:** Southern Bluefin Tuna

Ingests nowcasts: EcoCast, TOTAL
Ingests forecasts: Maine lobster fishery decision-making

URLs

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- *https://coralreefwatch.noaa.gov/product/marine_heatwave/;*
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- *http://www.cmar.csiro.au/gab-forecasts/habitat-forecasts.html*

- *https://coastwatch.pfeg.noaa.gov/ecocast/;*
- *https://coastwatch.pfeg.noaa.gov/loggerheads/loggerhead_closure.html;*
- *https://gmri.org/projects/multi-scale-forecasts-and-analyses-maine-lobster-fishery/*