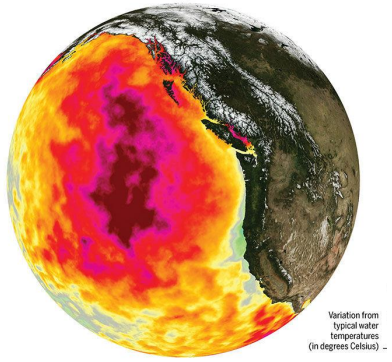
Scales of whales:

Using nowcasts, forecasts, and projections to predict climate impacts on the California Current Ecosystem

Elliott Hazen, Nerea Lezama-Ochoa, Heather Welch and **many** others!
NOAA Southwest Fisheries Science Center / University of California Santa Cruz

Our climate impacts whale distributions across multiple timescales

Ephemeral features that concentrate prey



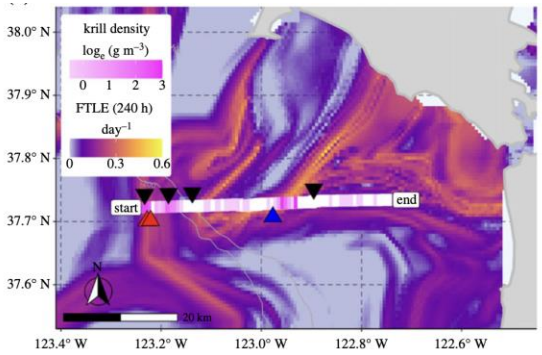
ENSO cycles

0 -10 days

Weeks to months

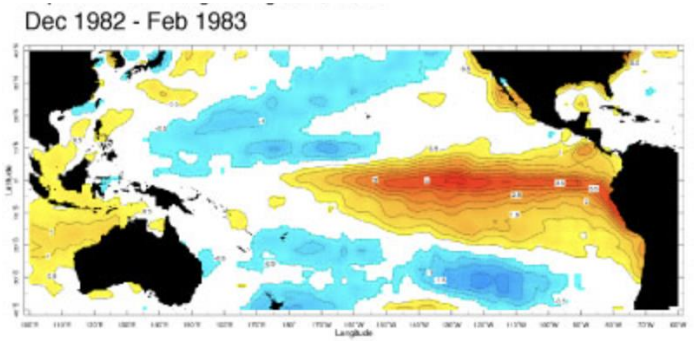
Year to decade

Decades to century

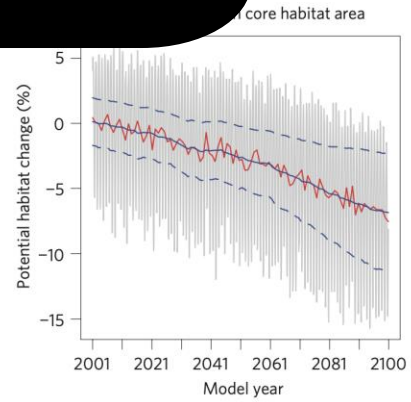


Fahlbusch et al. 2022, 2024

Marine heatwaves



Climate change



Hazen et al. 2013

Whale conservation and management decision-making also occurs across multiple timescales

Vessel speed reductions

Permitting for seismic surveys

0 -10 days

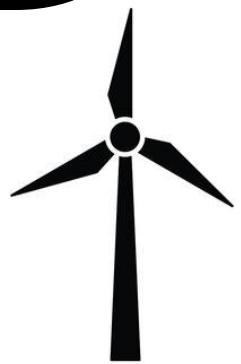
Weeks to months

Year to decade

Decades to century

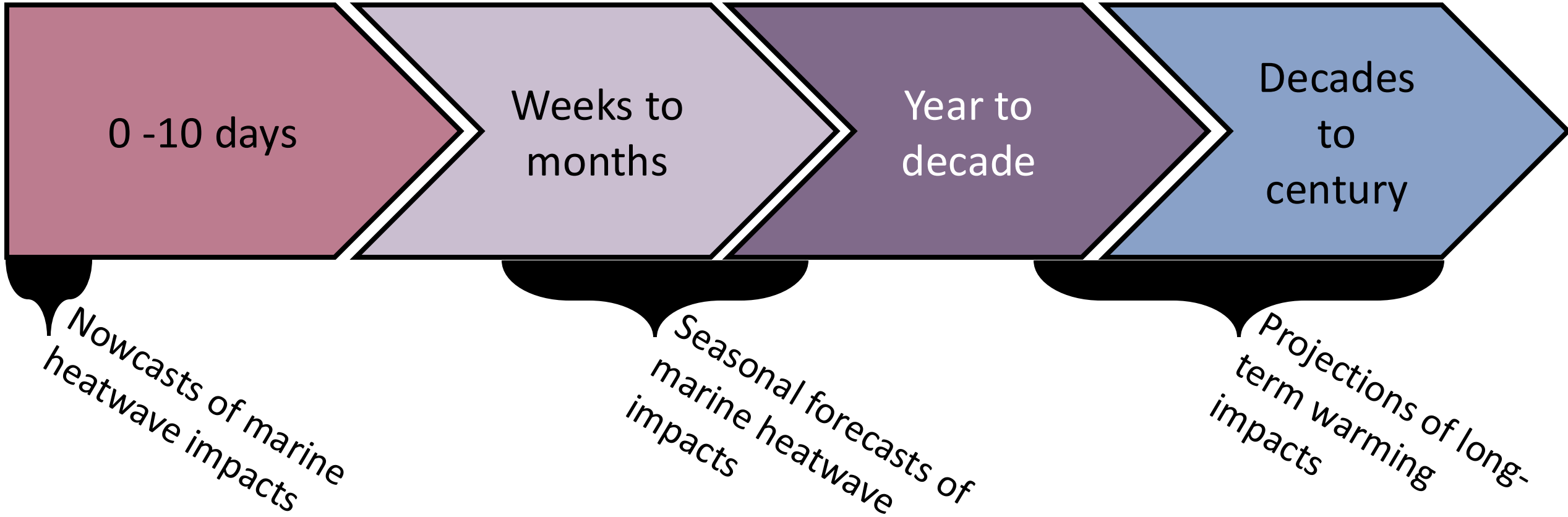
Fishing zone closures

MPA planning; Semi-permanent structures e.g. wind farms



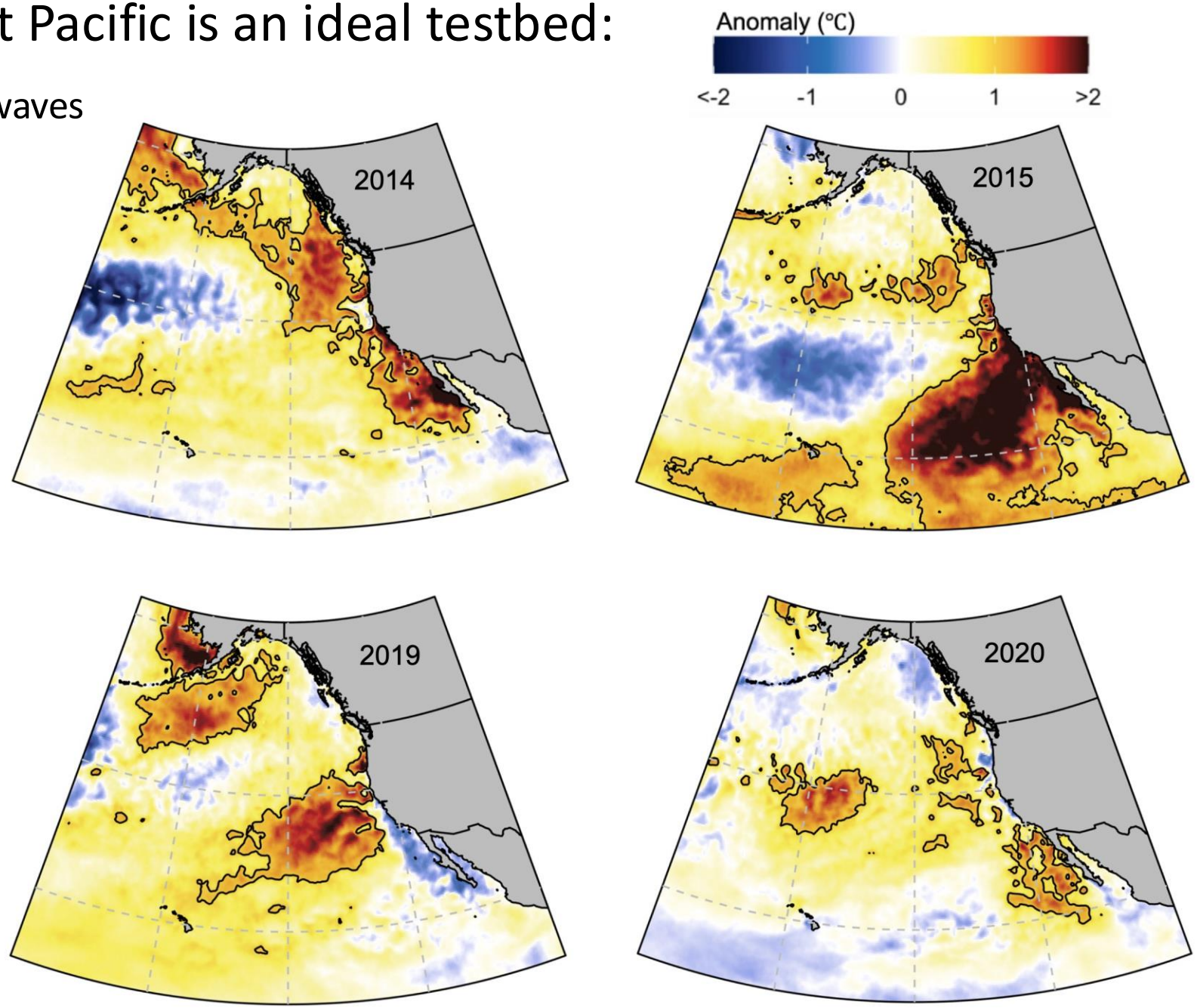
Thus, accurate predictions of whale distributions across multiple time-scales can support climate-ready decision-making

Three California Current case-studies:



The northeast Pacific is an ideal testbed:

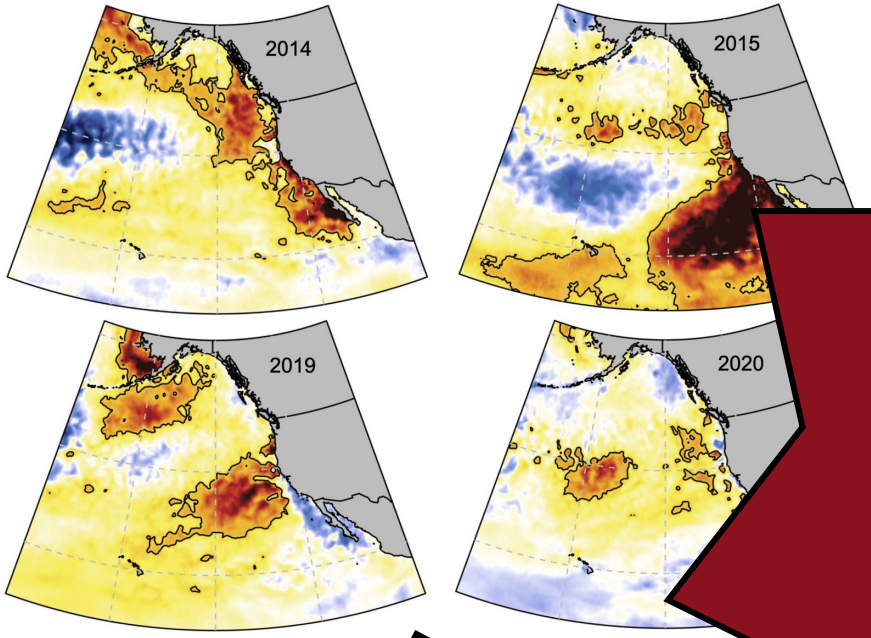
Many recent heatwaves



Welch et al 2023.
Nat Comms

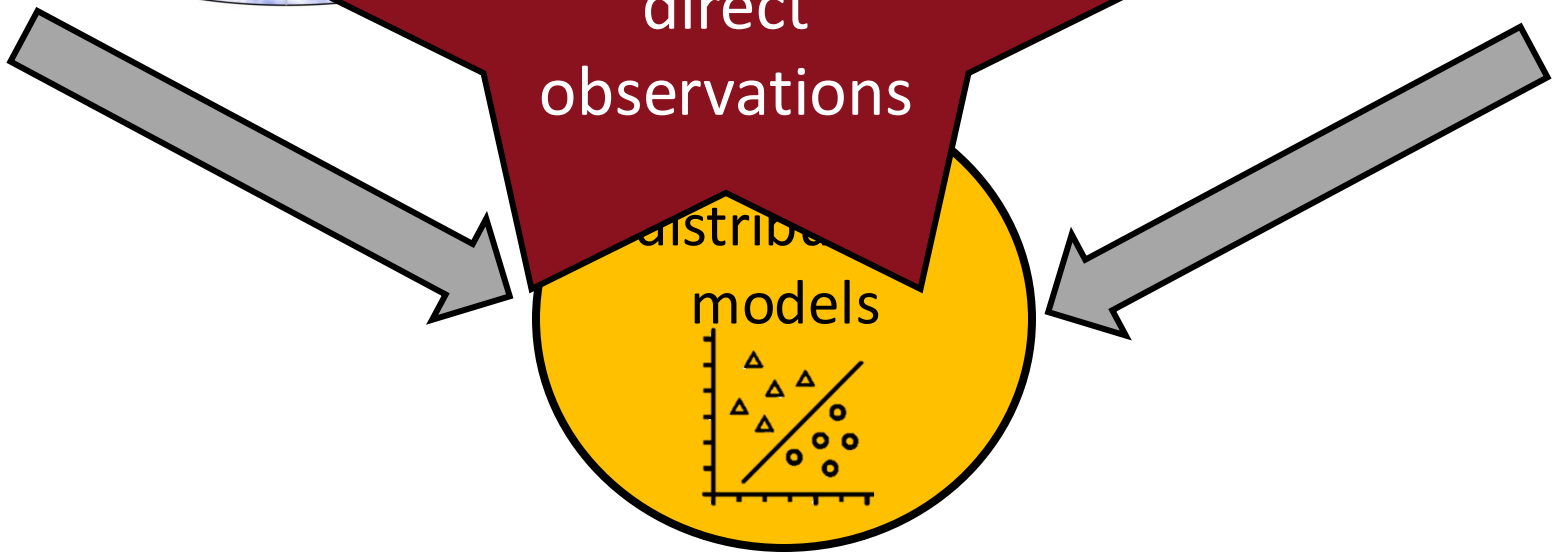
The northeast Pacific is an ideal testbed:

Four marine heatwaves



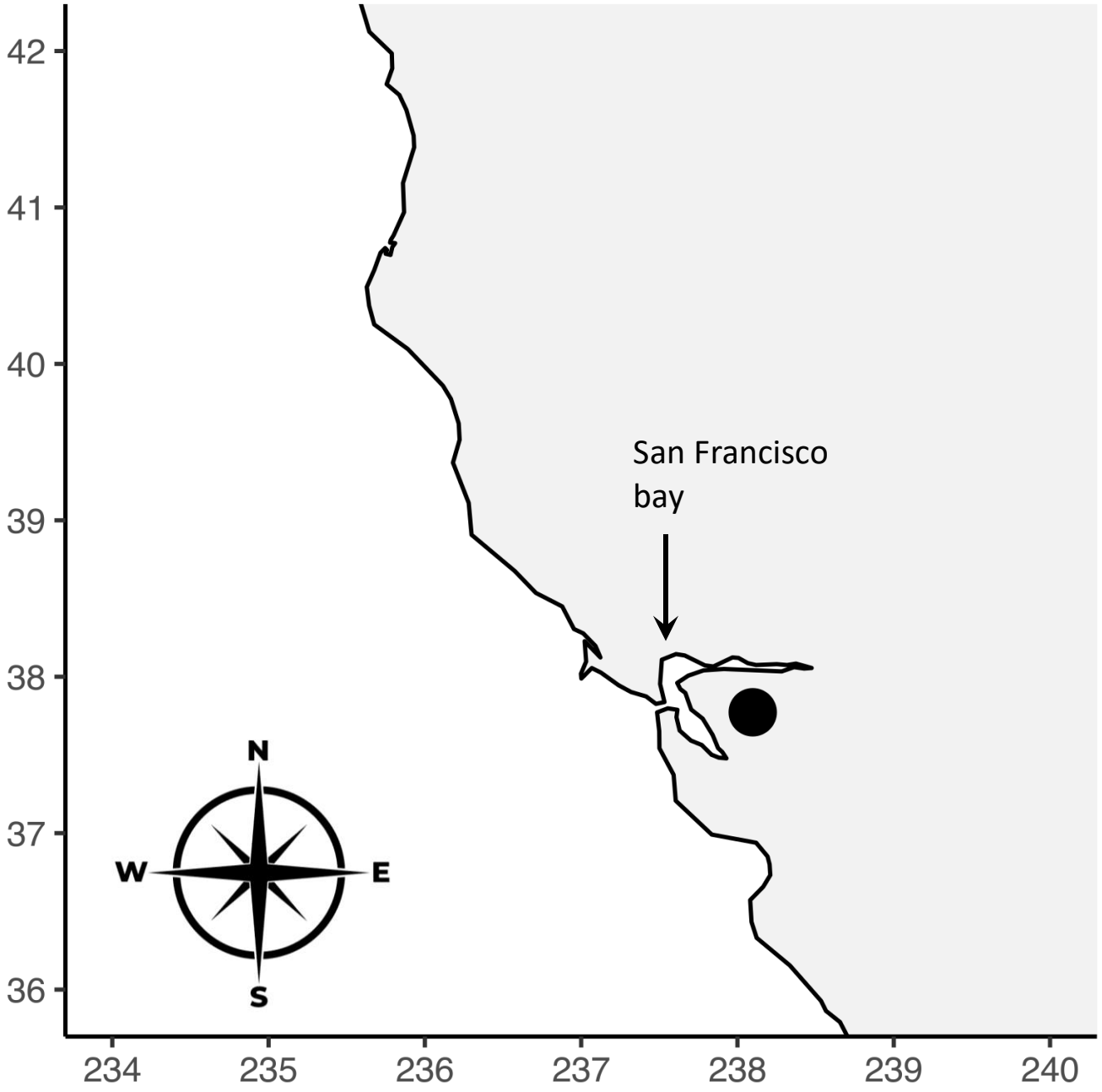
Blue whale tagging data

Results are **inferences** from models as opposed to direct observations



Welch et al 2023. Nat Comms

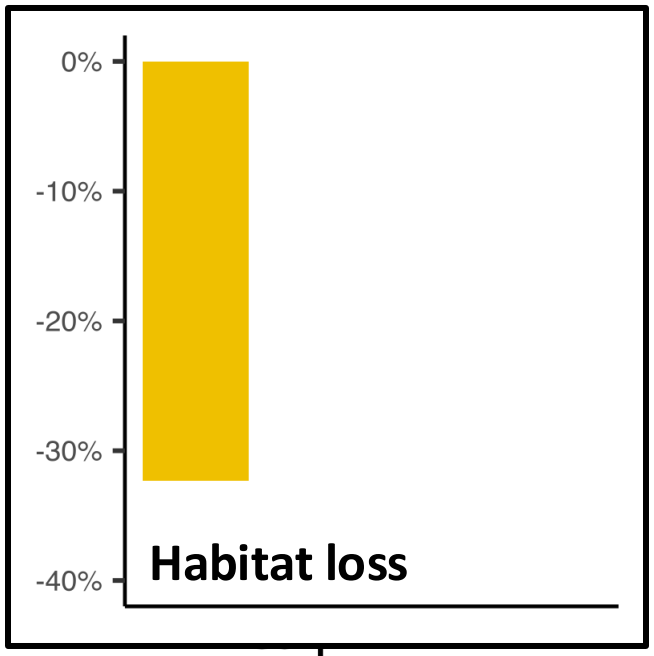
Marine heatwave impacts on blue whales are surprisingly diverse



● Average location of habitat
Aug-Oct 2000-2020

Welch et al 2023.
Nat Comms

Marine heatwave impacts on blue whales are surprisingly diverse



- Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the → 2014 heatwave

Welch et al 2023. Nat Comms

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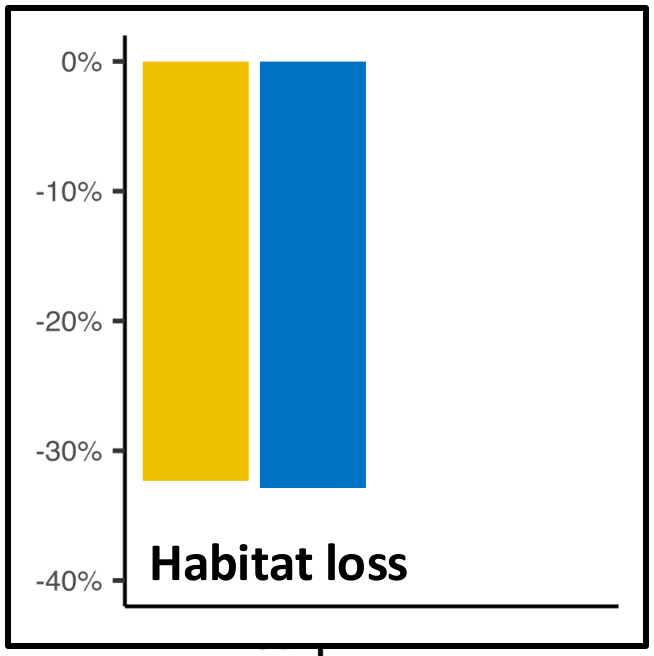

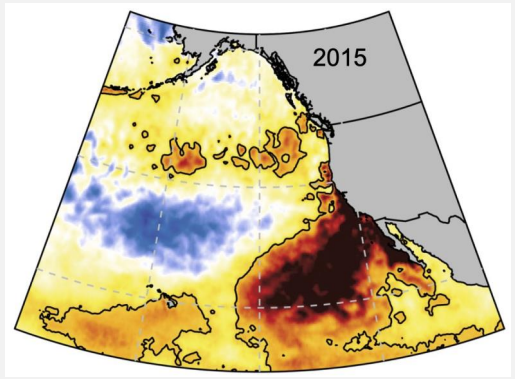

- Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the
- 2014 heatwave
- 2015 heatwave

Welch et al 2023. Nat Comms

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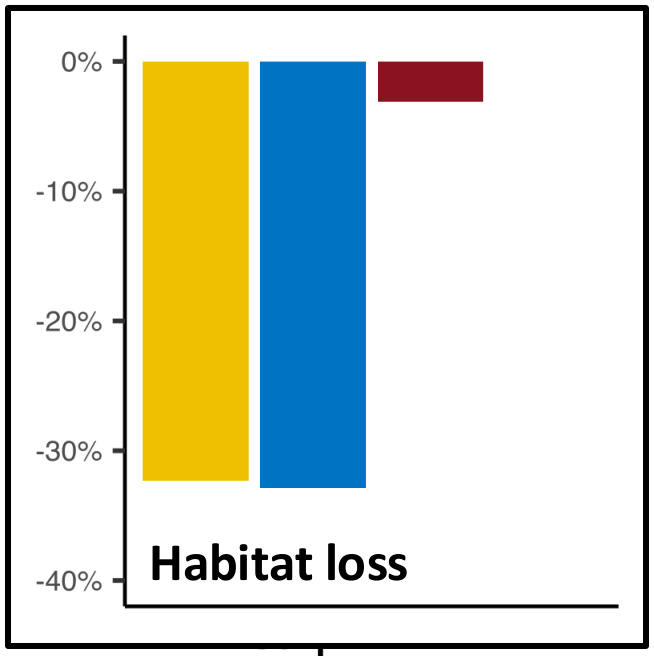

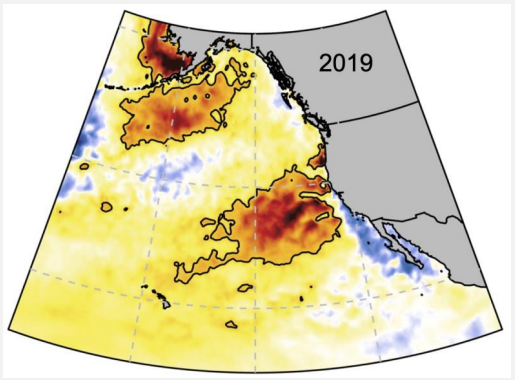

San Francisco bay

38
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S

- Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the
- 2014 heatwave
- 2015 heatwave
- 2019 heatwave

Welch et al 2023. Nat Comms

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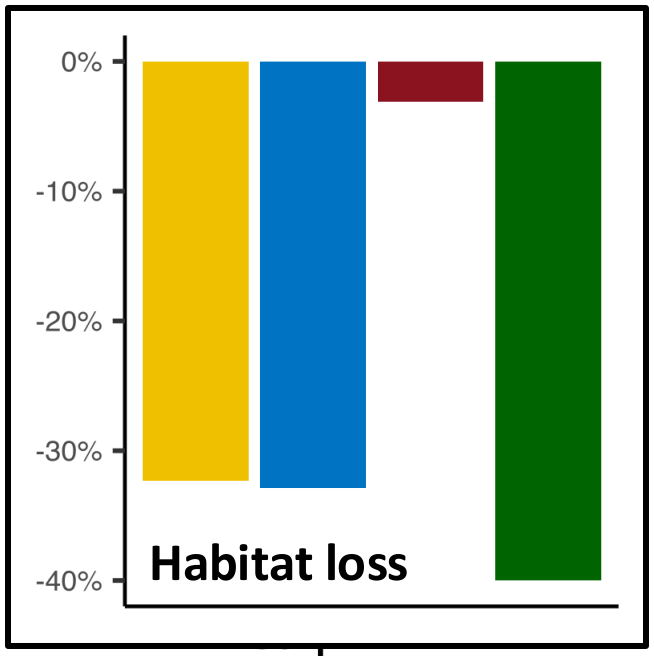
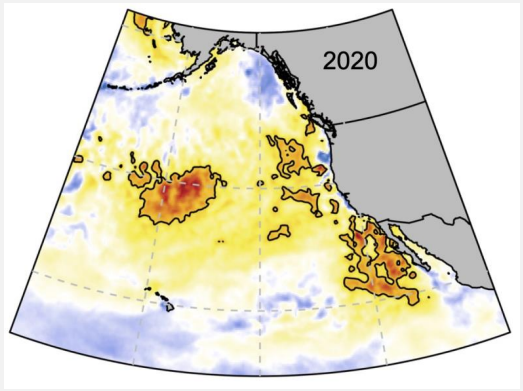




- Average location of habitat Aug-Oct 2000-2020

Displacement of habitat during the

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

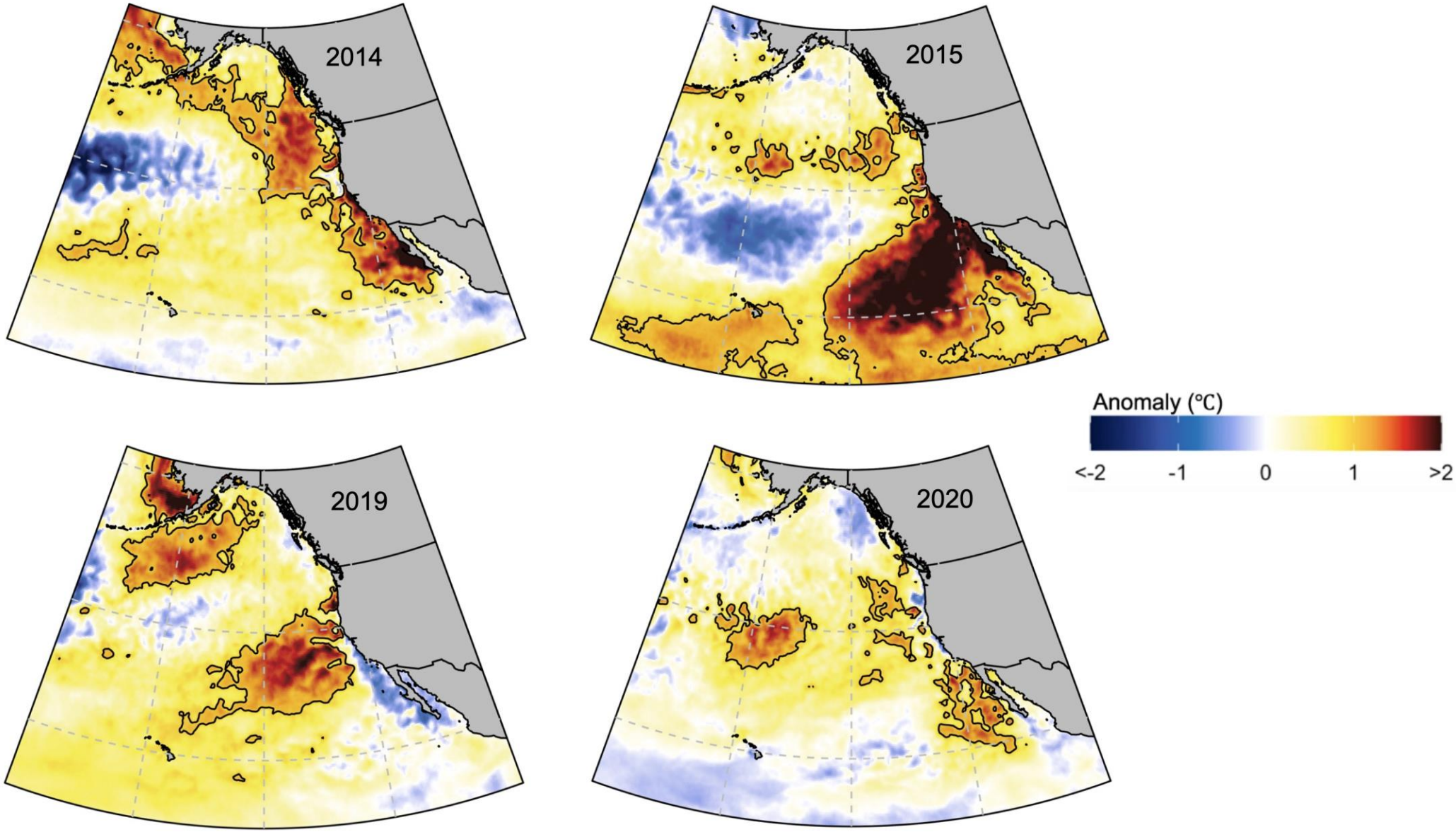
Welch et al 2023. Nat Comms

Marine heatwave impacts are surprisingly diverse

Can’t assume future marine heatwaves will have the same impact as past events

However, marine heatwave impacts are highly predictable in modeling space

And we can predict impacts in real-time as marine heatwaves unfold



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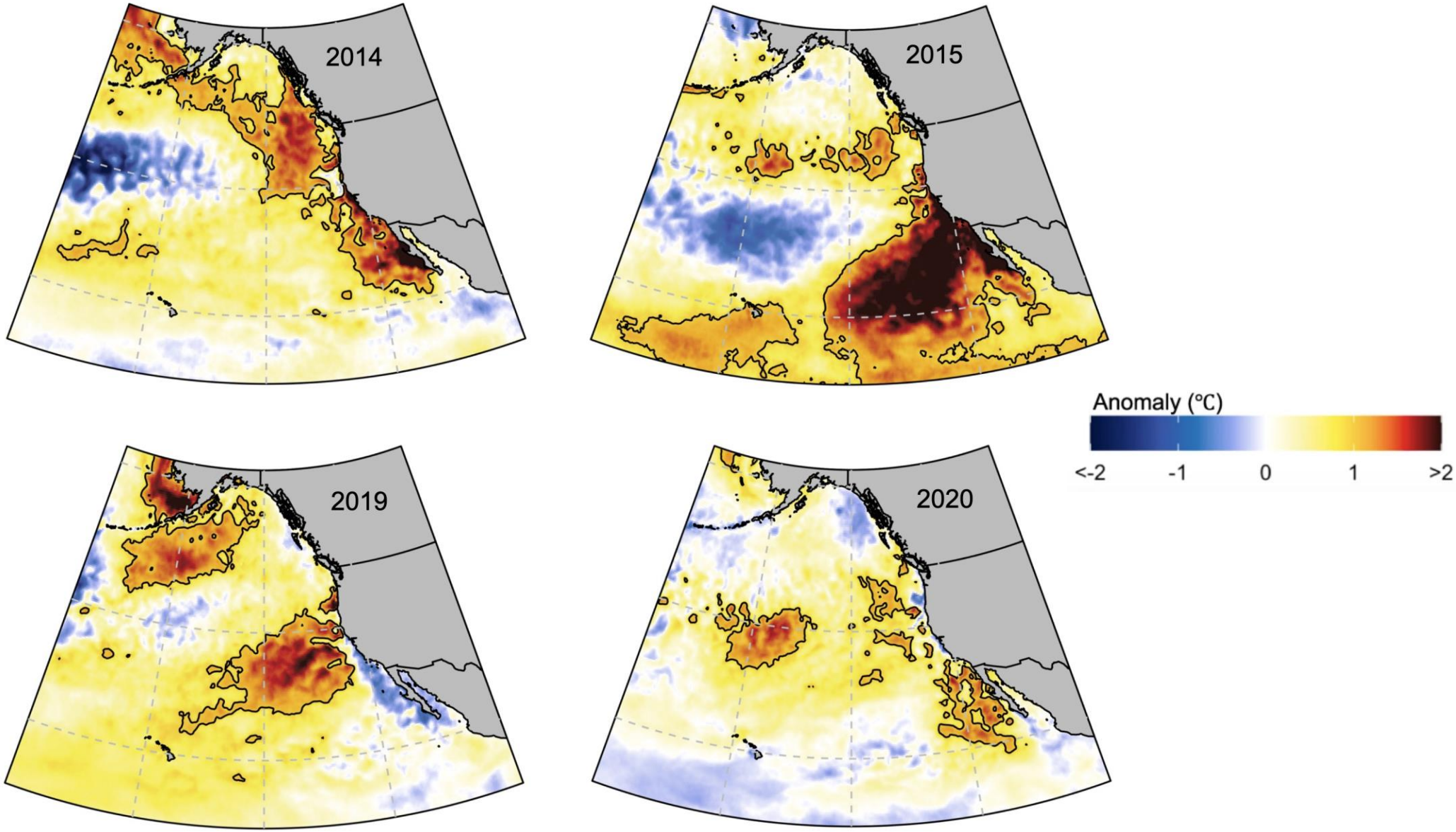
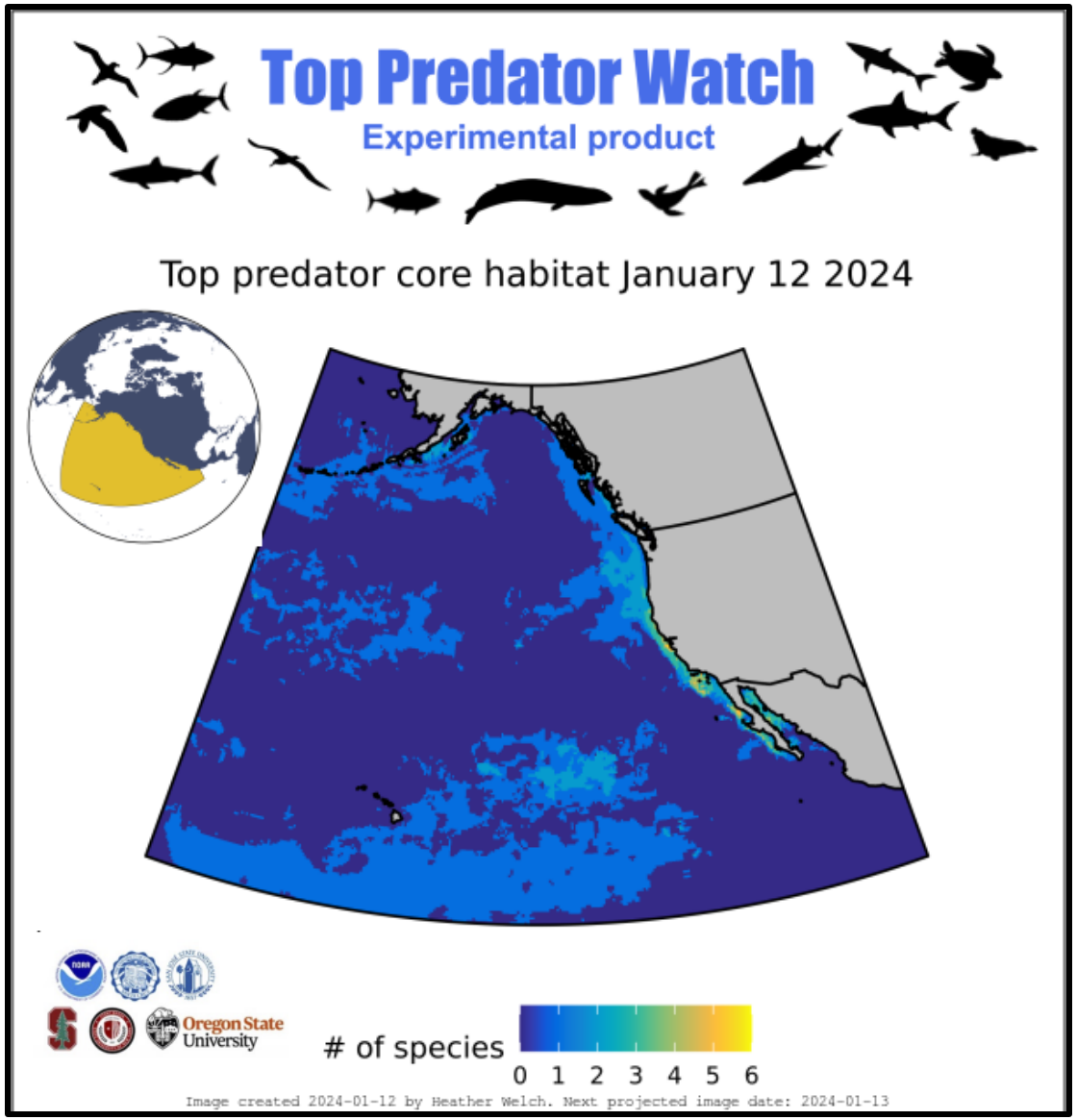
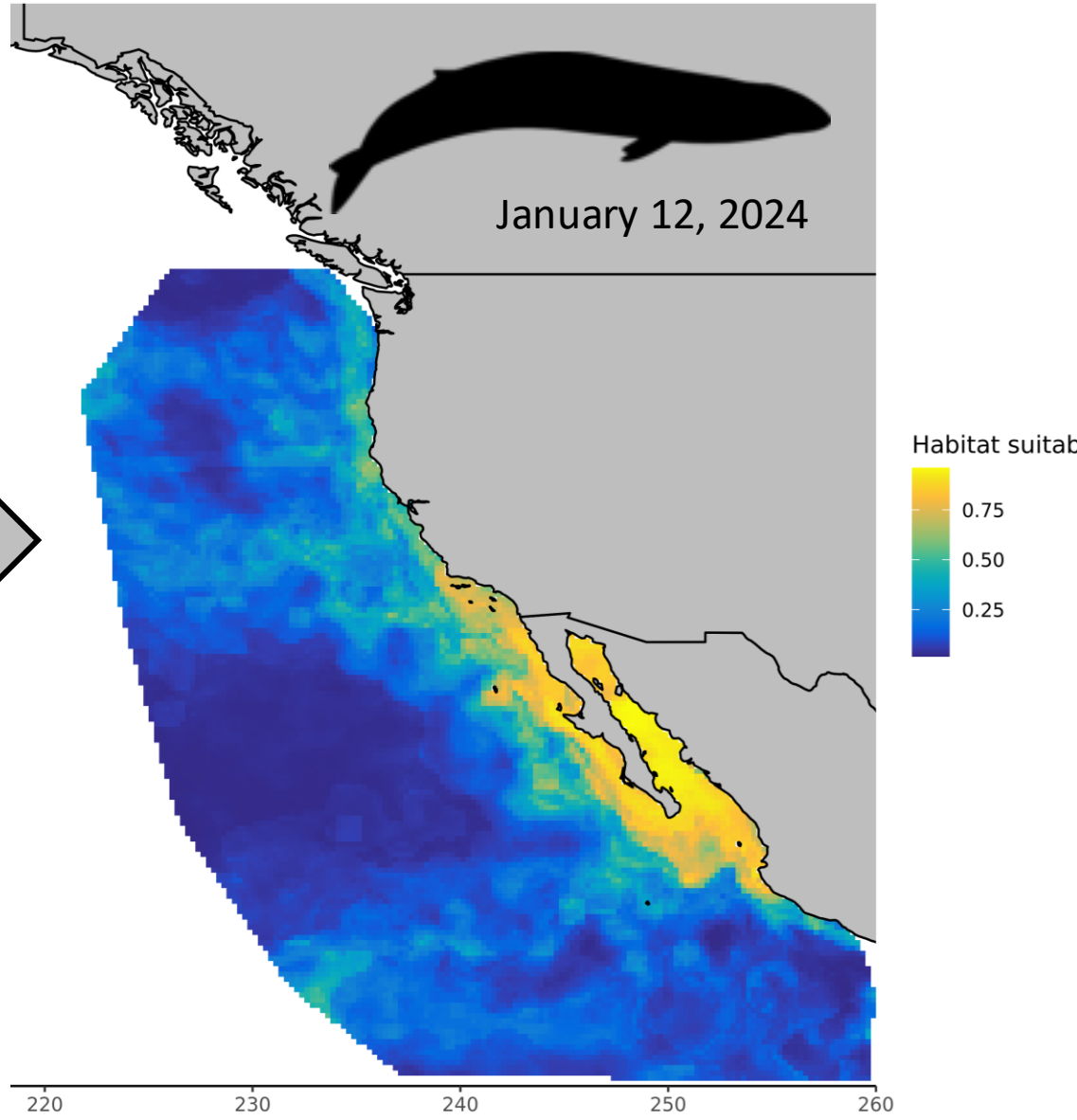


Nowcasts:
Real-time information



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

Forecasts:
Forward-looking information



The Habitat Compression Index (HCI)

2013

2014

2015

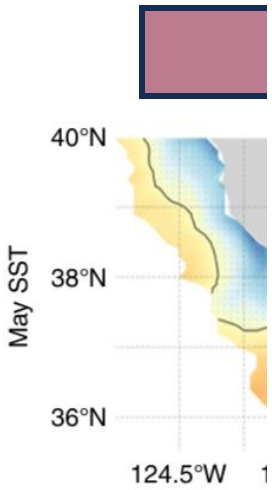
2016

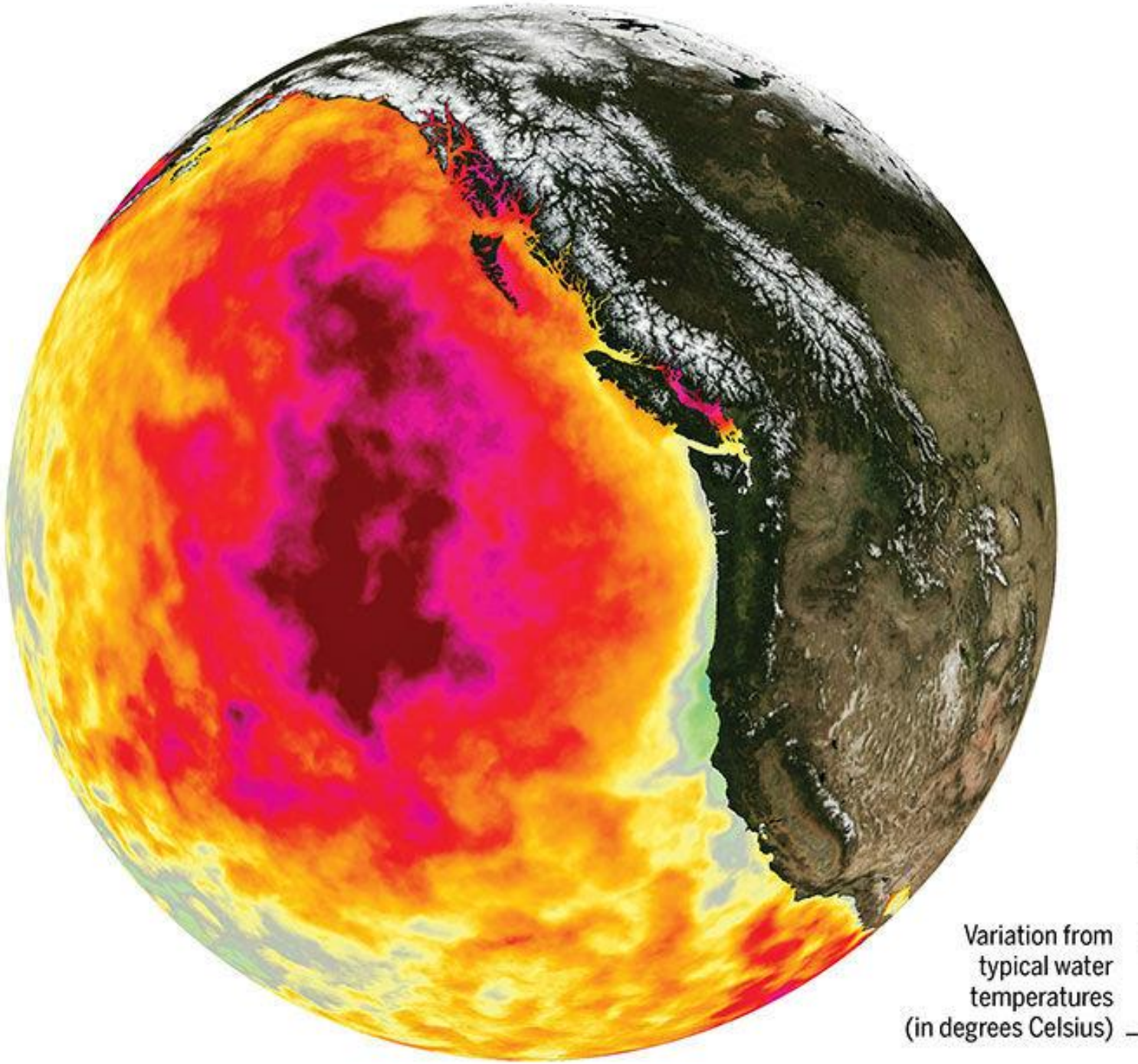
Time

Forms in the Gulf of Alaska

Expands to reach U.S. West Coast

Amplified by a strong El Niño





Variation from typical water temperatures (in degrees Celsius)

The Habitat Compression Index (HCI)

Increasing habitat compression

2013

2014

2015

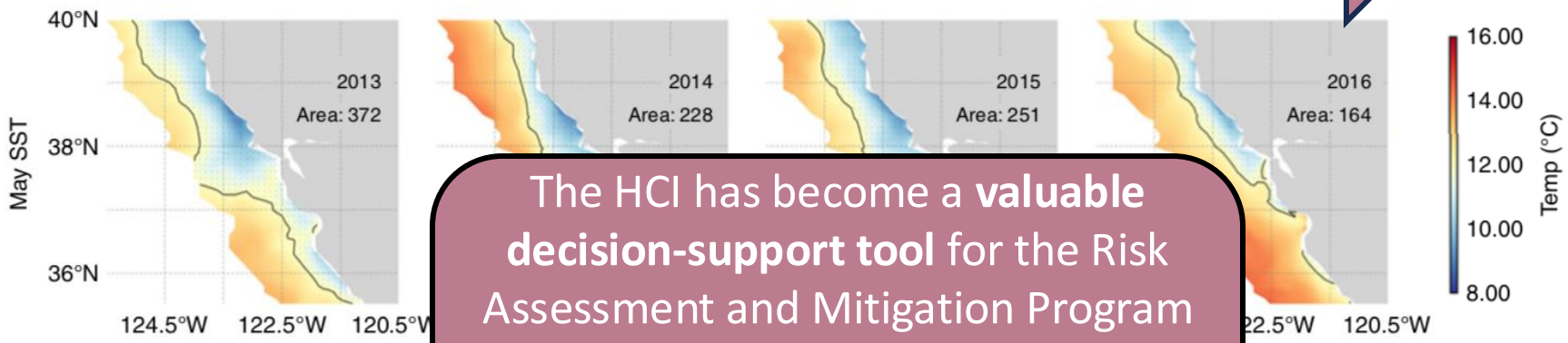
2016

Time

Forms in the Gulf of Alaska

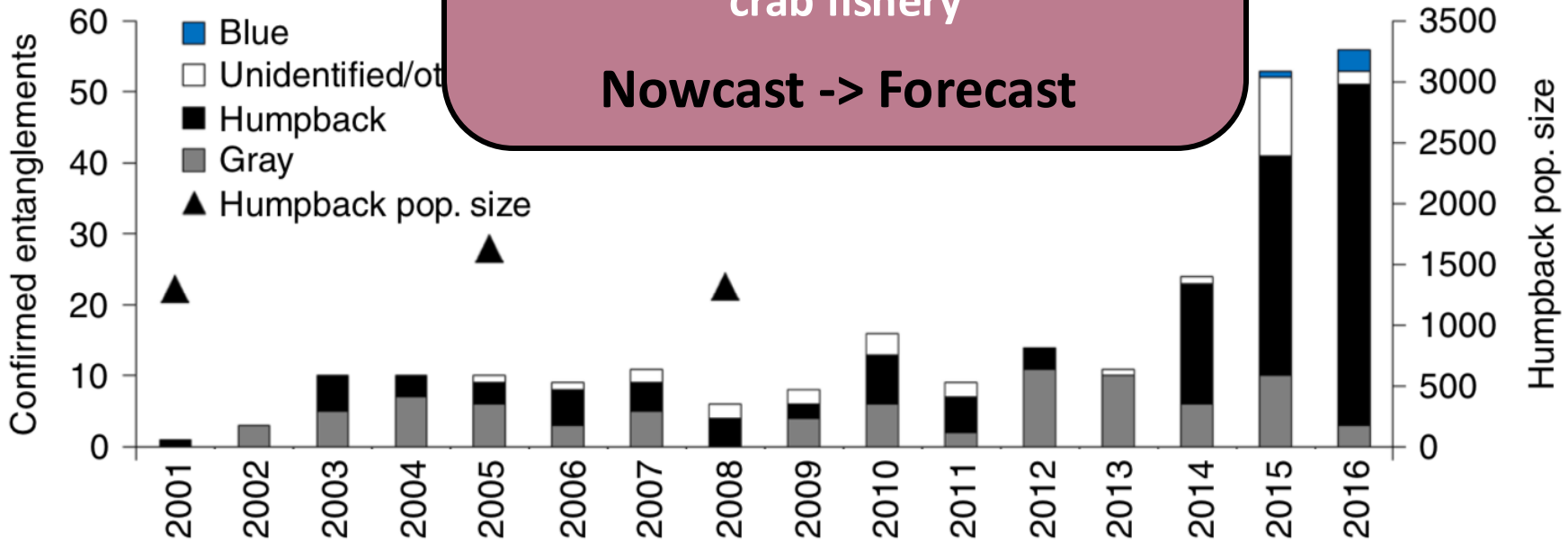
Expands to reach U.S. West Coast

Amplified by a strong El Niño



The HCI has become a **valuable decision-support tool** for the Risk Assessment and Mitigation Program (RAMP) regarding **closures of the crab fishery**

Nowcast -> Forecast

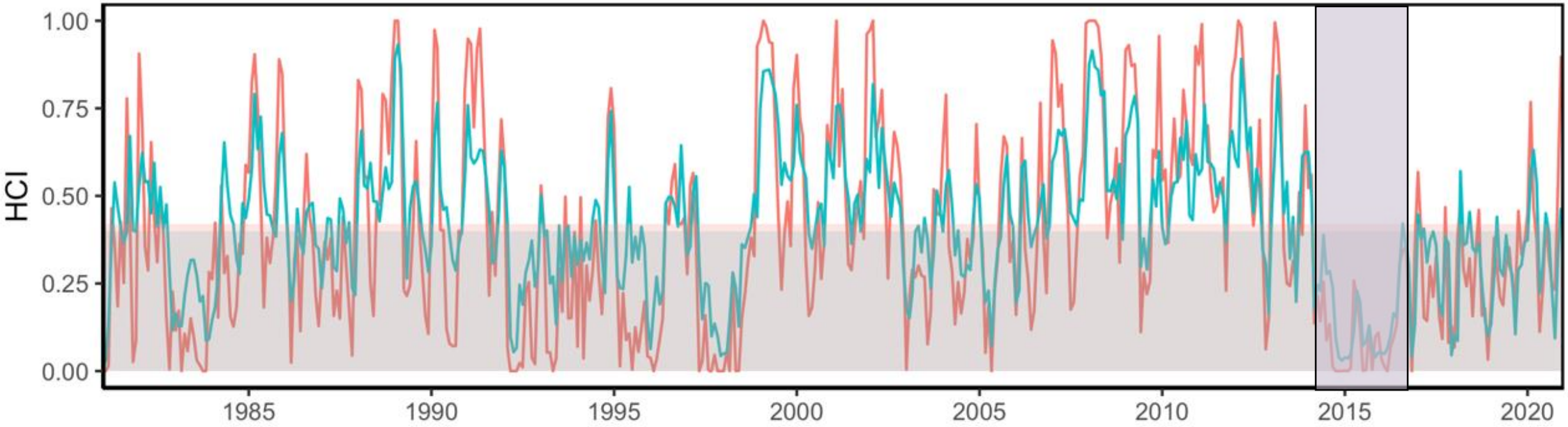


Santora et al 2020. Nat Comms

Seasonal forecasts of the HCI

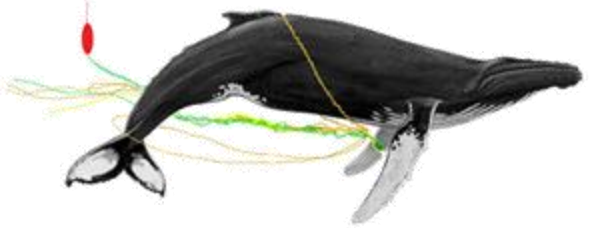
Observed
Forecast

Habitat Compression Index (1-month forecast)



- **94%** of forecasts **correctly** identified high habitat compression Mar 2014–Dec 2016

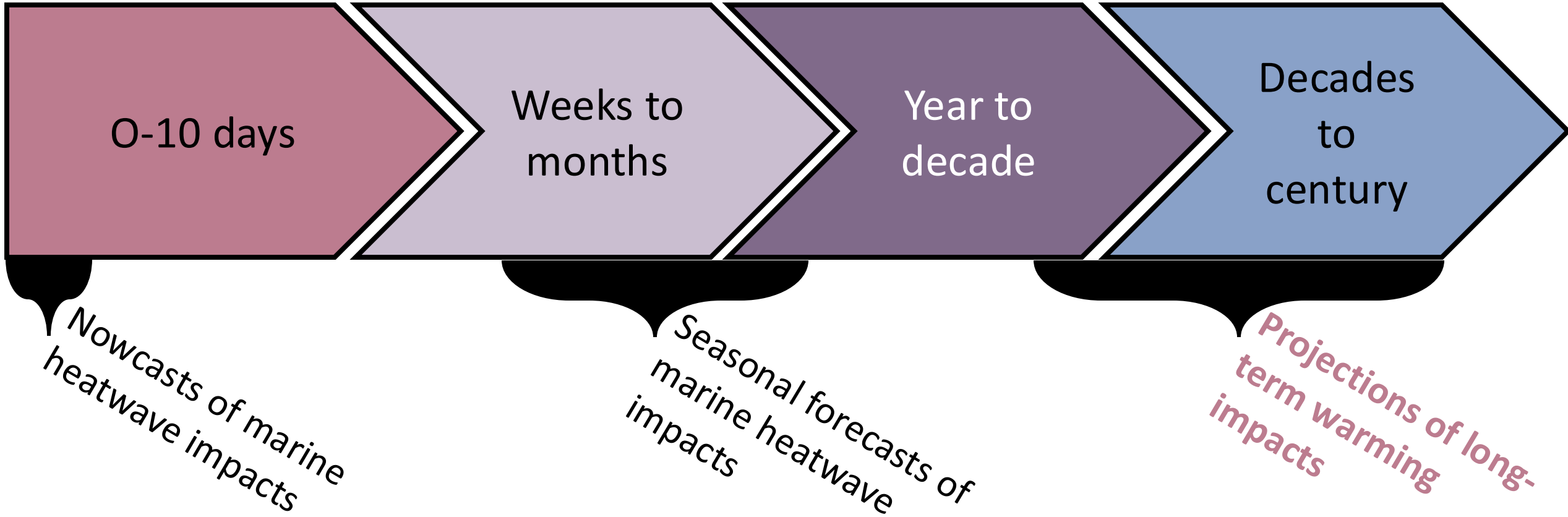
- HCI forecasts **correctly predicted** high compression during Mar 2014–Dec 2016 up to **11.5 months in advance**



Brodie et al 2023. Nat Comms

Accurate predictions across multiple time-scales are needed to support climate-ready decision-making

Three California Current case-studies:



Background Projections

Species Distribution Model outputs

Three high-resolution (~10 km) downscaled ocean models under the high emissions scenario (RCP8.5)

Daily Habitat Suitability (HS) (1980-2100)

Changes in suitability

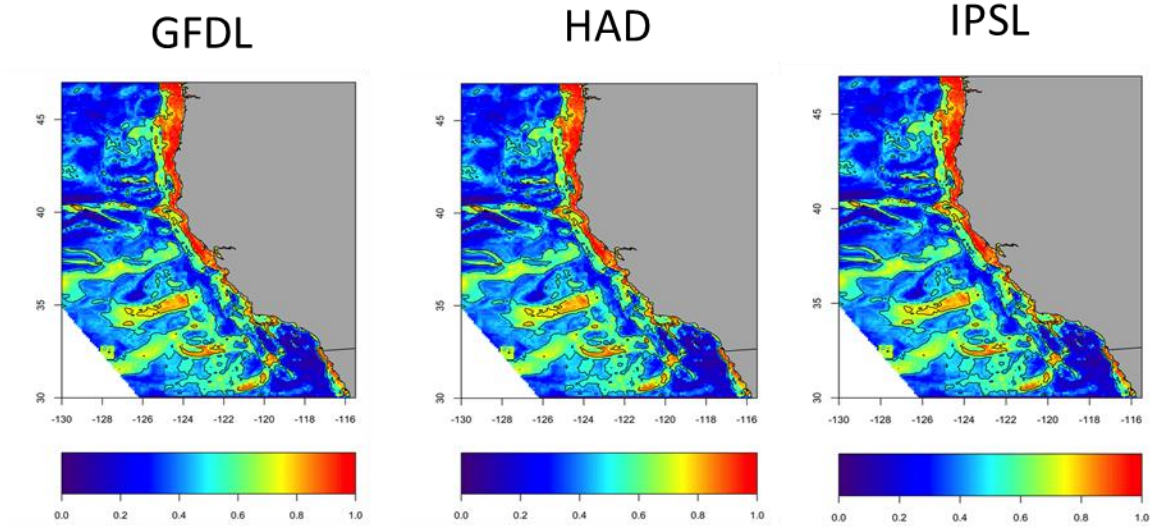
Distance Direction

National Marine Sanctuary Refugia/Bright Spots

A Dynamically Downscaled Ensemble of Future Projections for the California Current System

Mercedes Pozo Buil[1,2], Michael G. Jacox[1,2,3], Jerome Fiechter[4], Michael A. Alexander[3], Steven J. Bograd[1,2], Enrique N. Curchitser[5], Christopher A. Edwards[4], Ryan R. Rykaczewski[6] and Charles A. Stock[7]*

[1] Institute of Marine Science, University of California, Santa Cruz, Santa Cruz, CA, United States, [2] NOAA Southwest Fisheries Science Center, Monterey, CA, United States, [3] NOAA Earth System Research Laboratory, Boulder, CO, United States, [4] Ocean Sciences Department, University of California, Santa Cruz, Santa Cruz, CA, United States, [5] Department of Environmental Sciences, Rutgers University, New Brunswick, NJ, United States, [6] NOAA Pacific Islands Fisheries Science Center, Honolulu, HI, United States, [7] NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ, United States



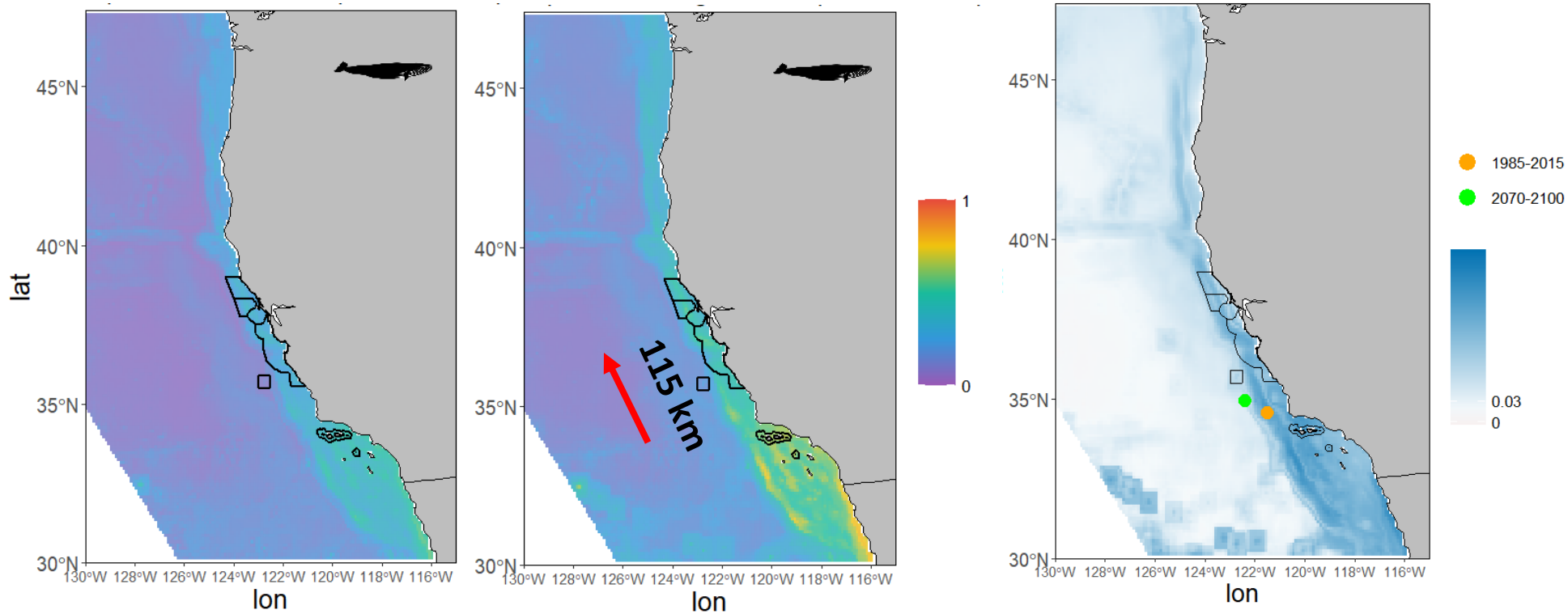
Results 1. Project blue whale distribution

Habitat suitability CCE

Historical (1985-2015)

Future (2070-2100)

Future minus historical



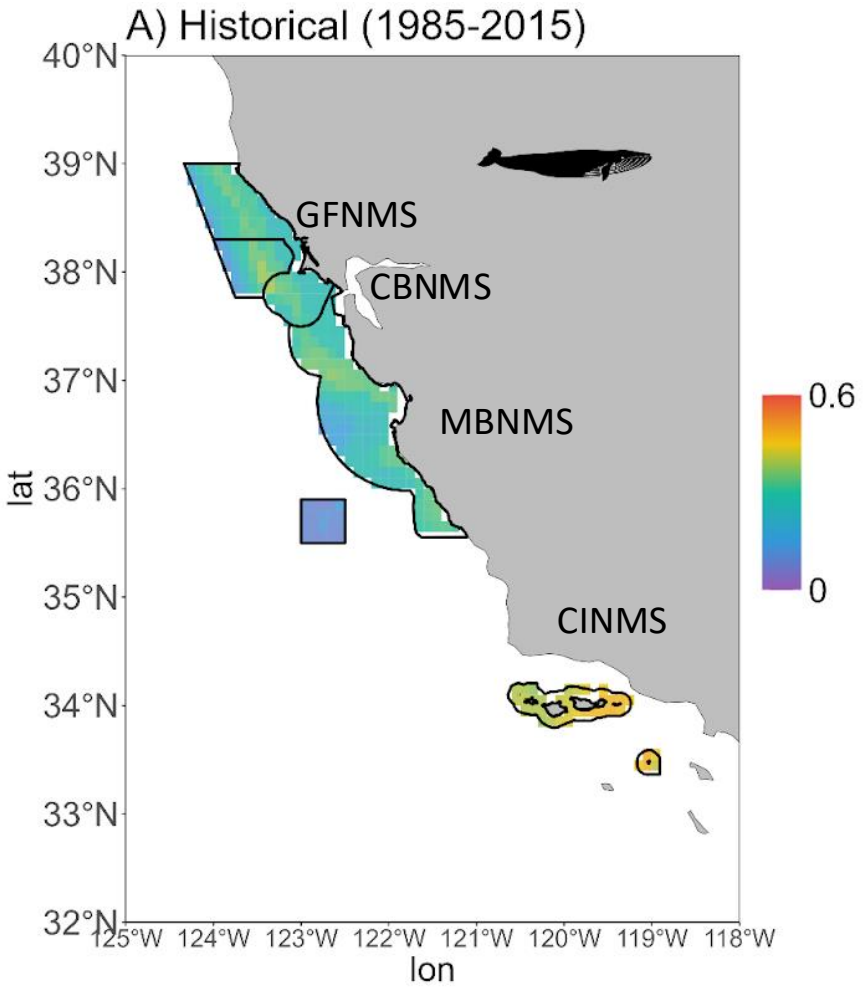
Lezama-Ochoa et al., 2024 (in prep.)

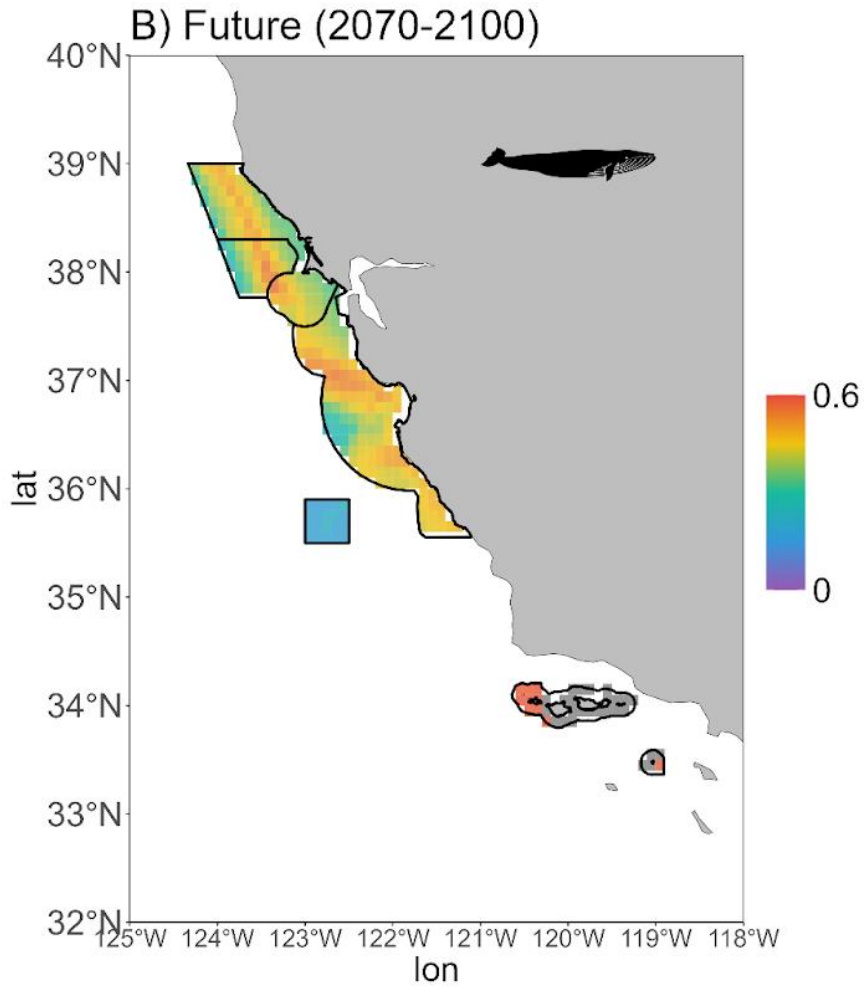
Results

1. Project blue whale distribution

Habitat suitability CCE

Habitat suitability NMS
+42%





Lezama-Ochoa et al., 2024 (in prep.)

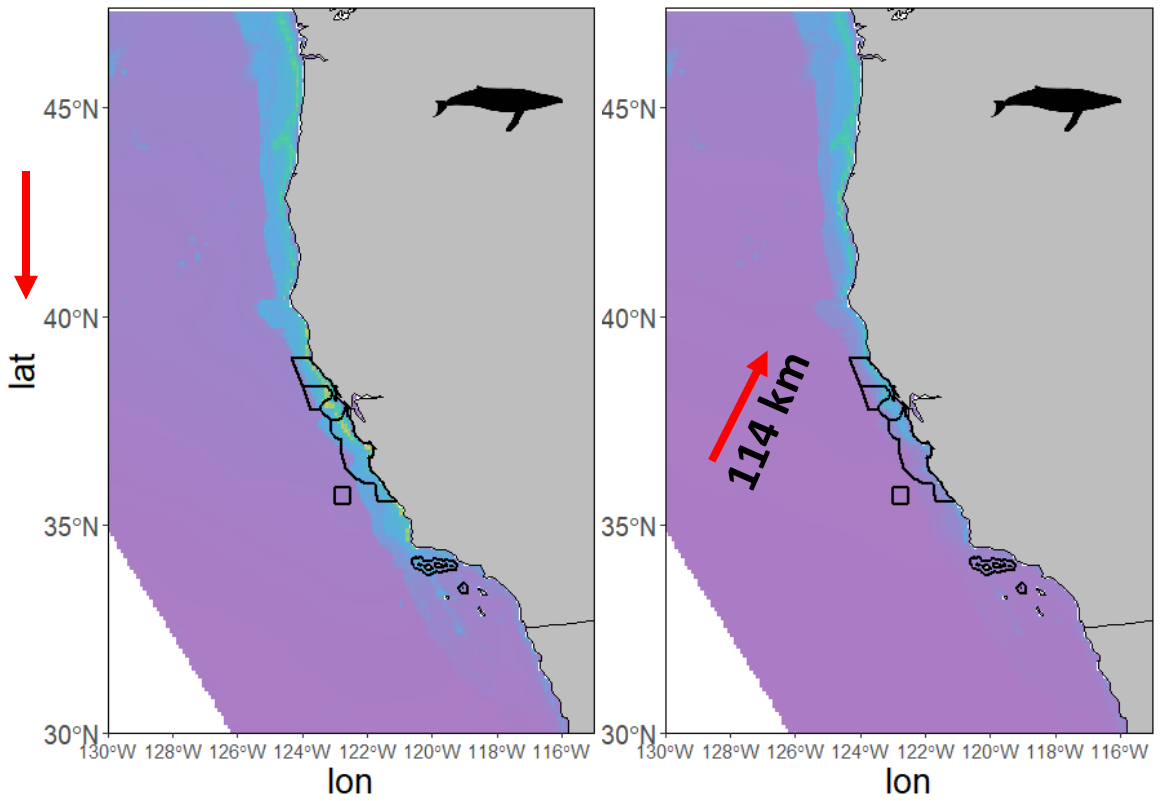
Results 1. Project humpback whale distribution

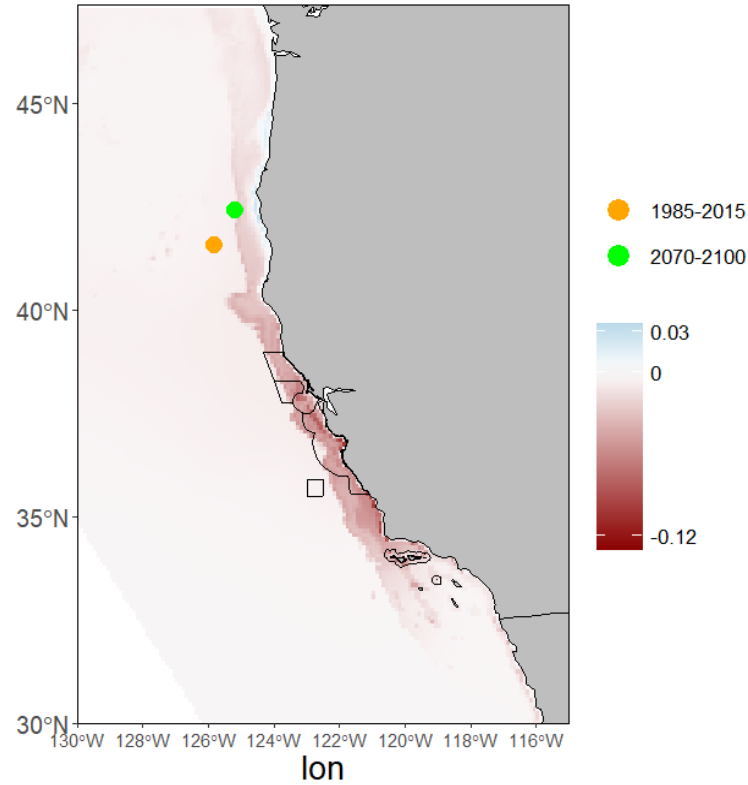
Habitat suitability CCE

Historical (1985-2015))

Future (2070-2100)

Future - historical





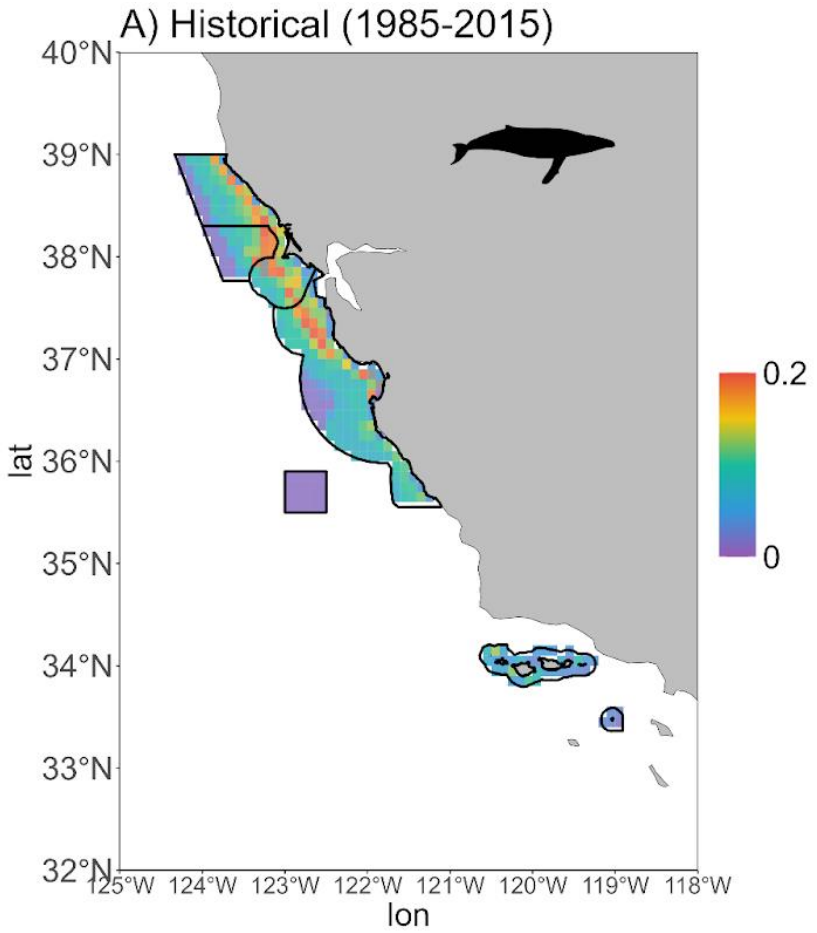
Lezama-Ochoa et al., 2024 (in prep.)

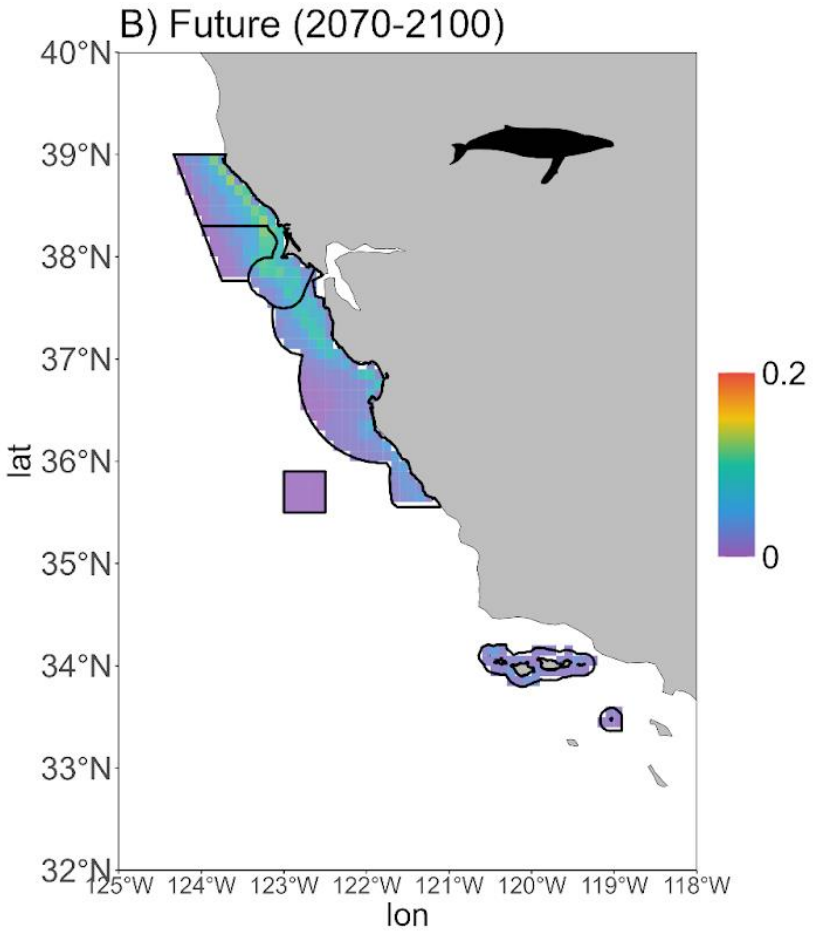
Results

1. Project humpback whale distribution

Habitat suitability CCE

Habitat suitability NMS
-40%

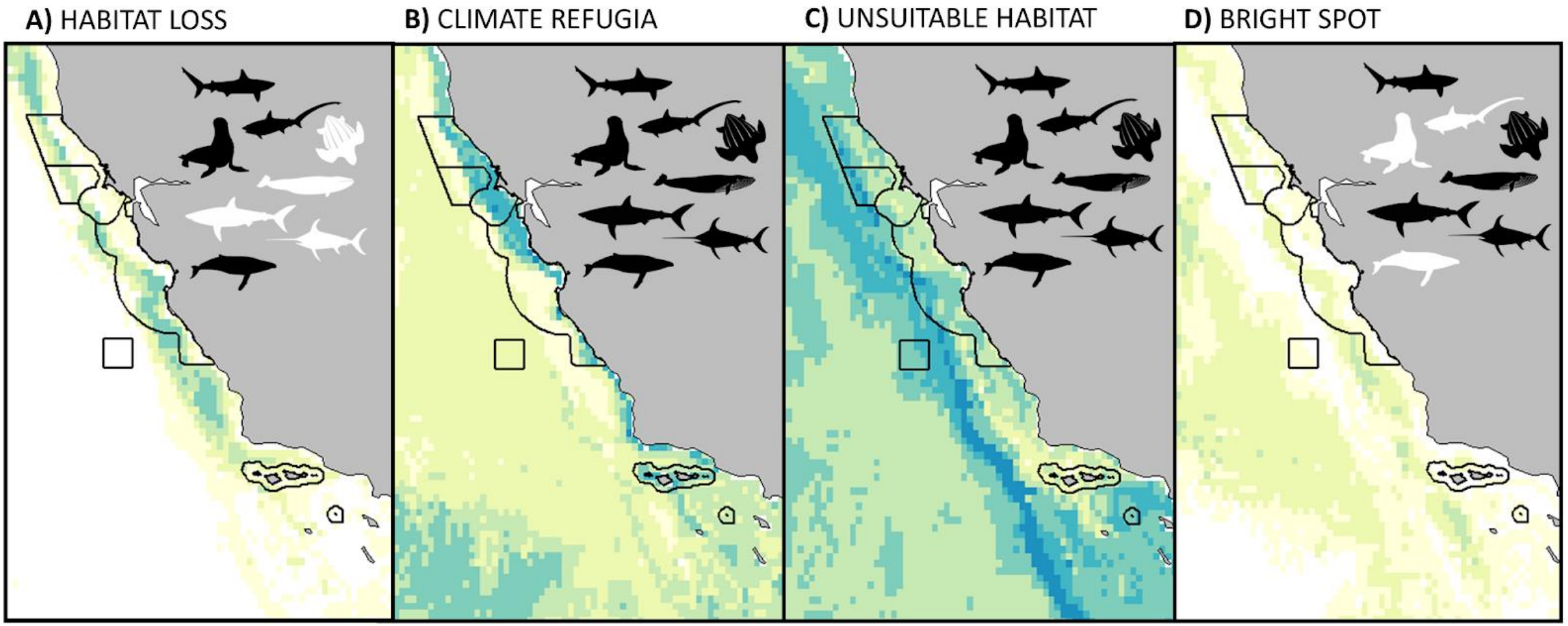




Lezama-Ochoa et al., 2024 (in prep.)

Results

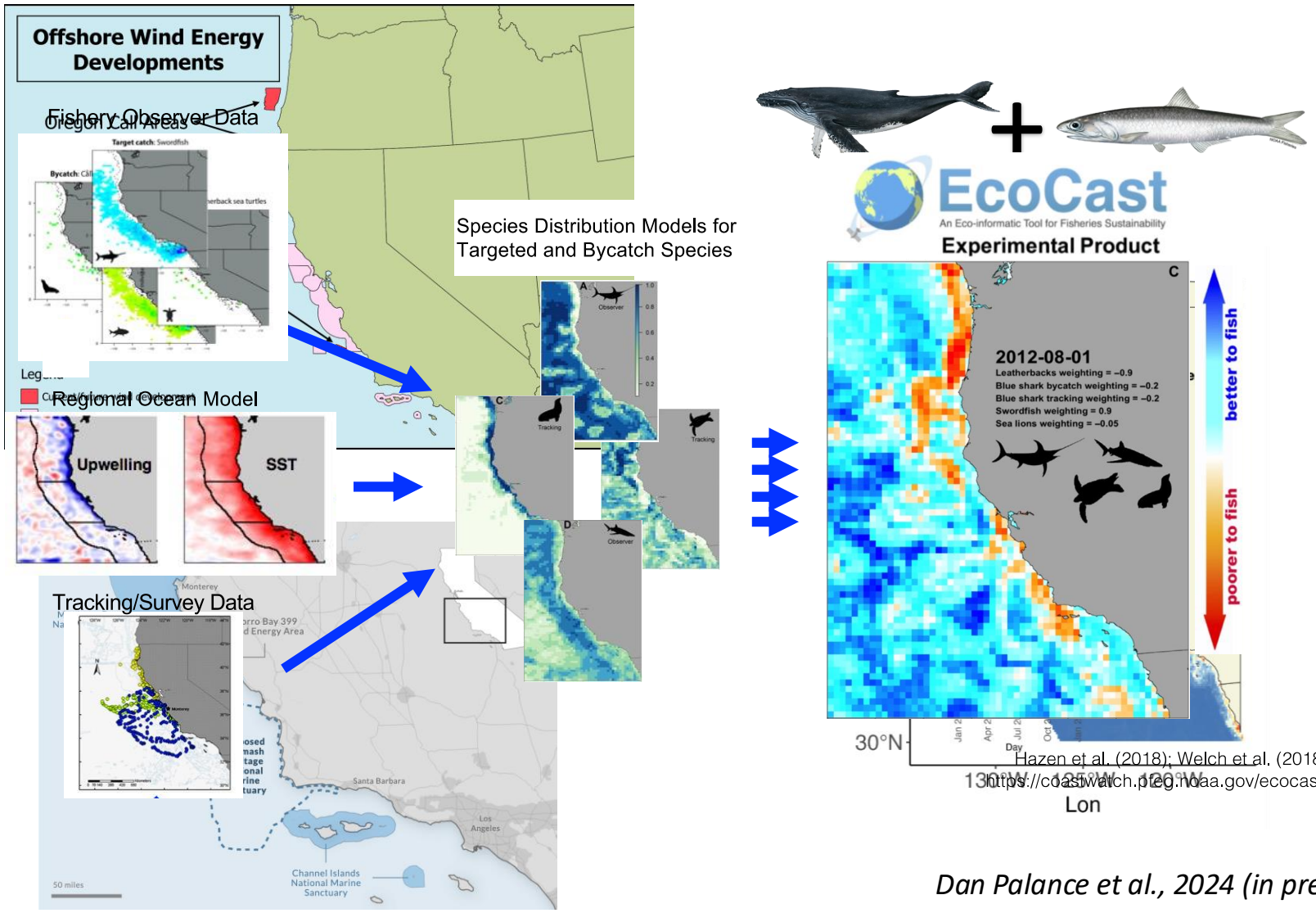
2. Identify climate refugia & bright spots



Applications

Marine Spatial Planning

- Spatial closures (fisheries)
- National Marine Sanctuaries
- Chumash designation planning
- Long term planning & development (WEIAs)
- Overlap between predators-prey
- Informing ecosystem models

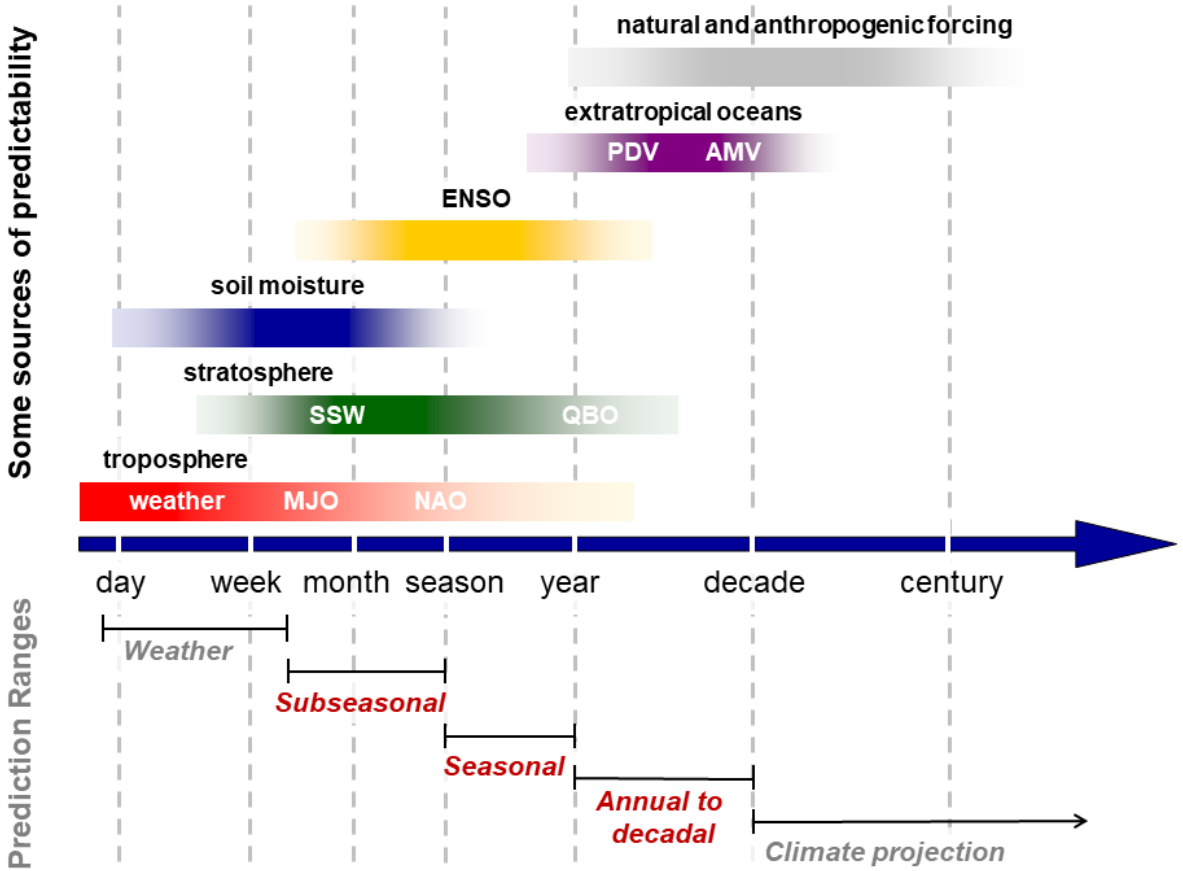


Dan Palance et al., 2024 (in prep.)

Conclusions

We **can** build an integrated portfolio across scales to improve our ability to assess climate variability & change.

Atmospheric predictability



Merryfield et al. 2020

Conclusions

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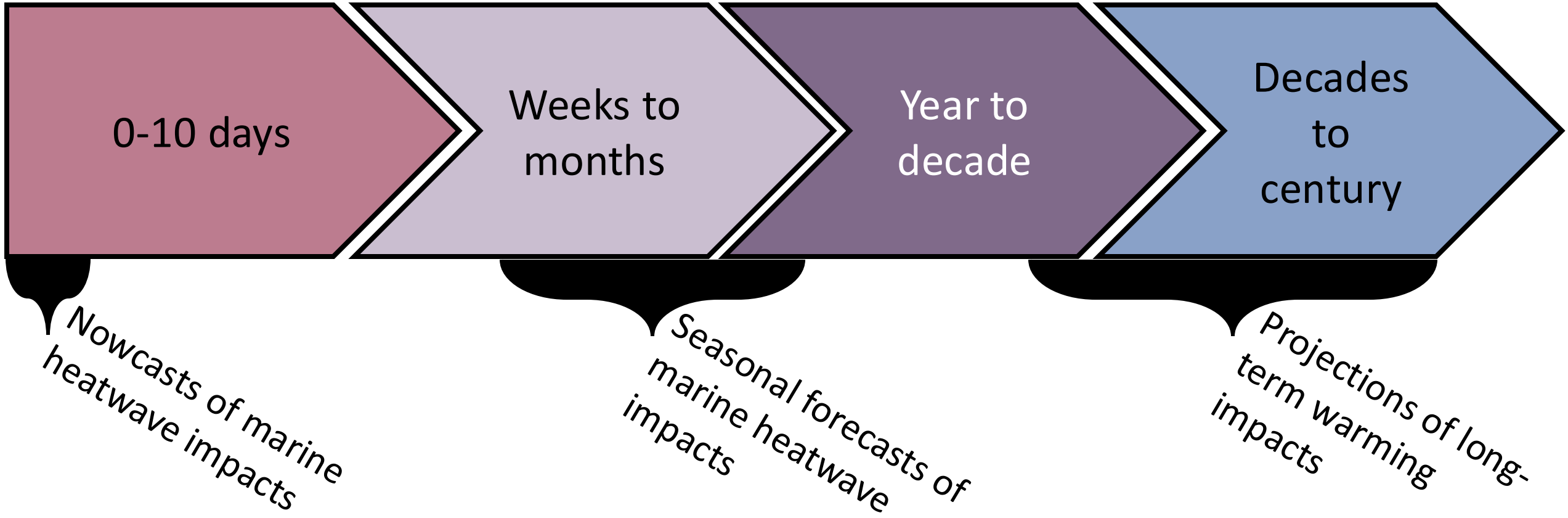

Thanks!

Heather Welch SWFSC

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CINMS

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CINMS

Briana Abrahms UW

Scott Benson
SWFSC

Nerea Lezama Ochoa UCSC

Steven Bograd SWFSC

Danielle Lipski
CBNMS

Owen Liu
NWFSC

Barbara Muhling
SWFSC

Karin Forney
SWFSC

Mercedes Pozo Bui
UCSC-NOAA

Jameal Samhouri
NWFSC

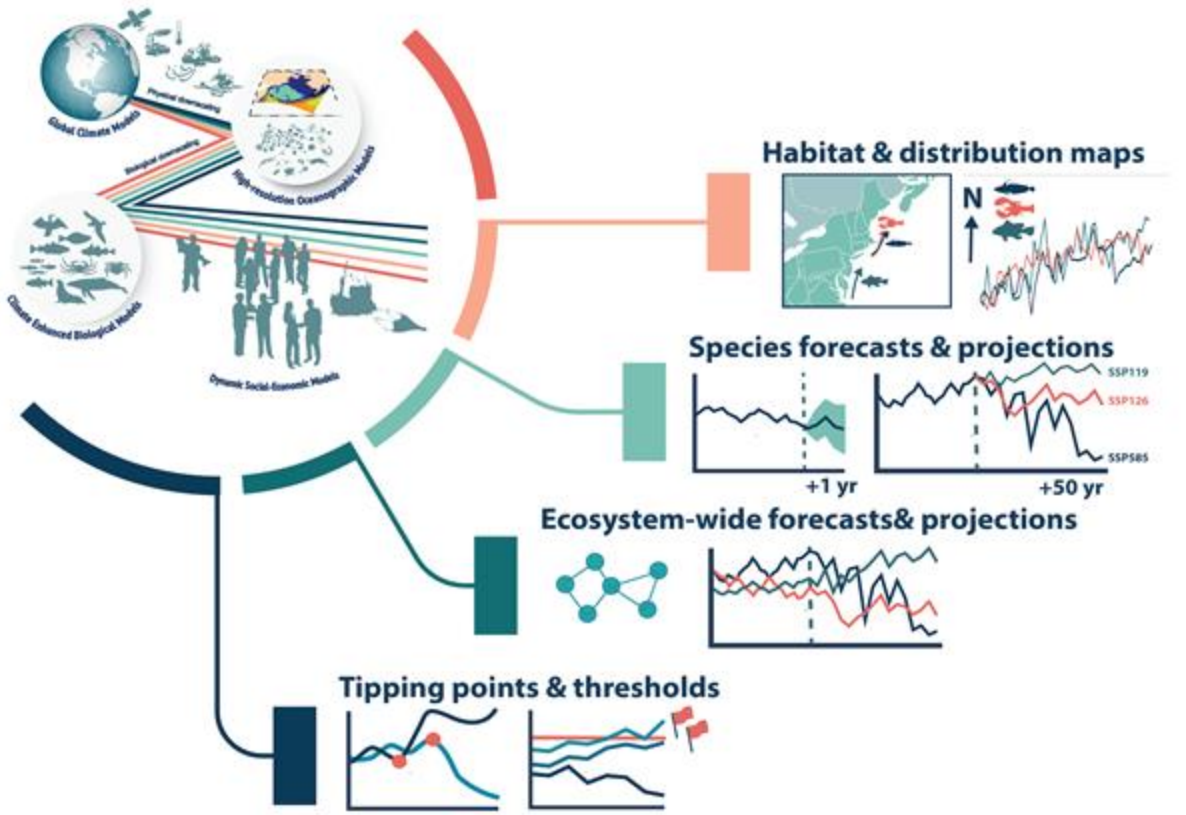
….and many more

Elliott.hazen@noaa.gov

Climate, Ecosystems, and Fisheries Initiative (CEFI): forecasts in support of fisheries management and adaptation strategies

- Provide a national capacity for sustained provision of regional ocean and climate information **across LMR management time scales.**

Ocean Predictions **Decision Support Teams**



Slide from Cisco Werner