Application of ROMS-BEC to investigate the effects of anthropogenic nutrient inputs

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On behalf of colleagues from:

Is nutrient management a solution worth considering?

- California is investing in strategies to mitigate effects of climate change
  - Reducing land-based nutrient inputs was identified as one strategy to address ocean acidification and hypoxia
- What tools can be used to evaluate solutions prior to implementation?
  - Here, we applied ROMS-BEC to evaluate these management questions

Goals of talk

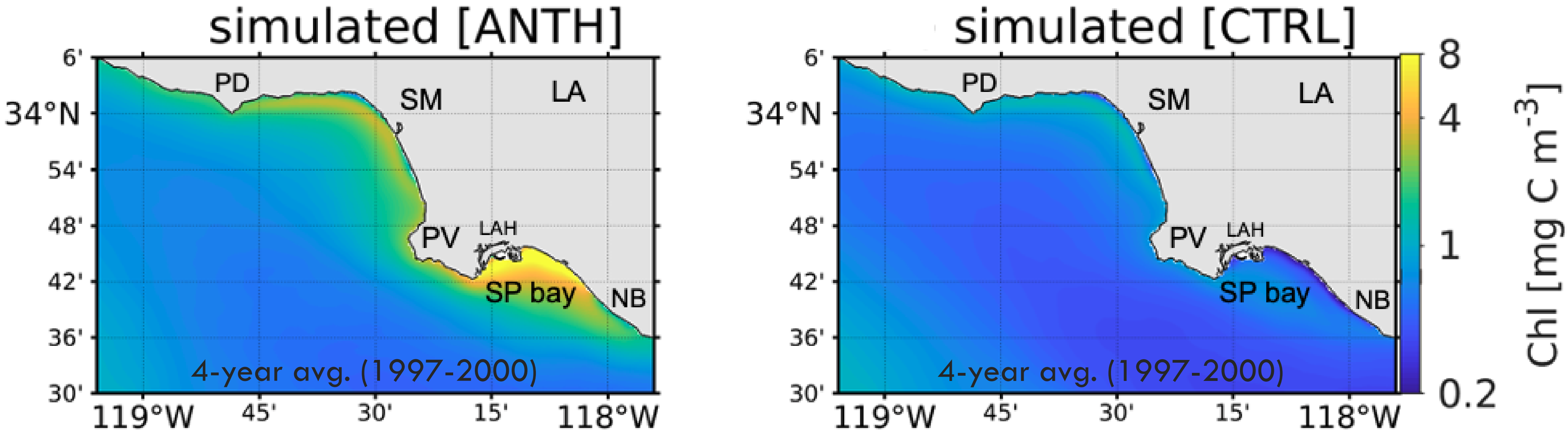
Present the Findings for Three Management Questions

- What are the effects of anthropogenic nutrients on seawater chemistry?
- How do those changes translate to biological effects?
- How do outcomes change with nutrient management scenarios?

Provide an Overview of Ongoing Work

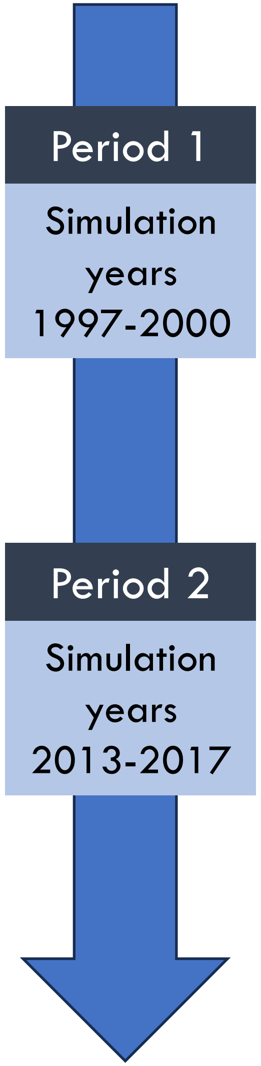
How is ROMS-BEC used to predict the biogeochemical effects of land-based nutrients?

Approach: Assess the difference between two scenarios: (1) with land-based nutrient inputs (ANTH) and (2) no land-based nutrient inputs (CTRL)



- River inputs
- Outfalls
- N deposition

Applied this change assessment approach across two time periods



__Chemical Changes__

Kessouri et al. 2021 PNAS
doi.org/10.1029/2020MS002296

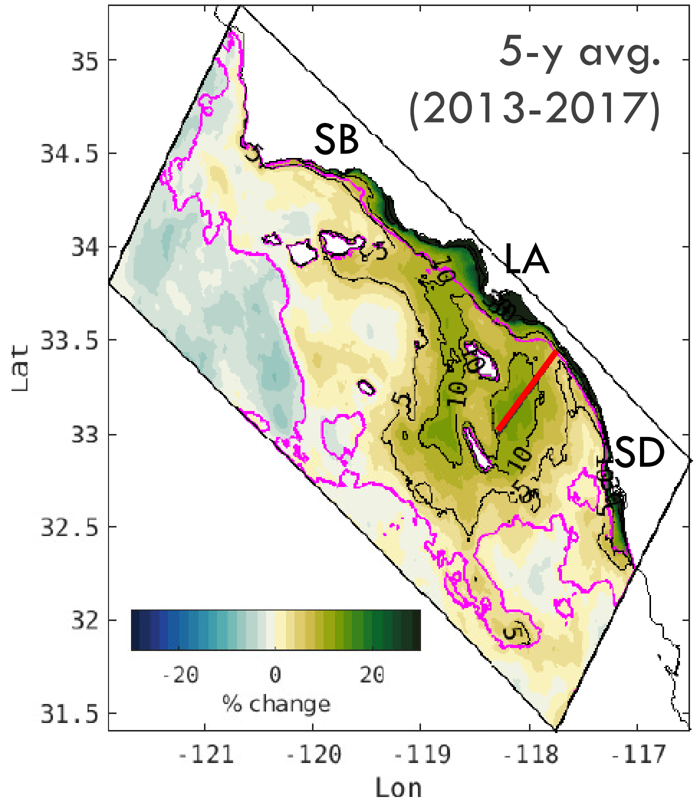
Kessouri et al. (In Review) Scientific Reports
doi.org/10.21203/rs.3.rs-2693479/v1 (preprint)

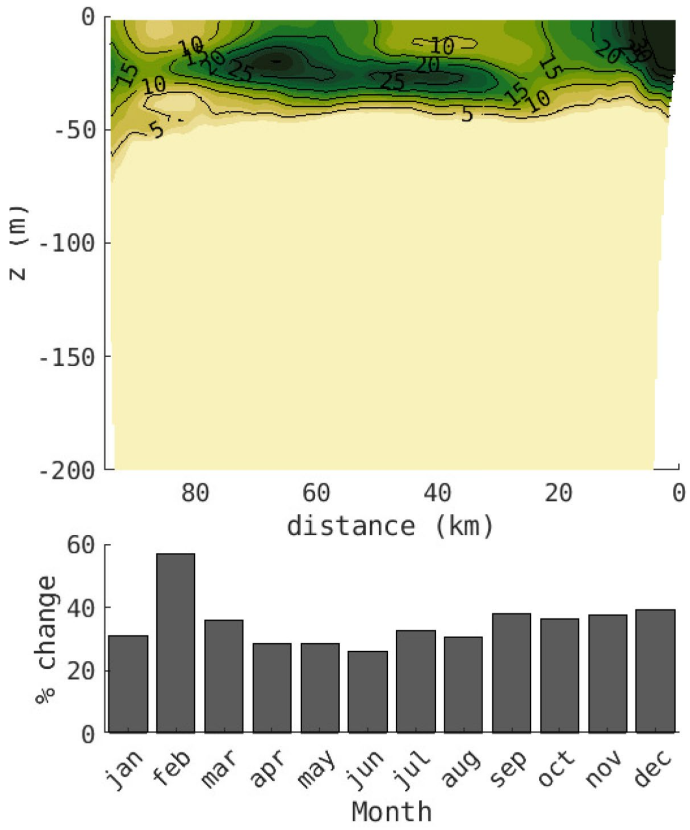
__Habitat Changes__

Frieder et al. (In Review) Scientific Reports
doi.org/10.22541/essoar.167870388.82984110/v1 (preprint)

Model predicts that anthropogenic nutrients lead to persistent increase in algal biomass

% Change in Algae Biomass
(ANTH-CTRL)/CTRL





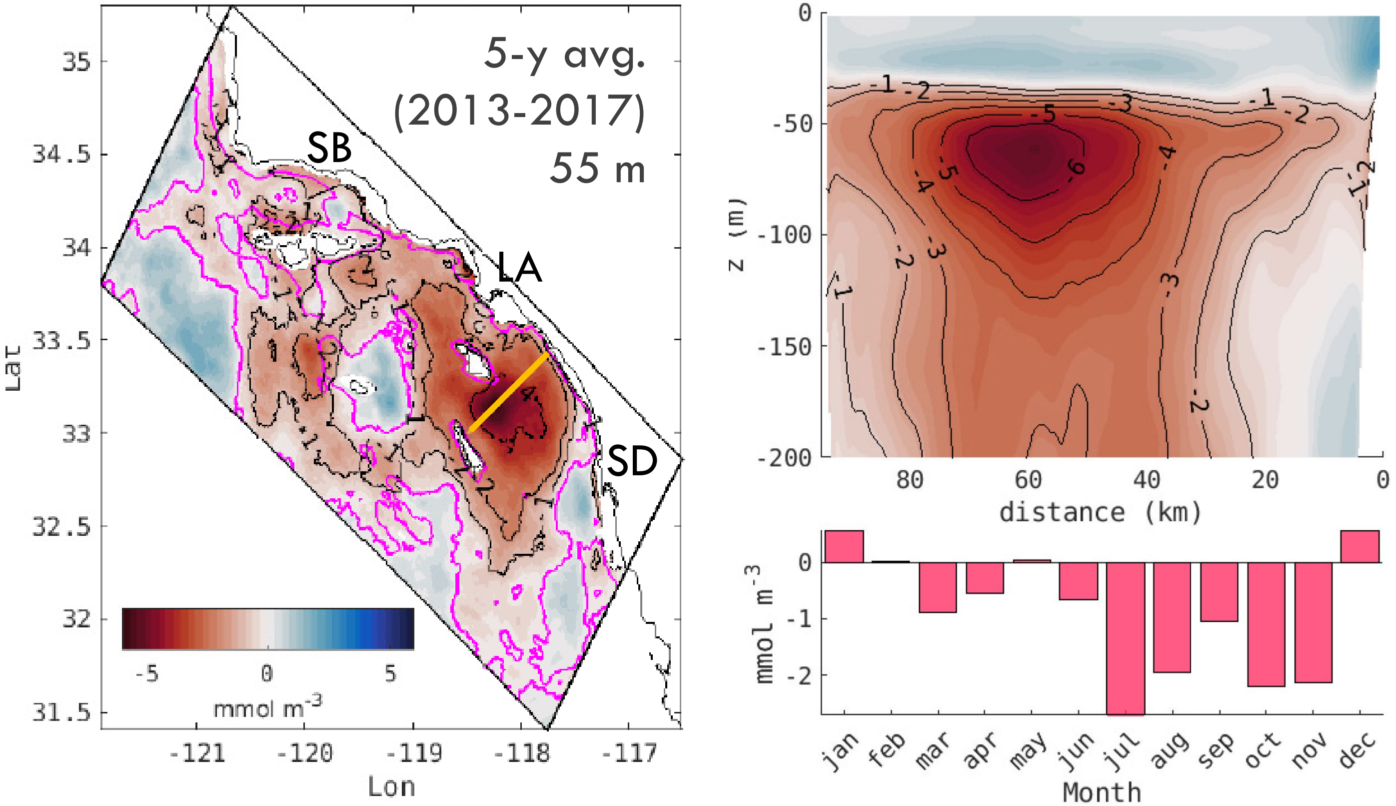
- Effect most pronounced along the coast
- Within upper mixed layer (cross-shore transect in red)
- All year

Concomitant subsurface acidification and oxygen loss, most pronounced offshore and seasonally

Pathways confirmed

- Cross-shore transport advects inorganic and organic matter away from the coast
- Recurrent eddies trap material
- Enhanced remineralization leads to subsurface oxygen loss and acidification

Change in O_2
(ANTH-CTRL)



Q2: How do these changes translate to biological effects?

Applied biological translation toolkit for both oxygen loss and acidification

- Recap of thresholds
- Findings of change assessment
- Sensitivity tests

Assess two sentinel organisms to predict biological effects for epipelagic habitat

For OA, we used pteropods

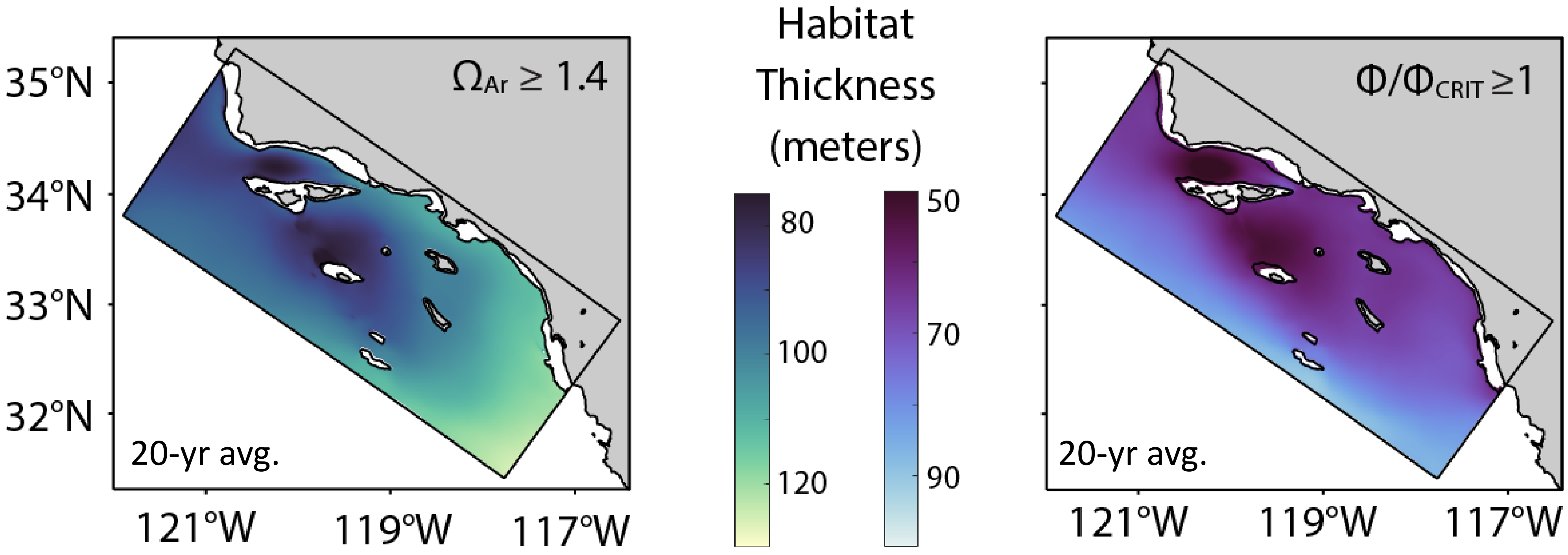
For O_2, we used Metabolic Index for northern anchovy

<u>Thresholds</u>

- Sublethal, Ω_{Arag} = 1.4
- Lethal, Ω_{Arag} = 1.0

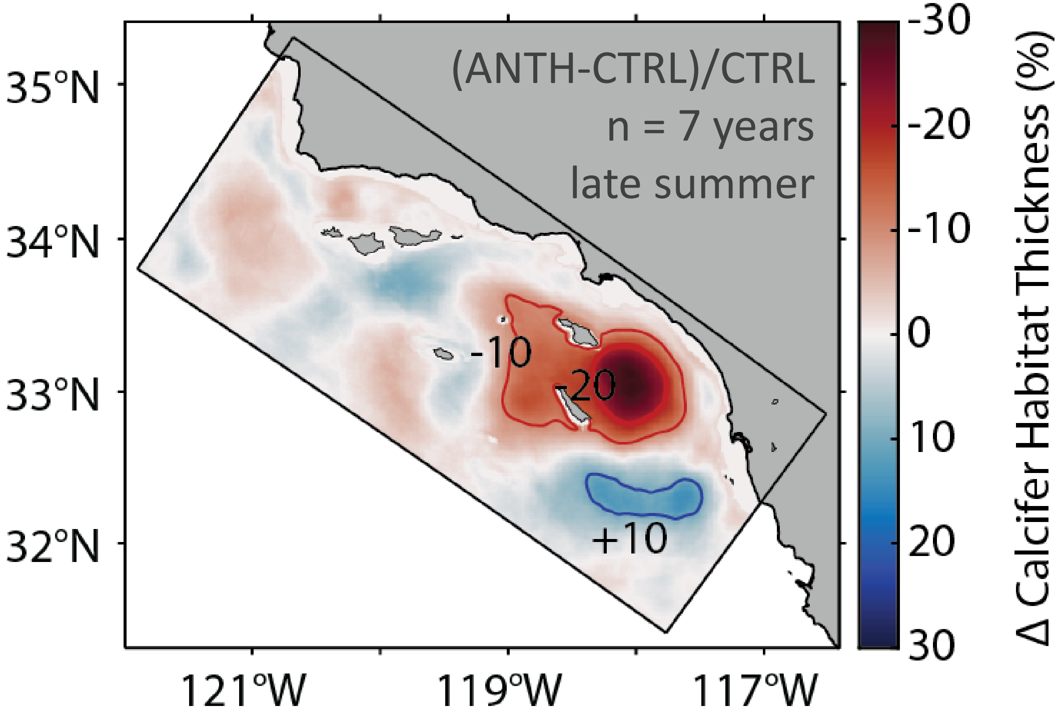
- Sublethal, Φ_{CRIT}
- Lethal, Φ = 1

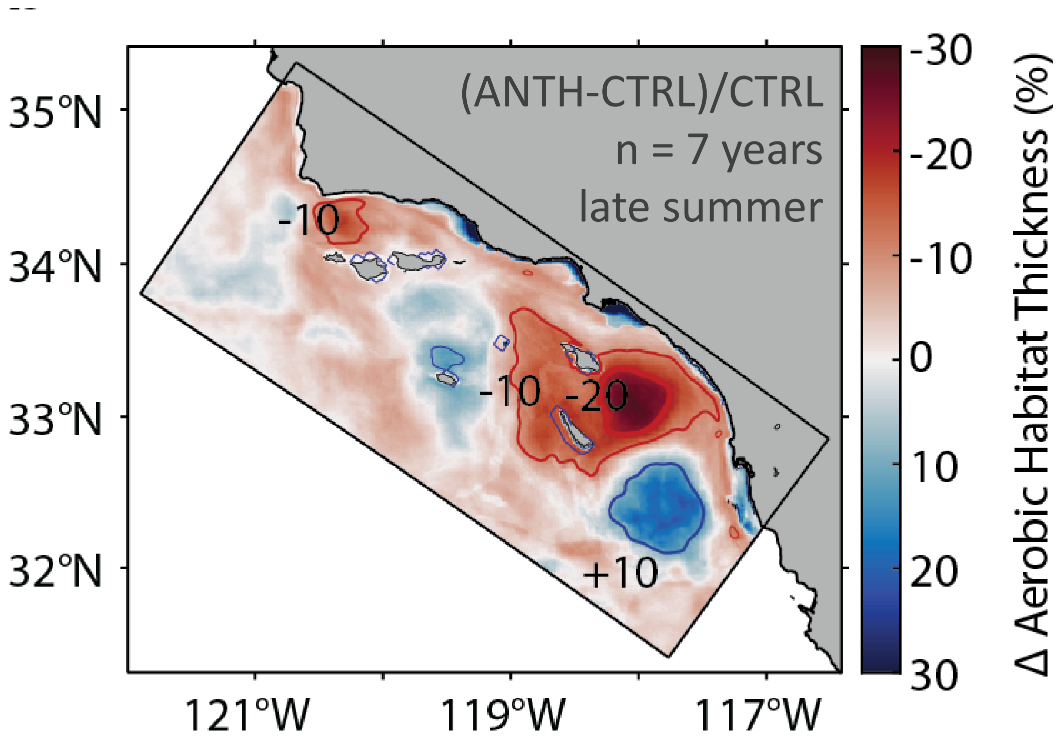
While lethal thresholds are rarely triggered in the epipelagic, sublethal thresholds are pervasive



Model predicts habitat compression of sublethal thresholds. This is not a Bight-wide, nor persistent, feature.

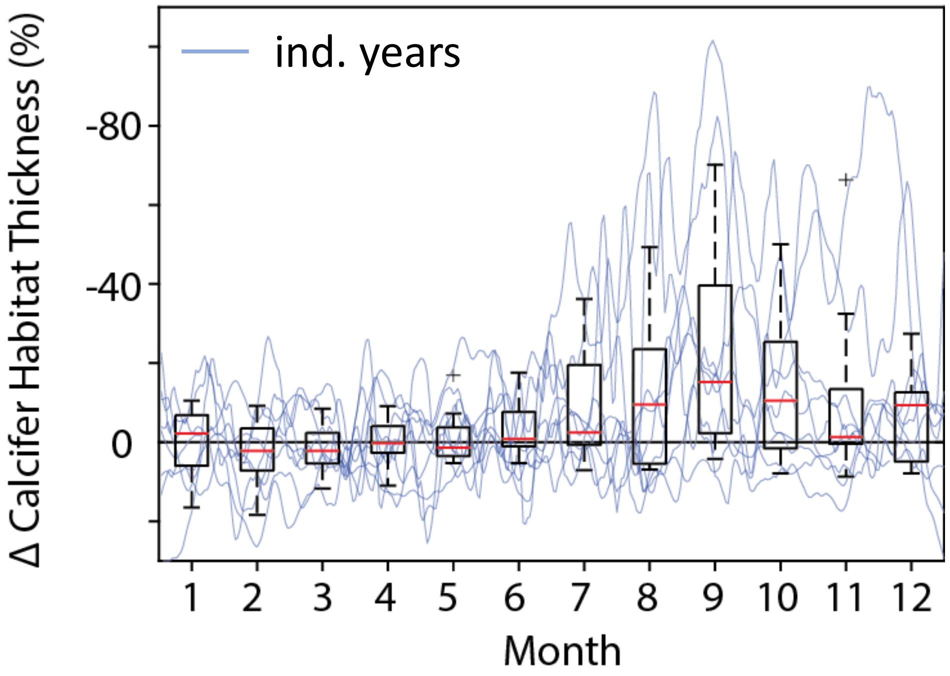
- Region of recurrent habitat compression southeast of Catalina Island, thousands of km^2 in size

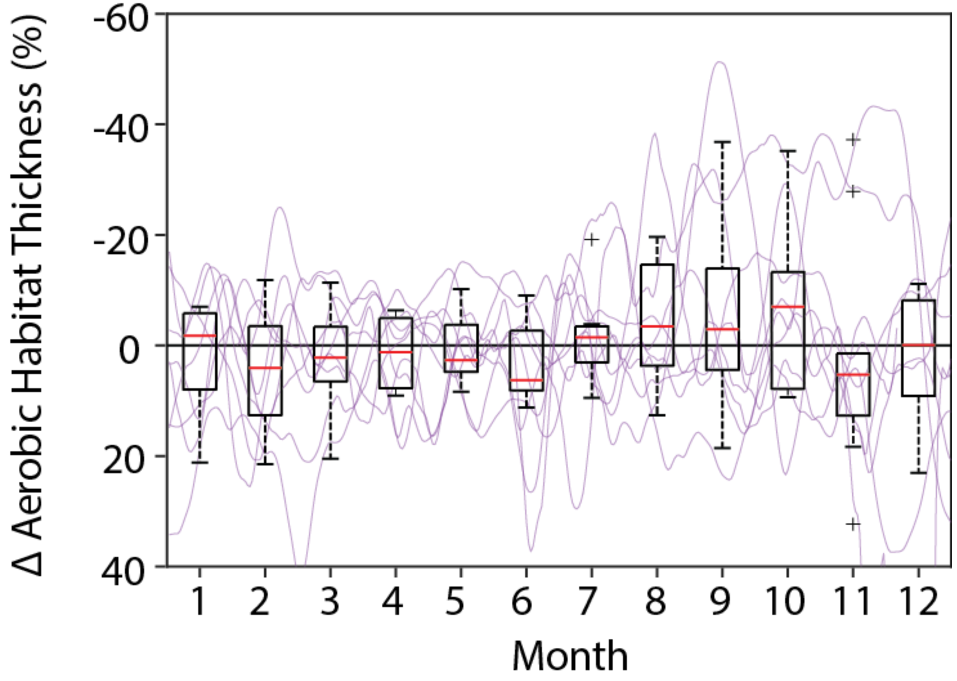




Where it occurs, habitat compression is a seasonal phenomenon

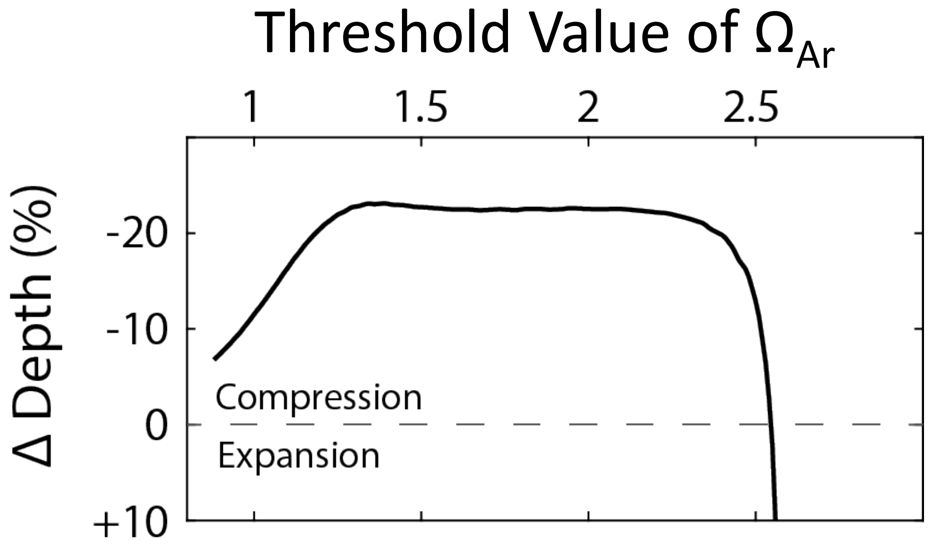
- Coincides with seasonality of natural compression, late summer to early fall



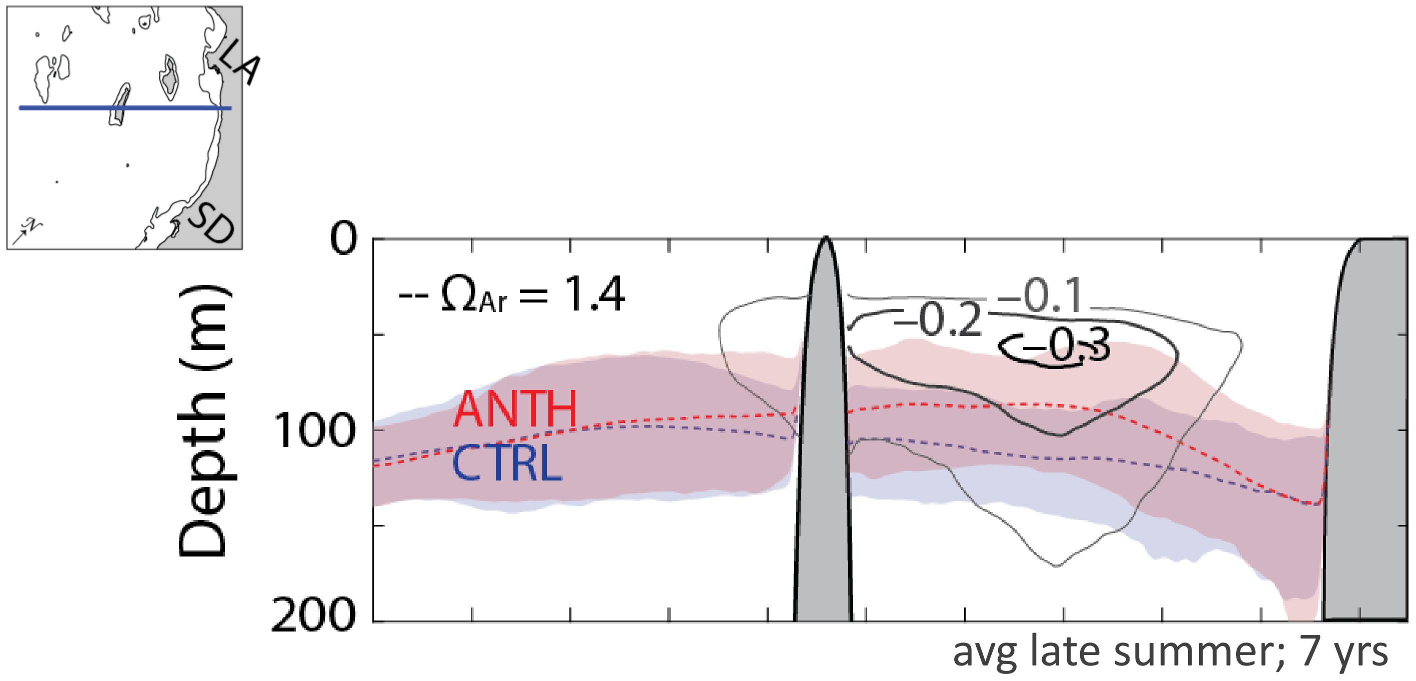


Habitat change assessment is minimally sensitive to choice of acidification threshold value

- 20% vertical reduction in habitat consistent across a broad range of Ω_{Ar} values; [1.2 – 2+]



Changes in chemistry occur across a broad depth range, encompassing range of Ω_{Ar} values

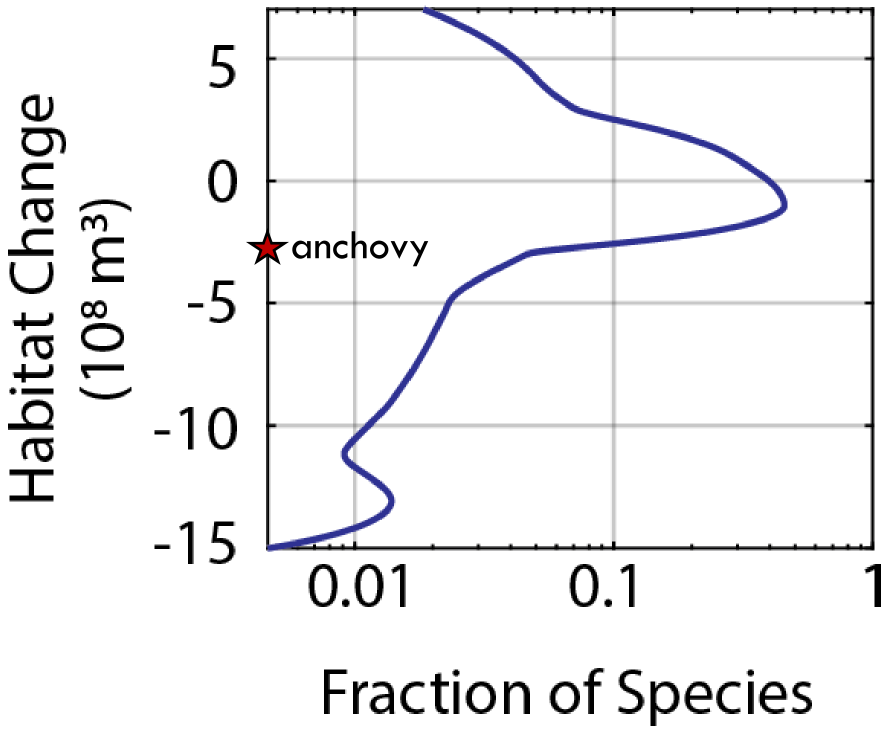


- Grey contours show chemical changes (Δ_{Ar} = ANTH – CTRL)
- Depth of habitat metric shown in red (ANTH) and blue (CTRL)

The loss in aerobic habitat predicted for northern anchovy is consistent with prediction for most species

- Compare the outcome for northern anchovy with the full suite of measured marine metabolic traits

- In this case, majority of species are losing habitat, while a few are gaining



Q3. Can nutrient management scenarios modify outcomes of ANTH?

Ho et al. 2023 Scientific Reports
https://doi.org/10.1038/s41598-023-48588-2

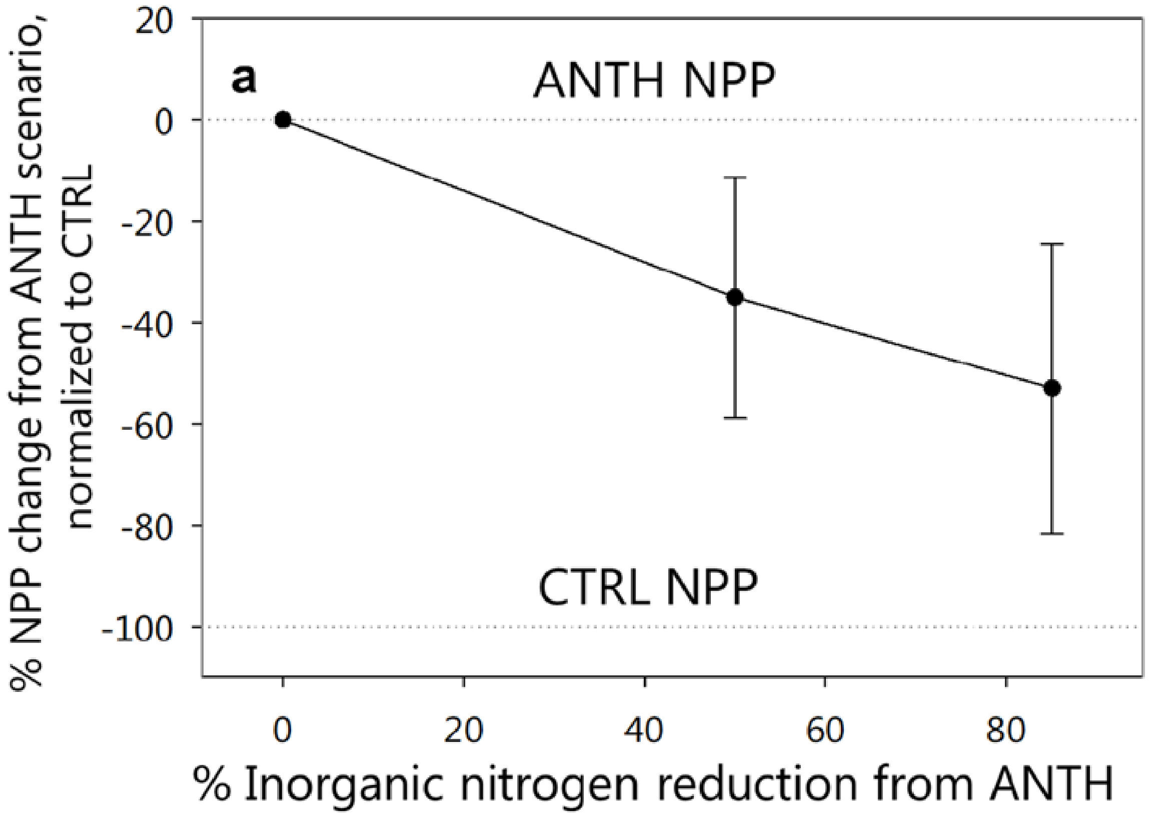
- Perform an additional set of scenarios to identify if decreasing outfall inorganic nitrogen loading influences effects
  - First, evaluate how reducing inorganic nitrogen loads modifies effects alone
  - Second, consider potable water recycling in combination with reducing inorganic nitrogen loads

Two additional scenarios performed. Reductions applied across all ocean outfalls.

Scenario		
Nutrient Management Options	Current loading ~40 mg/L inorganic nitrogen	ANTH
	50% reduction in inorganic nitrogen loading	X
	85% reduction in inorganic nitrogen loading	X

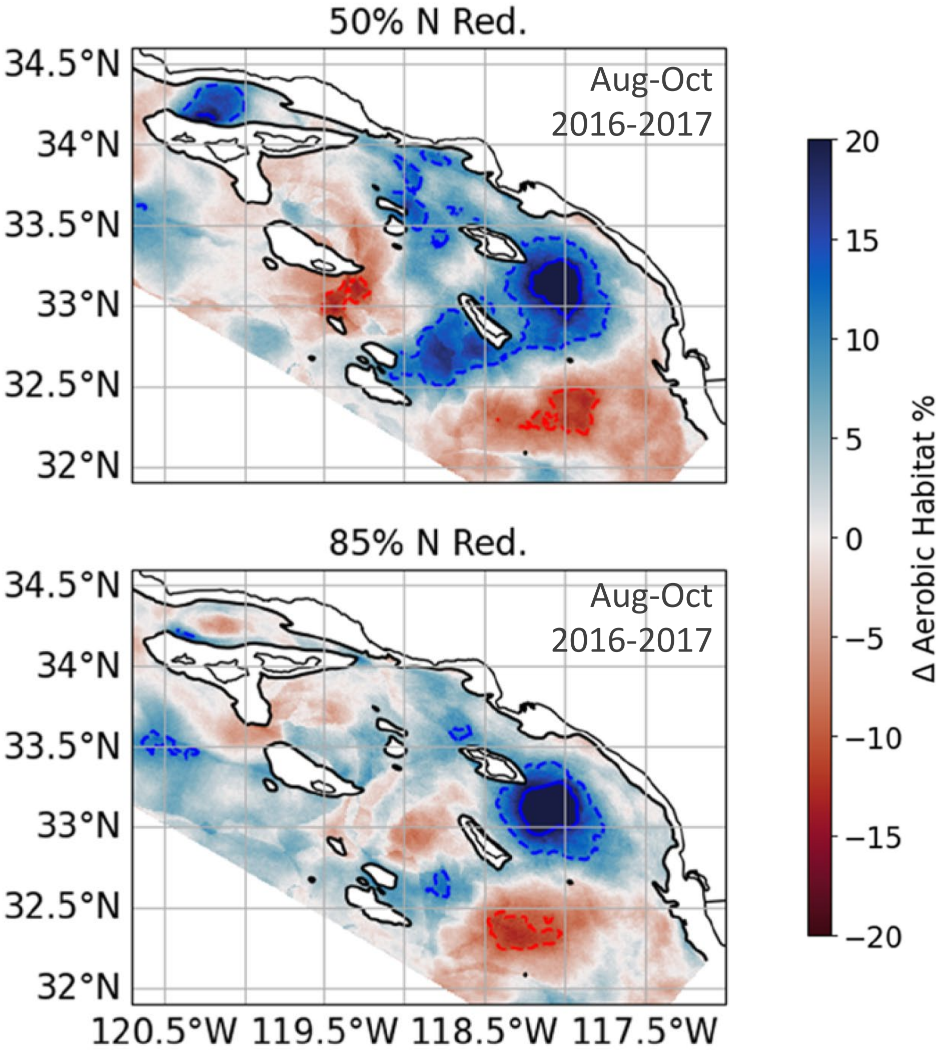
- Changes only made to all outfalls; other inputs (rivers, etc.) held constant
- Four years of simulation for each; [1999-2000; 2016-2017]

Model predicts that reducing nitrogen loading reduces Bight-wide primary production



n = 4 years

That reduction in primary production improves subsurface chemistry and suitable habitat area



- Relative to ANTH
- There is recovery in habitat for region undergoing seasonal compression by full nutrient loads

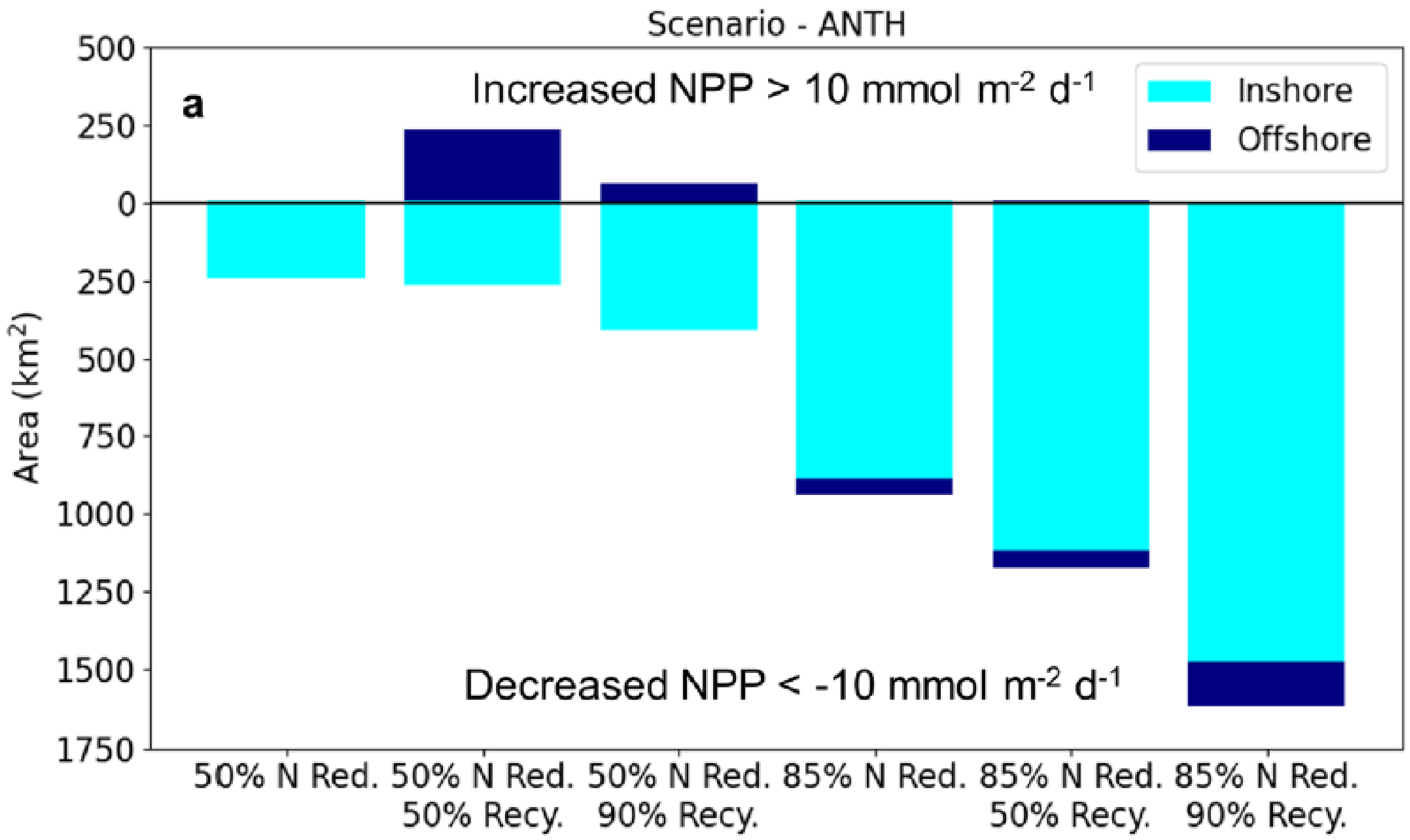
Investments already planned to recycle water as well.

- Are findings from reduced nitrogen loading consistent when water recycling considered as well?

Scenarios		Range of % Outfall Volume Recycled for Potable Reuse		
		0%	50%	90%
Nutrient Management Options	Current loading ~30 mg/L inorganic nitrogen	ANTH		
	50% reduction in inorganic nitrogen loading	X	X	X
	85% reduction in inorganic nitrogen loading	X	X	X

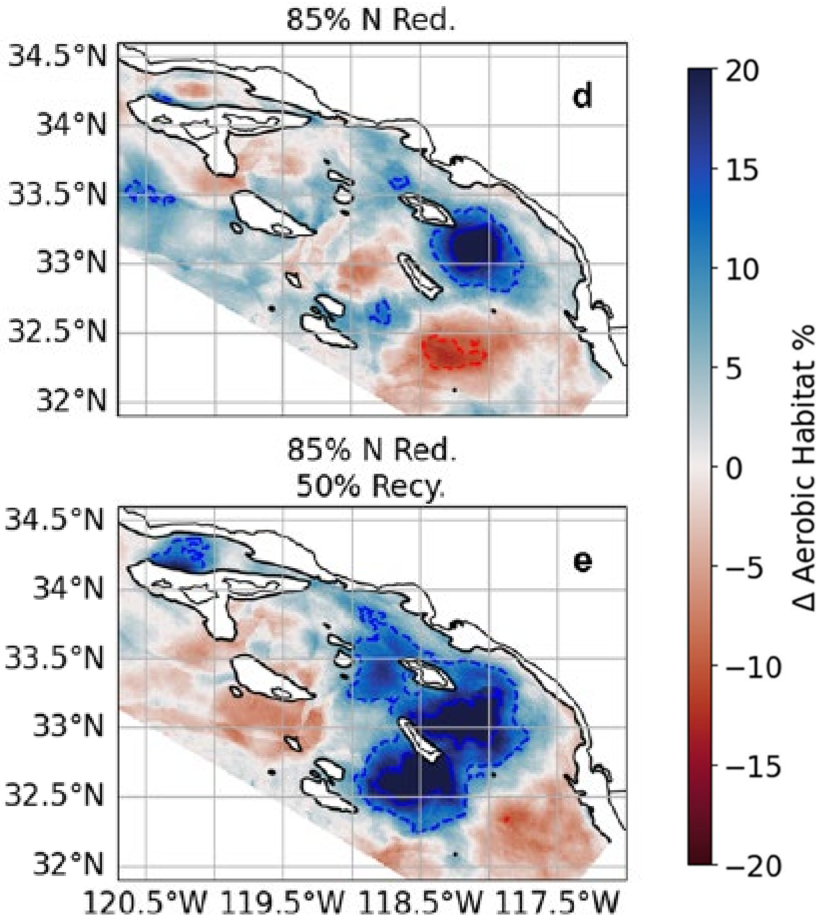
- Maintaining DIN loads with water recycling results in increased discharge concentrations
- 2 years of simulation for each; 2016-2017

Reducing high phytoplankton production rates generally consistent across water recycling scenarios



- Relative to ANTH
- Overall reduction in areas exhibiting extreme primary production rates

Translates to subsurface chemistry and benefits to habitat recovery



- Relative to ANTH
- Ongoing benefit to habitat recovery with water recycling, particularly at 85% N reduction

Goals of talk

Present the Findings for Three Management Questions

- What are the effects of anthropogenic nutrients on seawater chemistry?
- How do those changes translate to biological effects?
- How do outcomes change with nutrient management scenarios?

Provide an Overview of Ongoing Work

Ongoing ROMS-BEC scenario activities

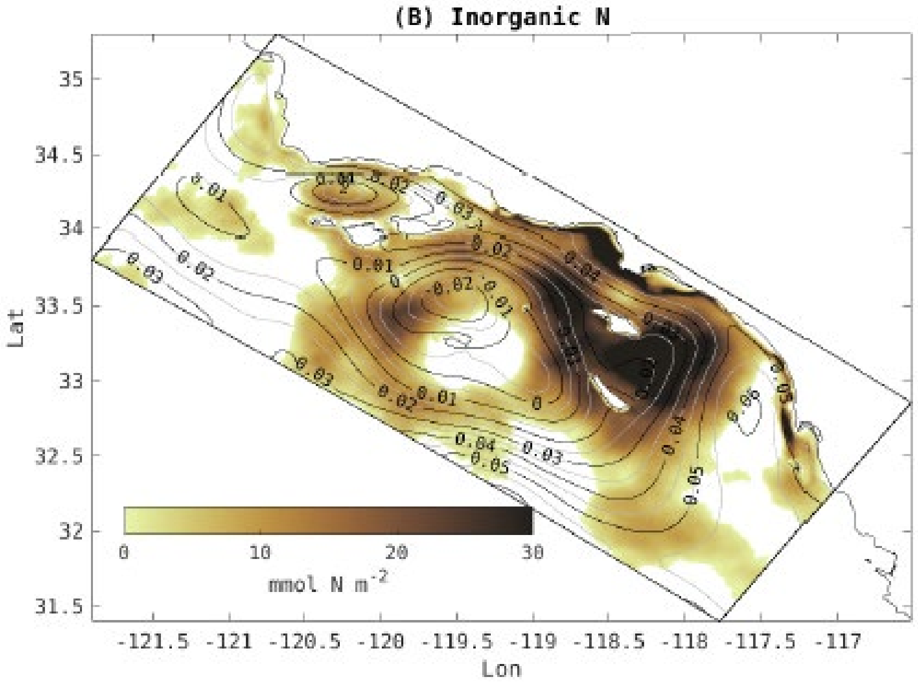
- Attribution of effects of "sources"
  - What is the relevant contribution of point-source, non-point source, and natural sources of nutrients?
  - What is the contribution of Mexican versus U.S. point sources?

- Place nutrient reduction in context of natural variability and rising atmospheric CO_2 conditions
  - How much loss in habitat has occurred since pre-industrial era? And what is anticipated with climate change?

Questions?

Why are we seeing pronounced effects offshore?

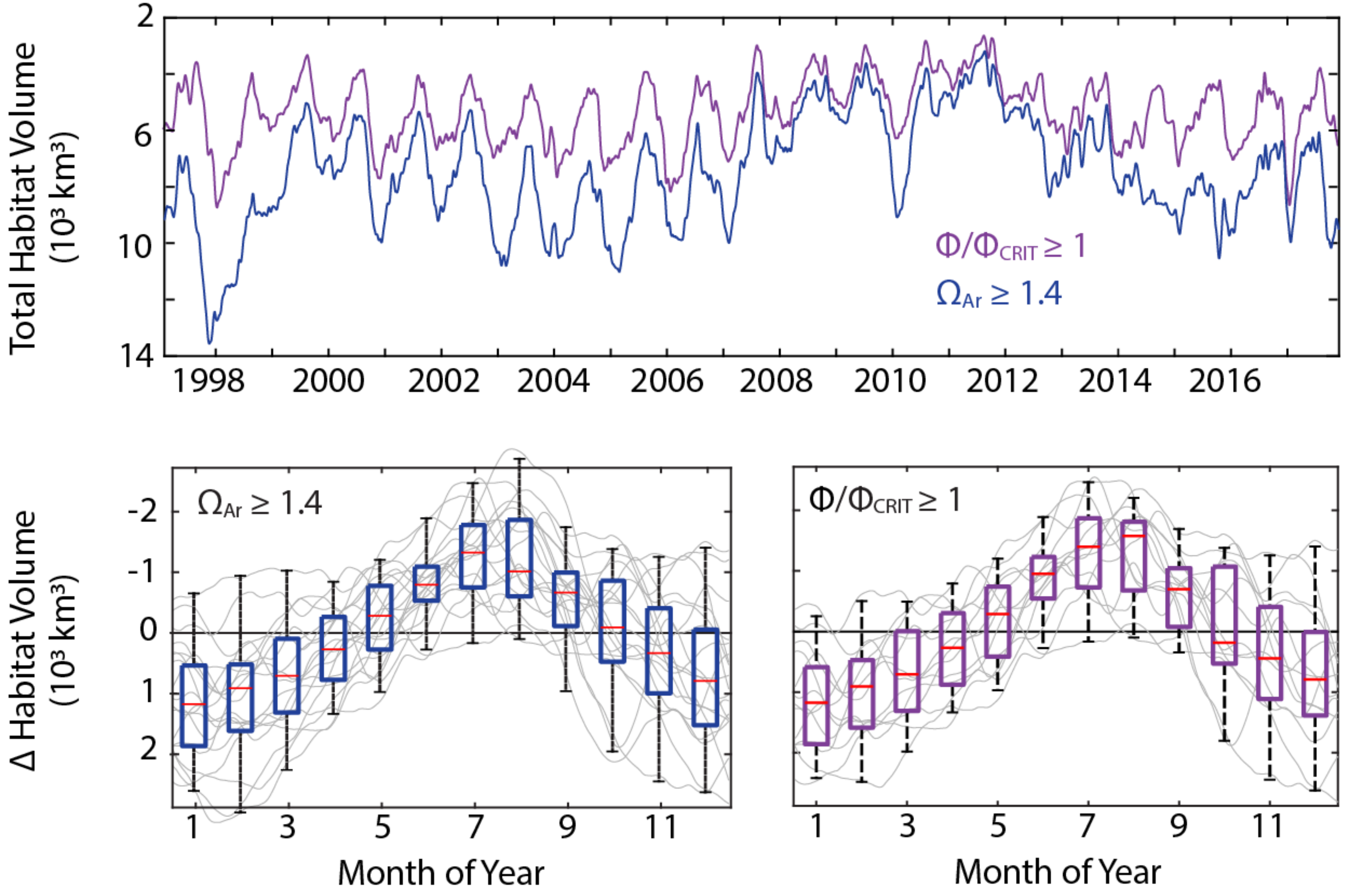
Recurrent eddies are trapping inorganic nitrogen and phytoplankton organic matter, leading to more pronounced O_2 and pH loss in those locations



- Contours of surface elevation demonstrate areas of recurrent eddies
- Coincides with accumulation of inorganic N
- Enhanced remineralization as cause of chemical changes confirmed with mass balance analysis

Kessouri et al. (In Review) Scientific Reports; Fig. 3 and 6

The temporal scales of variability in habitat volume are seasonal and interannual



Frieder et al. (In Review) Scientific Reports; Fig. 1

Six additional model scenarios were performed to test theoretical combinations of nutrient loads and water recycling

Scenarios		Range of % Outfall Volume Recycled for Potable Reuse*		
		0%	50%	90%
Nutrient Management Options	Current loading ~30 mg/L inorganic nitrogen	X (ANTH)		
	50% reduction in inorganic nitrogen loading	X	X	X
	85% reduction in inorganic nitrogen loading	X	X	X

- Changes only made to all outfalls; other inputs (rivers, etc.) held constant

* Assume water treatment concentrate returned to outfall, so nutrient loading not altered by water recycling alone