



# FUTURE SEAS

Evaluating impacts of climate change on California  
Current ecosystems, fisheries, and communities

Barbara Muhling

On behalf of many others

Including co-PIs Desiree Tommasi, Isaac Kaplan, Mercedes Pozo Buil

**Future Seas is a collaborative, interdisciplinary effort to explore potential impacts of climate change on U.S. west coast fisheries and to evaluate strategies for managing those impacts.**

### **Fisheries**

We are focused on fisheries for highly migratory species, coastal pelagic species, and groundfish off the US West Coast

### **Science**

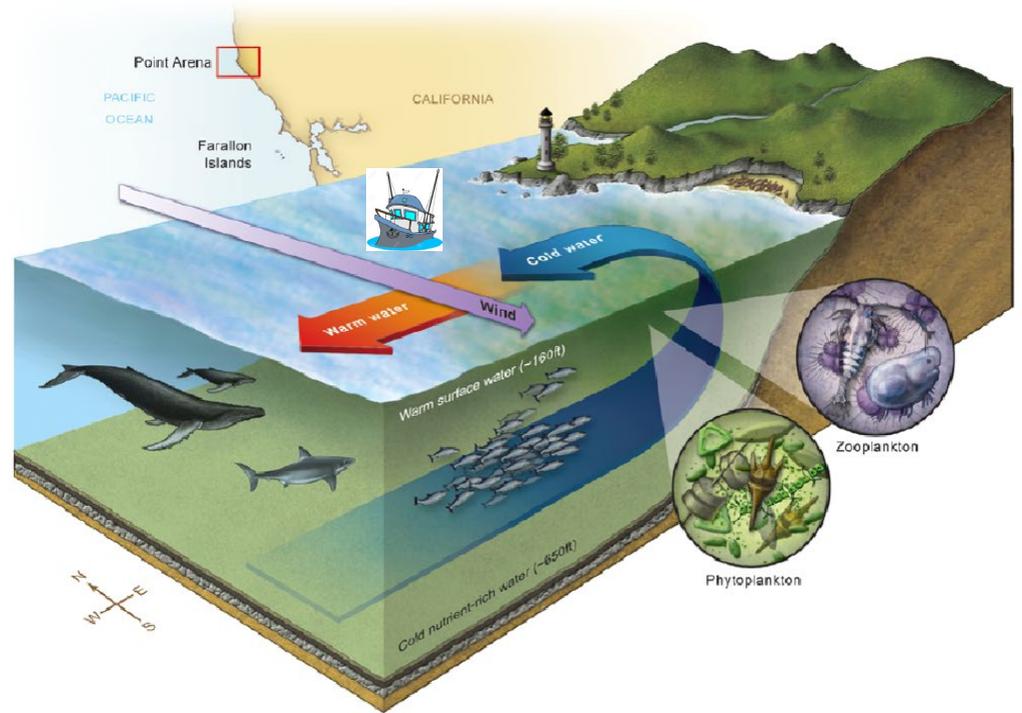
We are combining dynamical, statistical, and conceptual models to project physical, ecological, and socioeconomic change

### **Team**

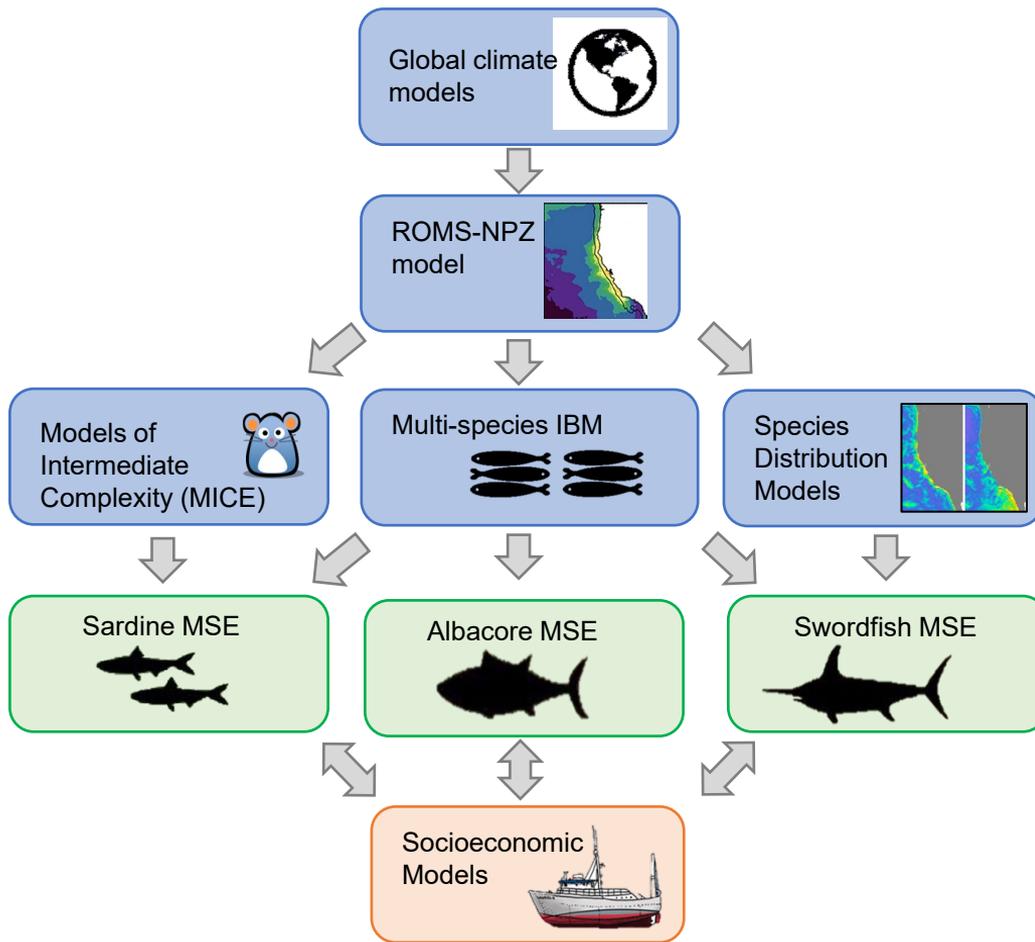
We are climate scientists, oceanographers, ecologists, economists, and social scientists, working closely with fishers and fishery managers

# The California Current Ecosystem

- Productive upwelling ecosystem
- Provides many ecosystem services
- Forage species transfer energy from plankton to upper trophic levels, including protected species, commercial fisheries and recreational fisheries



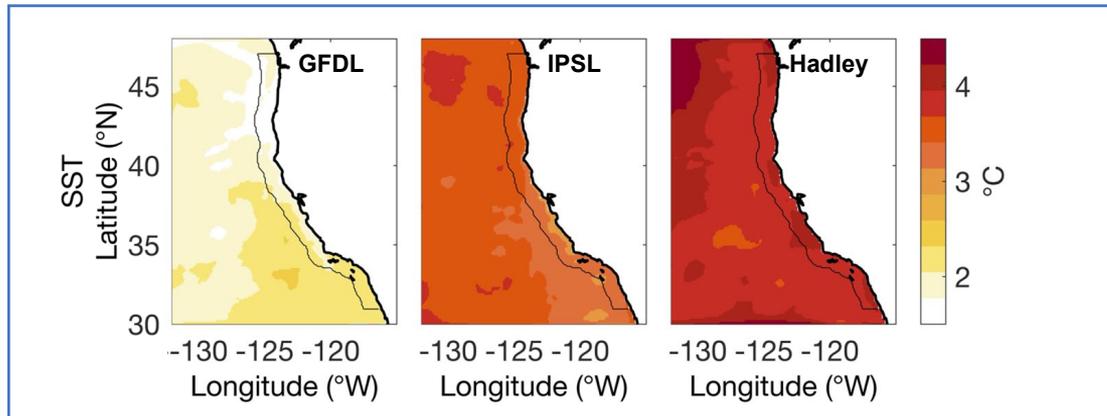
Phase I: 2017 - 2021



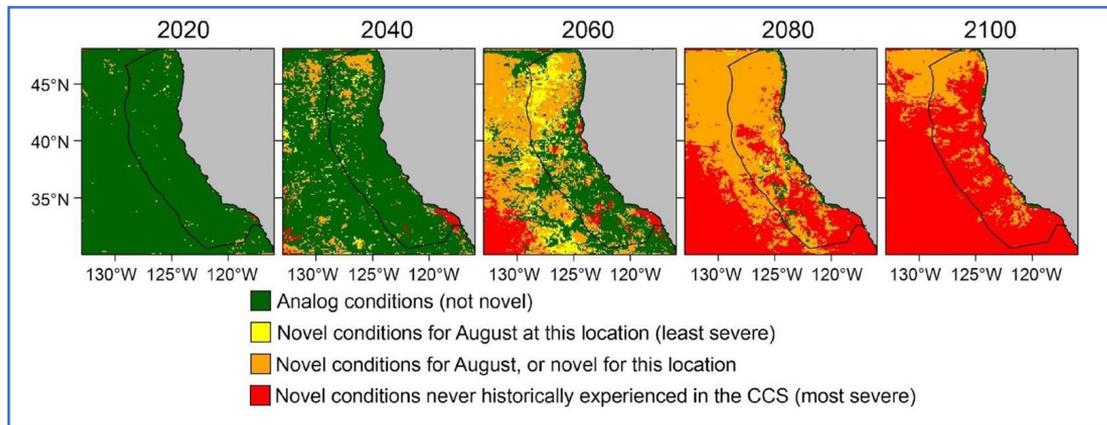
### Phase I: 2017 - 2021

### Major outputs

Warming and changing oceans  
(Pozo Buil et al. 2021)



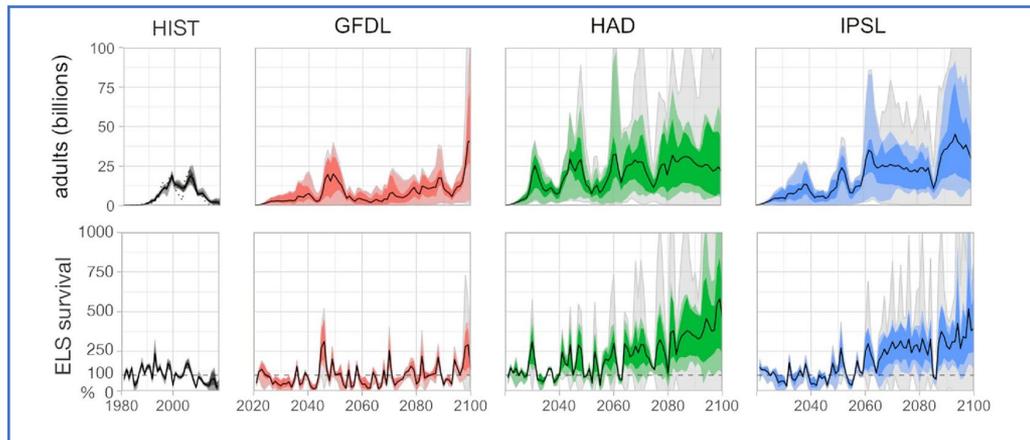
Increasingly novel ocean conditions  
(Smith et al. 2022)



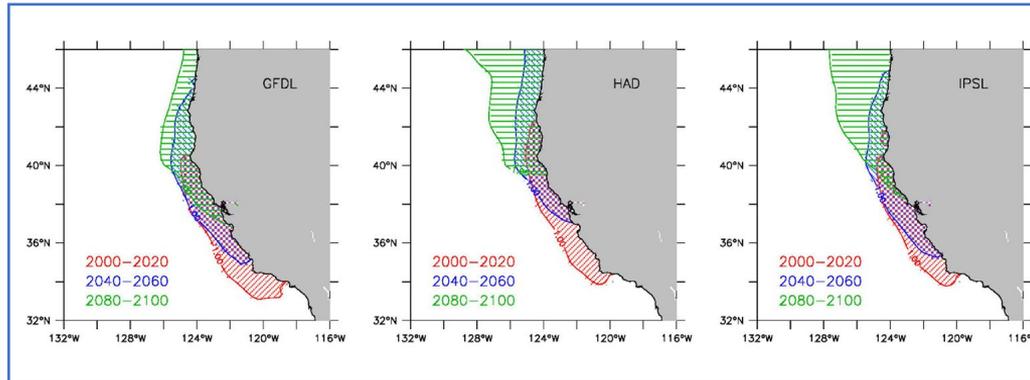
### Phase I: 2017 - 2021

### Major outputs

Increasing sardine  
abundance  
(Koenigstein et al. 2022)



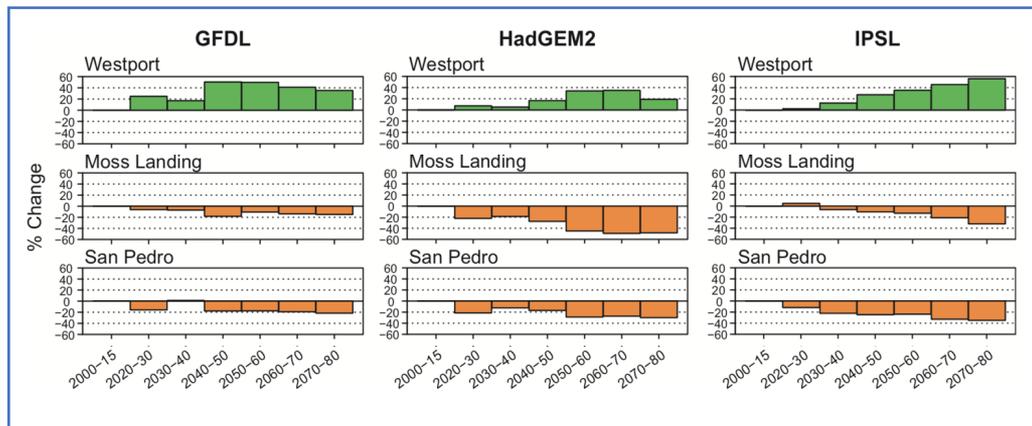
Northward sardine  
distribution shift  
(Fiechter et al. 2021)



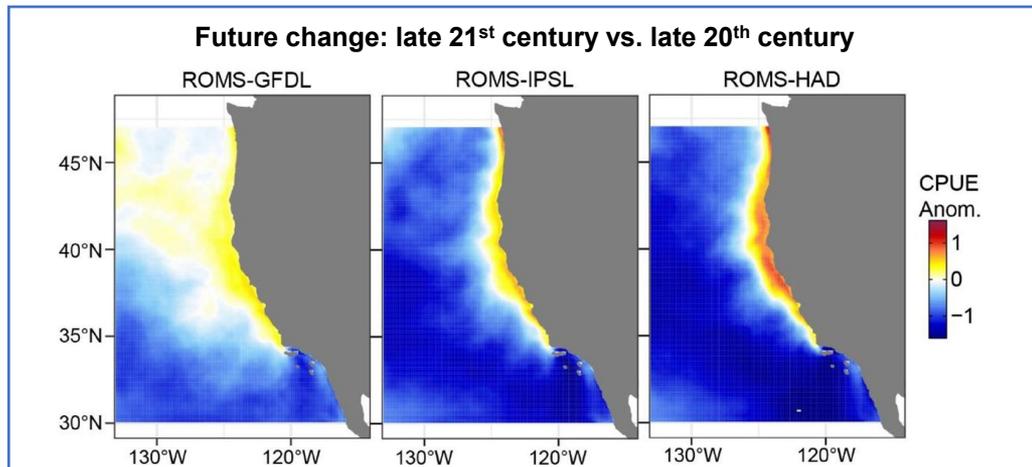
### Phase I: 2017 - 2021

Northward shift in sardine distribution and landings  
(Smith et al. 2021)

### Major outputs

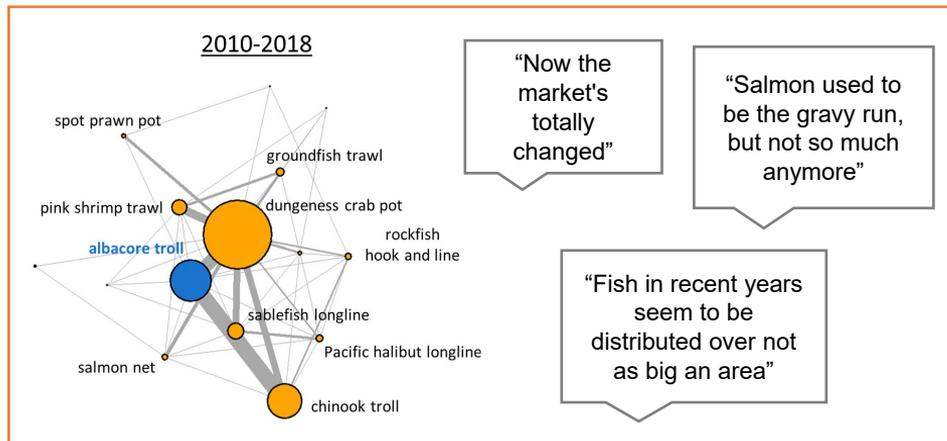


Shoreward contraction of albacore fishing grounds  
(Smith et al. 2023)

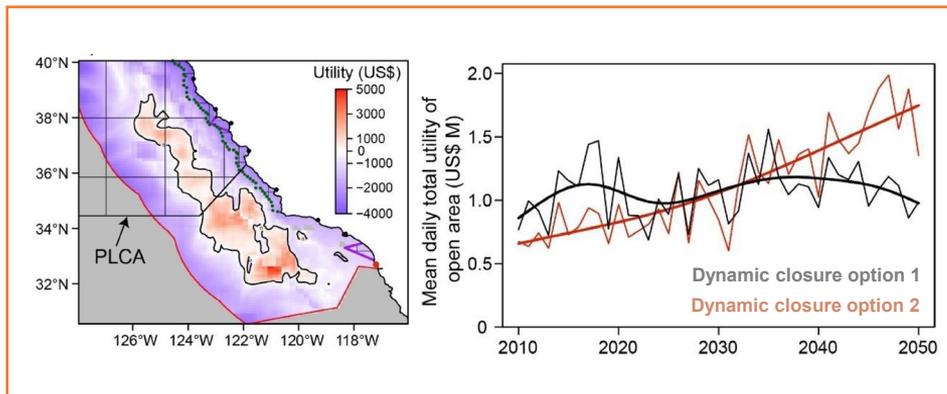


### Phase I: 2017 - 2021

Changing historical social-ecological connections  
(Frawley et al. 2021)



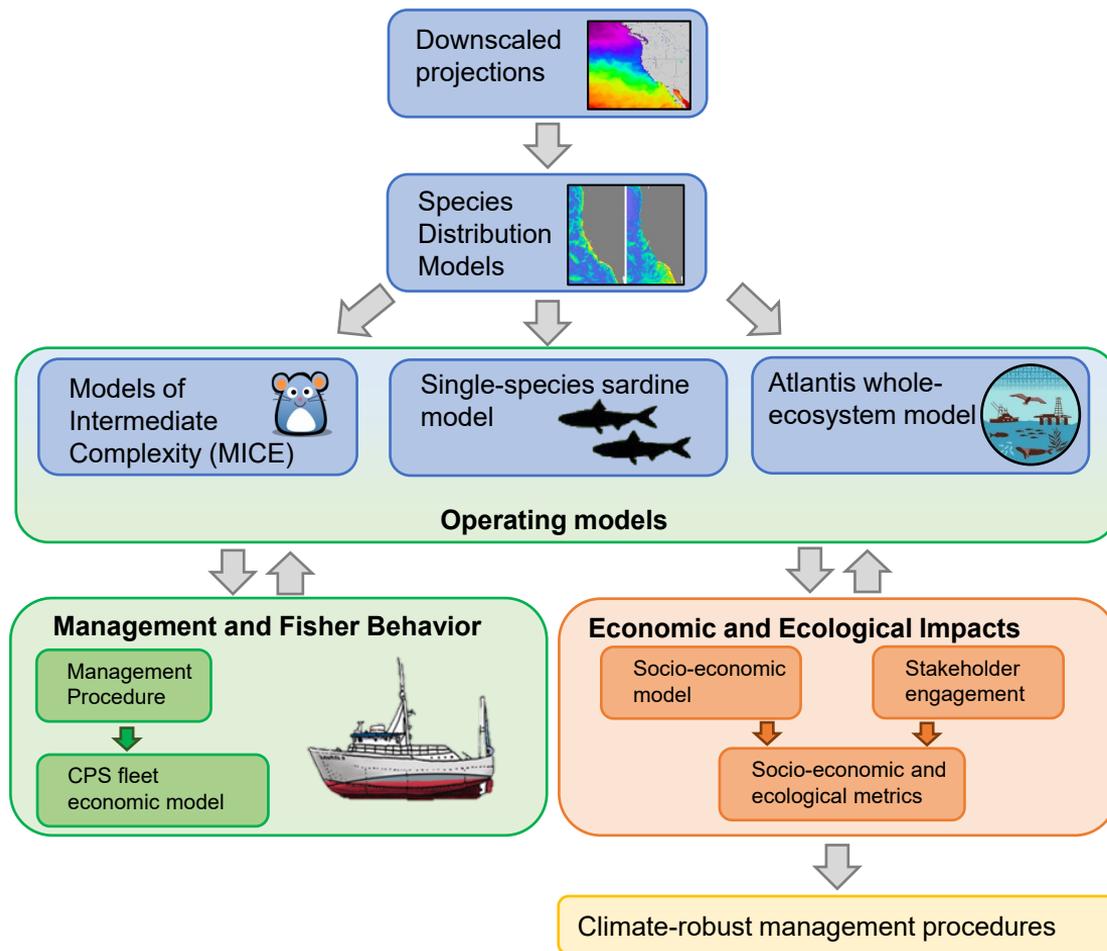
Changing opportunities for swordfish fishermen  
(Smith et al. 2023)



# FUTURE SEAS II

Impact of climate and ecosystem change on the California Current forage complex and the fishing communities and predators it sustains

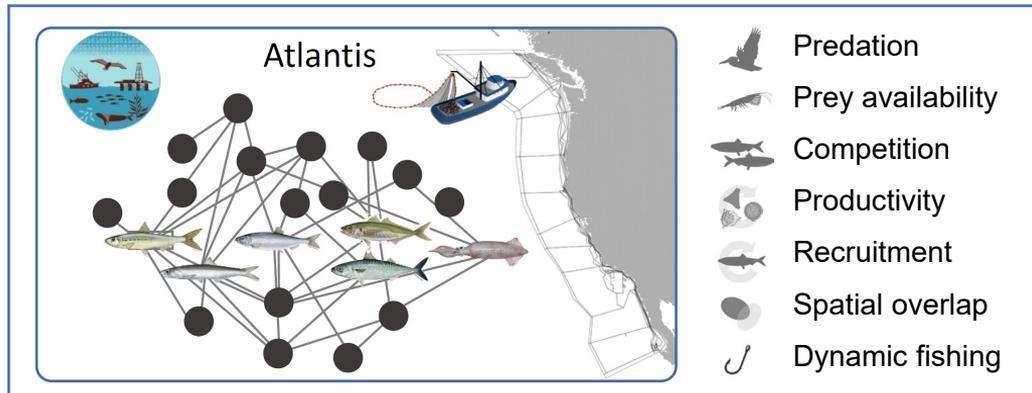
Phase II: 2020 - 2024



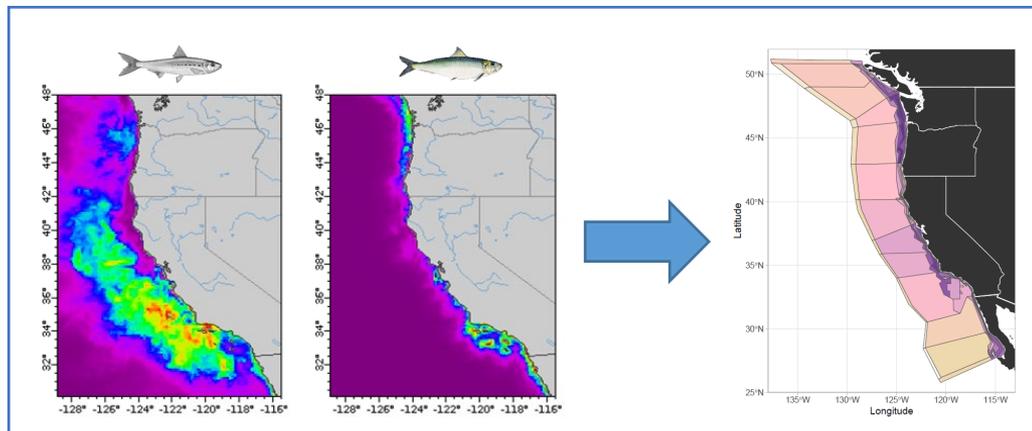
Phase II: 2020 - 2024

Rebuilt West Coast  
Atlantis model  
(Hervann et al. in prep)

### Major outputs



Incorporate SDMs into  
Atlantis  
(Kaplan et al. in prep)



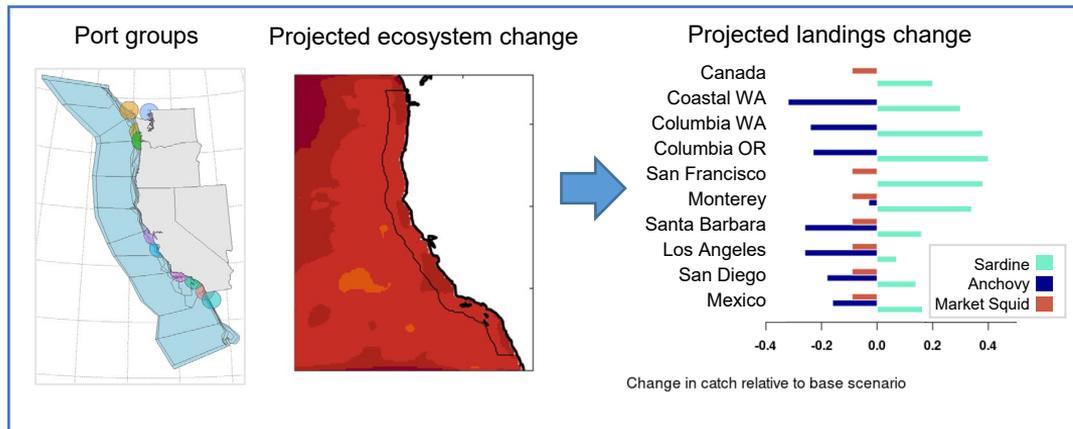
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Impact of climate and ecosystem change on the California Current forage complex and the fishing communities and predators it sustains

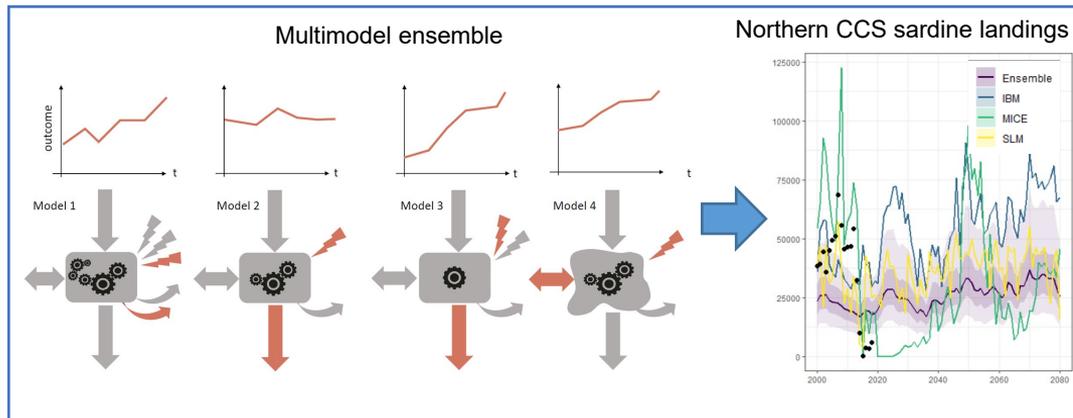
Phase II: 2020 - 2024

## Major outputs

Project future landings by species using fleet footprints (Liu et al. in prep)



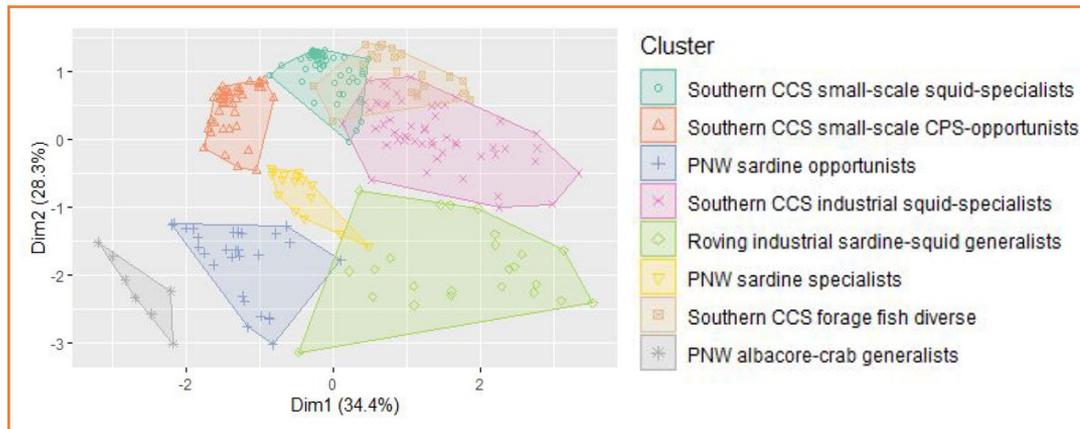
Examine ecosystem model ensembles (Hervann et al. in prep)



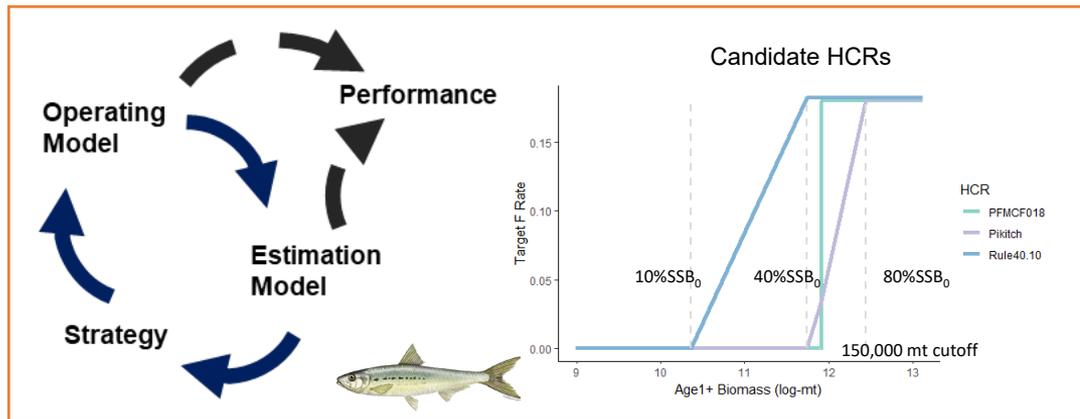
Phase II: 2020 - 2024

### Major outputs

Determine fleet segments for vessels targeting CPS  
(Quezada et al. 2023)



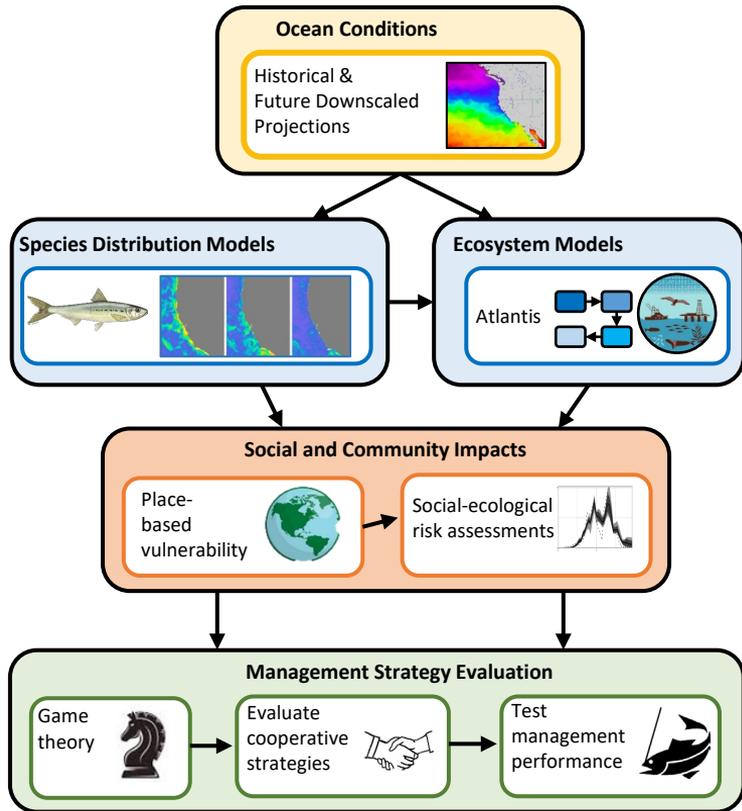
Assess robustness of sardine Harvest Control Rules using MSE  
(Wildermuth et al. 2023)



# FUTURE SEAS III

Ensuring resilience and adaptive capacity of California Current System fisheries under climate-driven ecosystem shifts

Phase III: 2024 - 2027



## Deliverables

• Downscaled CMIP6 biogeochemical projections

• Future ecosystem states  
• Ecosystem Indicators

• Vulnerability assessment and resilience strategies for fishing communities

• Resilience of stock assessments and harvest control rules

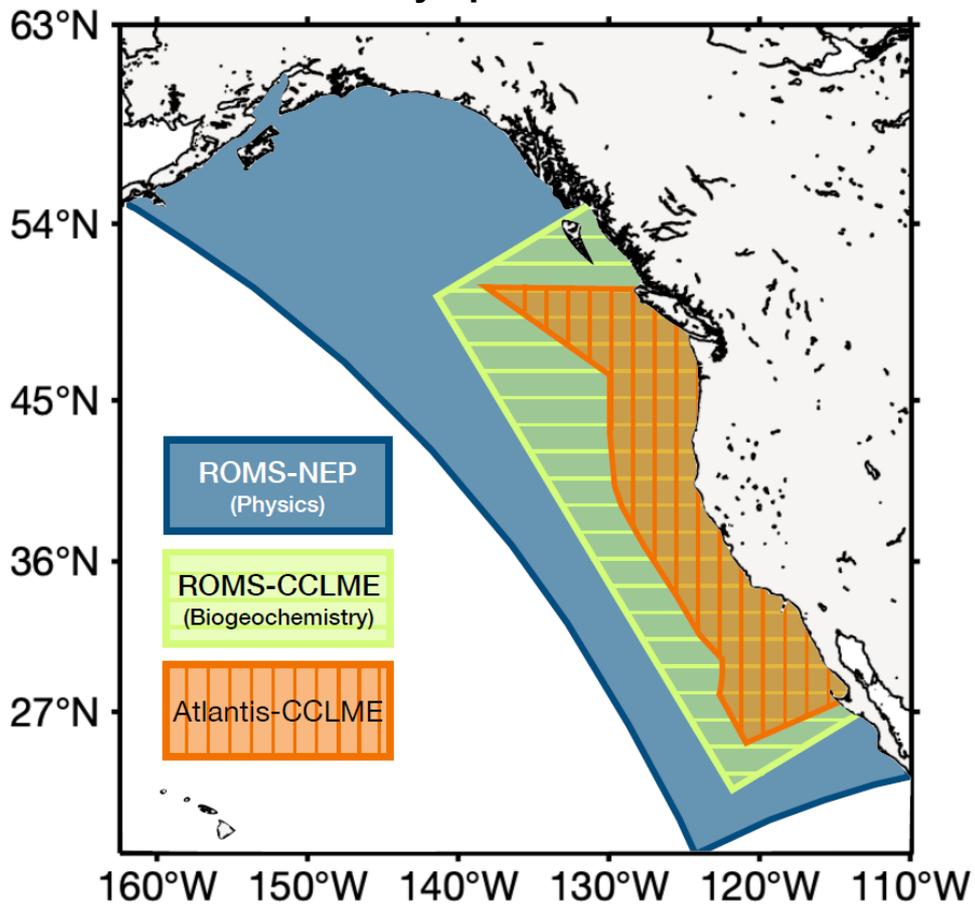
## Management Applications

PFMC Initiatives

NOAA Fisheries Climate Science Strategy



## Key updates

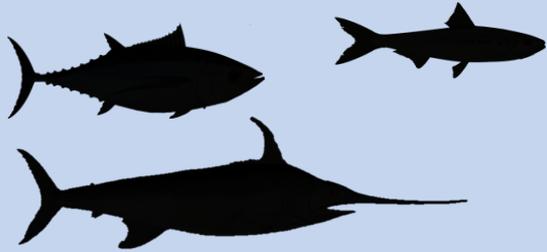


# FUTURE SEAS III

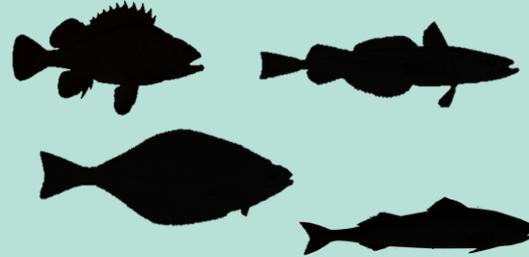
Ensuring resilience and adaptive capacity of California Current System fisheries under climate-driven ecosystem shifts

## Key updates

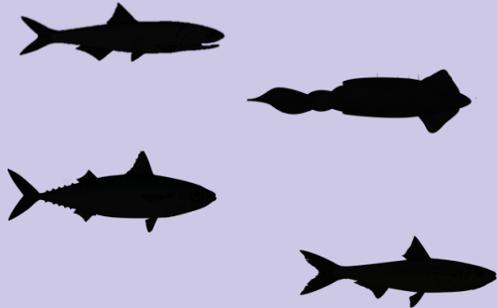
Future Seas 1  
Pacific sardine, albacore, swordfish



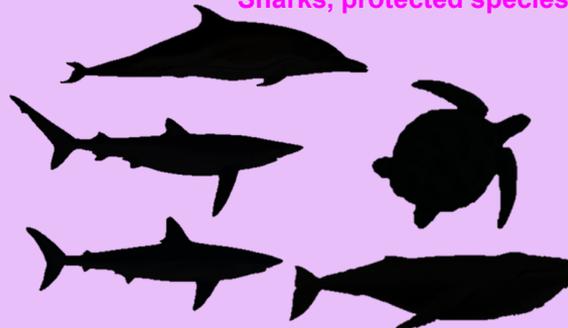
Groundfish, Climate Change,  
and Communities (GC5)  
Groundfish complex



Future Seas 2  
CPS complex

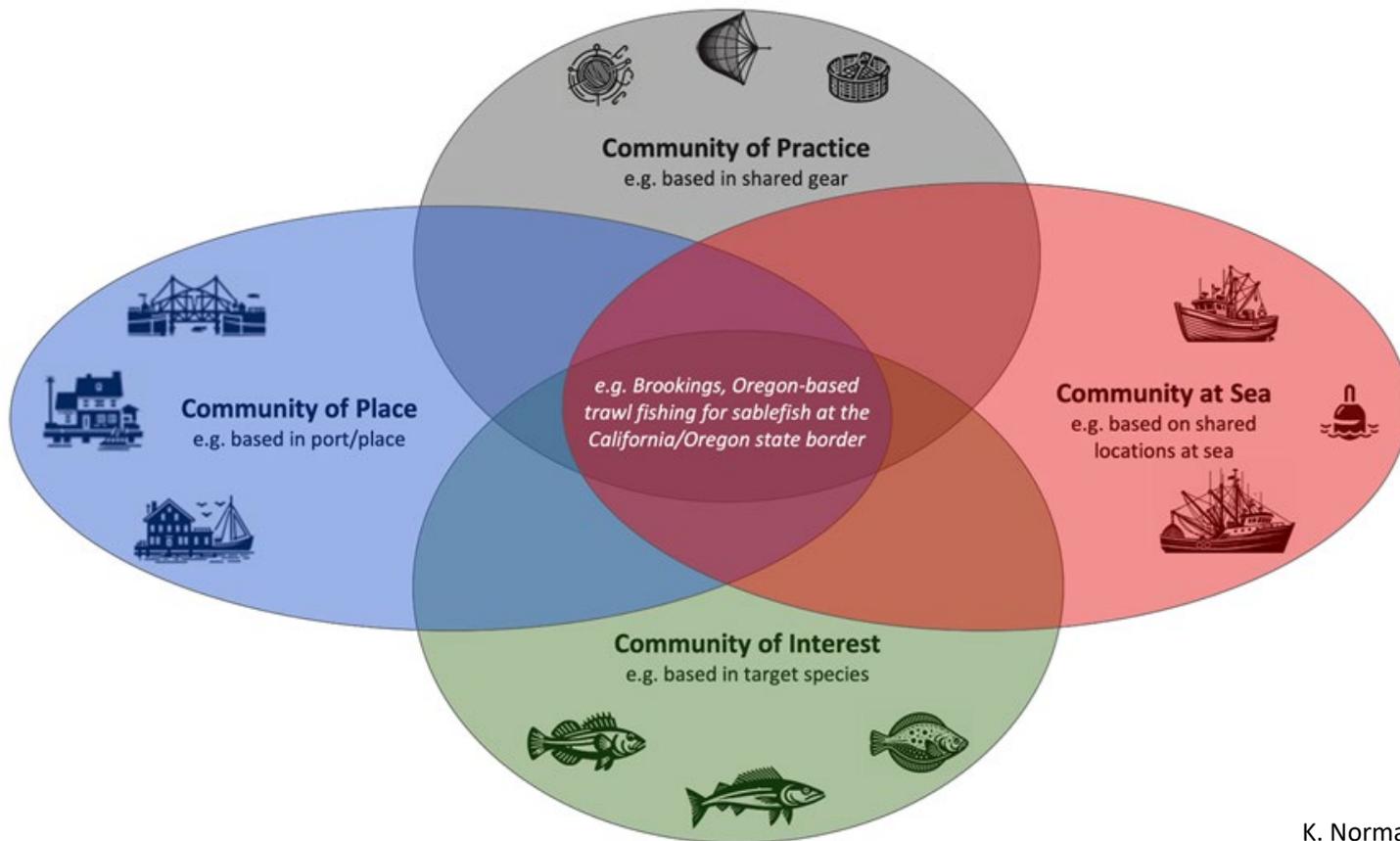


Ecosystem Science Division work  
Sharks, protected species



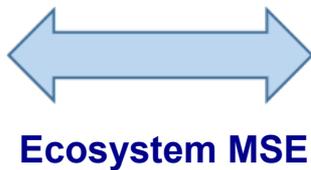
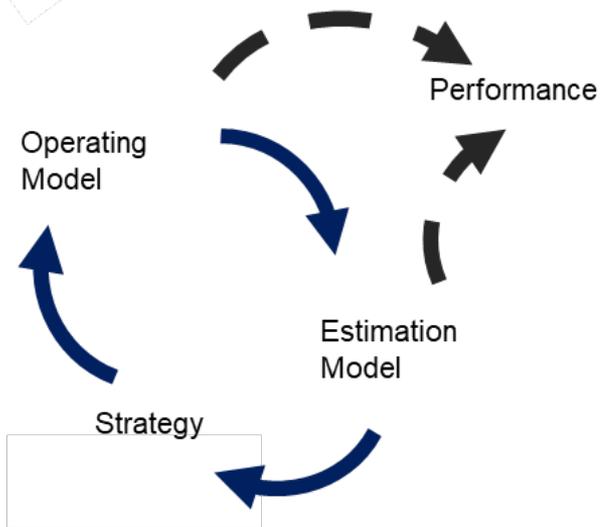
Future Seas 3

### Key updates

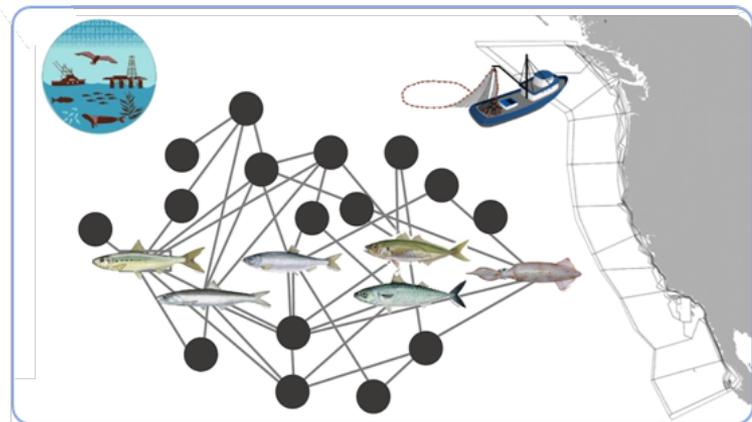


## Key updates

### Management Strategy Evaluation



### Atlantis Ecosystem Model



# Emerging Management Needs

Shifting habitats will impact:

- Survey planning
- Stock structure
- Transboundary management
- Bycatch
- Predator-prey interactions
- Emerging fisheries



# Emerging Management Needs

Changing stock productivity will impact:

- Stock assessment parameters and stock forecast performance
- Management strategy effectiveness
- Ecosystem dynamics
- Socio-economic metrics
- Fishing communities



# Lessons Learned

- Tailor modeling framework to specific context
- Calibrate ecological/economic models to ensure they can capture past dynamics
- Capture and communicate uncertainty
- Engage stakeholders often
- Multidisciplinary teams are necessary!

## **WORKSHOP REPORT**

**Management Strategy Evaluation (MSE) Workshop for the NOAA OAR/NMFS Project  
“Future Climate Change and the California Current (Future Seas) - A Physics to Fisheries  
Management Strategy Evaluation”**

March 28, 2018  
Scripps Seaside Forum  
University of California San Diego, La Jolla, CA



# FUTURE SEAS

A Physics-to-Fisheries Management Strategy  
Evaluation for the California Current System



All publications  
mentioned are  
available here

→ [future-seas.com](http://future-seas.com)

## Thank you!

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