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One for all, all for one: Using an ensemble of climate-informed ecological models to characterize climate and ecosystem-driven uncertainty in the California Current

Pierre-Yves Hernvann, Robert P. Wildermuth, **Desiree Tommasi**, Daniele Bianchi, Steven J. Bograd, Jerome Fiechter, Dylan Gomes, Jerome Guiet, Elliott L. Hazen, Charlie Hinchliffe, Michael G. Jacox, Isaac C. Kaplan, Stefan Koenigstein, Nerea Lezama-Ochoa, Colleen M. Petrik, Jim Ruzicka, James A. Smith, Michael A. Spence, Andrew R. Thompson and Kelly Vasbinder

2026 SPF Symposium, Session 1 May 6, 2026 La Paz, Mexico

CAFA Climate and Fisheries Adaptation

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

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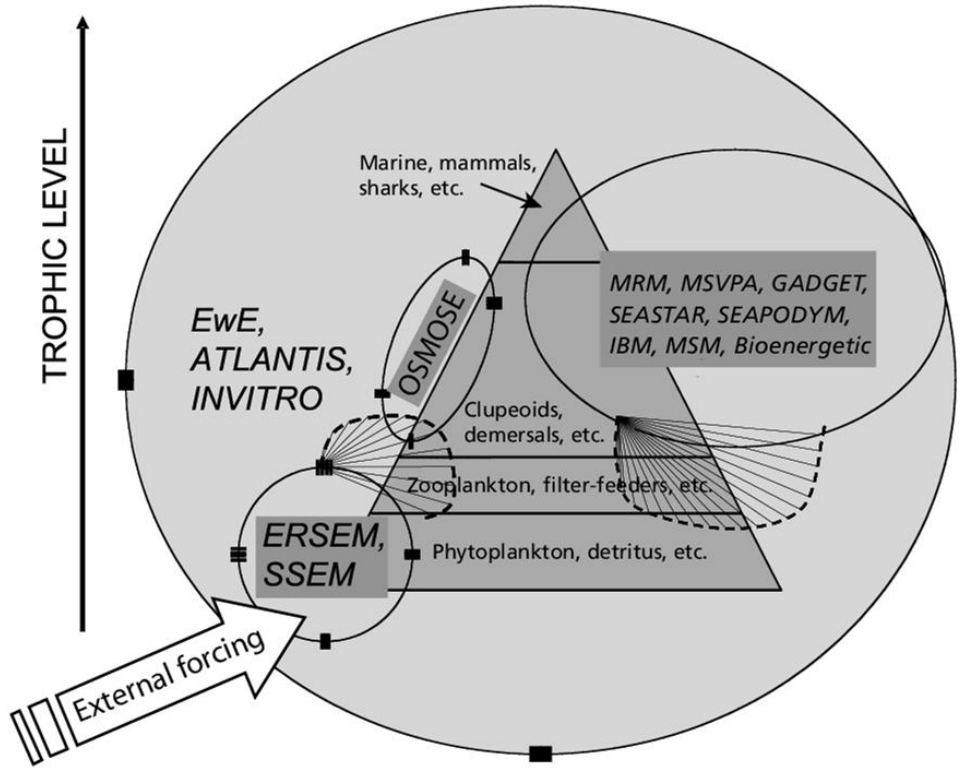
Model ensembles in fisheries

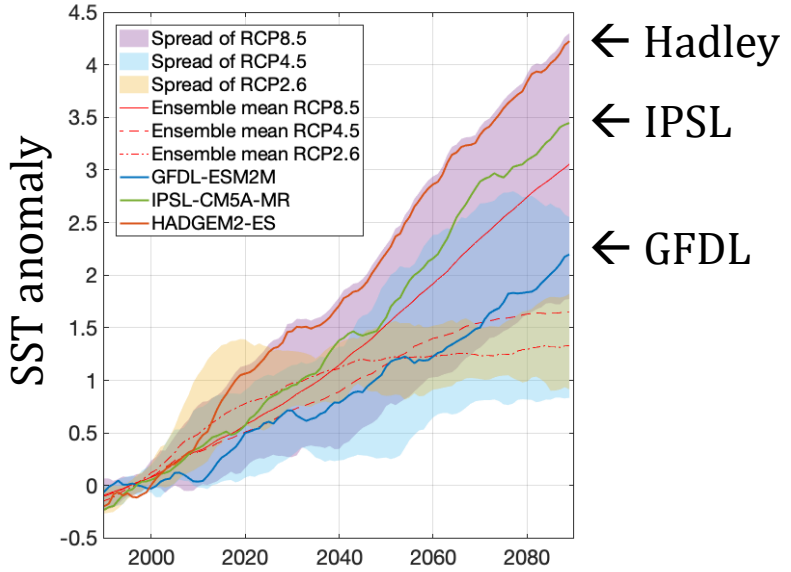


Plaganyi et al. 2007

- Integrate uncertainties in model predictions due to:
  - Parameter sensitivities
  - Model structure
- May provide more robust estimates of quantities of interest (Jardim et al. 2021)
- Can help summarize and communicate dynamics and uncertainty to stakeholders
  - Provides closer evaluation of assumptions and member model behavior (Reum et al 2021)

Climate applications of model ensembles

- Common in climate projections (IPCC Climate Model Intercomparison Project)
  - Often model uncertainty spread larger than scenario uncertainty
- Fish-MIP aims to link Earth system model projections to marine ecosystem model ensembles



Liu et al. 2025, Fig S12
after Pozo Buil et al. 2021

FISHERIES & MARINE ECOSYSTEM
FISH-MIP
MODEL INTERCOMPARISON PROJECT

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Model ensemble methods

- Contrasting ways to combine models
  - Qualitative comparison
  - "Best" model = zero/sum
  - Mean or median
  - Weighting
    - EcoEnsemble package by Spence et al. 2023
  - "Super ensembles," emulators
    - E.g Anderson et al. 2017

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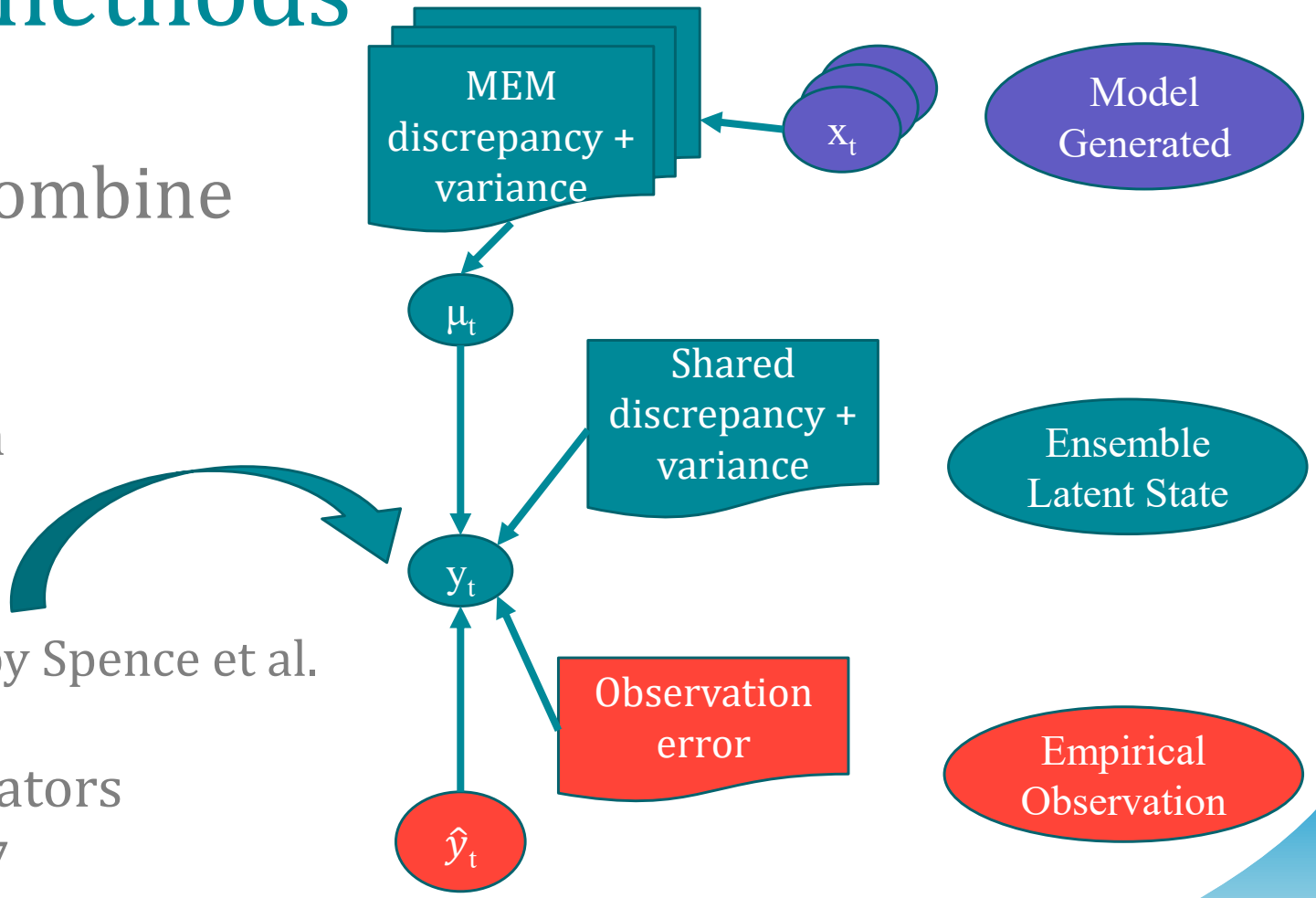
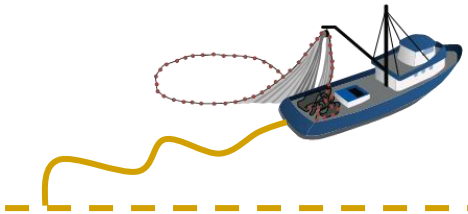
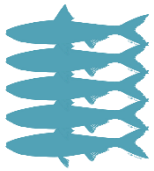


Pacific sardine in the California Current

Climate Change

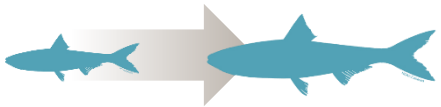


Total Biomass



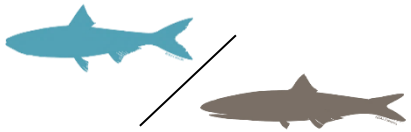
Catch distribution

Growth / Condition



Population productivity

Importance for CPS



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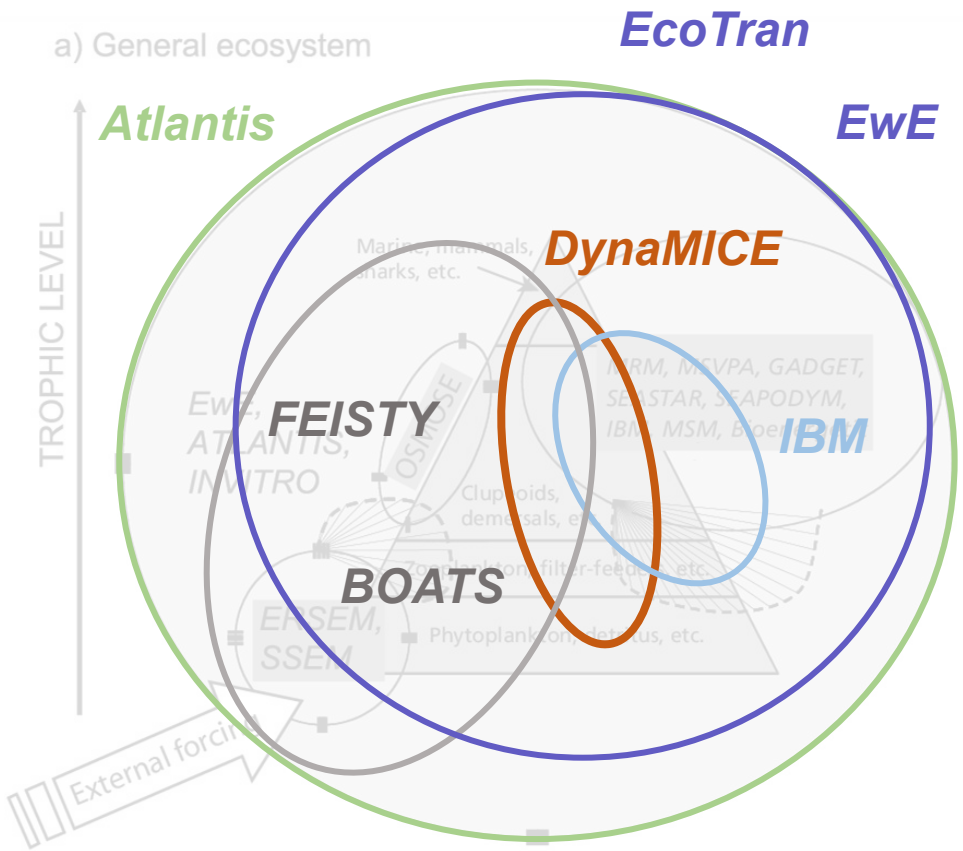
Marine ecosystem models (MEMs) for the California Current



Plaganyi et al. 2007

- ✓ Individual Based Model
  Fiechter et al. (2015, 2021)
- ✓ Model of Intermediate Complexity
  DynaMICE - Koenigstein et al. (2022)
- ✓ Mass-balance food-web model
  EcoTran - Ruzicka et al. (under review)
- ✓ End-to-end ecosystem model
  Atlantis - Marshall et al. (2017), Liu et al. (2025)
- ✓ Size- /type-based model
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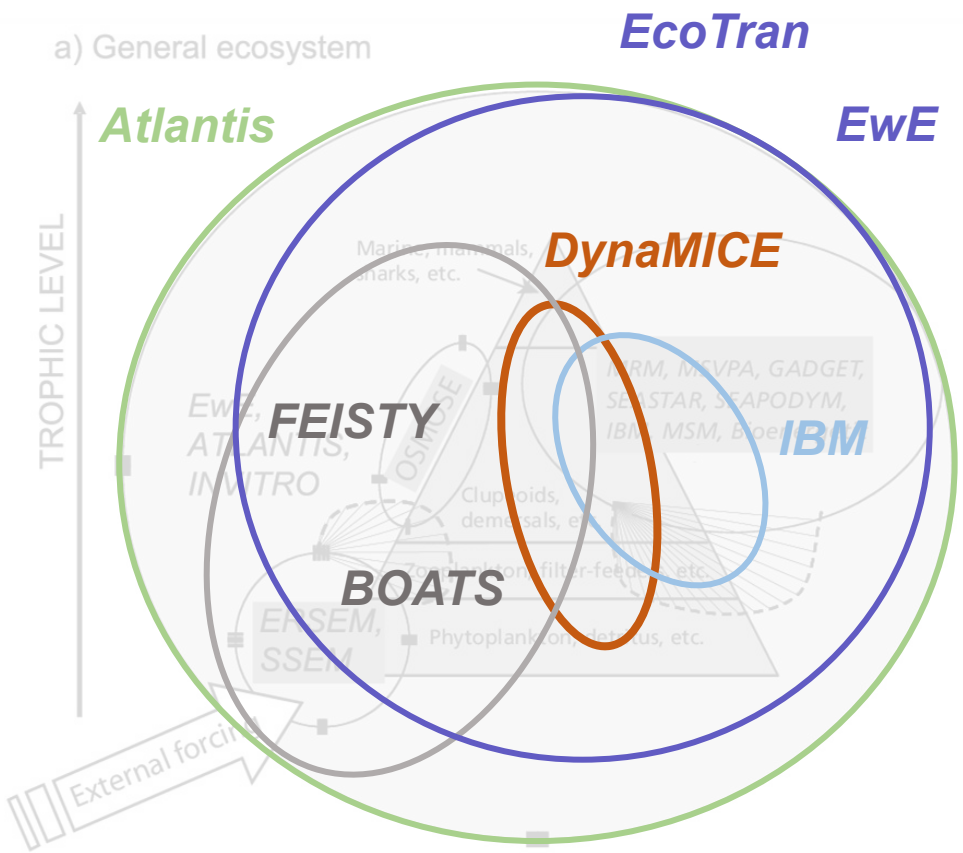

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X 3 Earth system models

Plaganyi et al. 2007

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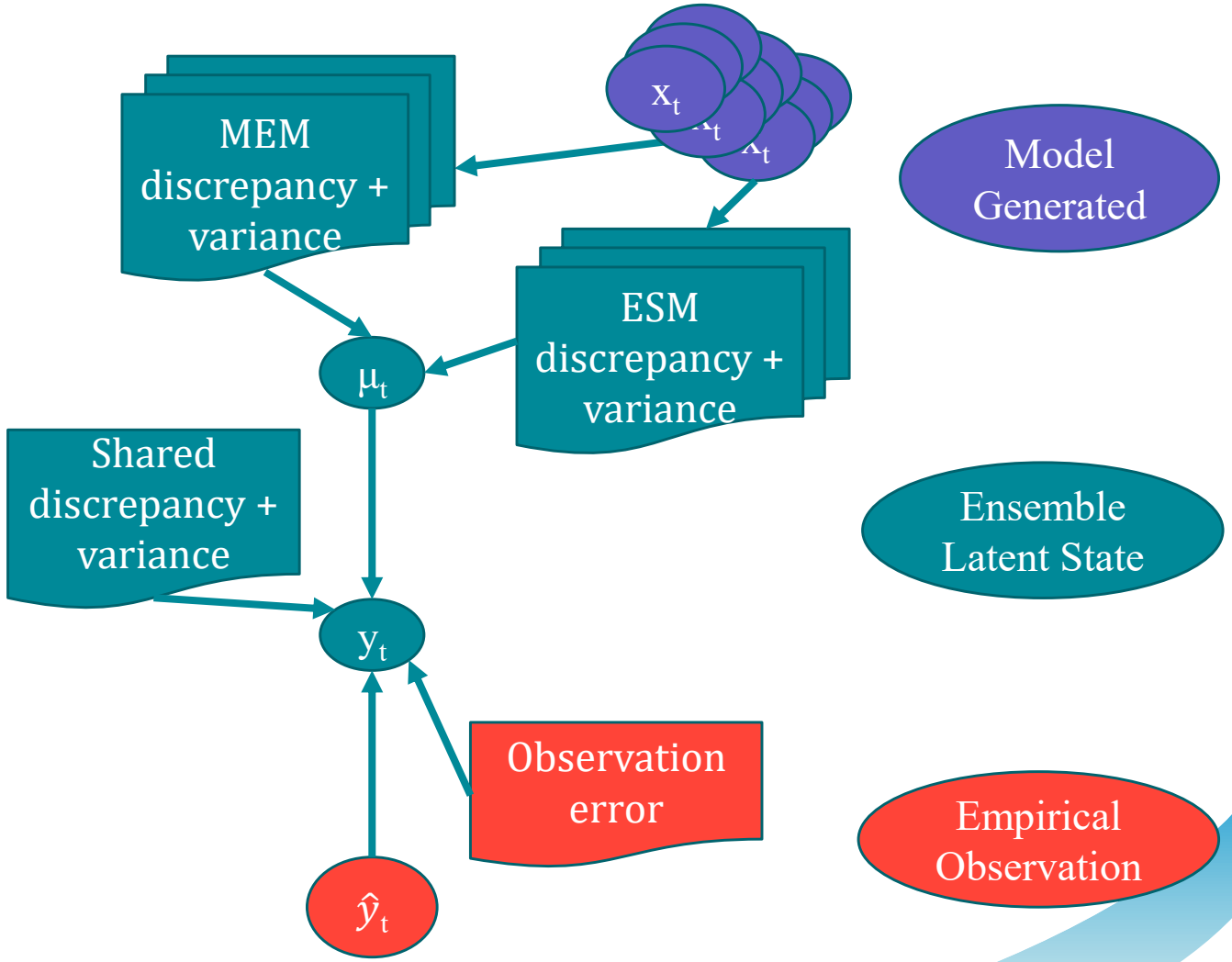
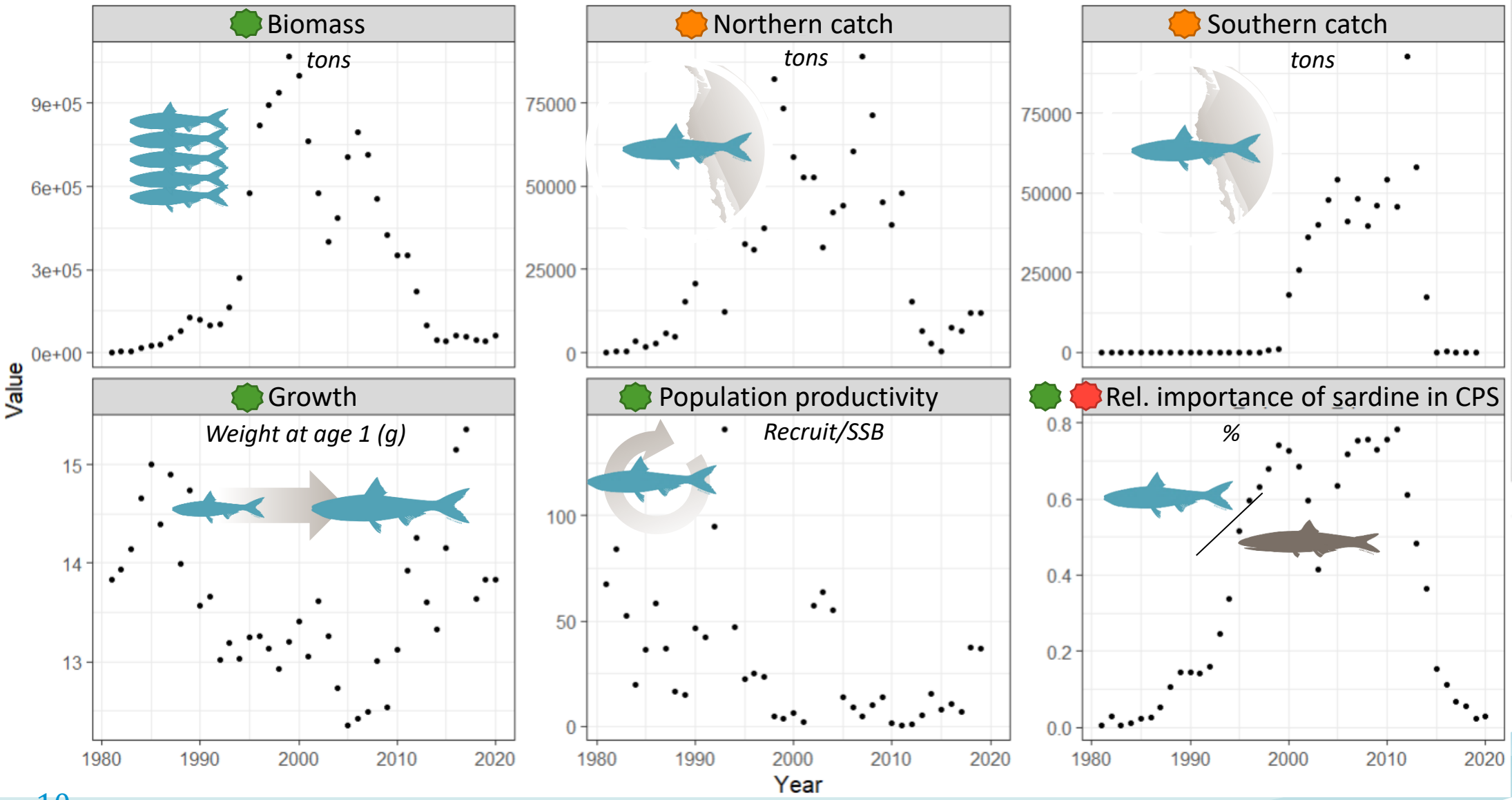
Climate extension for EcoEnsemble

- Incorporate discrepancies for each climate model
  - Modeled outputs for each MEM x ESM combination



Quantities of interest: system observations

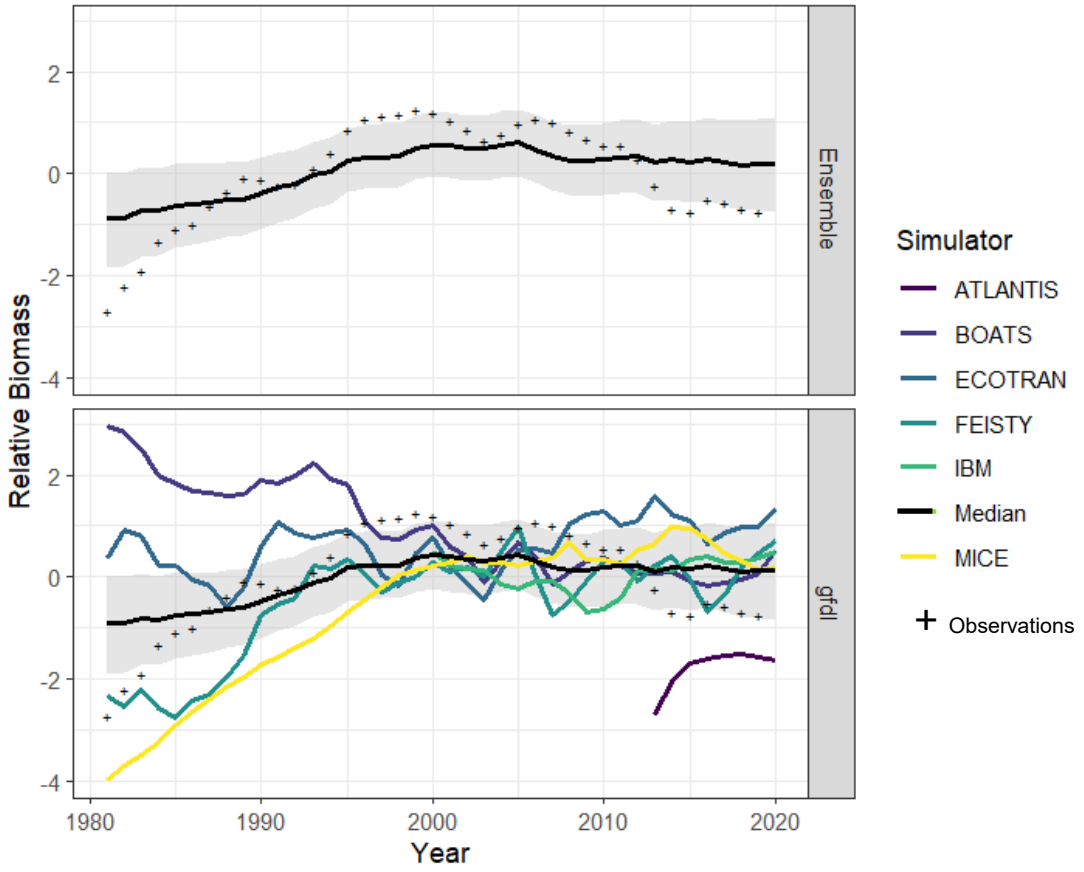


- Sardine research assessment
- Kuriyama et al. 2020
- Hinchliffe et al. 2025; Crone 2015, 2019

Preliminary Results

Ensemble model fit

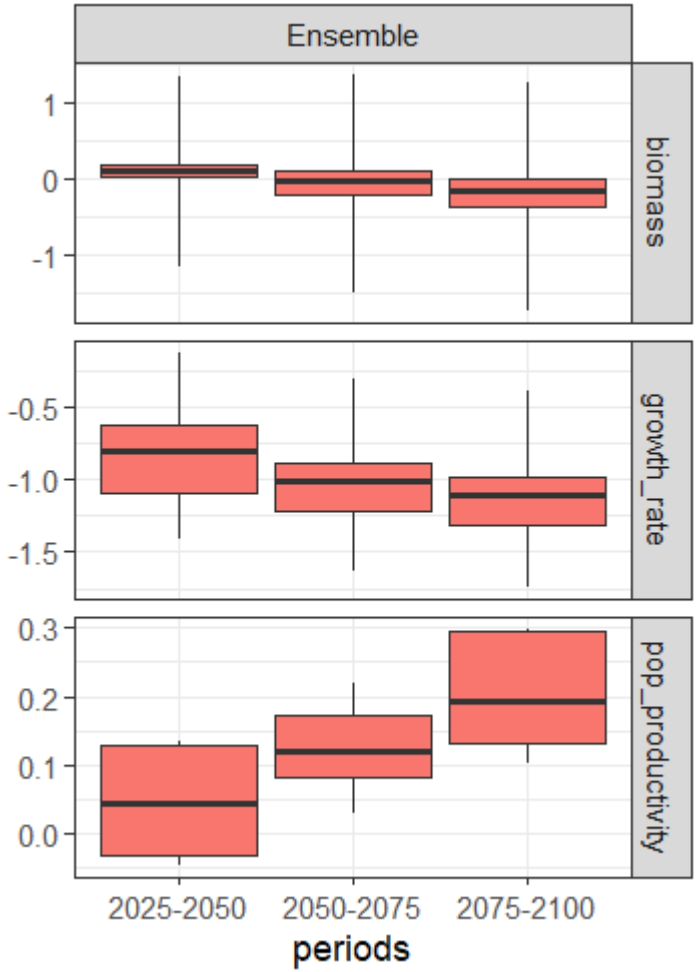
- High contrast in modeled trends leads to high ensemble uncertainty
- Variation in MEM calibration to historical observations leads to additional ensemble uncertainty
  - Did not calibrate models to historical reforecasts
  - Conflicting signals among ESMs, MEM structure, and observations affects ensemble estimates



Preliminary Results

Climate projections

- Ensemble estimate of increased productivity and decrease in growth leads to slight decrease in biomass by 2075-2100 relative to historical period
- Highly discordant MEM outputs swamp any contrast among ESMs
  - Sometimes no agreement on trends



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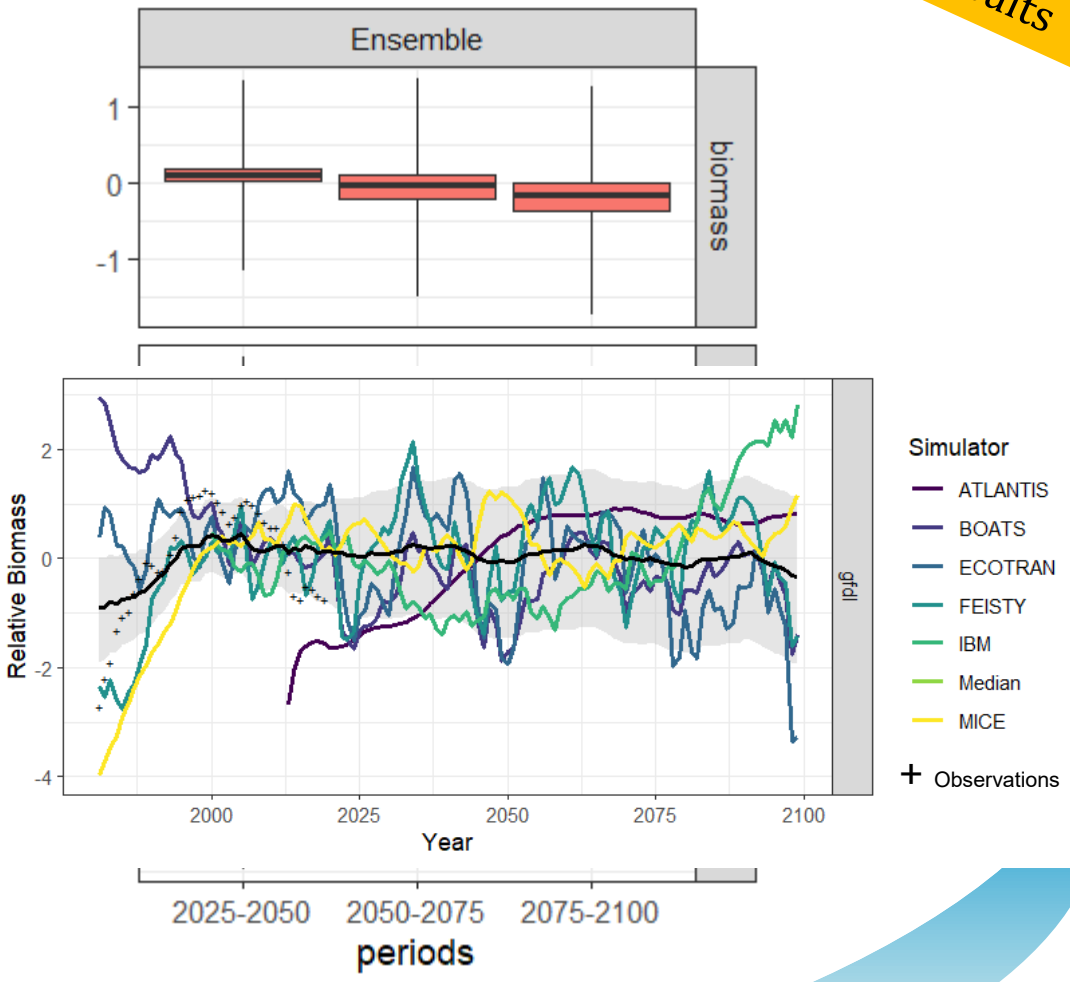

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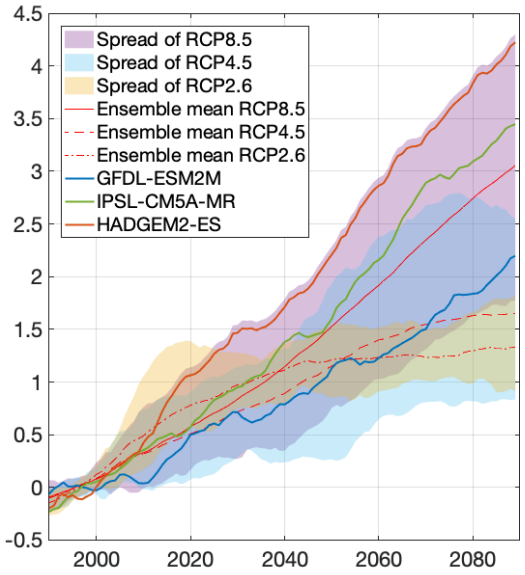
Ecosystem model uncertainty is key

- MEM structure > ESM structure > ESM scenario
  - Fishing scenario forcing confounds projections



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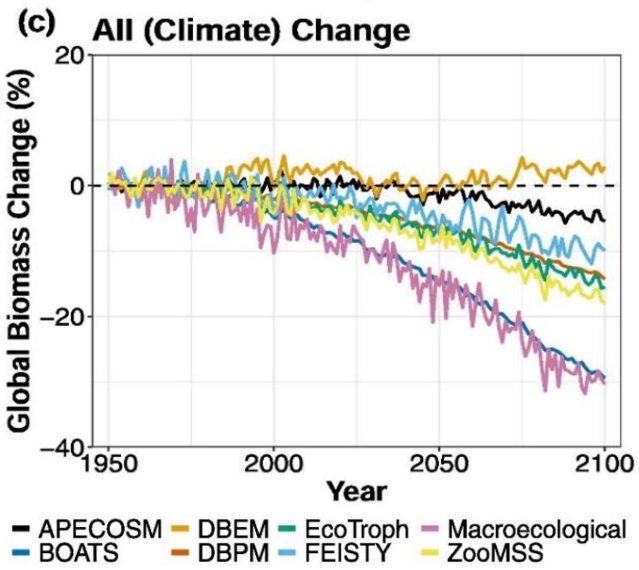
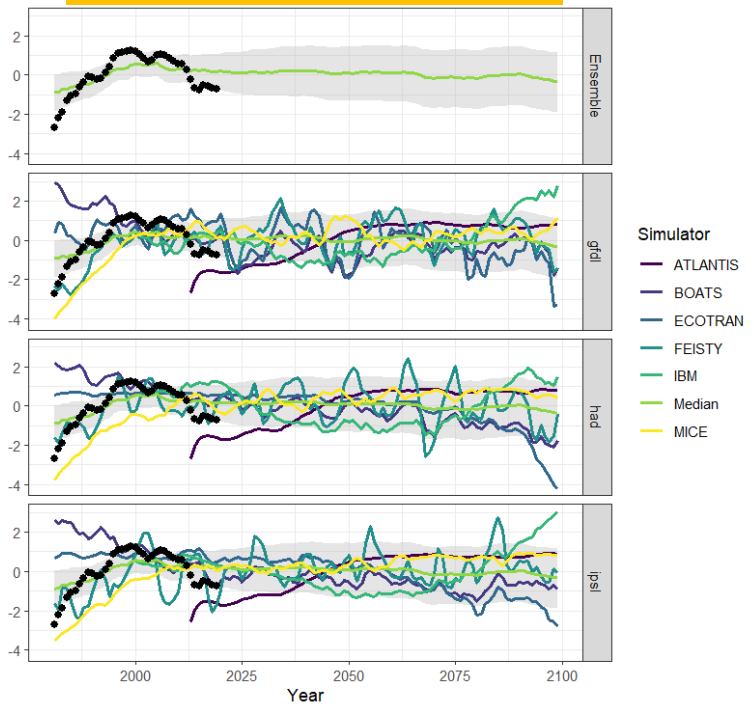


Heneghan et al. 2021

Preliminary Results



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Lessons learned (the hard way)

- Many conclusions support best practices summarized in Blanchard et al.'s (2024) Fish-MIP 2.0 protocols
- Use 2-phase process of historical calibration + future projection
- Must be accounted for in comparisons:
  - Model structure and calibration
  - Forcing scenarios = climate + fishing
  - Variable calibration (apples ≠ oranges)
- Coordination from start of model development crucial for successful ensemble development

Thank you!

EcoEnsemble –

- Spence et al. 2018, Fish Fish
- Spence et al. 2023, Methods Ecol Evol

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