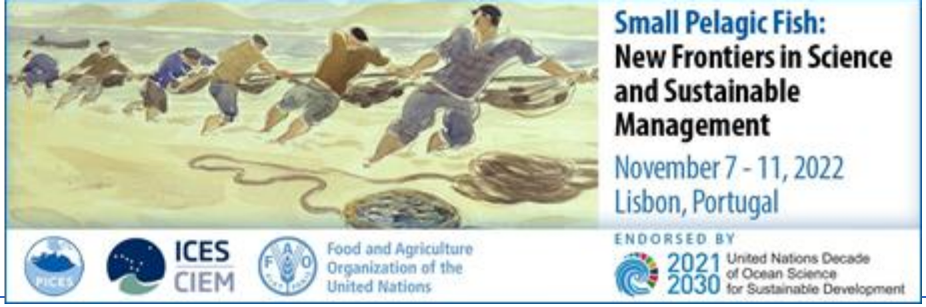
Product from PICES/ICES Small Pelagic Fish conference



Coupling small pelagic fish distribution models to complex ecosystem models: tools and choices to support ecosystem-based fishery management and climate assessment

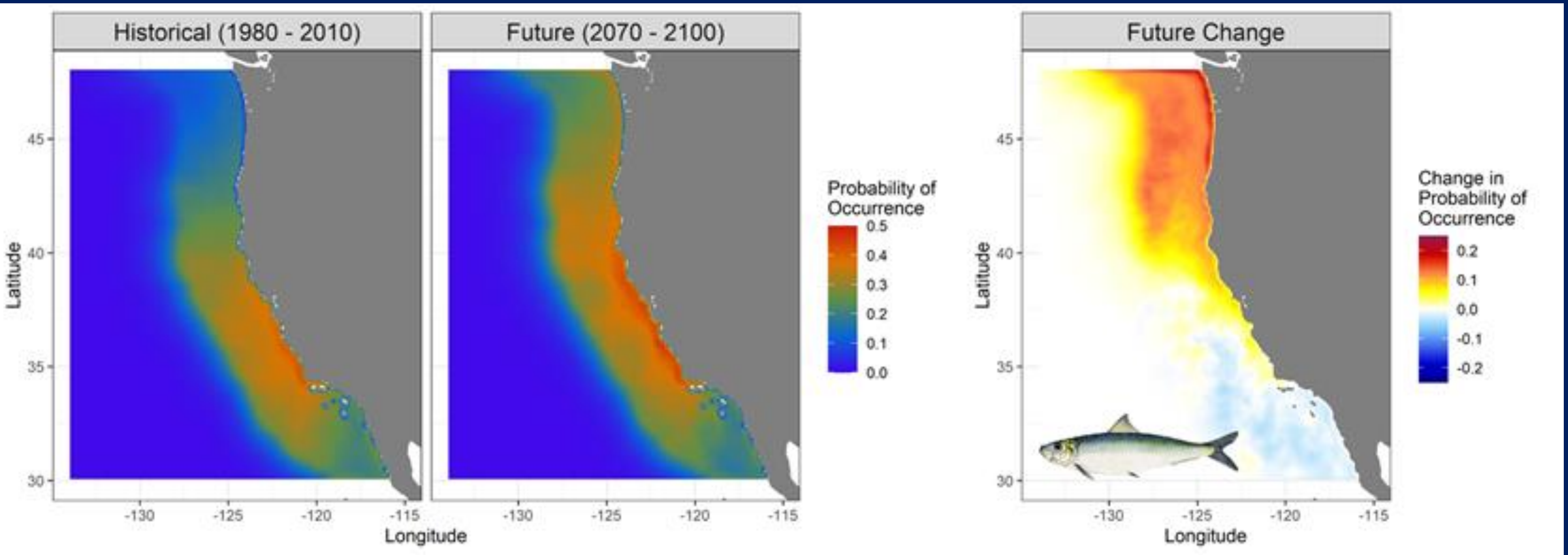
Isaac C. Kaplan, Elliott L. Hazen, Stefan Koenigstein, Nerea Lezama-Ochoa, Mariana Hill Cruz, Pierre-Yves Hernvann, Owen R Liu, Dylan G.E. Gomes, Sebastian I. Vásquez, Criscely Lujan, Stephanie Green, Matthew R. Baker, Ricardo Oliveros-Ramos, Alberto Rovellini, Rebecca G. Asch, and Barbara Muhling

PICES Annual meeting, Oct 30, 2024

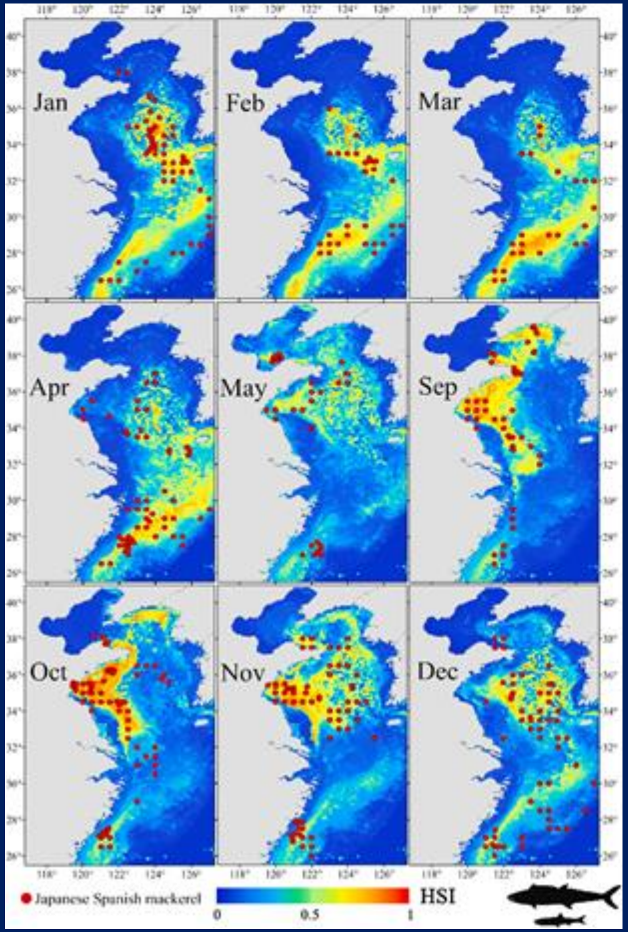
Goals

Identify best practices for the detailed decisions ("the devil's in the details") required to couple the burgeoning field of species distribution models (SDMs) to more complex multispecies and end-to-end models such as Ecospace, Ecosim, Atlantis, OSMOSE, EcoOcean, and MICE models

Species distribution shifts by decade and season: Coastal pelagic species



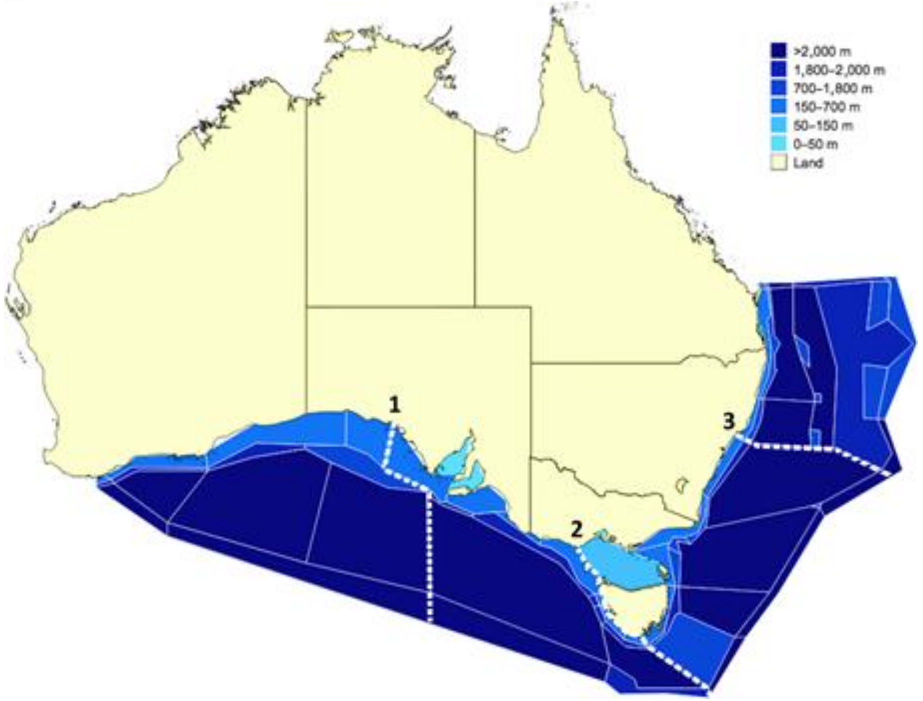
Projected shifts in April sardine distribution
Muhling et al.



Japanese Spanish Mackerel distribution
Liu et al. 2023

COMPLEX ECOSYSTEM MODELS

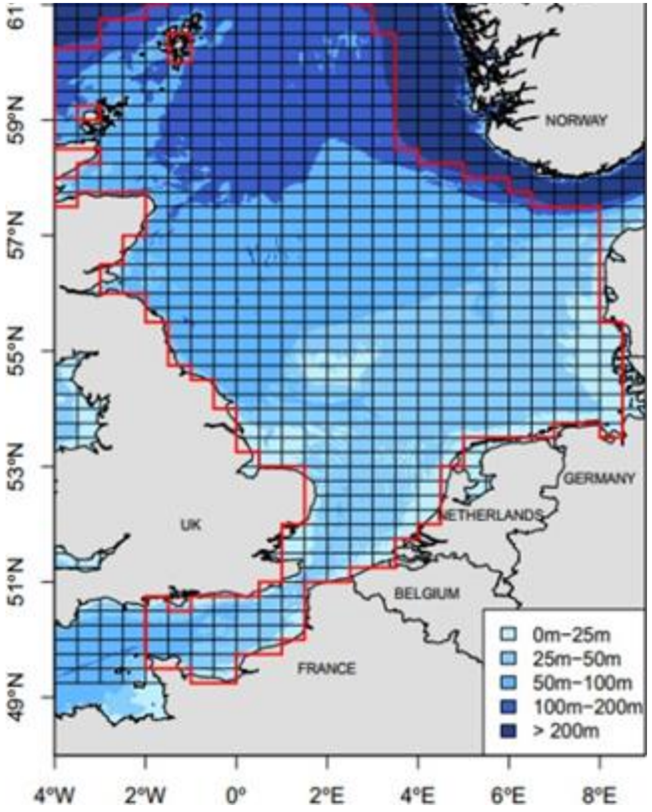
CSIRO Atlantis



Fulton et al. 2018

Osmose

Object-oriented Simulator of Marine Ecosystems

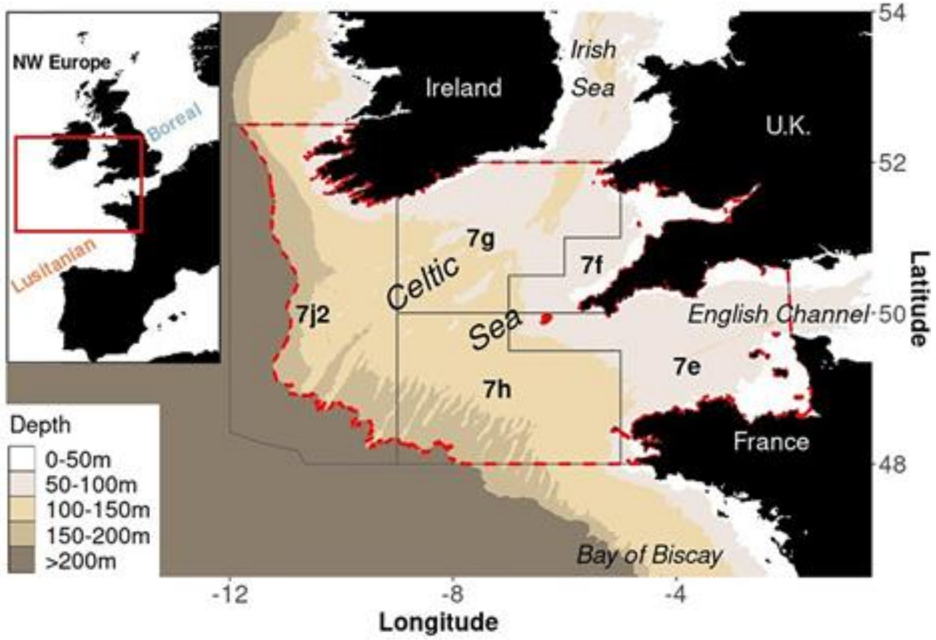


Morell et al. 2023

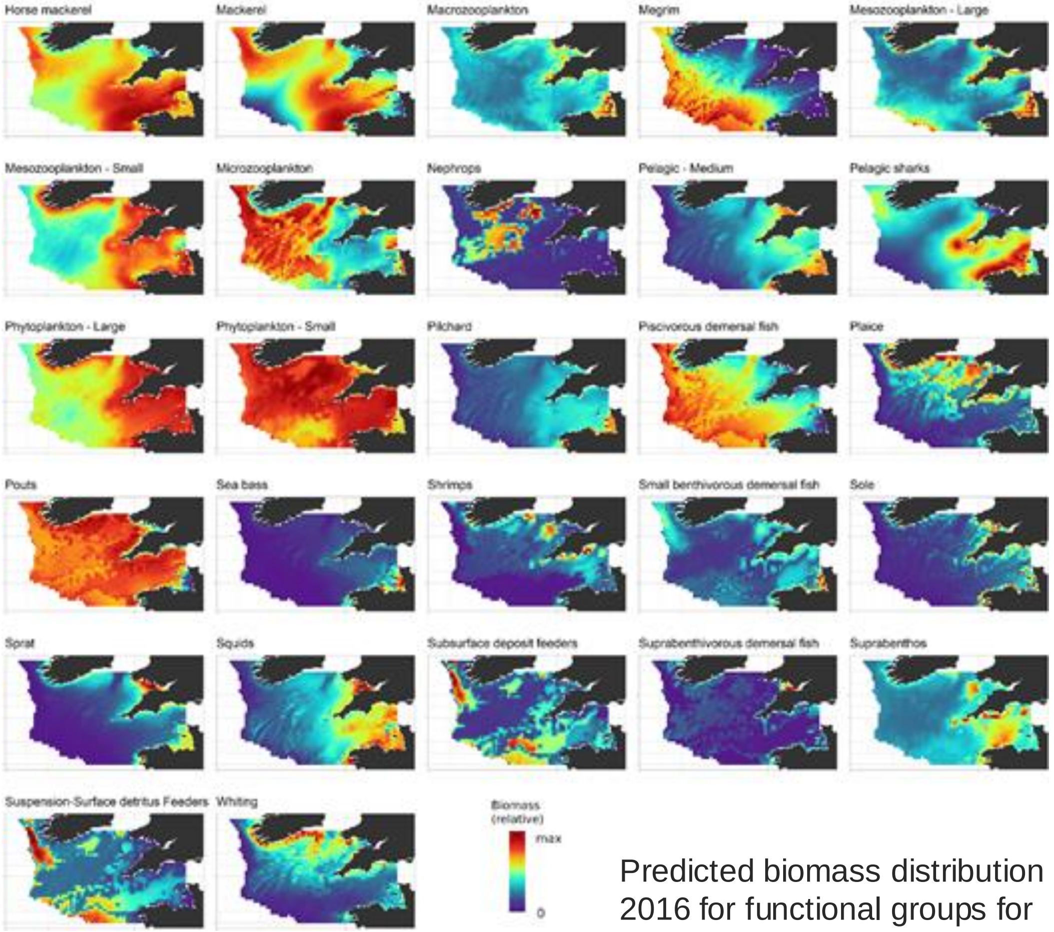
COMPLEX ECOSYSTEM MODELS

Ecopath with Ecosim

No fish is an island



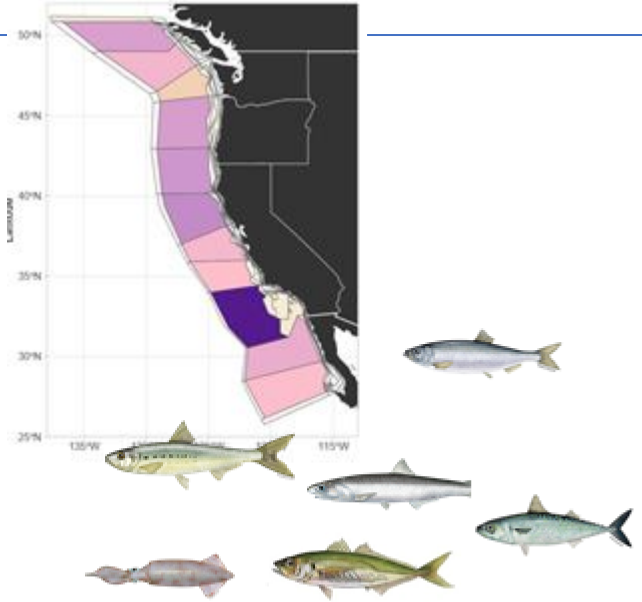
Hernvann et al. 2023



Predicted biomass distribution in 2016 for functional groups for which statistical habitat models (generalized additive models) were developed

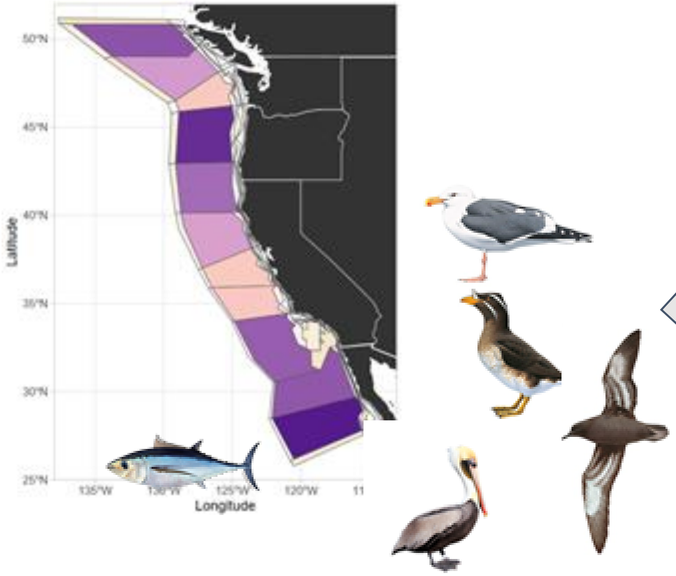
IS THIS A GOOD IDEA?

Forcing complex ecosystem model with…



Small Pelagics distribution

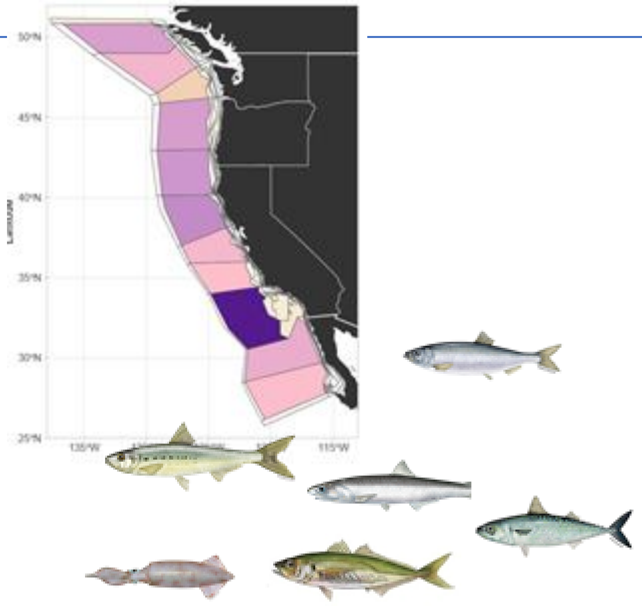
Projections of population and food web response



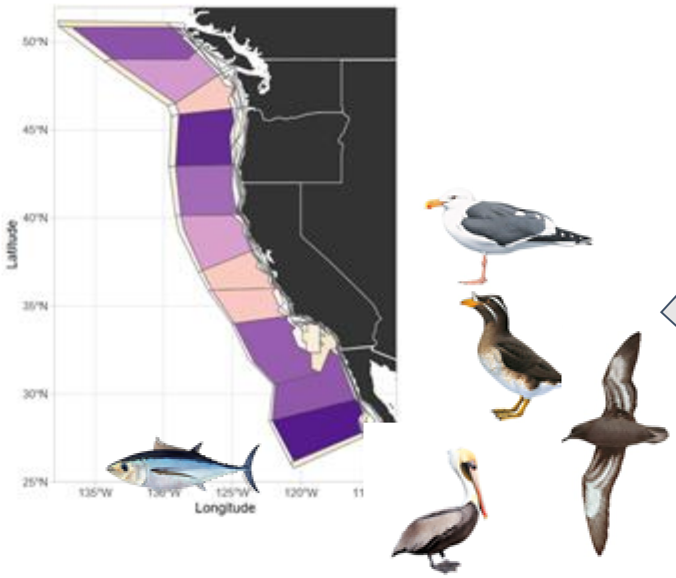
Predators' distribution

BENEFITS!

Forcing complex ecosystem model with…



Small Pelagics distribution



Predators' distribution

Projections of population and food web response

Improving ecosystem model's

- **age-structured distributions**
- **interannual distribution shifts**
- **thermal responses**

GOALS

Decisions, Decisions, Decisions: Choices when coupling Species Distribution models to complex ecosystem models

Decisions during construction of the SDM

- **SDM structure:** Should an SDM model abundance or the probability of presence? Which covariates should be included in the SDM?
- **Spatial, temporal, and/or ontogenetic mismatches:** How to best handle cases in which SDMs omit regions (based on the spatial domain), years, seasons, or life stages included within the complex models? How to work across models that vary in spatial and temporal resolution?
- **Is the SDM intended to represent the fundamental niche or a realized niche**? The **fundamental niche** indicates broad habitat preferences (a species could survive and thrive there), while the **realized niche** is which habitat a species actually occupies

GOALS

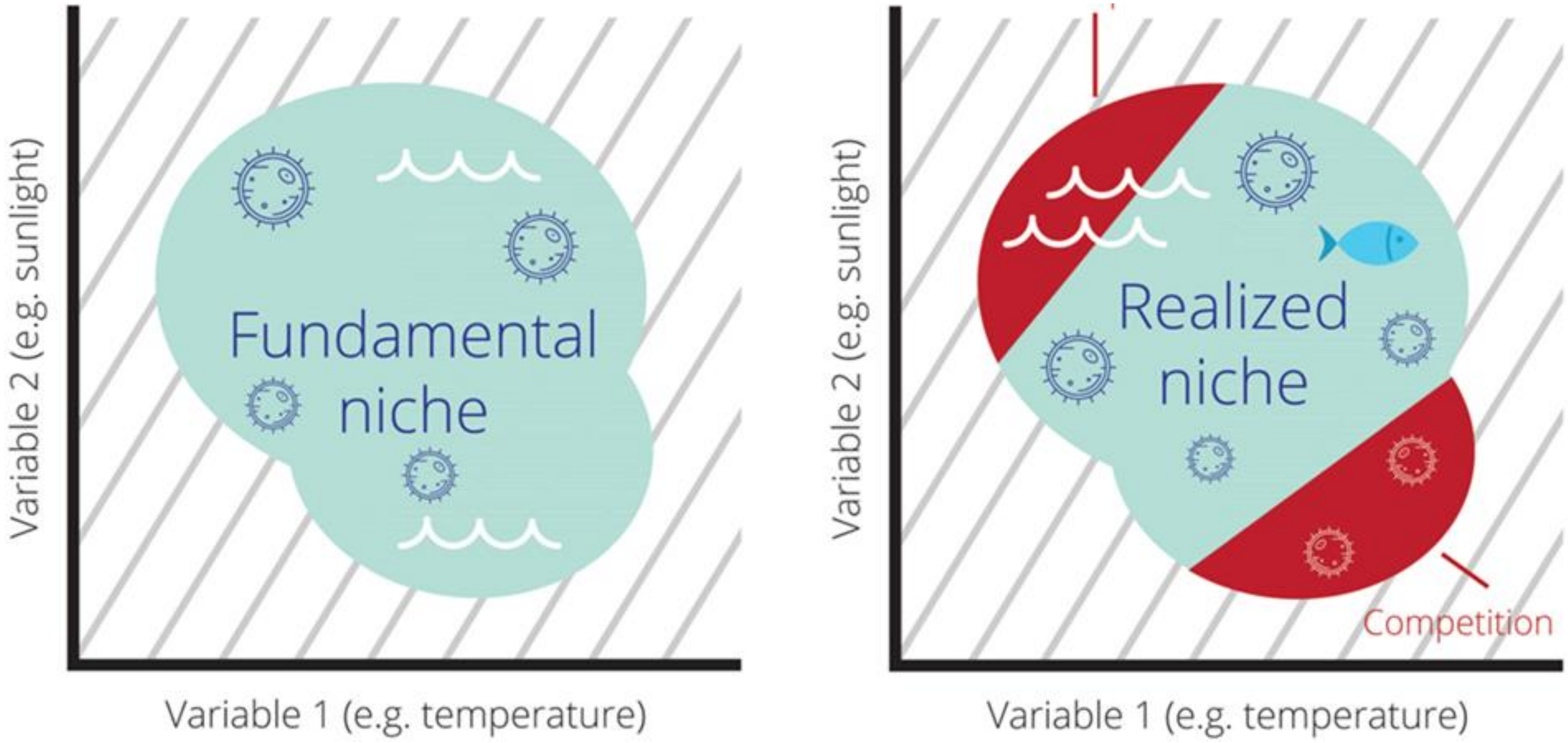
Decisions, Decisions, Decisions: Choices when coupling Species Distribution models to complex ecosystem models

Decisions within complex ecosystem models when linking to SDMs

- **Explicit movement**: Should the more complex models include processes like movement rates or foraging behavior, should they simply be forced by the SDM? Are detailed studies modeling processes such as advection of individual organisms needed to inform the ecosystem model?
- **Life history / dispersal:** How to handle different spatial habitats for multiple life history stages ? What is the necessary stage resolution in ecosystem models, and should we (and how do we) include processes such as density-dependence and larval transport?
- **Non-spatial ecosystem models:** How can complex, but non-spatial or coarsely-spatial ecosystem models be forced or informed by SDMs?
- **Propagating uncertainty:** How can estimates of uncertainty from SDMs be incorporated within the more complex models?

BEST PRACTICE #1: DECIDE ON REALIZED VS FUNDAMENTAL NICHE

Be cognizant of how, and in which model, the realized versus fundamental niches are represented, and whether this is appropriate for the questions at hand.



Escobar et al. 2017

BEST PRACTICE #1: DECIDE ON REALIZED VS FUNDAMENTAL NICHE

Be cognizant of how, and in which model, the realized versus fundamental niches are represented, and whether this is appropriate for the questions at hand.

OSMOSE, Northern Humboldt Current

Oliveros et al. 2017

Covariates from the SDMs used as inputs to the OSMOSE model in the Northern Peru Current Ecosystem

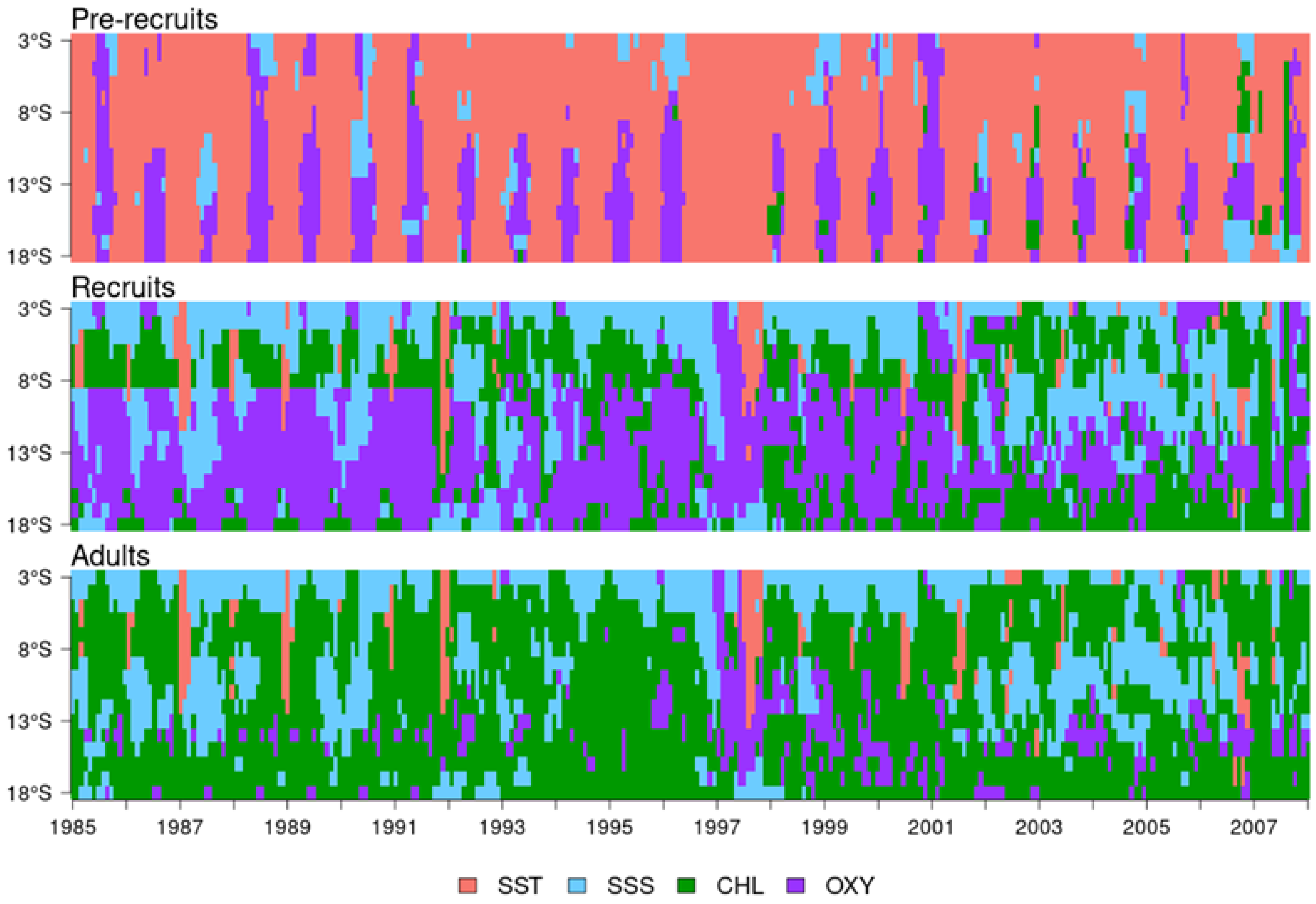
Type of SDM	Covariates
Fundamental Niche	Temperature, Salinity, Oxygen. A concave functional shape is assumed for all variables.
Realized Niche	Temperature, Salinity, Oxygen. Net primary productivity (proxy of prey for small pelagics) Bathymetry, distance to the shelfbreak (negative within the shelf). Abundance (local average density at several scales, e.g. 200km).

BEST PRACTICE #2: EARLY LIFE STAGES MAY REQUIRE NEW MECHANISTIC APPROACHES

For some cases, such as early life stages of fish, explicit, mechanistic studies of dispersal and movement may be more appropriate than correlative approaches.

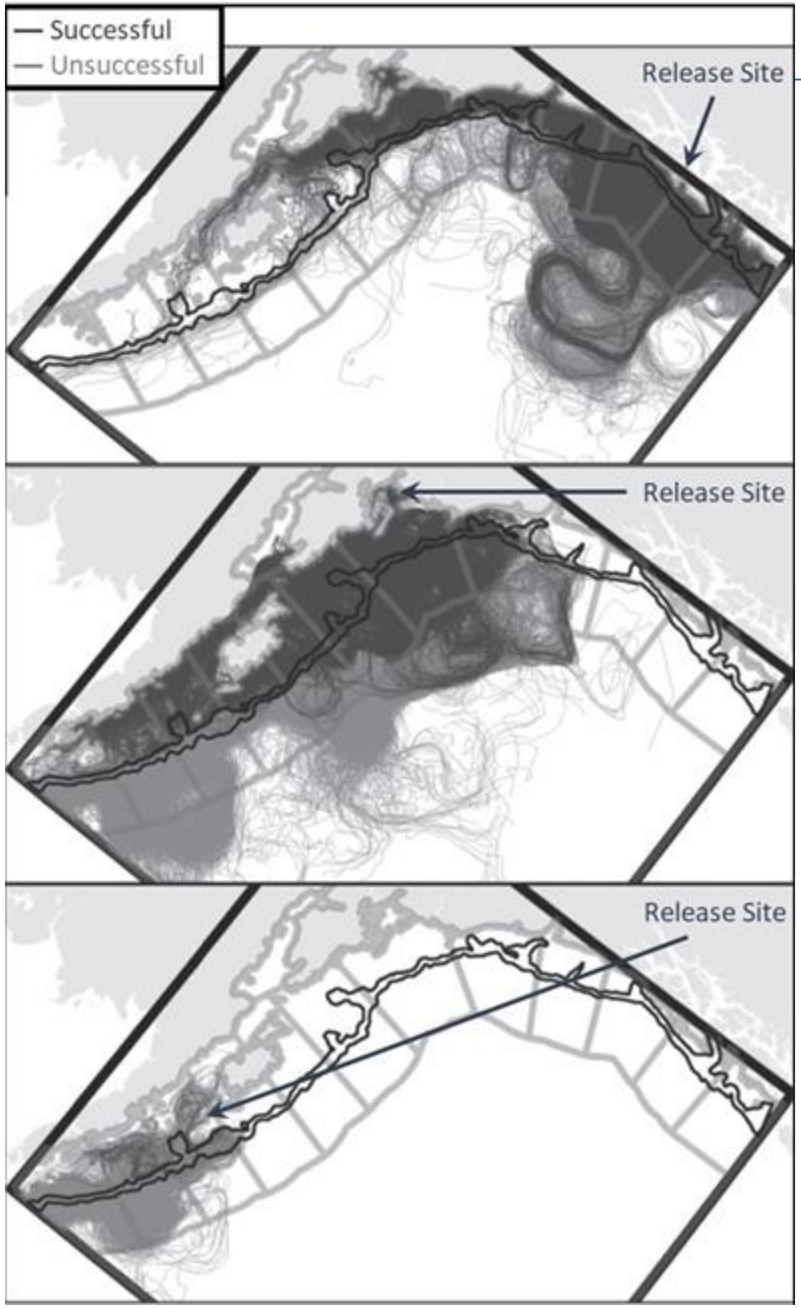
MAIN LIMITING FACTOR OF ANCHOVETA – BY STAGE

Fundamental niche varies by life stage



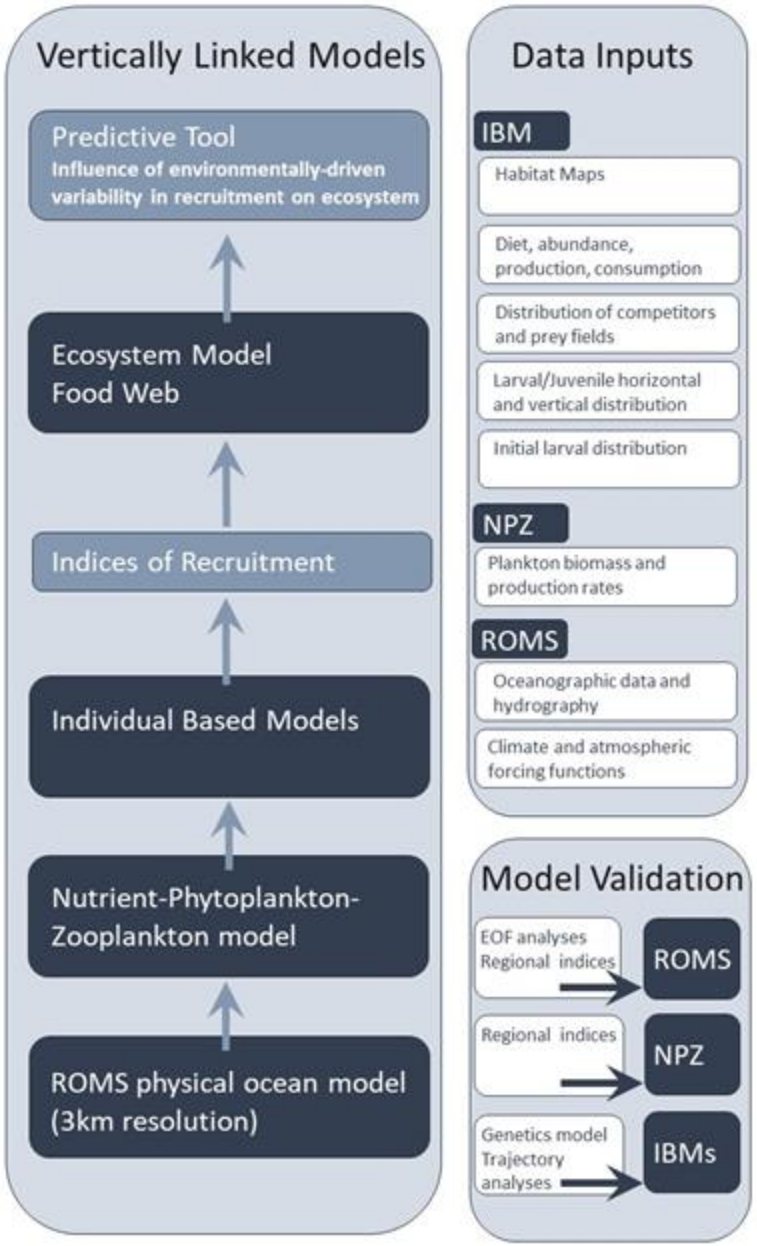
Lujan et al. 2016

GULF OF ALASKA



Understanding distribution of earliest life stages may require dispersal modeling

Stockhausen et al. 2019



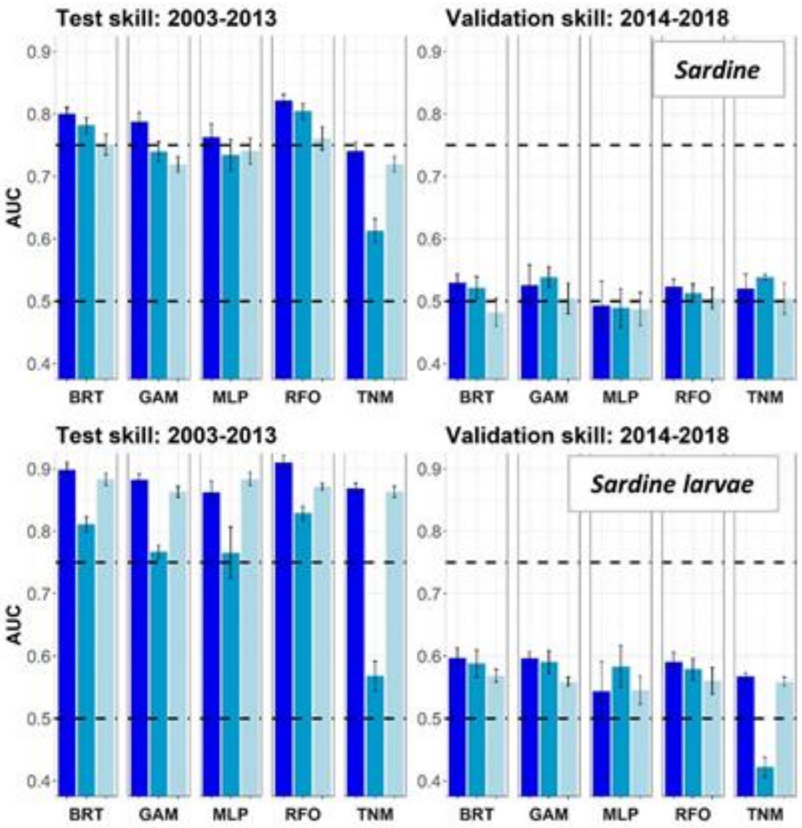
BEST PRACTICE #3: USE CARE WHEN EXTRAPOLATING IN TIME AND SPACE

Best practices for climate change projections will involve the use of covariates available at such decadal time-scales, while also being conscious of the challenges of extrapolating to novel conditions and areas.

Liu et al. in review,
Hernvann et al in prep

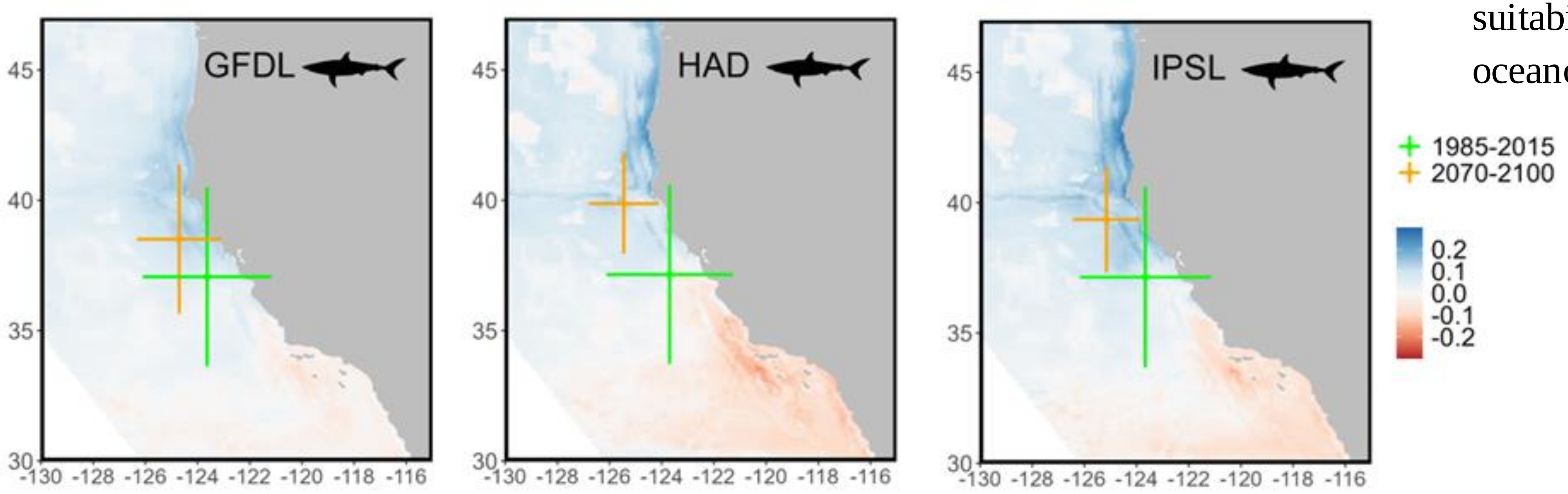
New ocean downscaling via GLORYS, rather than extrapolating from smaller ROMS grid

Muhling et al. 2020



SDM skill degrades in projections into heat wave years

Climate change projections also should quantify uncertainty in environmental conditions, and the subsequent implications for species distributions and for the full ecosystem.

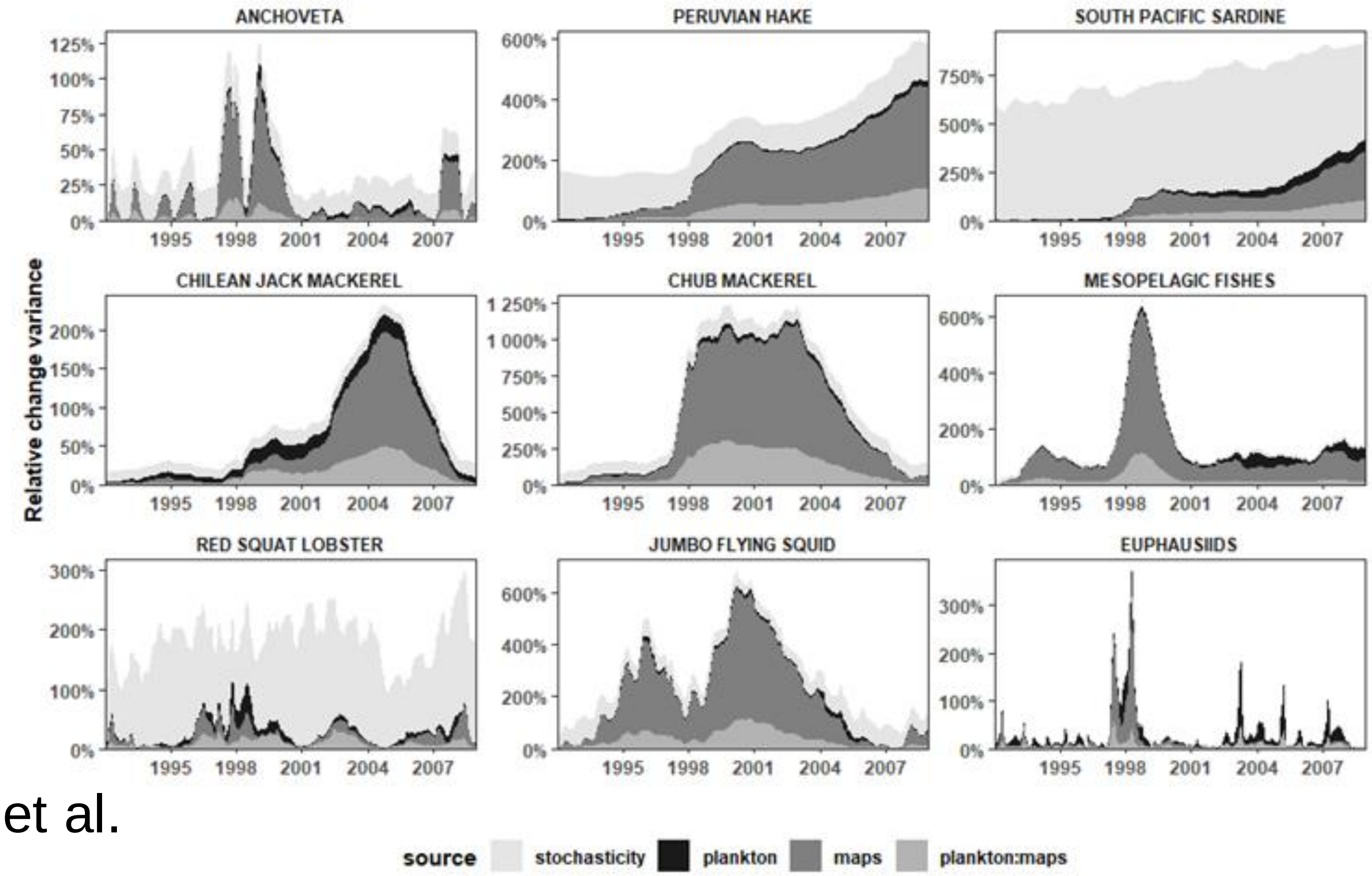


Change in blue shark habitat suitability under three different oceanographic projections.

Lezama Ochoa et al. 2024

BEST PRACTICE #4: QUANTIFY UNCERTAINTY

Best practices include quantifying the uncertainty stemming from the SDMs, and how such uncertainty propagates through the linked ecosystem models.

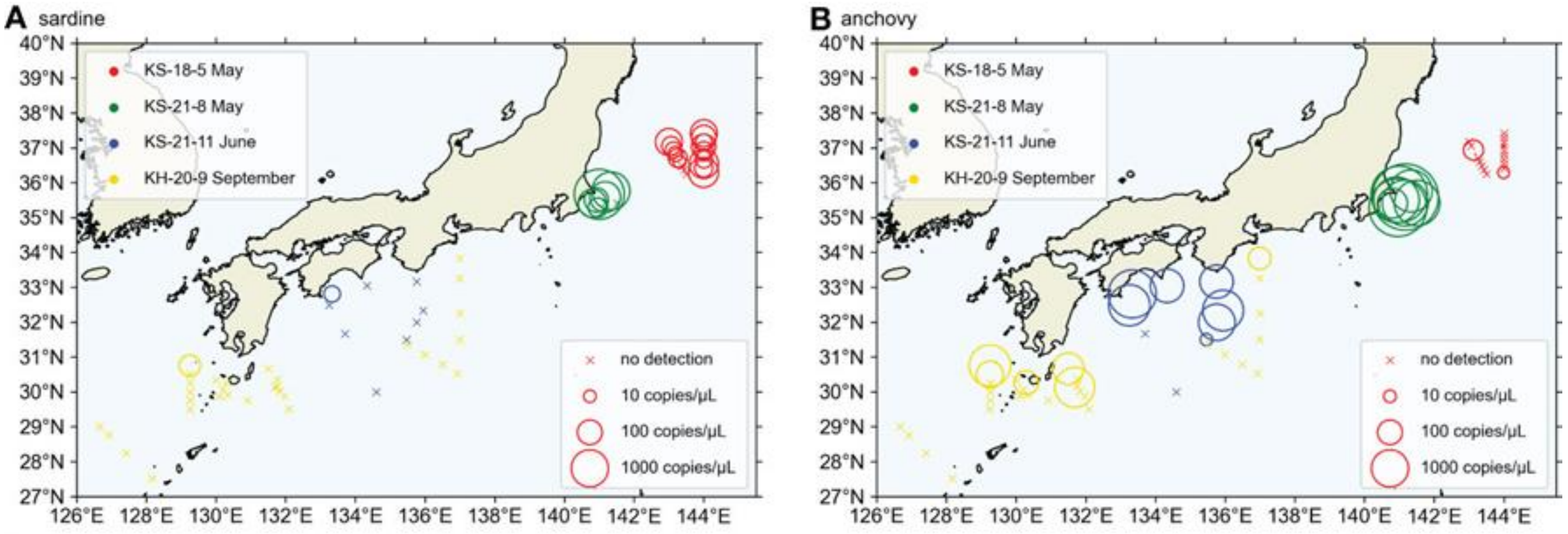


Model variability driven by SDMs (maps) and mapsXplankton

Hill Cruz et al. 2022

BEST PRACTICE #5: EMBRACE NEW OBSERVATIONS

Novel methods (such as eDNA and the use of fishery-dependent data) should be embraced.



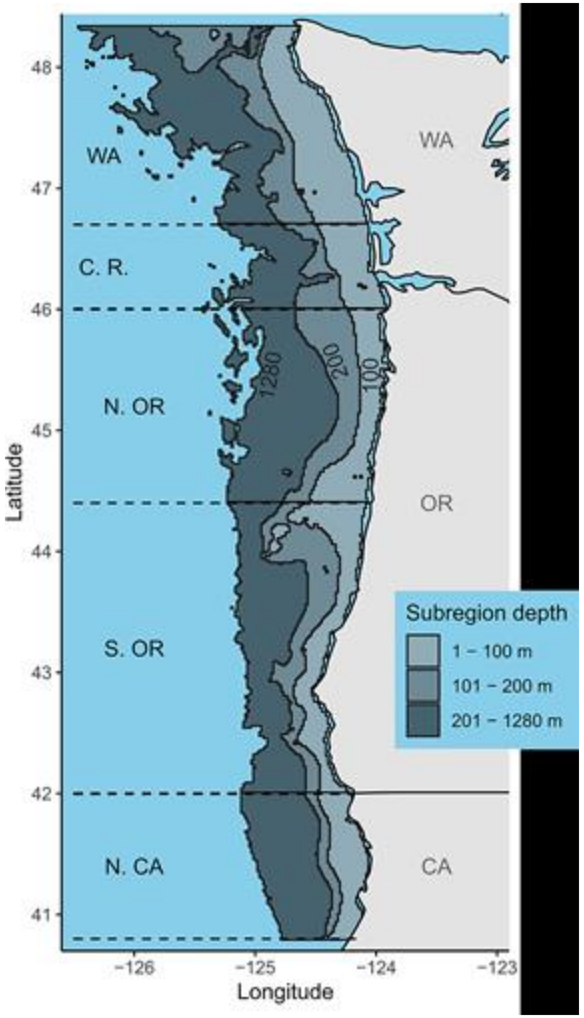
Sardine and anchovy eDNA in the Kuroshio

Yu et al. 2023

BEST PRACTICE #6: SDMS CAN BE USED EVEN IN NON-SPATIAL ECOSYSTEM MODELS

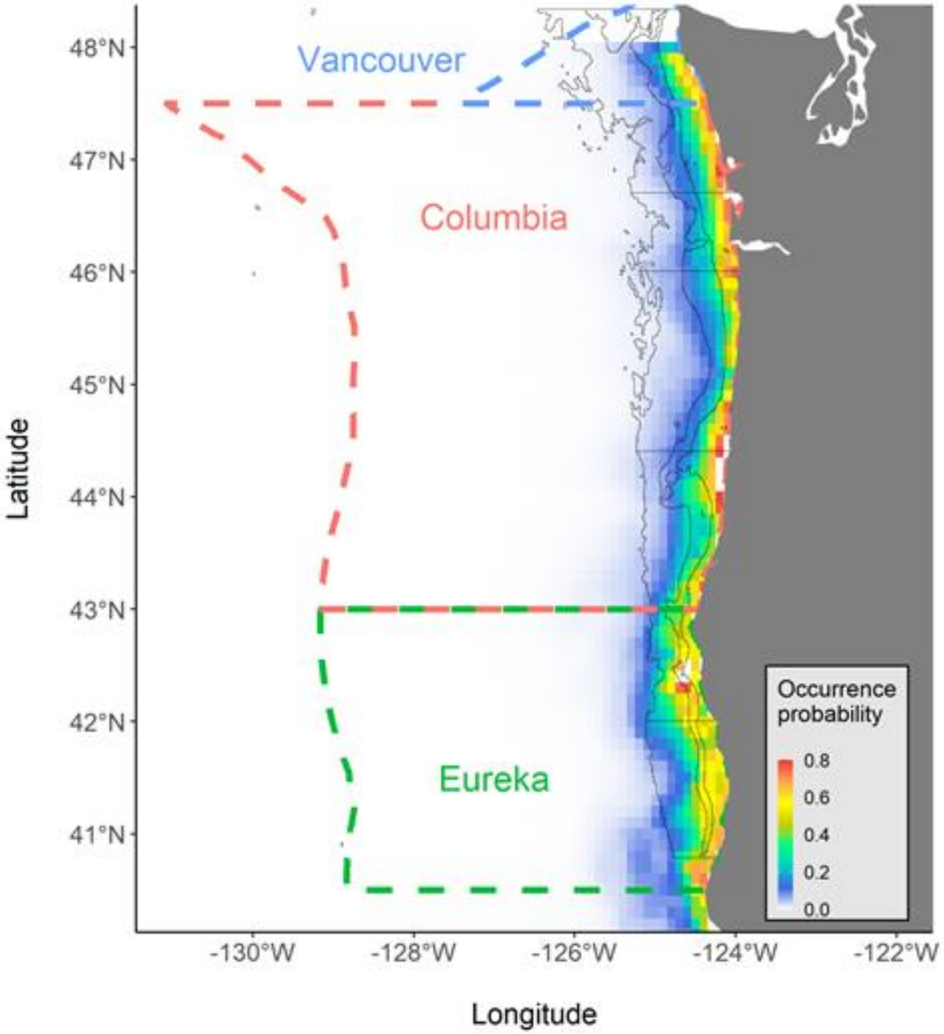
Practical applications of SDMs include for instance better spatial apportionment of catches, and translation of environmental performance curves (e.g. thermal niches) to improve understanding of population and ecosystem productivity.

CALIFORNIA CURRENT – ECOTRAN

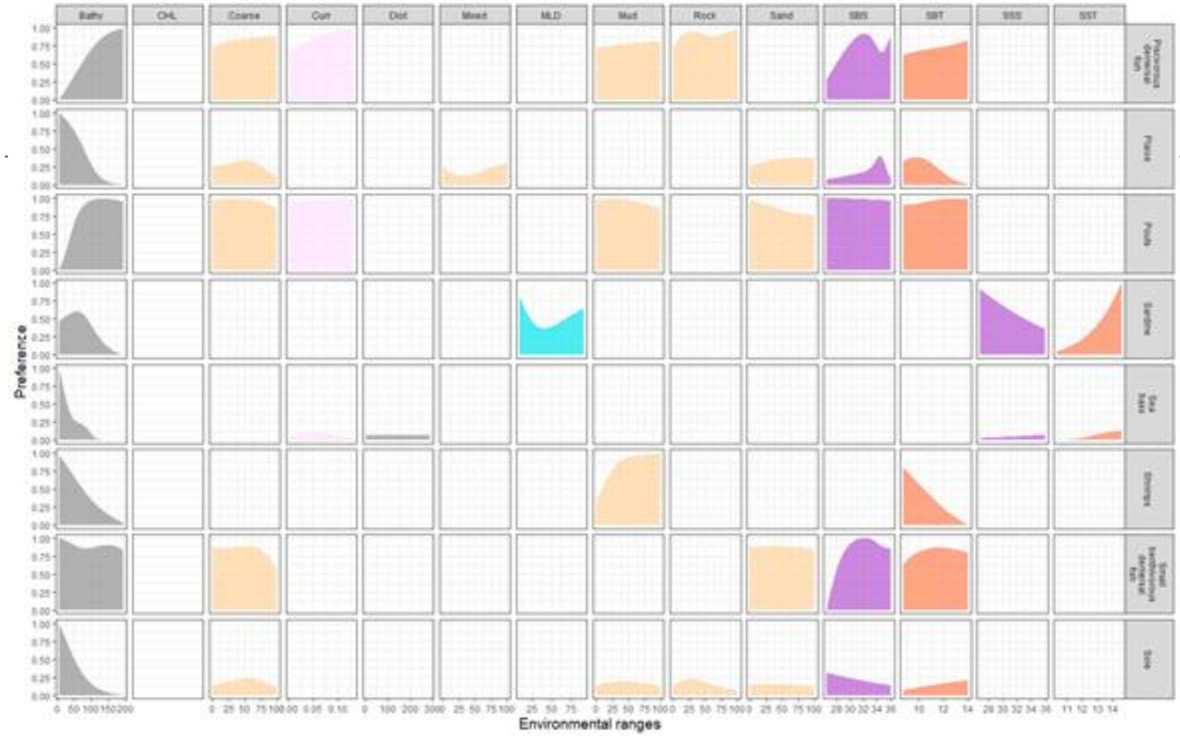


← Gomes et al. 2024– 15 spatial zones in ECOTRAN model

→ SDMs assist with catch apportionment to coarse spatial polygons within the ECOTRAN model

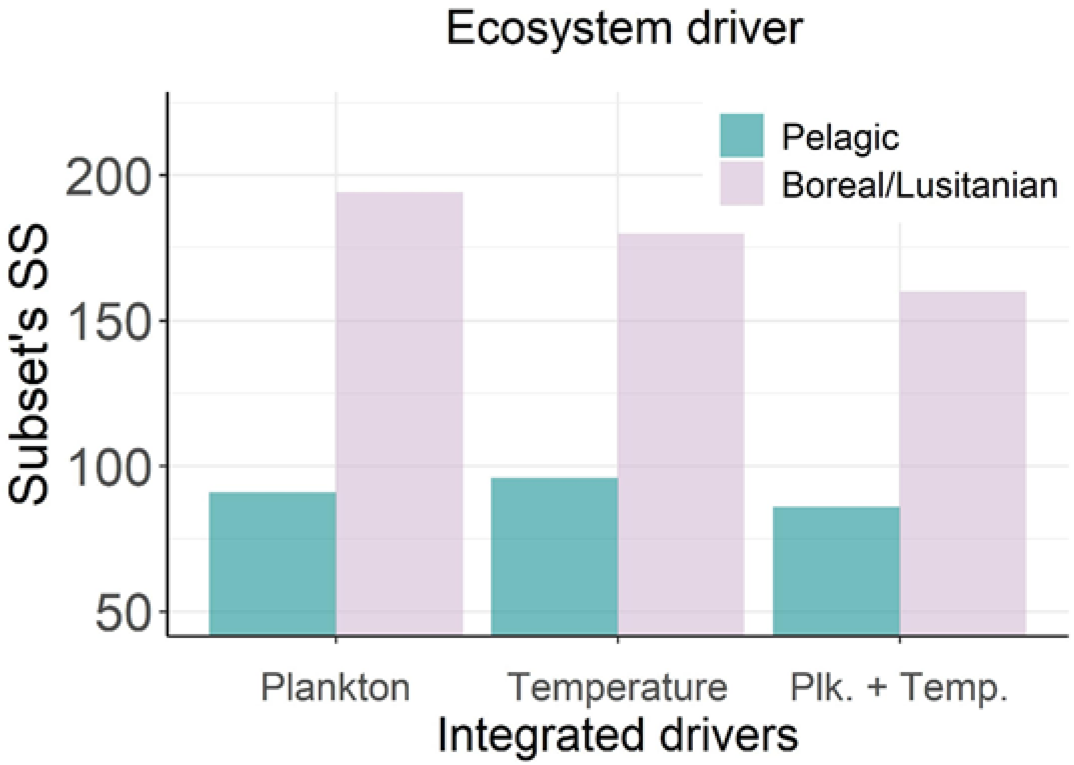


CELTIC SEA – ECOSIM



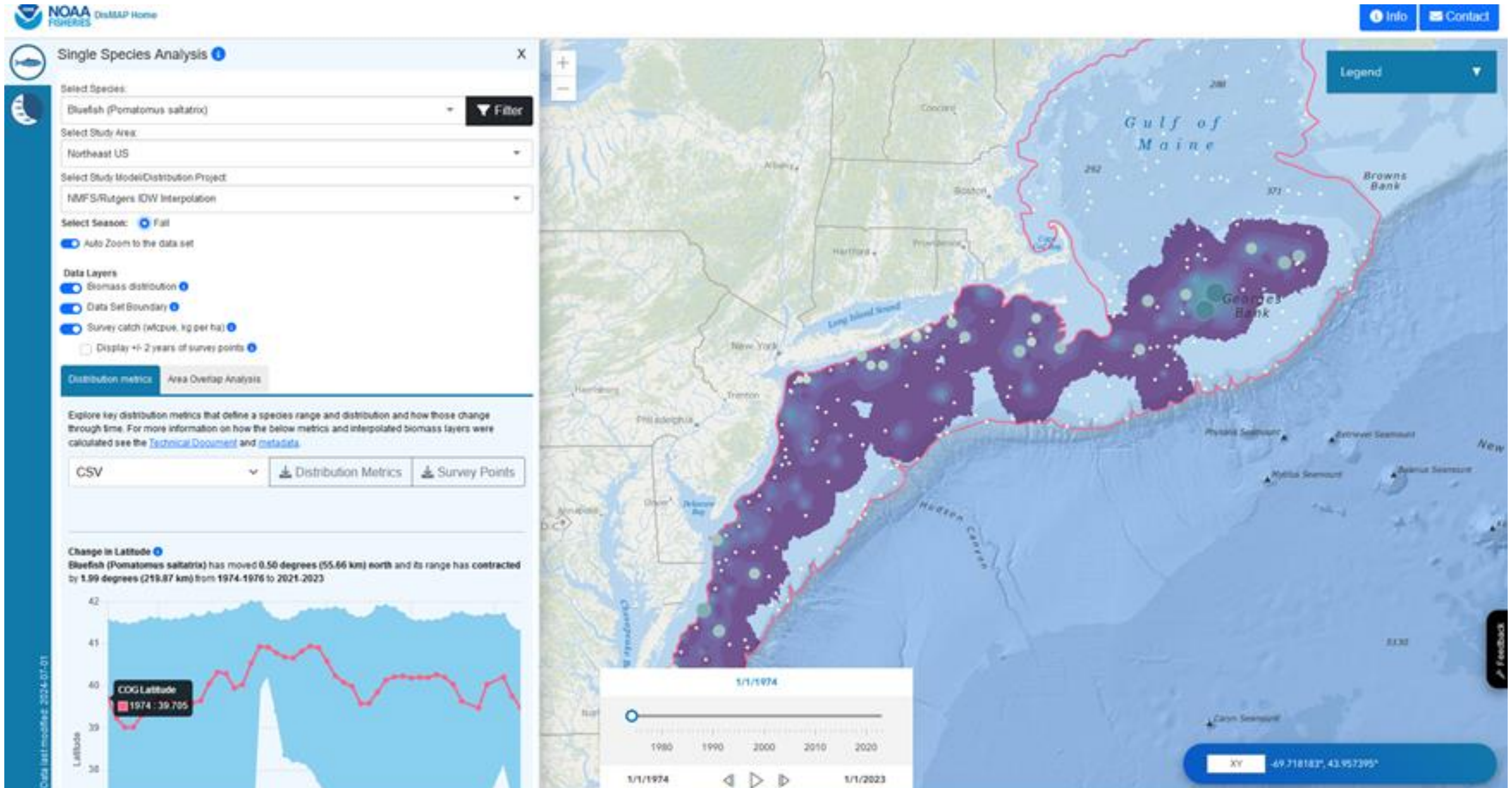
→ Hernvann et al. 2020

Ecosim model fits to data improved when SDM-derived temperature-to-productivity relationships were included



BEST PRACTICE #7: PROMOTE DIALOG BETWEEN DISCIPLINES, AND SHARE PRODUCTS VIA DATA PORTALS

Critically, opportunities for open dialog between SDM developers, ecosystem modelers, oceanographers, and others is necessary and productive, as is dissemination of products via data portals to facilitate use, integration, and evolution.



NOAA DisMAP portal https://apps-st.fisheries.noaa.gov/dismap/DisMAP.html

Key messages

- **Practitioners from many regions have begun linking SDMs to ecosystem models, for small pelagic fish and other species**
- **This allows more dynamic and realistic ecosystem models, including**
  - **age-structured distributions**
  - **interannual distribution shifts**
  - **thermal responses**
- **This linking requires some careful decisions, guided by best practices.**
- **Contact us if you are experimenting with this yourself!**

THANKS!

This work is a product of the ICES PICES Working Group on Small Pelagic Fish. The work stems from a workshop at the 2022 ICES PICES Small Pelagic Fish Symposium.

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