Gulf of Alaska Climate - Integrated Modeling Project

Funding: NOAA Climate Program Office & North Pacific Research Board

An operational suite of coupled socio-ecological models for climate fisheries hindcasts, forecasts, projections and management strategy evaluation

CSIRO

North Pacific Research Board

National Oceanic and Atmospheric Administration PMEL Pacific Marine Environmental Laboratory

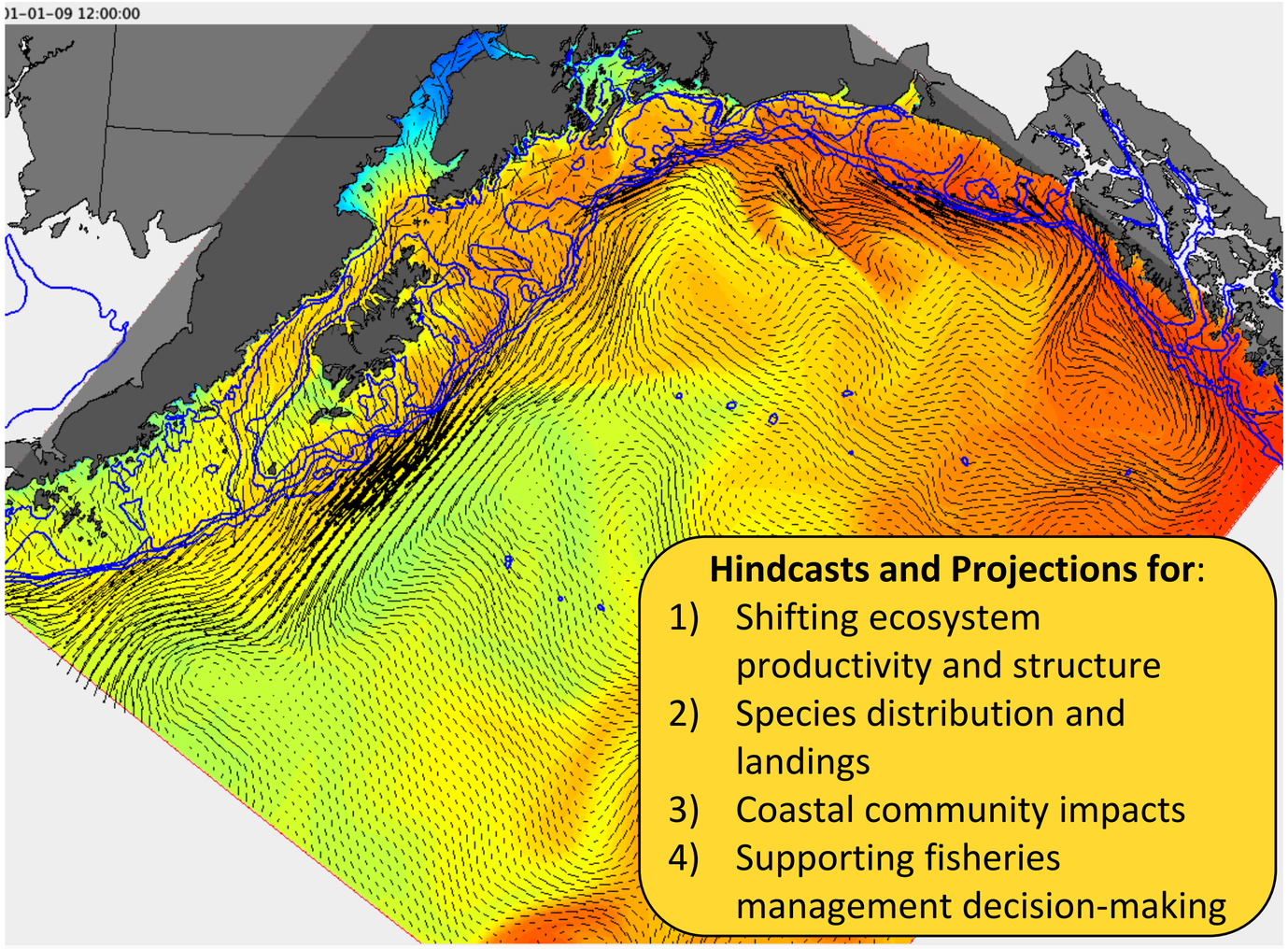
Fisheries and Oceans Canada

Pêches et Océans Canada

Cooperative Institute for Climate, Ocean & Ecosystem Studies

National Oceanic and Atmospheric Administration U.S. Department of Commerce NOAA FISHERIES

University of Washington SAFS School of Aquatic and Fishery Sciences



Hindcasts and Projections for:

1) Shifting ecosystem productivity and structure
2) Species distribution and landings
3) Coastal community impacts
4) Supporting fisheries management decision-making

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From climate to communities in the Gulf of Alaska: using an integrated modeling approach to evaluate drivers of present and future system-level productivity and assess climate impacts on fishing-dependent communities

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PIs: Beth Fulton, Alan Haynie, André Punt, Marysia Szymkowiak, Elizabeth McHuron

Additional NPRB project PIs: Isaac Kaplan, Kristin Marshall

COCA project Co-PIs: Kerim Aydin, Caihong Fu, Brian Fadely, Albert Hermann, Kirstin Holsman, Anne Hollowed, Stephen Kasperski, Jamal Moss, Olav Ormseth, Lauren Rogers, Chang Seung, James Thorson, Katie Sweeney

Funding: NPRB: $472K over 3 years, NOAA COCA funding: $1.5M over 3 years, plus in kind support from NOAA IEA program, and NOAA Fisheries core funding.

Institutional partners

AFSC: Marine Mammal Laboratory, REFM, Auke Bay Laboratories.

CSIRO: Technical support and advice on Atlantis model development, Contact Beth Fulton.

DFO: Advice on ecosystem modeling, Contact Caihong Fu.

PMEL: ROMS modeling, Contact Al Hermann.

School of Aquatic and Fisheries Sciences/CICOES: Post-doctoral scholars Matthieu Veron—climate-enhanced single species models, Alberto Rovellini—Atlantis modeling, Gemma Carroll—food web spatial modeling, Adam Hayes—fleet dynamics modeler. Research scientist Liz McHuron—Sea lion foraging and bioenergetics.

Pacific States Marine Fisheries Commission: Andrew Steinkruger - sociology post-doctoral scholar.

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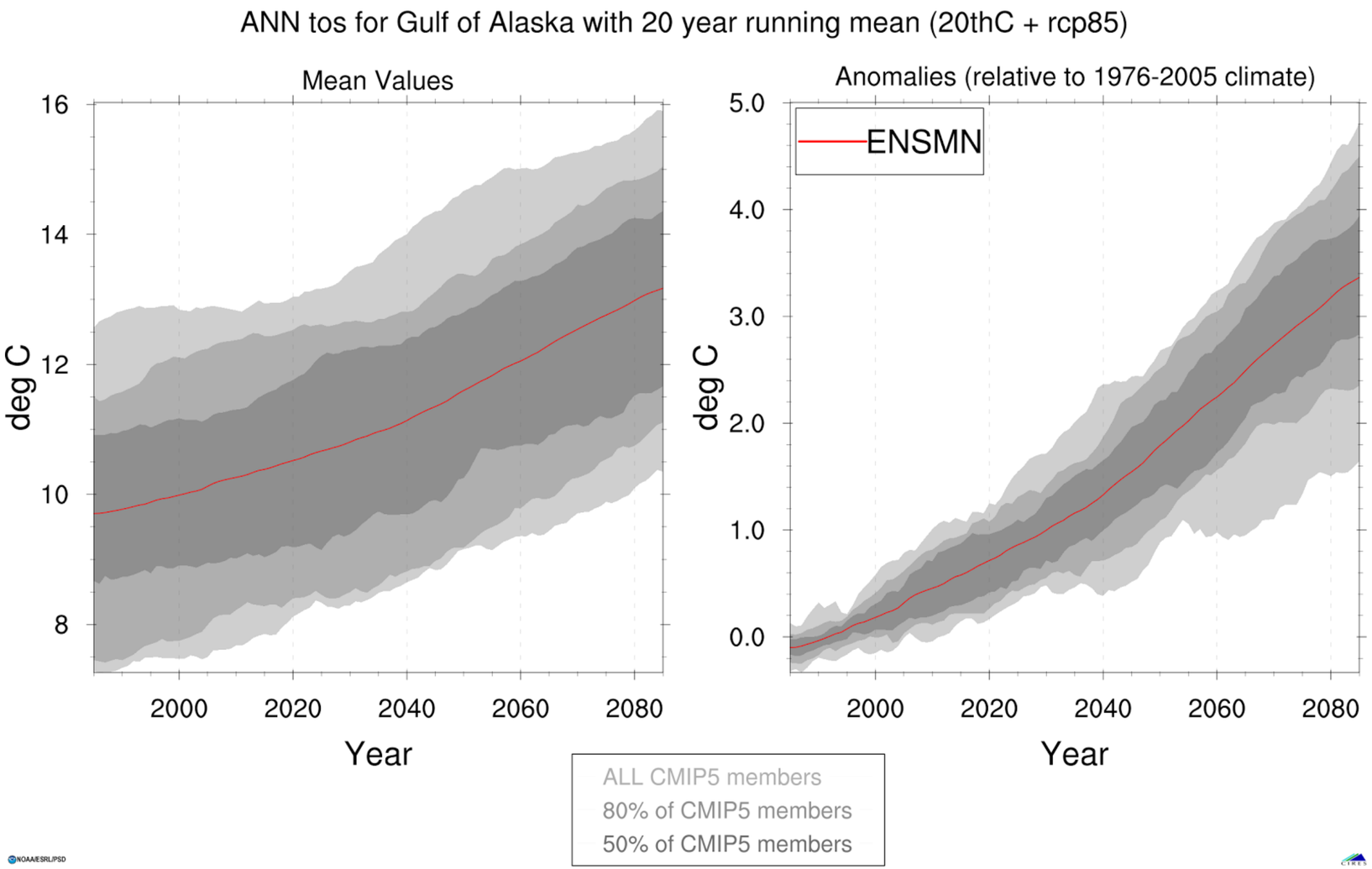
Projected climate changes:

- Ocean warming
- Ocean acidification
- Oxygen limitation
- Changes in ocean circulation and stratification



Projected increases in sea surface temperature for the Gulf of Alaska (left) and future temperatures relative to historic means (right).

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GOA-CLIM is an integrated research program that:

1) leverages ongoing research at the Alaska Fisheries Science Center,

2) is closely aligned with the successful eastern Bering Sea ALCIM project, and

3) represents a substantial step towards meeting the objectives of GOA Climate Science Regional Action Plan (Dorn et al. 2018) and the NMFS climate science strategy (Link et al. 2015).

Overarching research questions concern the drivers of system-level productivity under climate change, the ways that fisheries management can promote resilient fisheries in a changing climate, and development of a coupled modeling approach that extends from climate to communities to evaluate economic and social impacts of climate change on resource-dependent communities in the GOA.

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Presently funded ROMS simulations for the GOA include downscaling "time slices" of future conditions;

Under this project we would fill out those time periods with a continuous simulation of GOA dynamics at 3km resolution from the present through 2100 under multiple projections across ESMs and RCP scenarios to support climate enhanced ecosystem and stock assessment models.

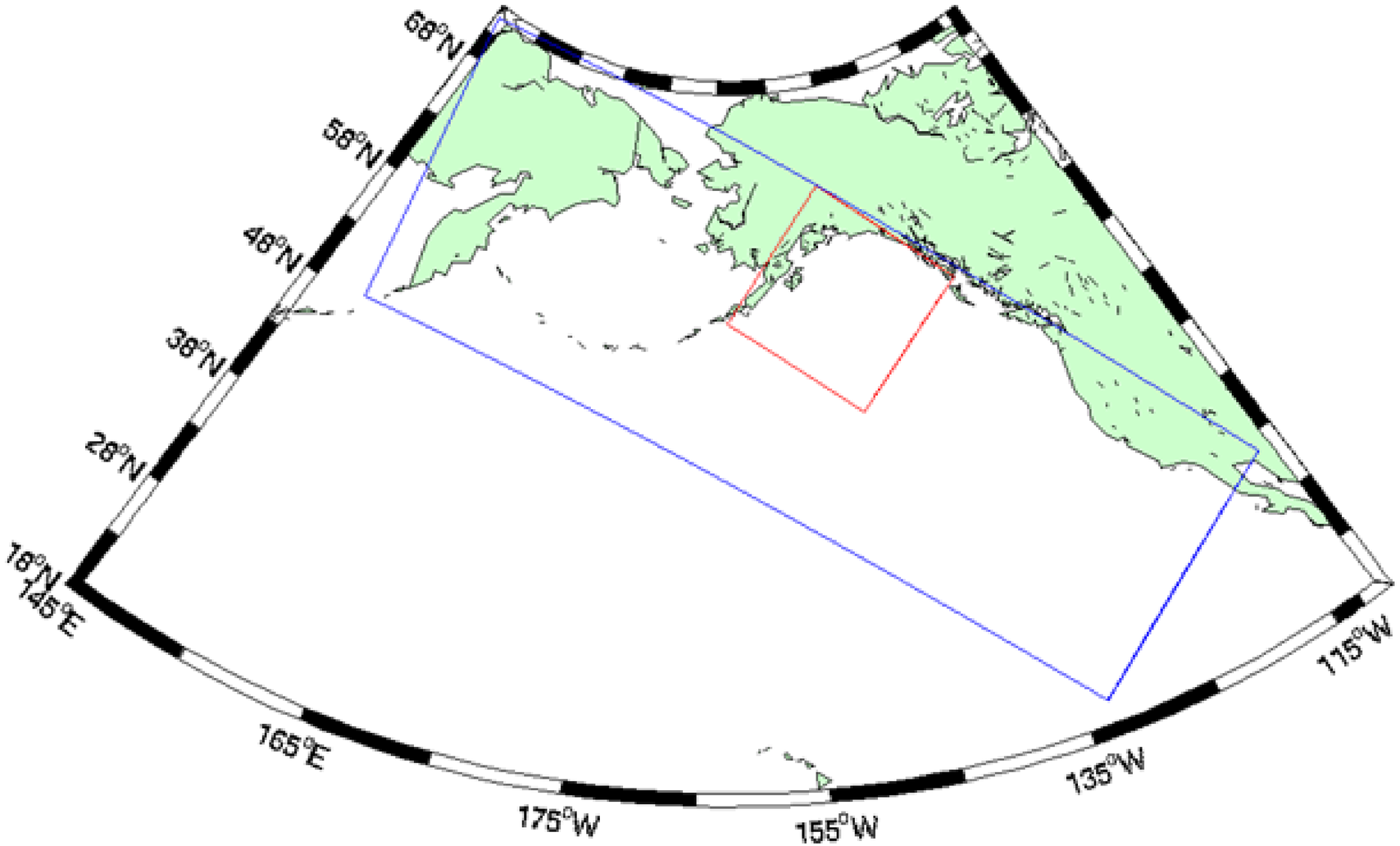

Figure 1. Spatial domain of the GOA-3K model (red outline) shown using the Lambert conformal conic projection. The GOA-3K model is embedded in NEP-10K model (blue outline).

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Three research pathways:

- Research pathway 1: Development and application of the Atlantis model as an element of a multi-model ensemble to evaluate fisheries management strategies in a changing climate.
- Research pathway 2: Evaluate and predict the impacts of major environmental anomalies to the endangered Western DPS population of Steller sea lions
- Research pathway 3: From Climate to Communities. Building the tools and knowledge-base to couple the ecosystem models to regional economic models to evaluate the impacts of climate change on resource-dependent communities.

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Research pathway 1: Development and application of the Atlantis model as an element of a multi-model ensemble to evaluate fisheries management strategies in a changing climate

- Build, develop input data sets, including ROMS output, for, and calibrate an Atlantis end-to-end ecosystem model for the Gulf of Alaska.
- Other candidate models for the multi-model ensemble: CEATTLE multi-species model (Grant Adams PhD), climate-enhanced single species models (Matthieu Veron postdoc), Ecopath with Ecosim Bridget Ferriss, Szymon Surma UAF postdoc
- Conduct model experiments to evaluate the drivers of present and future ecosystem-level productivity in the GOA, focusing on the impact of the marine heat wave, and climate projections to 2100.
- Apply a multi-model approach to evaluate the current OY range in the GOA, taking into account model uncertainty

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Primer on optimum yield

- The optimum yield for groundfish in the GOA is specified as a range (140,000–800,000 t), which provides both lower and upper limits on total groundfish removals (with the expectation that catches will be at least as high as the lower limit).

- The OY upper limit was estimated in 1987 early in the history of Federal fisheries management as the sum of the single species estimates of MSY and reduced to account for ecosystem considerations and uncertainty.

- Unlike the BSAI 2 million ton cap, the upper limit in the Gulf of Alaska has never been constraining, suggesting that the original estimate was inaccurate.

- The GOA Groundfish FMP notes that “The Magnuson-Stevens Act requires Councils to “review on a continuing basis, and revise as appropriate, the assessments and specifications made ...with respect to the optimum yield.”

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Research pathway 2: Evaluate and predict the impacts of major environmental anomalies to the endangered Western DPS population of Steller sea lions.

- This pathway will build on the ecosystem modeling tools developed in the first pathway
- Output from the ROMS/NPZ, CEATTLE and Atlantis models will be used to evaluate changes in ecosystem structure and function prior to and during the 2013-2016 marine heat wave in the GOA. Mechanisms underlying observed SSL population-level responses will be tested.
- A second approach is to develop new bioenergetic models for SSLs to test how the marine heatwave affected energy consumption and estimate the level of prey reductions that could have led to the observed reproductive failure.
- Goal is to provide climate-informed management guidance for this protected species.

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Research pathway 3: From Climate to Communities. Building the tools and knowledge-base to couple the ecosystem models to regional economic models to evaluate the impacts of climate change on resource-dependent communities.

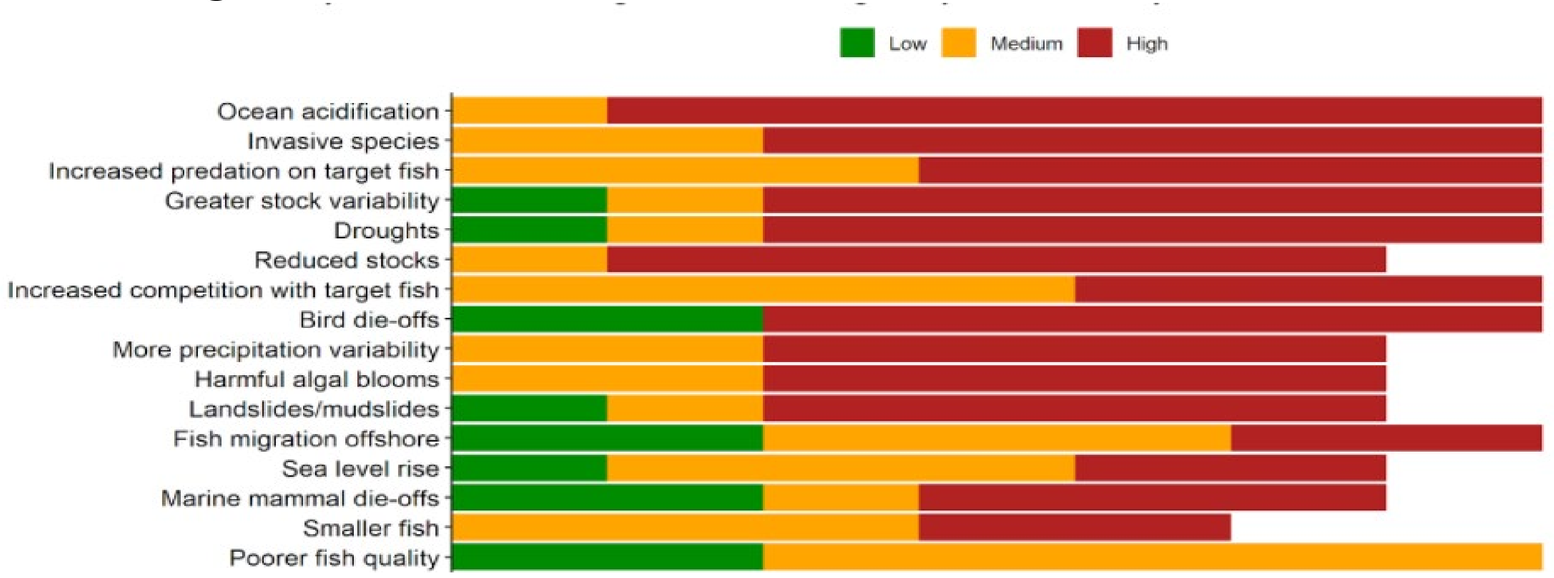
- This pathway will also build on the ecosystem modeling tools developed in the first pathway
- There are three projects:
  - A fleet dynamics model. Modeling fleet dynamics and fishery landings responses to ecosystem and management change
  - A sociological project to examine how individuals, families, and communities across GOA adapt to climate variability and associated changes in fisheries and marine ecosystems
  - Community Economic Modeling. Regional Computable General Equilibrium models for borough and census areas in the GOA

Building conversations around climate change with Gulf of Alaska communities

Marysia Szymkowiak (AFSC) & Andrew Steinkruger (PSFMC)

- Employing multi-pronged engagement approach - interviews and workshops
  - Individual interviews allow deep conversations and prepare participants for group engagement
  - Group meetings provide for group learning and innovation
- Held two virtual workshops so far with GOA fishermen, focusing on:
  - What are the ecological changes occurring in your fisheries and local marine ecosystem?
  - What can you do to adapt to these changes?

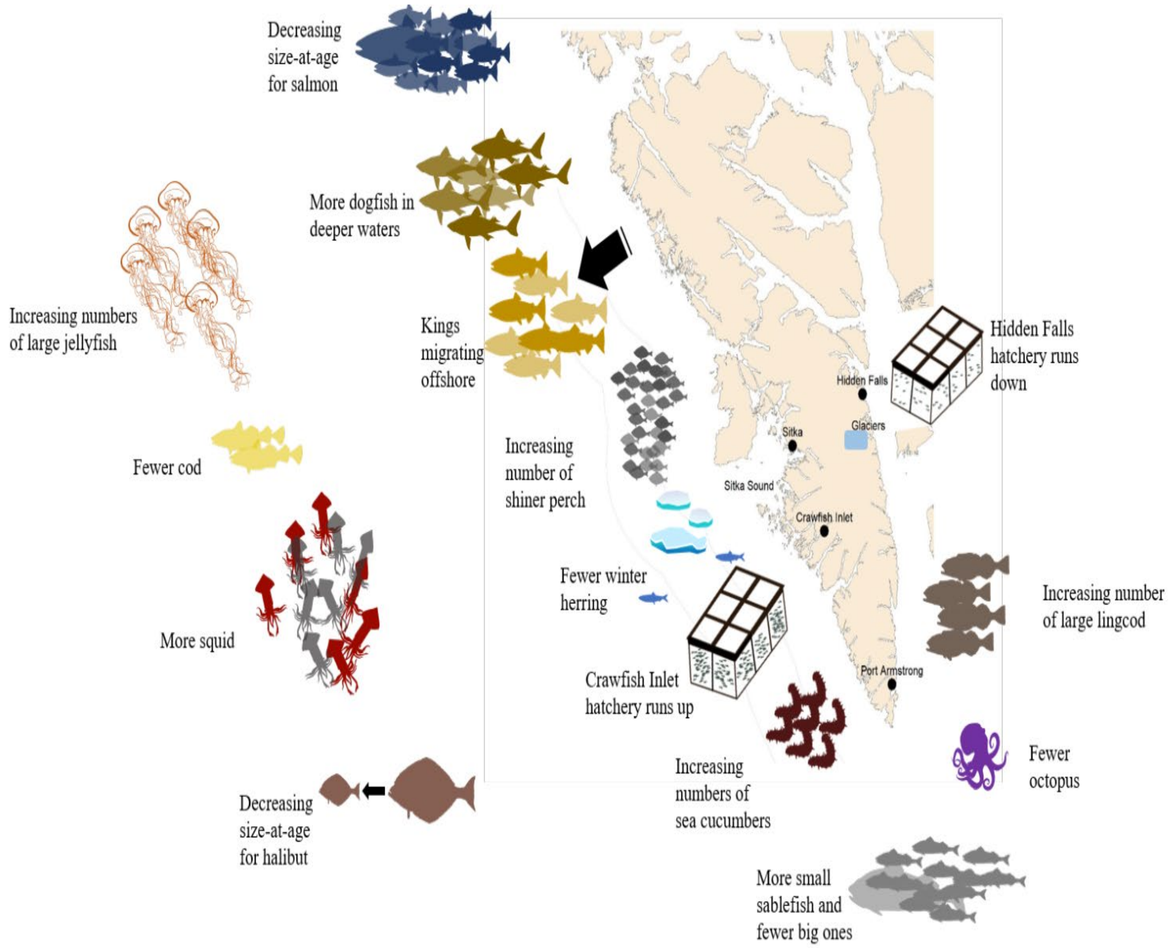
Identifying perceptions of risk associated with ecological changes noted by participants.



Understanding climate change adaptation necessitates long-term relationship building

Preliminary conversations indicate that:

- Perceptions of climate change are tenuous, fluid
  - Climate change = “black box”
  - Changes are not static
  - Raise questions about:
    - Is this “here to stay”?
    - Is this a regime shift?
- Adaptation necessitates persistence of change and economic stimulus
- “Shifting baselines” and “new normals” are leaving people questioning what is actually an observed change
- Communication about science of climate change needs to improve
  - Need for definitive science around what is happening now in marine systems
  - Involve fishermen in science generating process
  - Communicate directly with fishermen



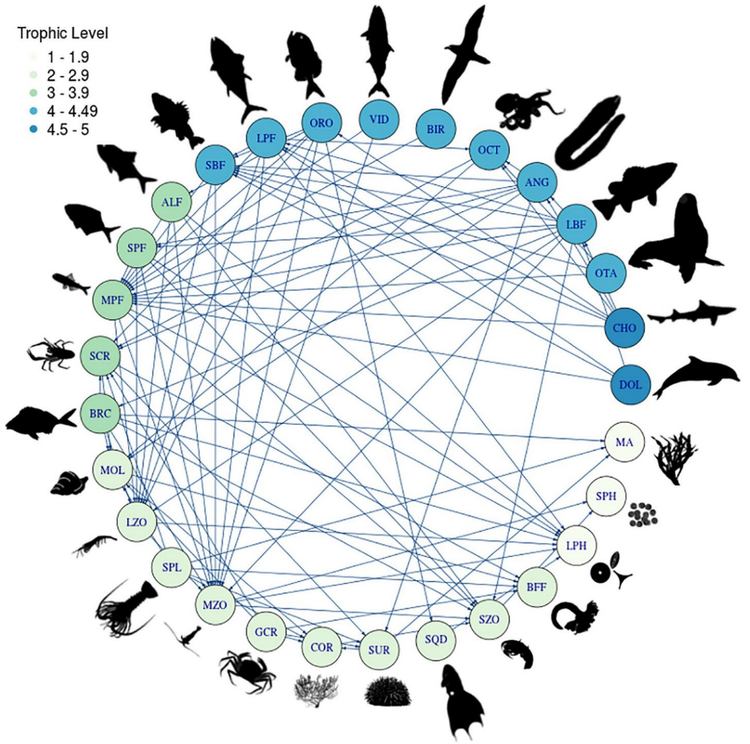
Building a map of ecosystem changes with Sitkan stakeholders to create a “baseline” of change for future conversations

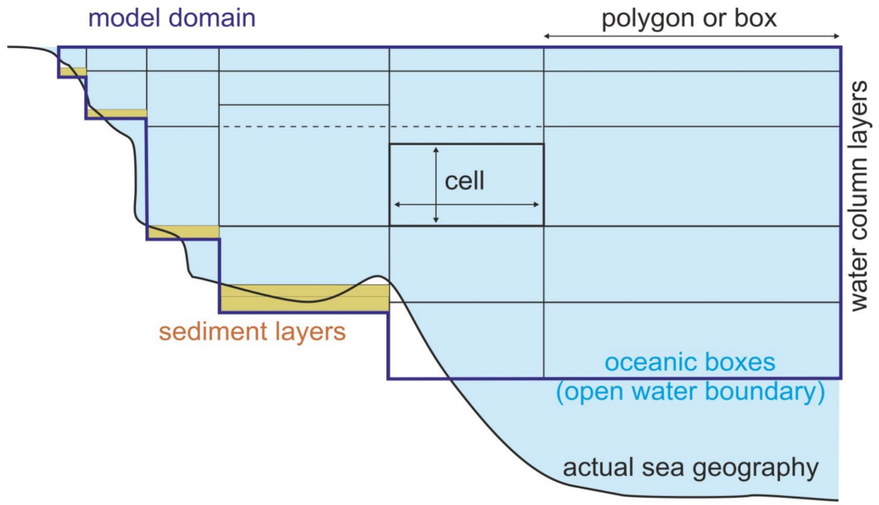
Atlantis model objectives

1. Develop a new Atlantis model for the Gulf of Alaska
2. Use the model in hindcast to study past events (2013-2016 heat wave and regime shifts)
3. Use the model in forecast to project changes in groundfish productivity in the GOA under global climate change
4. Use the model to evaluate optimum yield for groundfish

Atlantis technical overview

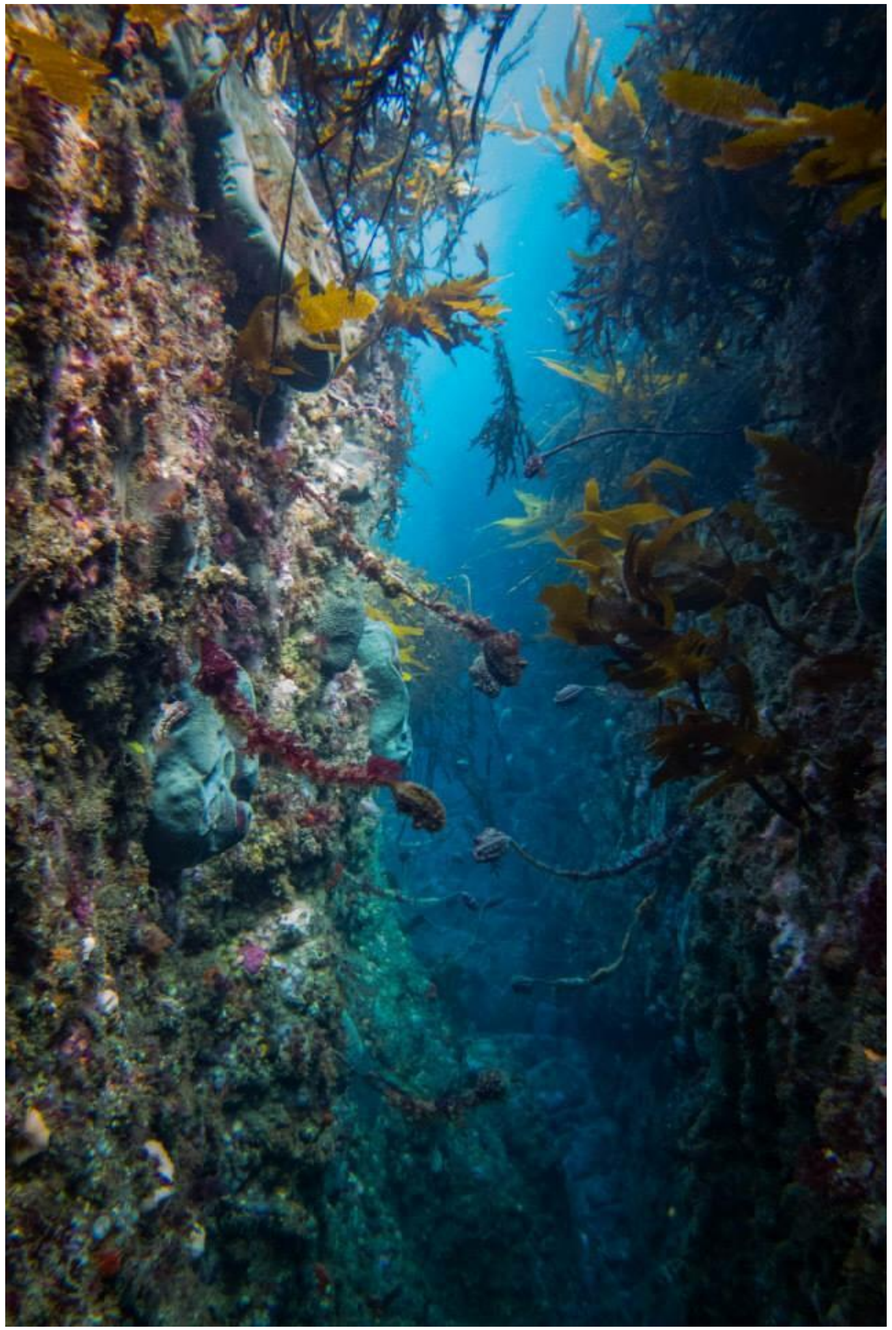
- C++ simulation code base developed by Beth Fulton CSIRO
- Differential equations (forward difference) describing production and consumption in the system
- Tracks nutrients through the ecosystem (nitrogen is the “common currency”)
- 3 dimensional structure: set of polygons and vertical layers
- Linked to oceanographic models (e.g., ROMS)



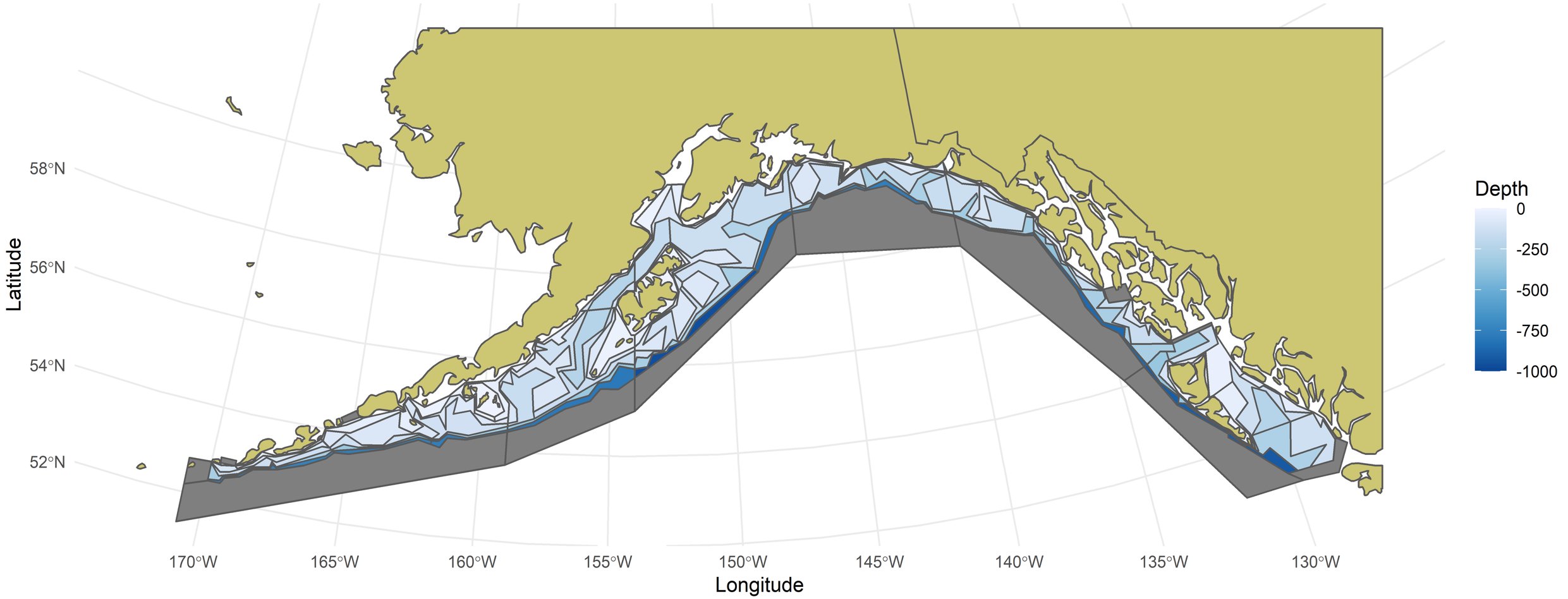


Atlantis technical overview

- Modules for fishery and economy (2-way coupling)
- Invertebrates: biomass pools
- Vertebrates: size classes
- Multiple options for movement, predation, recruitment, response to environmental variables, etc.
- 50 year runs in about 16 hrs (but depends on the size and complexity of the model)

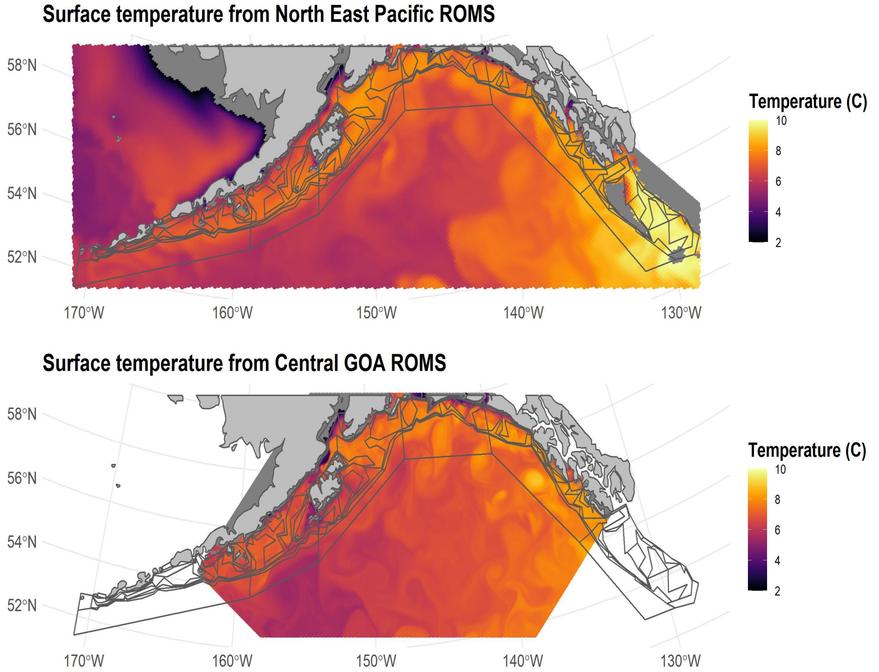


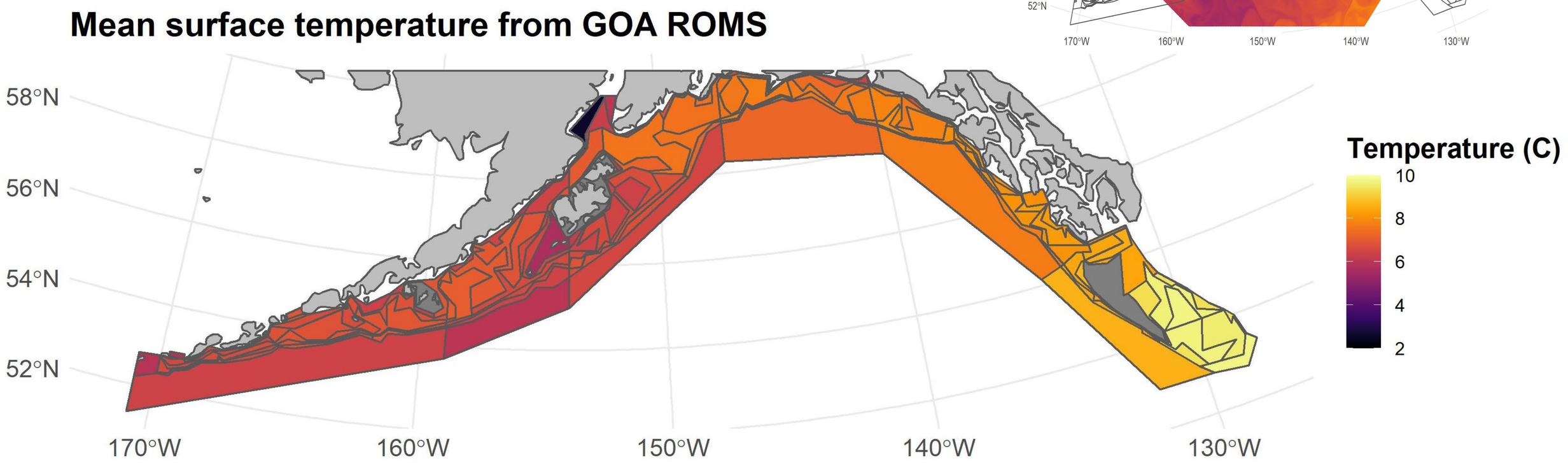
Model geometry



124 boxes (110 dynamic, 14 boundary).

Physics: Mapping ROMS to Atlantis





Biology: “populating” Atlantis

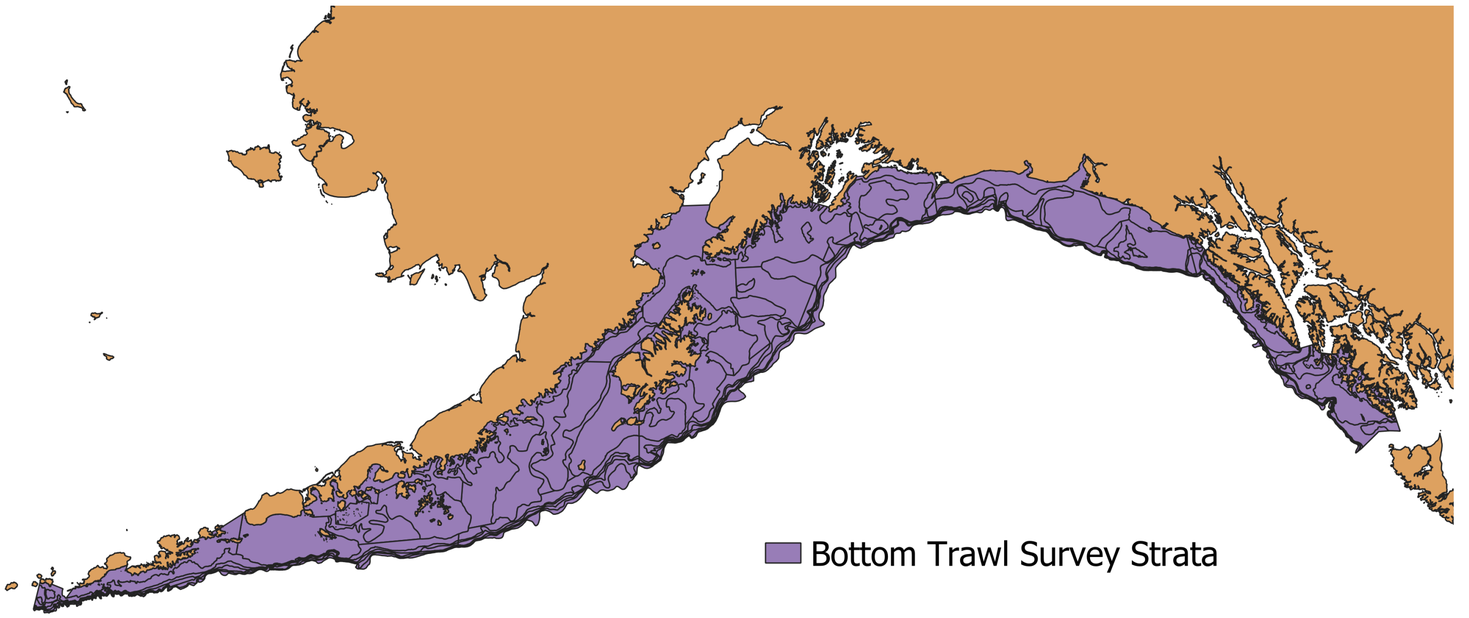
Need to define initial values of biomass (starting point of simulation runs)

Many data sources

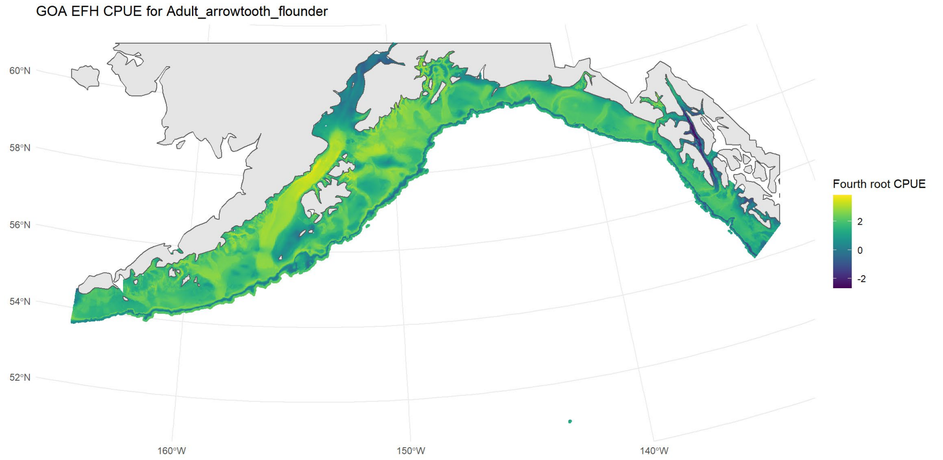
NOAA GOA bottom trawl surveys: trawl data from 1984-2019

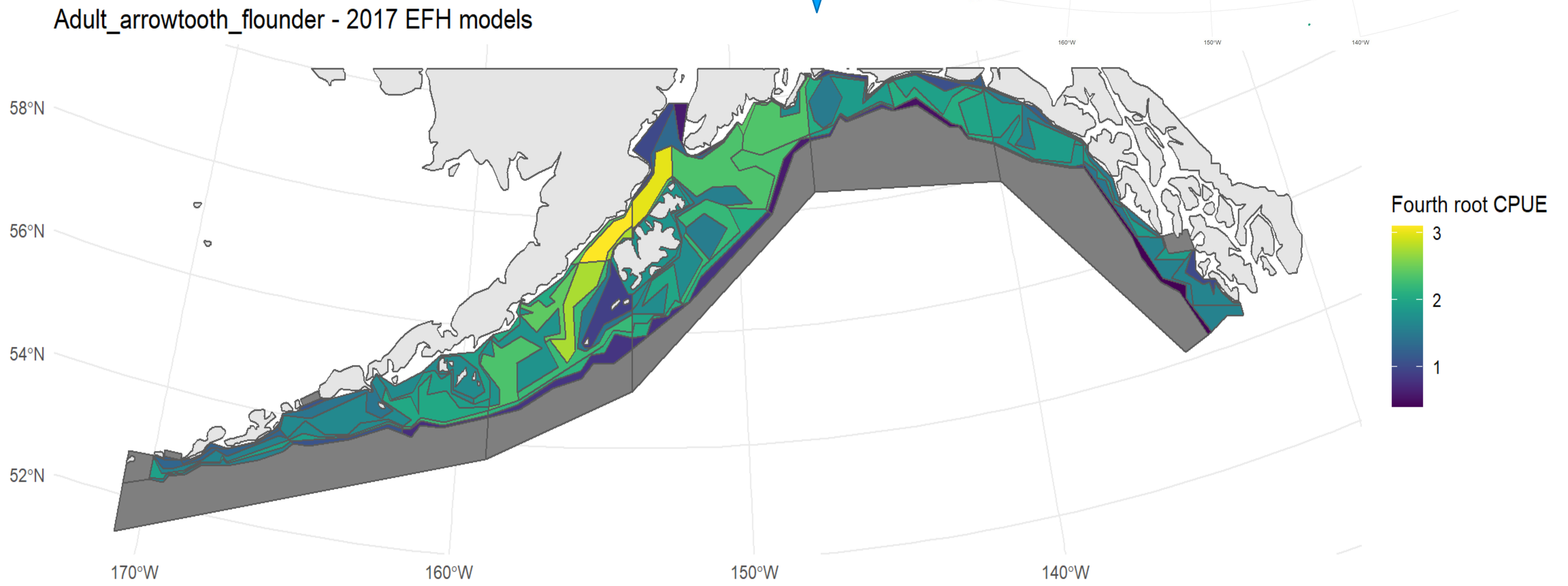
For key groundfish species:

1. Essential Fish Habitat (EFH)
2. Custom Species Distribution Models (SDMs)

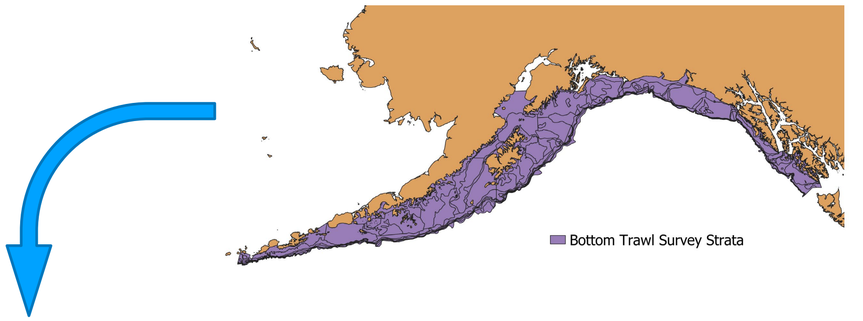


Biology: Essential Fish Habitat

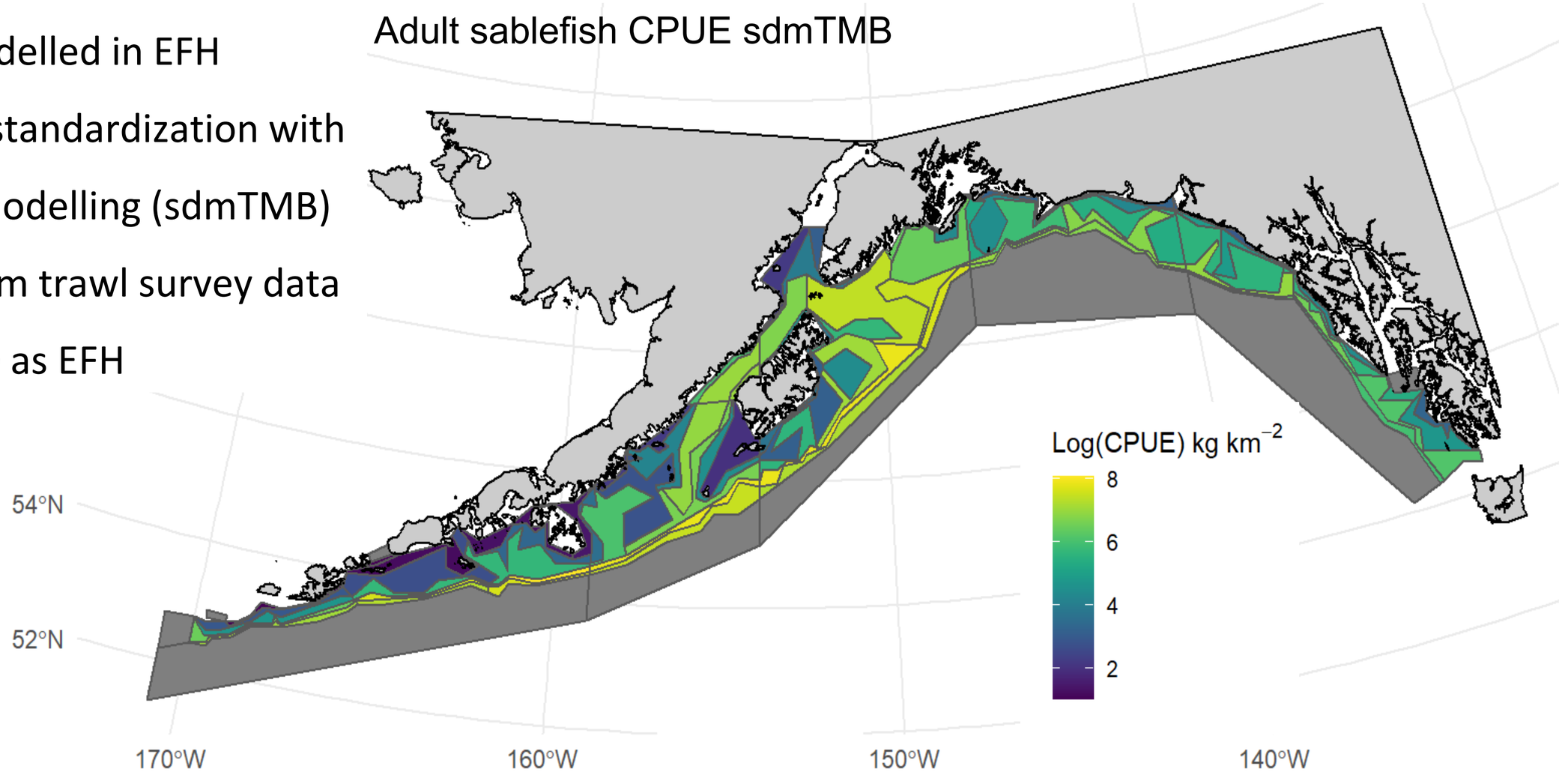




Biology: custom SDMs



- Species not modelled in EFH
- Biomass index standardization with geostatistical modelling (sdmTMB)
- Based on bottom trawl survey data
- Not as accurate as EFH



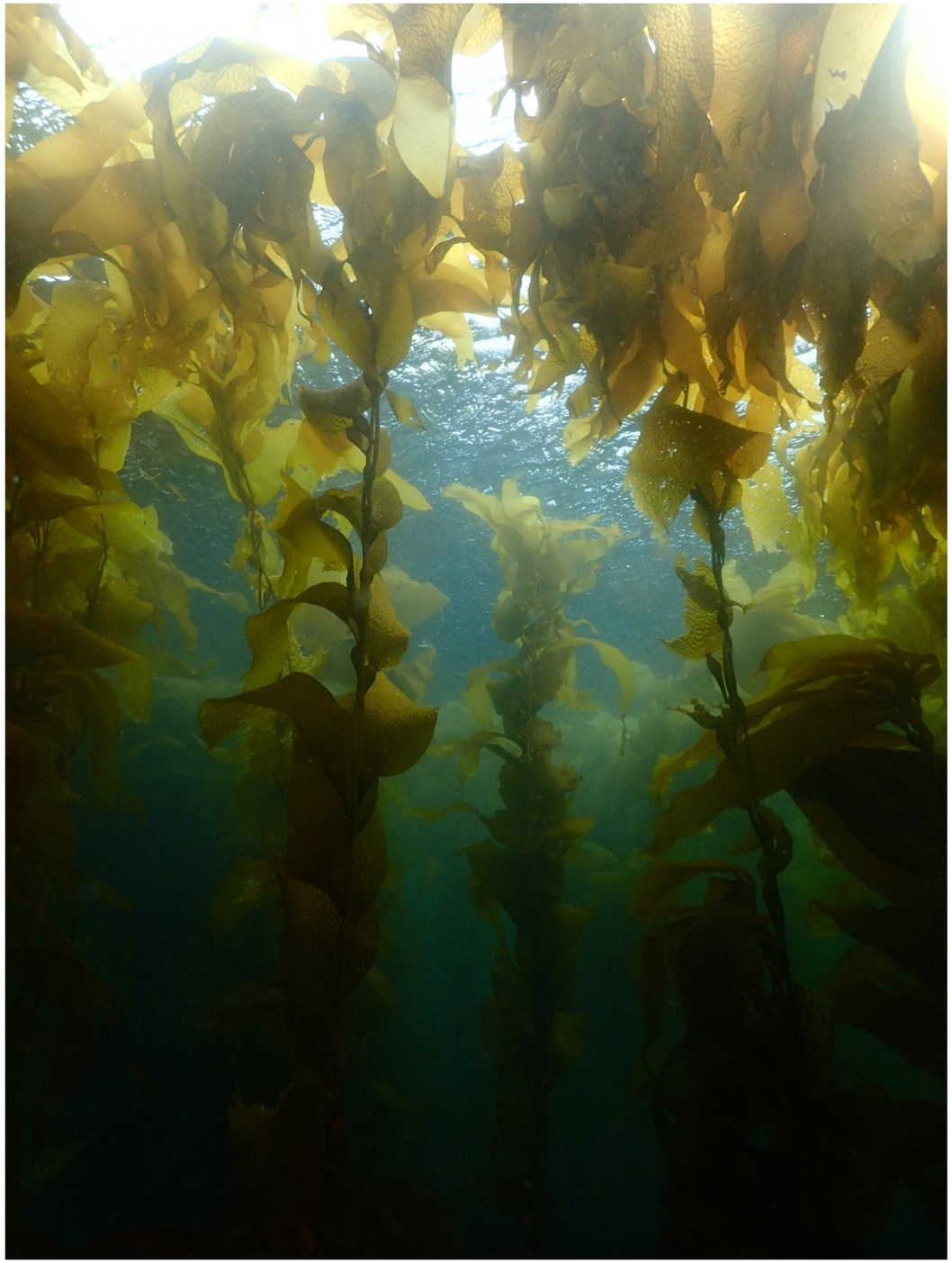
Next steps for Atlantis

Parametrization

- Life history (e.g. growth, length-weight relationships, mortality, …)
- Trophic interactions with diet data

Define fleet structure

- Commercial fisheries
  - Federally managed
  - State-managed
- Recreational and subsistence fisheries



GOA-CLIM engagement with SSC/Council

- The goal today is to inform the Council and advisory bodies of the project
- A major focus of GOA-CLIM is to evaluate performance of fisheries management of the GOA under climate change (and to consider alternatives to status quo)
- Broad categories of potential issues for SSC/AP/Council consideration:
    - Management responses to changing system level productivity (e.g., marine heatwaves)
    - Response to shifting reference points/baselines
    - Structural obstacles to adaptation
        - Federal/State/IPHC distributed management
        - Other?