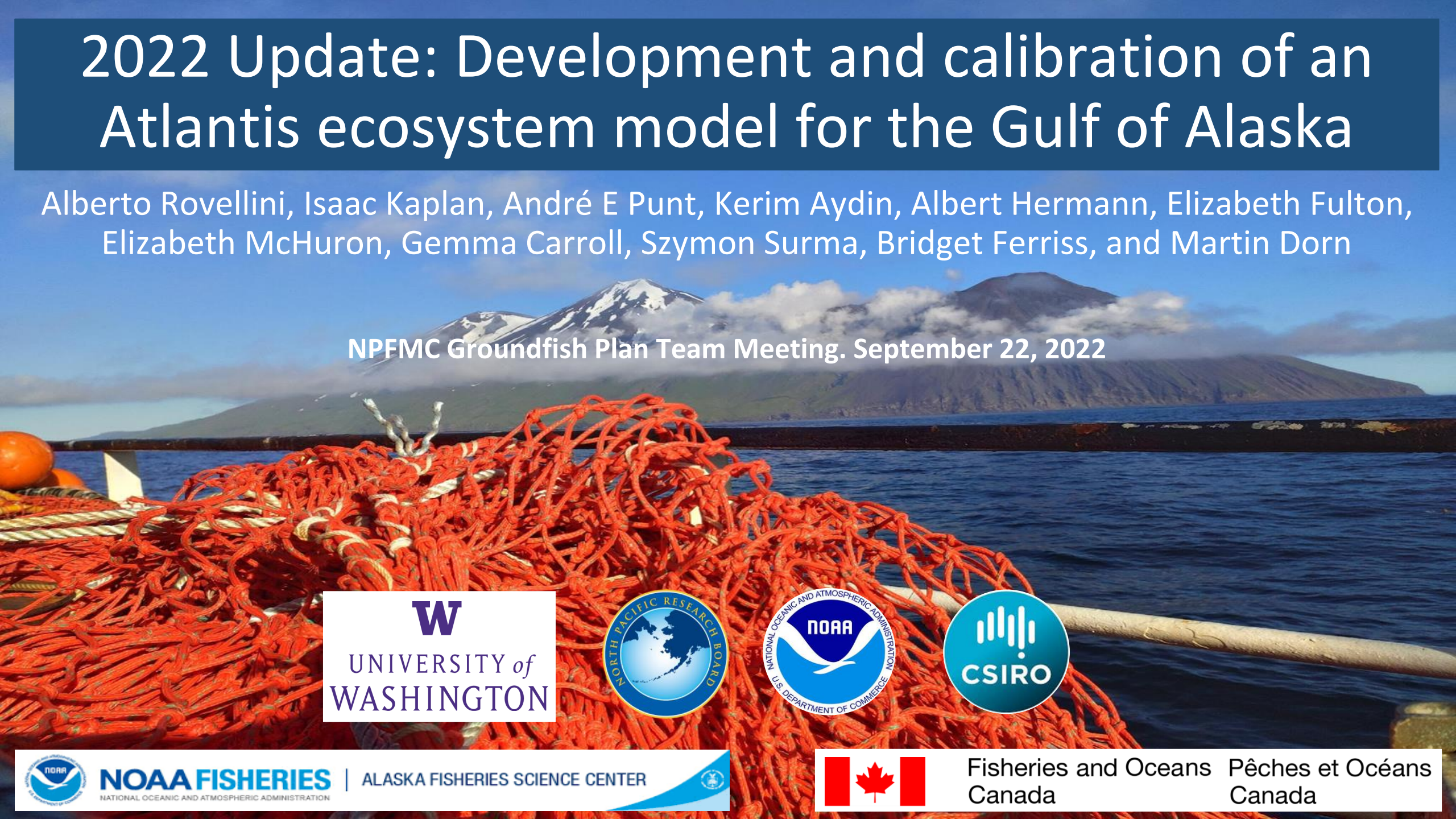
# 2022 Update: Development and calibration of an Atlantis ecosystem model for the Gulf of Alaska

Alberto Rovellini, Isaac Kaplan, André E Punt, Kerim Aydin, Albert Hermann, Elizabeth Fulton, Elizabeth McHuron, Gemma Carroll, Szymon Surma, Bridget Ferriss, and Martin Dorn

**NPFMC Groundfish Plan Team Meeting. September 22, 2022**



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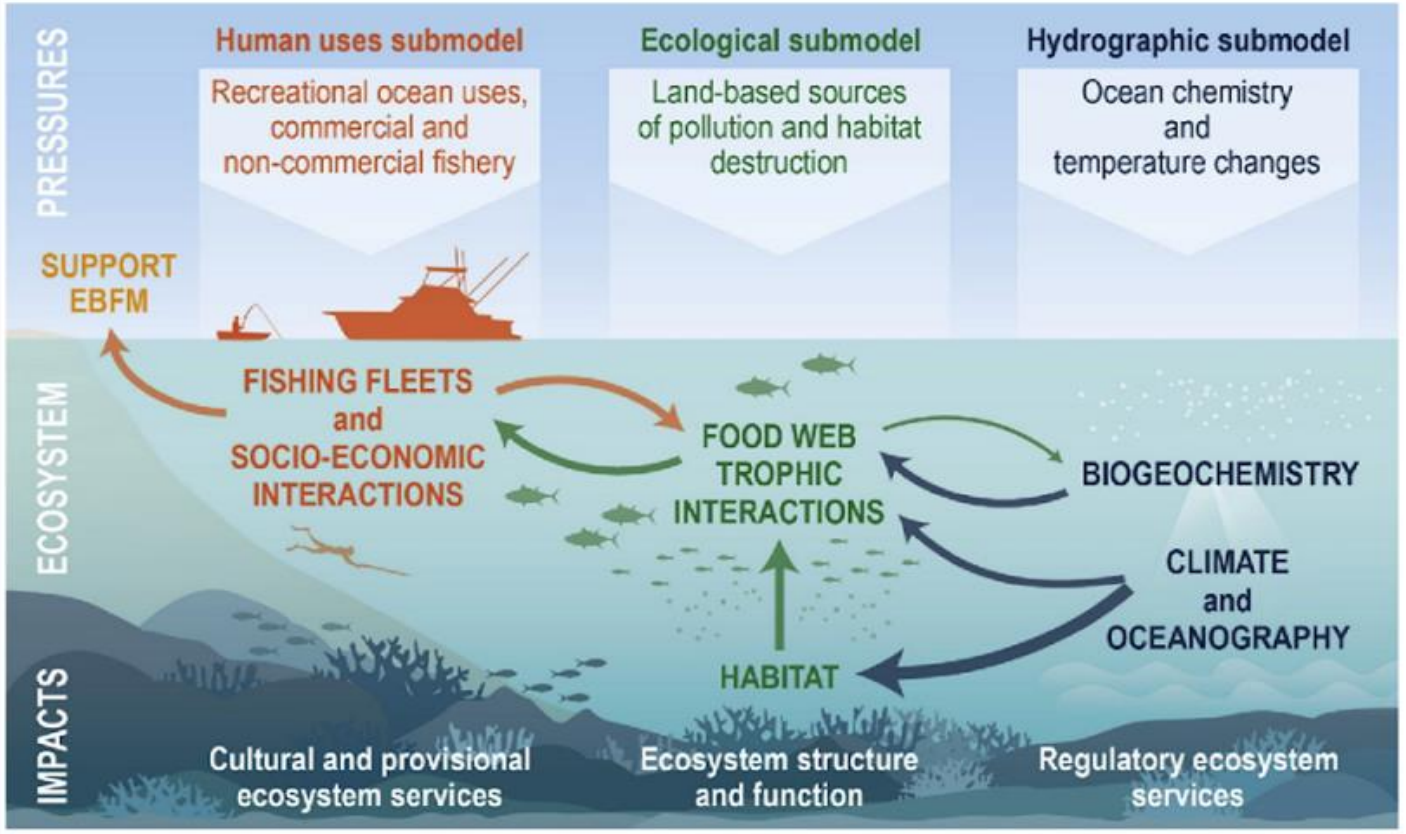
# Overview of the Atlantis framework

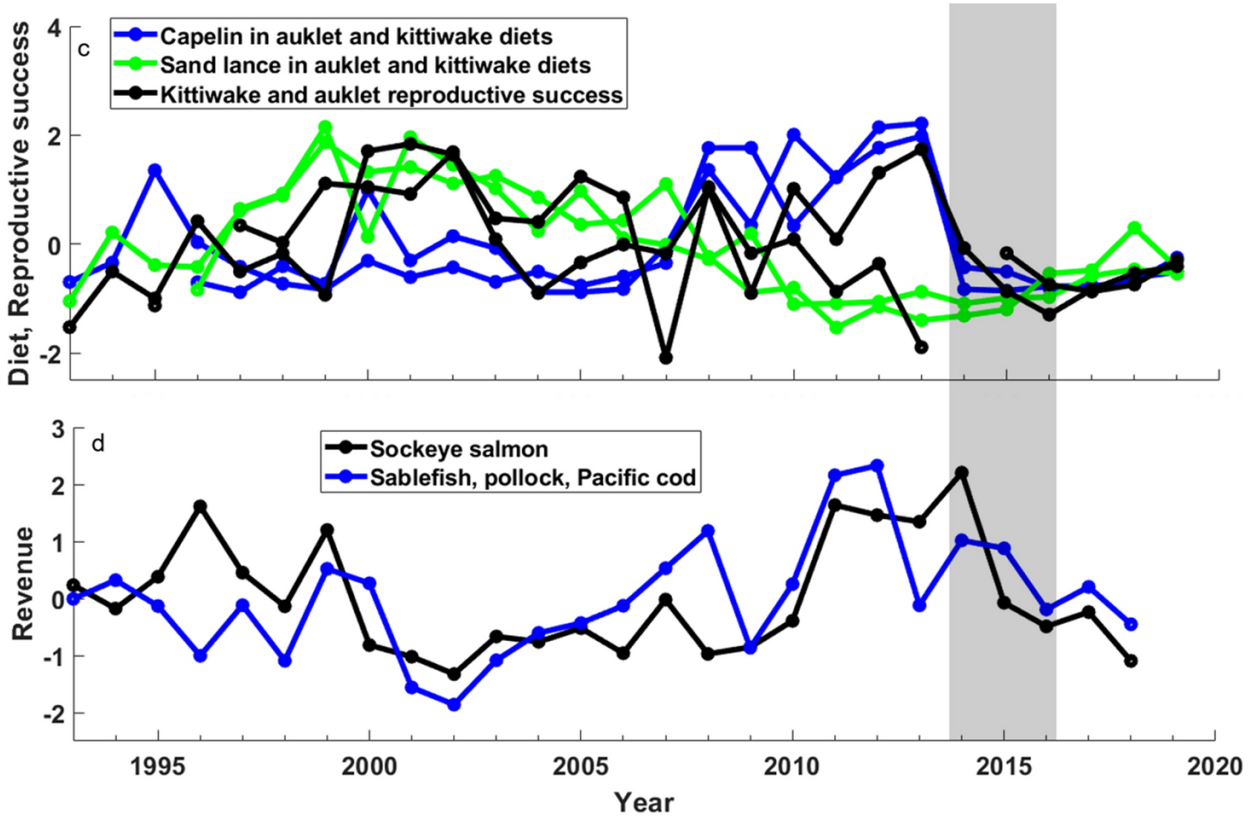
- First developed by Dr Beth Fulton (CSIRO, Australia)
- End-to-end dynamic simulation model
- Deterministic
- Two-way coupling of physical, biogeochemical, socioeconomic sub-models
- 3D spatial structure
- Forced by physical models (e.g., ROMS)
- Age structure for vertebrates, invertebrates as biomass pools
- Flexible representation of fishing
- 30+ applications around the world




Pethybridge et al. 2019

# Aims: hindcast runs and projections

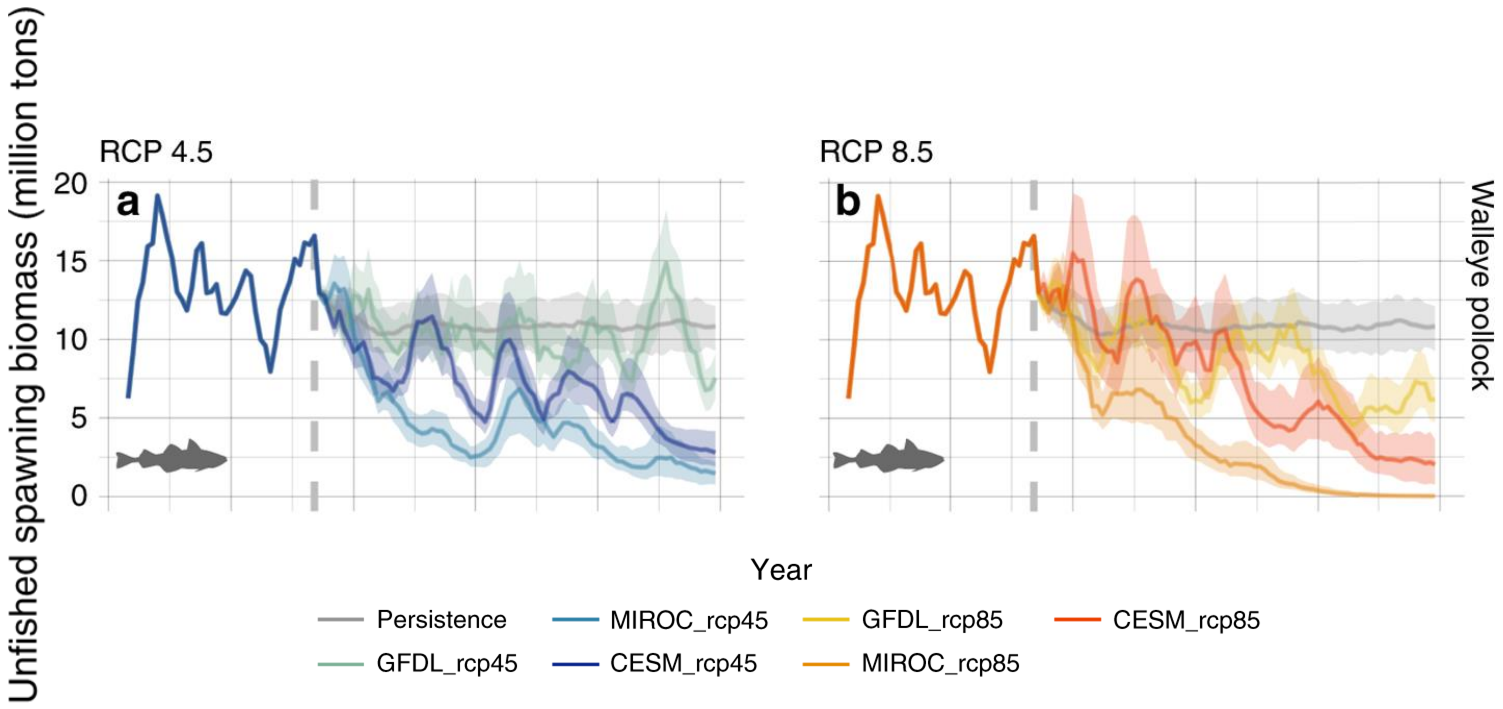
- Hindcast: explore ecosystem-level effects of 2013-2016 North Pacific heat wave
  - Force with ROMS for 1990-2020




Suryan et al. (2021)

# Aims: hindcast runs and projections

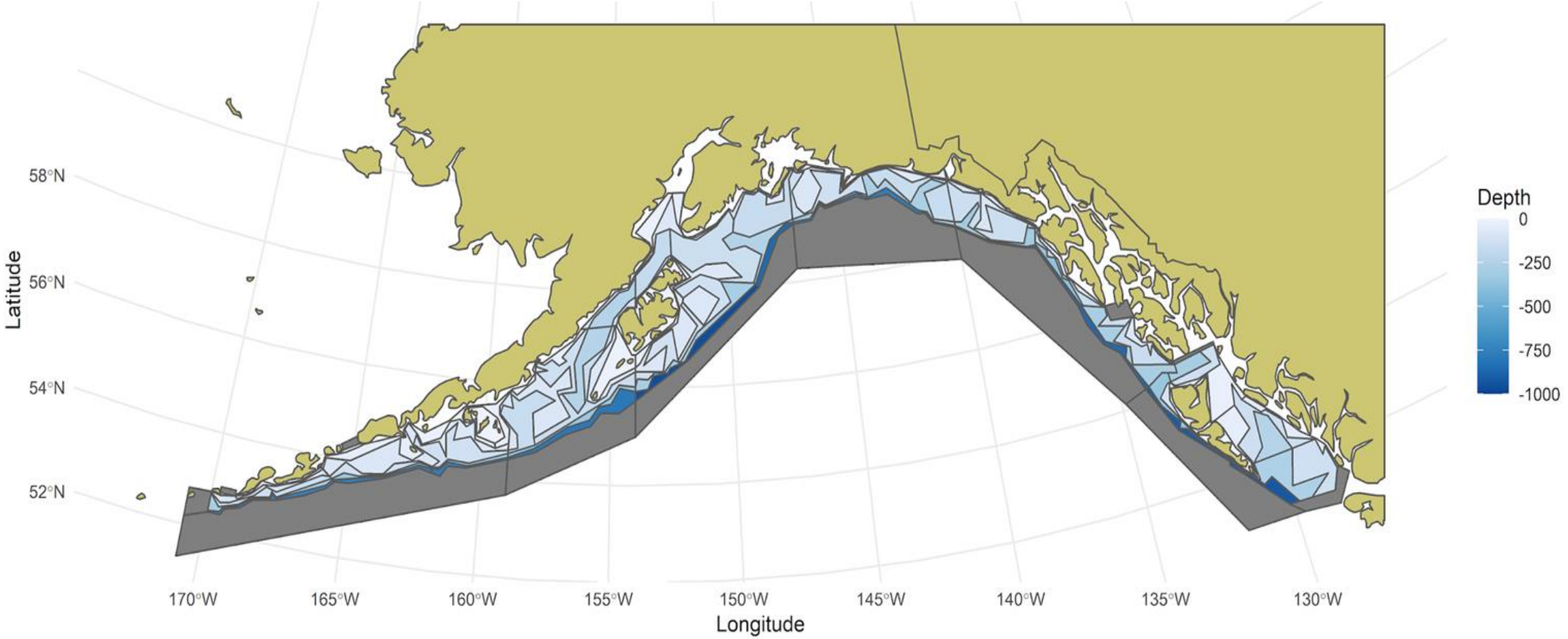
- Hindcast: explore ecosystem-level effects of 2013-2016 North Pacific heat wave
  - Force with ROMS for 1990-2020
- Projection: explore changes in ecosystem productivity under climate change
  - Force with ROMS for 2020-2100
  - Main purpose is **scenario testing**
  - Thermal response of functional groups modeled as bioenergetic shifts and limitations to spatial distributions
  - Evaluate management strategies (e.g., Optimum Yield cap on GOA groundfish)




Holsman et al. (2020)

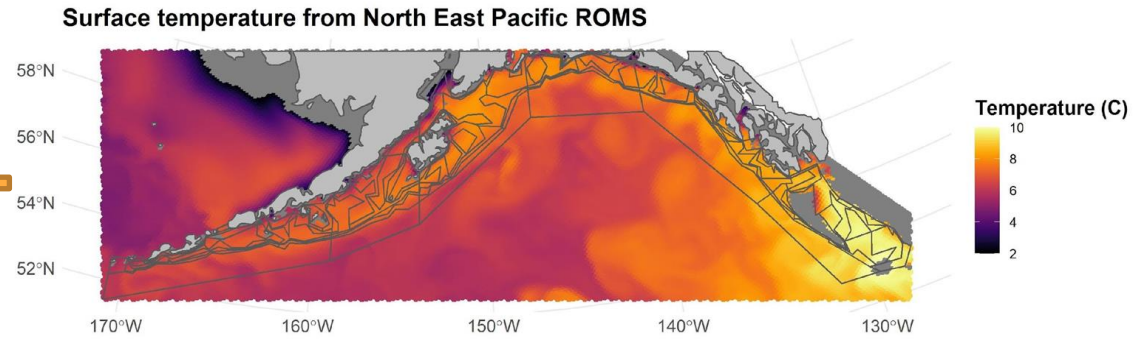
# Atlantis GOA: Spatial domain

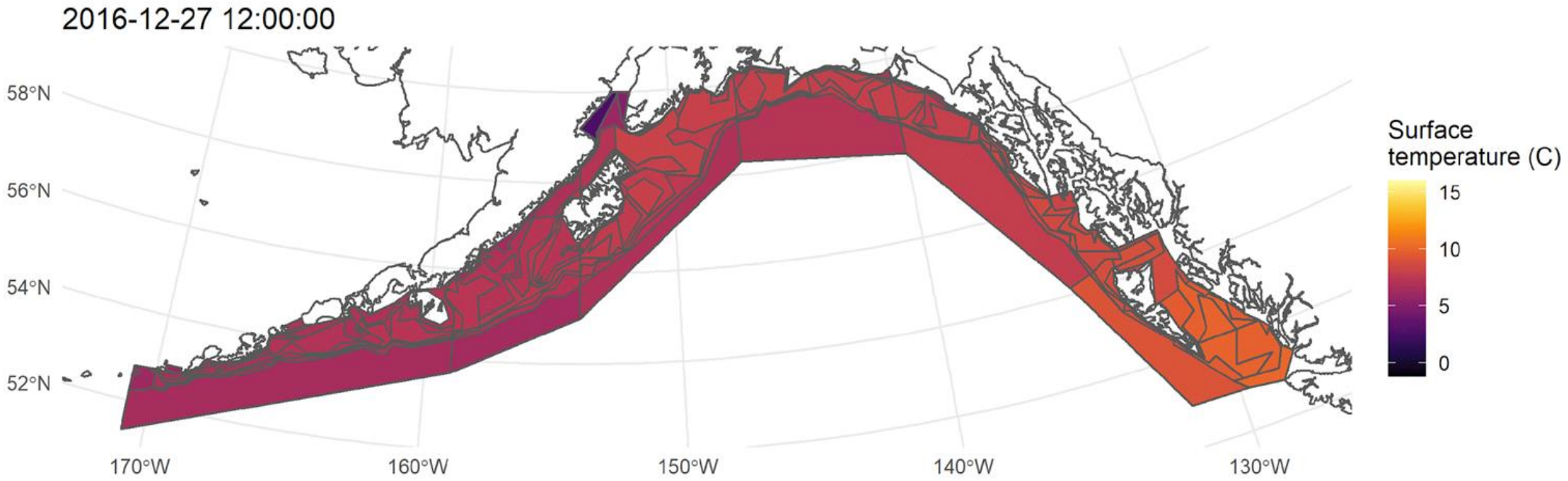
- 109 spatial boxes
- GOA shelf and upper slope from British Columbia to 170 W
- No Upper Cook Inlet, Prince William Sound, SE Alaska fjords
- Captures bathymetry, management areas, survey spatial extent, oceanographic features…



# Atlantis GOA: Physics

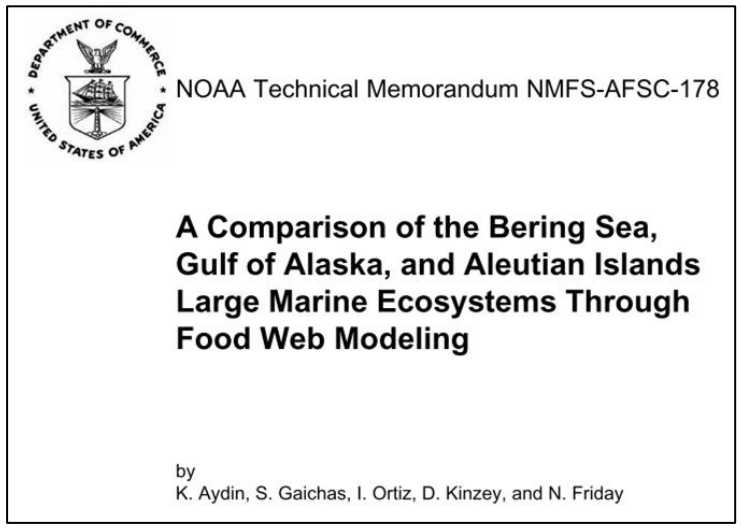
- Physical forcings from ROMS
- Northeast Pacific (10 km)
- Temperature, salinity, and water transport



# Atlantis GOA: Biology – functional groups

- **78** functional groups:
  - 28 bony fish (focus on commercially important **groundfish**)
  - 3 sharks
  - 3 skates
  - 9 mammals
  - 4 birds (by feeding mode)
  - 26 invertebrates
  - 2 bacteria
  - 3 detritus





Walleye pollock


Pacific cod


Arrowtooth flounder


Pacific ocean perch


Sablefish


Pacific halibut


Chinook salmon


Spiny dogfish


Humpback whale


Steller sea lion


Grey whale


Killer whale


King crab


Squids

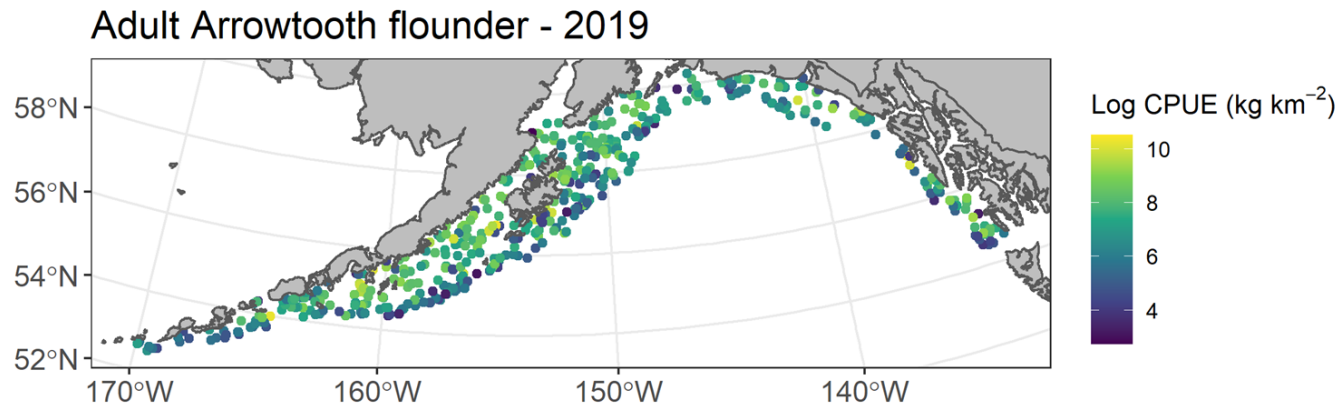

Tanner crab

NOAA Species Directory

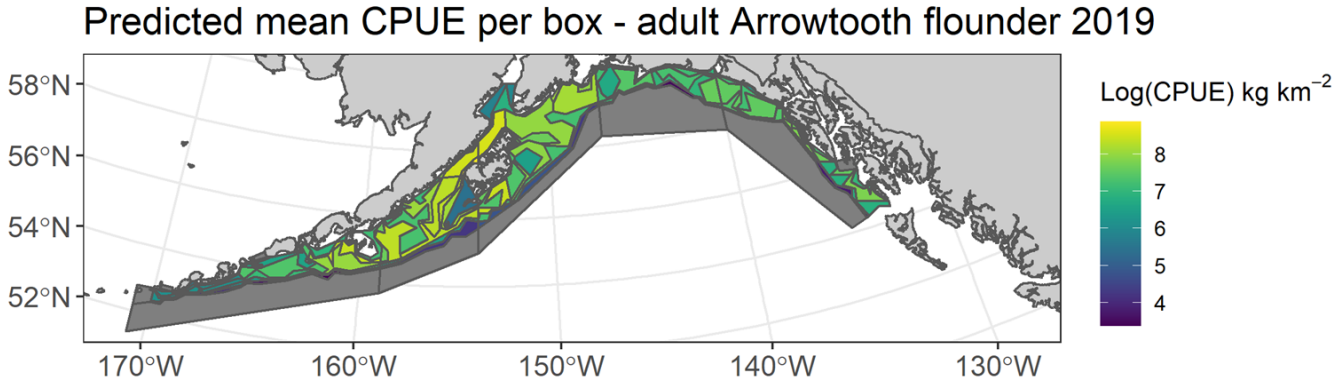
# Atlantis GOA: Biology – distributions and diets

Spatial distributions from several sources, including:

- Bottom trawl data smoothed with geostatistical models for groundfish (sdmTMB)
- Surface trawl data for pelagic species
- NPZ models for plankton




(sdmTMB)



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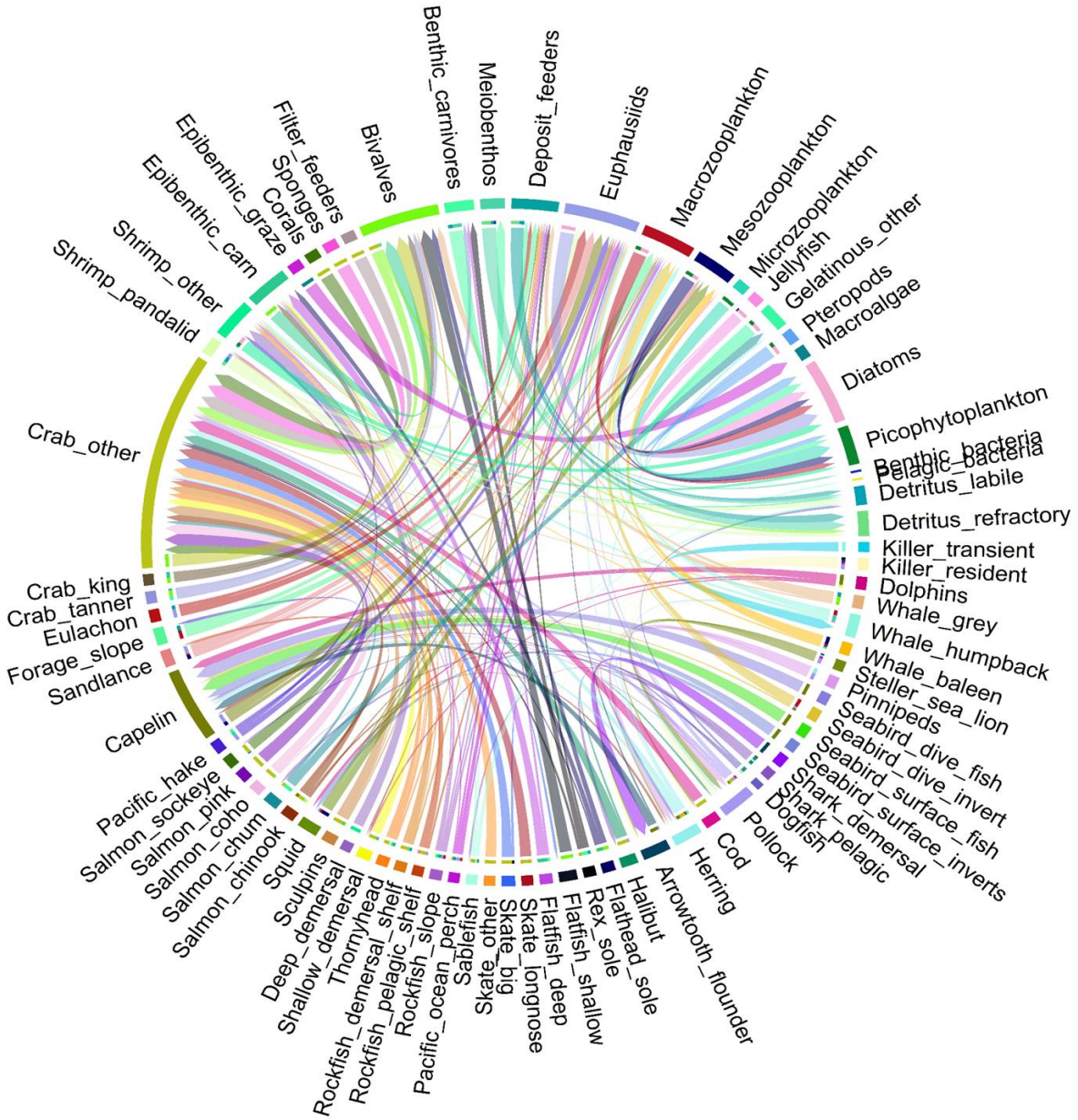
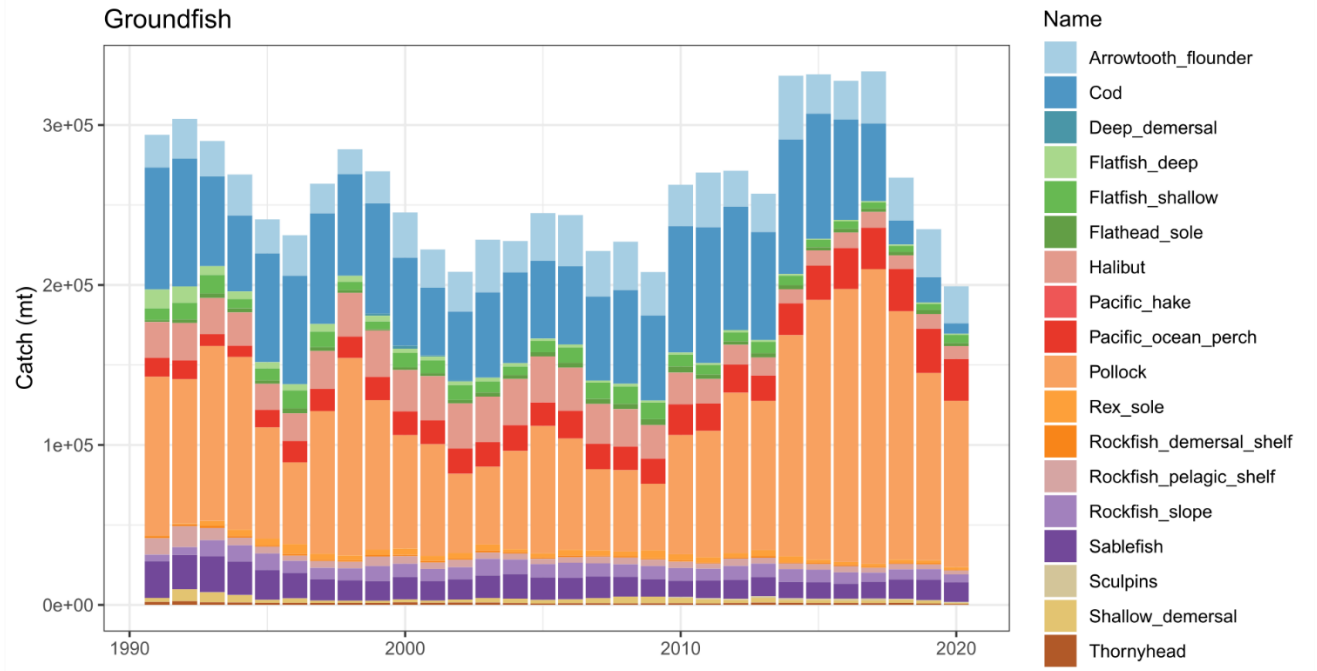
Diets in Atlantis entered as prey availability by ontogenetic stage.

Main (but not only) source:

- **43,000+** stomachs from the Resource Ecology and Ecosystem Modeling program (NOAA AFSC) – 1990-2011 across GOA shelf (Dr Kerim Aydin AFSC)

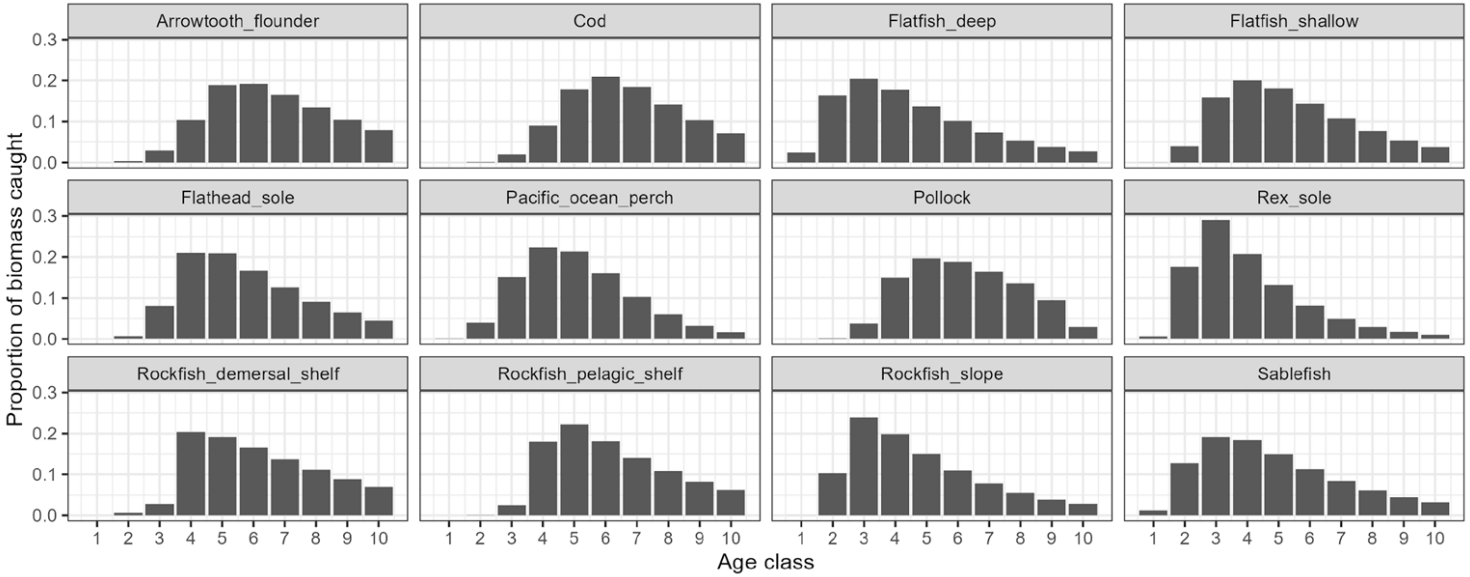


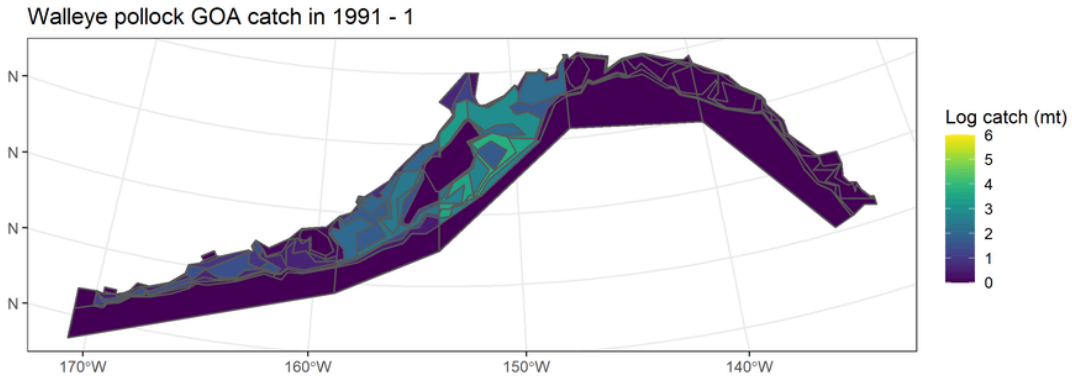
# Atlantis GOA: Fisheries for hindcast




For hindcast runs: Forcing removals with catch time series (1991 – present)

- Data from AKRO-BLEND, DFO, IPHC, ADF&G
- Age-selectivity is enforced
- Removals are spatially-explicit

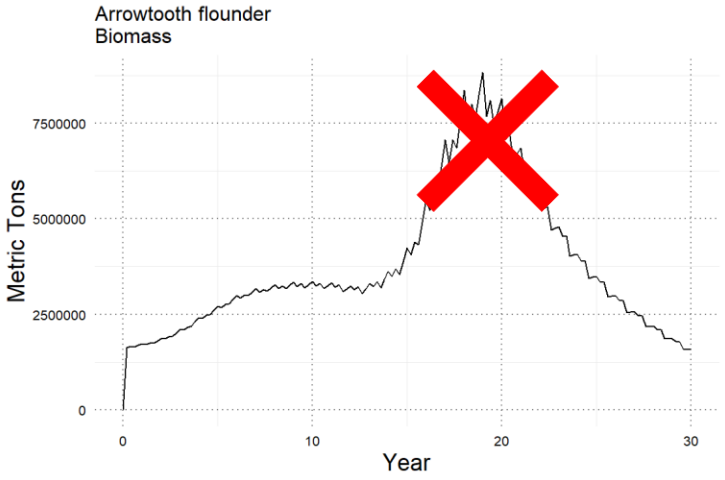


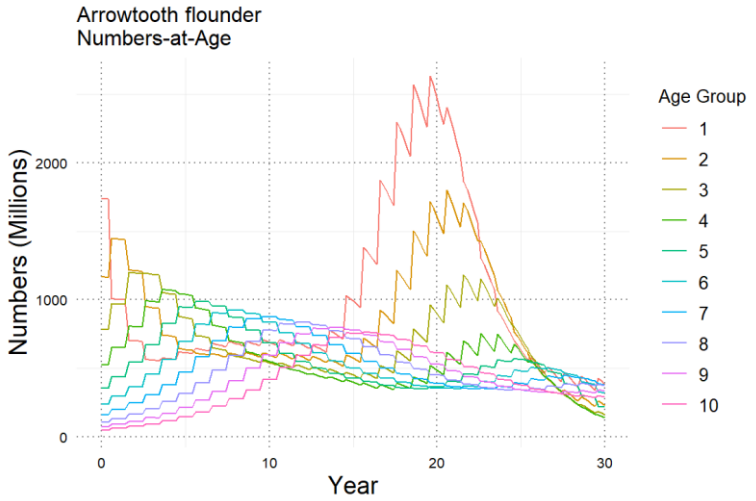



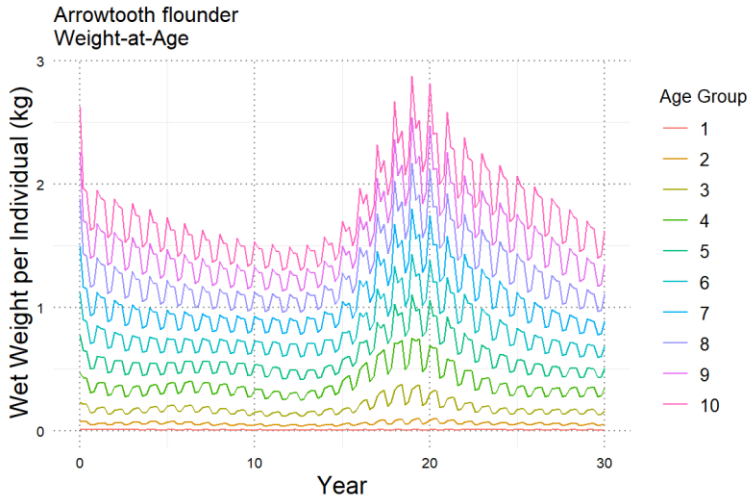
# Current focus (1/3): Calibration

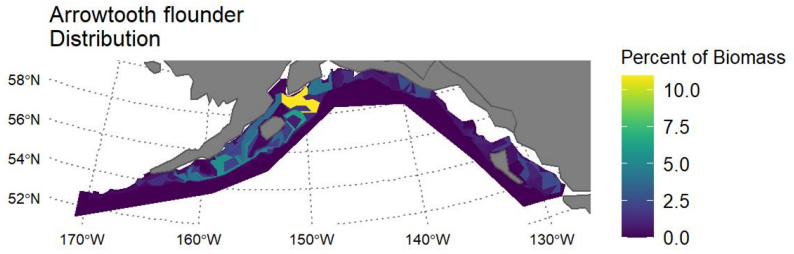
Goal: attain **unfished equilibrium**

- Tune input parameters until model dynamics match observations
- Parameters commonly adjusted include recruit production, growth and consumption rates, diet preferences
- Calibration criteria
  - Biomass at $t_{end}$ within ±20% of biomass at $t_0$
  - No temporal trends
  - Reasonability of age composition and weight at age
  - Spatial patterns match expectation



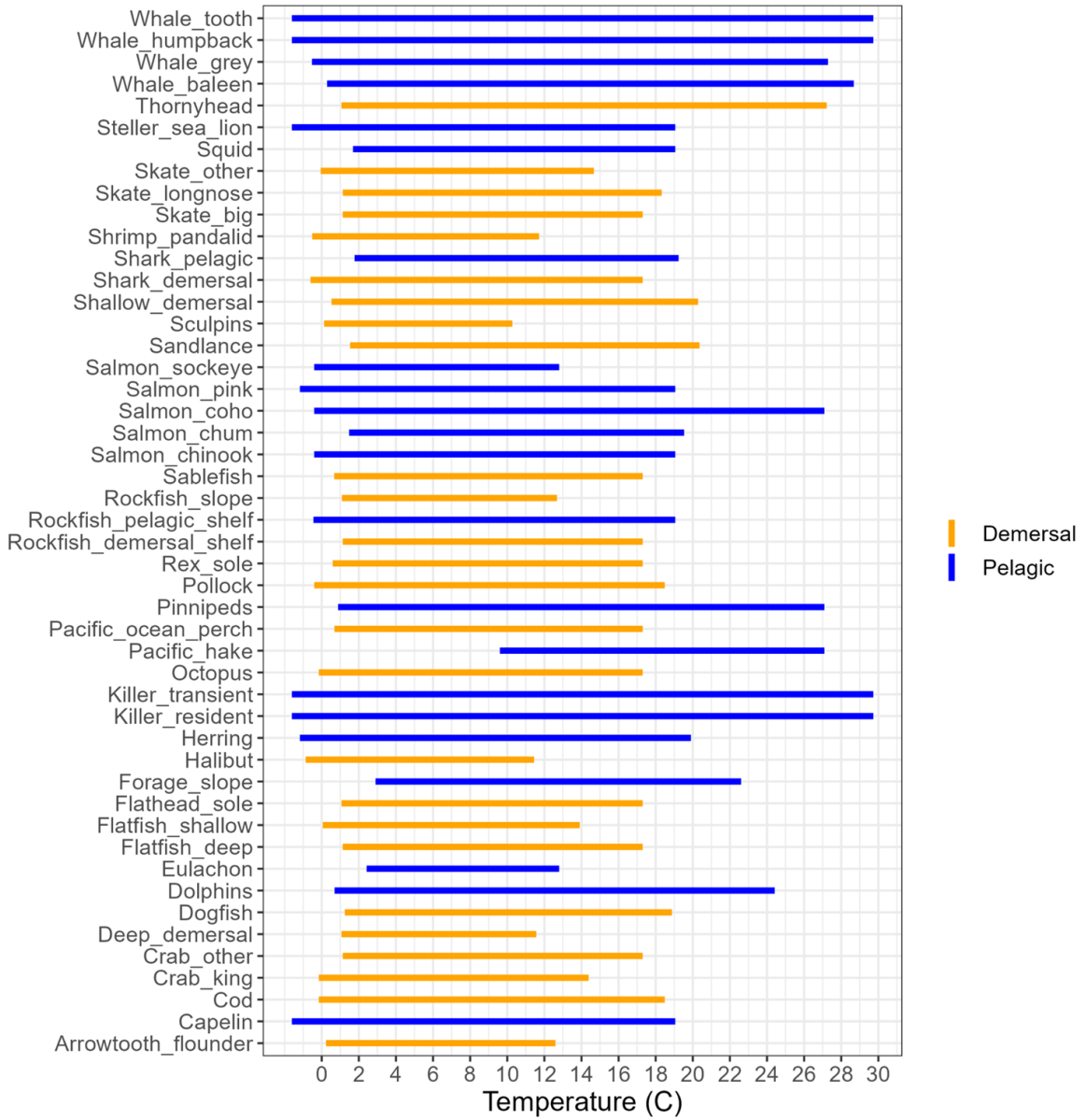



# Current focus (2/3): Thermal responses

Goal: Link the effects of increased temperature to species distributions and physiology

- Thermal niches ($T_{min} > T > T_{max}$) restrict spatial distributions



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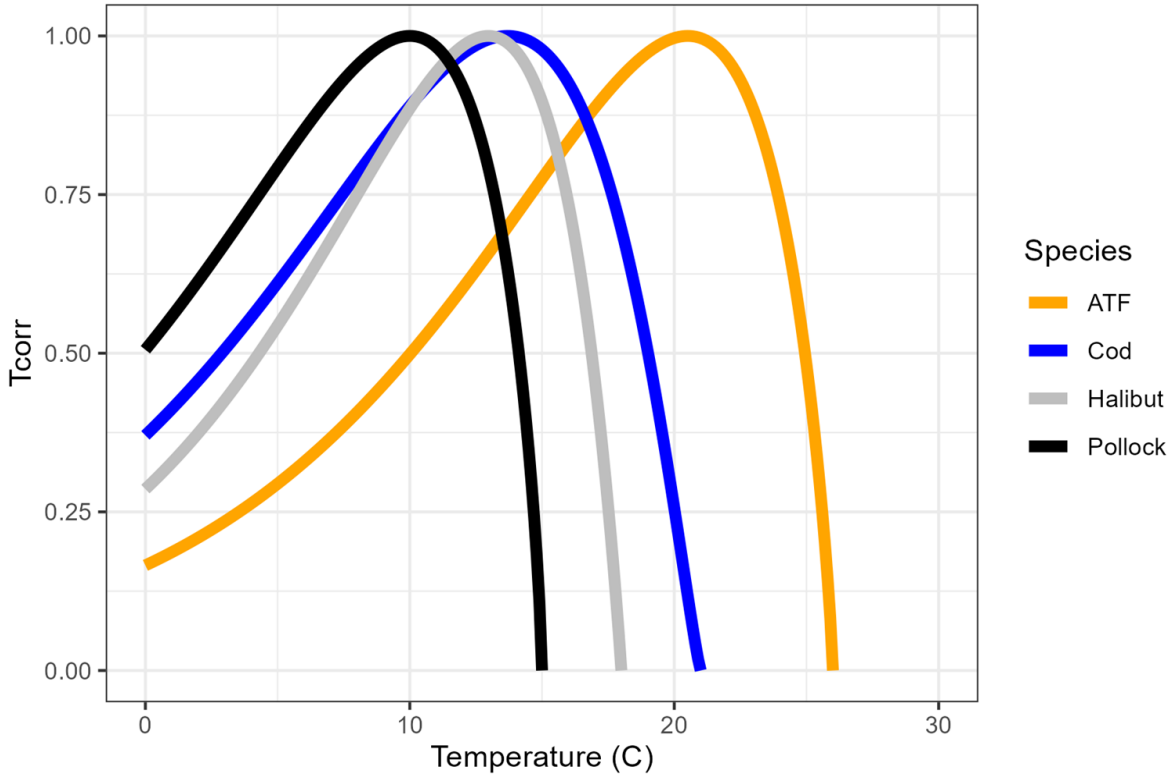

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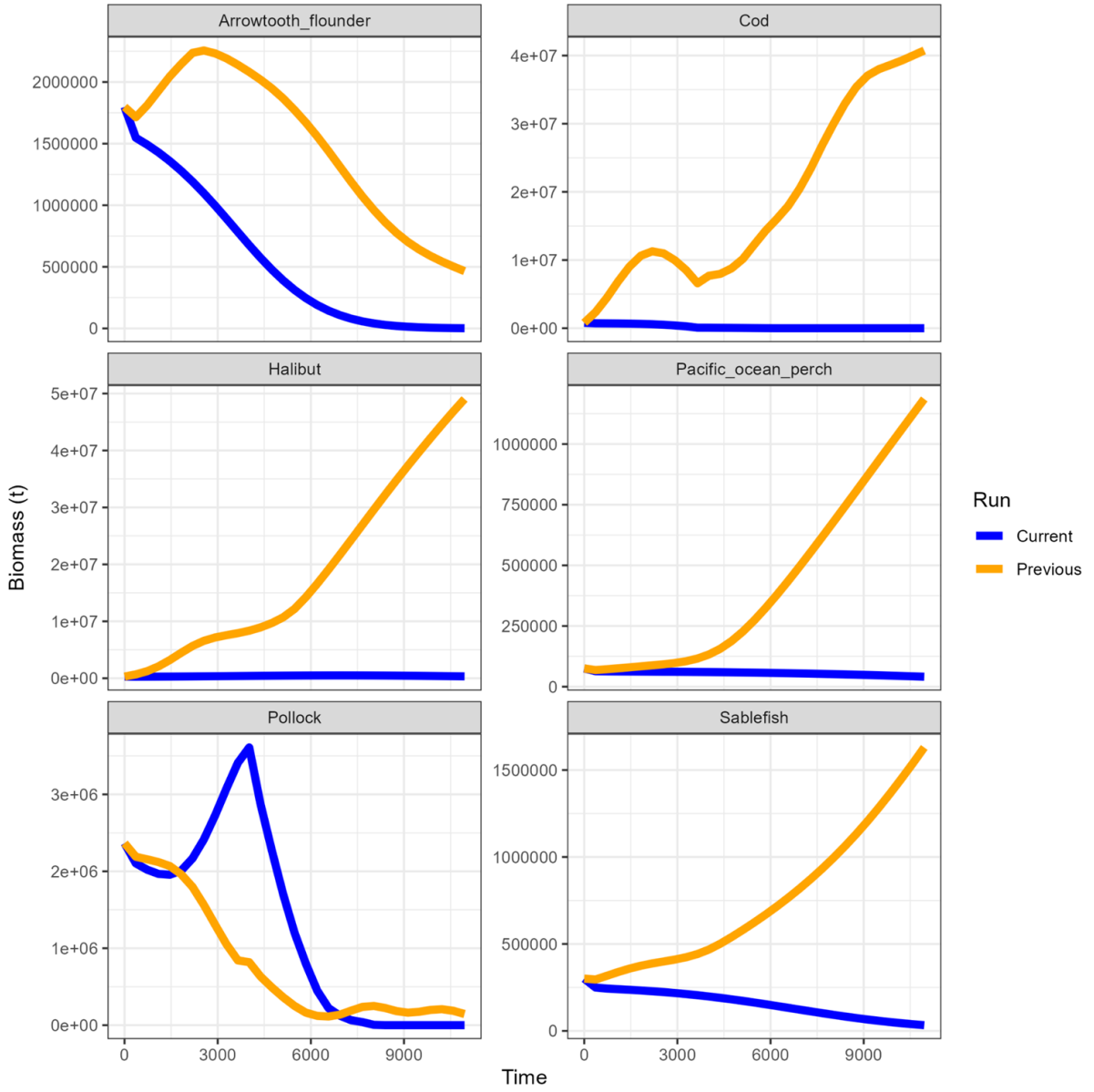
- …But blending the two is difficult

**Major effects on model results**



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Step 1: define a set of fleets, based (minimally) on:

- Target
- Gear
- Spatial footprint (e.g., fishing areas and / or ports of landing)
- Management type (federal/state)
- Commercial/recreational/subsistence

| |
|---|
| Rockfish_NON PELAGIC |
| Pollock - midwater_PELAGIC |
| Arrowtooth Flounder_NON PELAGIC |
| Pacific Cod_LONGLINER |
| Sablefish_LONGLINER |
| Pacific Cod_NON PELAGIC |
| Shallow Water Flatfish - GOA_NON PELAGIC |
| Rex Sole - GOA_NON PELAGIC |
| Pollock - bottom_PELAGIC |
| Rockfish_PELAGIC |
| Pacific Cod_POT OR TRAP |
| Halibut_LONGLINER |
| Flathead Sole_NON PELAGIC |
| Pollock - bottom_NON PELAGIC |
| Sablefish_NON PELAGIC |

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Port of landing is important for socioeconomic considerations – e.g., passing Atlantis output to regional economic models

Input-output models

Marine Policy 36 (2012) 947–954

Contents lists available at SciVerse ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

From krill to convenience stores: Forecasting the economic and ecological effects of fisheries management on the US West Coast

Isaac C. Kaplan [a,*], Jerry Leonard [b]

[a] NOAA Fisheries, Conservation Biology Division, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112, USA
[b] NOAA Fisheries, Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112, USA

Ecological Economics 186 (2021) 107072

Contents lists available at ScienceDirect

Ecological Economics

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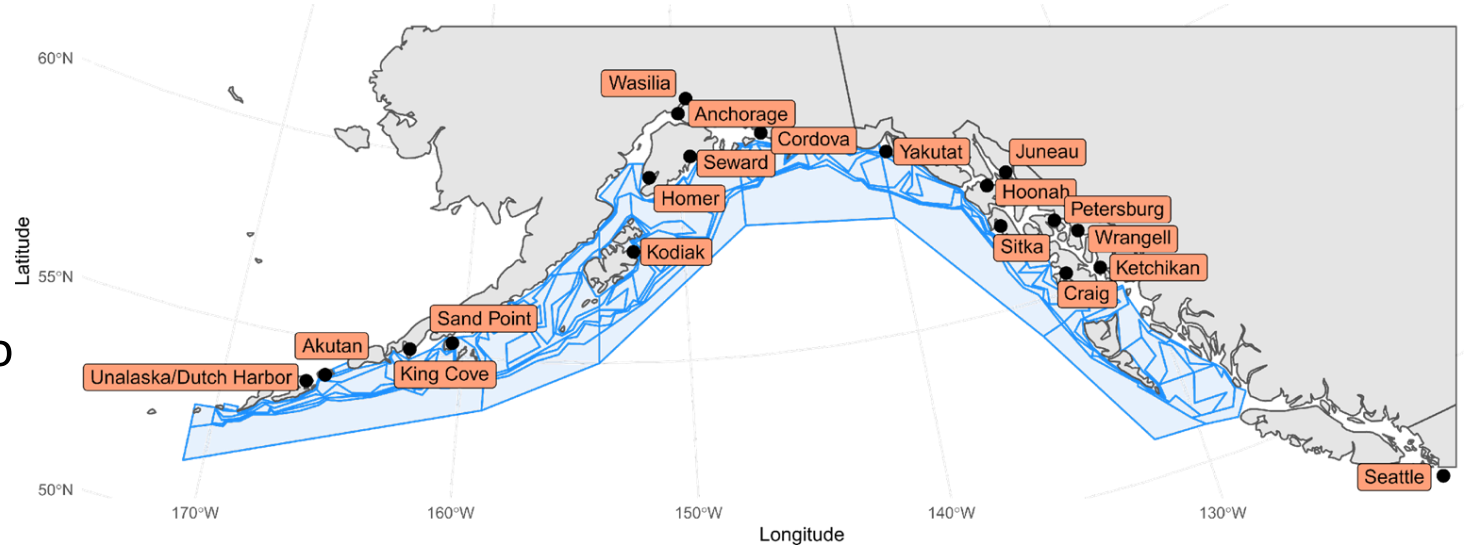
Computable general equilibrium

ANALYSIS

Community-level economic impacts of a change in TAC for Alaska fisheries: A multi-regional framework assessment

Chang K. Seung [a,*], Edward C. Waters [b], Steven J. Barbeaux [a]

[a] NOAA, National Marine Fisheries Service, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, WA 98115-6349, USA
[b] Cascade Economics, LLC, 2800 SE 370th Ave, Washougal, WA 98671, USA



# Questions for the Plan Team

We seek input / feedback:

1. How do we couple these modeling efforts to the Council's decision-making process?
2. What can Atlantis do for the Council?
3. What level of spatial resolution is useful for catch or biomass projections? Stock-wide, region, port, other?
4. What is the time scale of useful projections?
5. What management strategies should we explore?

Contacts:

alberto.rovellini@noaa.gov

martin.dorn@noaa.gov

isaac.kaplan@noaa.gov

# Acknowledgements


Funders:

- North Pacific Research Board
- NOAA


Collaborators:

- Martin Dorn (AFSC)
- André Punt (UW)
- Isaac Kaplan (NWFSC)
- Kerim Aydin (AFSC)
- Beth Fulton (CSIRO)
- Albert Hermann (JISAO PMEL)
- Meaghan Bryan (AFSC)
- Szymon Surma (UAF)
- Adam Hayes (UW)
- Bridget Ferriss (AFSC)
- Liz McHuron (UW)
- Jamal Moss (AFSC)
- Gemma Carroll (EDF)
- Hem Nalini Morzaria Luna (LLTK)
- Owen Liu (NWFSC)
- Pierre-Yves Hernvann (NWFSC)
- *et al.*

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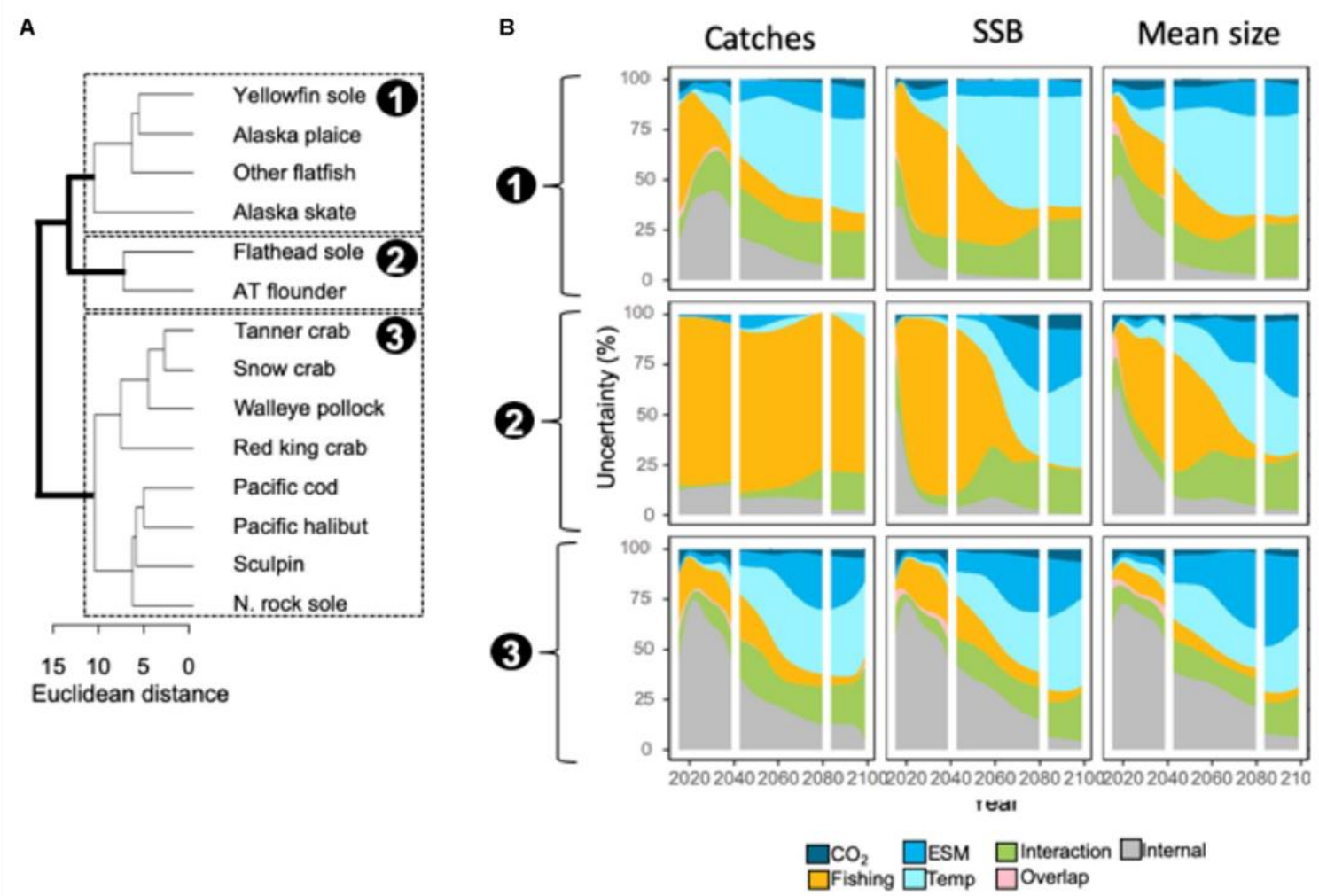
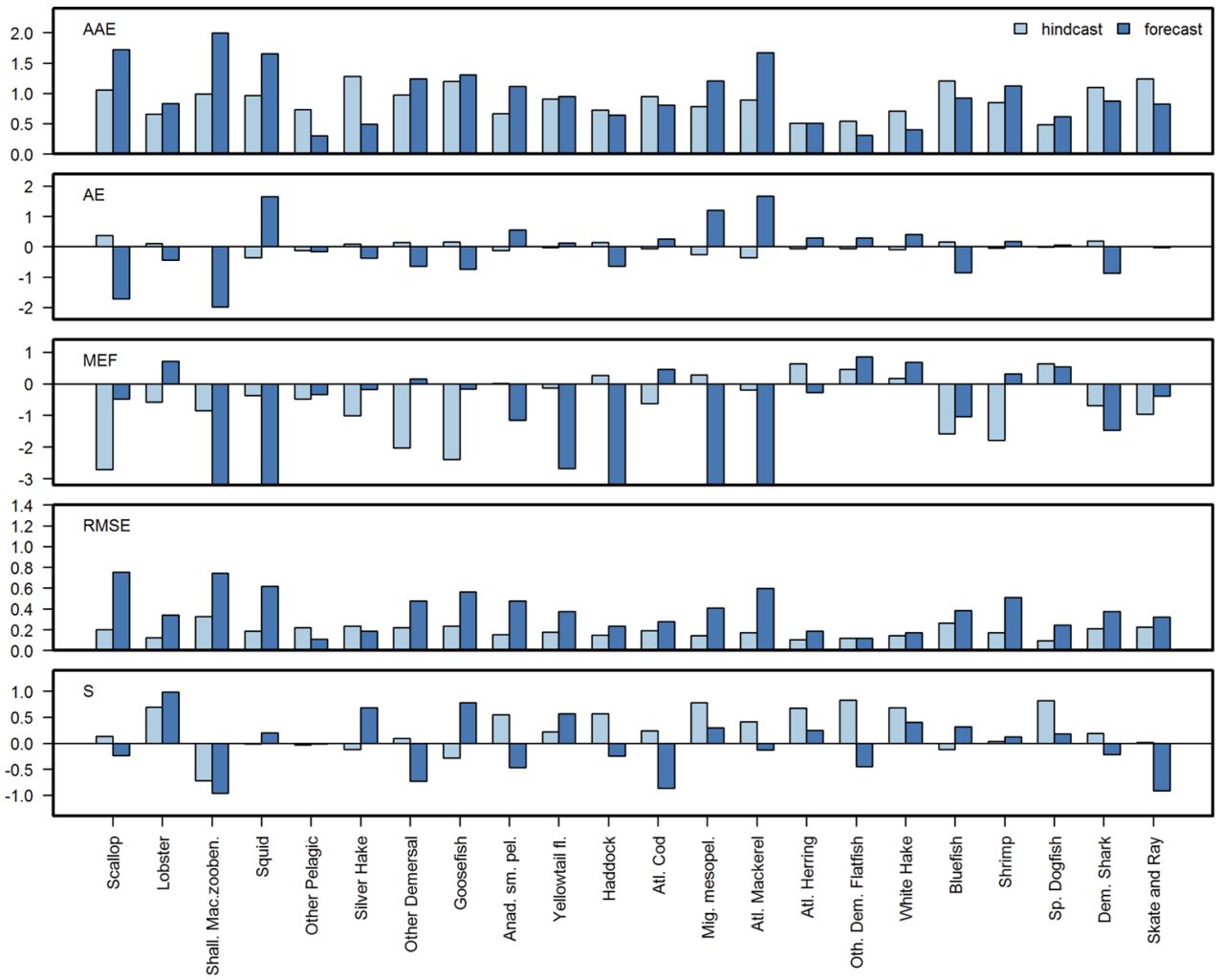
# Uncertainty in Atlantis

- Atlantis is deterministic
- Uncertainty from different sources changes over time and between species
- Different model specifications should be tested
- Sensitivity analysis can help identify major sources of uncertainty
- Ranges of parameters can be used for model initialization and the outputs can be compared




Reum et al. (2020)

# Skill assessment




Olsen et al. (2016)

Requirements to meet:

- **Pattern matching:** output matches observations at a range of spatial scales
- Key population dynamics are captured
- Productivity, mortality, age and length structure, and diets match empirical observations and ecological theory

Can derive **ecological indicators** of the real world *vs* the model and compare (e.g., correlation coefficients, error, etc.).