“*Fragile ecosystems, robust assessments? Performance testing stock assessments for the California Current and Nordic and Barents Seas under climate change*”

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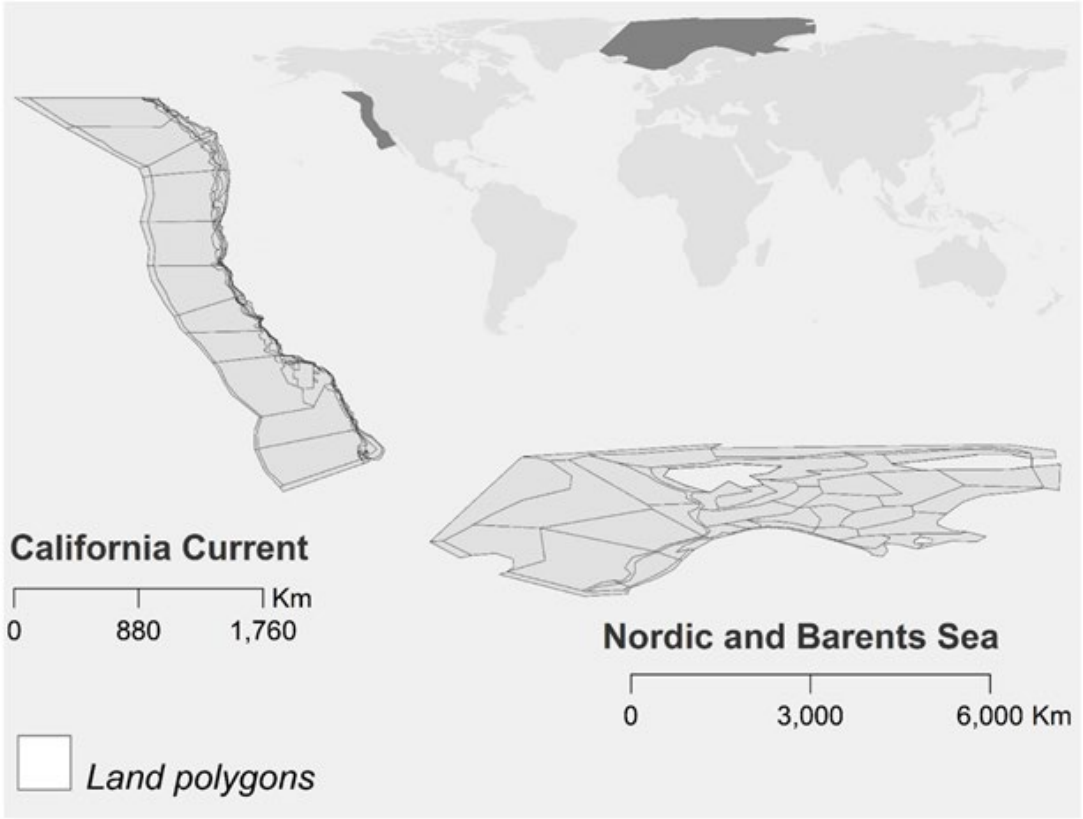
- Improve our ability to project global change impacts in the California Current and Nordic/Barents Seas

- Test the performance of stock assessments to these impacts.

First step: Operating models or ‘virtual worlds’ to simulate climate change scenarios

California Current and Nordic and Barents Seas

Atlantis end-to-end ecosystem models→ Stock Assessment



- Atlantis models (Hansen et al. 2016, 2018, Marshall et al. 2017, Kaplan et al. 2017)
- Building on previous global change projections (Hodgson et al. 2018, Olsen et al. 2018)

California Current and Nordic and Barents Seas

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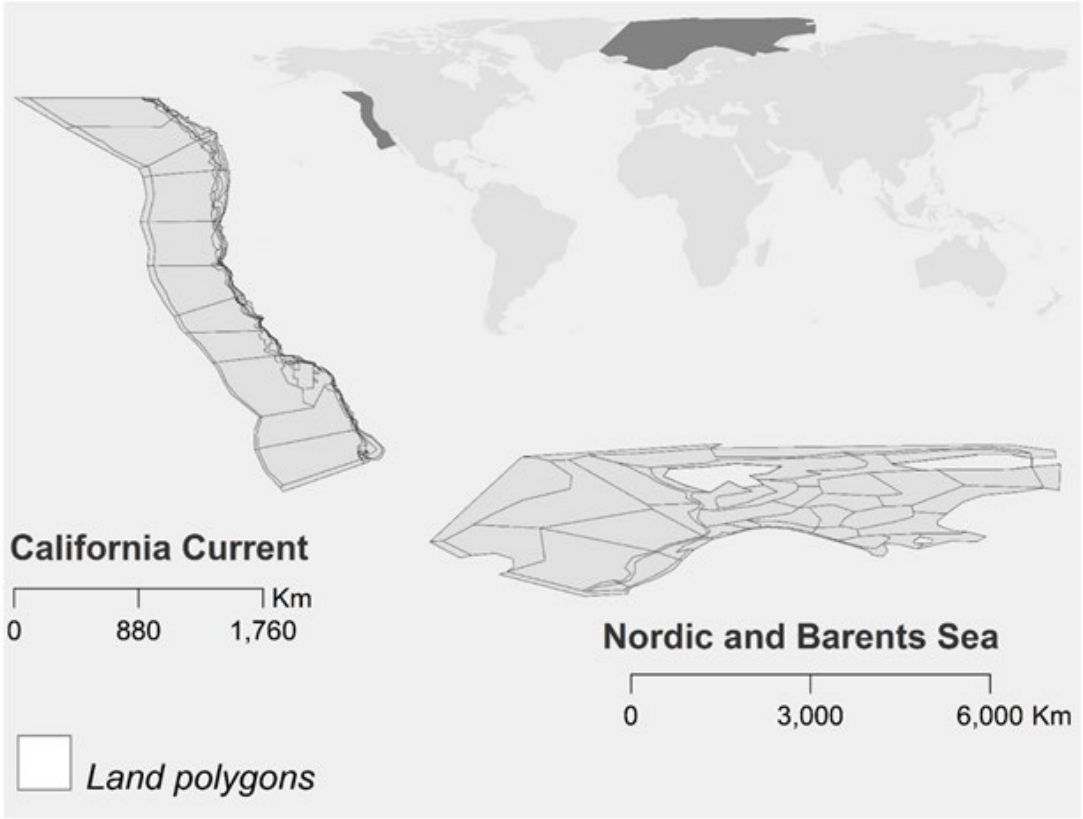

- Scenarios for effects of temperature on growth, natural mortality
- Focus on key assessed stocks (Pacific **sardine** and hake; cod and herring)
- Pass output to *AtlantisOM* → Stock Synthesis assessment (Methot and Wetzel 2013)

California Current and Nordic and Barents Seas

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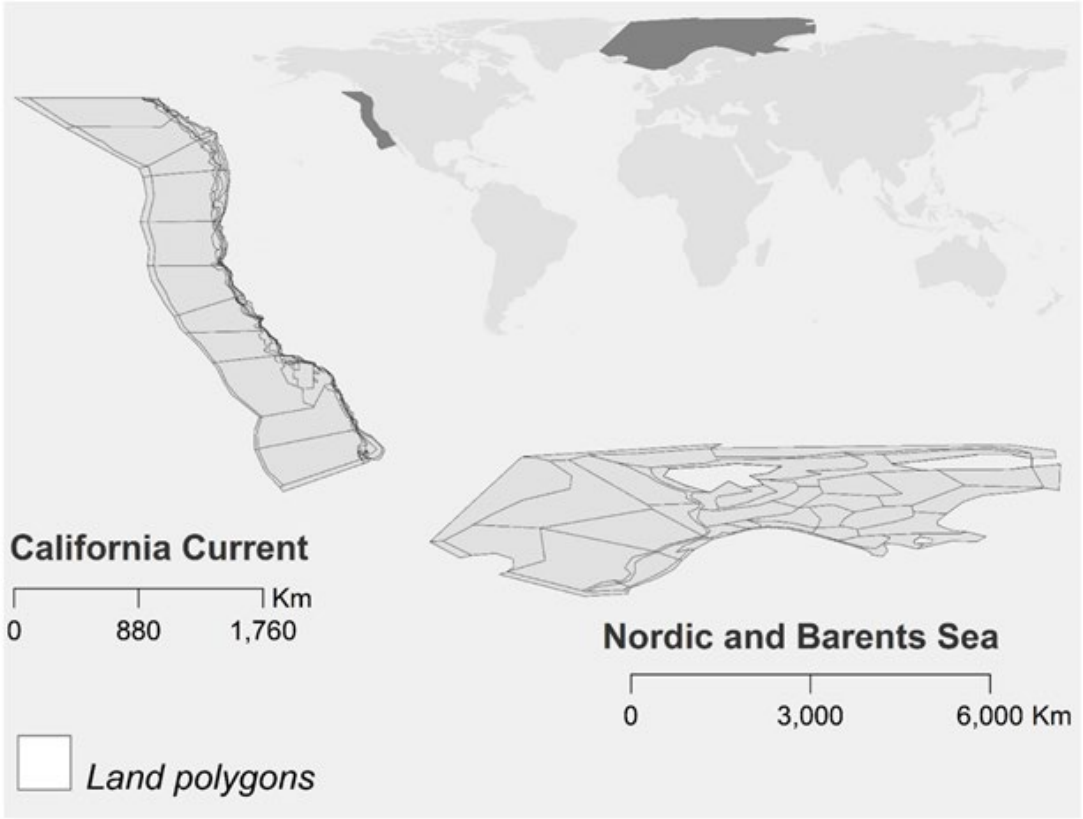

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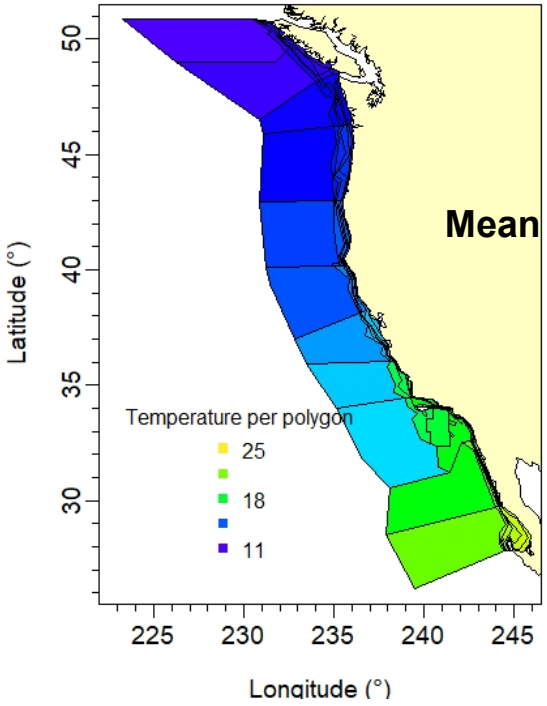
‘Virtual worlds’ forced by Regional Ocean Modeling System (ROMS) scenarios

IPCC scenario RCP8.5 (‘business as usual’) in 2063, forced by GFDL ESM2M.

Continue present conditions vs.

2013, top 50m

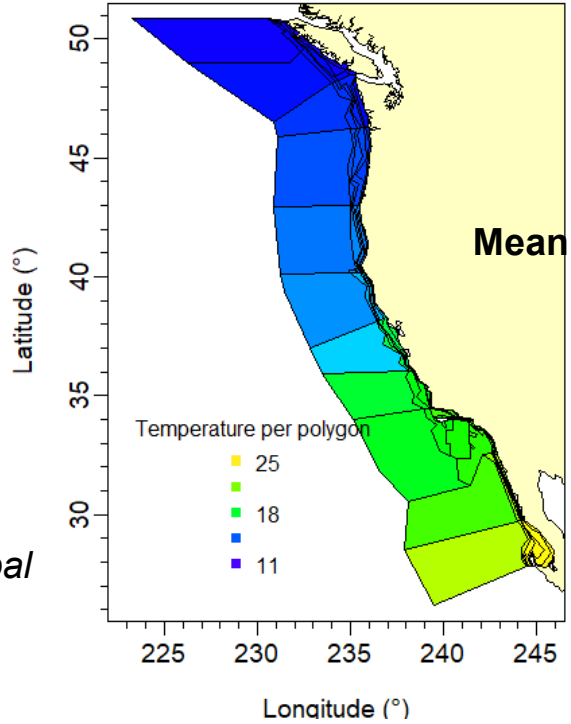


Mean = 16.2 C

Sardine,
Sardinops sagax

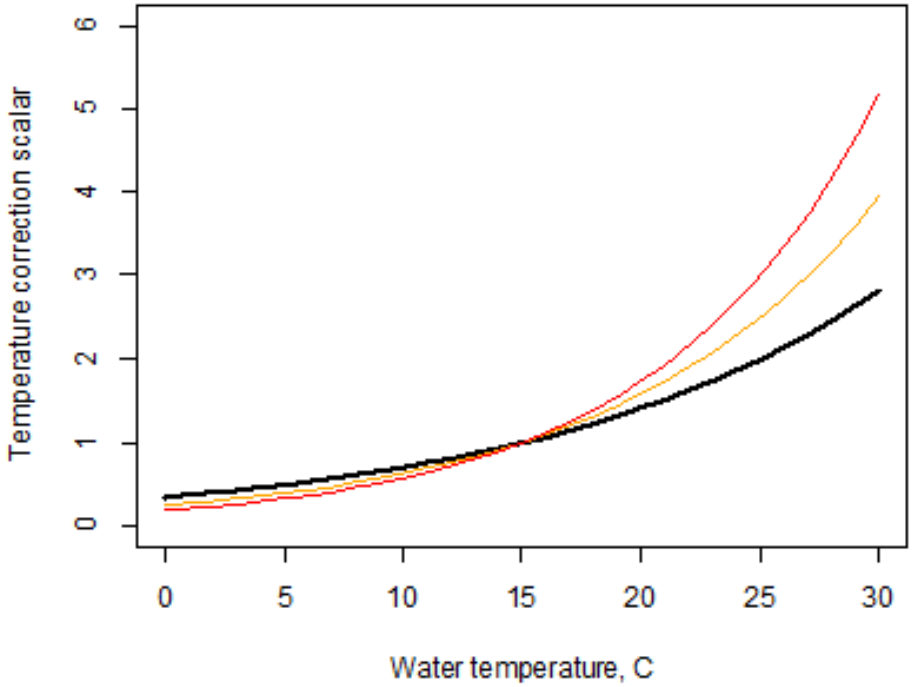
Marshall et al 2017 *Global Change Biology*
Hodgson et al. 2018 *Ecological Modelling*

2063, top 50m, RCP 8.5



Mean = 17.2 C

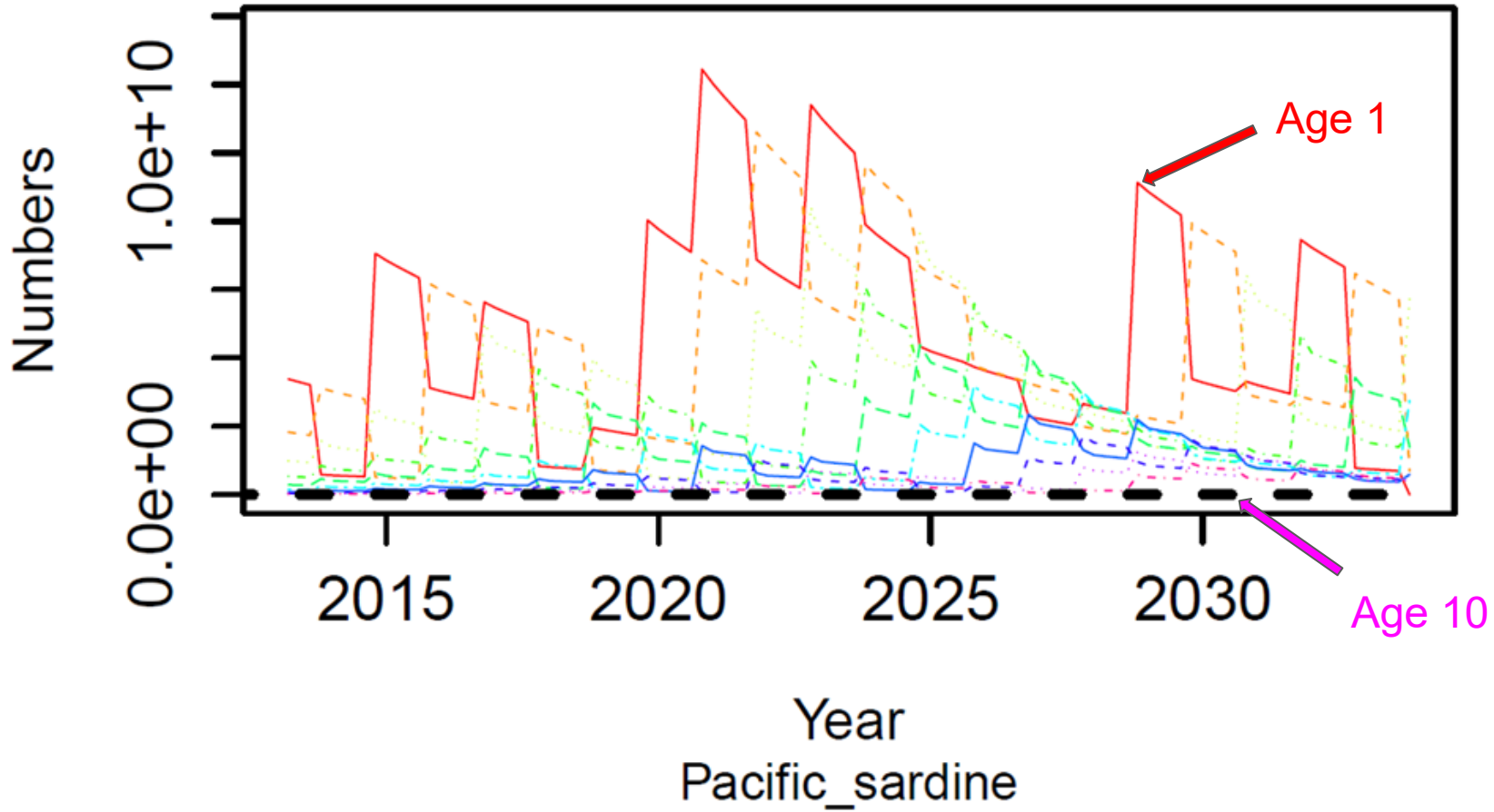
‘Virtual worlds’ include temperature dependence of rate parameters (Q10)

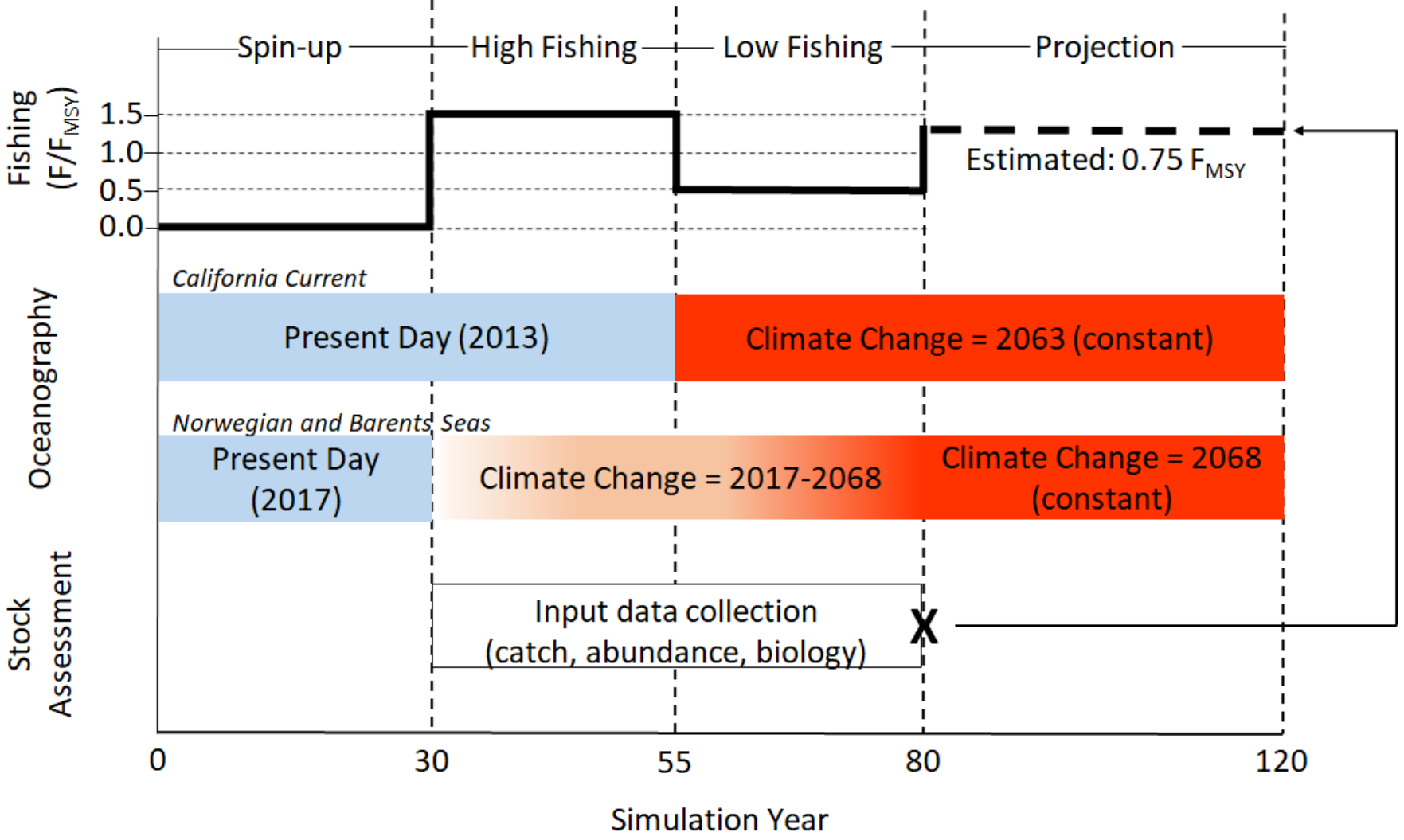


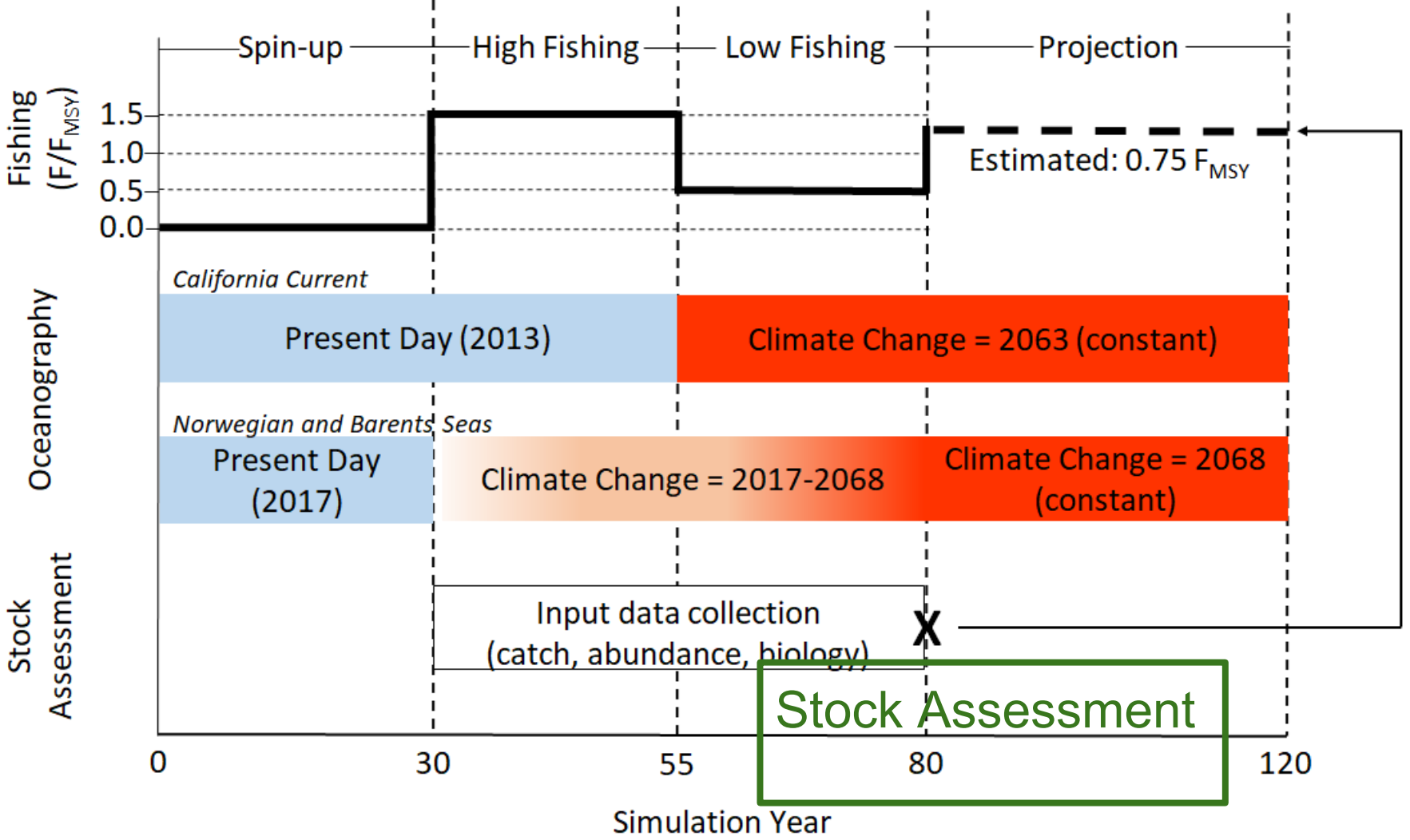
- Primary producer growth rate
- Predator search volume
- Rates of consumption, growth, and unexplained natural mortality
- Rates of detrital breakdown
- Testing Q10= 2.6 (Dell, Pawar, Savage. 2011. PNAS)

Audzijonyte 2019 Methods in Ecol. and Evolution

‘Virtual worlds’ include recruitment variability about Beverton-Holt stock recruit curve.




Spin-up
High Fishing
Low Fishing
Projection
Fishing (F/F_MSY)
1.5
1.0
0.5
0.0
Estimated: 0.75 F_MSY
Oceanography
California Current
Present Day (2013)
Climate Change = 2063 (constant)
Norwegian and Barents Seas
Present Day (2017)
Climate Change = 2017-2068
Climate Change = 2068 (constant)
Stock Assessment
Input data collection (catch, abundance, biology)
X
0
30
55
80
120
Simulation Year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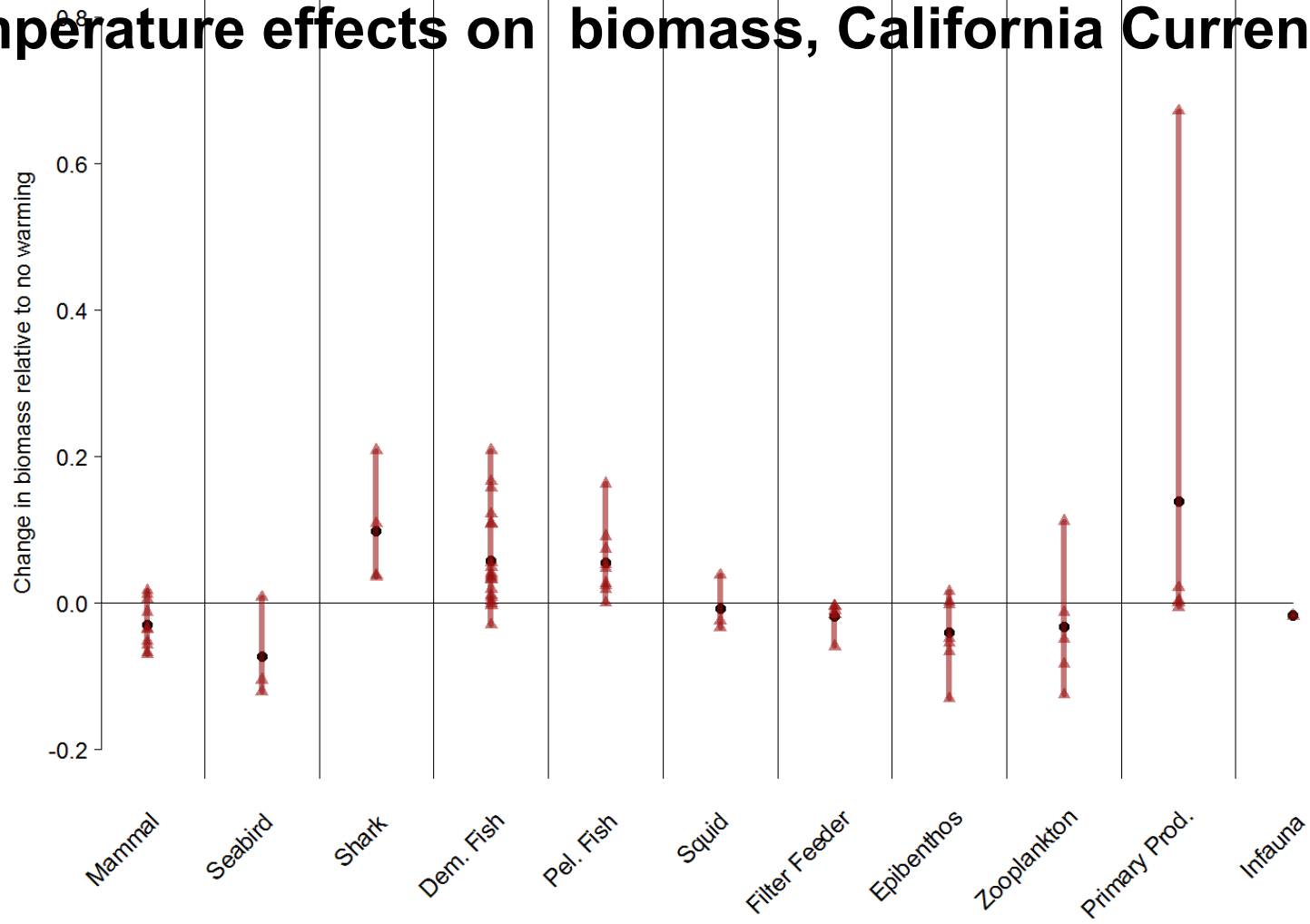
Results: temperature effects on biomass, California Current



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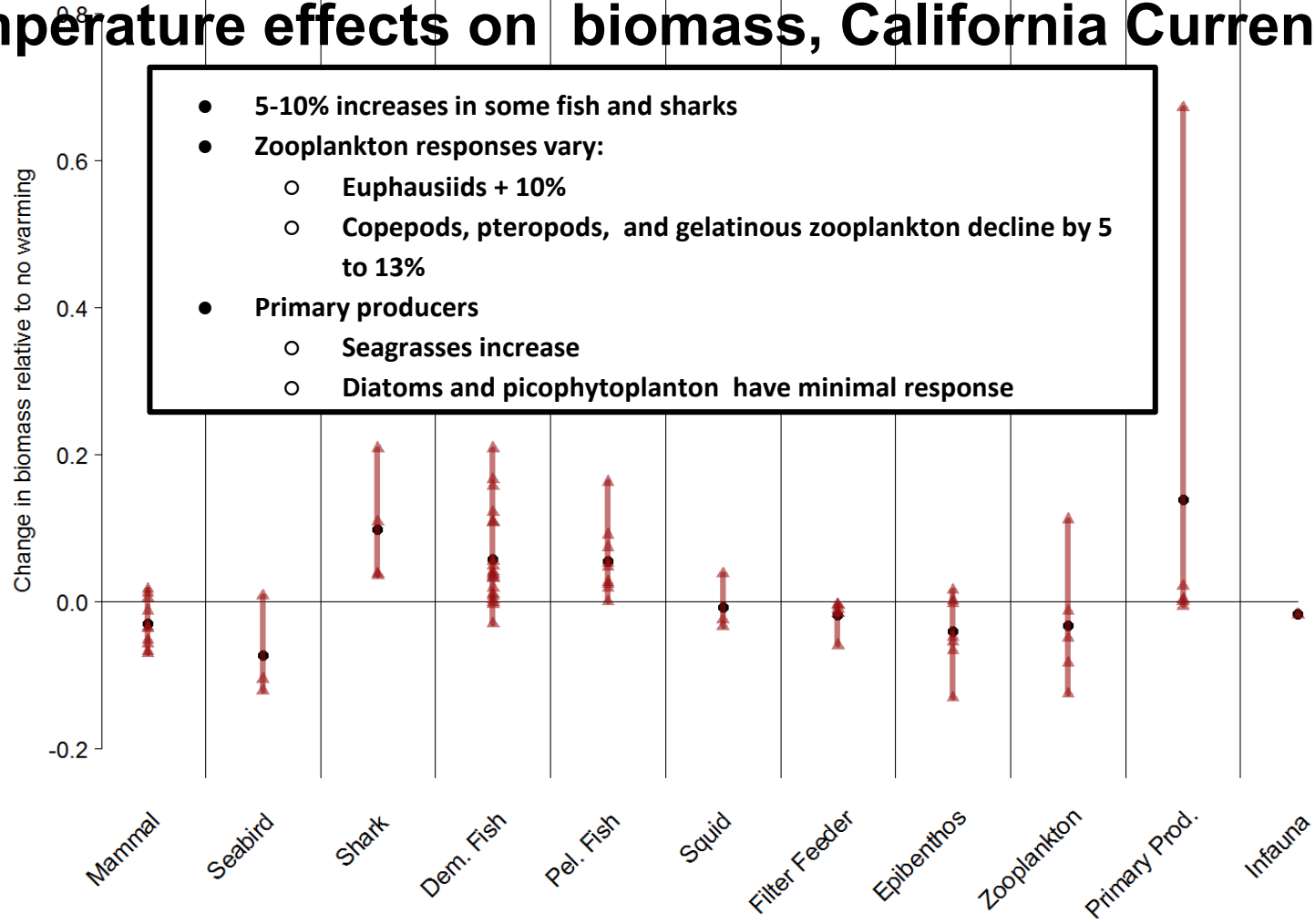
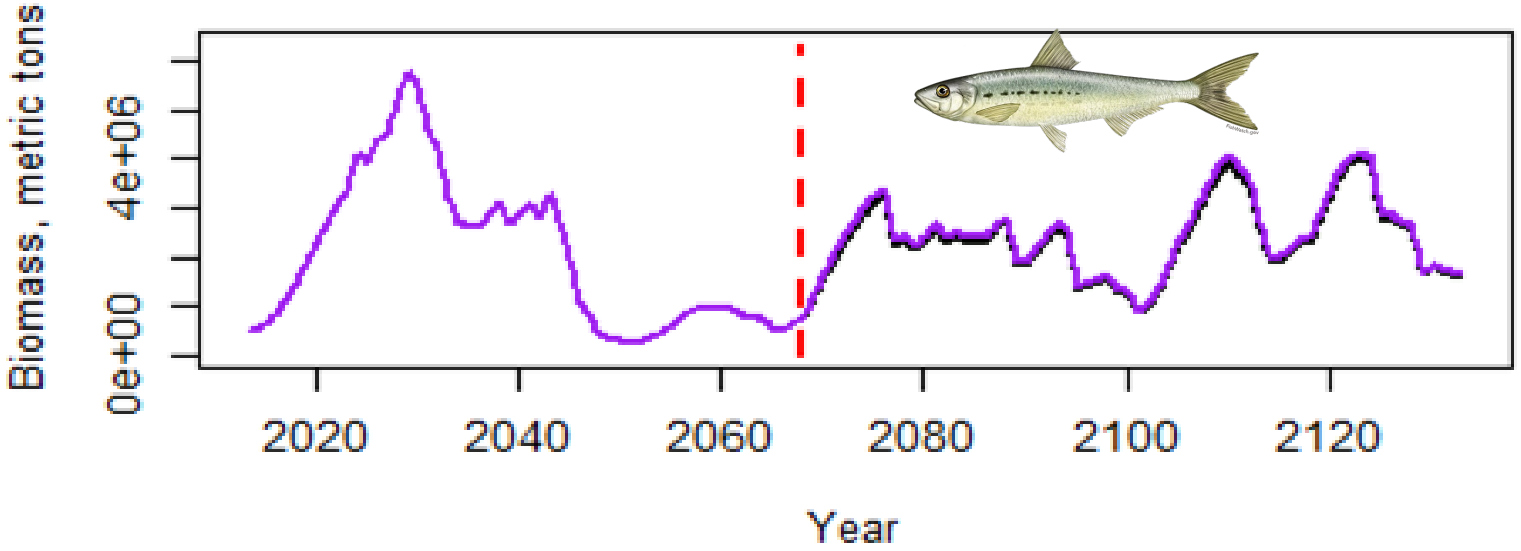


- 5-10% increases in some fish and sharks
- Zooplankton responses vary:
  - Euphausiids + 10%
  - Copepods, pteropods, and gelatinous zooplankton decline by 5 to 13%
- Primary producers
  - Seagrasses increase
  - Diatoms and picophytoplanton have minimal response

Results: temperature effects on sardine biomass

- Ocean conditions only differ by 0.5- 1℃
- Small positive (3-5%) effects on sardine (and hake) biomass



Red dashed line is year 2068, transition to warm conditions (simulation year 55)

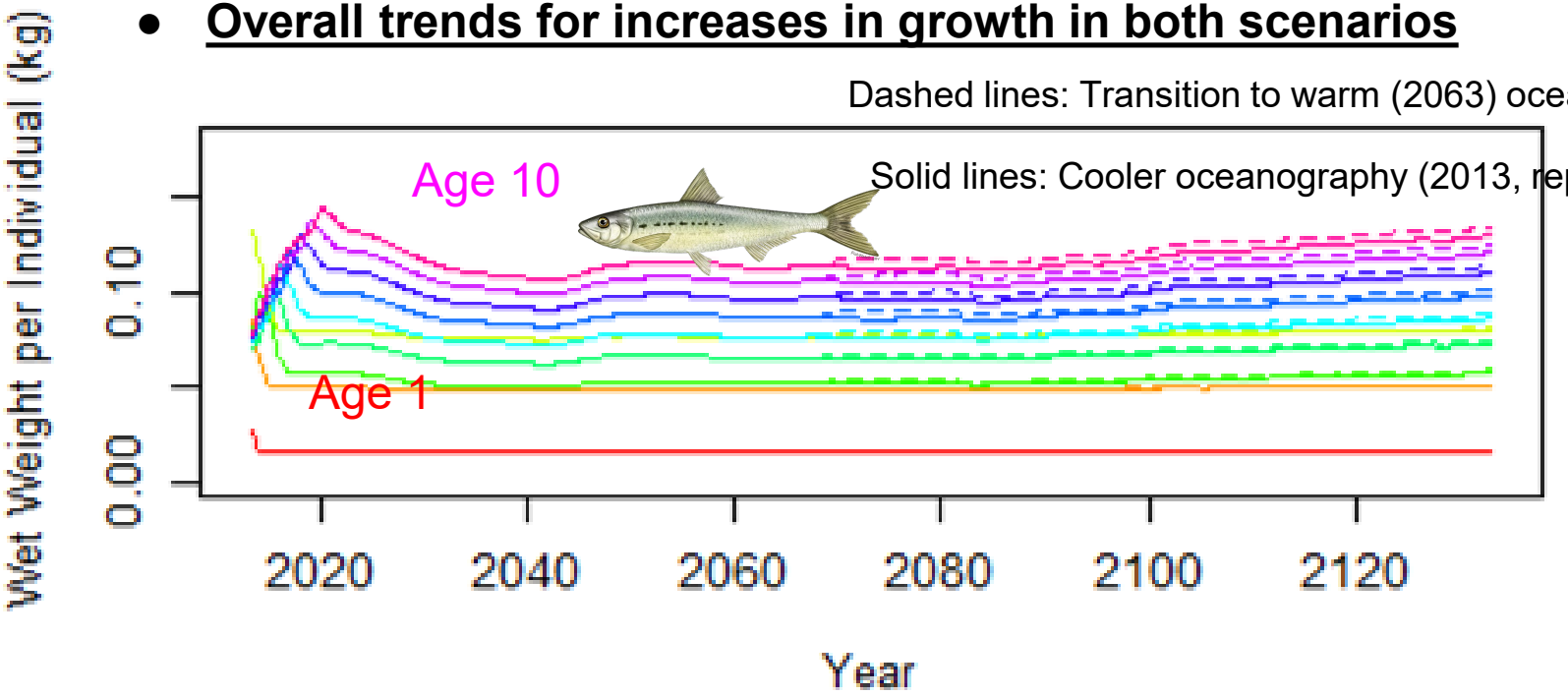
Black: Cooler oceanography (2013, repeated)
Purple: Transition to warm (2063) oceanography

Results: temperature effects on sardine growth

- Ocean conditions only differ by 0.5- 1℃
- **Small positive (<5%) effects on California Current vertebrates' growth : sardine (and hake)**
- **Overall trends for increases in growth in both scenarios**

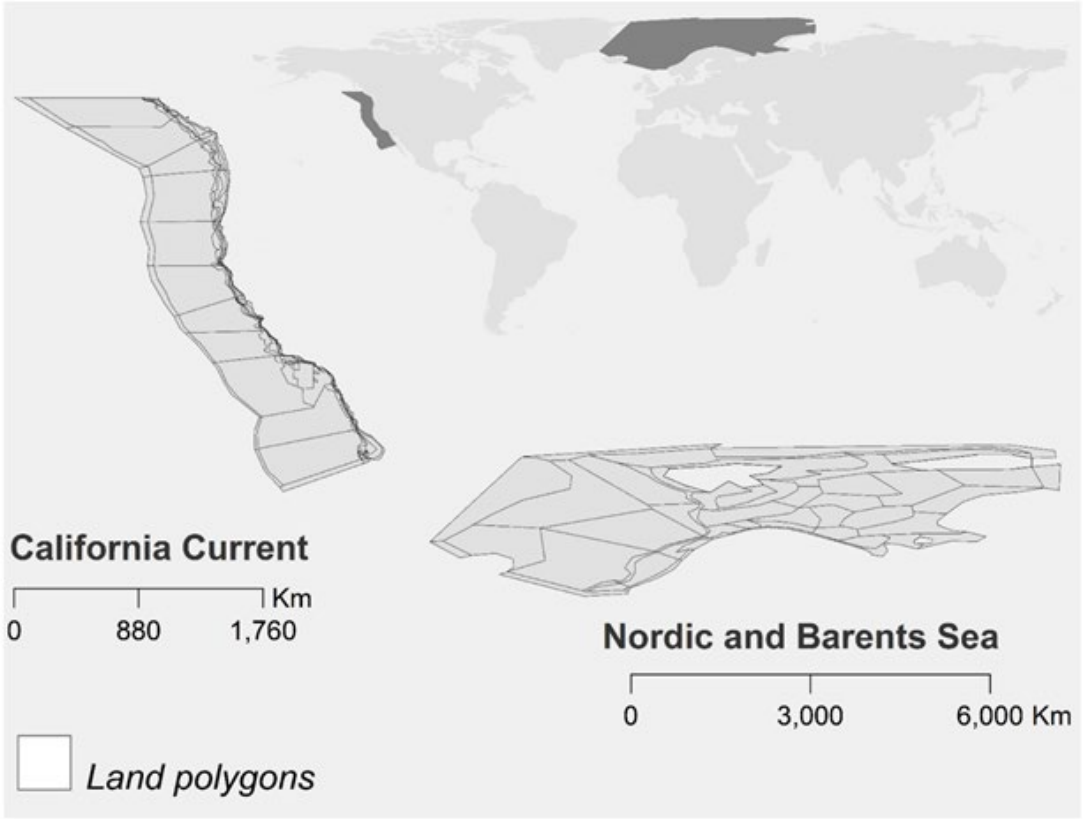
Dashed lines: Transition to warm (2063) oceanography

Solid lines: Cooler oceanography (2013, repeated)



California Current and Nordic and Barents Seas

Atlantis end-to-end ecosystem models→ Stock Assessment



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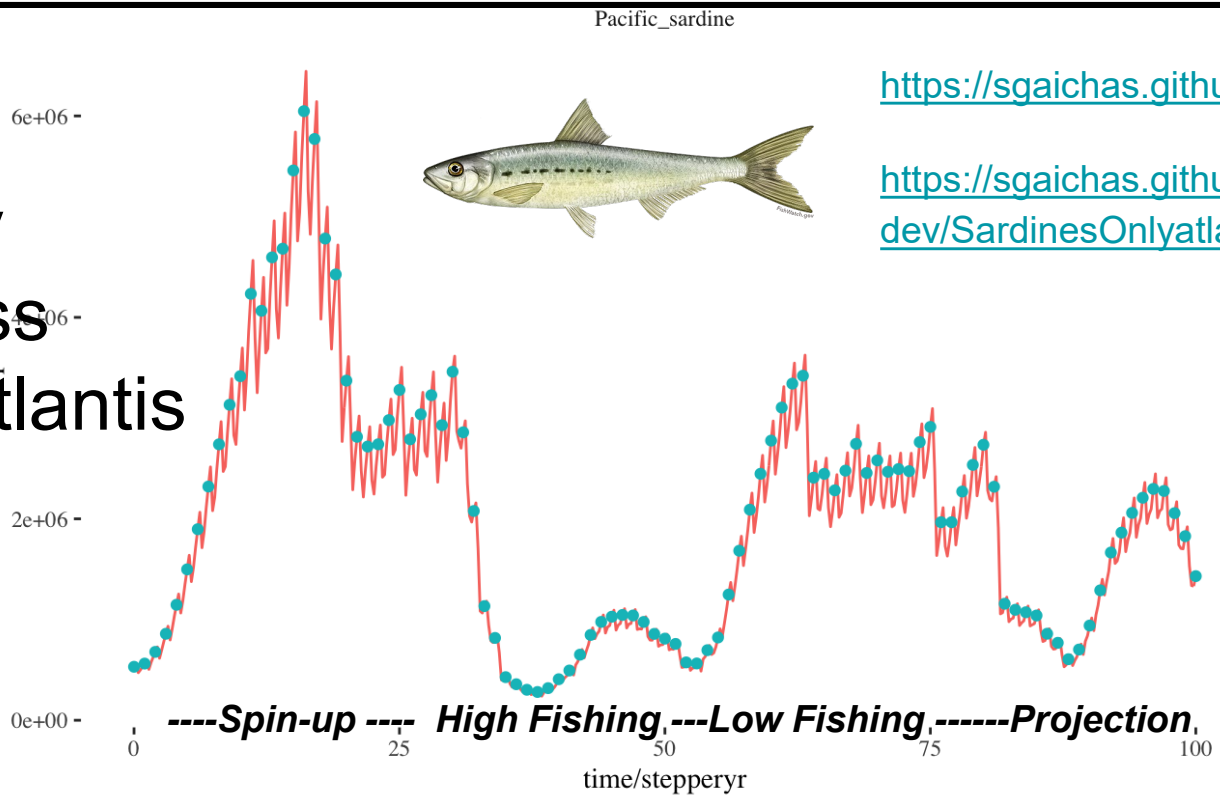
AtlantisOM and Poseidon-Dev Packages translate Atlantis 'virtual world' to input for Stock Synthesis 3 assessment

Survey biomass from Atlantis



https://sgaichas.github.io/poseidon-dev/

https://sgaichas.github.io/poseidon-dev/SardinesOnlyatlantisom2SStest.html

California Current and Nordic and Barents Seas

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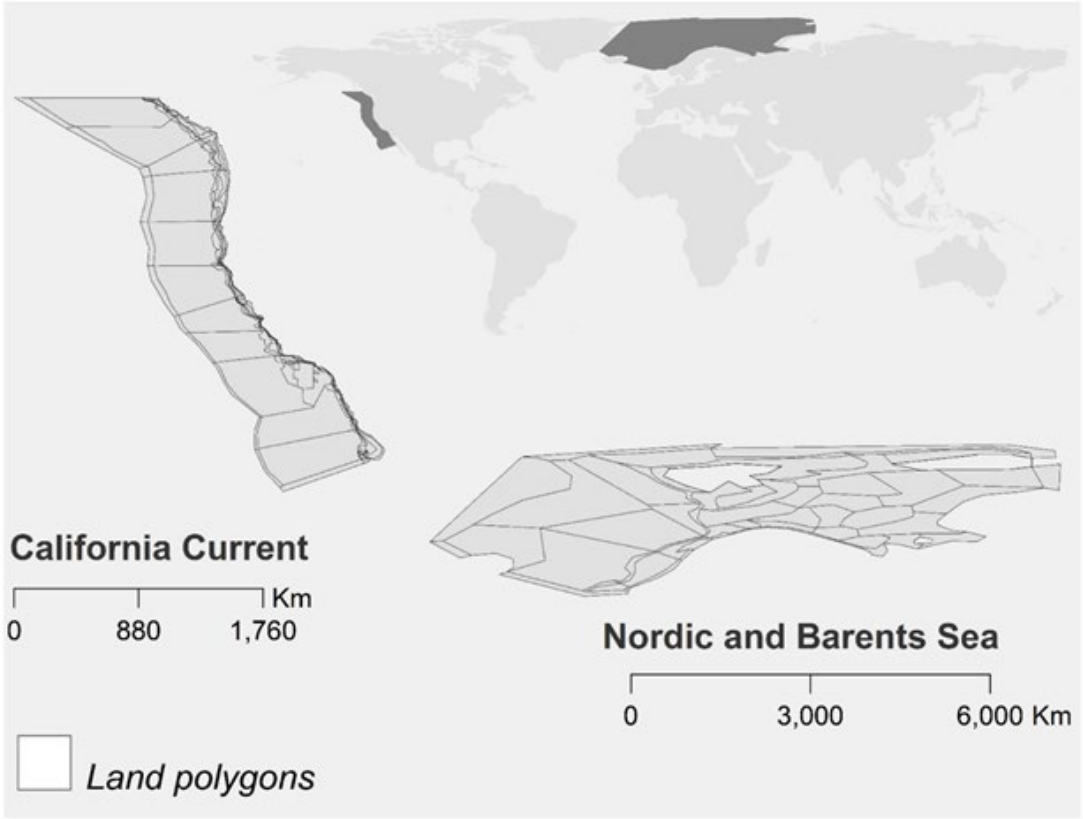

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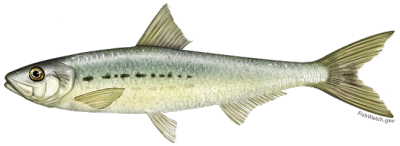
Stock Synthesis Assessment Model of sardine from Atlantis ‘virtual world’



(model based on actual Sardine assessment in Stock Synthesis 3)

Data:

- survey biomass index
- survey length composition
- survey age composition (conditional catch at age)
- fishery catch (tons)
- fishery length composition
- fishery age composition

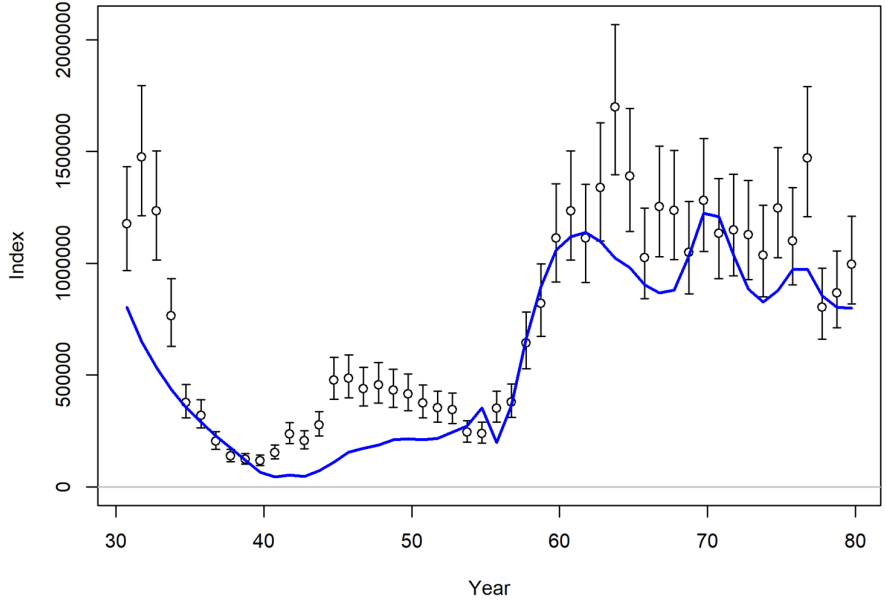
Parameters:

- natural mortality (from total mortality)
- growth curve (von Bertalanffy k)
- fishery and survey selectivity (age based)
- unfished recruitment (R0)
- Given: maturity at age (true)
- Given: weight-length curve (true)
- Given: stock-recruit steepness

Results: Stock Synthesis Assessment Model of sardine from Atlantis 'virtual world'

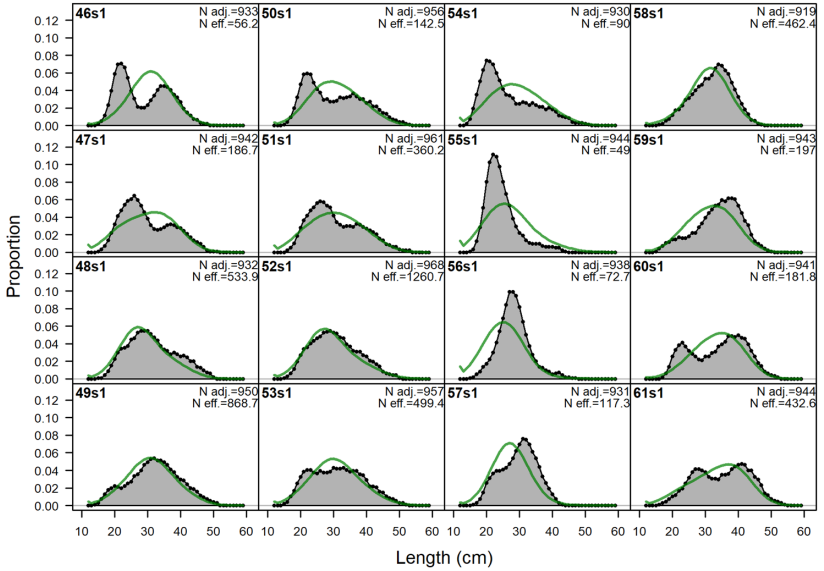
Stock Assessment

Survey biomass from Atlantis



Stock Assessment

Fishery length composition from Atlantis



Next steps: Stock Synthesis Assessment Model -- Options for Growth and Mortality (and their fluctuations under climate change)

- Growth:
  1. constant growth parameters
  2. regime shifts in growth parameters (Stawitz et al. 2019)
  3. empirical weight-at-age (Kuriyama et al. 2016)
- Natural mortality:
  1. fixed at an “uninformed” constant value of 0.2
  2. fixed at a constant value that reflects the true average value (over time) from the OM
  3. establishing regimes by fixing at the true average values from the OM over specified time blocks

Stay tuned !

Work in progress

- California Current and Nordic and Barents Seas
- Hake, cod, and herring Stock Synthesis models
- Tests of options for Stock Synthesis assessment
  - growth
  - mortality
- Plots of performance metrics

Thanks!

- PICES and Session 11 (Drs. Muhling, Holt, Holsman, and Kang)
- Erik Olsen (IMR) and REDUS project (http://redus.no/)
- Havforskningsinstituttet (IMR Norway)
- NOAA NMFS International Fellowship
- Friends, schoolteachers, soccer and tennis coaches who hosted Americans in Bergen