How do fishing and climate change interact to impact biomass available to future fisheries?

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Hawaii-based longline fishery

- Targets bigeye tuna
- Low volume (ranks 27th), high value (ranks 6th)
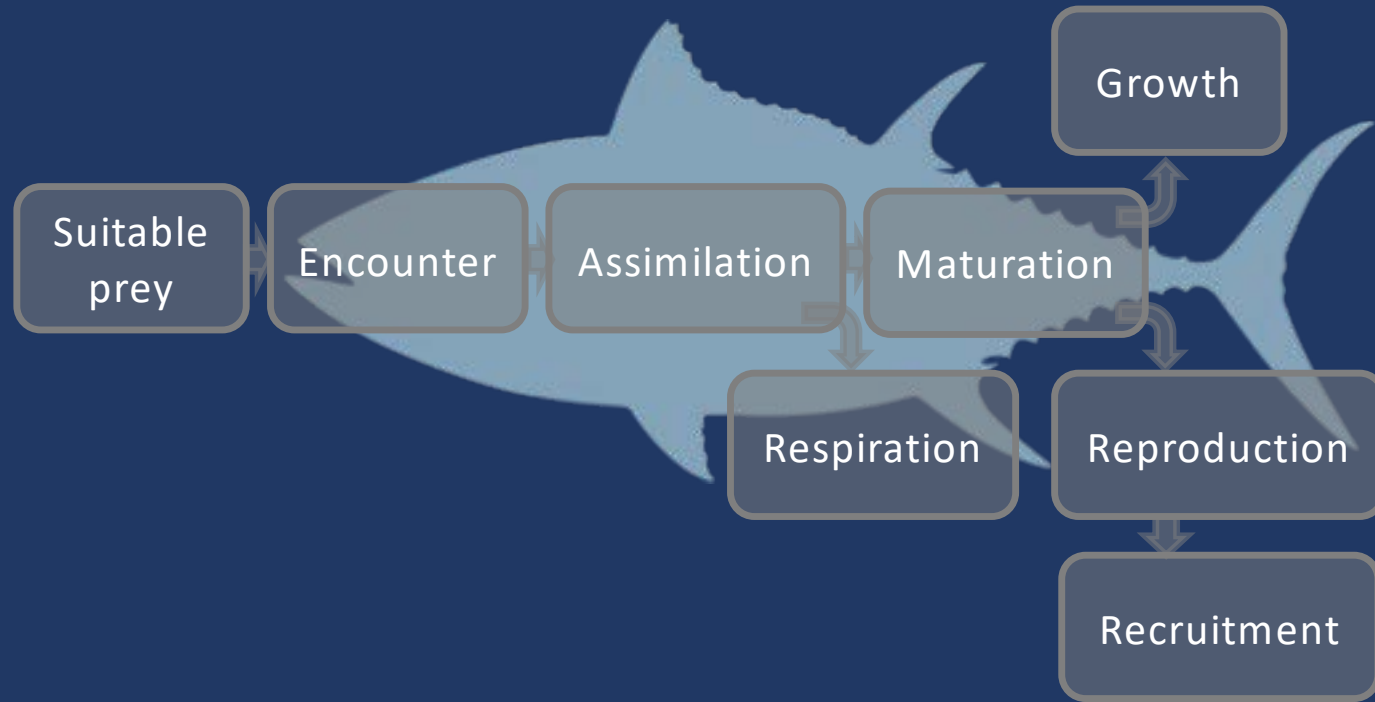- 9,546 jobs & $743 million sales impact

Climate projections

- Warming
- Increased stratification
- Declining productivity
- Shift to smaller body sizes

Approach

- Suite of CMIP5 models – RCP8.5
- Size-structured food web model
- Full vertical habitat

NOAA National Marine Fisheries Service; Bopp *et al*. 2013; Sarmiento *et al*. 2004;
Steinacher *et al*. 2010; Polovina *et al*. 2011; Cabre *et al*, 2015; Lehodey *et al*. 2011 & 2013; Taylor *et al*. 2012; Woodworth-Jefcoats *et al*. 2017; Cheung *et al*. 2013; Pinsky *et al*. 2013

mizer processes

R package available at:
https://github.com/sizespectrum/mizer

Suitable prey

Encounter

Assimilation

Maturation

Growth

Respiration

Reproduction

Recruitment

Figure modified from Scott *et al*. 2014
Tuna image courtesy of Amanda Dillon

mizerNPAC

Phyto- and Zooplankton densities   Temperature   Fishing mortality

Suitable prey → Encounter → Assimilation → Maturation → Growth

Respiration

Reproduction → Recruitment
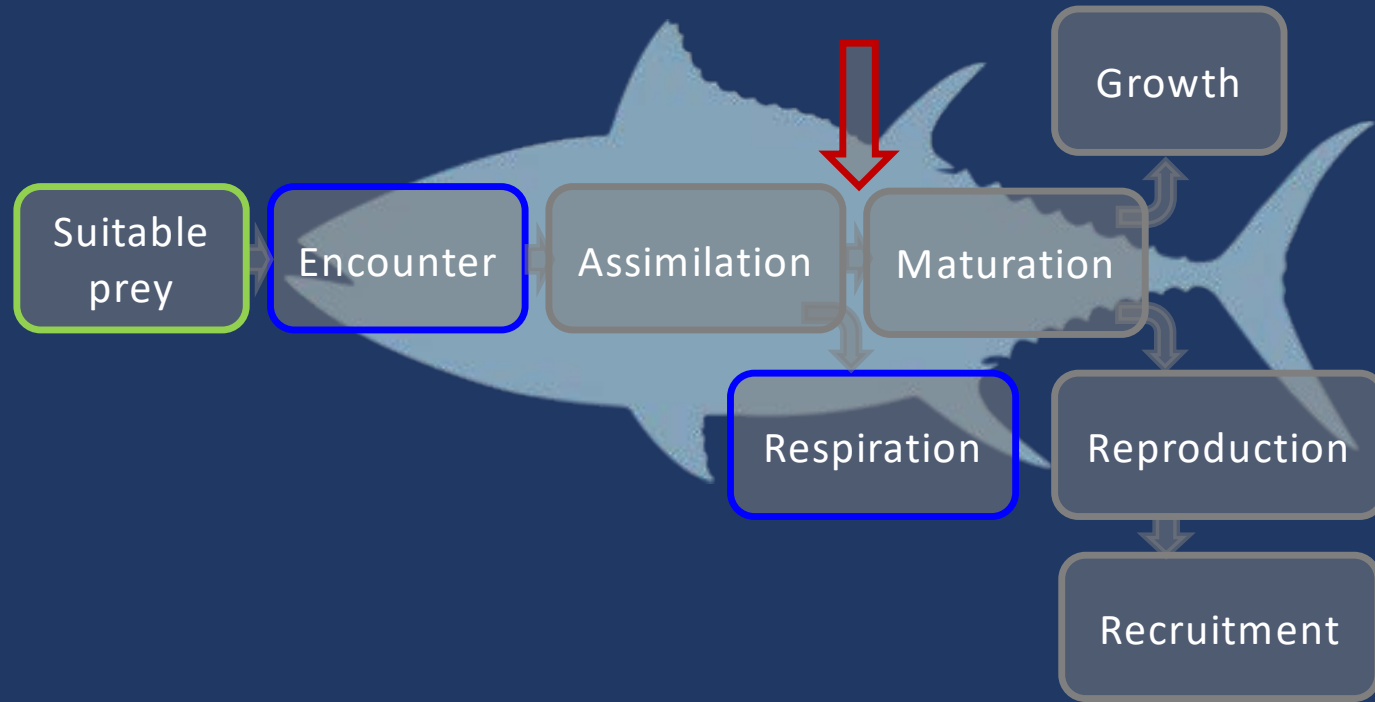
mizerNPAC R package available at: https://github.com/pwoodworth-jefcoats/Size-Based-Modeling

Figure modified from Scott *et al.* 2014
Tuna image courtesy of Amanda Dillon
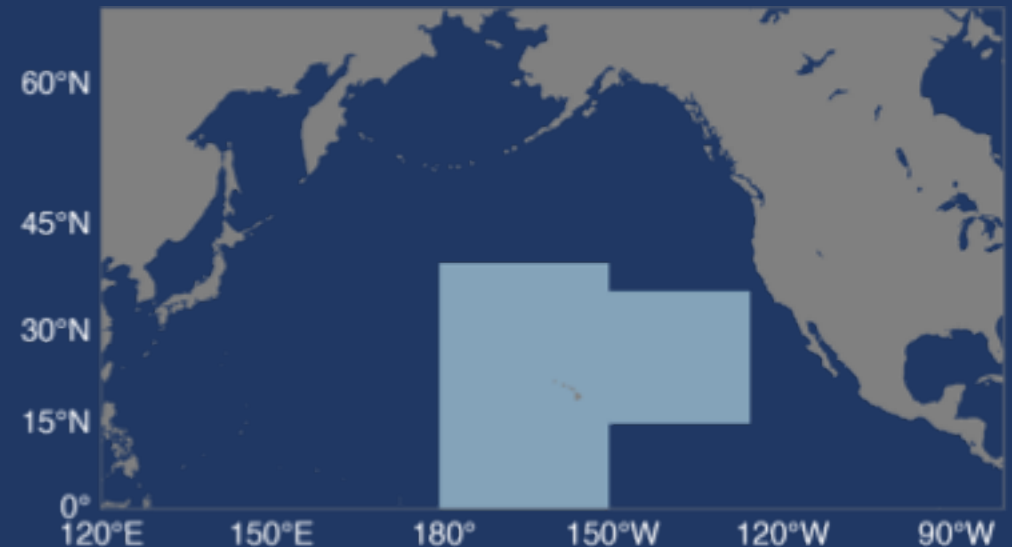
CMIP5 Model Suite

- Canadian Center for Climate Modeling and Analysis Earth system model (**CanESM2**)
- NOAA Geophysical Fluid Dynamics Laboratory Earth System Model
  - Generalized ocean layer dynamics (**GFDL-ESM2G**)
  - Modular Ocean Model 4 (**GFDL-ESM2M**)
- NASA Goddard Institute for Space Sciences ModelE2 Earth System Model
  - Carbon cycle coupled to the HYCOM ocean model (**GISS-E2-H-CC**)
  - Carbon cycle coupled to the Russell ocean model (**GISS-E2-R-CC**)
- Institut Pierre Simon Laplace
  - Low resolution CM5A (**IPSL-CM5A-LR**)
  - Medium resolution CM5A (**IPSL-CM5A-MR**)
  - Low resolution CM5B (**IPSL-CM5B-LR**)
- Max-Planck-Institute für Meteorolgie Earth System Model
  - Low resolution (**MPI-LR**)
  - Medium resolution (**MPI-MR**)
- Meteorological Research Institute Earth System Model Version 1 (**MRI**)

Fish Species

- Lancetfish
- Bigeye Tuna
- Mahi Mahi
- Blue Shark
- Skipjack Tuna
- Yellowfin Tuna
- Albacore Tuna
- Opah
- Wahoo
- Striped Marlin
- Bigeye Thresher Shark
- Swordfish
- Blue Marlin
- Shortfin Mako Shark

- Pomfret
- Snake Mackerel
- Escolar
- Shortbill Spearfish
- Pelagic Stingray
- Unidentified Tuna

Christian *et al*. 2010; Collins *et al*. 2011; Dufresne *et al*. 2013; Dunne *et al*. 2013; Giorgetta *et al*. 2013; Romanou *et al*. 2014; Schmidt *et al*. 2014; Taylor *et al*. 2012; Yukimoto *et al*. 2011

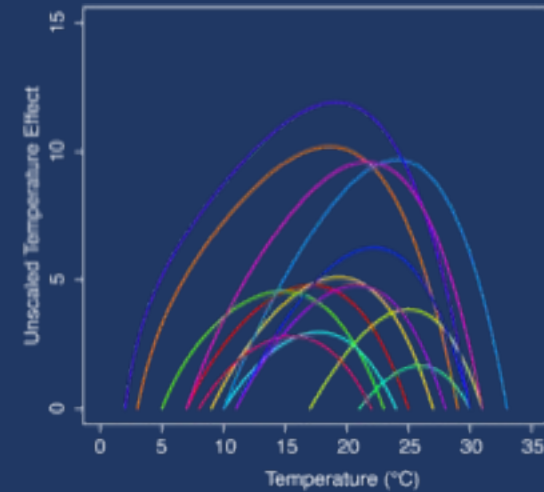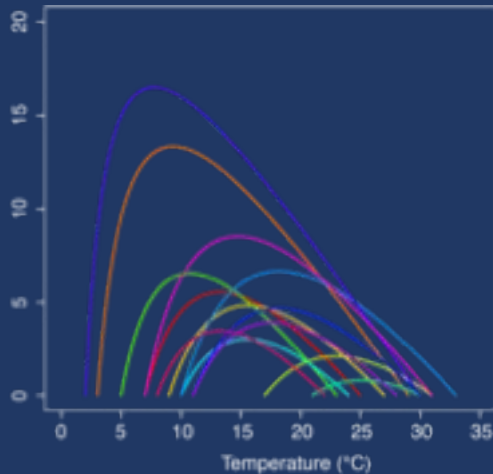# CMIP5 Model Spread - Plankton
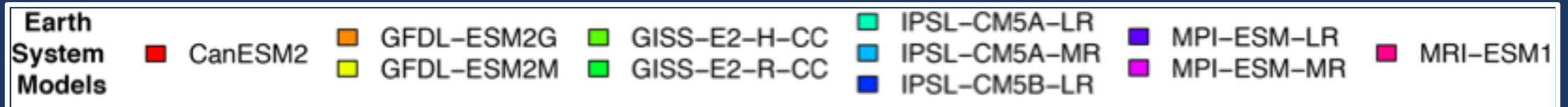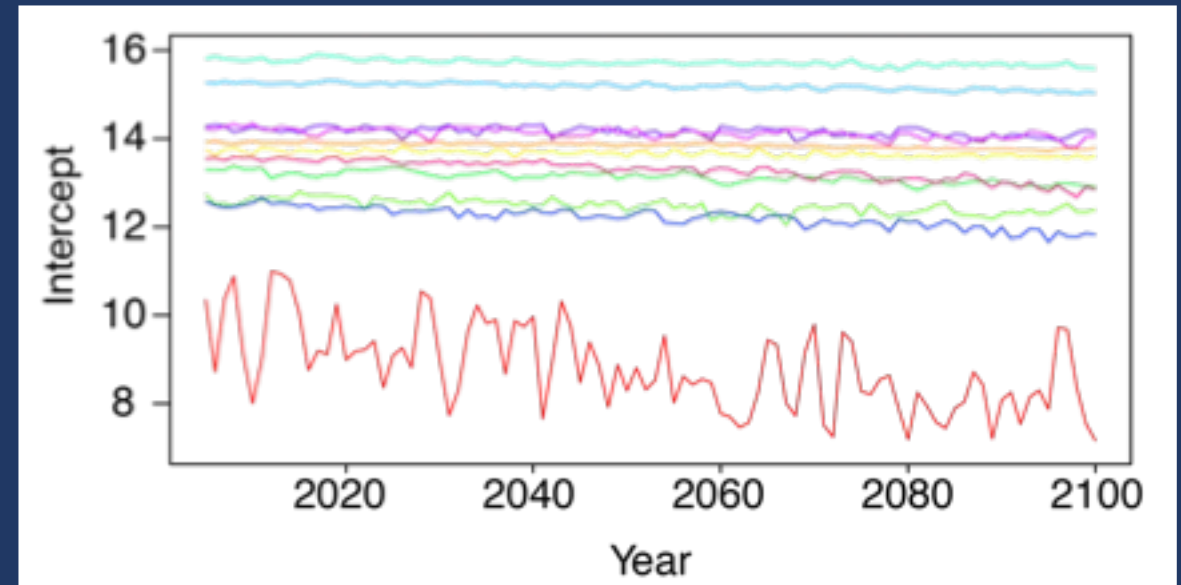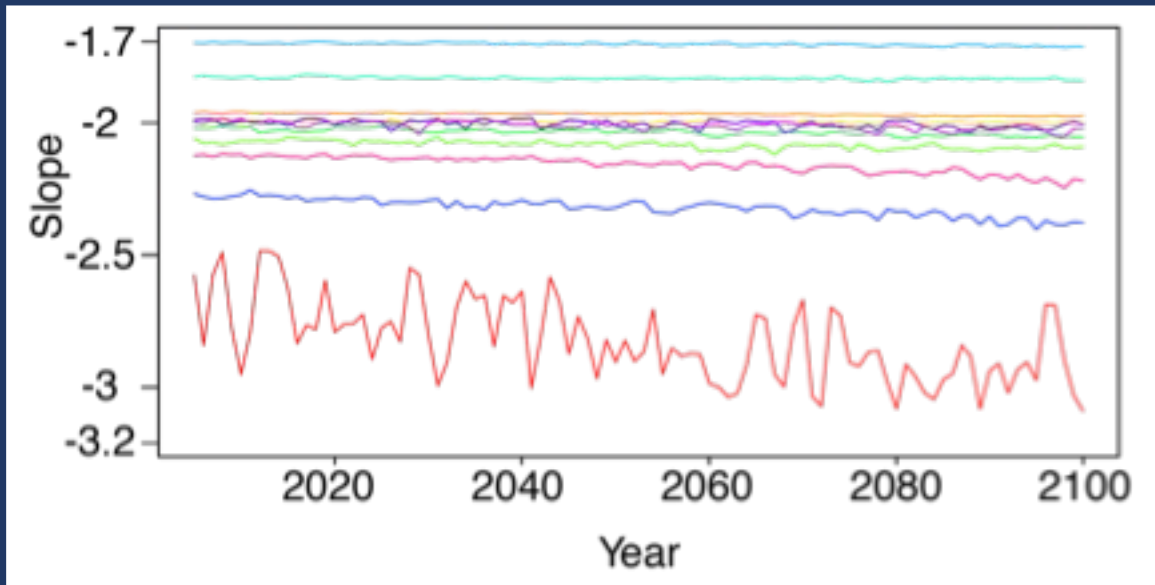
mizerNPAC temperature effect

Boltzmann factor or Arrhenius relation:

$$e^{\left(25.22 - \frac{0.63}{(8.52\times10^{-5})(T+273)}\right)}$$
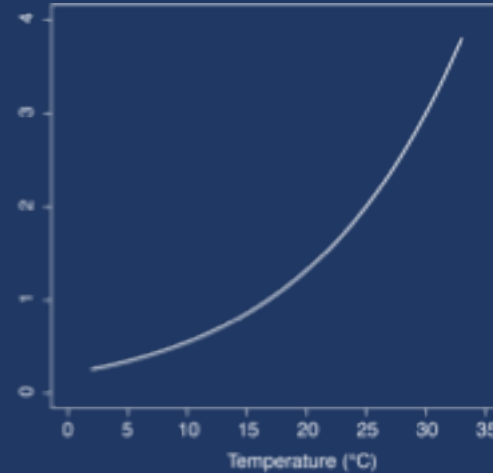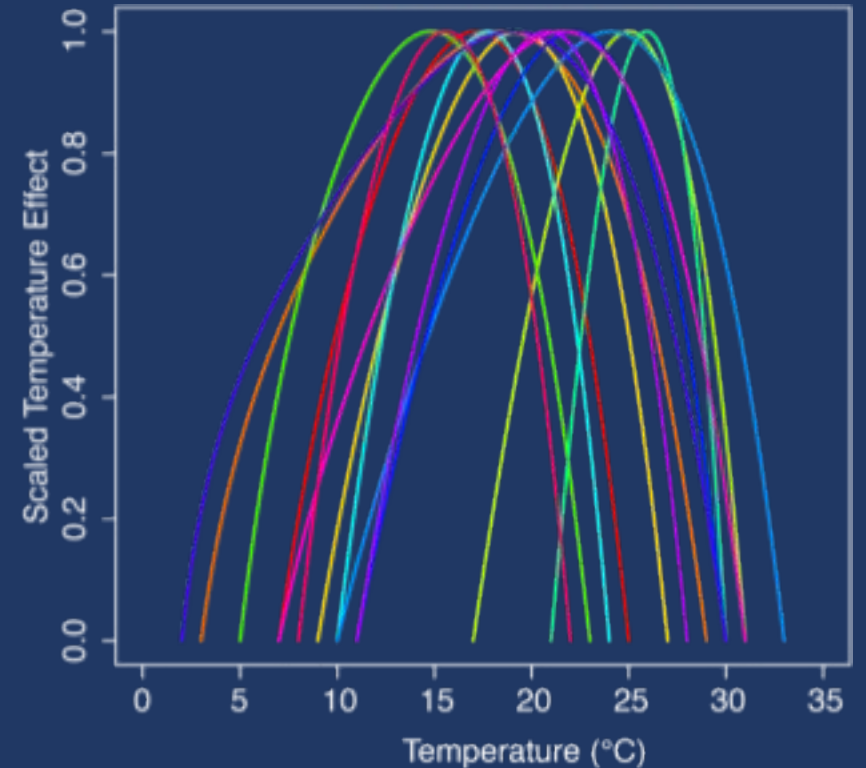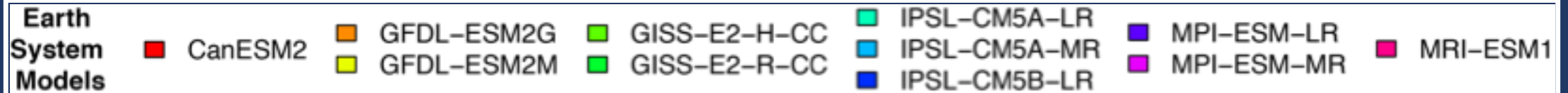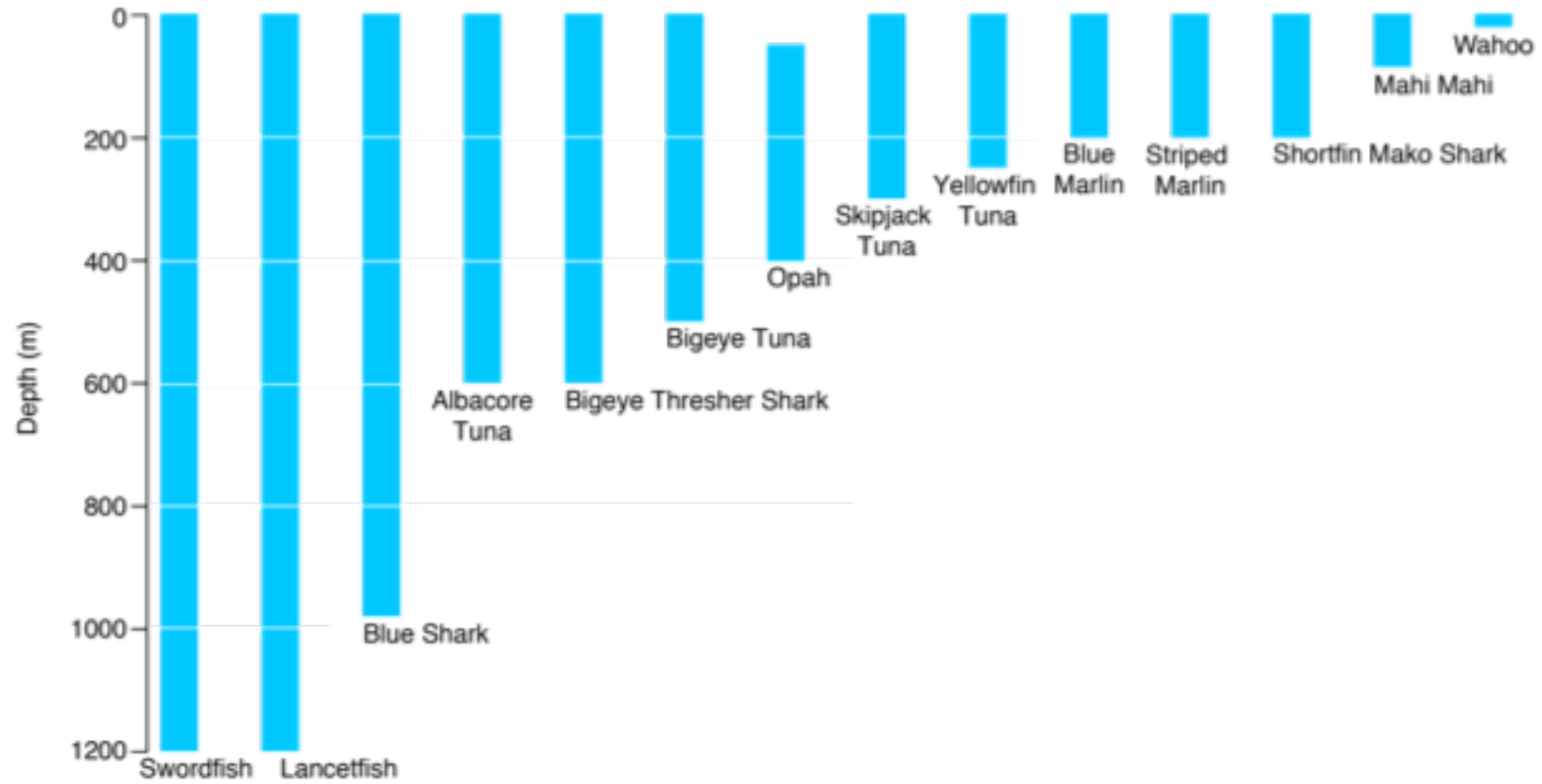
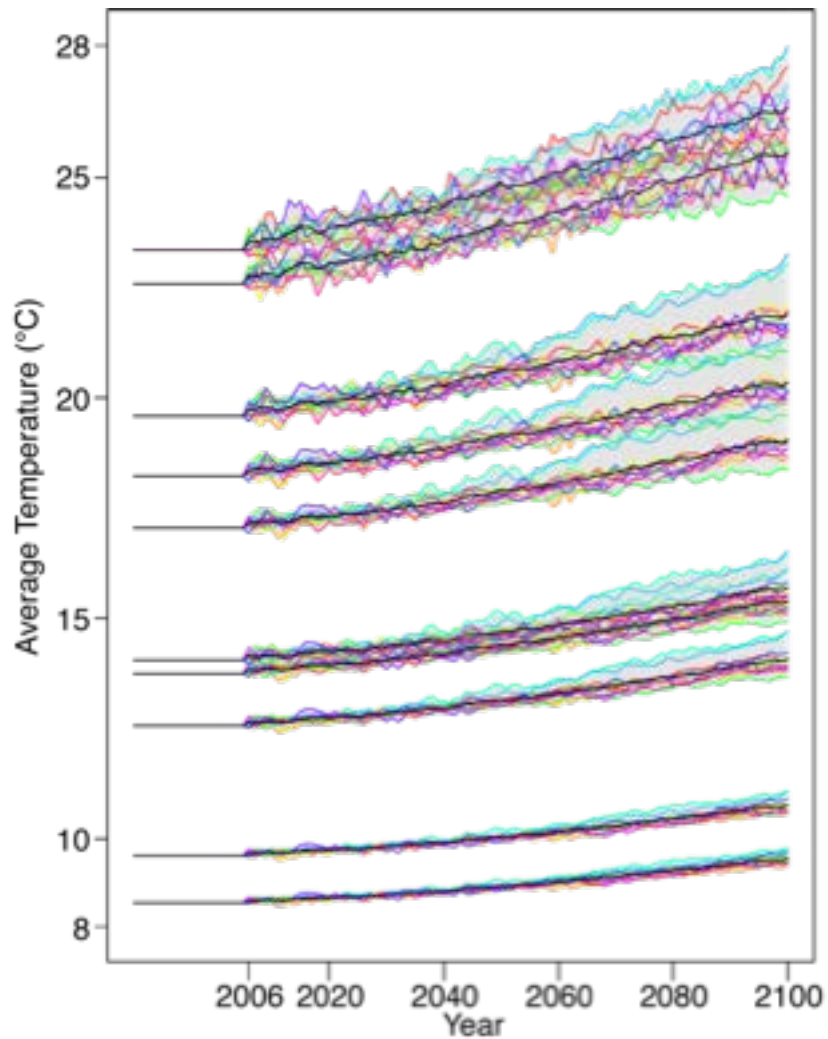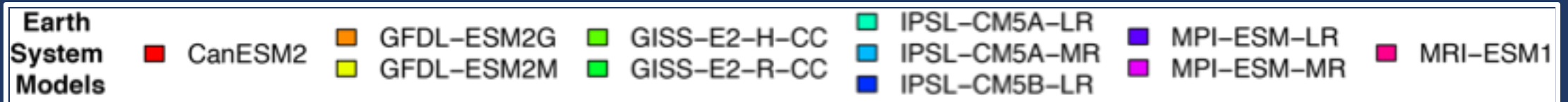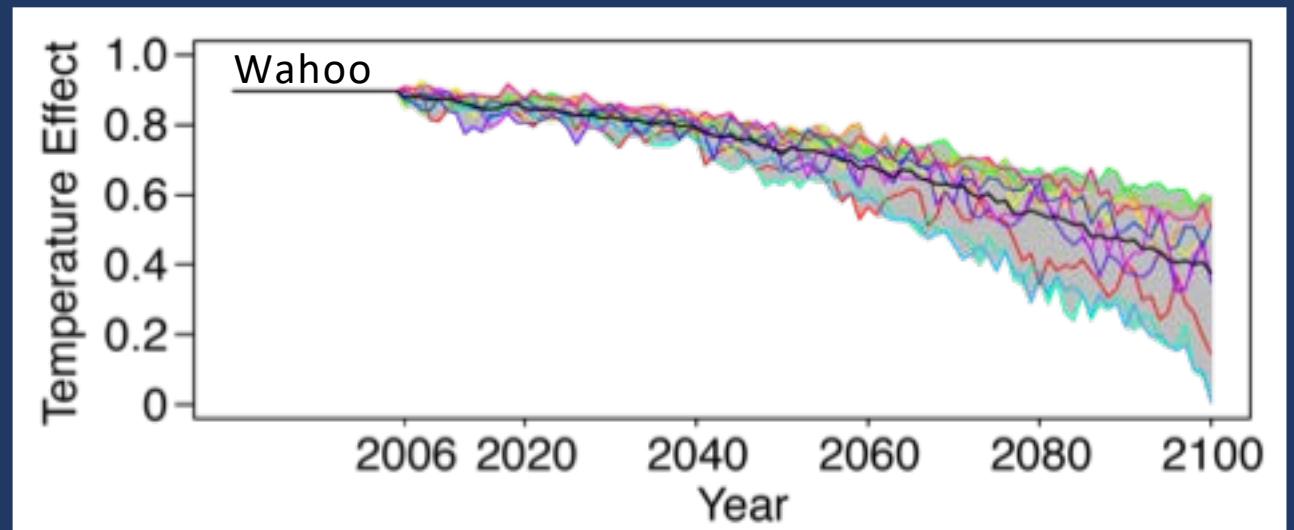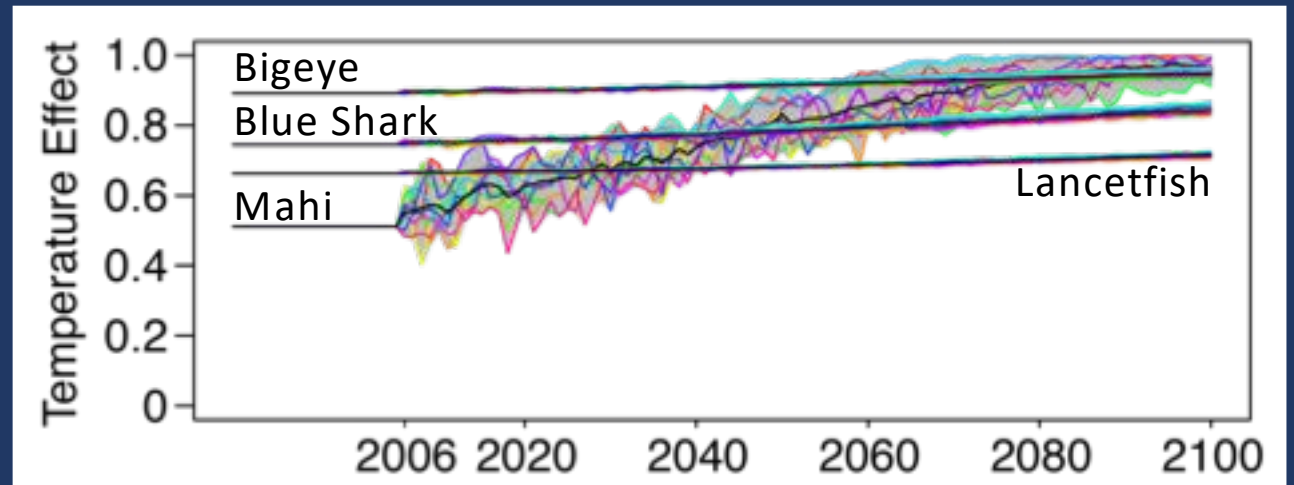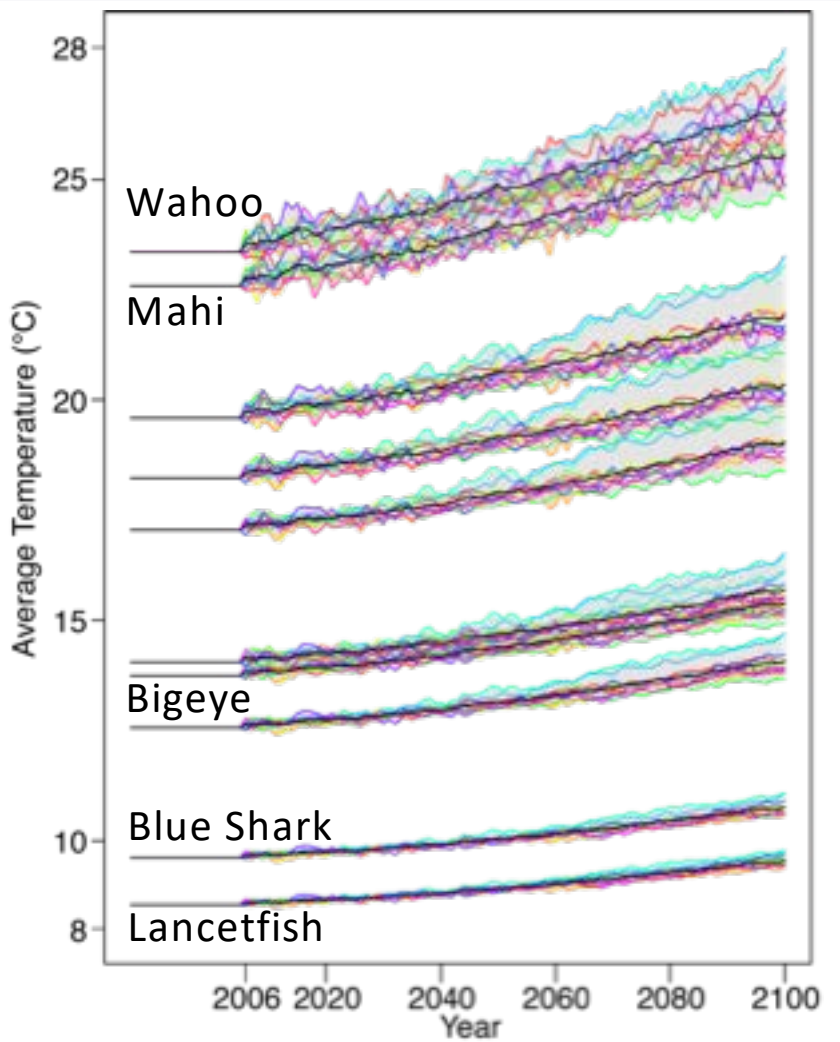Multiplied by a generic polynomial rate equation:

$$\frac{1}{T}(T - T_{min})(T_{max} - T)$$

Scale each species by its max value

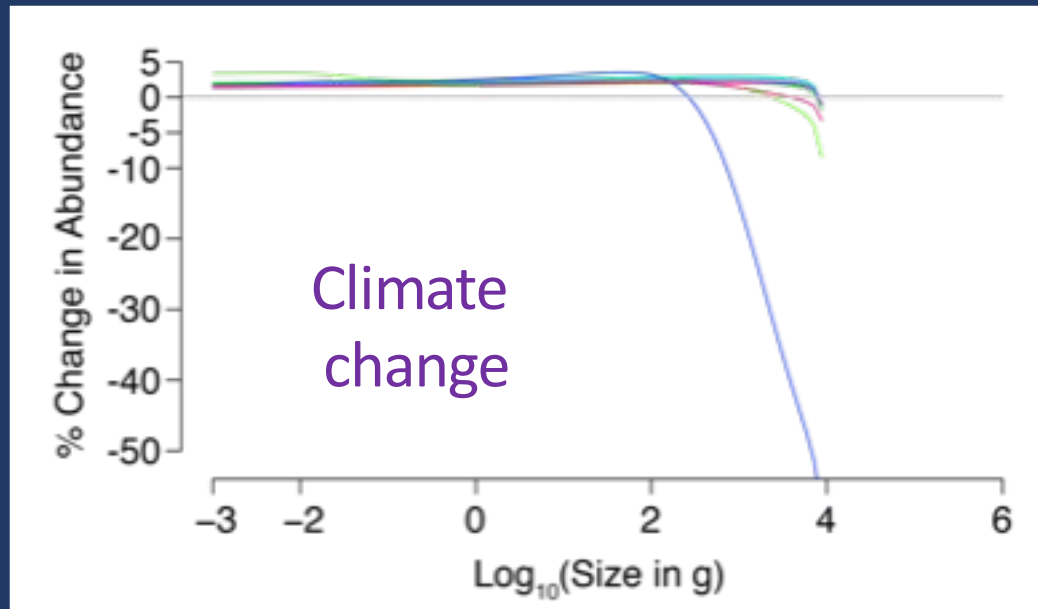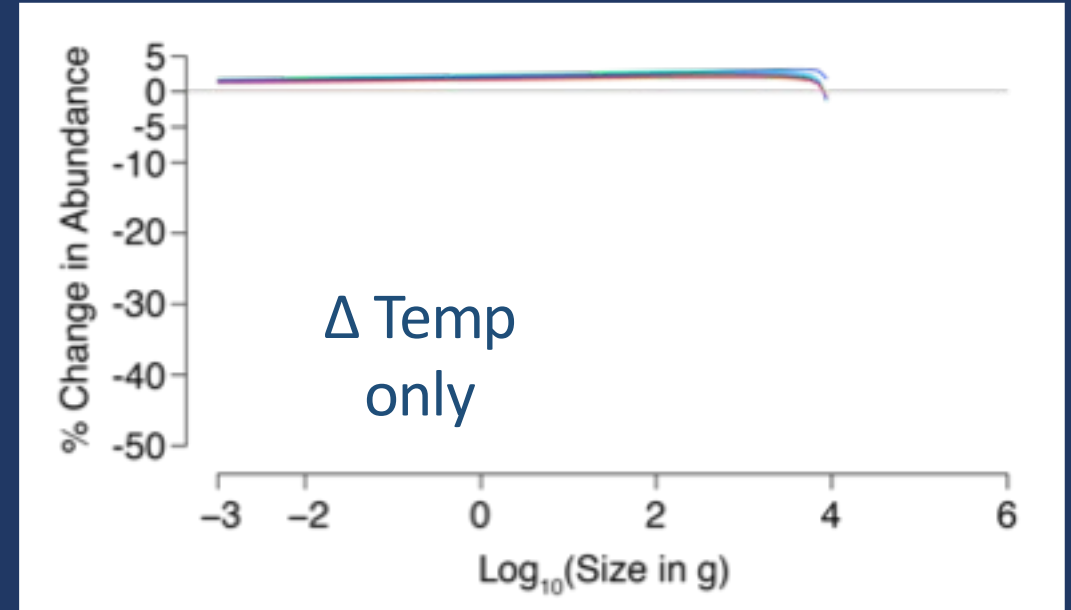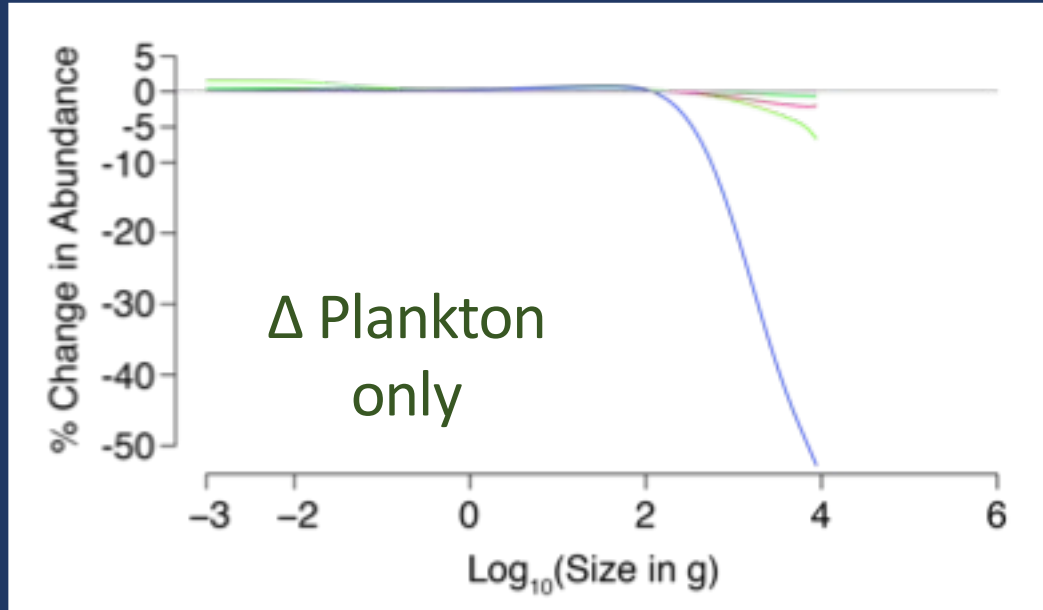Brown *et al*. 2004; Jennings *et al*. 2008; van der Heide *et al*. 2006
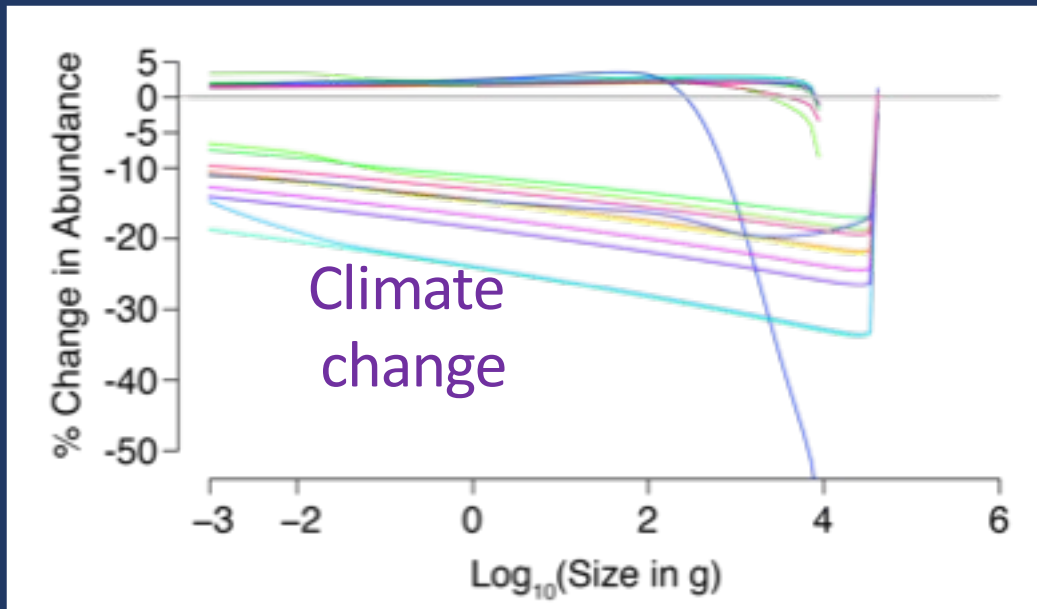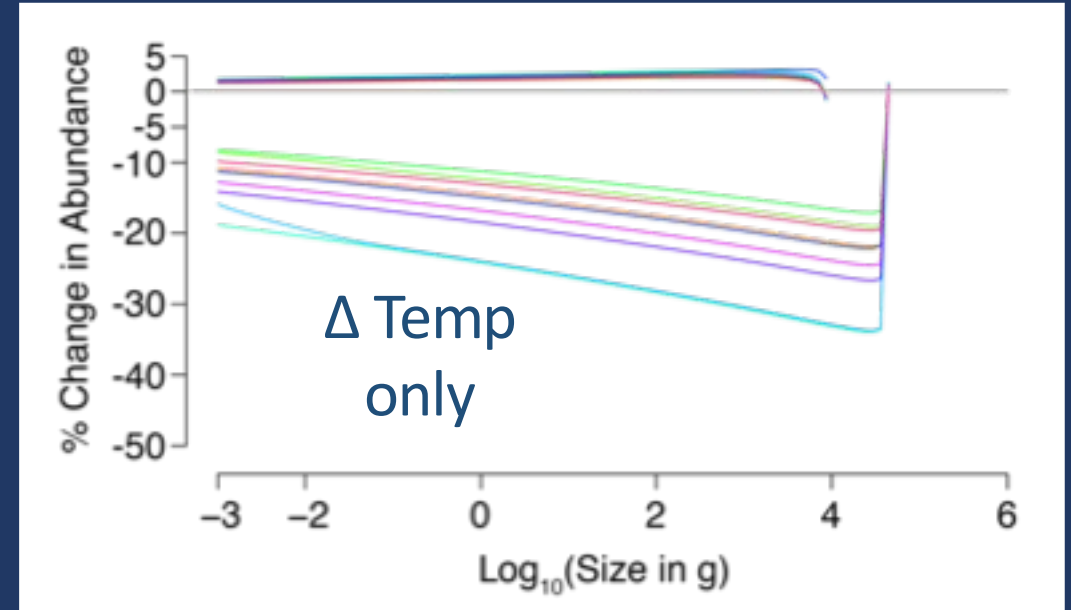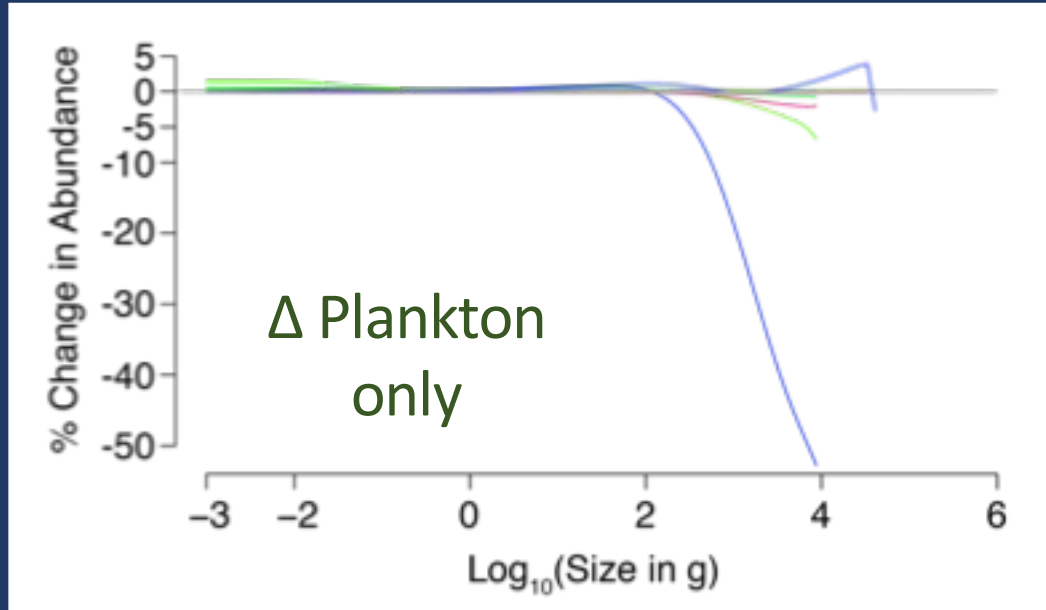
CMIP5 Model Spread - Temperature

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Change in abundance-at-size over the 21st century – Lancetfish, *F* = 0

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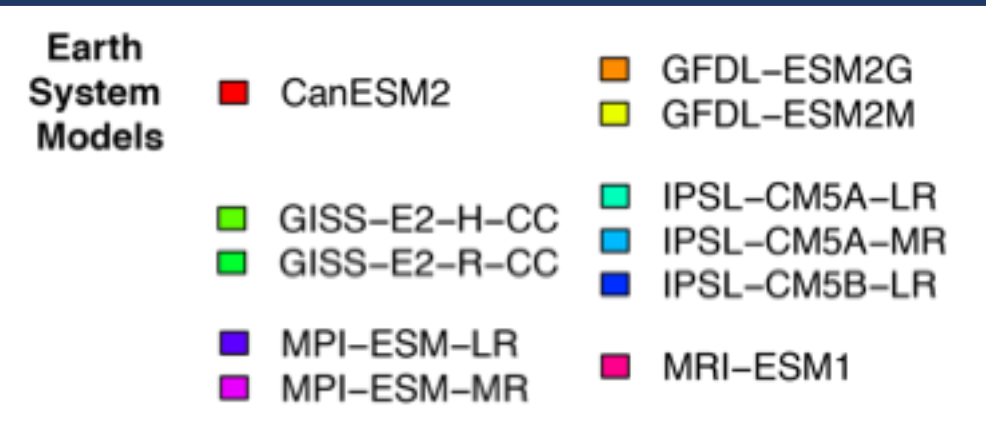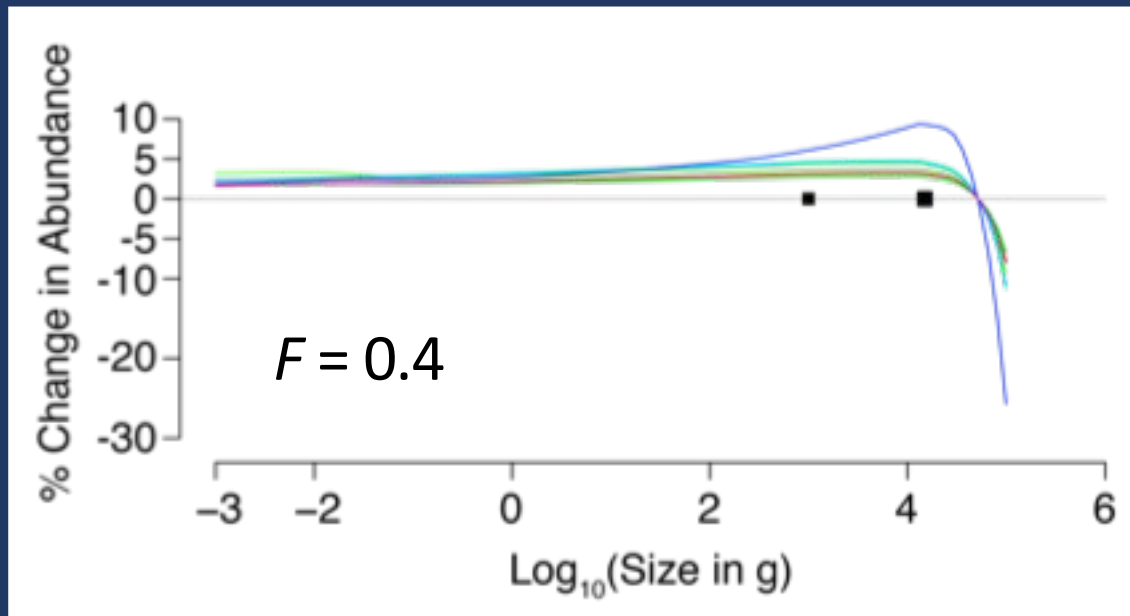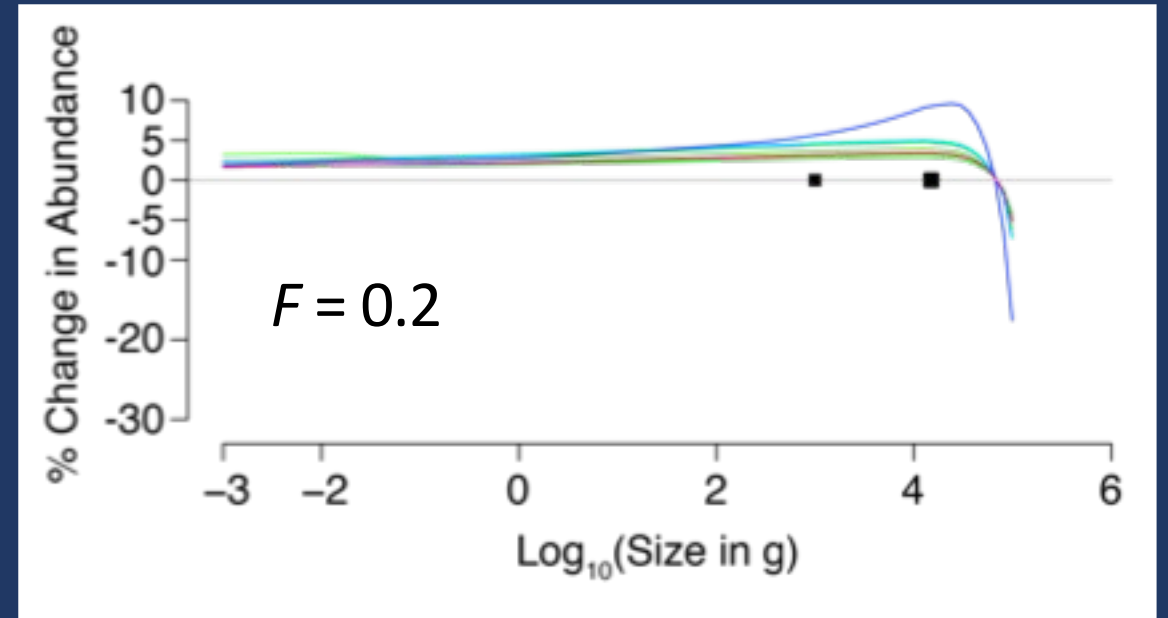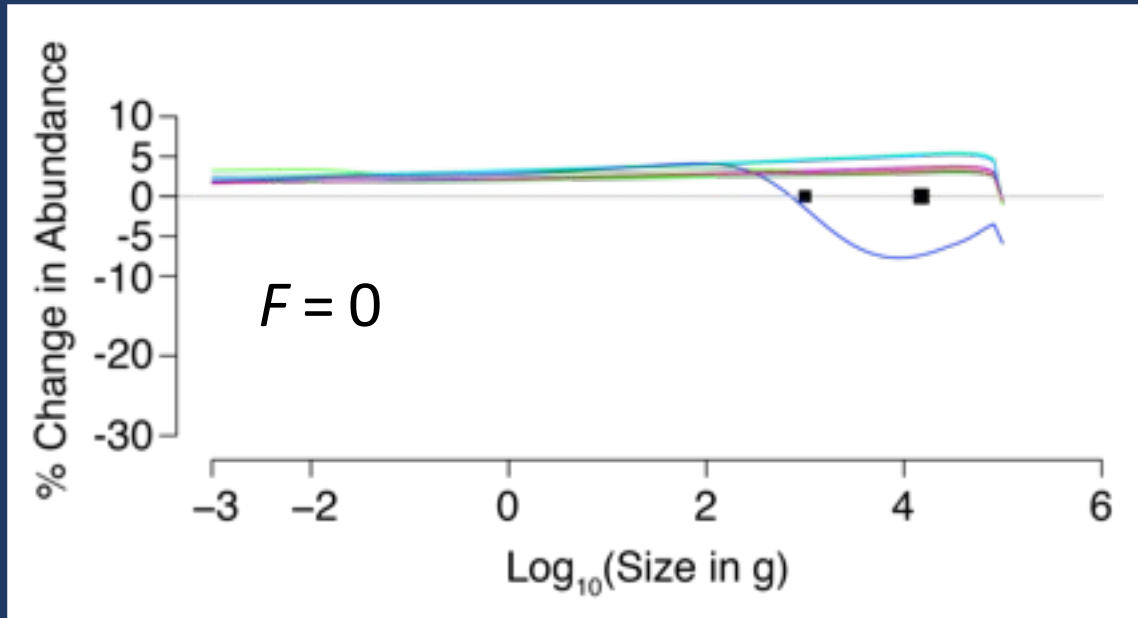# Change in abundance-at-size over the 21st century – Bigeye

Change in abundance-at-size over the 21ˢᵗ century
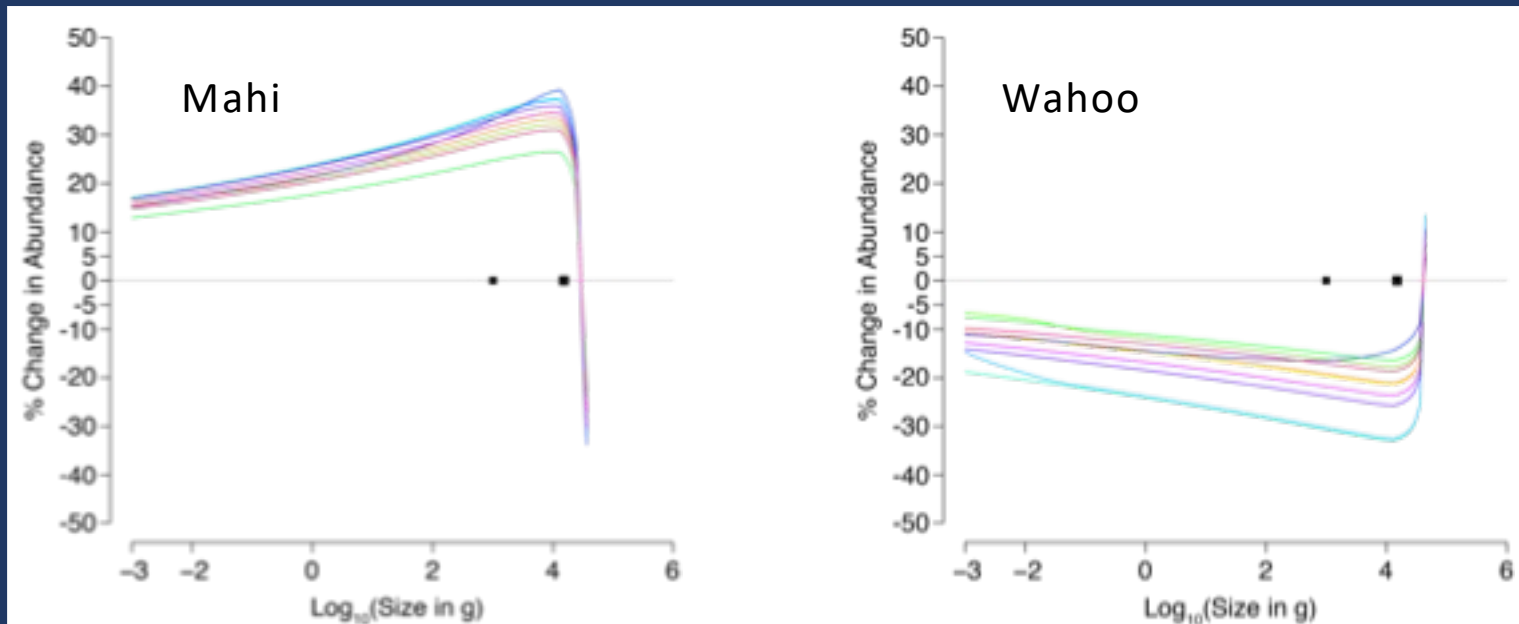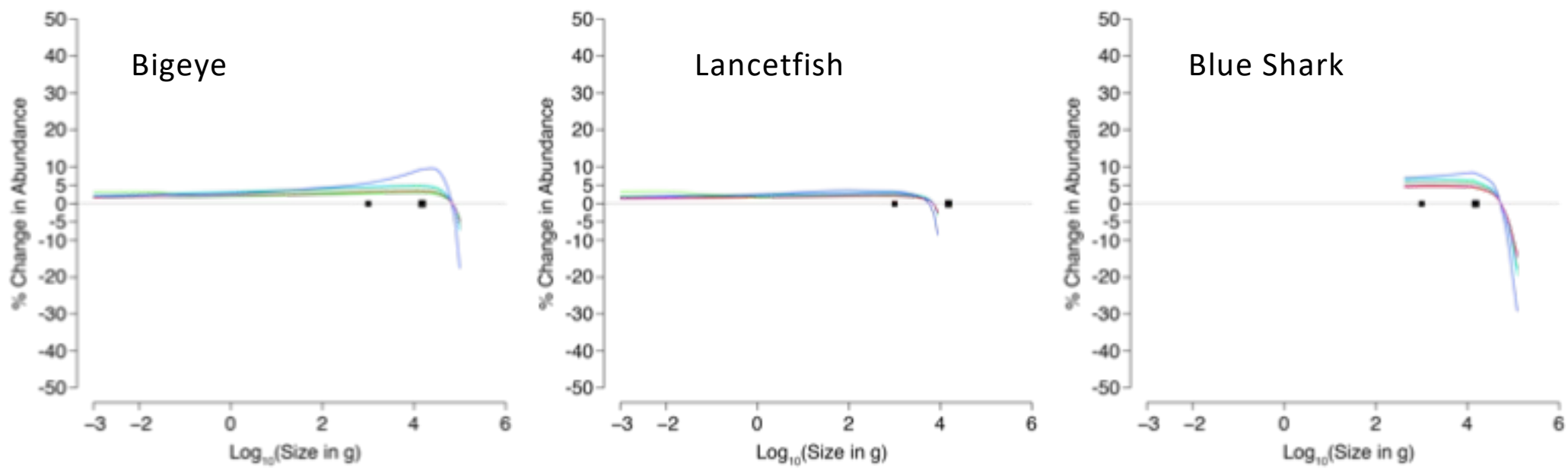
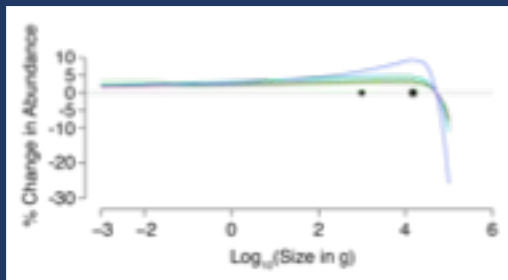# How do fishing and climate change interact to impact biomass available to future fisheries?
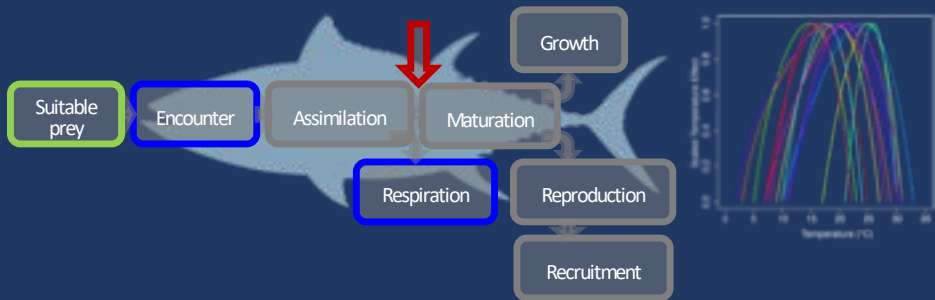
mizerNPAC, size-structured food web model with: individual fish species, dynamic climate, thermal optima
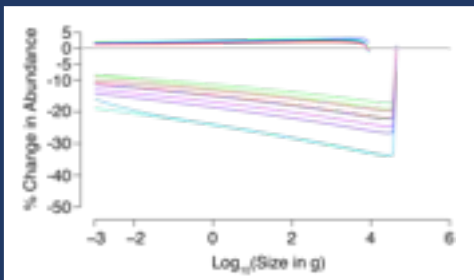
Temperature effect: depends on species' vertical habitat & thermal optima, outweighs plankton effects

Fishing exacerbates climate impacts, further changing size structure and ecosystem composition

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