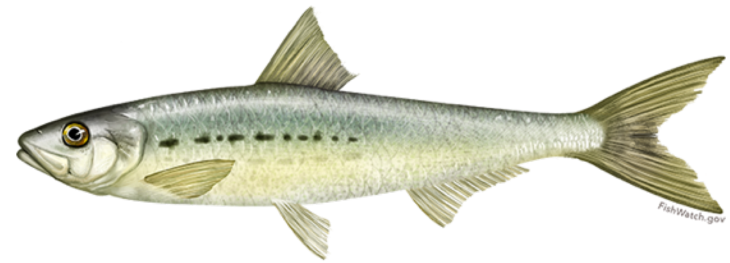

CaCu MICE update: Pacific sardine projections under environmental drivers and ecological uncertainty

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CCIEA-FutureSeas call Nov 10, 2020

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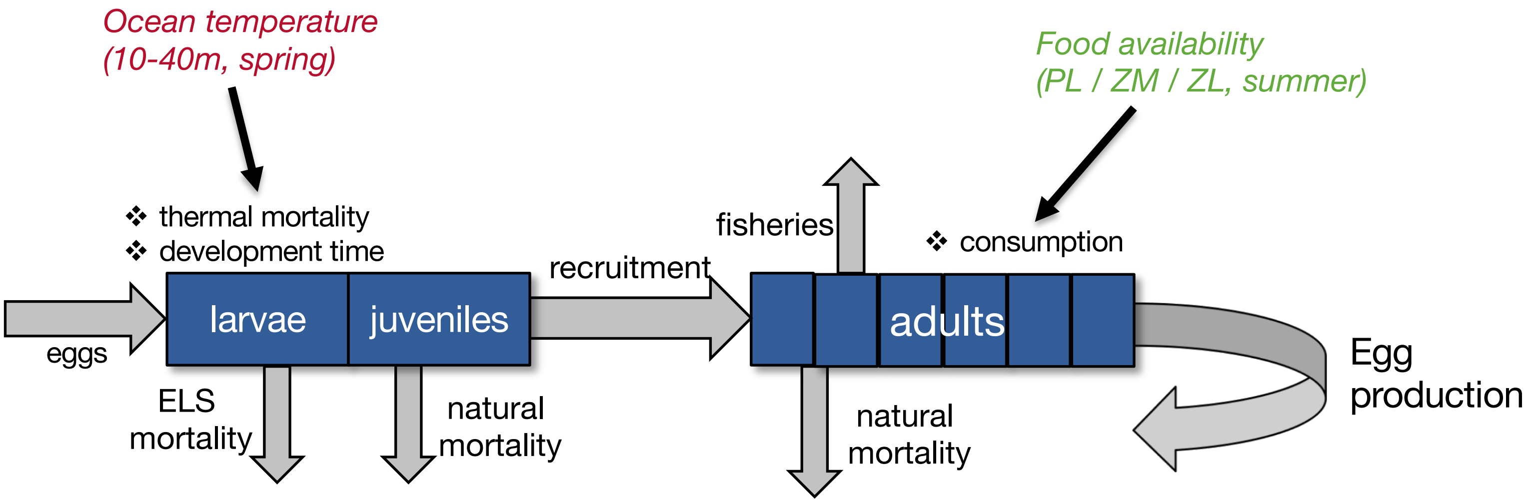
MICE for Pacific sardine: Model structure

- **M**odel of **I**ntermediate **C**omplexity (for **E**cosystem assessment)
- Aim to assess environmental drivers of past sardine fluctuations and project into future, assessing uncertainty
- Based on biological processes

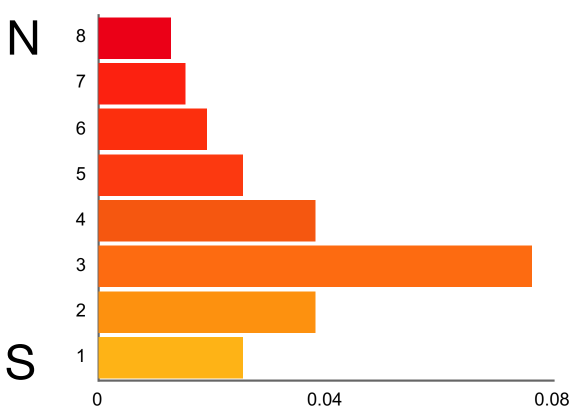
- Age-structured population model
  - 'Stocks' of individuals and 'flows' (life cycle, mortalities):
    (finite difference equations solved in weekly time-step)
  - Early life stages have temperature-dependent development time and mortality
  - Consumption (and age structure) determines egg production

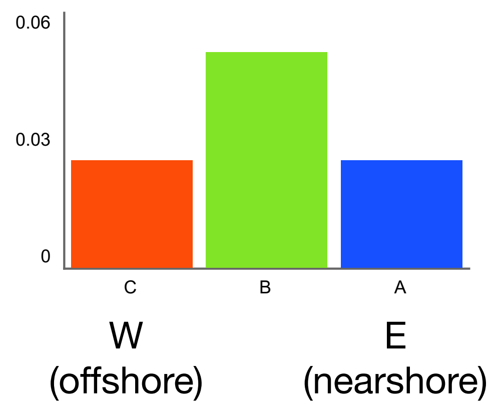
The Verge / Alexander H. Tuttle

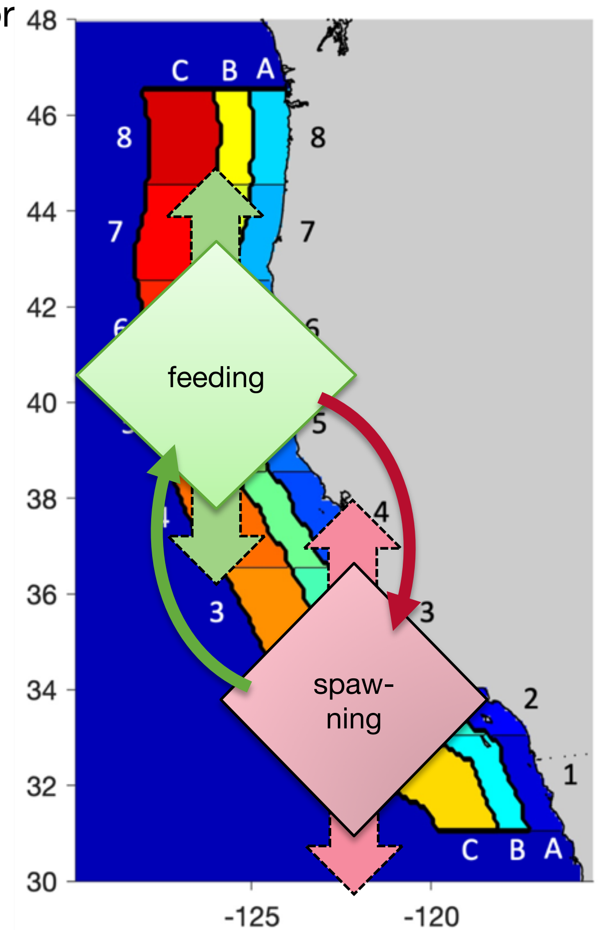


Environmental drivers and spatial life cycles

- Output from downscaled ROMS-NEMURO runs in 24 zones (8x3)
- Sardine density distribution function along N-S and W-E axes, for feeding and spawning
- Approximating sardine spatial life cycle by simplistic migration rules
  - Spawning where temperature is best on N-S
  - Feeding occurs where best food availability is on N-S

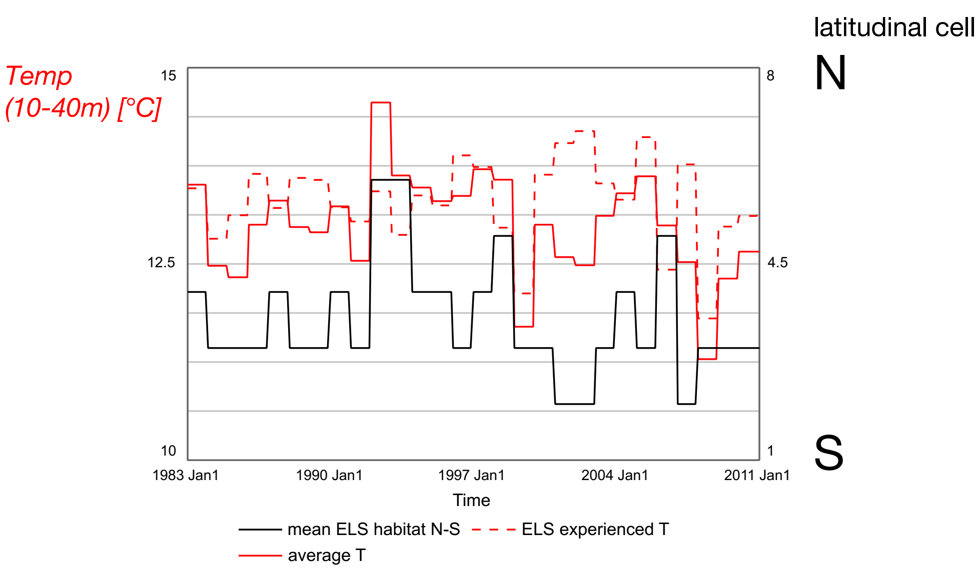


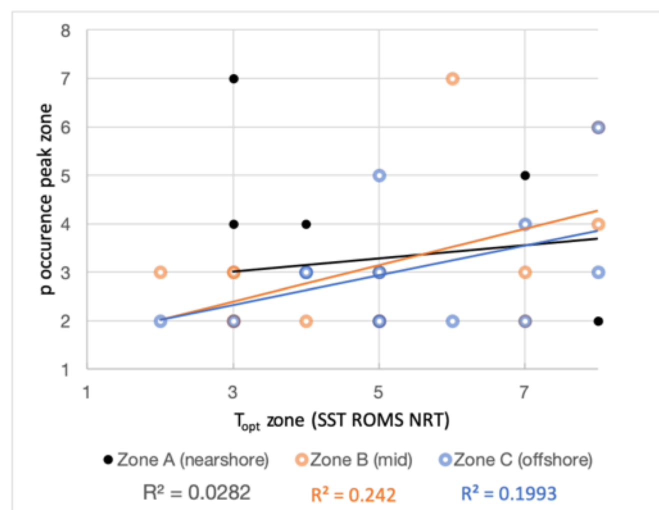




Spawning location

- Assumption: Sardine migrate towards SST_{opt} (±13°C) for spawning
- CalCOFI sardine larvae data binned into latitudinal zones 1-8
  - ➢ Spawning location for fitting period
- Scenario for degree of compensation derived from correlation pOc–SST_{opt} (ROMS nrt run, 2003-2018)
  - ➢ Adaptive annual spawning location for forecast



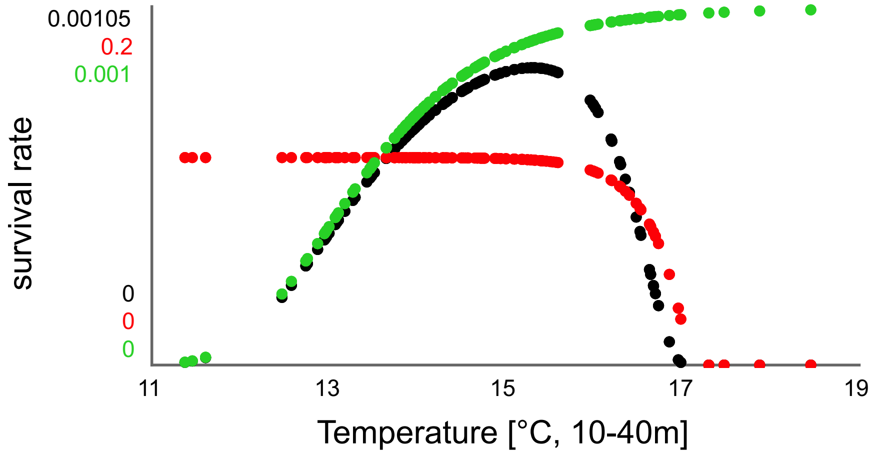


Early life stage survival

- Early life stages: Dynamic survival determined by T averaged over 10-40m depth (sardine spawning habitat)
  - ➢ thermal mortality and development time

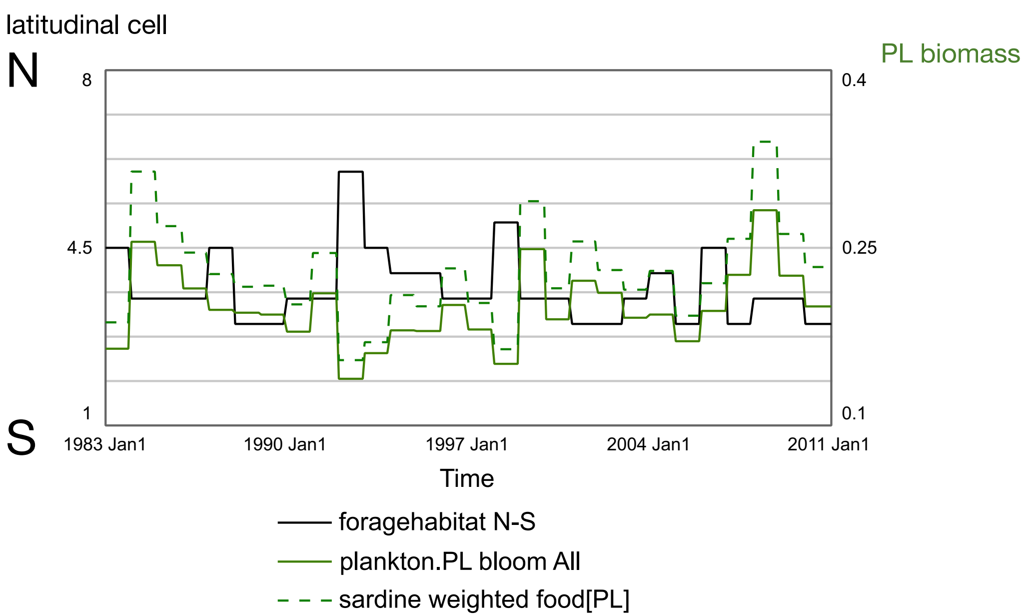
Example:

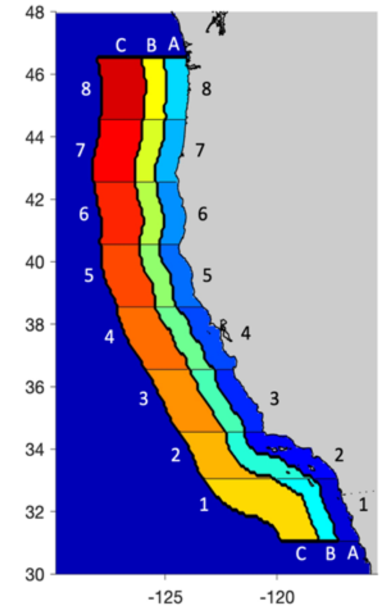
Thermal mortality x dev.time-dependent mortality = thermal response curve



Feeding

- Assumption: Sardine adults move to latitude of best food (PL) at peak plankton bloom time (fitting and forecast)
  - ➢ Check with adult data pending
  - ➢ Consumption determined by Type II functional response (3 food items PL/ZM/ZL)

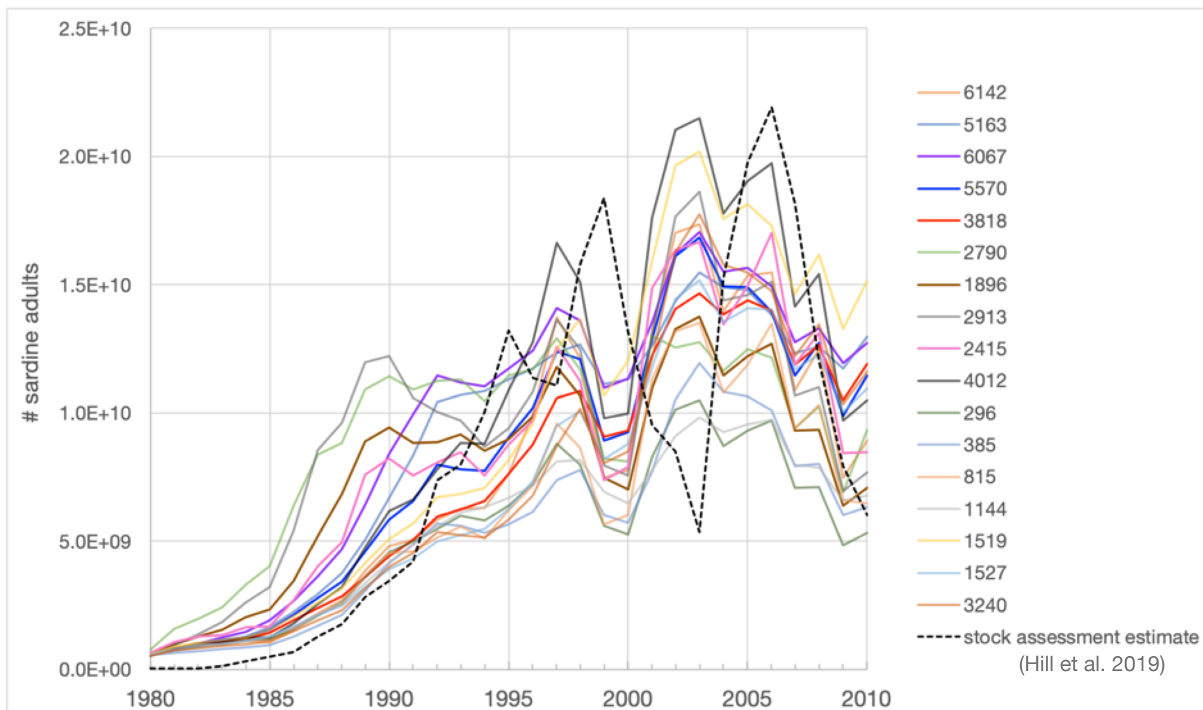




Model fitting

- Fitted to stock assessment estimate of numbers-at-age and catch-at-age, 1980-2010 (Hill et al. 2019)

- Wide search of parameter space (8000+ runs / Latin Hypercube etc.)
- Picked 18 model parameterizations with diverging parameters among best fits to stock assessment
  - ‘ecological uncertainty’



Assessing different model parameterizations *(overview)*

	ELS thermal response (Recruits / ELS Temp)	**Stock-recruitment** (Recruits / pop. no.)	**Feeding response** (Diet / plankton biomass)	**Age structure** (Mean age / pop no.)	**Egg production** (eggs / food availability)

e.g.

Run 2942

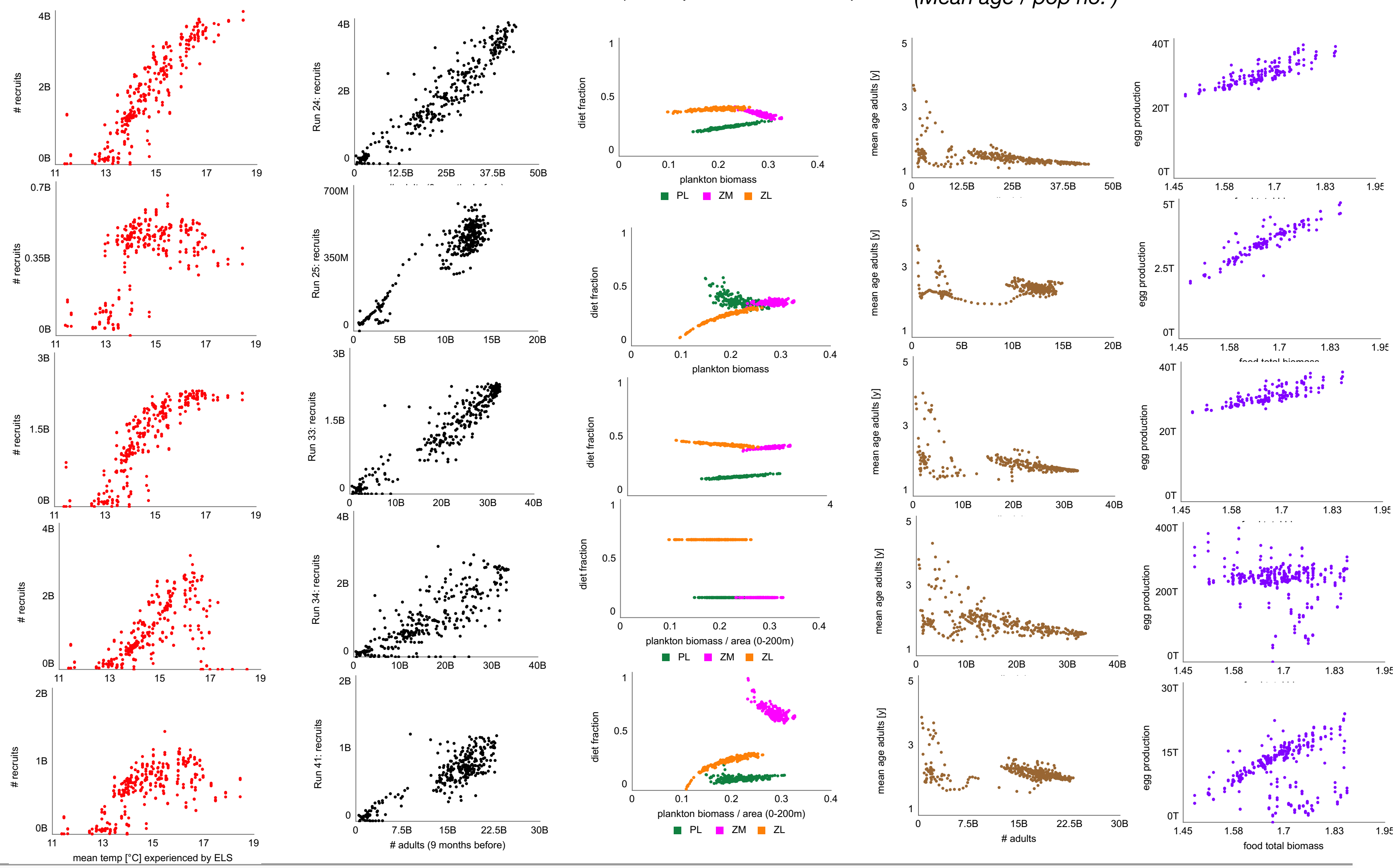
Run 1963

Run 4012

Run 296

Run 3340

...

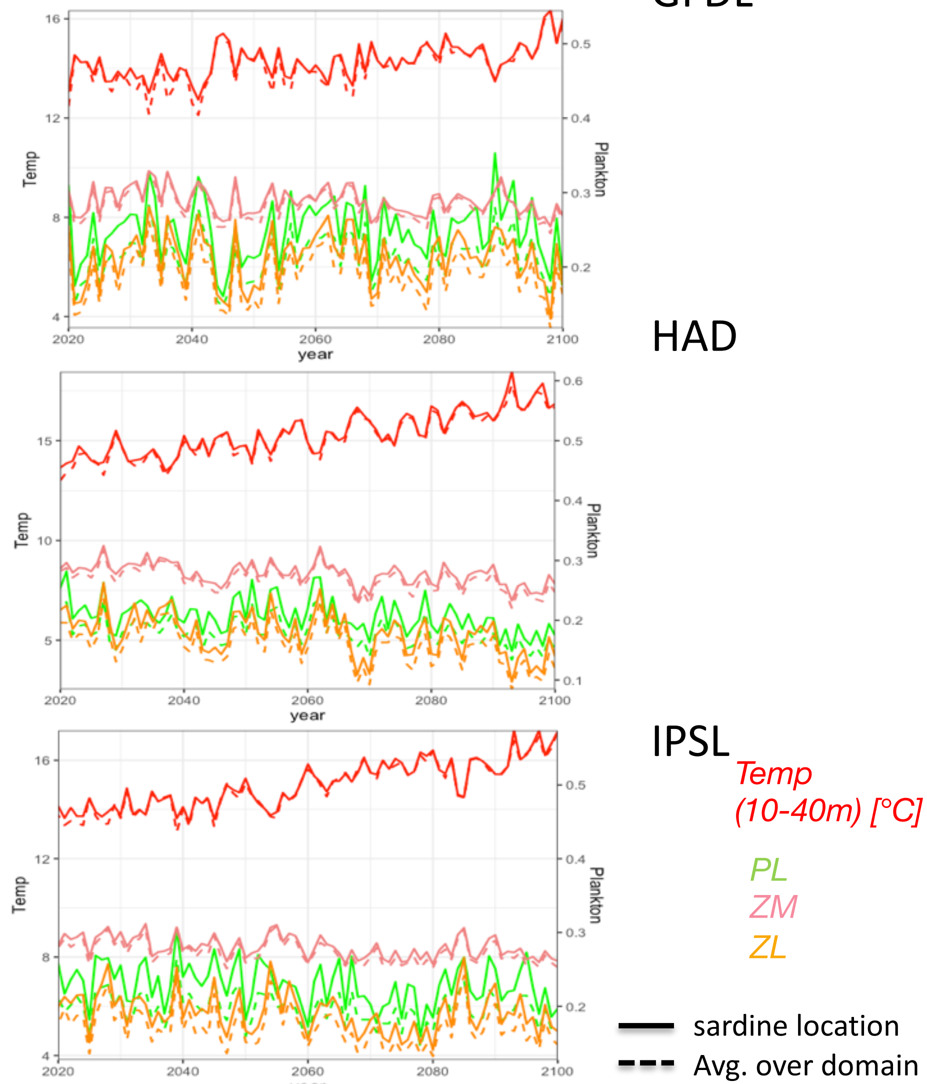


Environmental drivers in forecast scenarios

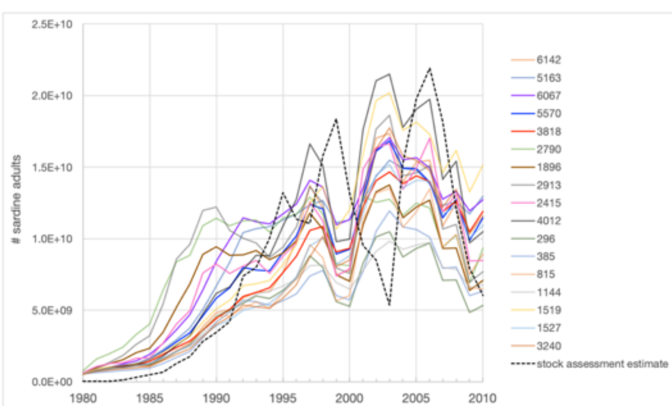
- ROMS-BGC (UCSC-NEMURO) downscaled from GCMs (CMIP5)
  → 2100 under IPCC RCP 8.5

- Combinations of driver trajectories differ among GCMs
- Slight adjustment by adaptation in spatial location (migration rules), differs among GCMs (interannual variability)

2020-2100 drivers



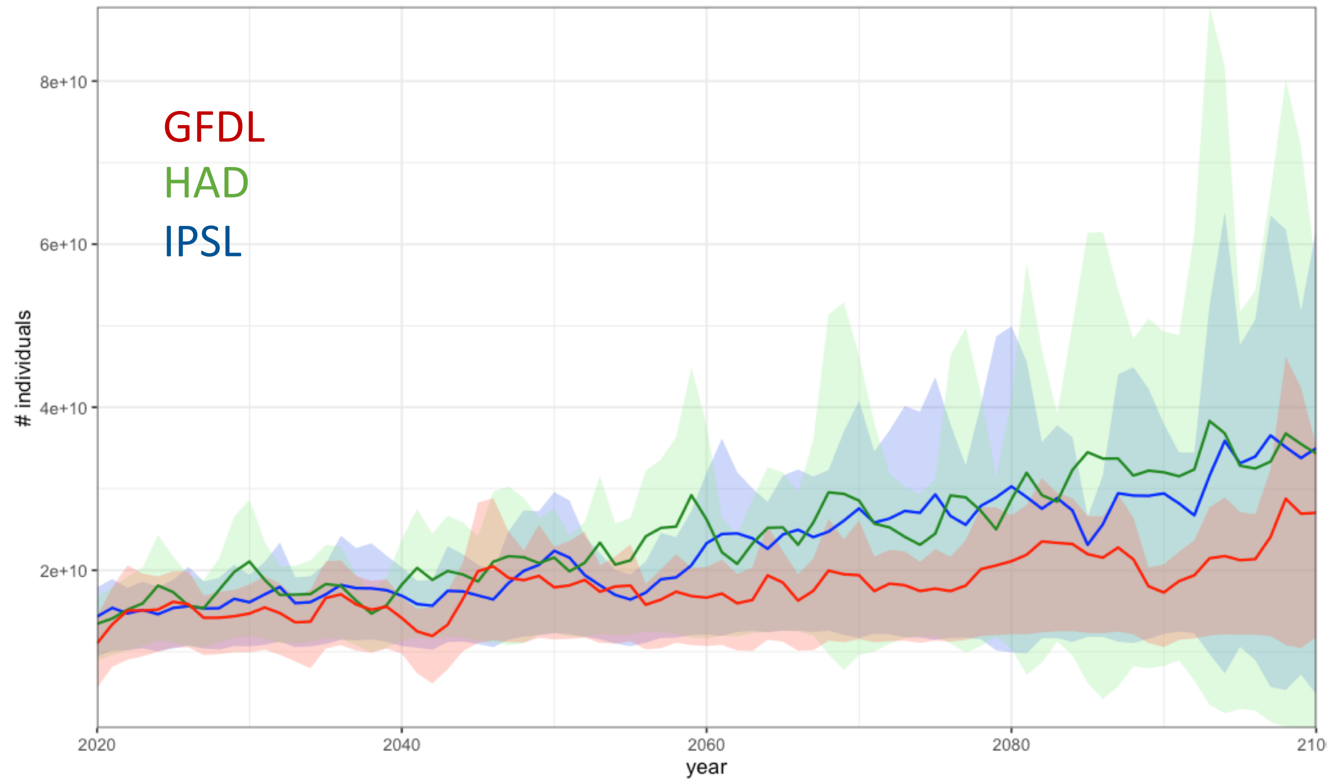
1980-2010 runs



Pacific sardine population trajectories *(preliminary projections)*

- Increasing population trends under all downscaled GCMs, due to general warming increasing ELS survival

- Range of future scenarios under different fitting scenarios (ecological uncertainty):
  - Projections forced by GFDL have lower uncertainty than HAD and IPSL



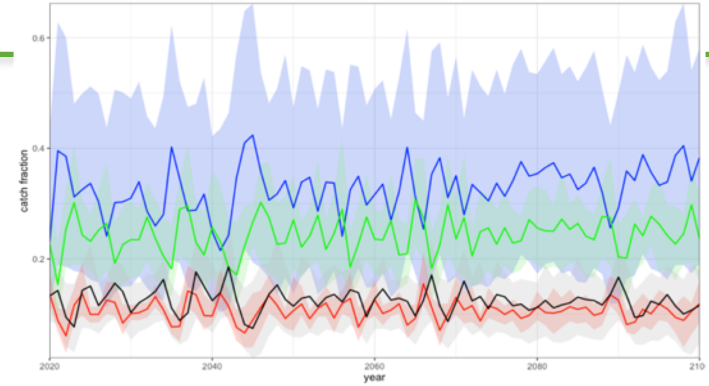
Catch-at-age projections

(preliminary projections)

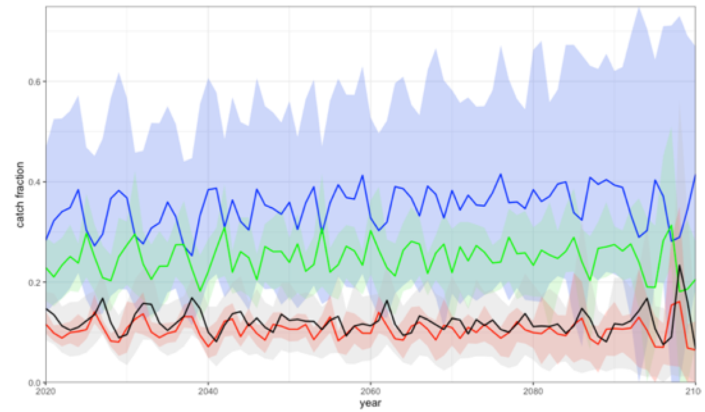
- *(Assuming one combined MexCal-PNW fleet with constant selectivity, and catch rules based on historical correlation)*
  - *catches are proportional to population and age structure*

- Ecological uncertainty is
  - much higher for age1 than age2+
  - larger than variation among GCMs, but: divergent response among GCMs in final years of forecast

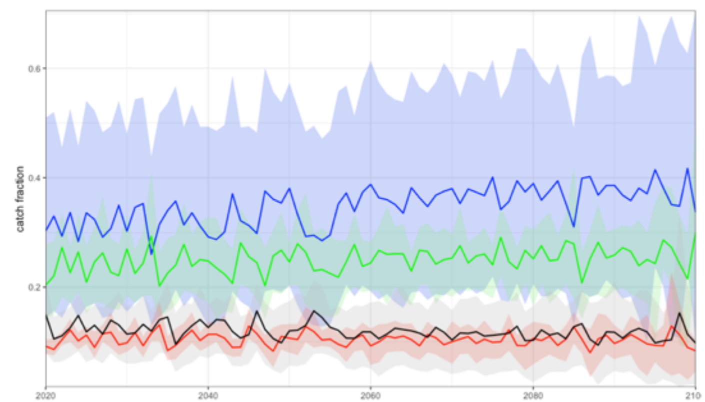
GFDL



HAD



IPSL



Mean catch fraction and range
age1
age2
age3
age4

Conclusions

- Pacific sardine population projected to increase under all downscaled GCMs due to ocean warming – food availability secondary driver
- Ecological uncertainty in forecasts increased under greater departure from historical conditions, and diverging (positive-negative impact) drivers

- Upcoming work
  - More sensitivity analyses: uncertainty in sardine migration, catches and stock estimates
    - *(first results: adds smaller amount of uncertainty to projections)*
  - Testing input from NEMURO-IBM (location, consumption…)
  - Adding predators (California Sea lions, Brown pelicans, Humpback whales…)

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