Body condition as a shared response to environmental conditions in a demersal fish assemblage

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Photo credit: Darienne Lancaster

Changes in abundance distributions are often correlated with climate, but we often don't know the mechanism...

- Movement
- Growth
- Recruitment

Could changes in fish body size provide any clues?



- 1. Calculate Le Cren's relative condition factors
- 2. Split specimens and catch by sex and maturity class
- 3. Estimate spatiotemporal biomass density
- 4. Estimate spatiotemporal condition
- 5. Calculate annual indices of condition
- 6. Identify common trends
- 7. Test for environmental correlates

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By sex and maturity class

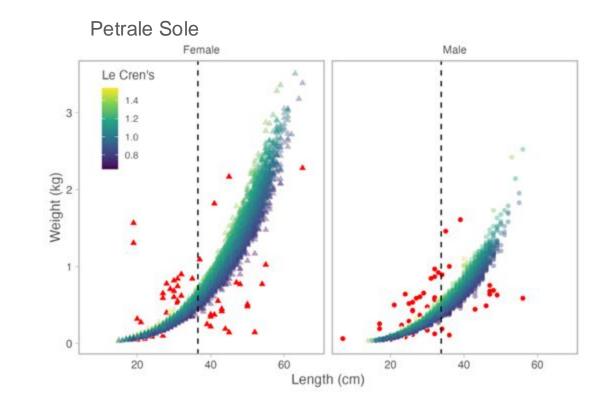
Assemblage-level (across species, within class)

1. Fish body condition

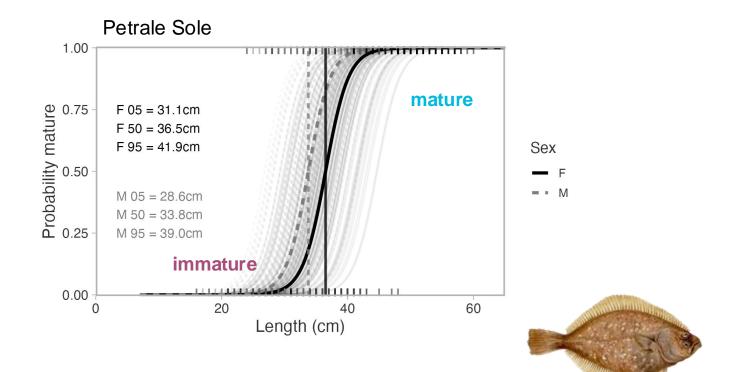
Le Cren's condition factor is the ratio of observed weight to predicted weight-at-length:

<u>Weight</u> a(Length)^b

*Likely sensitive to reproductive state, especially in females



2. Split specimens & catch by length at 50% mature

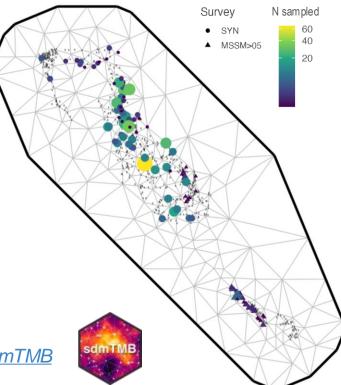


3 & 4. Spatiotemporal model configurations

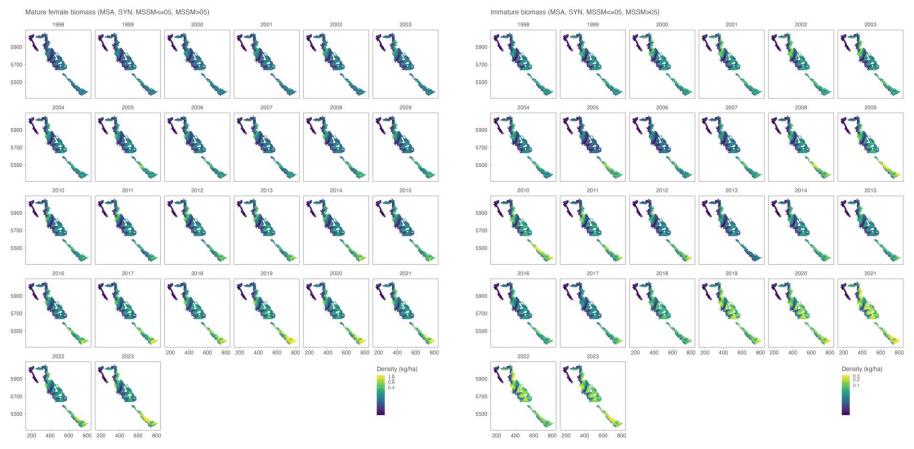
- Random-walk on spatiotemporal fields help bridge inconsistent spatial coverage between years
- Survey factor for differences in population sampled by different gear
- Day of year for seasonal changes
- Depth included in density models, not in condition models

CRAN.R-project.org/package=sdmTMB

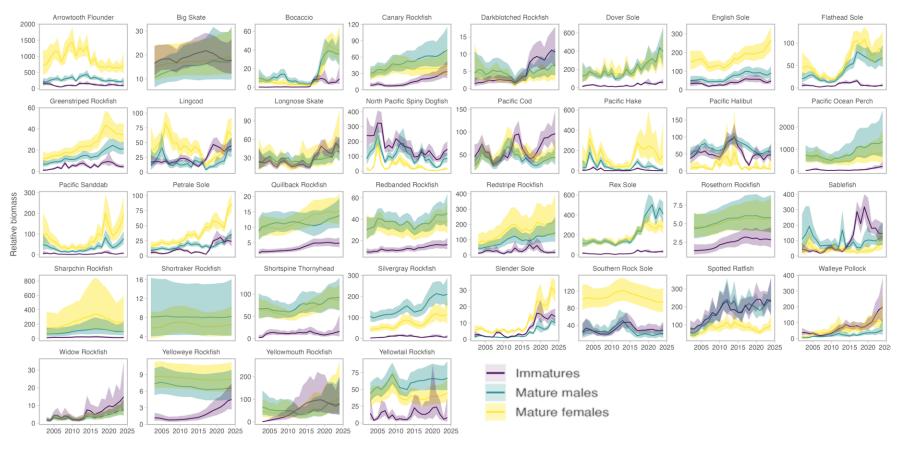
Tow locations and Petrale samples in 2007 overlaid on an SPDE mesh



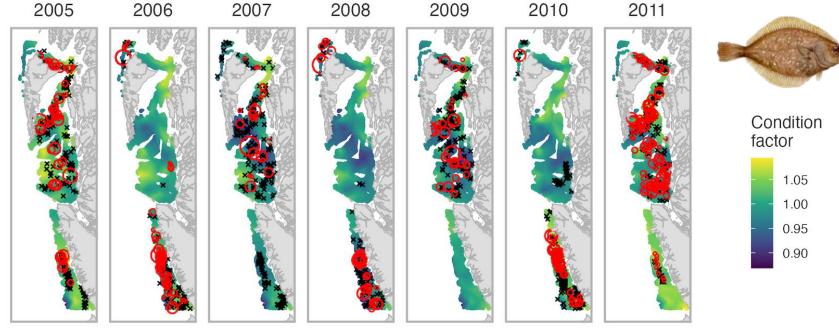
3. Maturity-specific spatiotemporal biomass predictions



3. Maturity-specific biomass indices



4. Spatiotemporal fish condition models



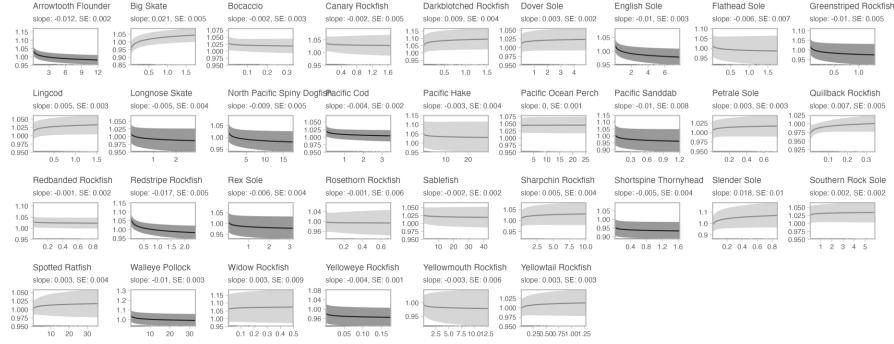
x – species caught but no measurements

O – condition measurements

Condition factor ~ survey + day of year + local density + RW spatiotemporal random fields

mmature condition factor

Condition factor ~ survey + day of year + local density + RW spatiotemporal random fields



Local biomass density of maturity class (slopes are in log space)

Condition factor ~ survey + day of year + **local density** + RW spatiotemporal random fields

- When density effect was negative exclude density-dependence (adjusted)
 - Predictions generated for mean local densities across years

Condition factor ~ survey + day of year + **local density** + RW spatiotemporal random fields

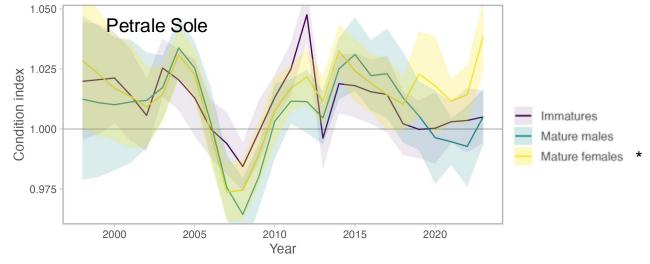
- When density effect was negative exclude density-dependence (adjusted)
 - Predictions generated for mean local densities across years

- When density effect was positive or neutral density-agnostic (not adjusted)
 - Rerun model without density covariate

Condition factor ~ survey + day of year + RW spatiotemporal random fields

5. Generate annual condition indices

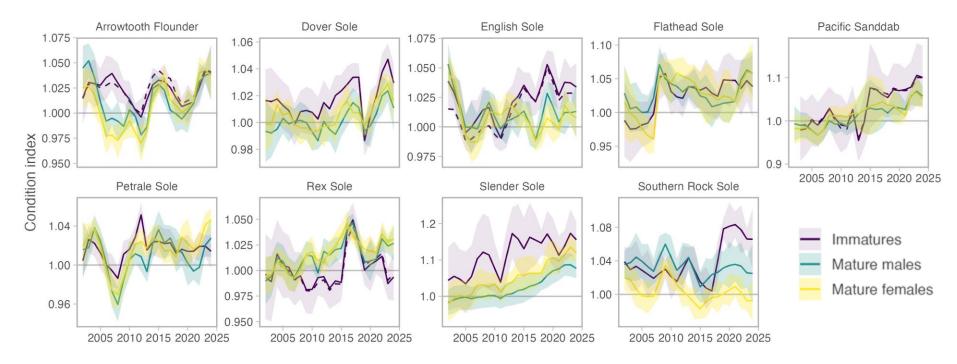
- Multiply each spatial estimate of fish condition by the proportion of that year's biomass predicted to have occurred at that location
- Sum these weighted estimates to create an annual index of average body condition



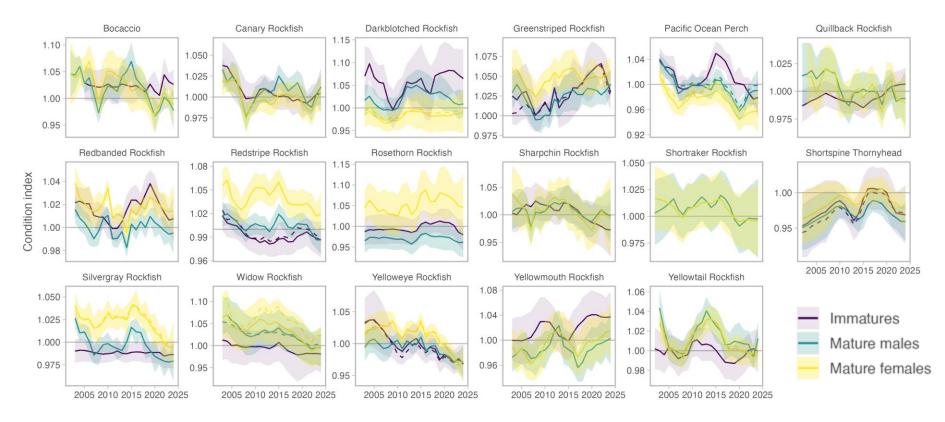
* Could be related to reproductive state?

5. Flatfish condition indices

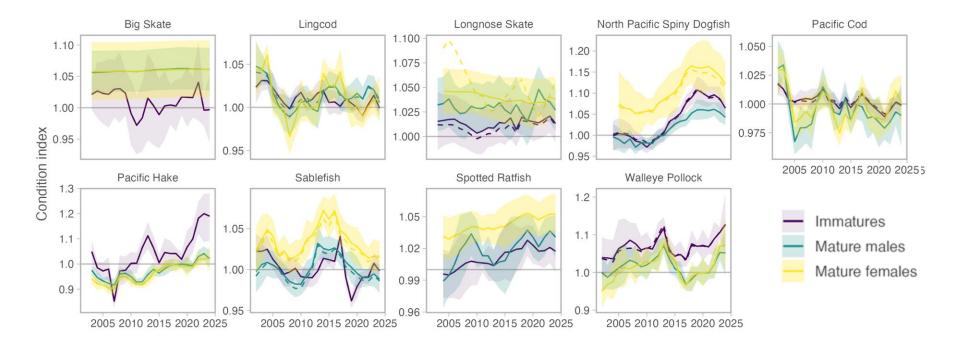
- Density-agnostic (not adjusted)
- Excluding density-dependence (adjusted)



5. Rockfish condition indices

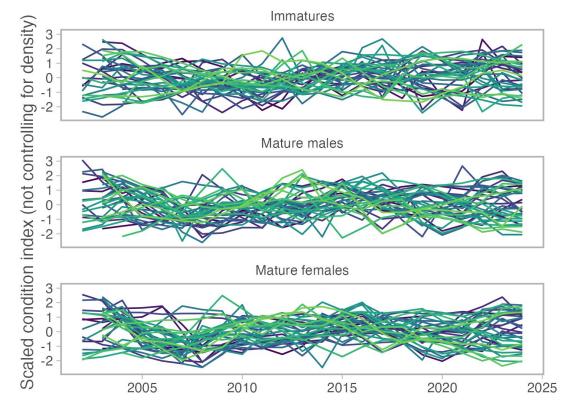


5. Other condition indices

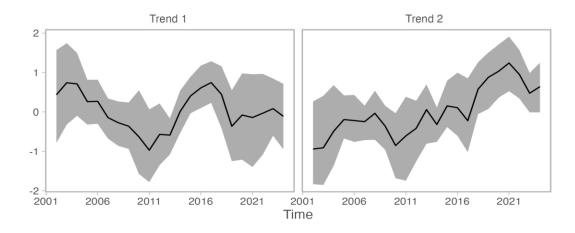


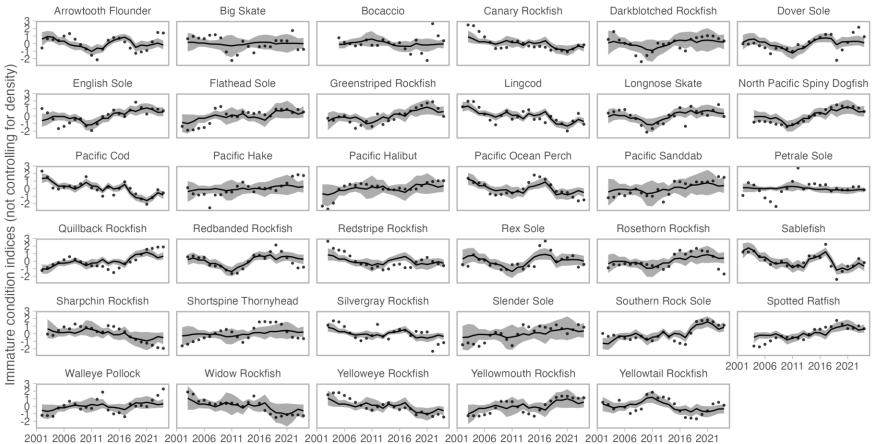
6. Bayesian Dynamic Factor Analysis (DFA)

Looks for common trends among species (*Ward et al.* 2019 in The R Journal)



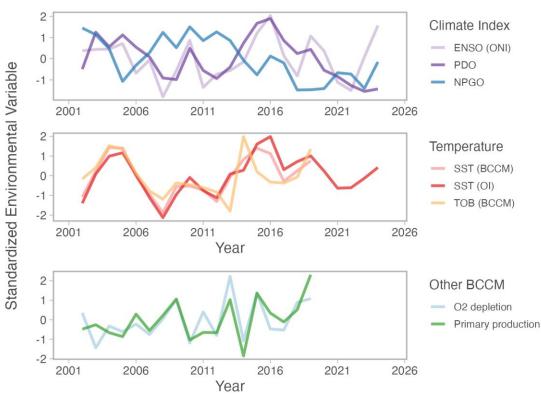
Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise





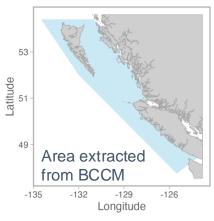
Time

7. Environmental variables



Assess correlations using post-hoc tests that propagate uncertainty (*Litzow et al. 2020 in Prog Oceanogr*)

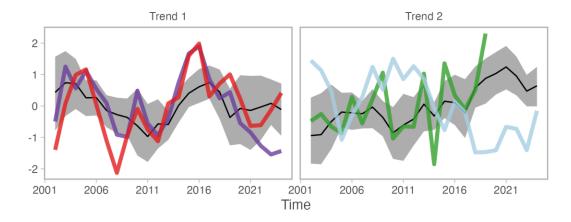
BCCM coupled physicalbiogeochemical ROMS model (*Peña et al. 2019*)



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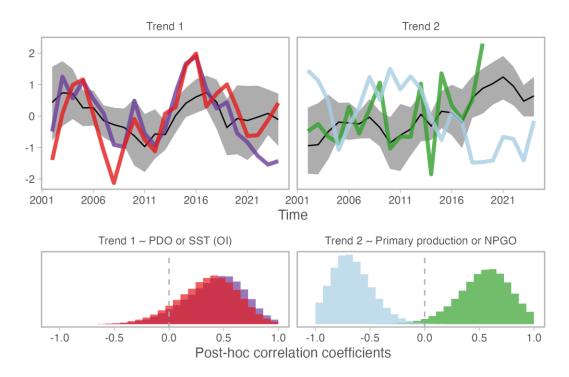
Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise

PDO SST (OI) Primary production NPGO



Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise

PDO SST (OI) Primary production NPGO



Trend 1

Rex Sole Sablefish

-2 -1 0

2 -2 -1

Loading

Trend 2

Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise

-1.0

-0.5

0.0

0.5

1.0

1.0

Post-hoc correlation coefficients

-1.0

-0.5

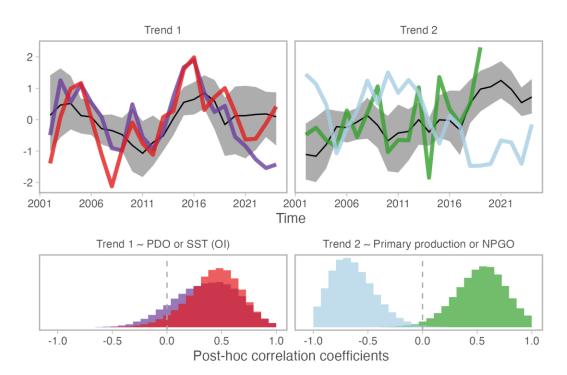
0.0

0.5

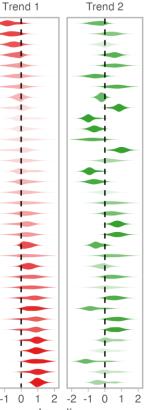
Yellowtail Rockfish Bocaccio PDO SST (OI) Primary production NPGO Pacific Halibut Flathead Sole Walleve Pollock Yellowmouth Rockfish Quillback Rockfish Trend 1 Trend 2 Southern Rock Sole Petrale Sole 2 Sharpchin Rockfish Pacific Hake Slender Sole Spotted Ratfish Shortspine Thornyhead Pacific Sanddab 0 **Big Skate** Canary Rockfish Pacific Cod -1 Widow Rockfish Greenstriped Rockfish Yelloweve Rockfish -2 Lingcod Rosethorn Rockfish 2001 2006 2011 2016 2021 2001 2006 2011 2016 2021 Silvergray Rockfish Time Darkblotched Rockfish **English Sole** North Pacific Spiny Dogfish Trend 1 ~ PDO or SST (OI) Trend 2 ~ Primary production or NPGO Redstripe Rockfish Longnose Skate Pacific Ocean Perch Redbanded Rockfish Dover Sole Arrowtooth Flounder

Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise

PDO — SST (OI) — Primary production — NPGO



Yellowtail Rockfish Walleve Pollock Bocaccio Pacific Halibut Flathead Sole Sharpchin Rockfish Yellowmouth Rockfish Petrale Sole Quillback Rockfish Pacific Cod Canary Rockfish Widow Rockfish Southern Rock Sole Pacific Hake Lingcod Yelloweye Rockfish **Big Skate** Slender Sole Shortspine Thornyhead Spotted Ratfish Greenstriped Rockfish Silvergray Rockfish Pacific Sanddab Redstripe Rockfish Rosethorn Rockfish Darkblotched Rockfish Longnose Skate Pacific Ocean Perch North Pacific Spiny Dogfish English Sole Redbanded Rockfish Dover Sole Sablefish Rex Sole Arrowtooth Flounder -2 -1 0 2



Loading

7. Common trends: mature male condition (adjusted)

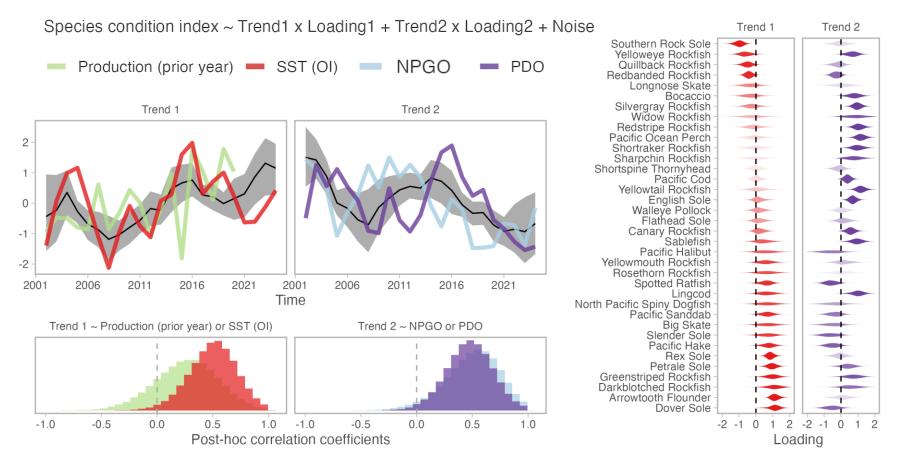
Trend 2

Trend 1

Species condition index ~ Trend1 x Loading1 + Trend2 x Loading2 + Noise

Southern Rock Sole Walleye Pollock PDO — SST (OI) — Primary production — NPGO Quillback Rockfish Flathead Sole Yelloweye Rockfish Yellowmouth Rockfish Widow Rockfish Trend 1 Trend 2 English Sole Pacific Cod 2 Shortspine Thornyhead Sharpchin Rockfish Yellowtail Rockfish Redbanded Rockfish Shortraker Rockfish Redstripe Rockfish 0 Spotted Ratfish Pacific Ocean Perch Longnose Skate Pacific Halibut **Rosethorn Rockfish** Bocaccio -2 Silvergray Rockfish Big Skate Slender Sole 2006 2021 2006 2011 2016 2021 2001 2011 2016 2001 Darkblotched Rockfish Time Pacific Hake Pacific Sanddab Canary Rockfish Trend 1 ~ PDO or SST (OI) Trend 2 ~ Primary production or NPGO Lingcod Arrowtooth Flounder Sablefish North Pacific Spiny Dogfish Petrale Sole Rex Sole Dover Sole Greenstriped Rockfish -1.0 -0.5 0.0 0.5 -1.0 -0.5 0.0 0.5 1.0 -2 -1 1.0 -2 -1 0 2 Post-hoc correlation coefficients Loading

7. Common trends: mature female* condition (adjusted)

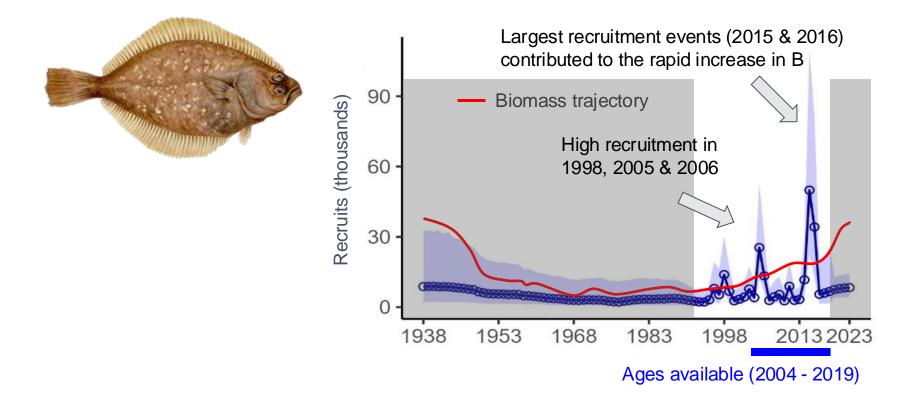


But do these changes matter...

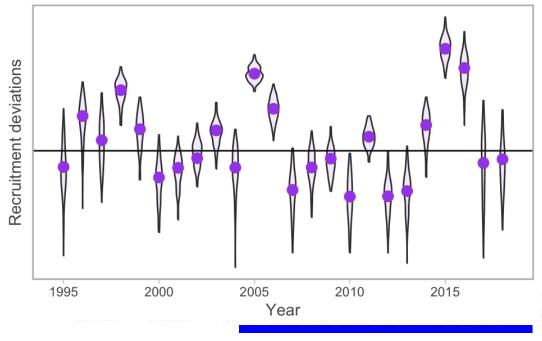


Assessment of Petrale Sole in British Columbia in 2024

By Mackenzie Mazur, Kendra Holt, Nick Fisch, Philina English



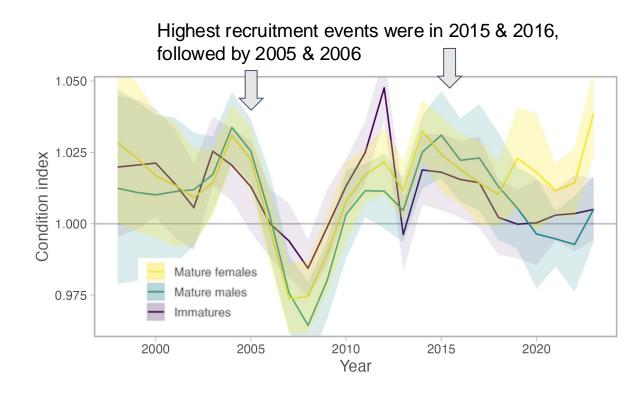
Recruitment deviations with uncertainty



100 MCMC samples of recruitment deviations for 1995 to 2018

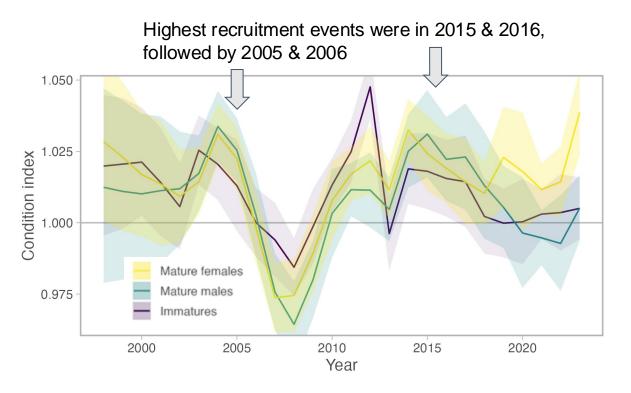
Ages available (2004 - 2019)

Body condition indices with uncertainty



100 posterior samples of condition index values for 1998 to 2023

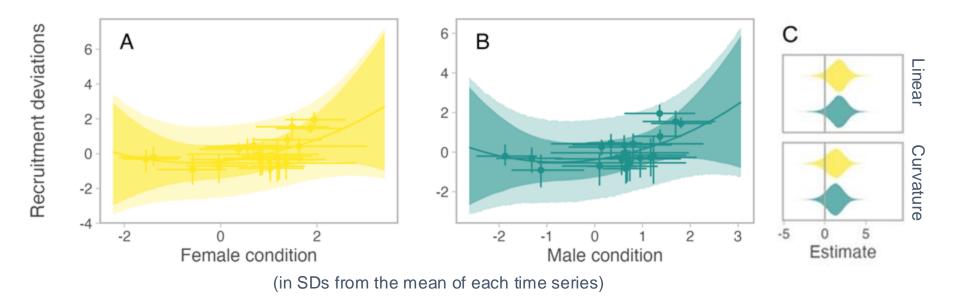
Body condition indices with uncertainty



100 posterior samples of condition index values for 1998 to 2023

Paired with next year's recruitment deviations for 100 Bayesian timeseries regressions with AR1 correlation structure

Is recruitment related to prior year's mature body condition?



95% CI for predicted relationship (dark) and predicted observations (lighter) (A, B) and coefficient densities (C) from combined posteriors of 100 time-series regressions (one for each pair of sample estimates

Next steps...

- Investigate relationships with recruitment and environmental variables for other species
- Incorporate local environment directly into spatial condition models
- Link results management advice
 - Incorporate empirical weight-at-age into assessments (*Kuriyama et al. 2016*)
 - Management strategy evaluation
 - Climate conditioned risk analysis (Duplisea et al. 2021)

Questions or suggestions?

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Photo credit: Darienne Lancaster