

# Canaries of the Arctic: collapse of eastern Bering Sea snow crab

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SCS7

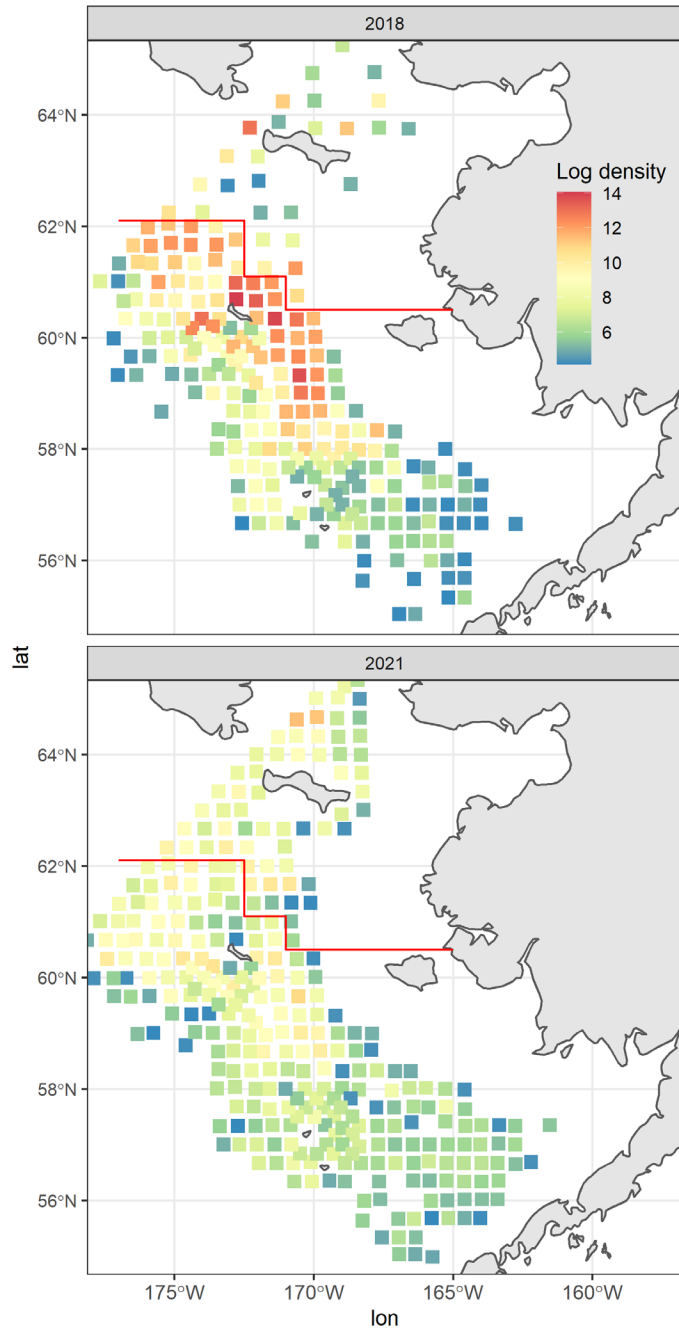
Sitka, AK



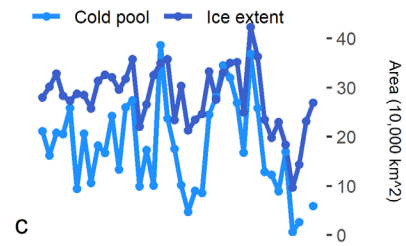
# Collapse of snow crab

- More crab than ever in 2018, fewer crab than ever in 2021 (a, c)
- Disappearance of crab was not size dependent (d)
- Cold pool was the smallest on record in 2018 and barely larger in 2019 (b)
- The stock was declared overfished and a rebuilding plan is underway

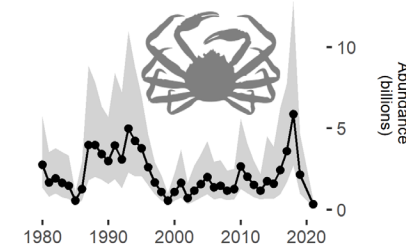
a



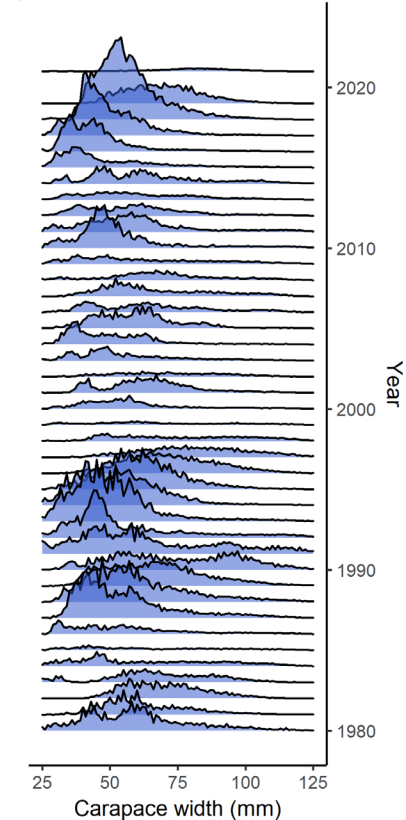
b



c



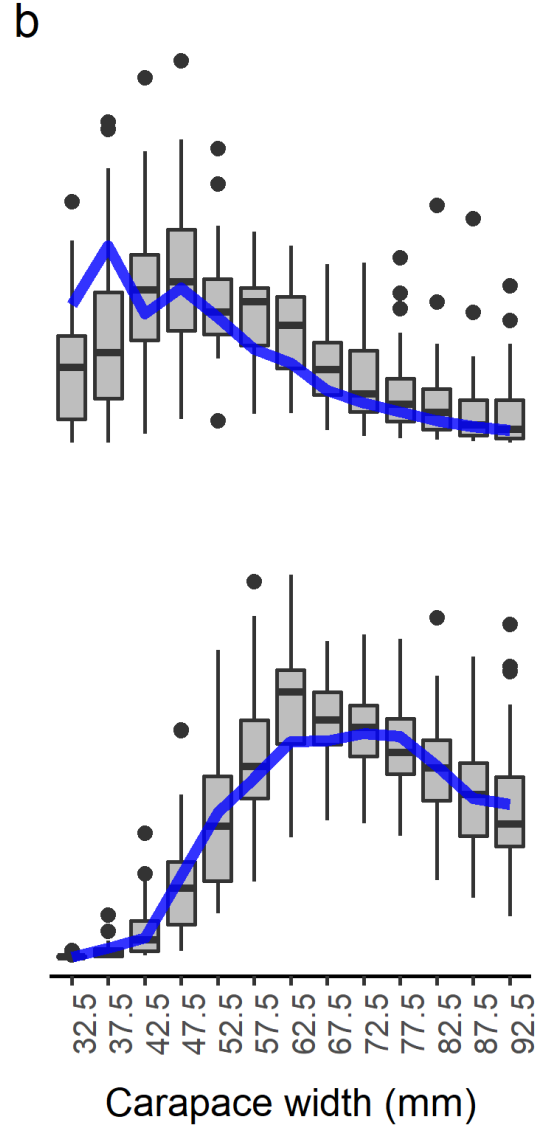
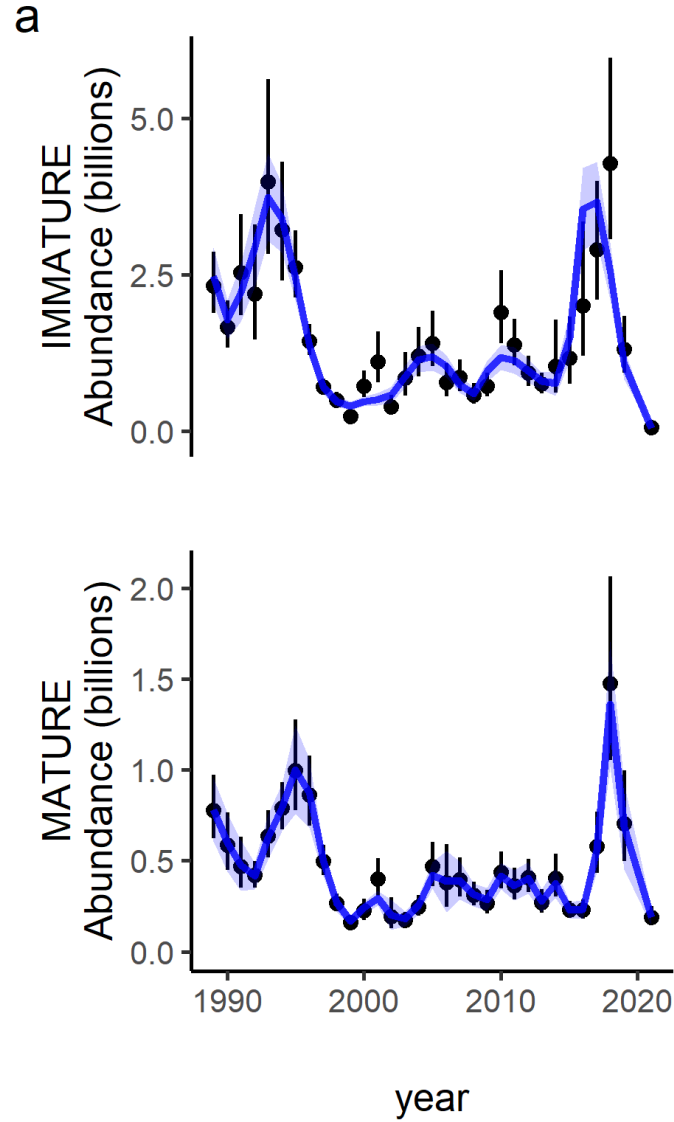
d



What happened?

What do we do now?

# Population Dynamics



## Step 1: Estimate time-varying total mortality

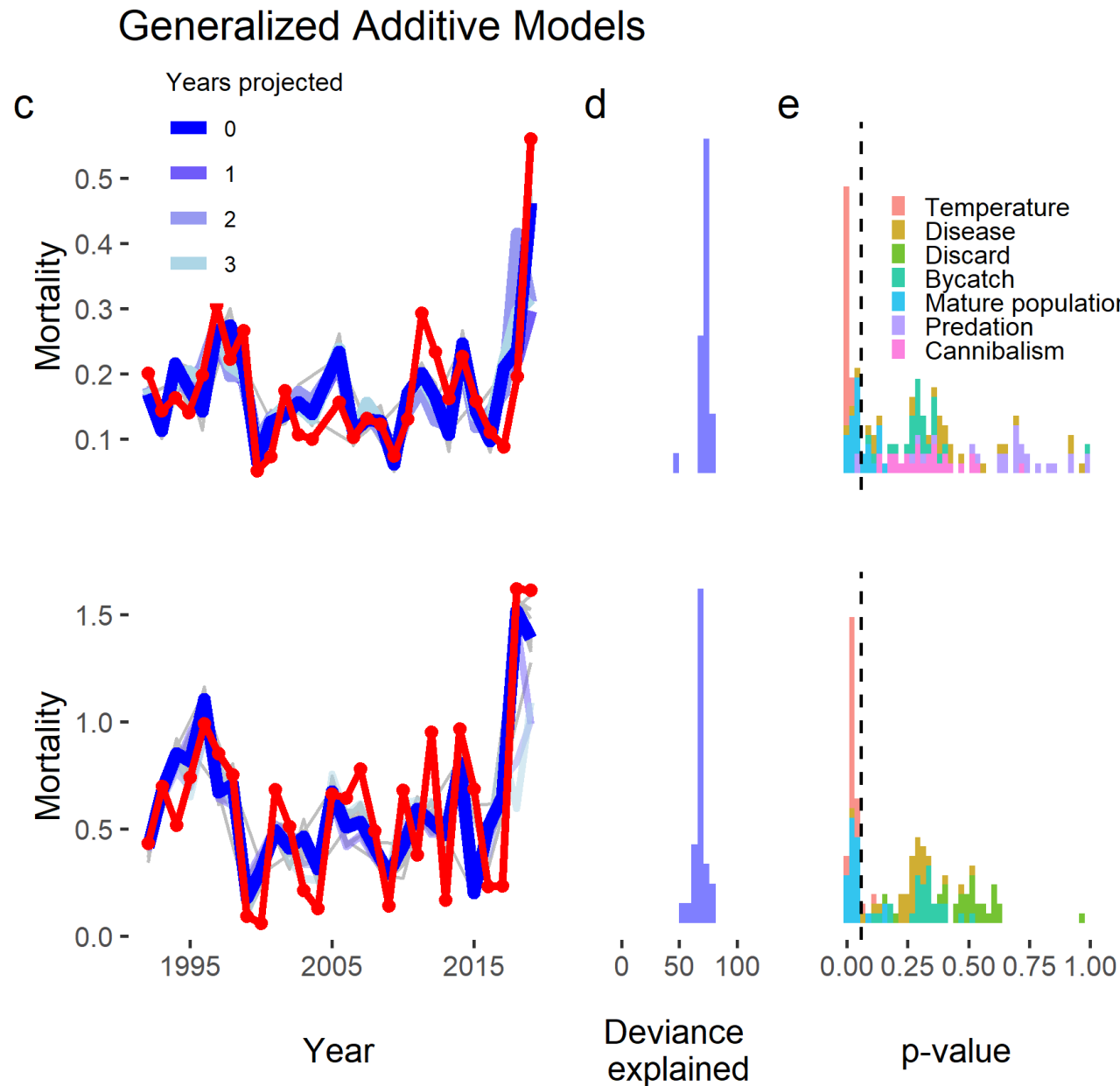
- Population dynamics model
- Male only
- 30-95 mm carapace width
- Total mortality, recruitment, initial numbers at size were estimated parameters
- Growth, maturity, and survey selectivity specified based on experimental data
- Simulation studies to evaluate ability of the model to estimate mortality

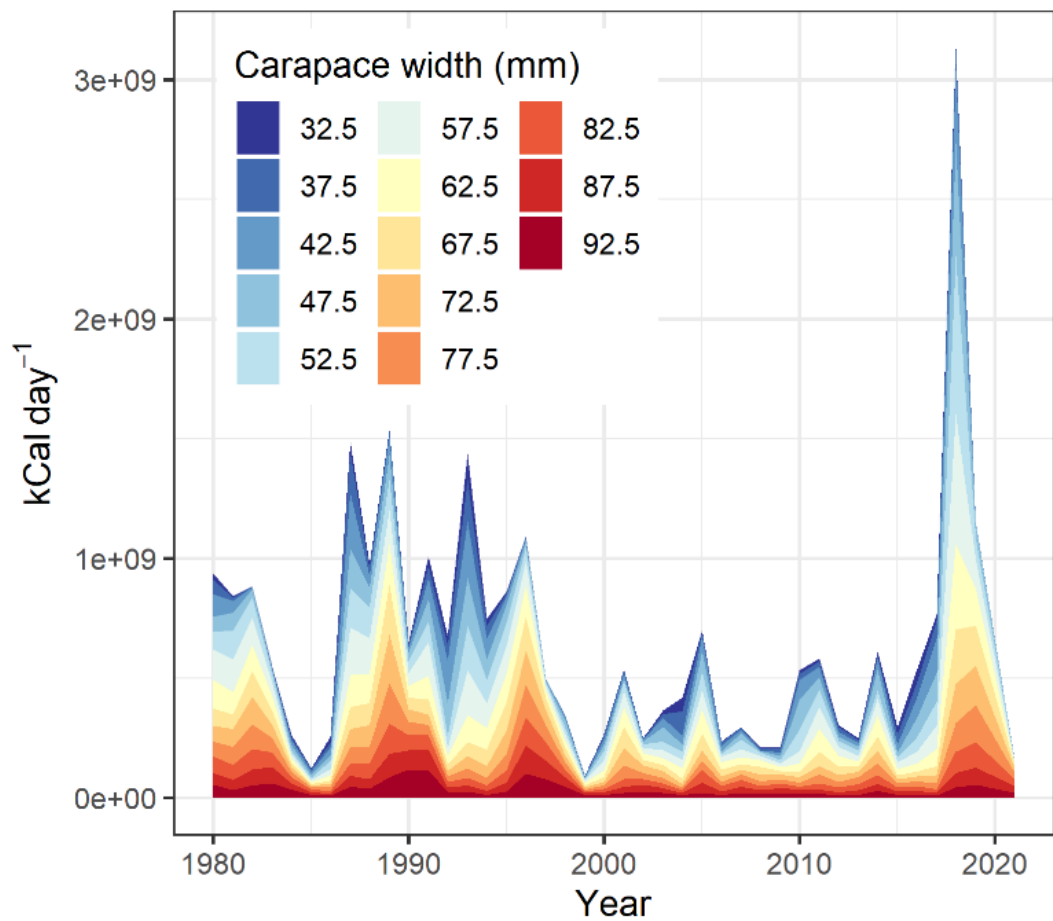
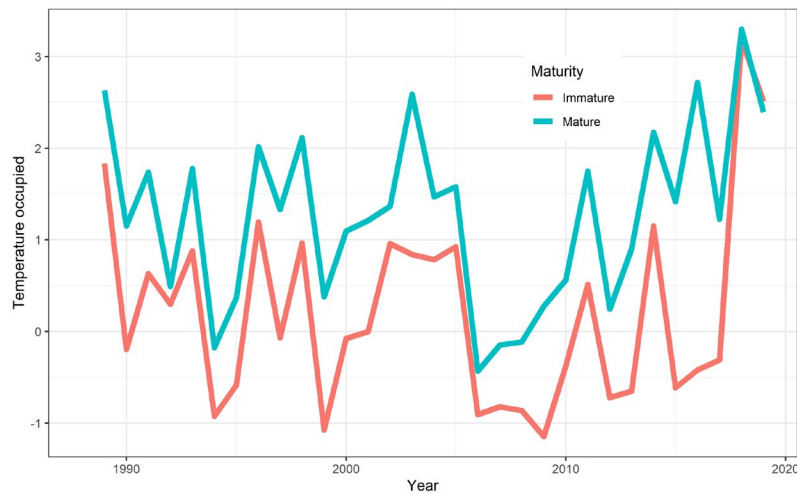
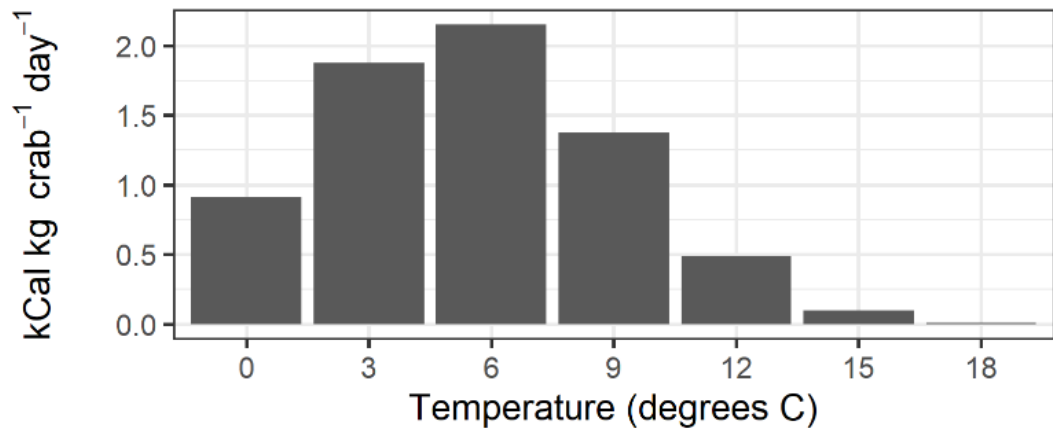
Estimated mortality from fits to the simulated data were highly correlated.

## Step 2: Relate estimated mortality to environmental stressors

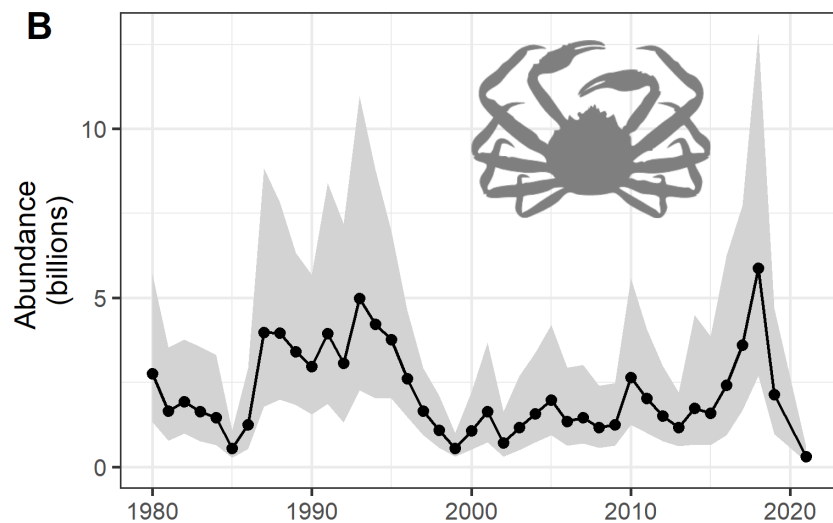
- Generalized additive models
- Covariate construction
  - Temperature occupied
  - Disease prevalence
  - Discards in directed fishery
  - Cannibalism
  - Bycatch in other fisheries
  - Mature population density
  - Predation by Pacific cod
- Cross-validation
- Prediction capabilities

**Temperature** and **mature population density** were the anomalous variables in 2018 and 2019 when the large mortality events occurred.

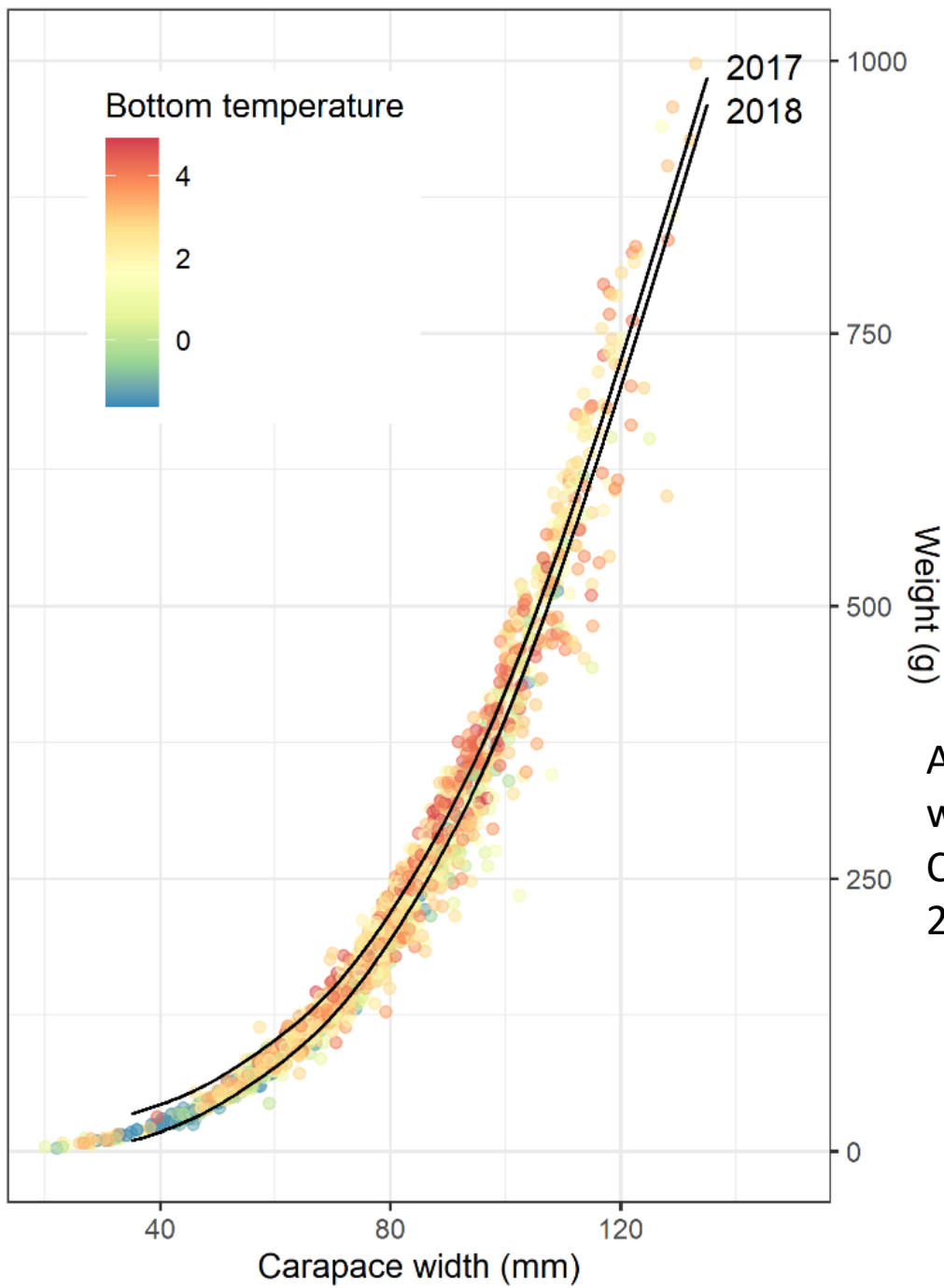
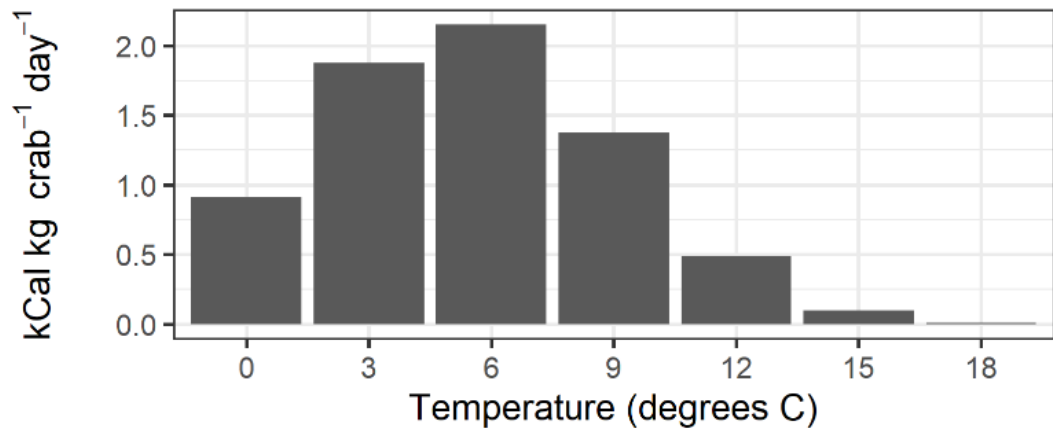




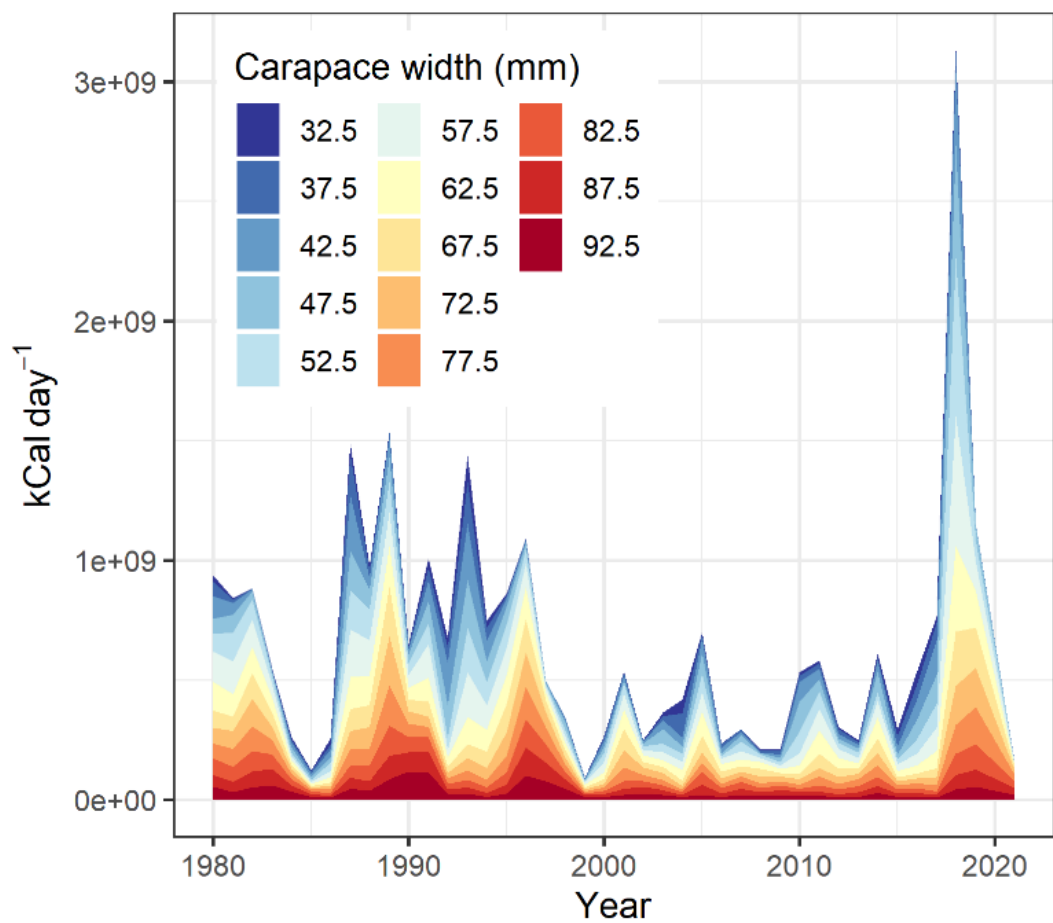
**B**



← Caloric requirements in 2018 were >4x 2017 and >2x previous high



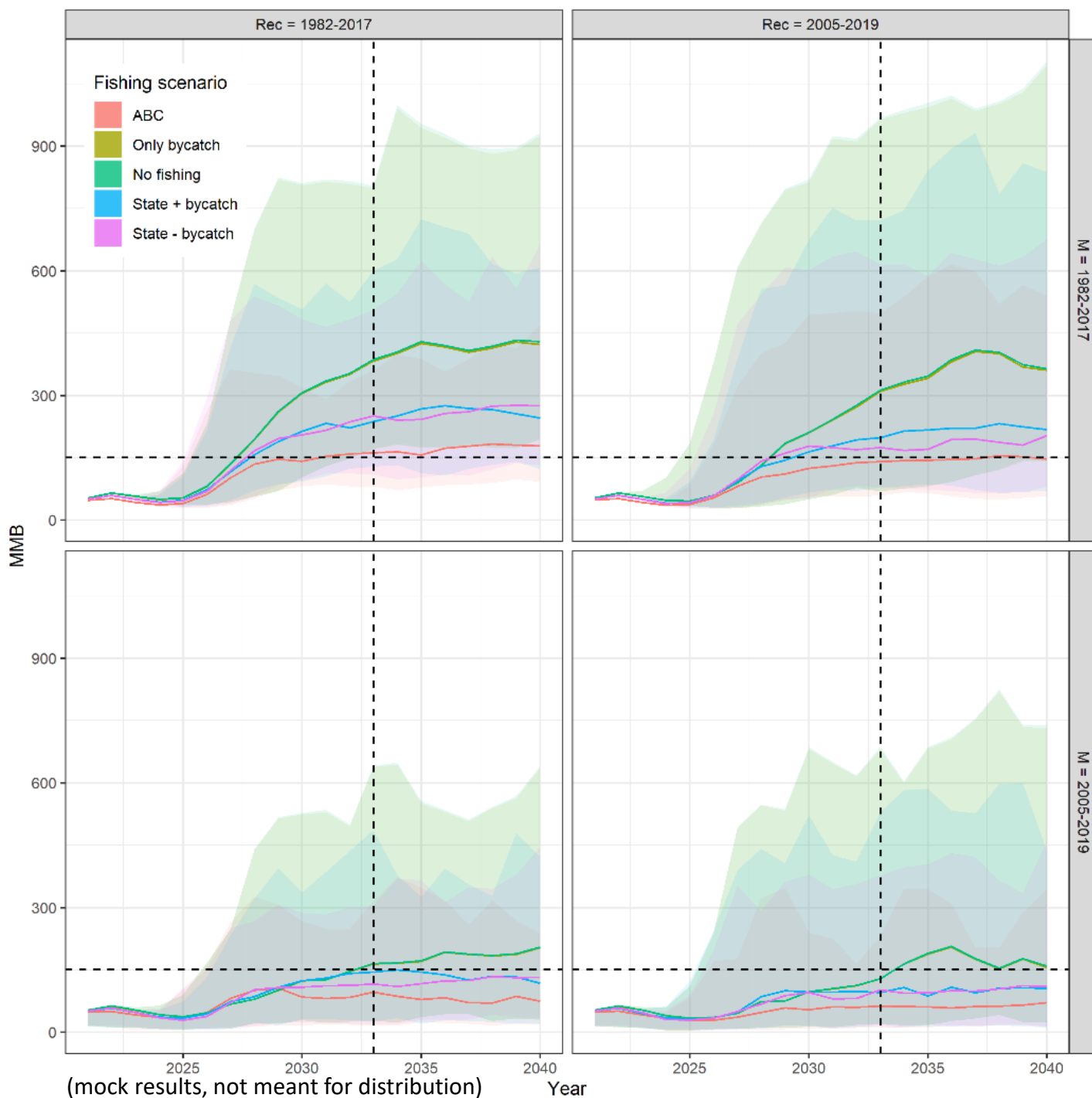
A 75 mm carapace width crab at 1 degree C was 15% lighter in 2018 than in 2017.



The **mass mortality** event in 2018 and 2019 appear to be related to unusually **high temperatures** and **high densities** of crab in the Bering Sea.



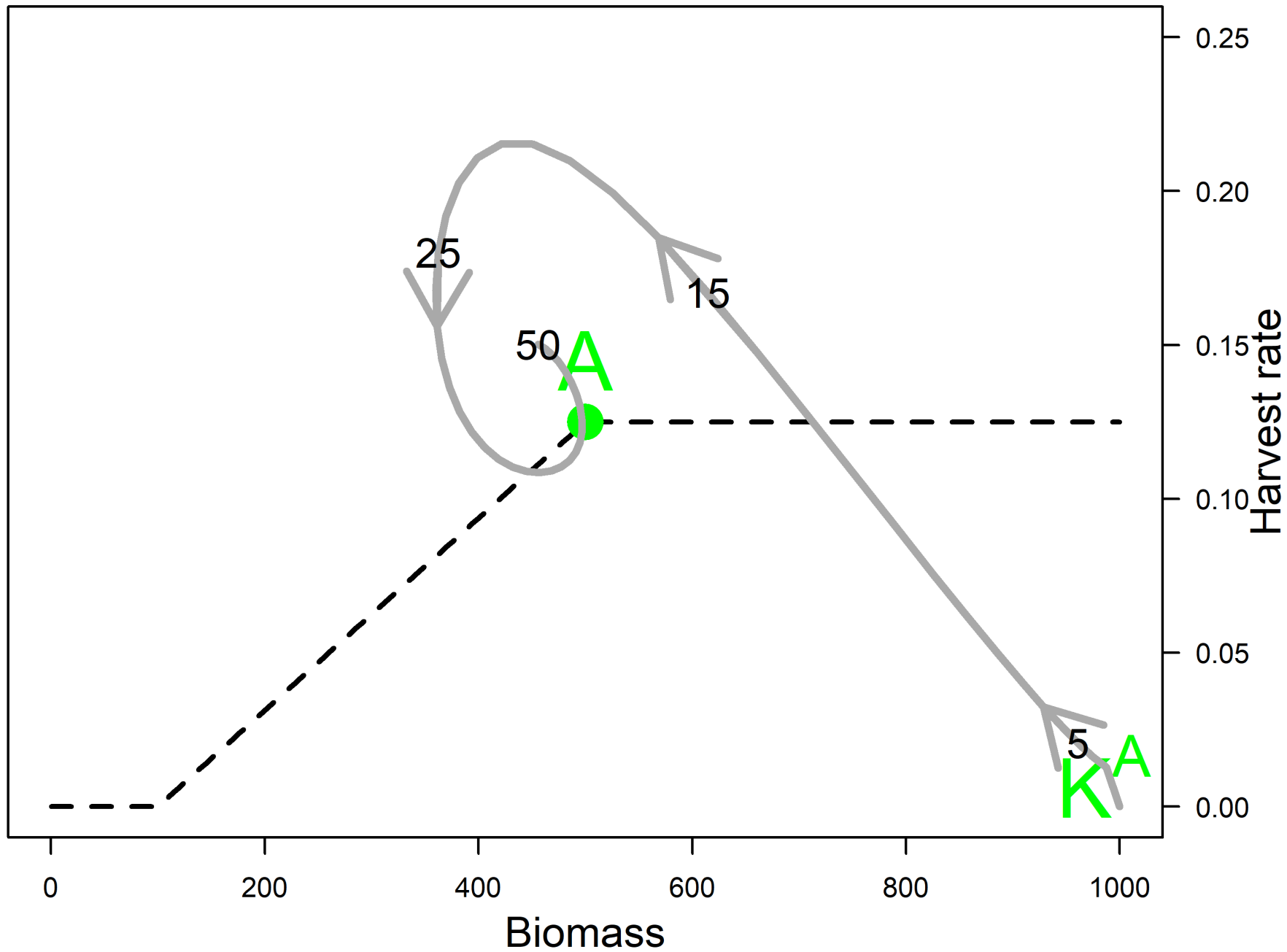
What do we do now?



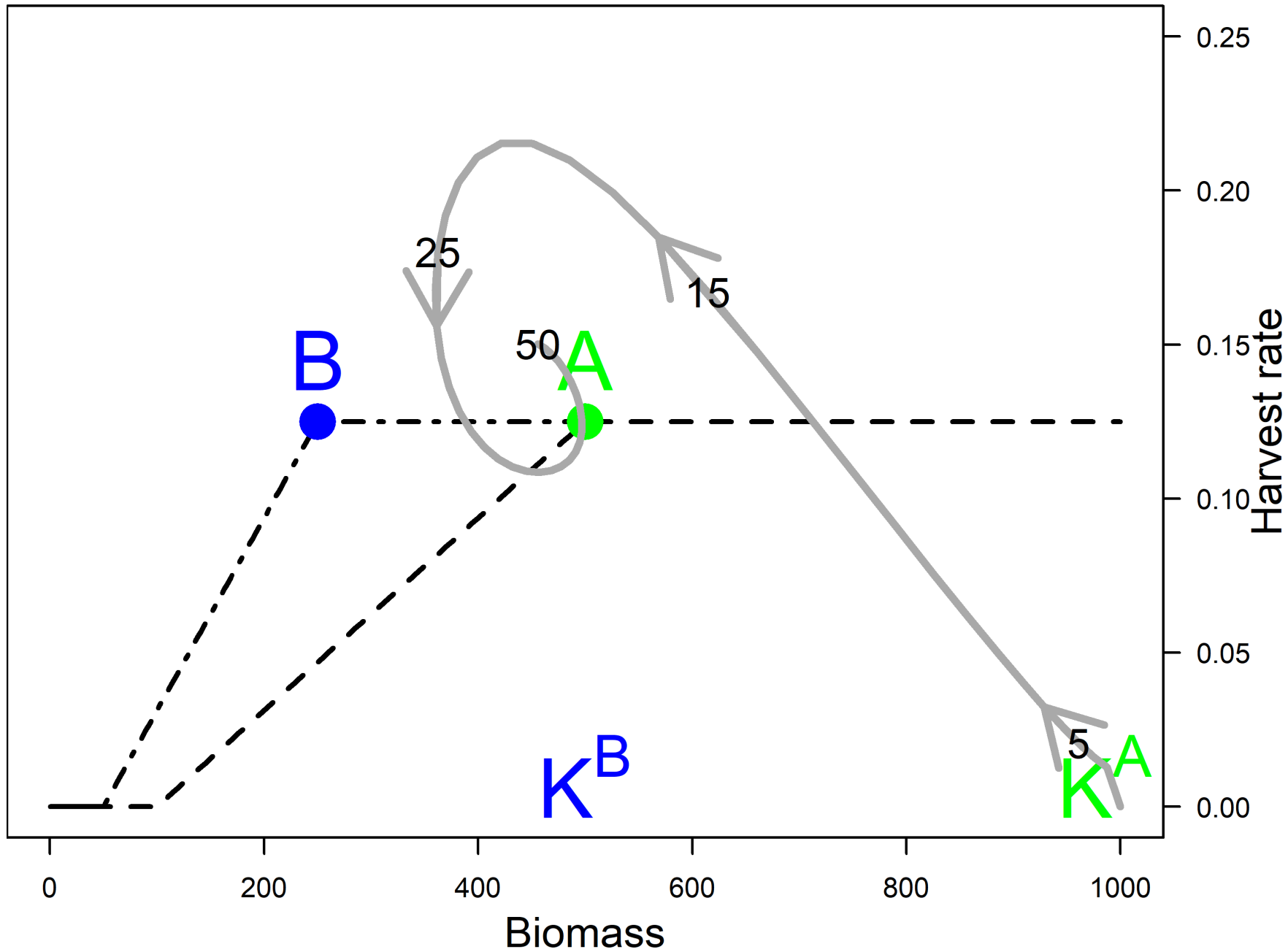
# Rebuilding analyses

- Identify trajectories of rebuilding under different fishing strategies
- Different assumptions imply different management actions, but little data exist to inform assumptions given departure from historical norms
- Should the targets be consistent with the conditions of projection?
- NS1 says targets should reflect prevailing conditions...

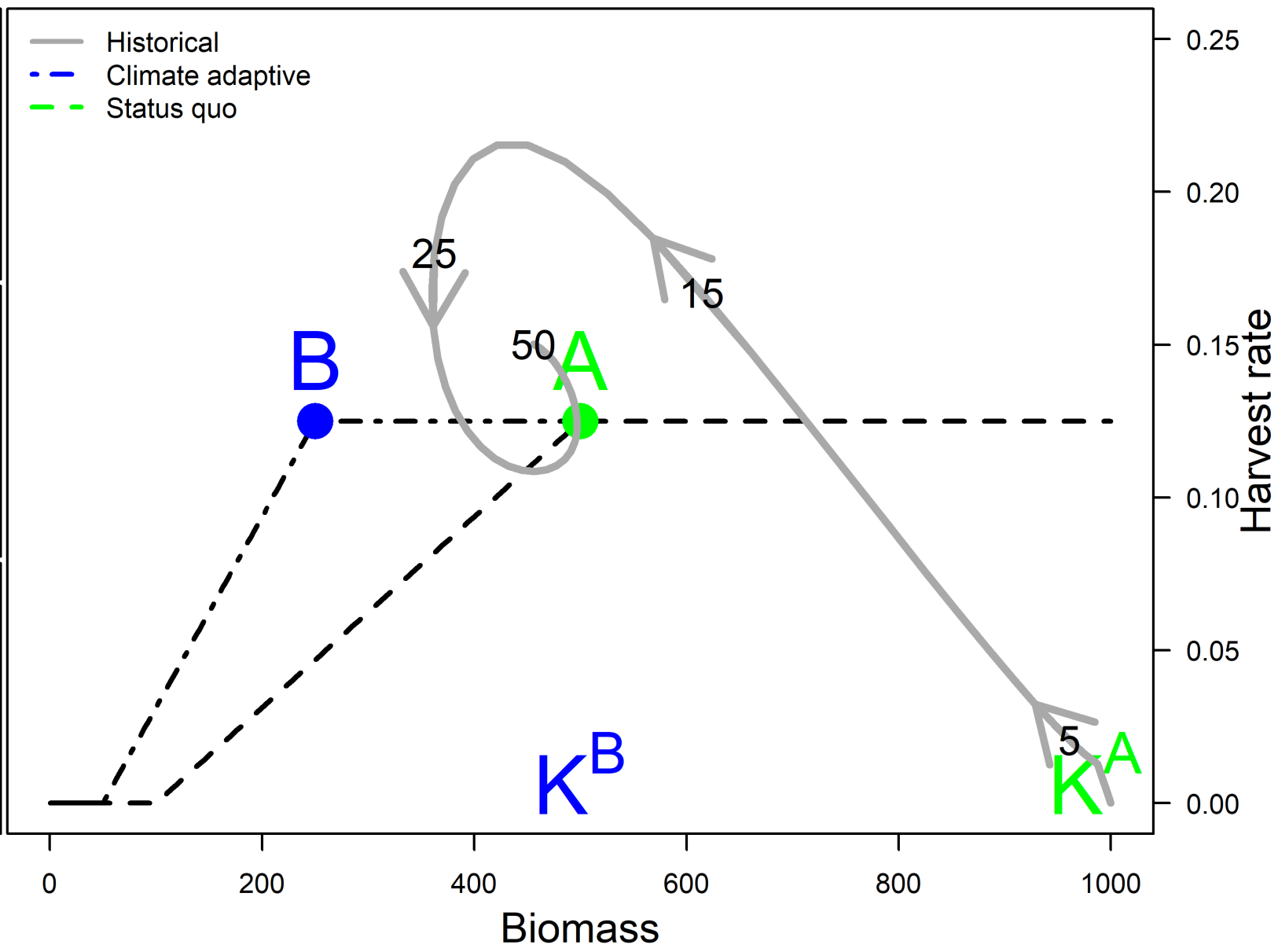
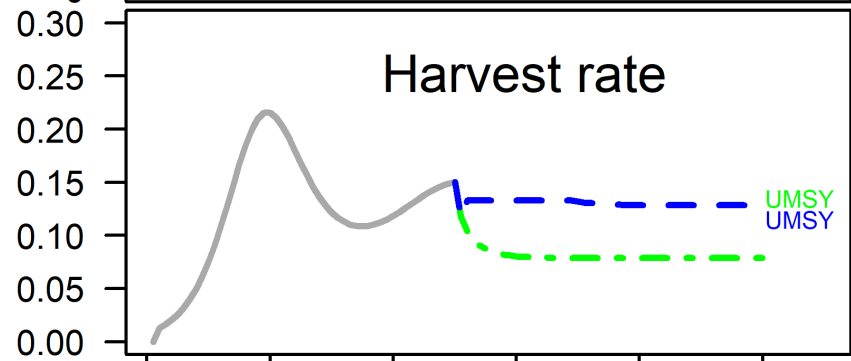
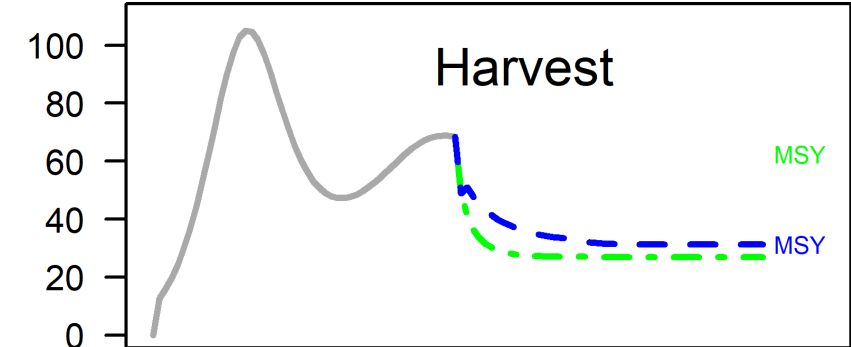
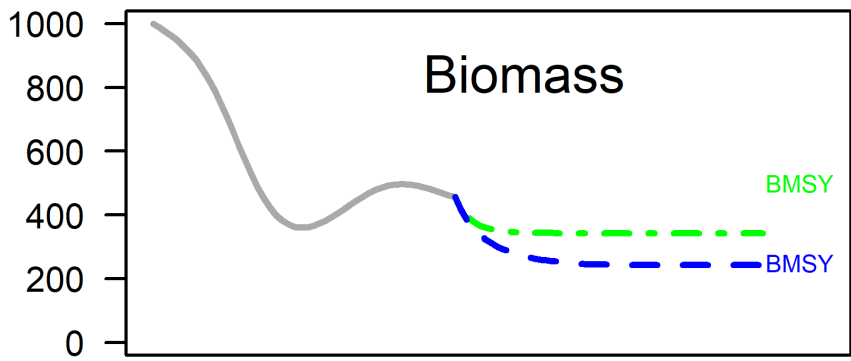
How should we define future  
management targets?



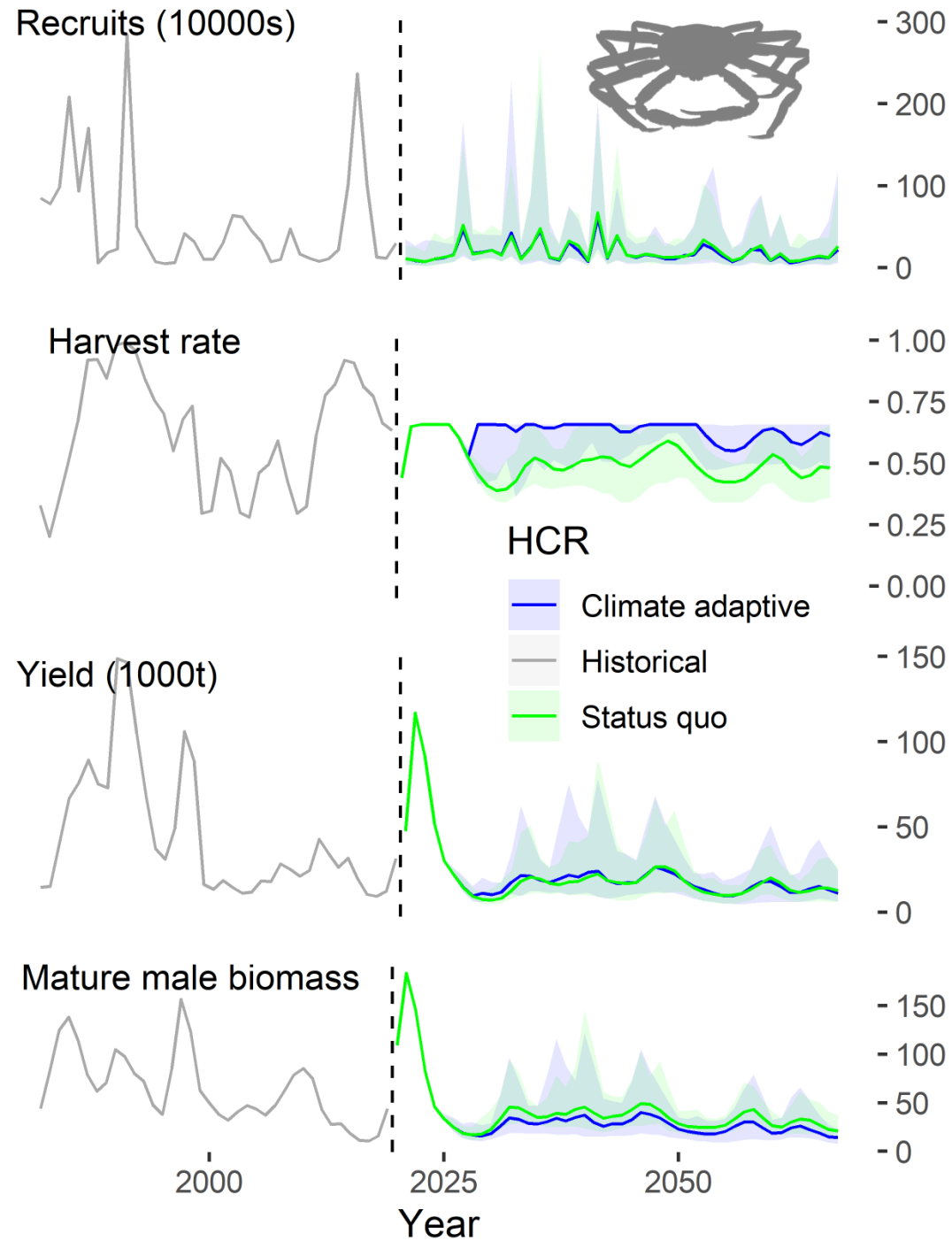
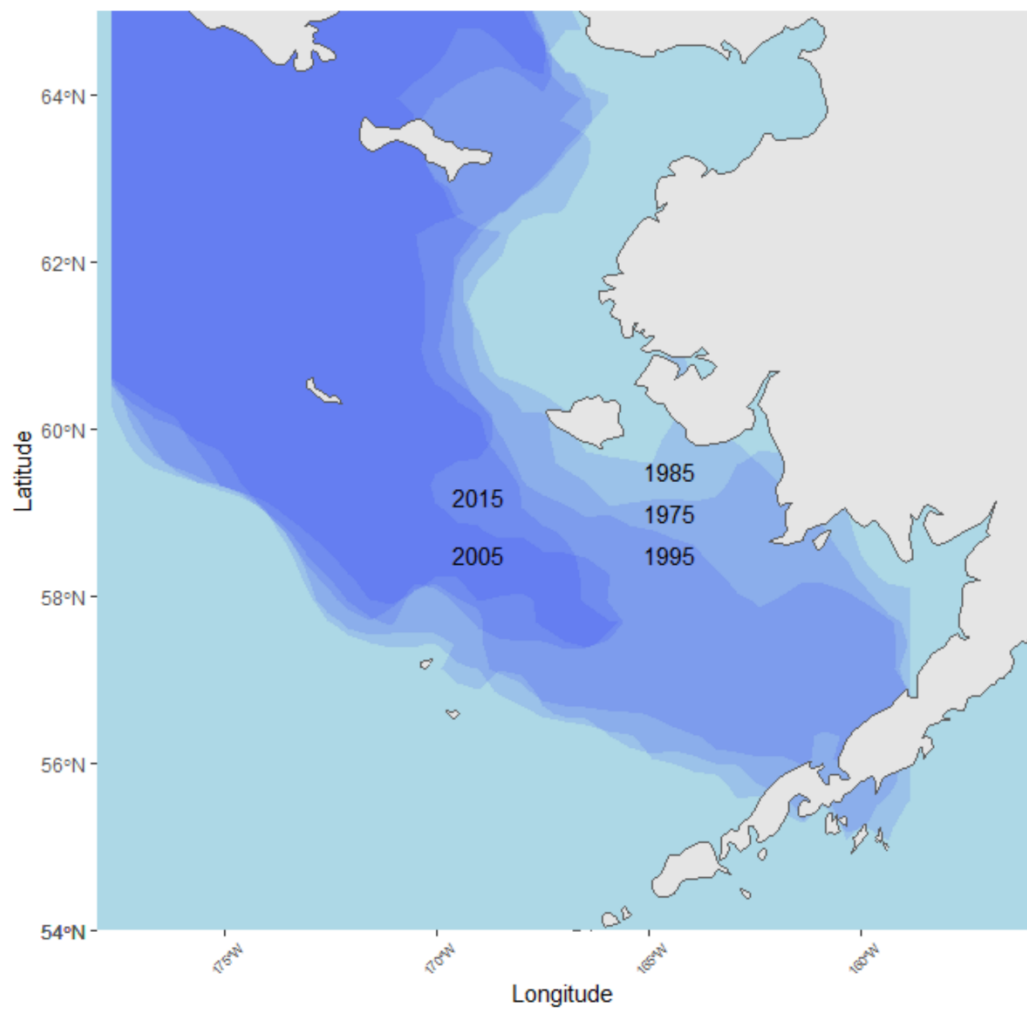
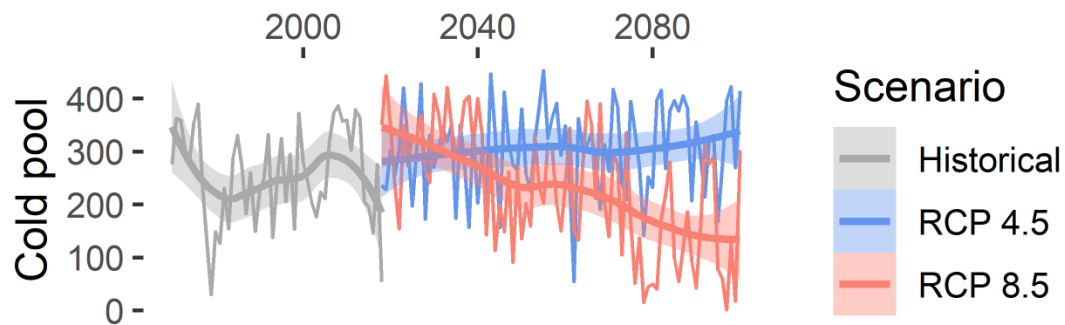
Surplus production model with effort dynamics determining harvest (sensu Thorson, 2014)



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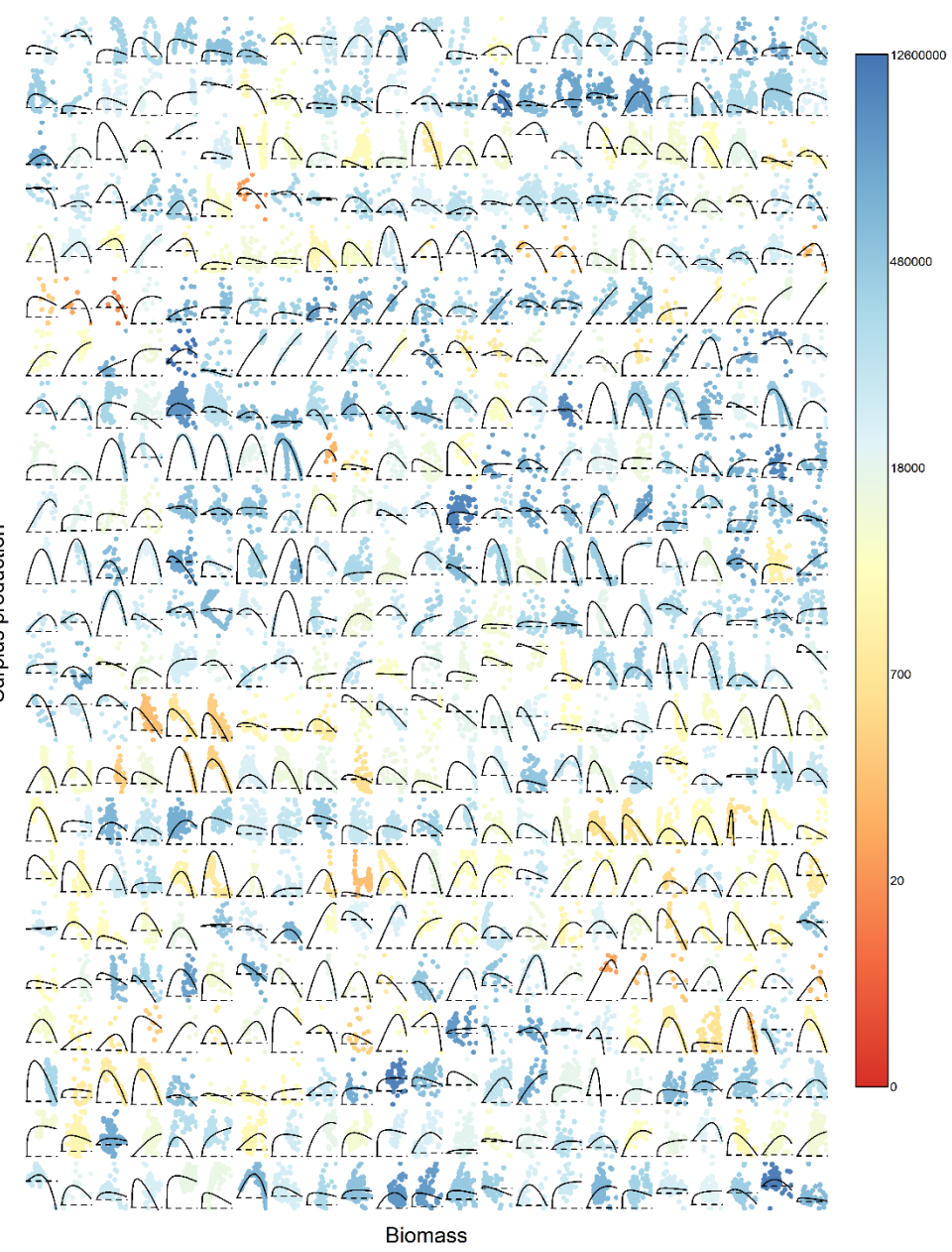


Adjusting management targets to reflect **decreased productivity** results in **higher exploitation** rates on populations under stress.



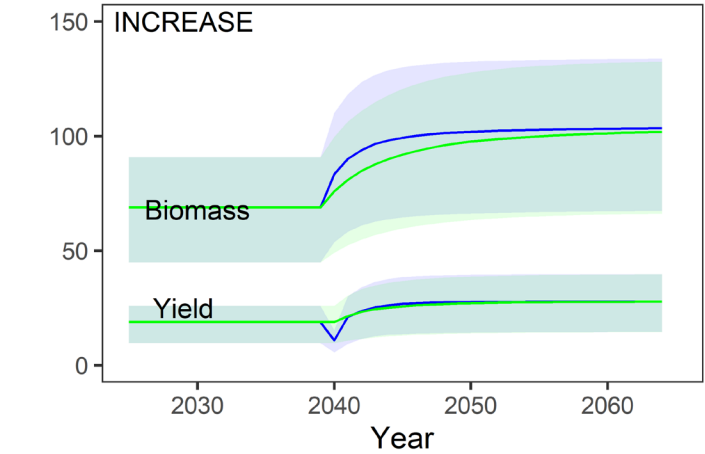
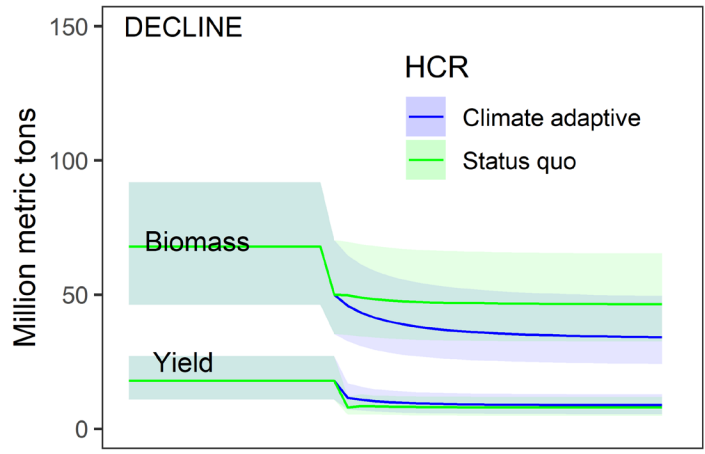
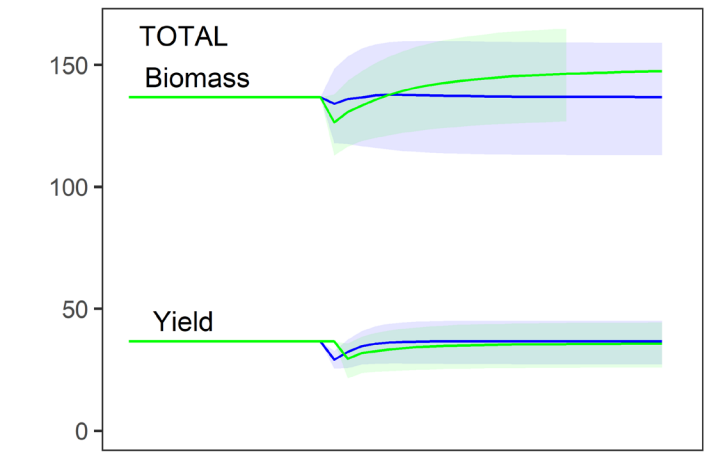


# Stocks in RAM Legacy Stock Assessment Database

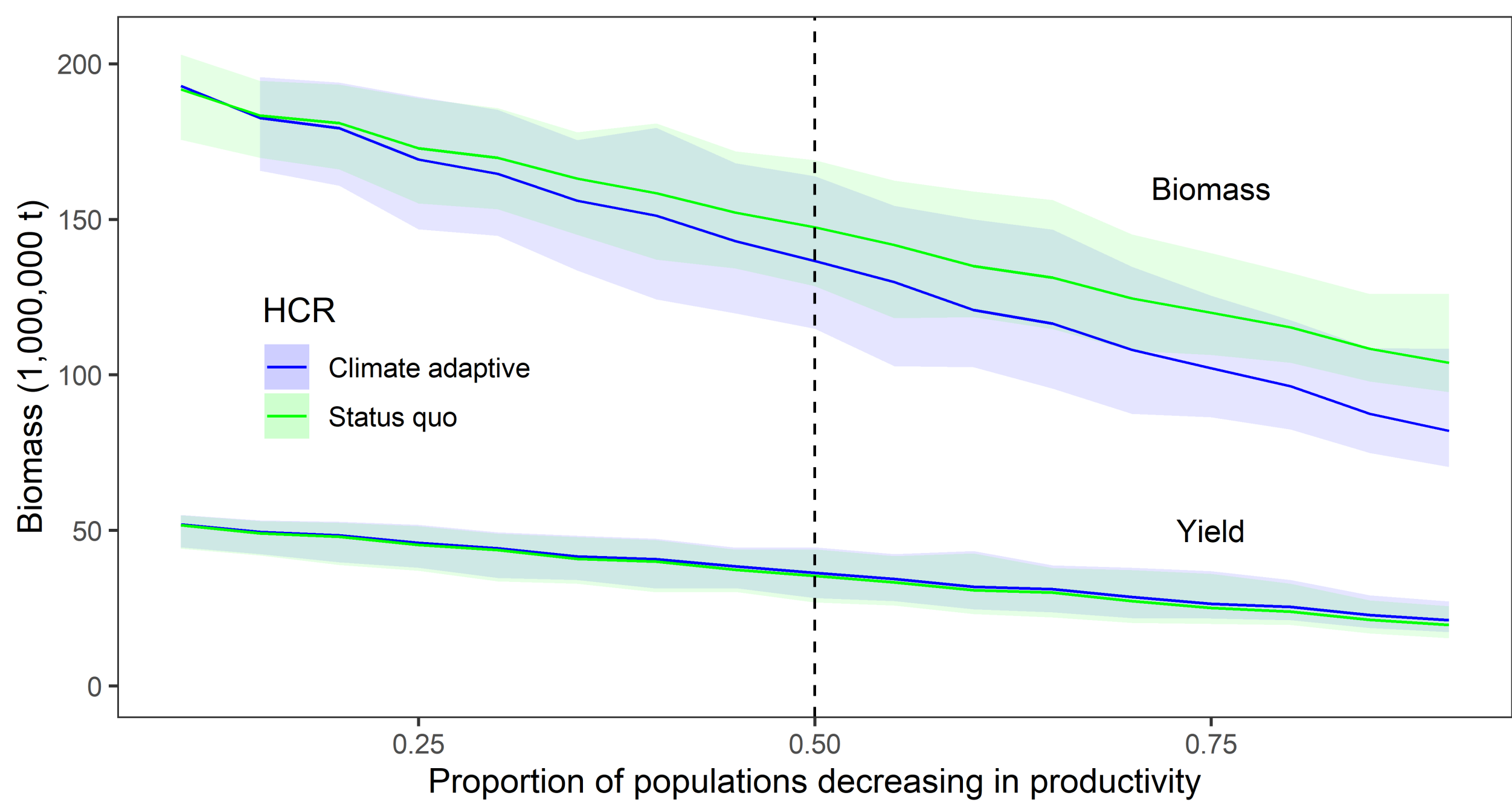


- Fit Pella-Tomlinson models to RAM stocks
- Simulate a shift in carrying capacity—randomly assign 50% up or 50% down
- Project under a control rule that either uses the status quo targets or ‘adapts’ to the new productivity
- Repeat 100X
- Compare biomass and yield

**Total yields are similar, under both strategies, but changing management targets results in declining species being pushed to much lower biomasses.**



Under wide-spread shifts in productivity, maintaining status quo targets produces similar global yields while leaving more biomass in the water, particularly for species under climate stress.



# Closing thoughts

Snow crab is not the first and it won't be the last.

'Status quo' is likely not the answer, but it was a useful comparison

Perhaps instead of chasing the declining productivity of climate-stressed stocks, we should let them rest and focus fisheries on the 'winners' of climate change.



# Things I wish I had time to talk about

- My fisheries existential crisis
- What would we have done differently if we could have perfectly predicted the collapse?
- Science vs. management & prediction vs. preparation
- Conflicting data at the end of a time series
- Discussion of alternate quota systems, mariculture, stock enhancement, ecosystem 'remediation' as responses to climate change