Patterns and drivers of snow crab maturity in the eastern Bering Sea

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Why does size-at-maturity matter for fisheries?

- Large mature individuals contribute disproportionately to reproductive output
- Large males are valuable to size- and sex-selective fisheries
- Shifts in size-at-maturity can:
  - Influence reproductive capacity
  - Alter management quantities

Borrell 2013, *Nature*

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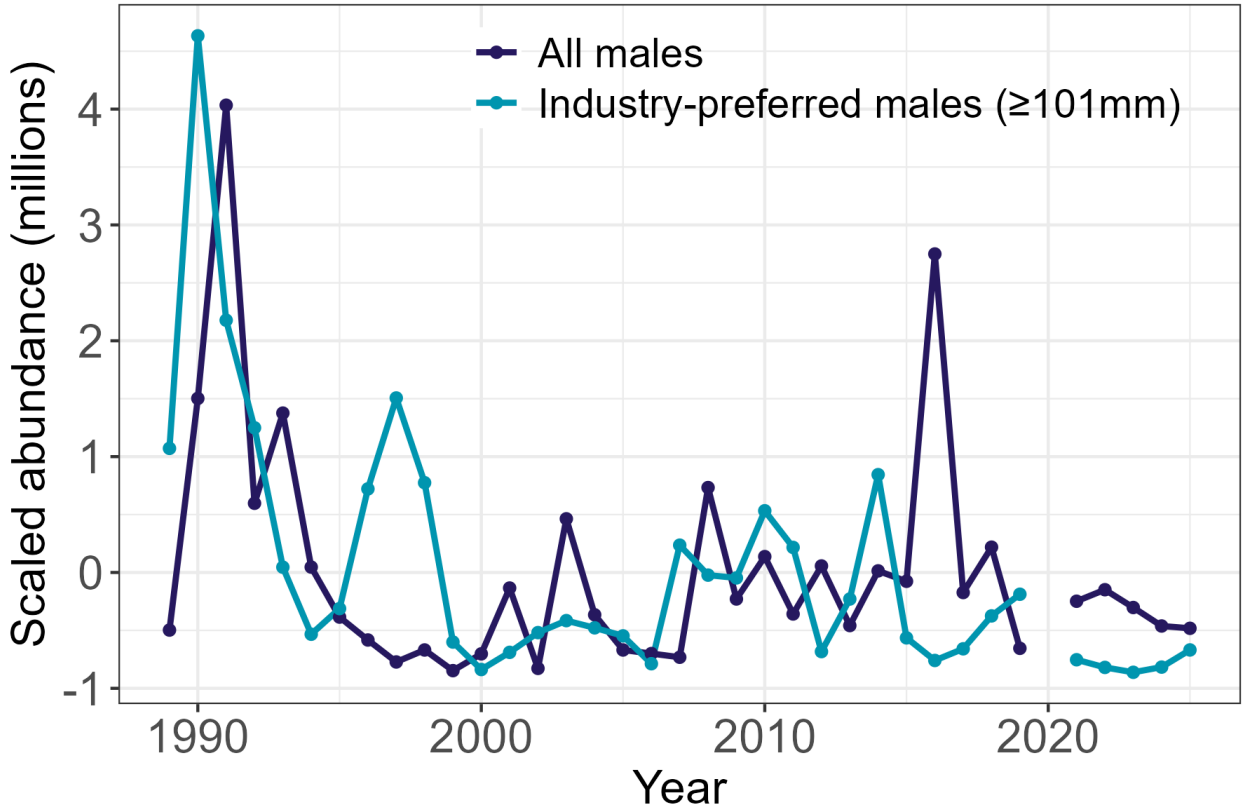

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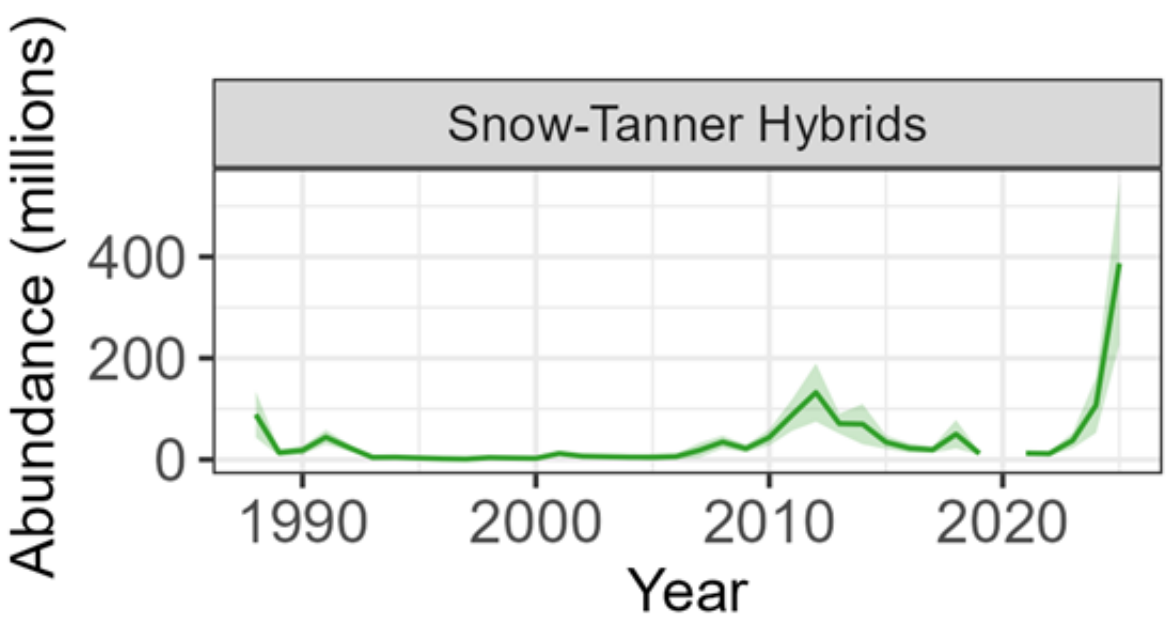

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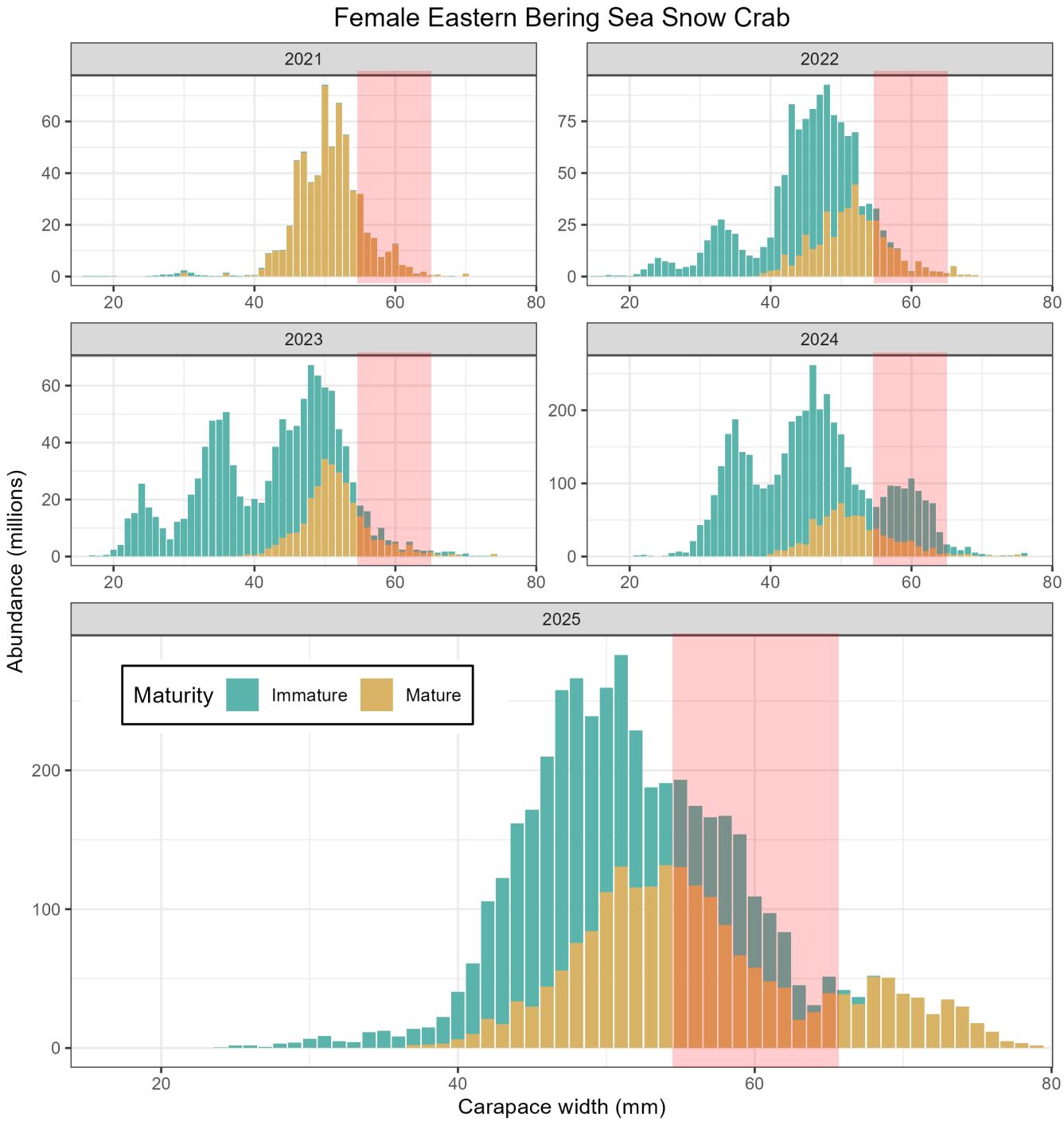

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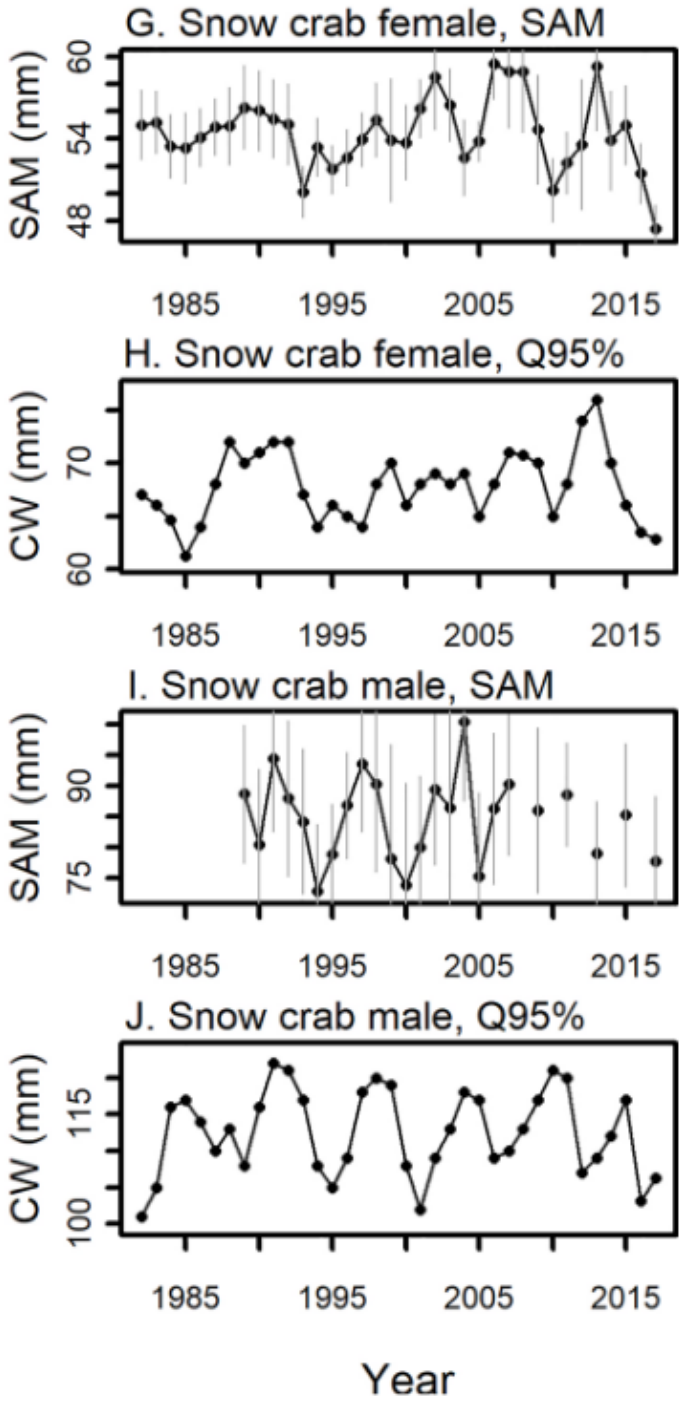
- Long-term maturity patterns last assessed in 2017



Murphy et al. 2021

Objectives

1. Test for directional trends in male and female maturity parameters over time.

2. Evaluate drivers of variable maturity parameters.

3. Simulate how different exploitation rates on large, industry-preferred sizes affect the number maturing at that size.

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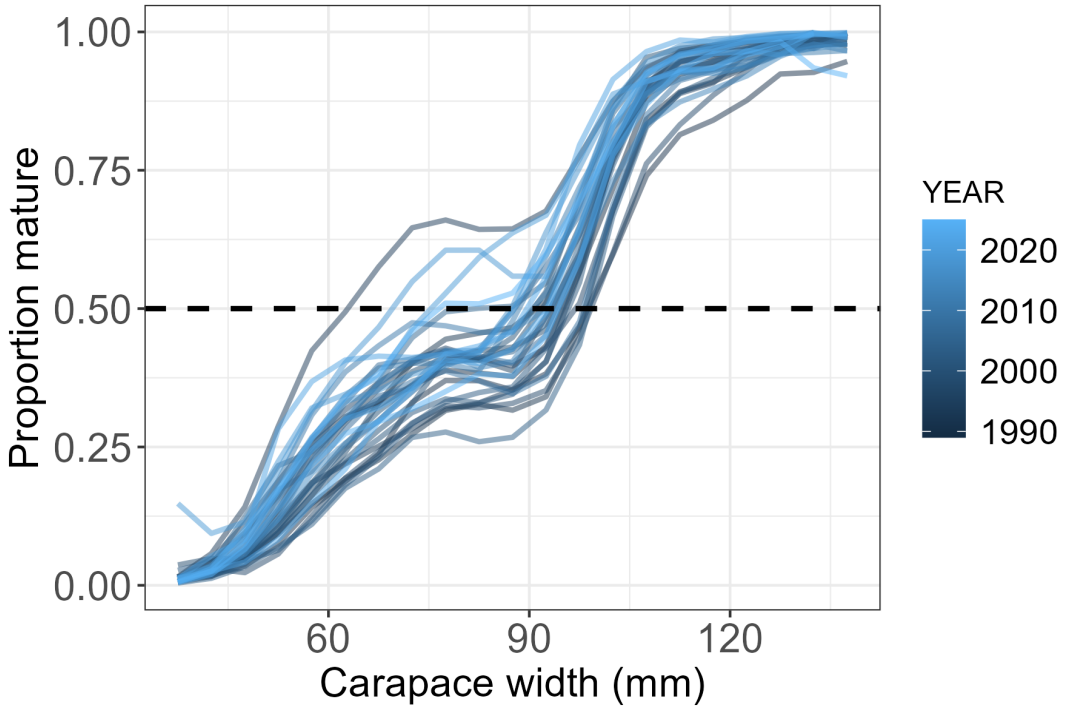
Objective 1: test for maturity trends

Male maturity responses

1. Male size-at-50% maturity
   - Derived from sdmTMB maturity ogives
2. Proportion of mature males ≥101mm
   - Newshell mature males ≥101mm/total newshell mature males



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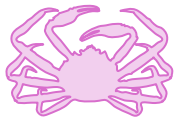

Female maturity responses

1. Female size-at-50% maturity
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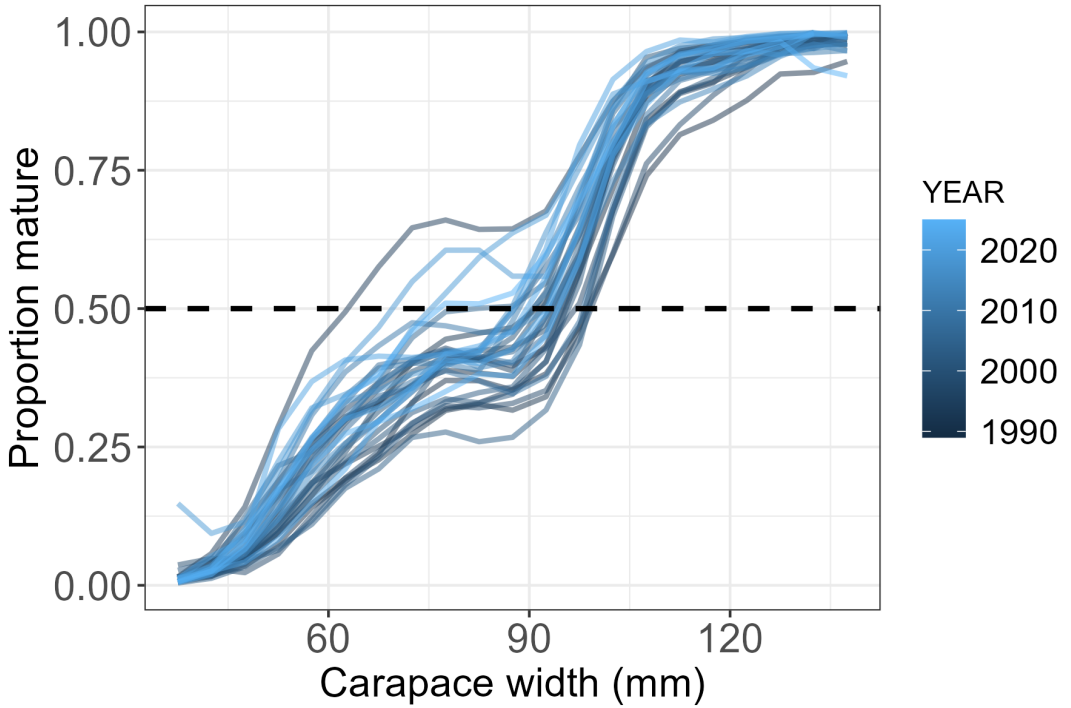
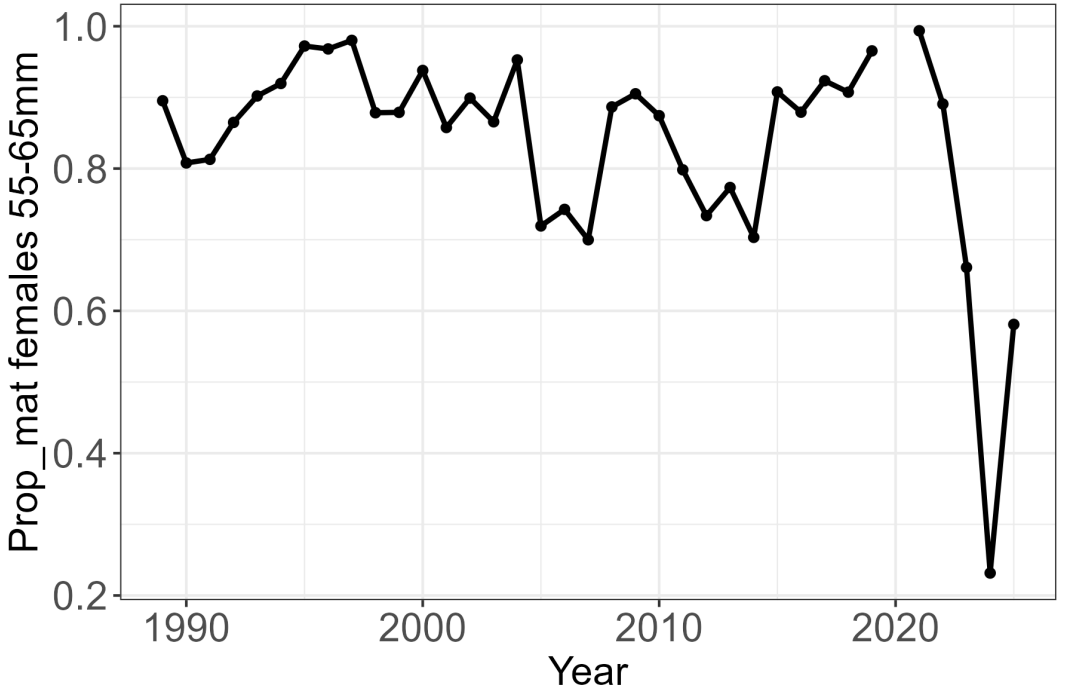
2. Proportion of mature females 55-65mm
   - Newshell mature females/total females





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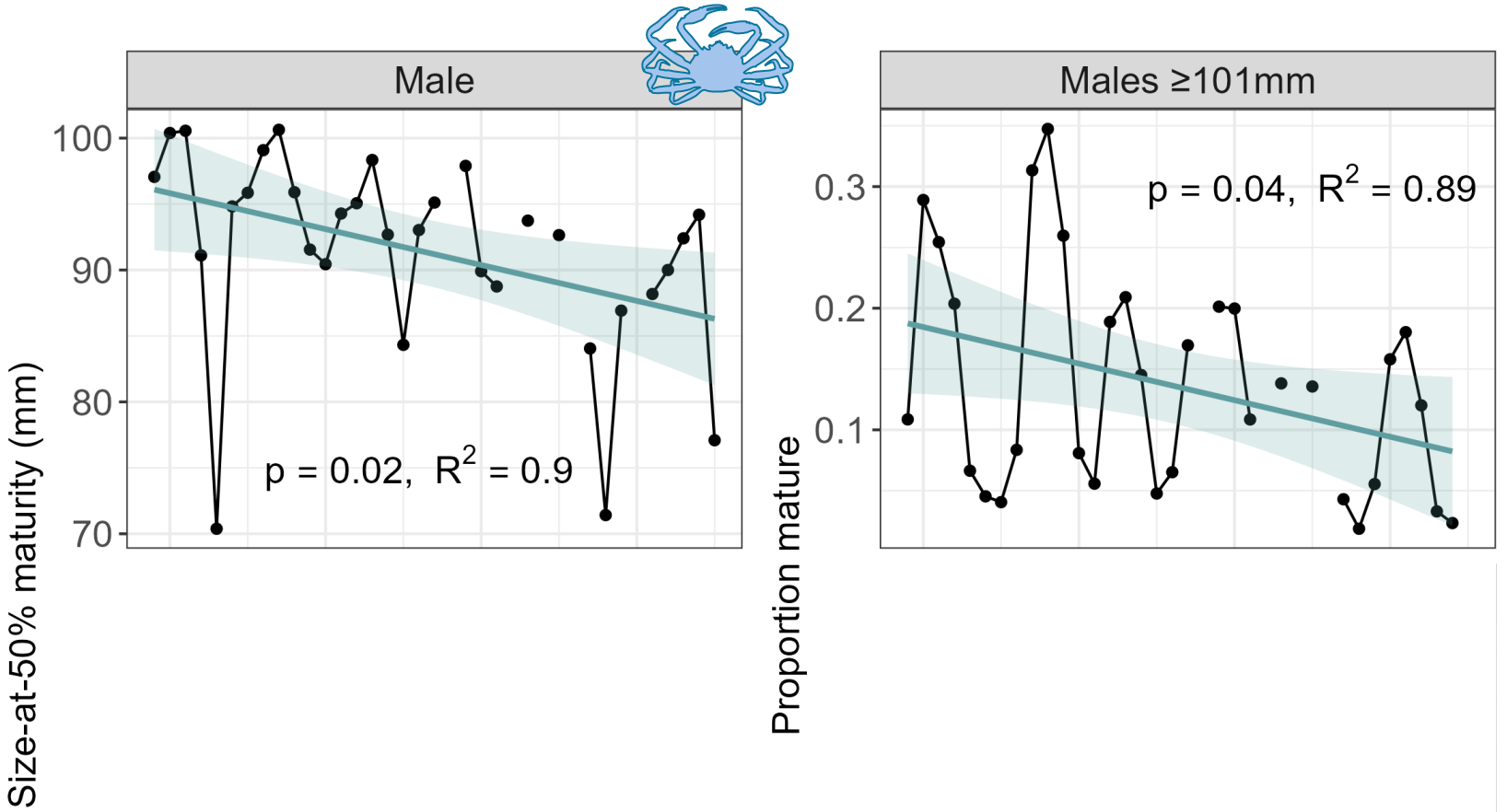
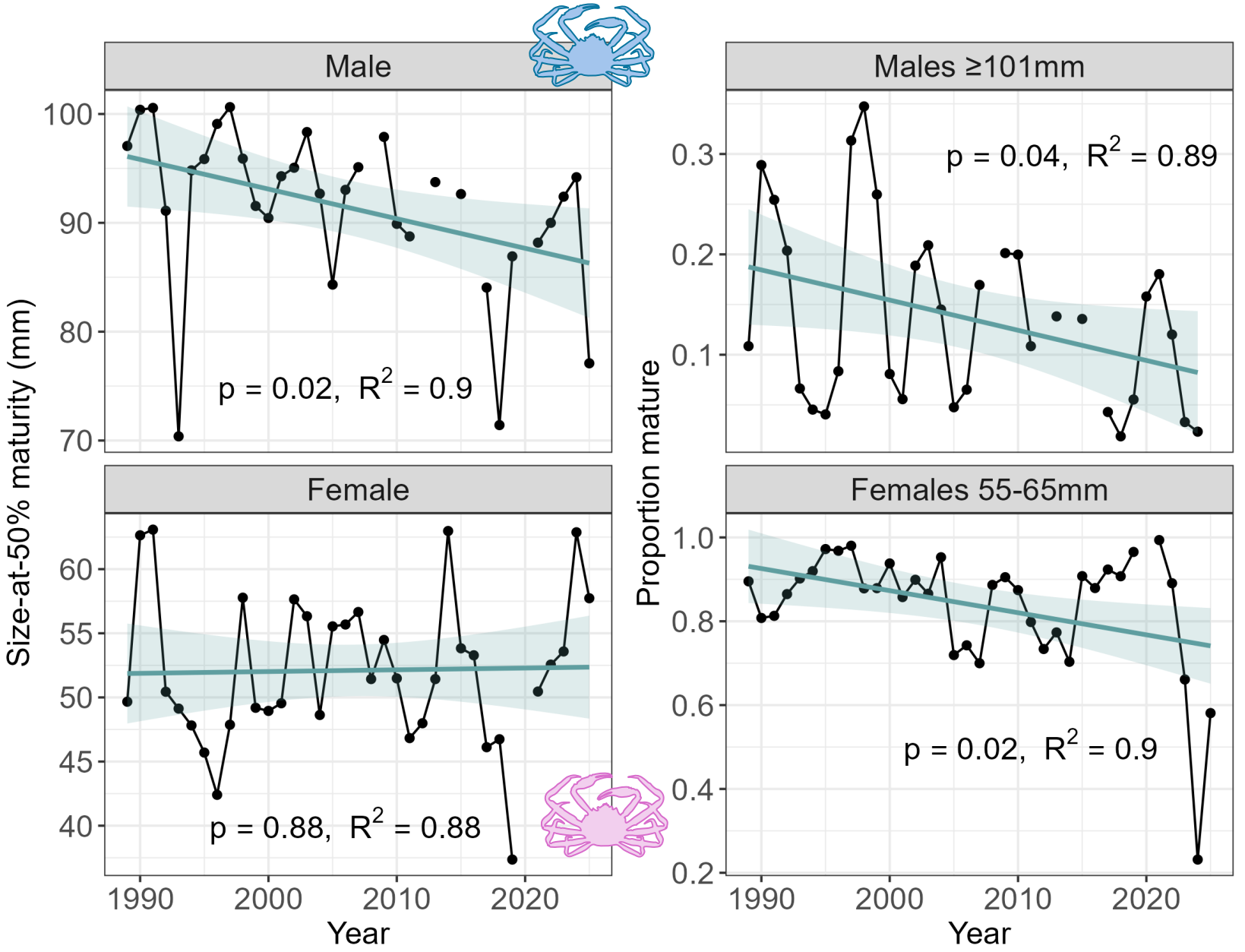


Objective 1: test for maturity trends

- Declining male size-at-50% maturity and proportion mature ≥101mm
- No detectable trend in female size-at-maturity
- Negative trend in proportion mature females 55-65mm → likely driven by last three years

*higher edf GAMMs attempted, but edf ≈ 1



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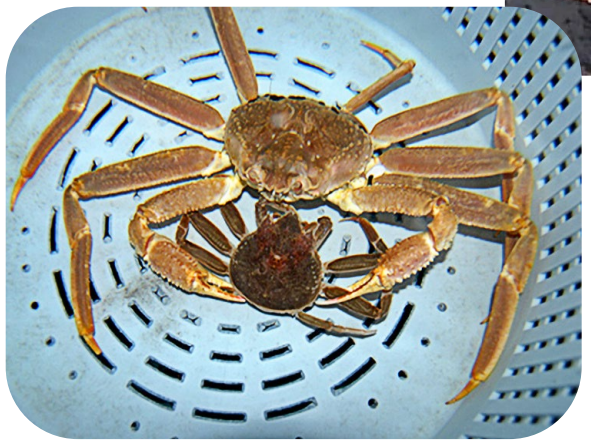

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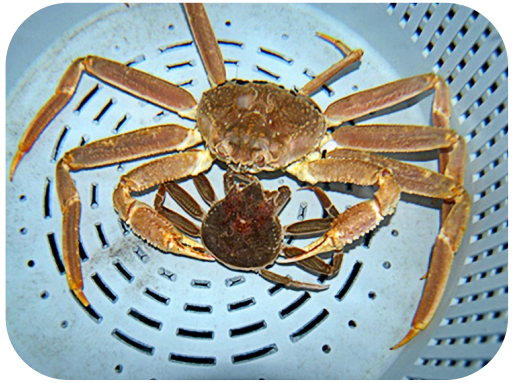
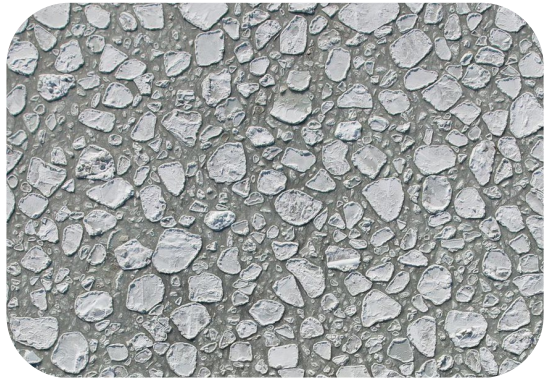
- Temperature/ice
  - Burmeister and Sainte-Marie 2010; Mullowney and Baker 2021; Zheng 2008

Objective 2: evaluate drivers of maturity

			
Cohort effects	Competition	Mate availability	Temperature
• Abundance of newshell crab entering terminal molt window (40-60mm males; 35-45mm females)	• Large male abundance ≥95mm (male models) • Mature female abundance (female models)	• Large male abundance ≥95mm (female models)	• Winter/spring sea ice extent • Temperature occupied

Objective 2: evaluate drivers of maturity

Responses

- Male size-at-50% maturity
- Male prop_mat ≥101mm

- Female size-at-50% maturity
- Female prop_mat 55-65mm

Covariates

1. **Specify data inputs**

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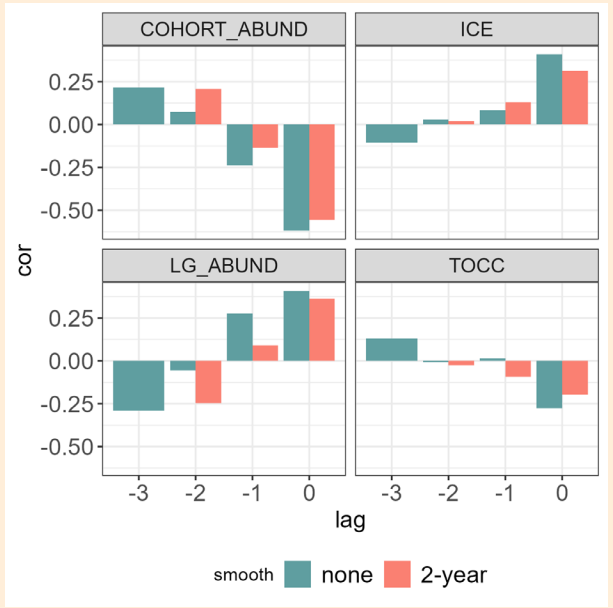

Lags/smooths

- Cohort strength: time *t* only
- Remaining covariates: max *t*-3

2. Evaluate biology-informed lags/smooths; select top two candidates per covariate via ccf

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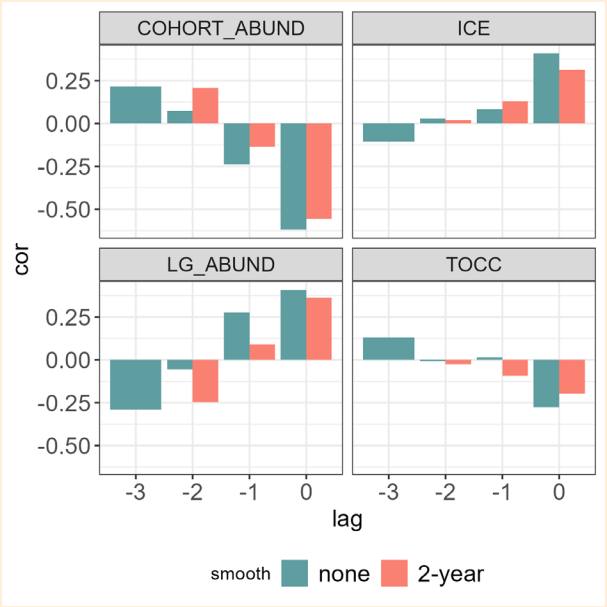

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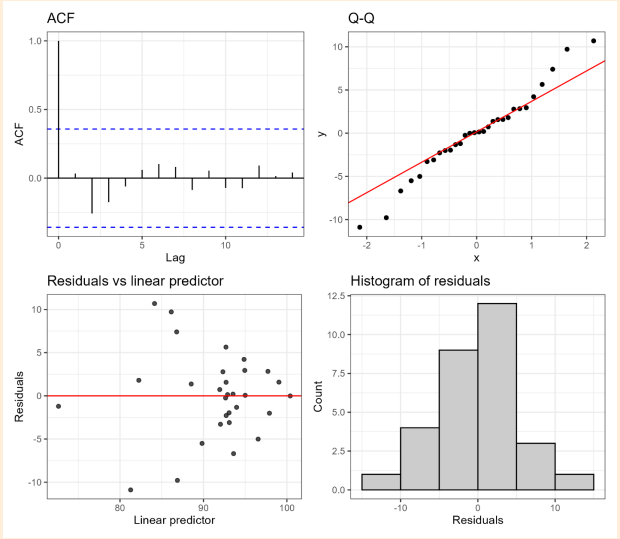
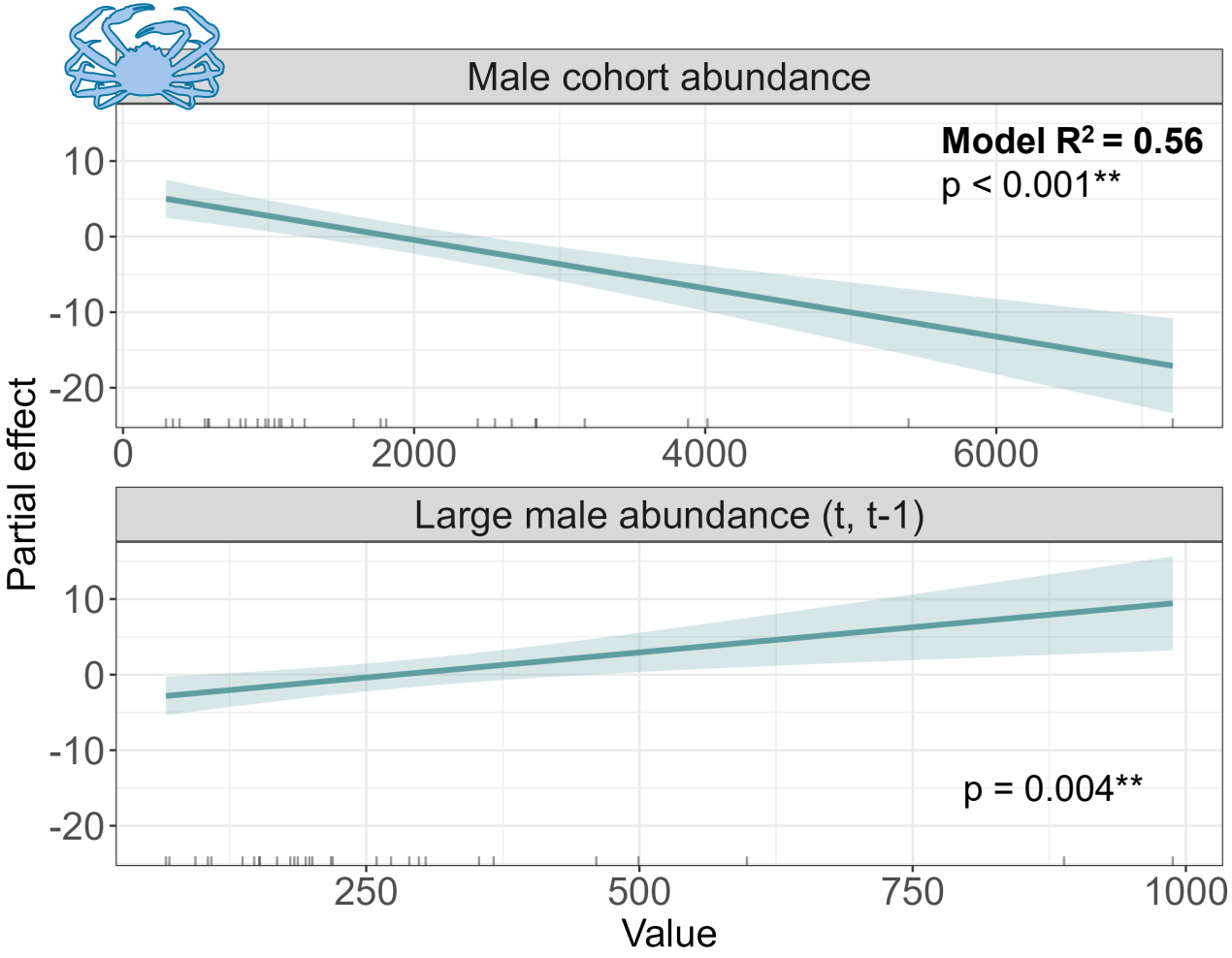


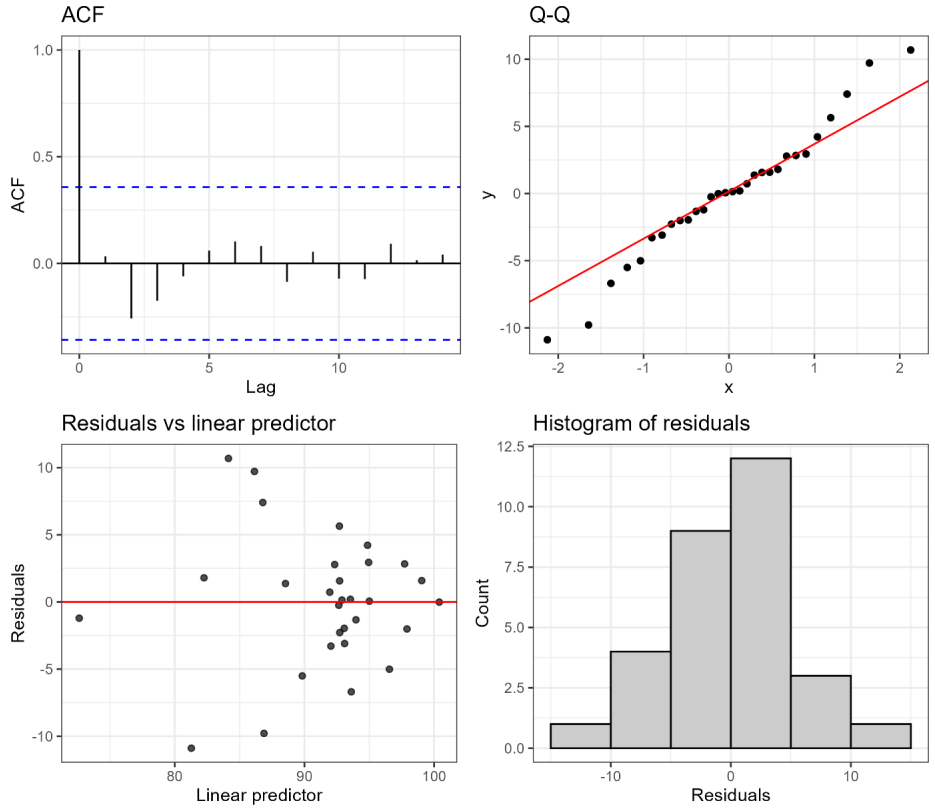
Diagnostics

- AIC
- RMSE
- DHARMa residuals

3. Fit GAM(M)s over candidate covariate grid; select best models using diagnostics

Male size-at-50% maturity decreases with cohort strength but increases with competition

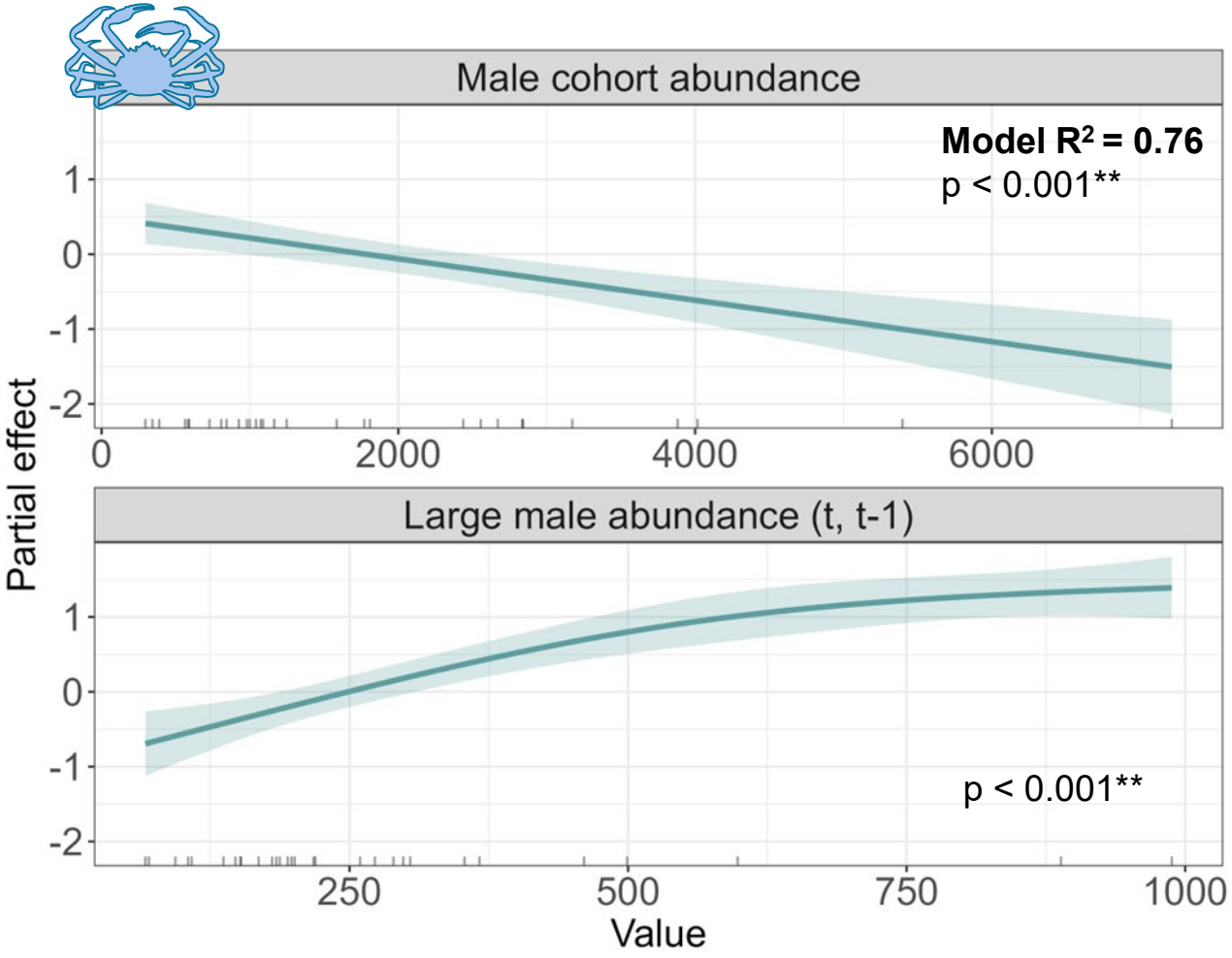


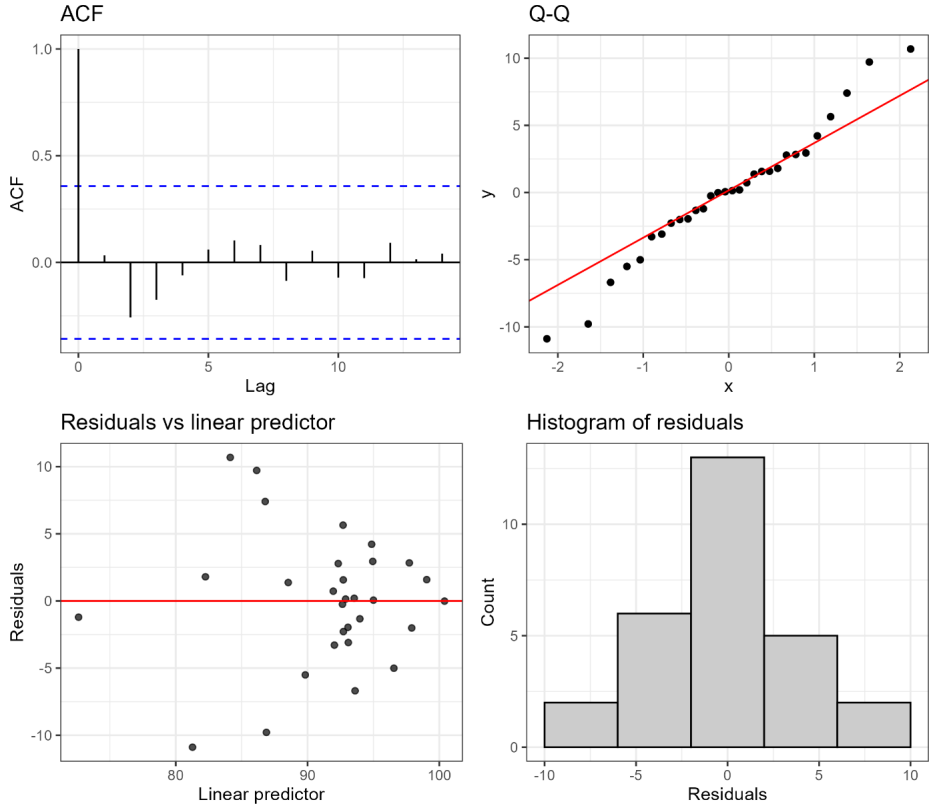


Male size-at-50% maturity

*Gaussian GAMM

The proportion of mature males ≥101mm also decreases with cohort strength but increases with competition

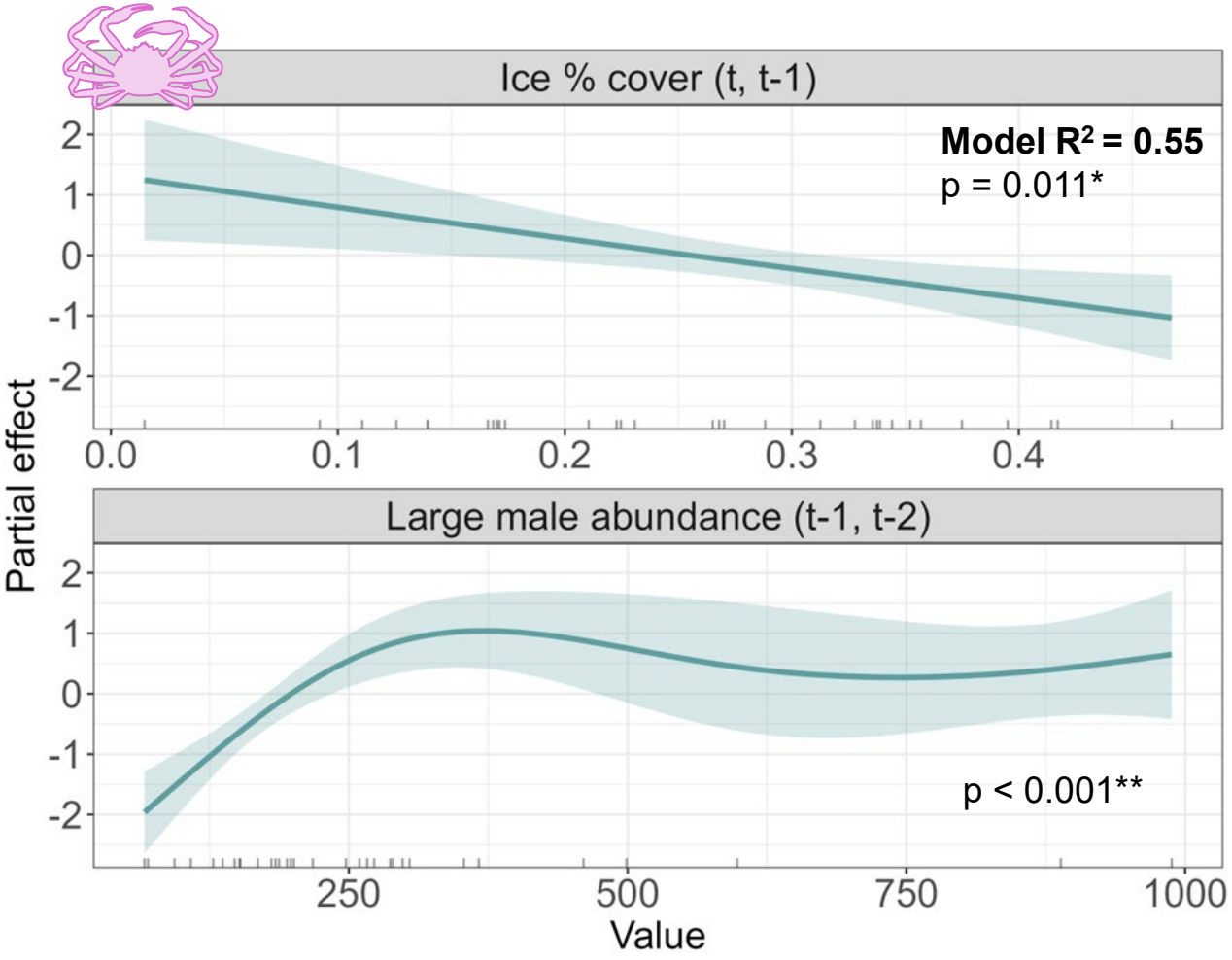


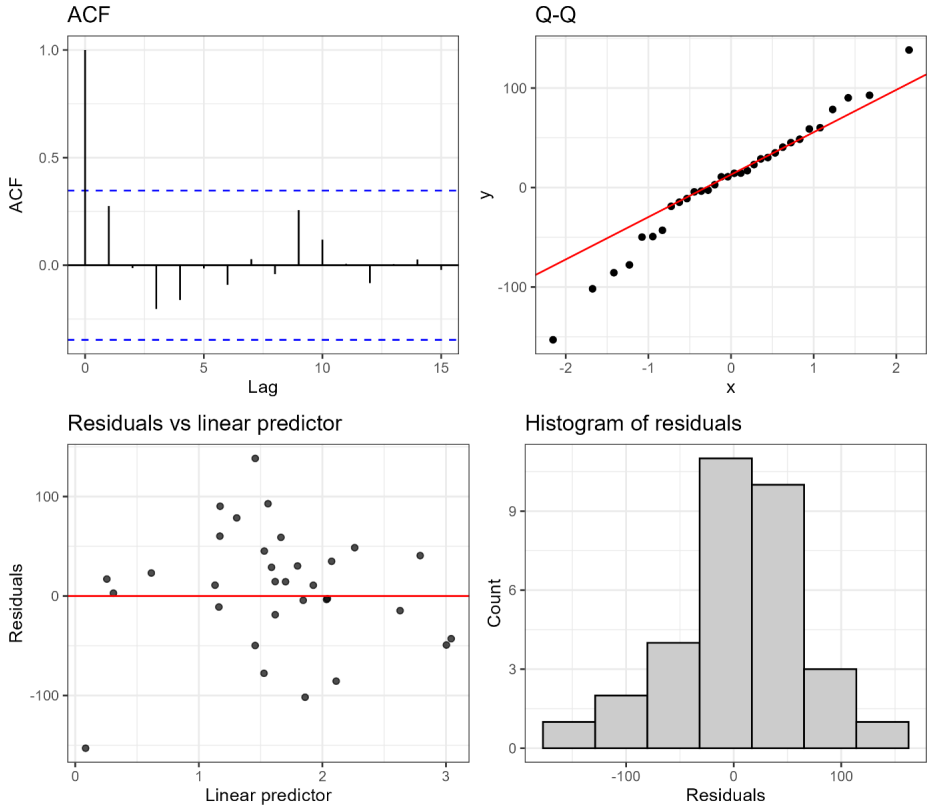


Male proportion mature ≥101mm

*Quasibinomial GAM

The proportion of large mature females 55-65mm decreases with cold temperatures but increases with mate availability





Female proportion mature 55-65mm

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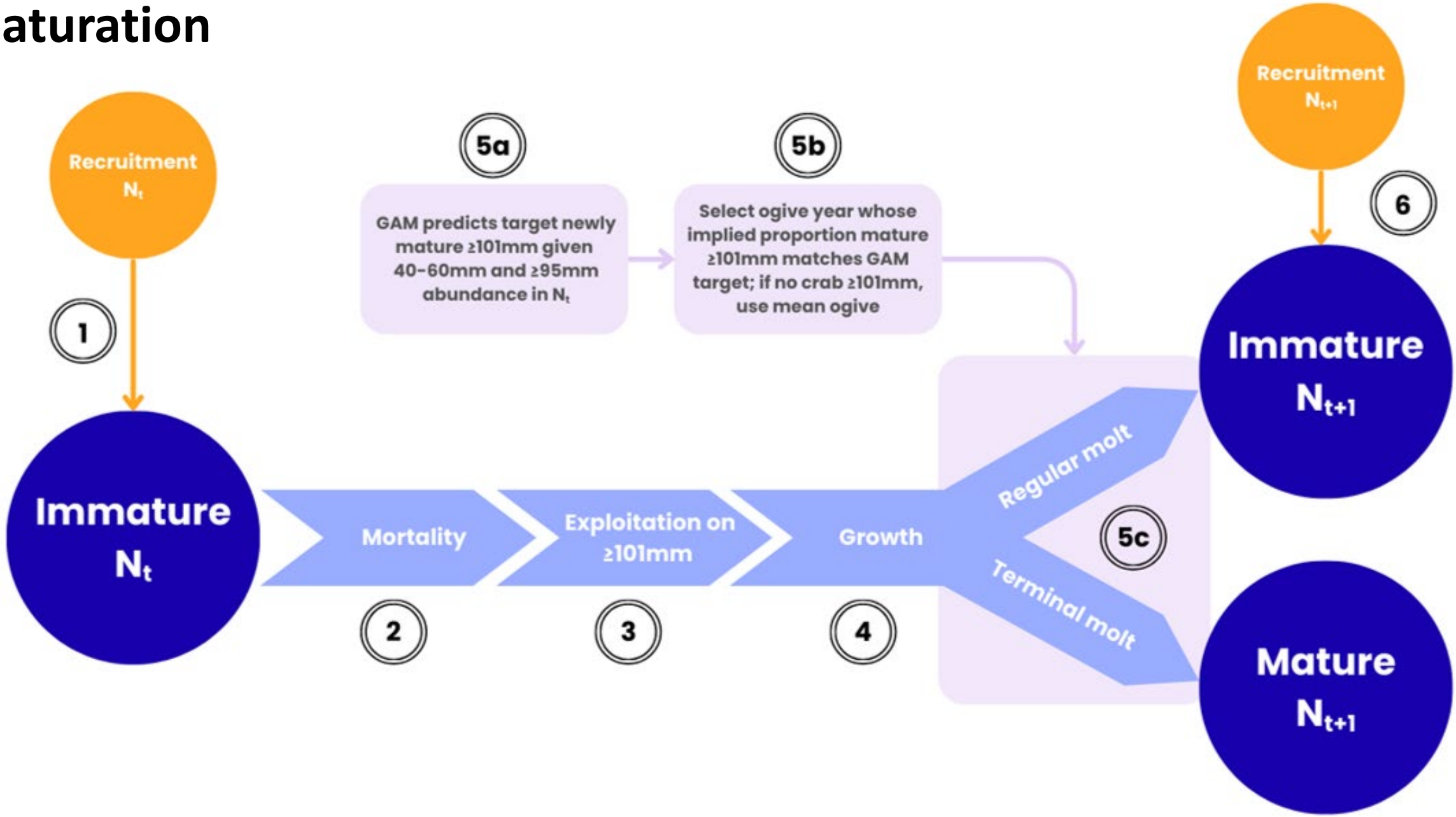

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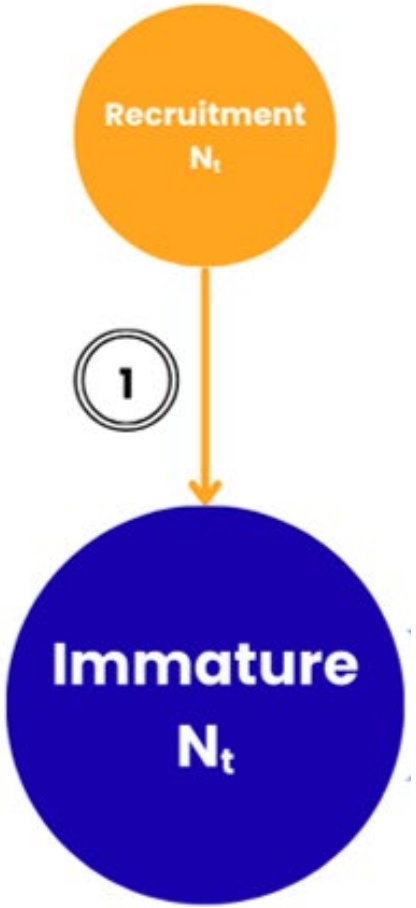

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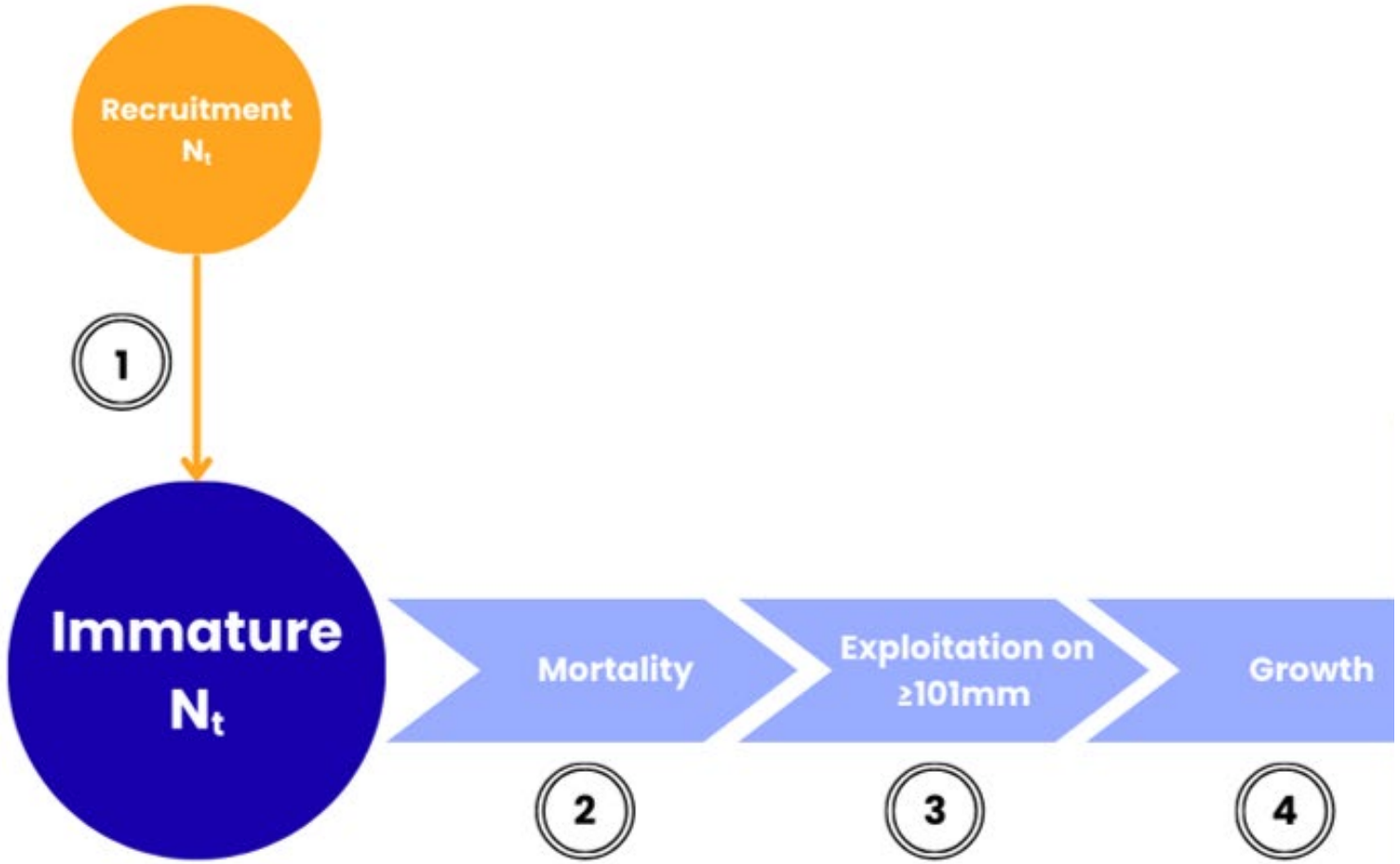

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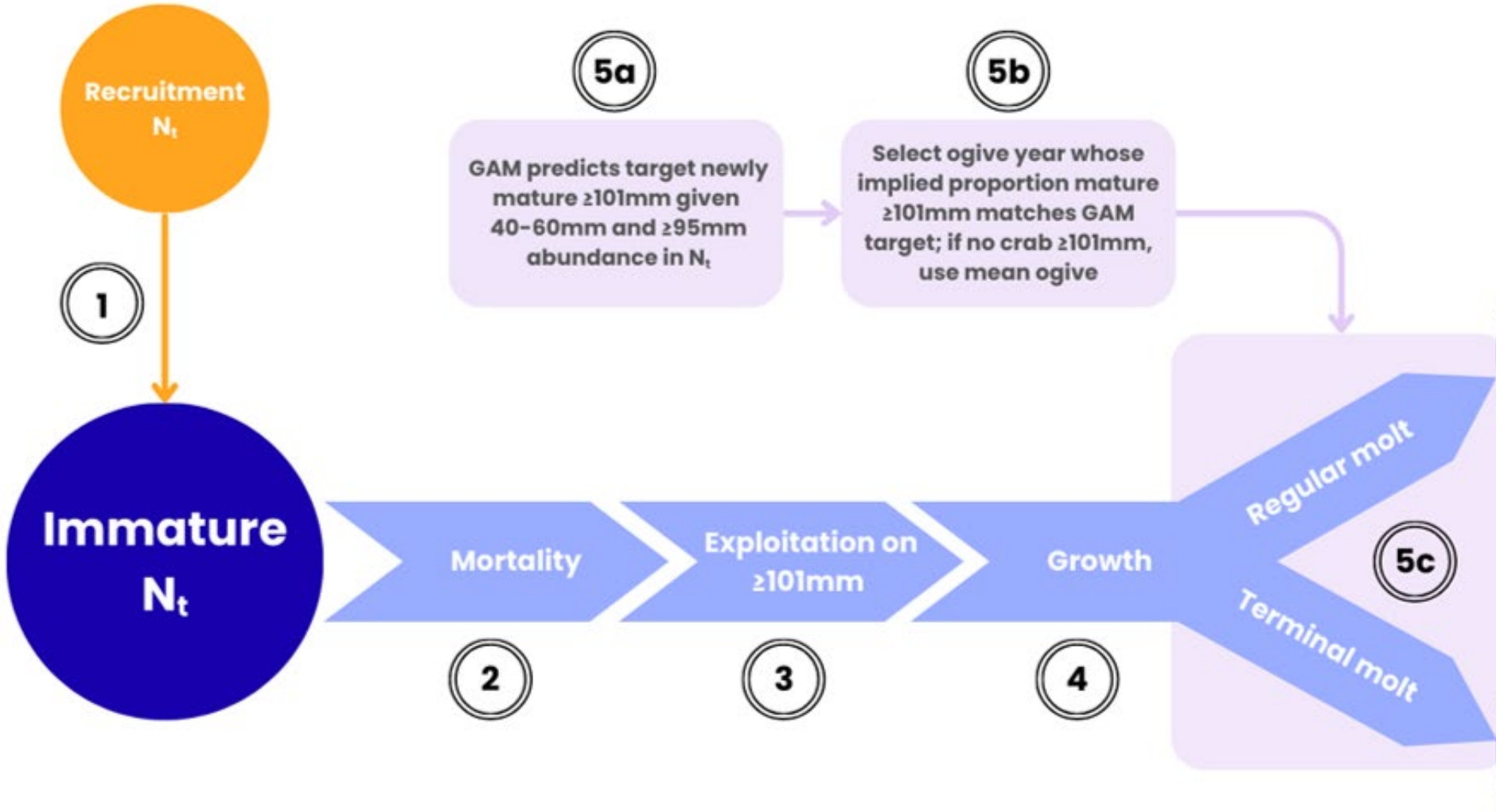

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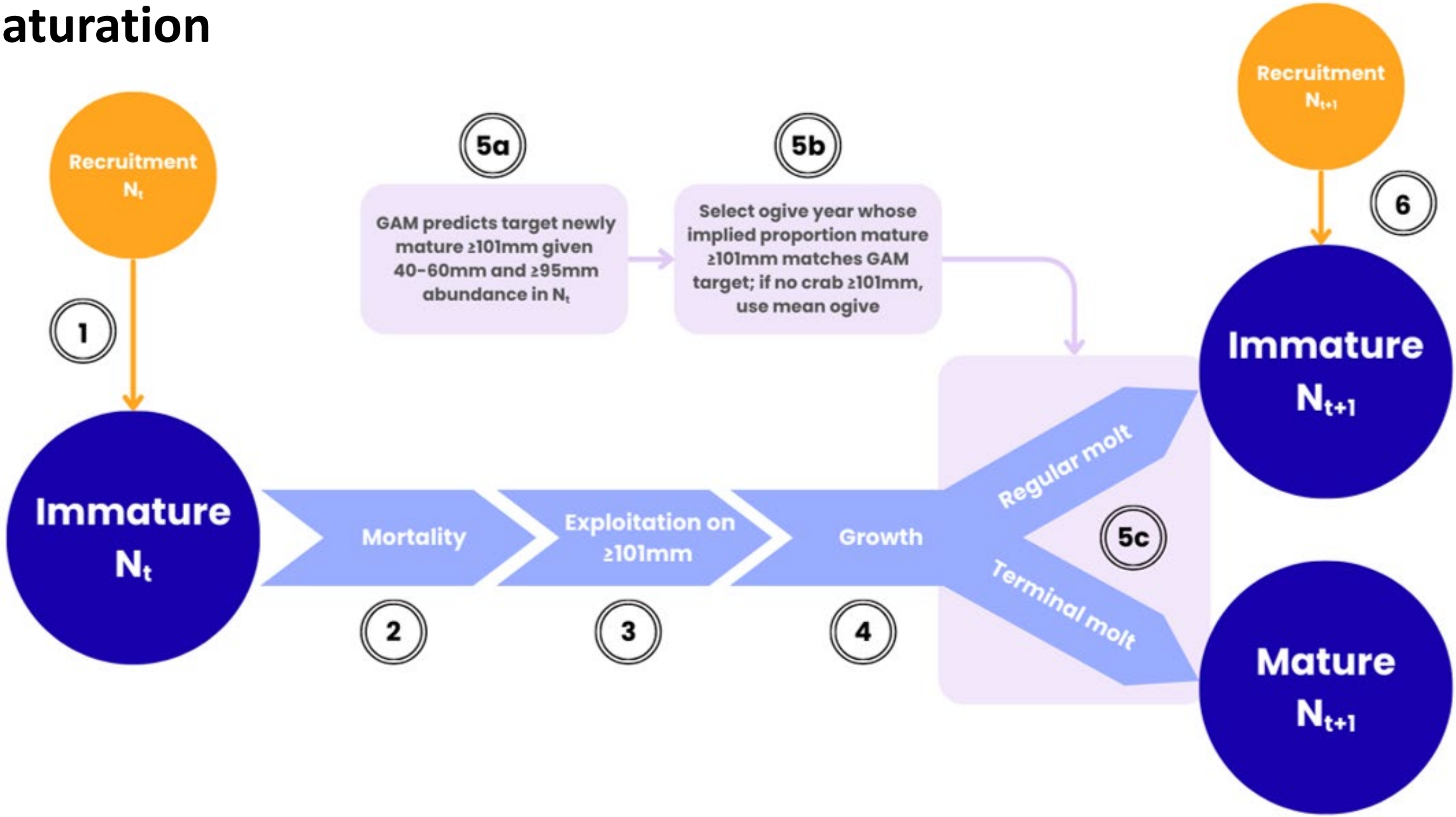
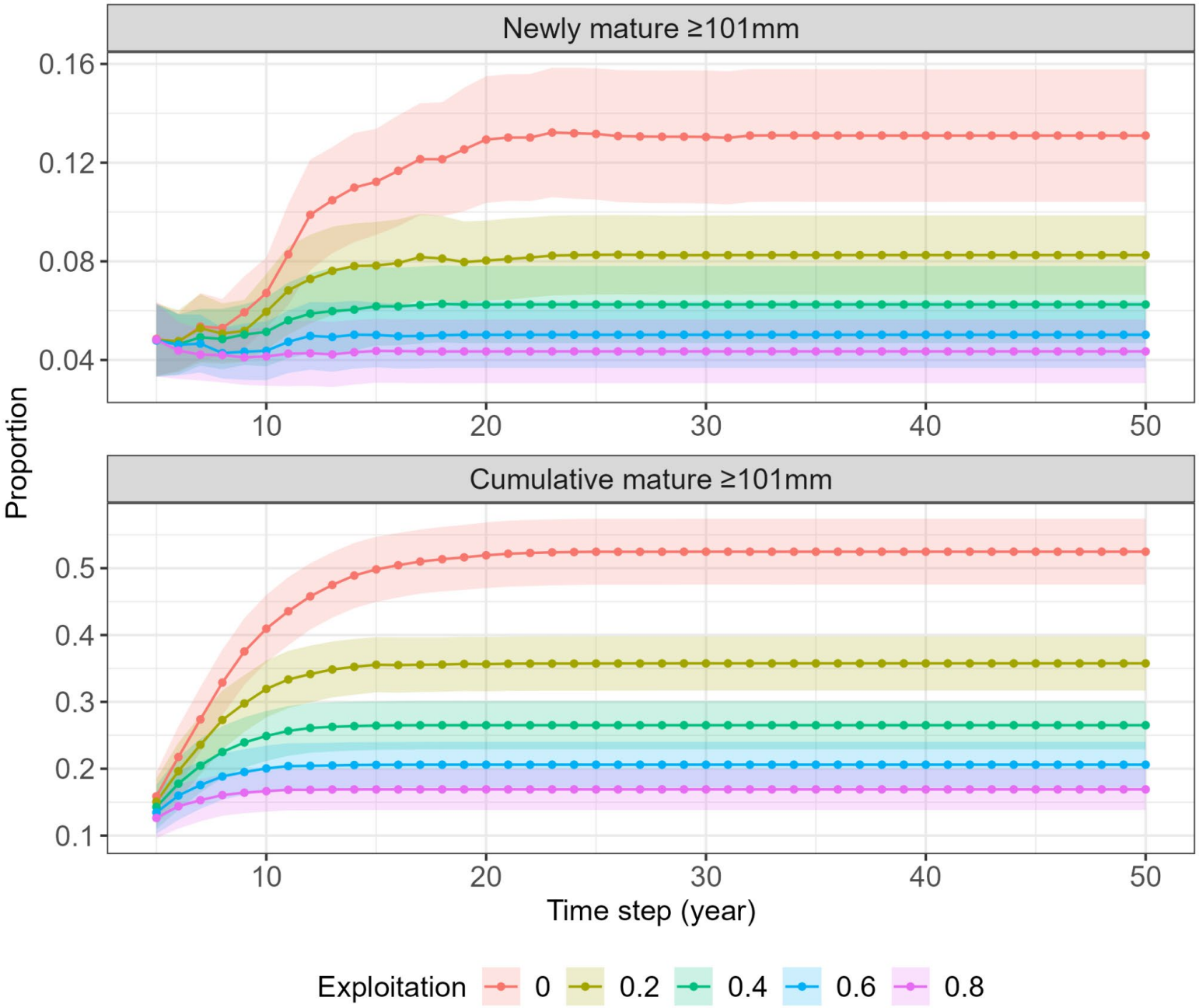


Exploitation decreases the proportion maturing at industry-preferred size



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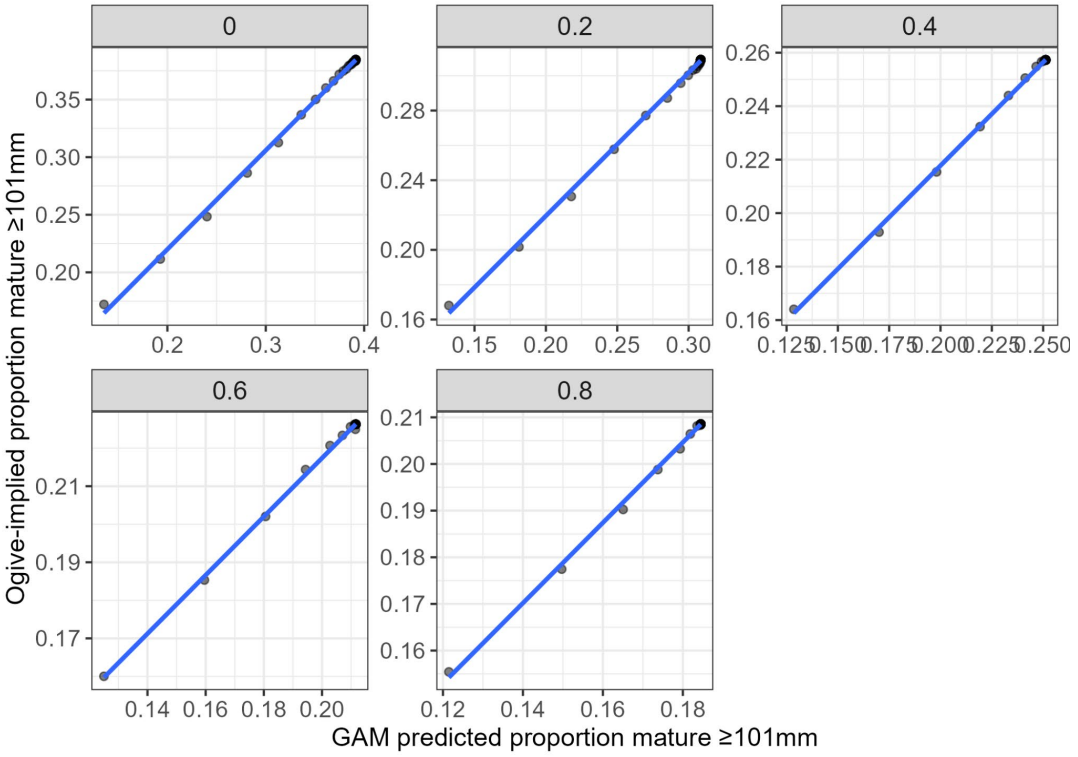

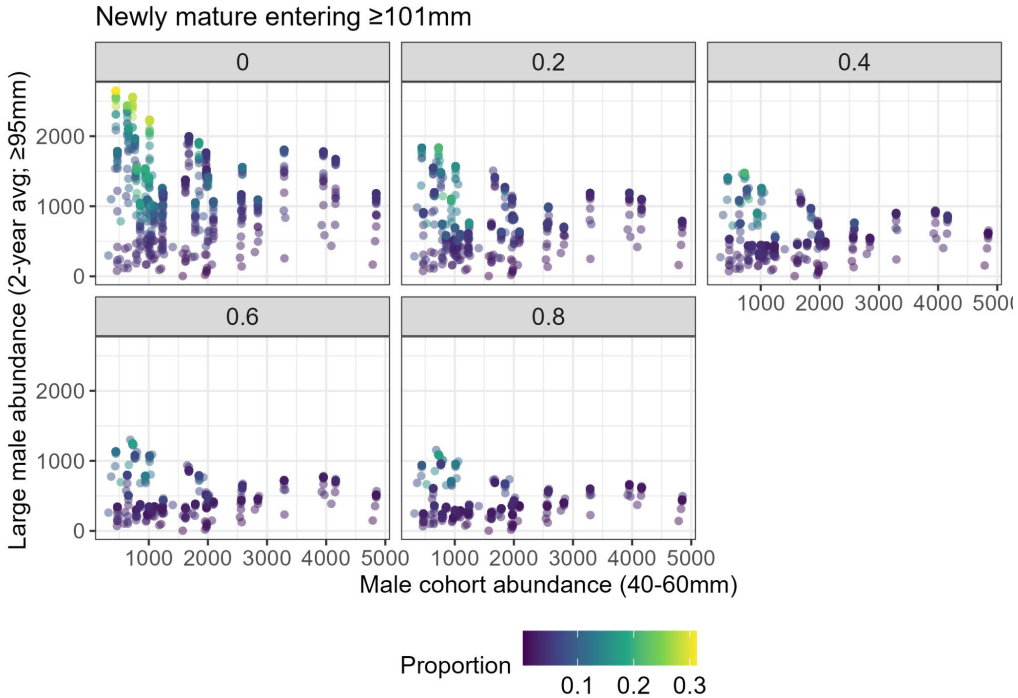

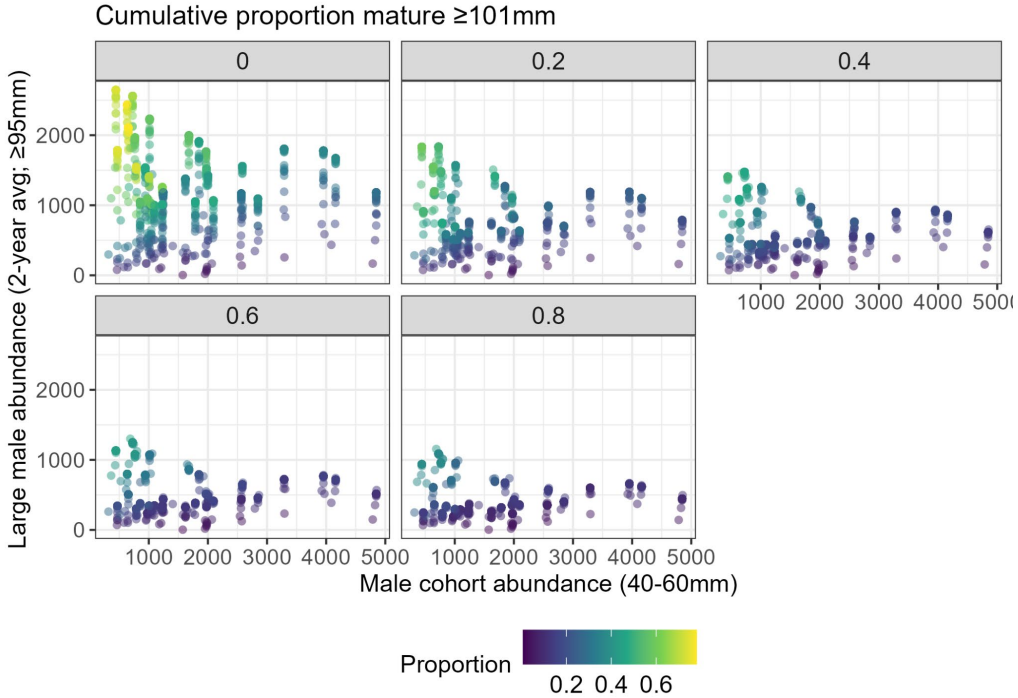

Conclusions

- Male size-at-50% maturity and proportion maturing ≥101mm are declining
  → These parameters are highest when large males are abundant and cohort strength is low
- Recent spikes in large immature females are likely driven by mate limitation delaying maturation
  → Delayed maturation increases the risk that females die before reproducing
- Large males are central to maturity parameters in both sexes
  → Declines in large males may reduce reproductive resilience and fisheries yield
- Exploitation can create a feedback loop by reshaping male size structure and, in turn, maturity

Questions?

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