Identification and success for pre-recruit and recruiting aggregations of the sea scallop (*Placopecten magellanicus*) to enhance spatial management.

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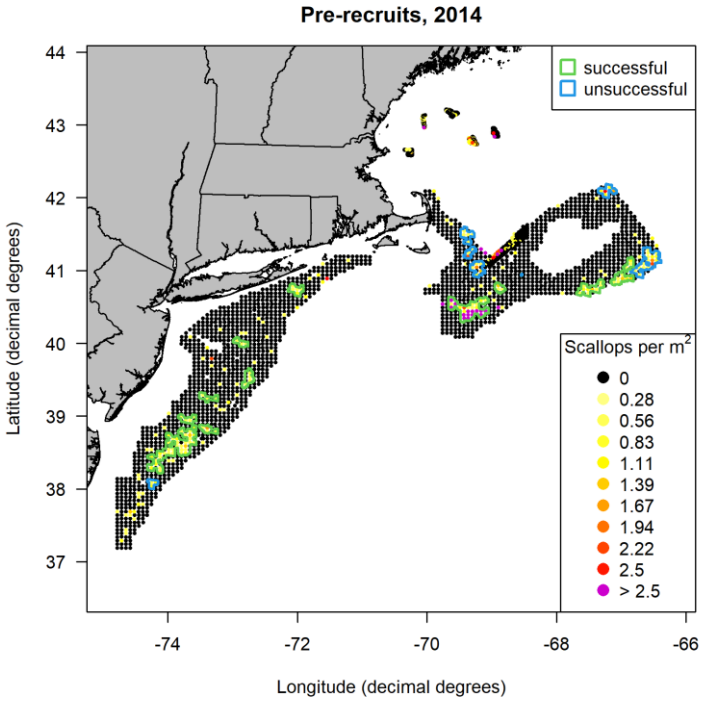
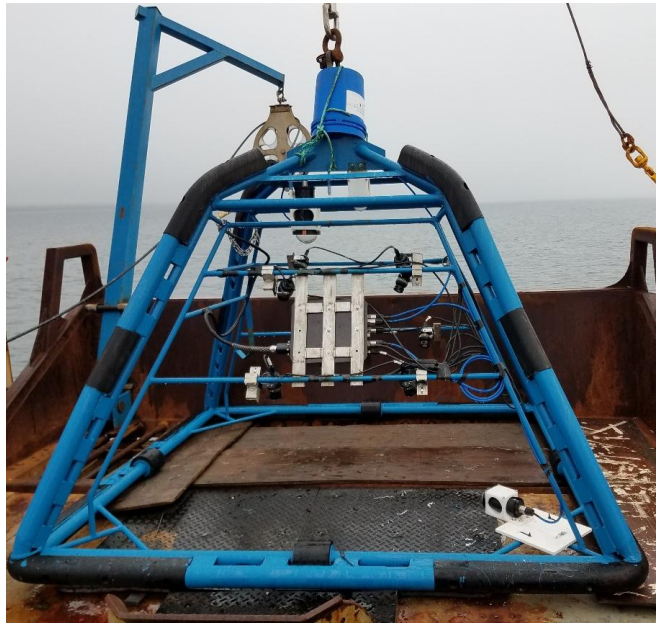




How often do small scallops grow into fishable beds?

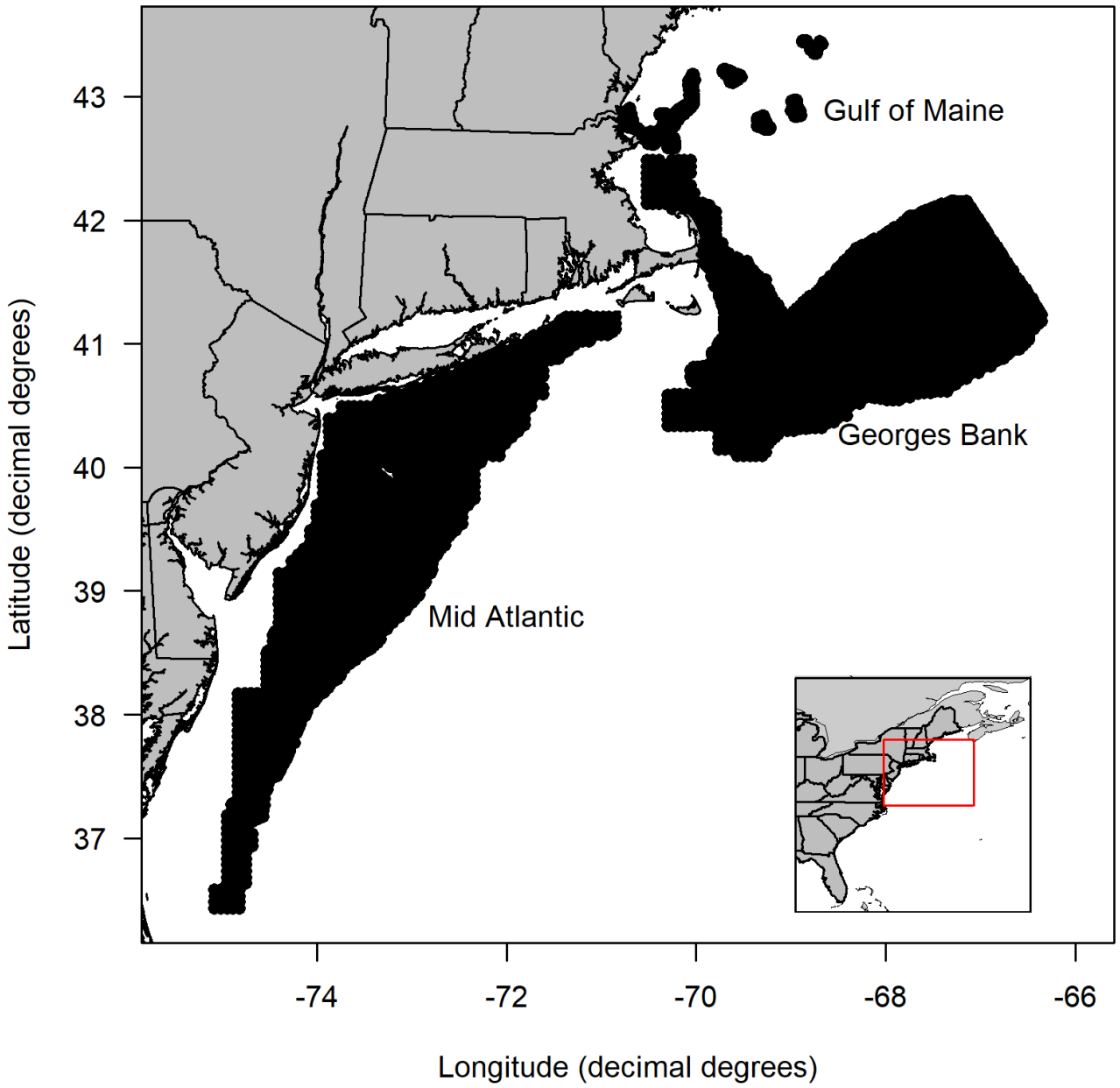
- US sea scallop fishery uses rotational management to protect juveniles.

- Fishery-independent surveys detect high-density juvenile aggregations, but variability in success (Bethoney et al. 2016; Hart & Chang 2022).

- What fraction of juvenile aggregations successfully grow into adult beds and what factors drive this?

Long-term drop camera survey

- 2003 to 2023, 21 years
- Georges Bank, Mid Atlantic, Gulf of Maine
- Systematic grid design with stations 1 to 5.6 km apart
- Scallops counted and measured, plus predators and substrate



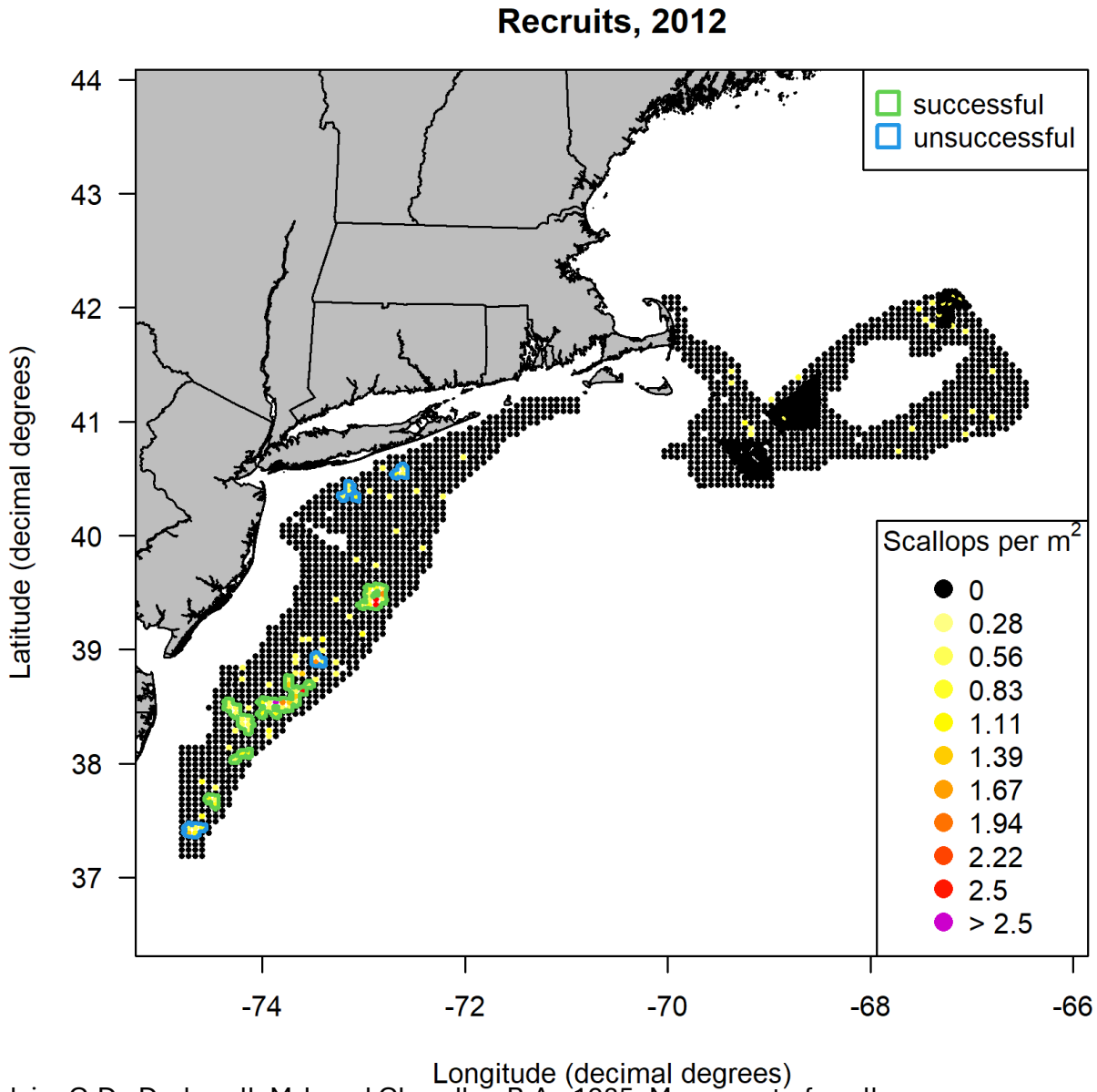
Identifying aggregations and tracking success

Process:

1. Identify: ≥ 3 contiguous stations with ≥ 0.4 scallops per m^2
2. Buffer: Add 10 km buffer around aggregation
3. Track: Look 1-3 years later for adult density increase
4. Quantify: Absolute density increase recorded or 0 for no increase

Two size groups examined:

- Pre-recruits (less than 35 mm shell height)
- Recruits (35 to 75 mm shell height)

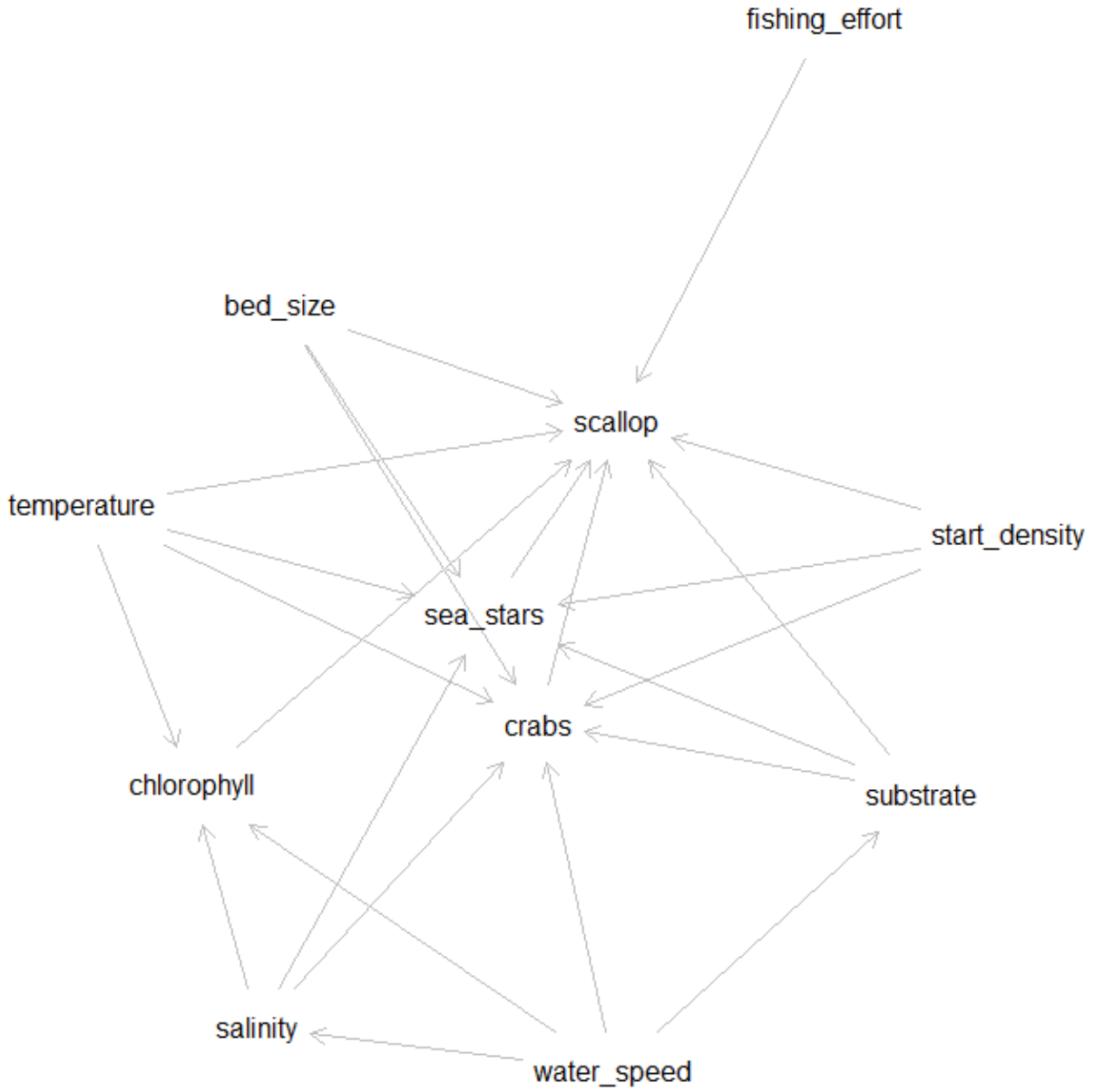


Bethoney, N.D., Asci, S. and Stokesbury, K.D., 2016. Implications of extremely high recruitment events into the US sea scallop fishery. *Marine Ecology Progress Series*, *547*, pp.137-147.

Melvin, G.D., Dadswell, M.J. and Chandler, R.A., 1985. Movement of scallops (*Placopecten magellanicus*) (Gmelin, 1791) (Mollusca: Pectinidae) on Georges Bank. Canadian Atlantic Fisheries Scientific Advisory Committee, Research Document 85/30, pp.29.

Modeling framework

- Bayesian hierarchical model with six linked sub-models
- Four models in total (two size groups x with/without fishing effort)
- Hurdle components employed to assess binary success and magnitude of success



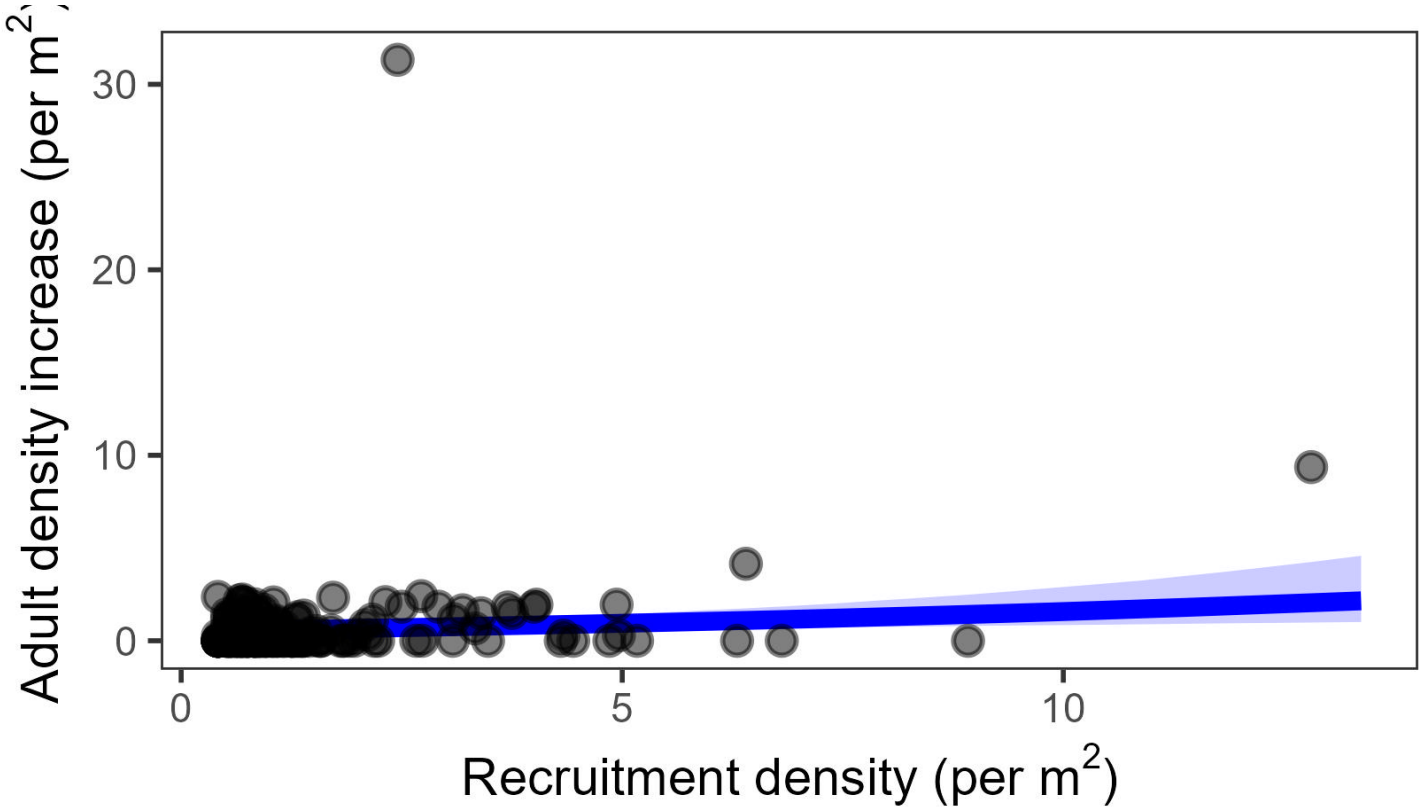
Causal modeling framework to account for confounding among covariates

Success rates

	Pre-recruits (< 35 mm shell height)		Recruits (35 to 75 mm shell height)	
	2003 to 2023, no fishing effort	2010 to 2023, fishing effort	2003 to 2023, no fishing effort	2010 to 2023, fishing effort
Aggregations identified	116	105	230	130
Successful	56 (48.3%)	51 (48.6%)	101 (43.9%)	60 (46.2%)
Unsuccessful	60 (51.7%)	54 (51.4%)	129 (56.1%)	70 (53.8%)

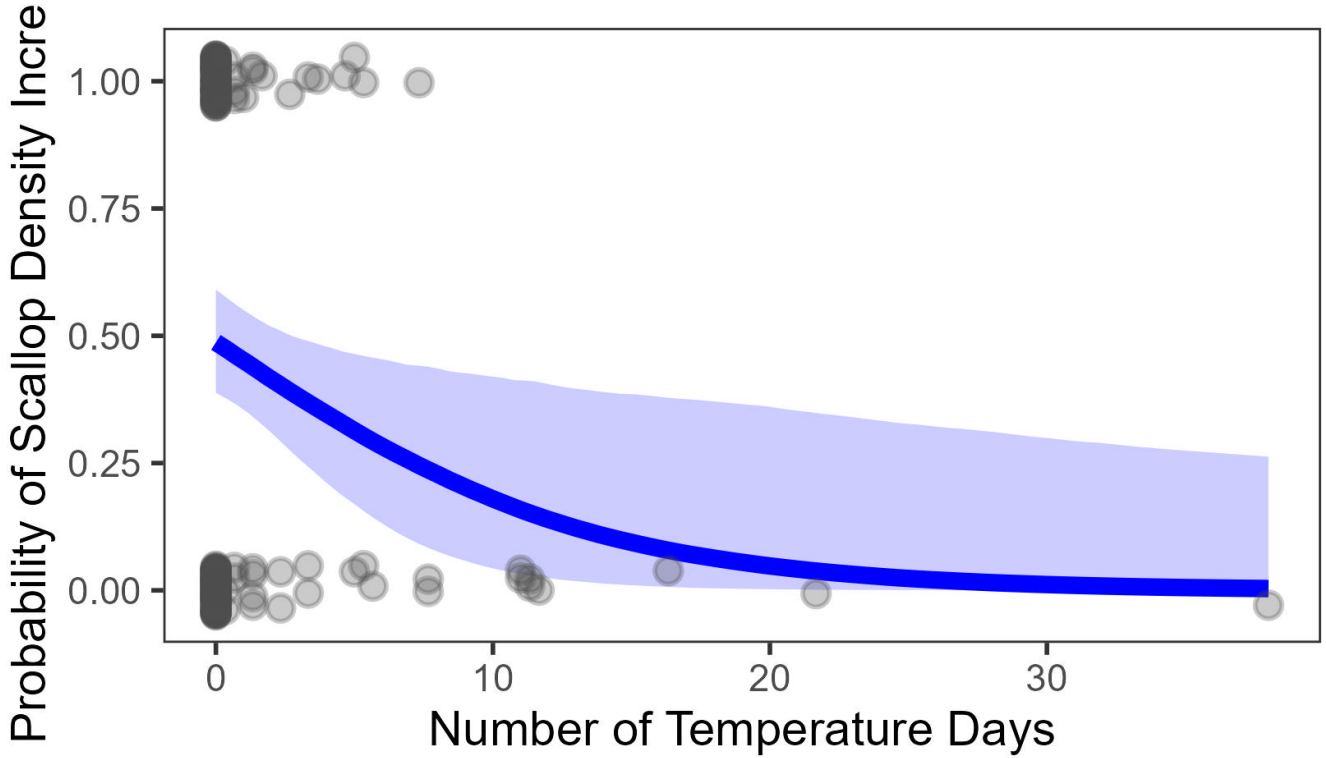
Higher juvenile density and greater adult scallop increase

- Higher juvenile density led to greater adult scallop density increase
- Consistent across all four models
- Sensitive to outliers in the recruit + fishing effort model

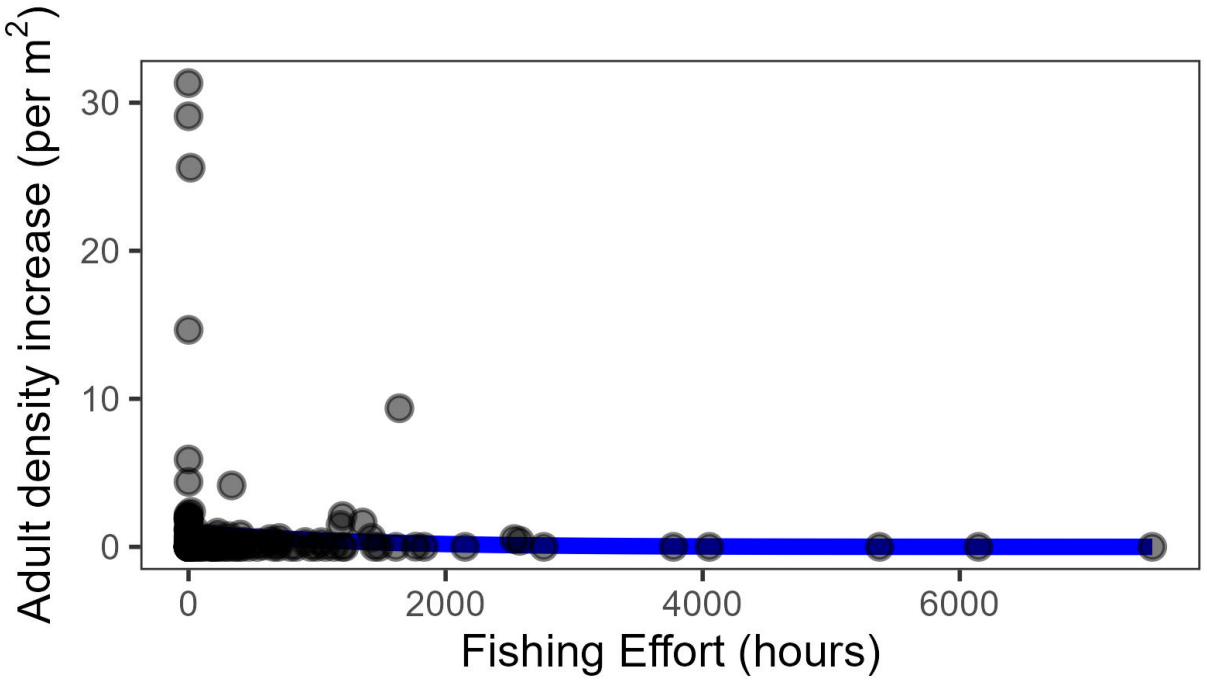


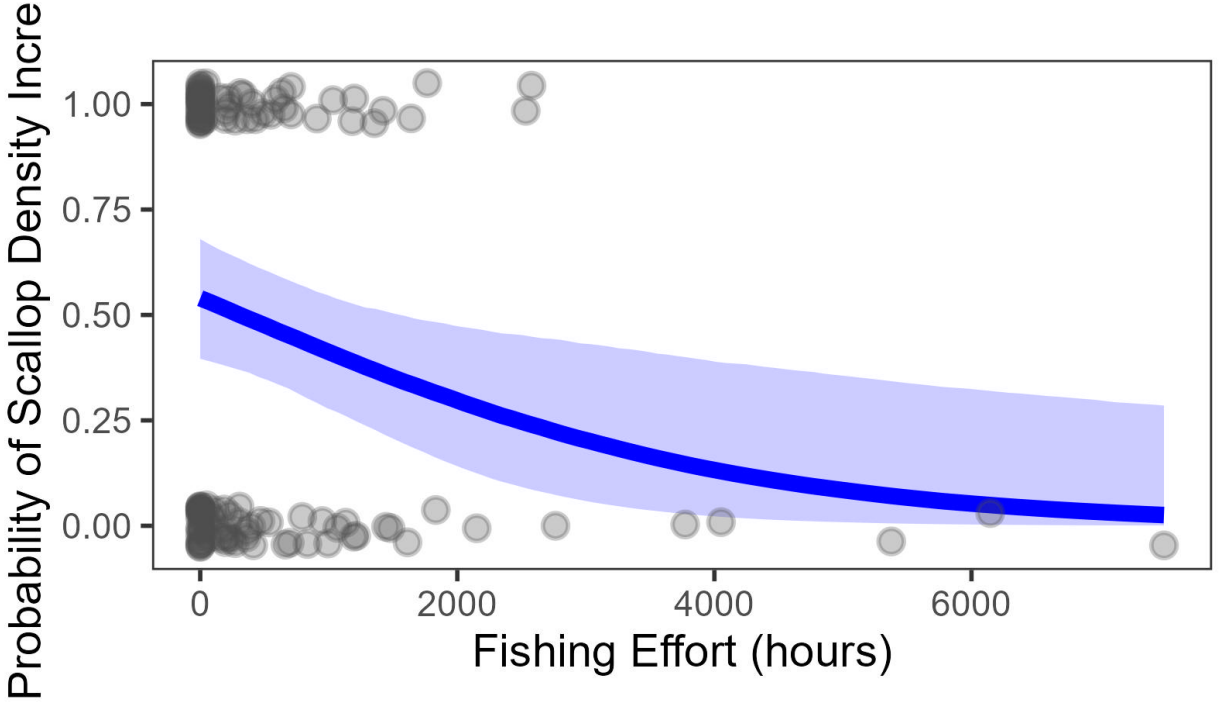
Temperature effect for recruits

- More warm days (> 18°C) leads to lower success for recruits
- Crab density significantly higher with more warm days in recruit model



Fishing effort on recruits





- No significant effect on pre-recruits

Patterns across models

Finding	Pre-recruit models		Recruit models	
Higher juvenile density leads to increase in adult density increase	✓	✓	✓	✓★
More warm temperature days changes probability of success	↑	↑	↓	↓
Higher fishing effort leads to lower probability and magnitude of success	Not significant		✓	

- Crabs more likely in large juvenile aggregations (all four models).
- Lower salinity associated with higher chlorophyll a concentrations (all four models) (Churchill et al 2003; Xu et al 2011; Friedland et al 2024).
- Sea stars denser on gravel and crabs denser on sand (Wong and Barbeau 2003).

Management implications

- Set expectations: 44-49% success rates
- Fishing effort significant finding for recruits strengthens arguments to protect scallops 35 to 75 mm SH from fishing pressure
- Temperature negatively affected recruit sized scallops
- The results and models could be adjusted to function operationally and make probabilistic forecasts about identified juvenile aggregations

Caveats and future work

- Survey coverage gaps meant some aggregations couldn’t be tracked
- Assignment of variables to juvenile aggregation polygons smoothed out variability
- Future work: Fine-scale predator-prey dynamics, better food availability data, and explicit modeling of acute fishing events

Summary

- Long-term fishery-independent survey.
- Identified 346 juvenile aggregations across the two groups, 44-49% success.
- Key drivers were juvenile density, temperature, and fishing effort.
- Keep monitoring and protect recruit sized scallops.

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