The Snow Crab IBM & BCM: Basis for Potential ESP Indicators?

William T. Stockhausen
Alaska Fisheries Science Center
May, 2022

Acknowledgments

- Contributors
  - Michael Torre, Christine Stawitz, Bob Foy, Cody Szuwalski
  - Al Hermann, Kelly Kearney, Wei Cheng
  - Erin Fedewa, Louise Copeman, Jon Richar
  - Kirstin Holsman, Kerim Aydin, Anne Hollowed

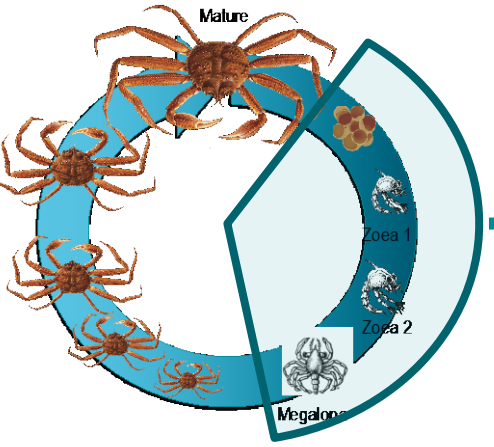
- Funding:
  - Magnuson-Stevens Act
  - FATE

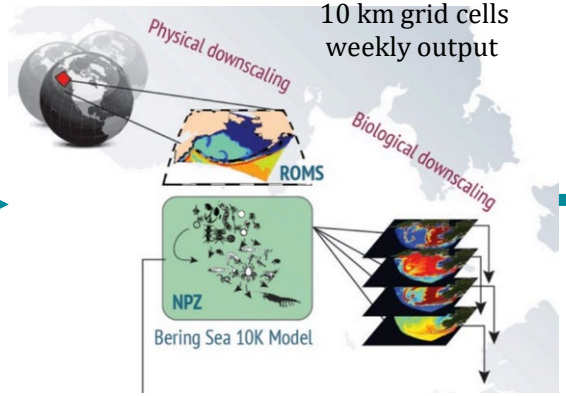
NOAA FISHERIES

What am I talking about?

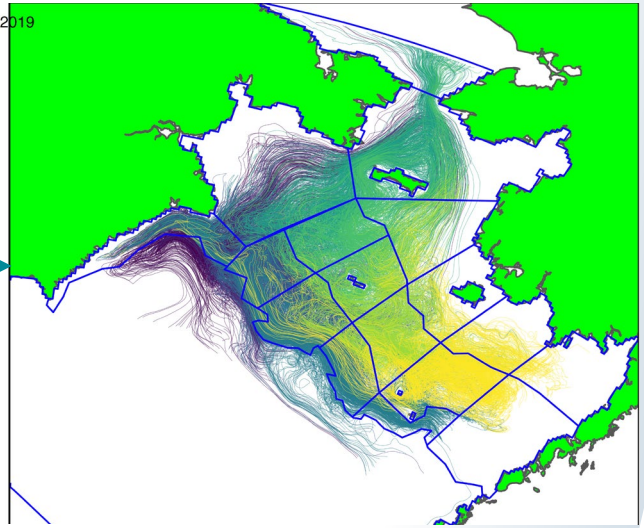
- IBM: individual-based model
  - tracks simulated individuals through larval, postlarval life stages from hatch location to settlement
  - movement patterns
    - ROMS ocean currents
    - vertical movement behavior
  - development (growth)
    - temperature dependence of molt duration (lab experiments)
    - in situ ROMS water column temperatures
  - mortality: assumed rates
  - settlement in benthic nursery habitats
    - (assumed) depth range + temperature range
- BCM: benthic cohort model (follow-on to IBM)
  - tracks benthic instar abundance in ROMS grid by settlement cohort
  - in situ ROMS bottom temperatures
    - temperature dependence of molt duration
    - temperature dependent mortality rates (think "cod predation")

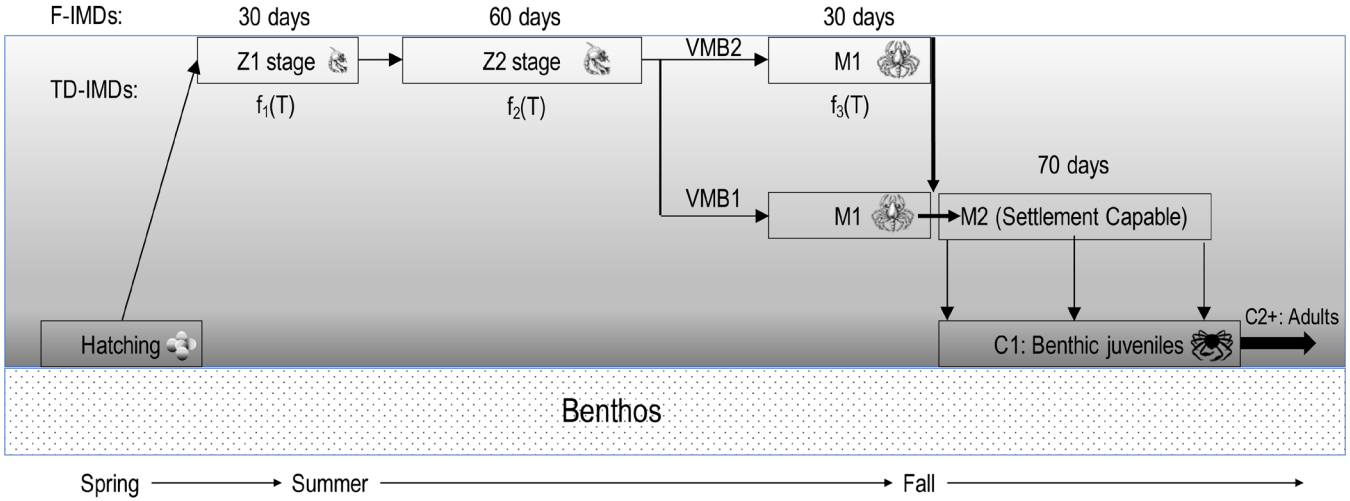
Snow crab IBM





32 vertical layers,
10 km grid cells
weekly output

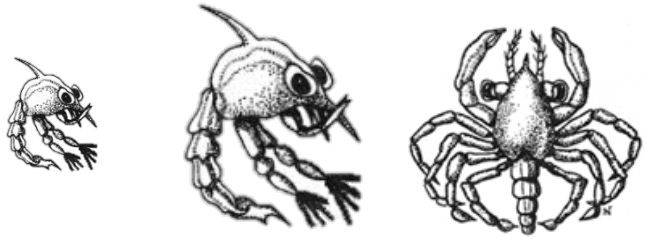




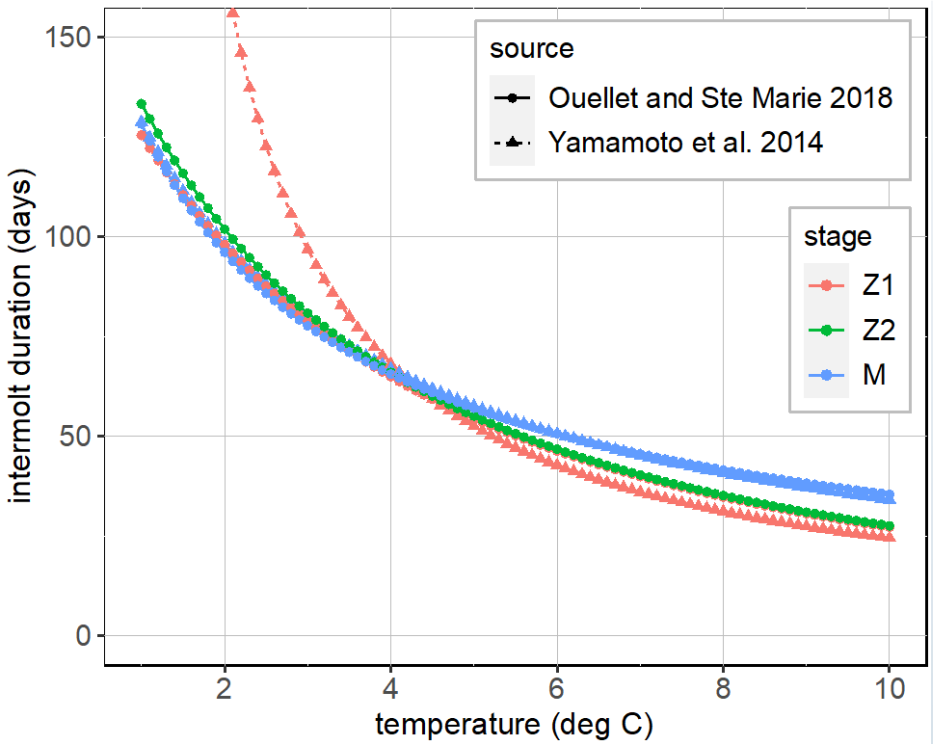
NOAA FISHERIES

Pelagic life stages

Z1 Z2 M



- temperature-dependent or fixed intermolt durations (IMDs)



- "swim" up or down into preferred depth ranges
  - zooea: 0 – 20 m (Incze 1987, Ouellet & Ste Marie 2018)
  - megalopae: 50 – 150 m (Lovrich 1995, Ouellet & Ste Marie 2018)
  - undergo vertical random walks within preferred depth ranges
  - no active horizontal movement (just drift)
- settlement habitat (suitable benthic nursery habitat)
  - assumed depth ranges (25-200 m)
  - assumed temperatureranges

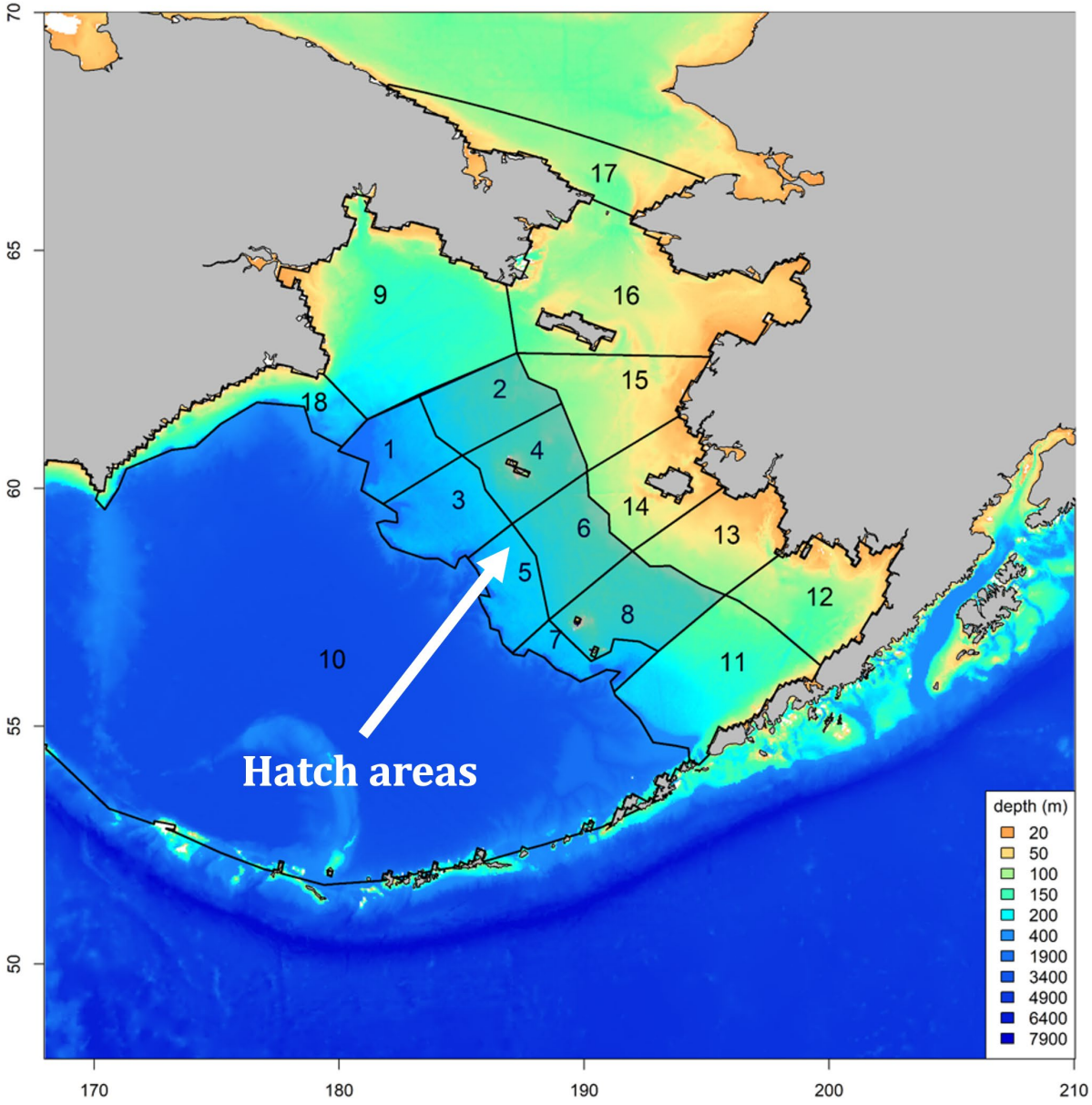
NOAA FISHERIES

Model start

Annual model runs
- 1971-2019
- start: hatch date
- end: Dec. 1

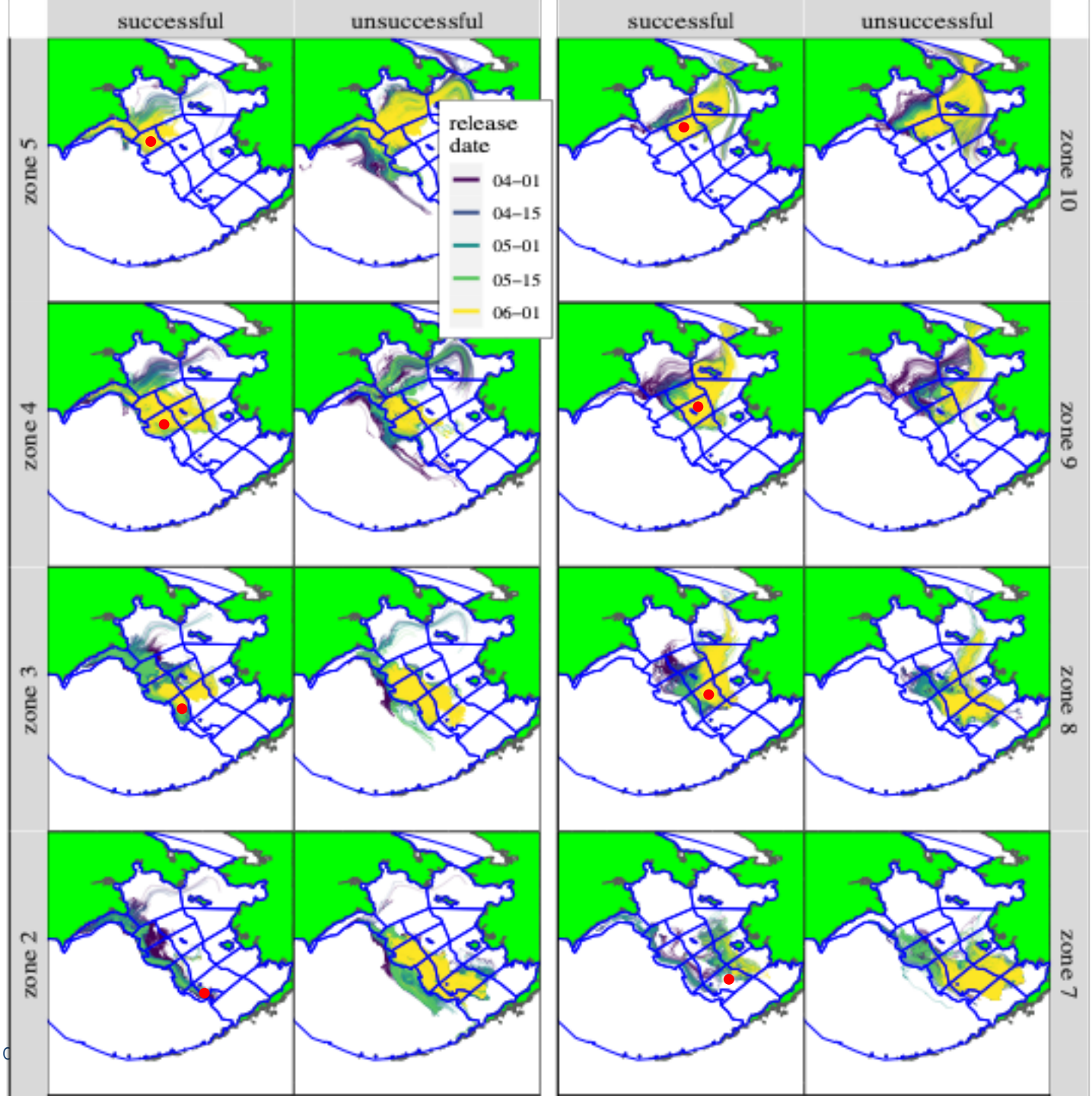
5 hatch dates
- Apr 1, 15
- May 1, 15
- Jun 1

32,651 individuals/hatch
- 3 km spacing

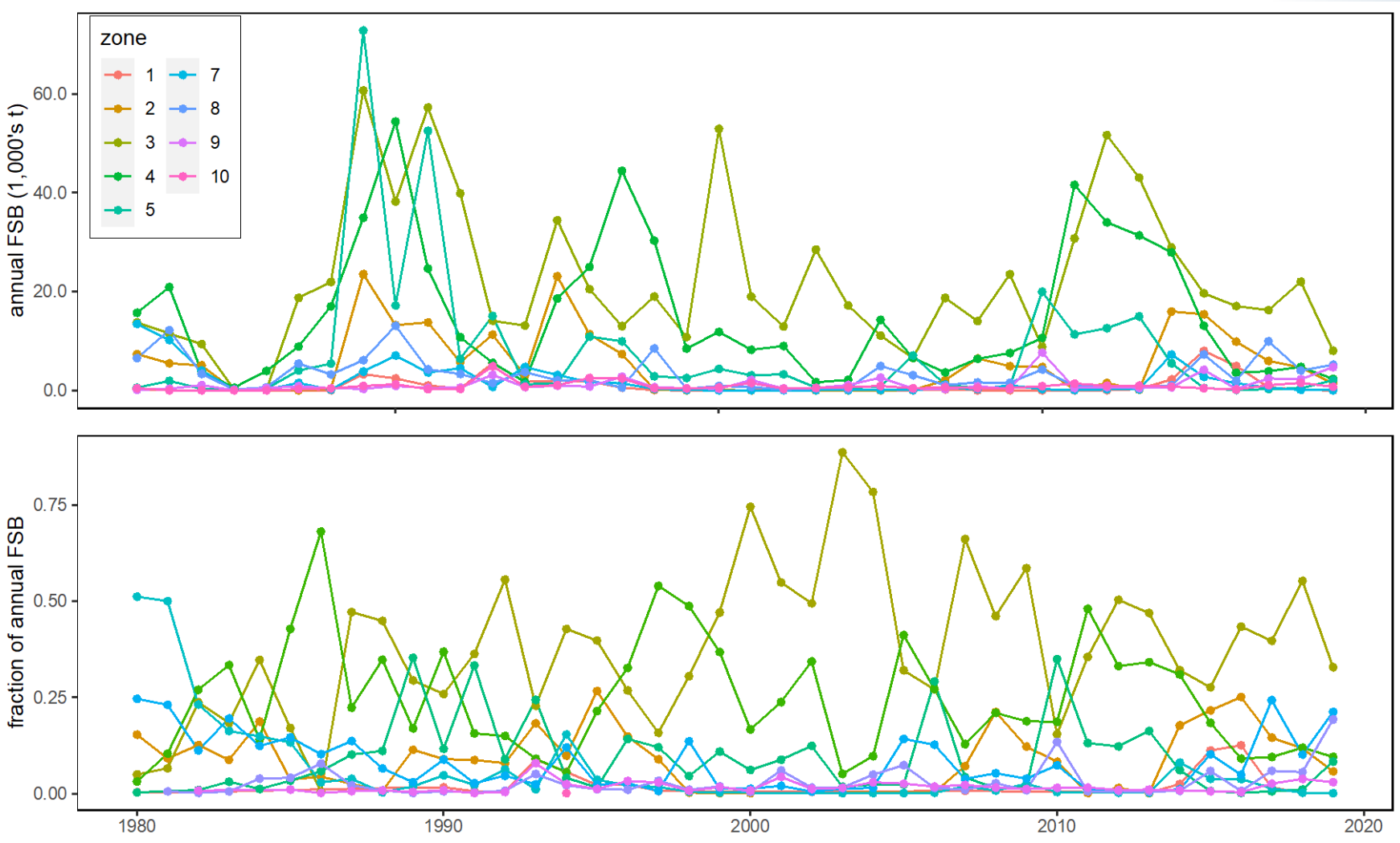


NOAA FISHERIES

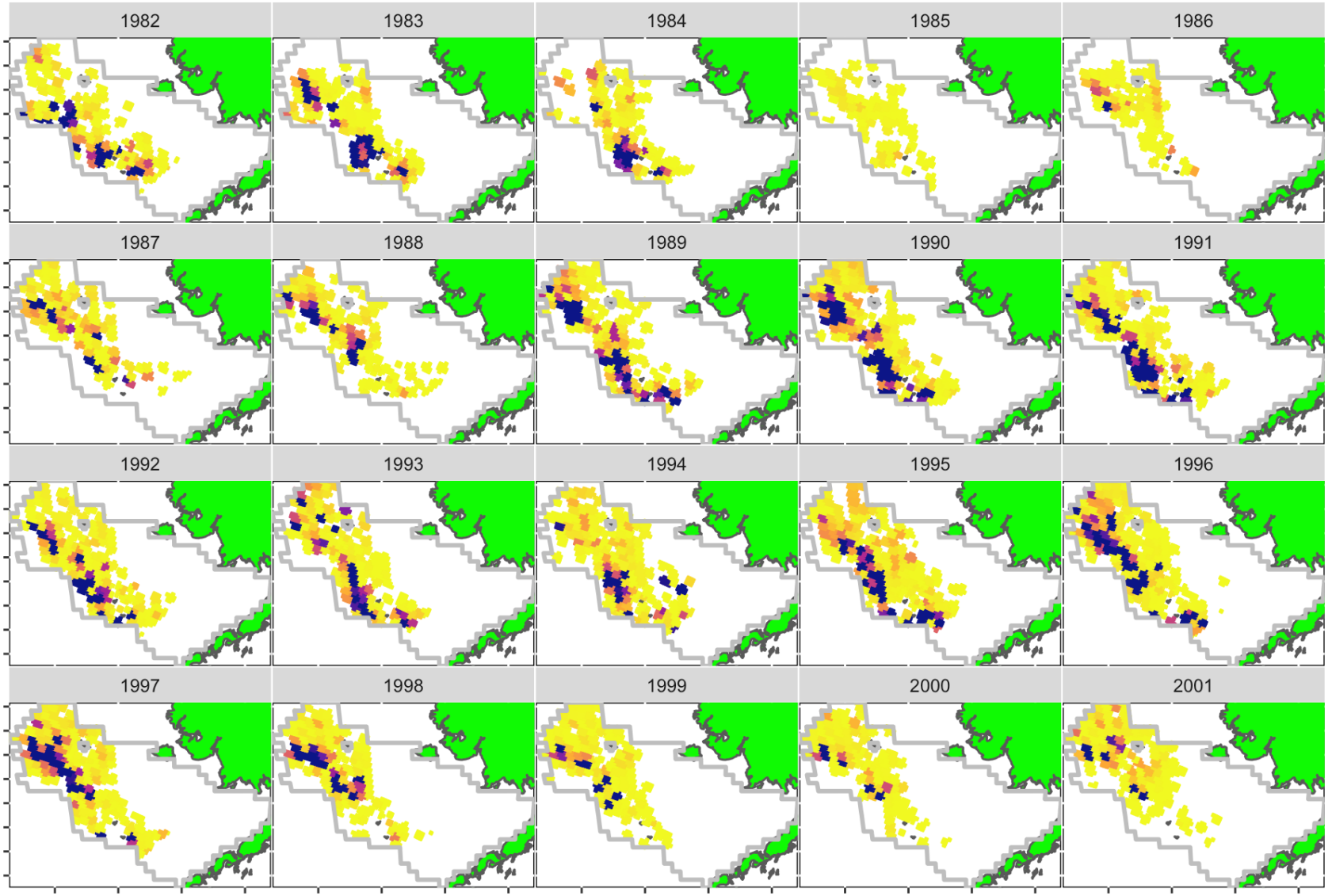
Example Trajectories



Adding in variability in egg production: spatiotemporal variation old shell female biomass



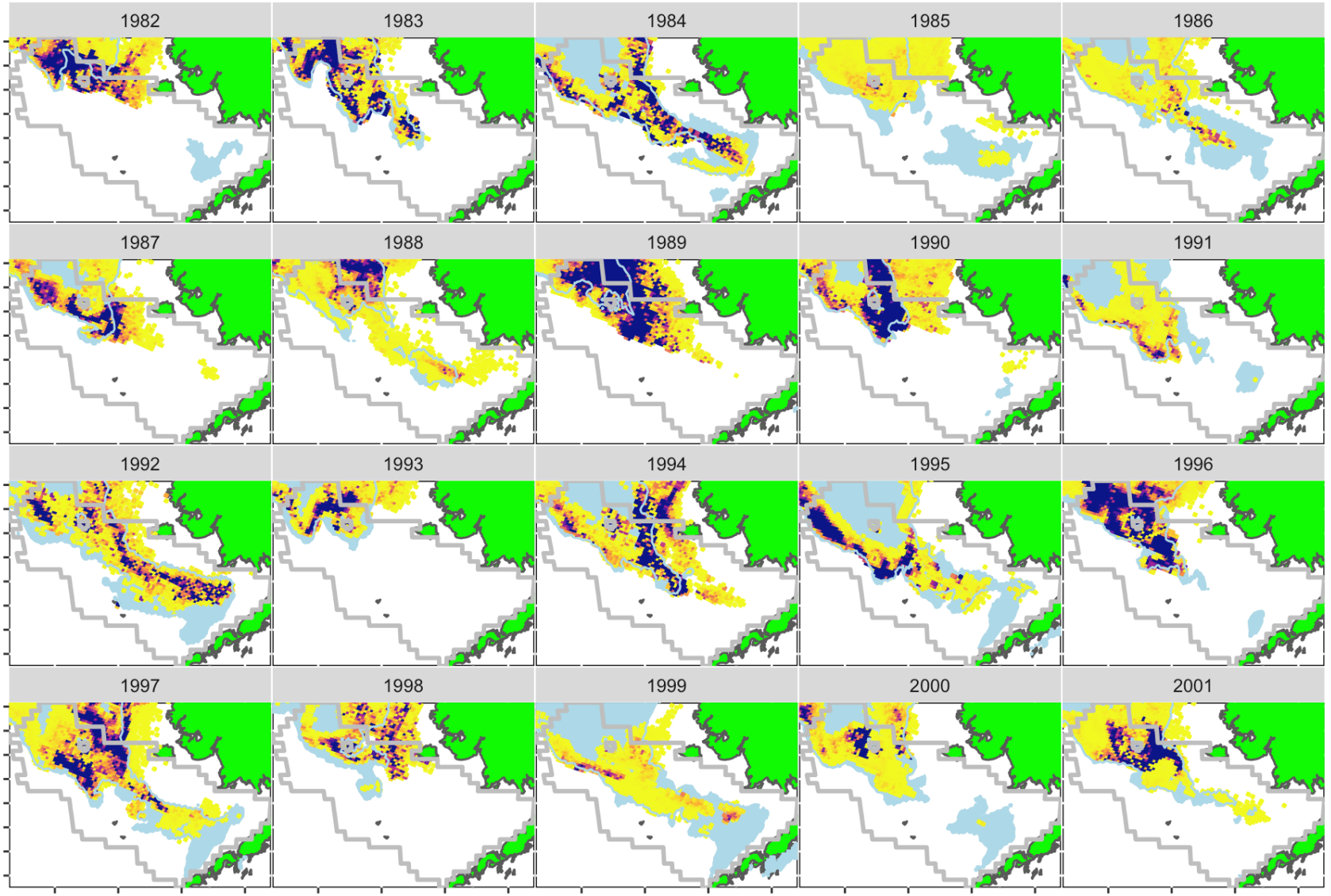
Hatch Patterns: 1982-2001



Settlement Patterns: 1982-2001

assumed: 0%/day mortality

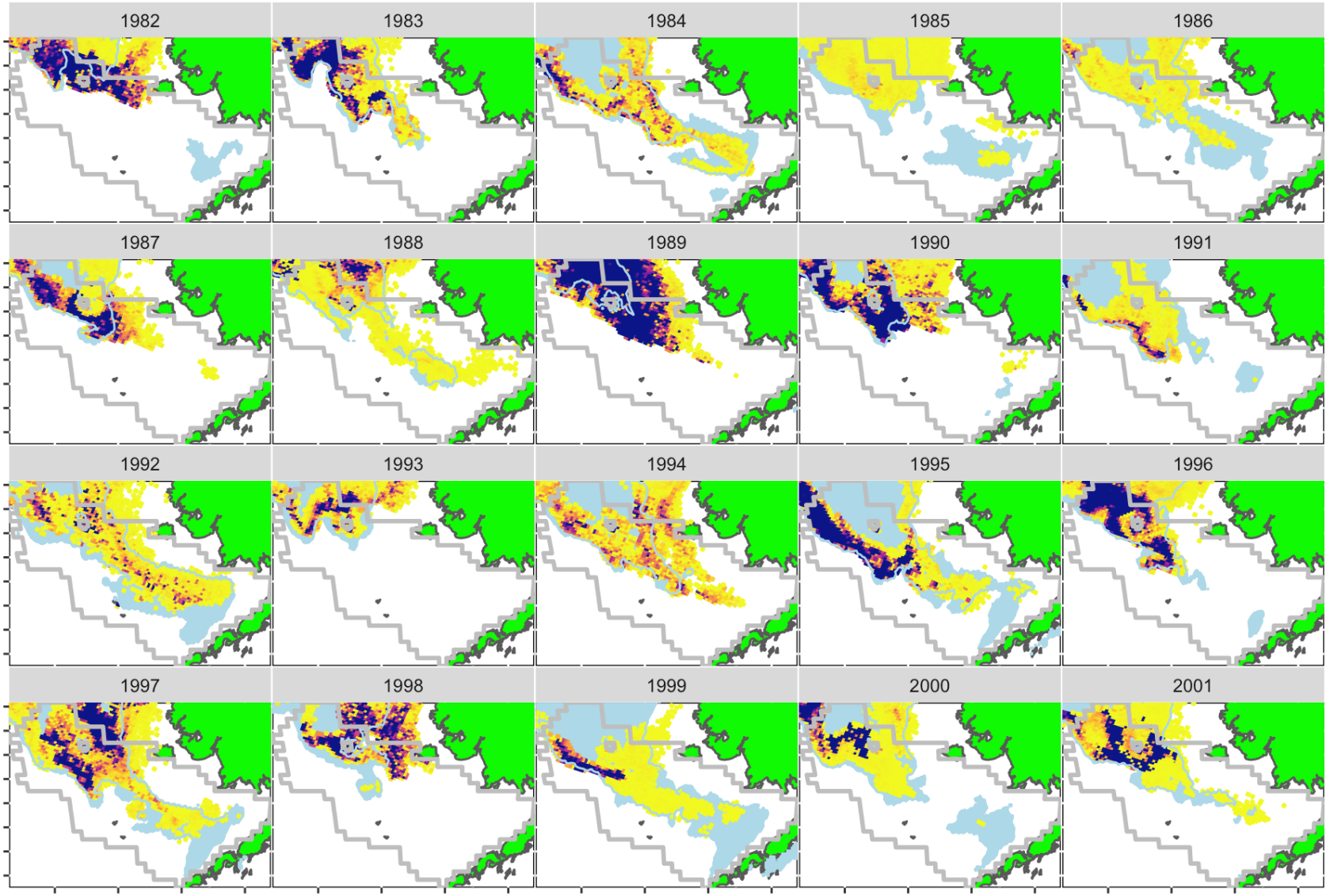
Base Model



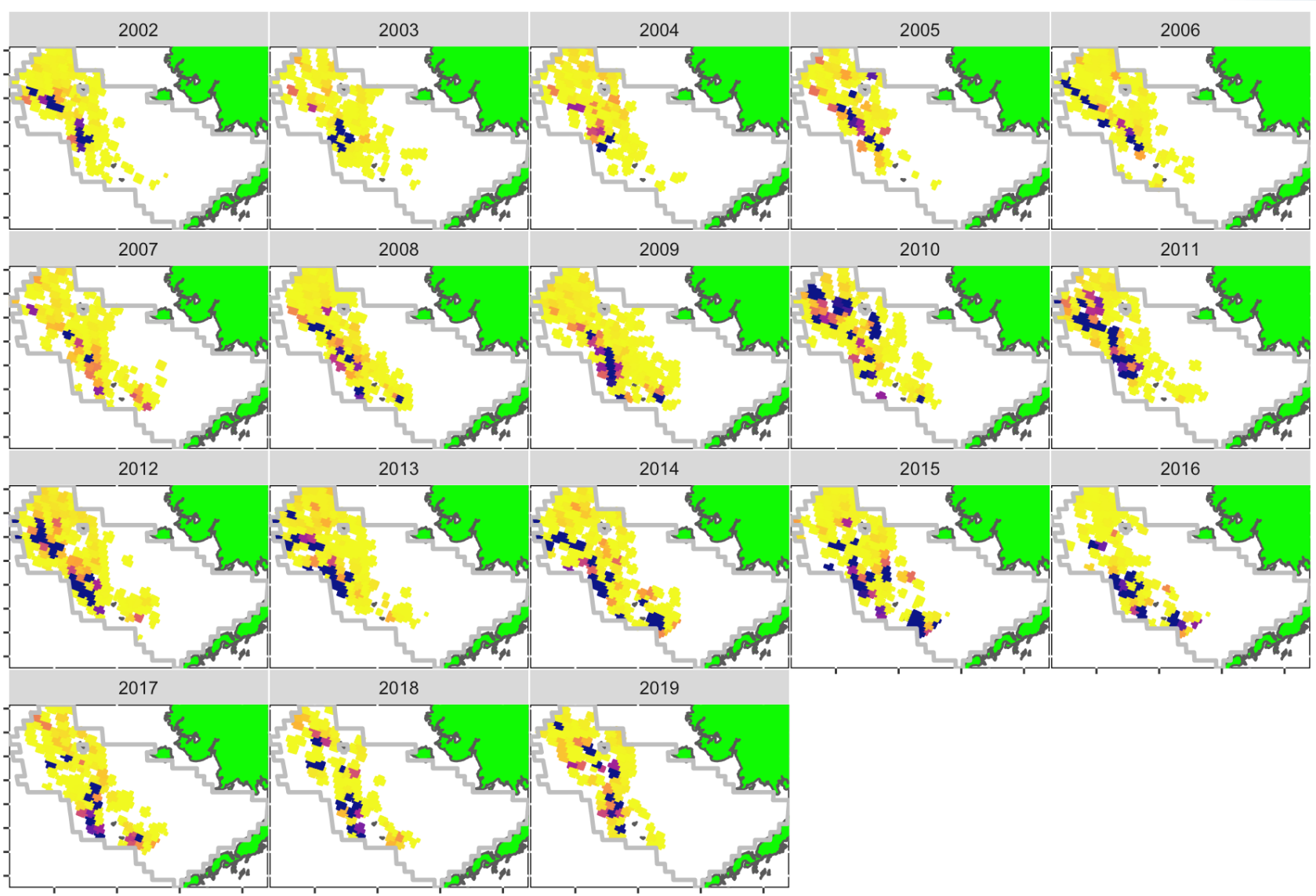
Settlement Patterns: 1982-2001

assumed: 8%/day mortality

Base Model



Hatch Patterns: 2002-2019

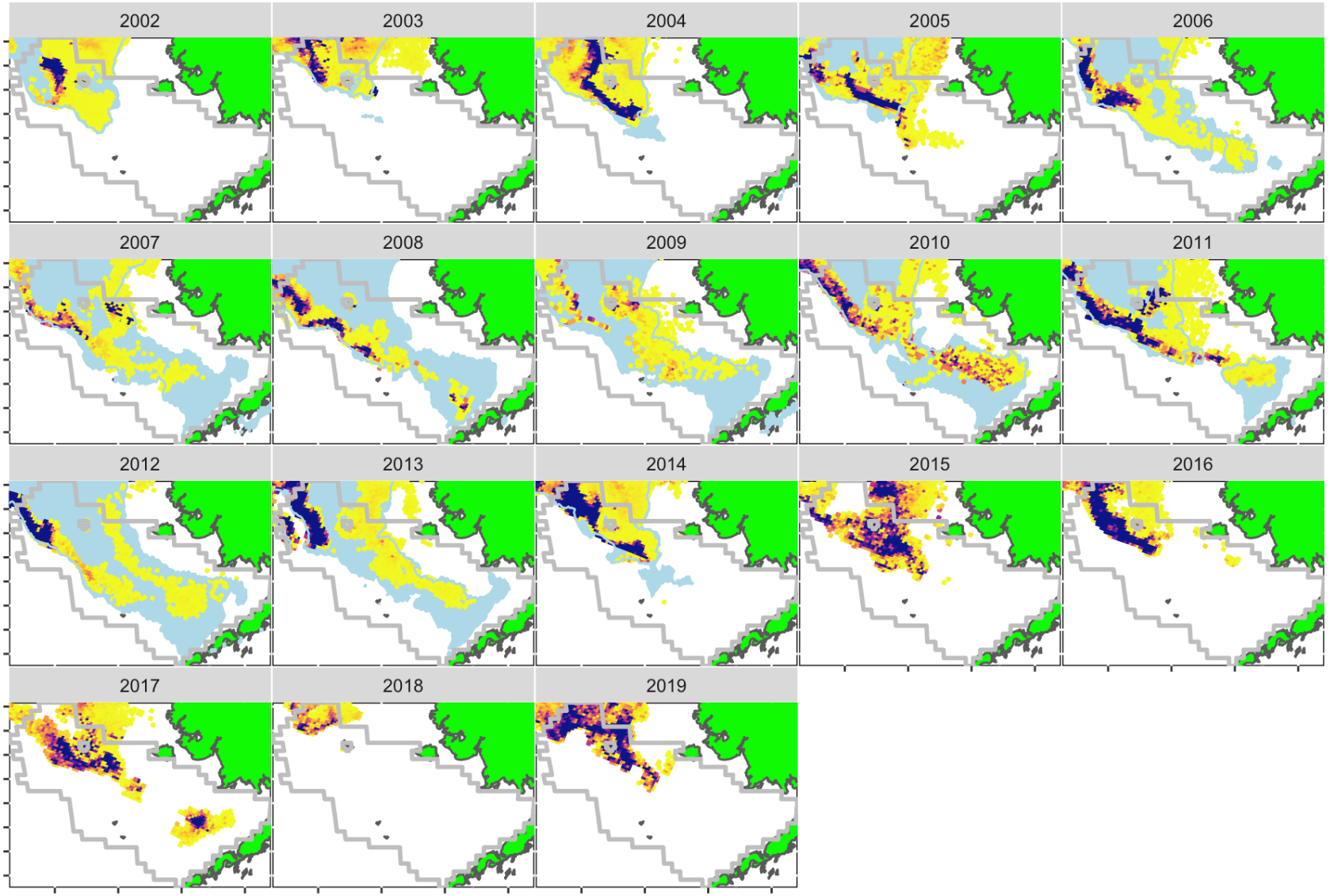


NOAA FISHERIES

Settlement Patterns: 2002-2019

assumed: 0%/day mortality

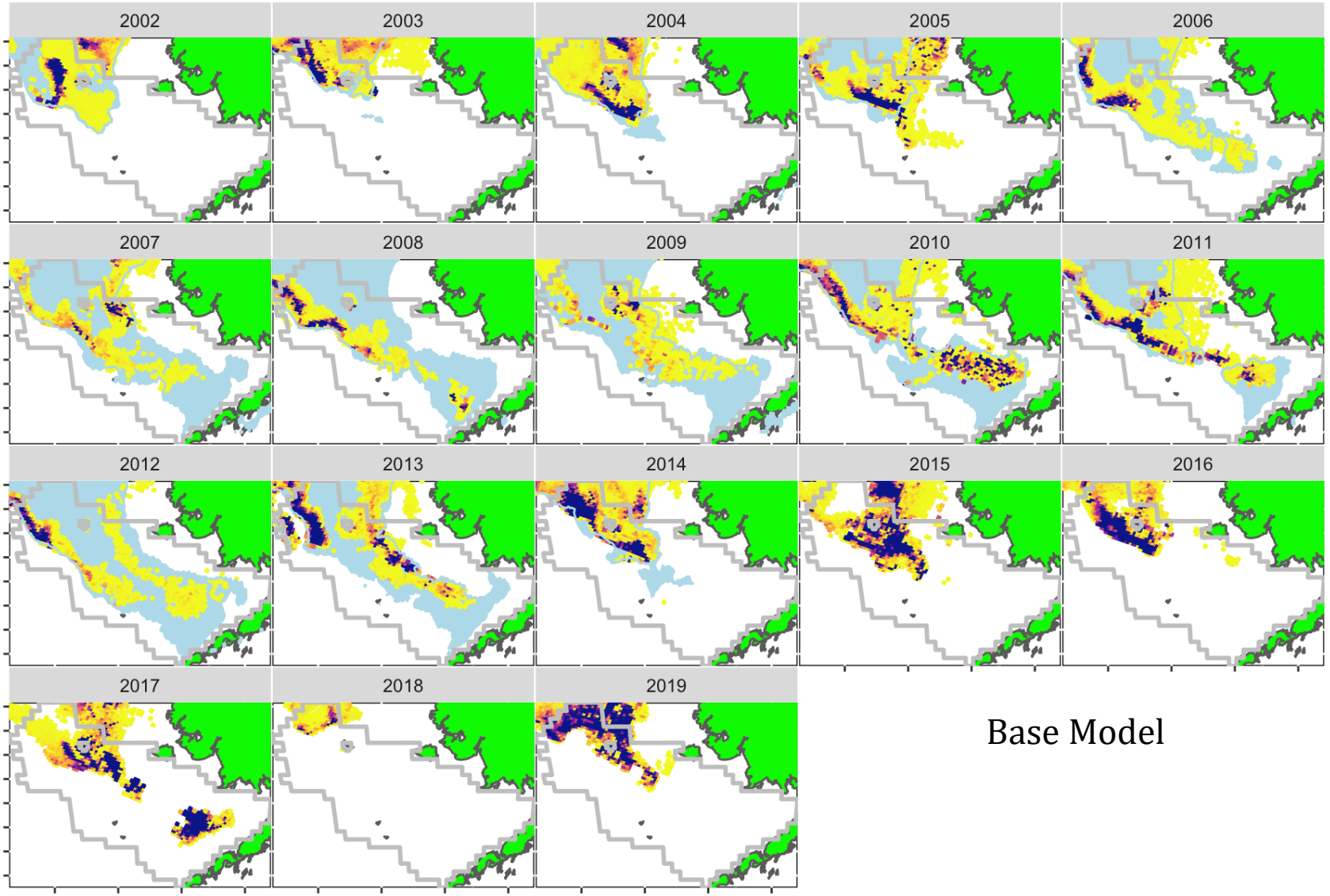
Base Model



Settlement Patterns: 2002-2019

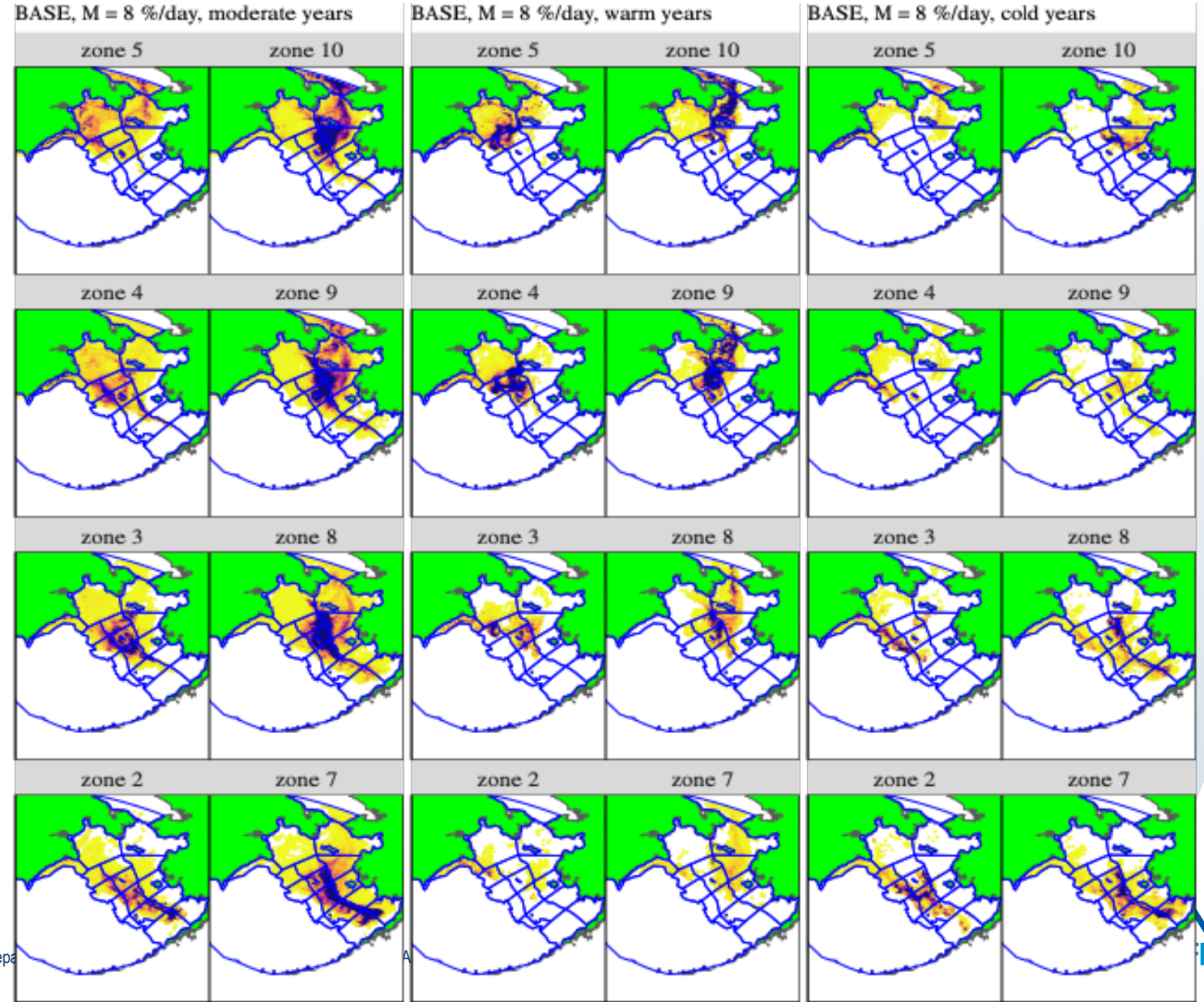
assumed: 8%/day mortality

Base Model



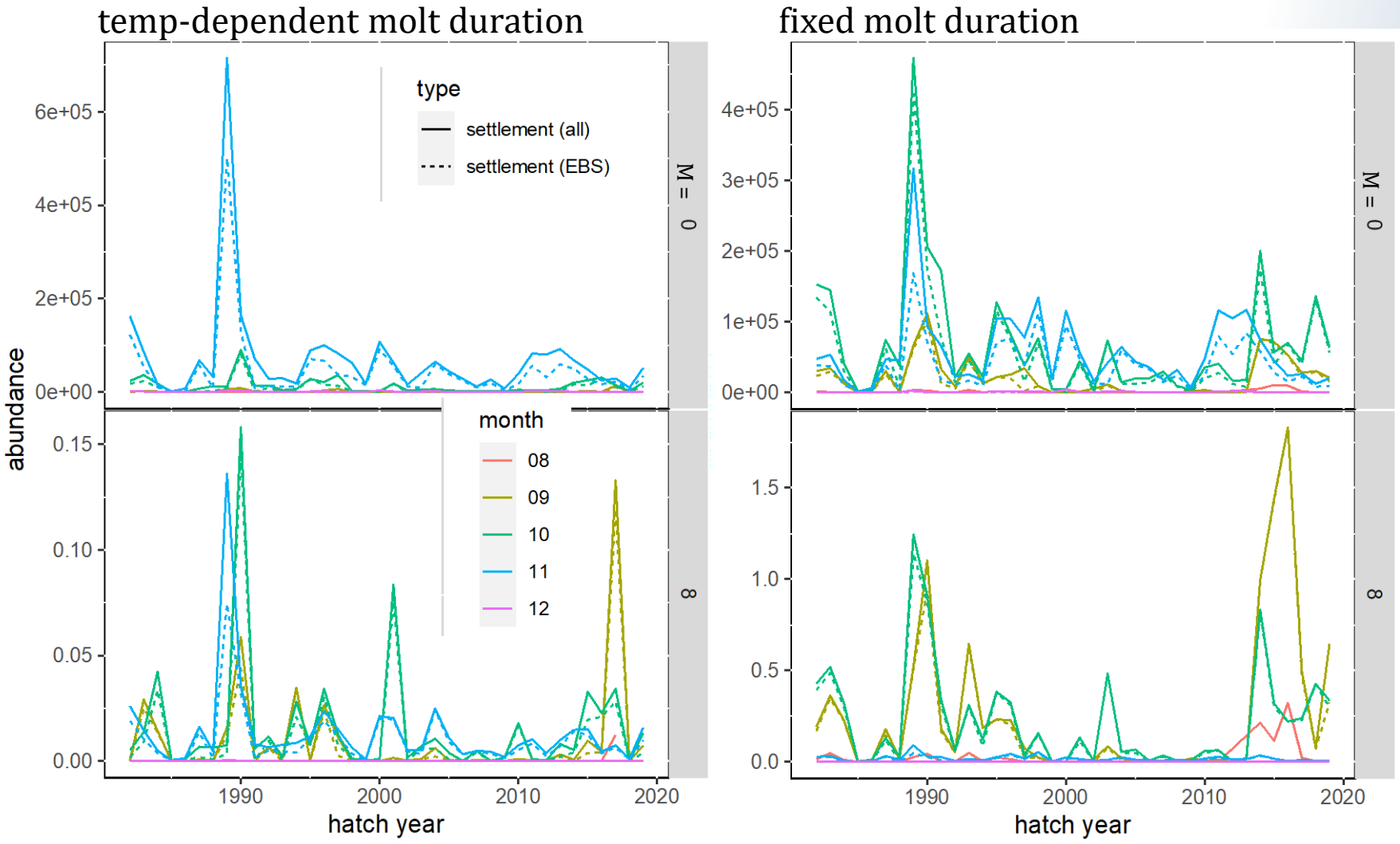
Base Model

Settlement results by temperature regime



NOAA FISHERIES

Settlement Abundance Time Series

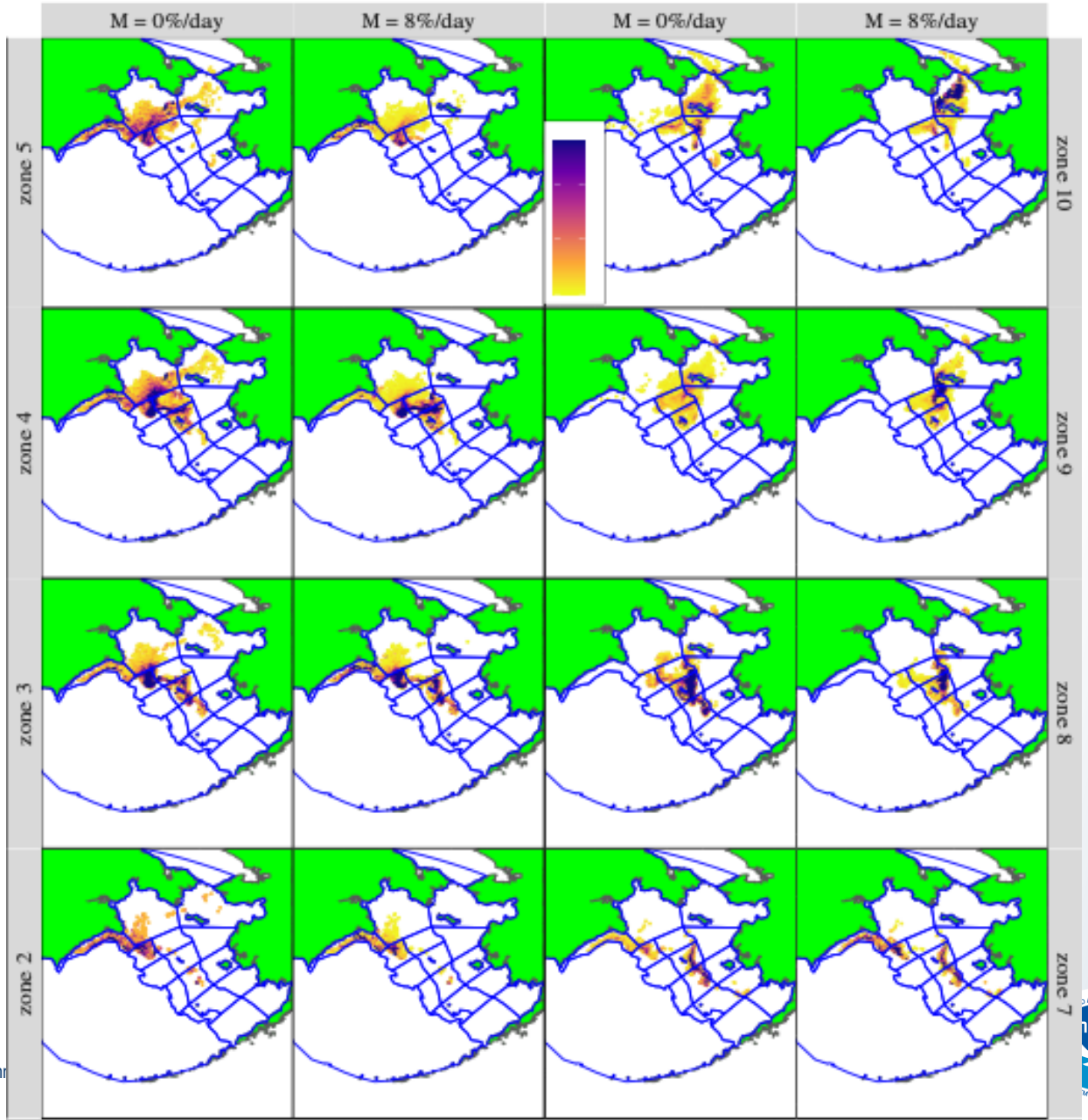


NOAA FISHERIES

Model uncertainty

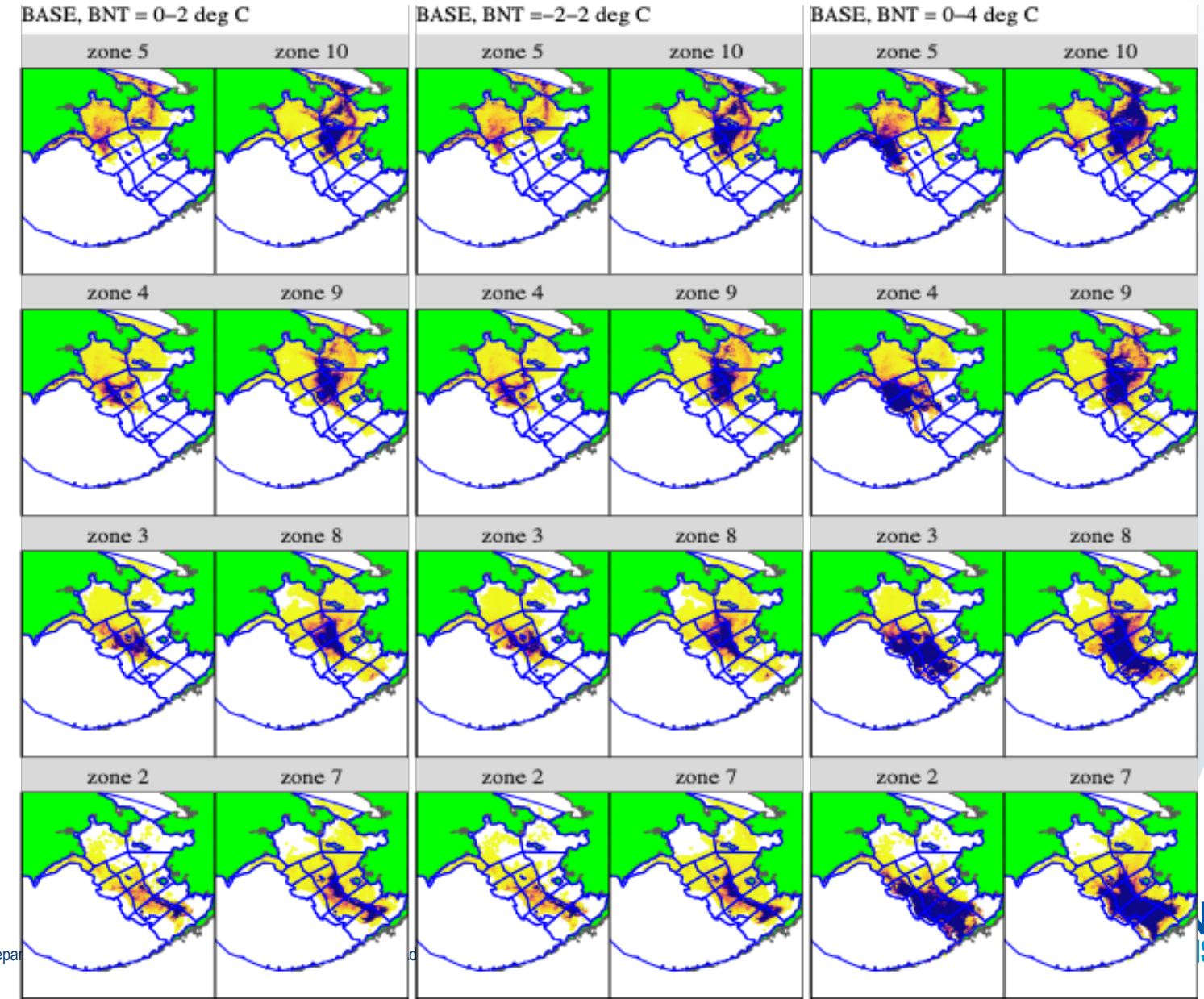
- within-season hatch variation
- benthic nursery characteristics
  - temperature range
  - bottom type
  - other factors
- mortality rates
  - starvation
  - predation

Model uncertainty: Mortality rates



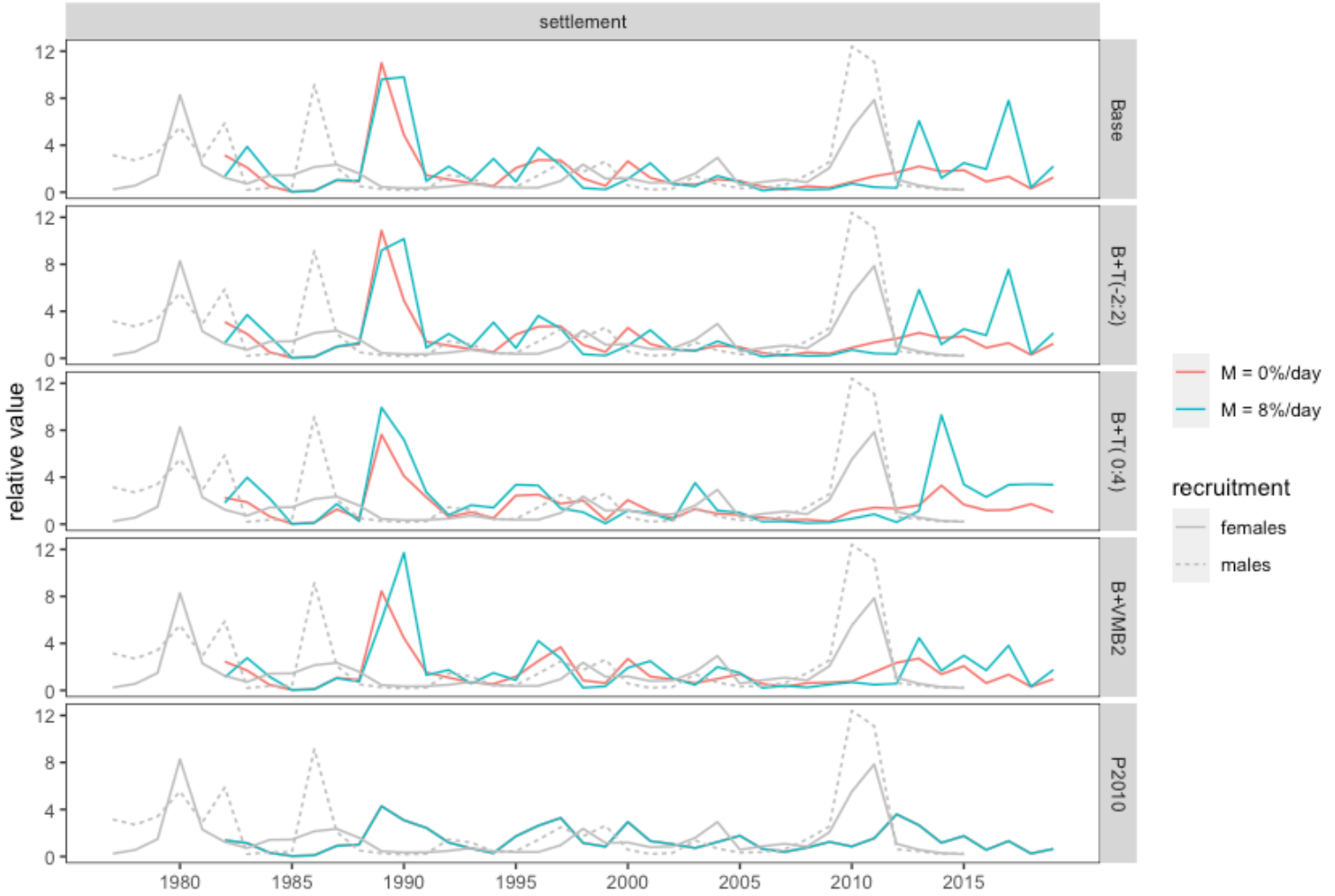
NOAA FISHERIES

Model uncertainty: variability with BNT



NOAA FISHERIES

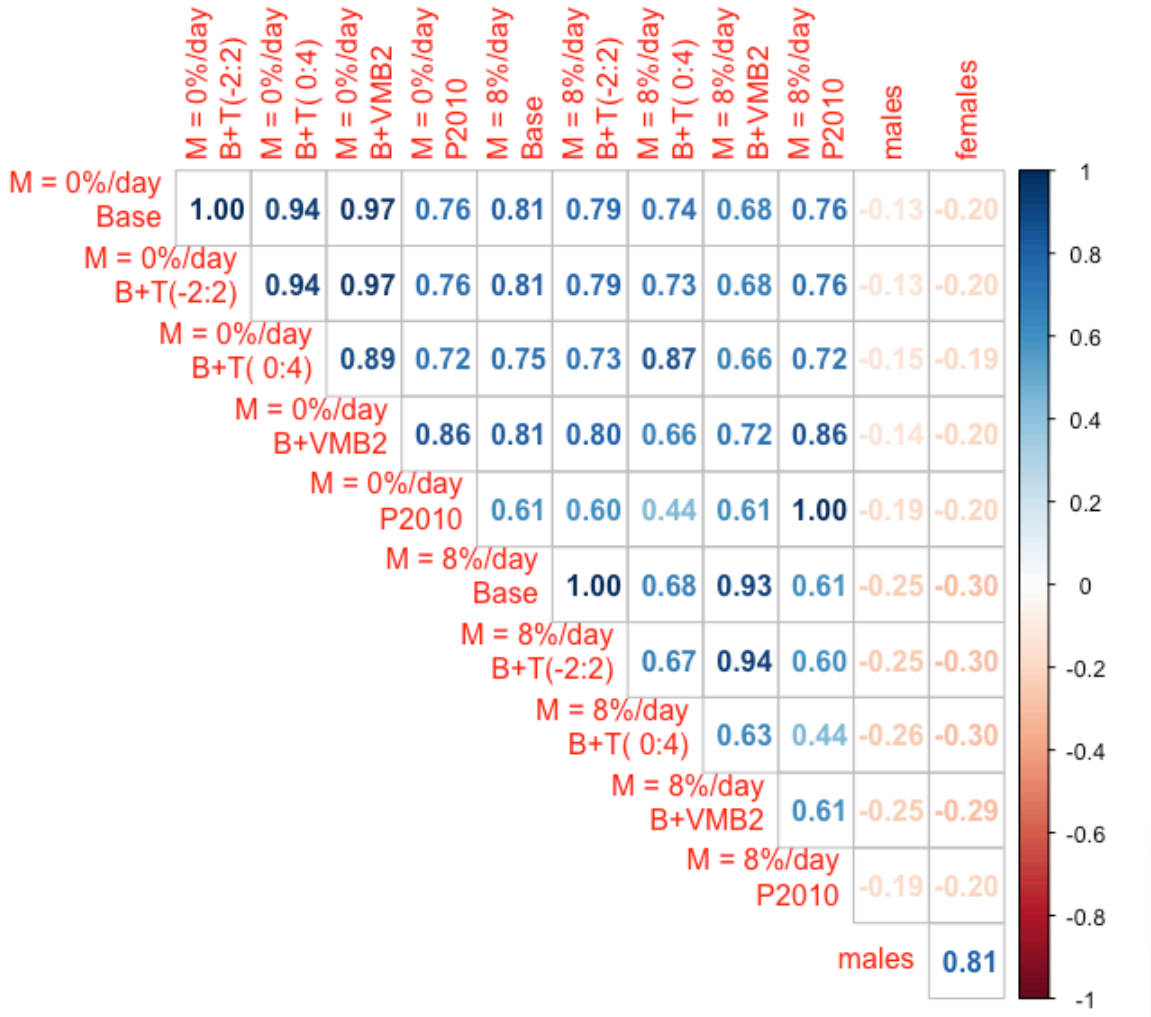
Predicted Settlement And Recruitment



Recruitment lagged 5 years

NOAA FISHERIES

Correlations between settlement and recruitment



Recruitment lagged 5 years

NOAA FISHERIES

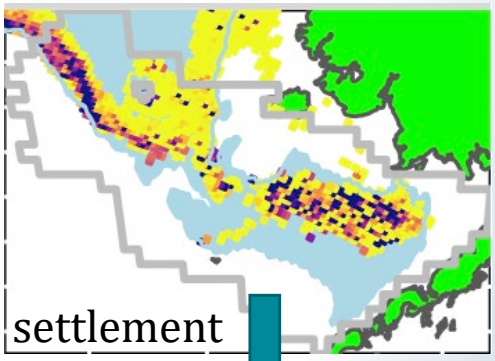
IBM Results: Key points

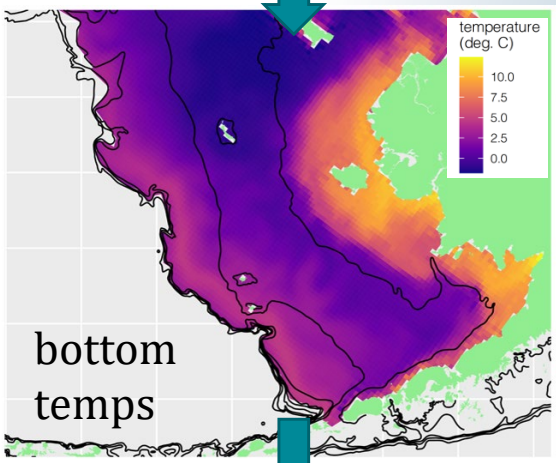
- integrates what we (think we) know about early life stages
  - lots we don't know
- EBS likely contributes to Chukchi stocks
- Some transport to southeast (counter to ratchet effect)
- moderate temperature years may be most productive
  - warmer temps -> faster development -> less pelagic mortality
  - colder temps -> more extensive settlement habitat
- settlement and recruitment are decoupled:
  - predicted settlement abundance has little relationship to estimated recruitment 5 years in the future
  - possibilities
    - IBM is missing a key factor?
      - starvation? spatiotemporal patterns in predation?
    - decoupling due to processes in benthic nurseries?

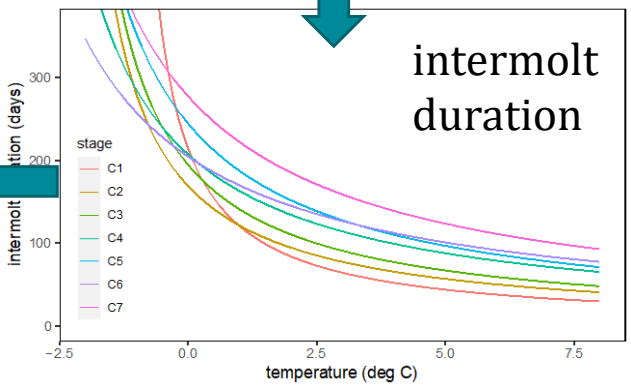
Benthic Cohort Progression Model

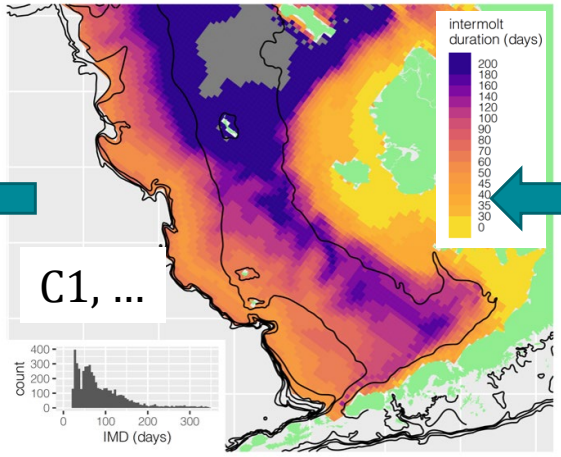
- Initial pattern: IBM settlement pattern by ROMS grid cell
- Molt stage projected using ROMS bottom temps, lab-determined development rates*
- Can include instar-specific, temperature-dependent mortality rates ("cod predation")
- Daily integration for abundance, instar within each ROMS grid cell

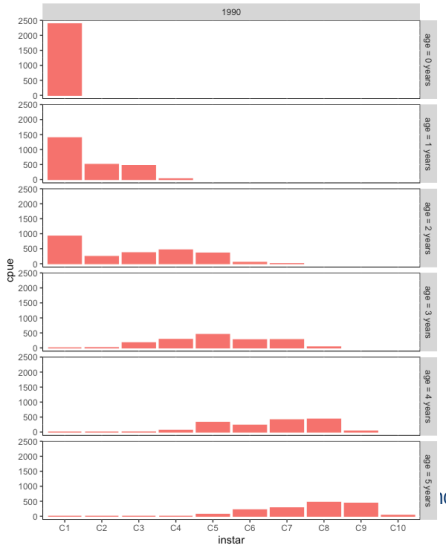
*Yamamoto et al (2015)



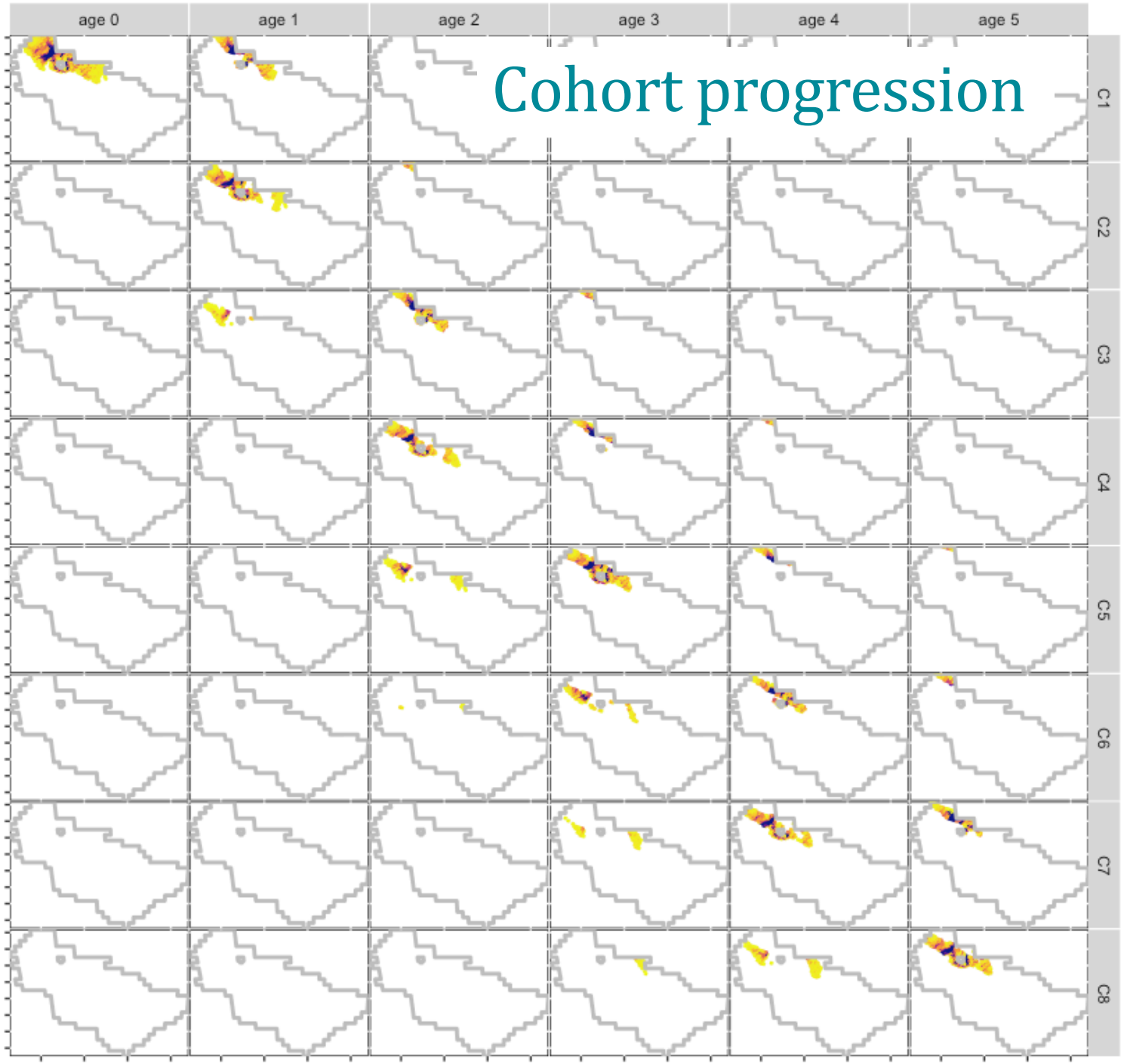






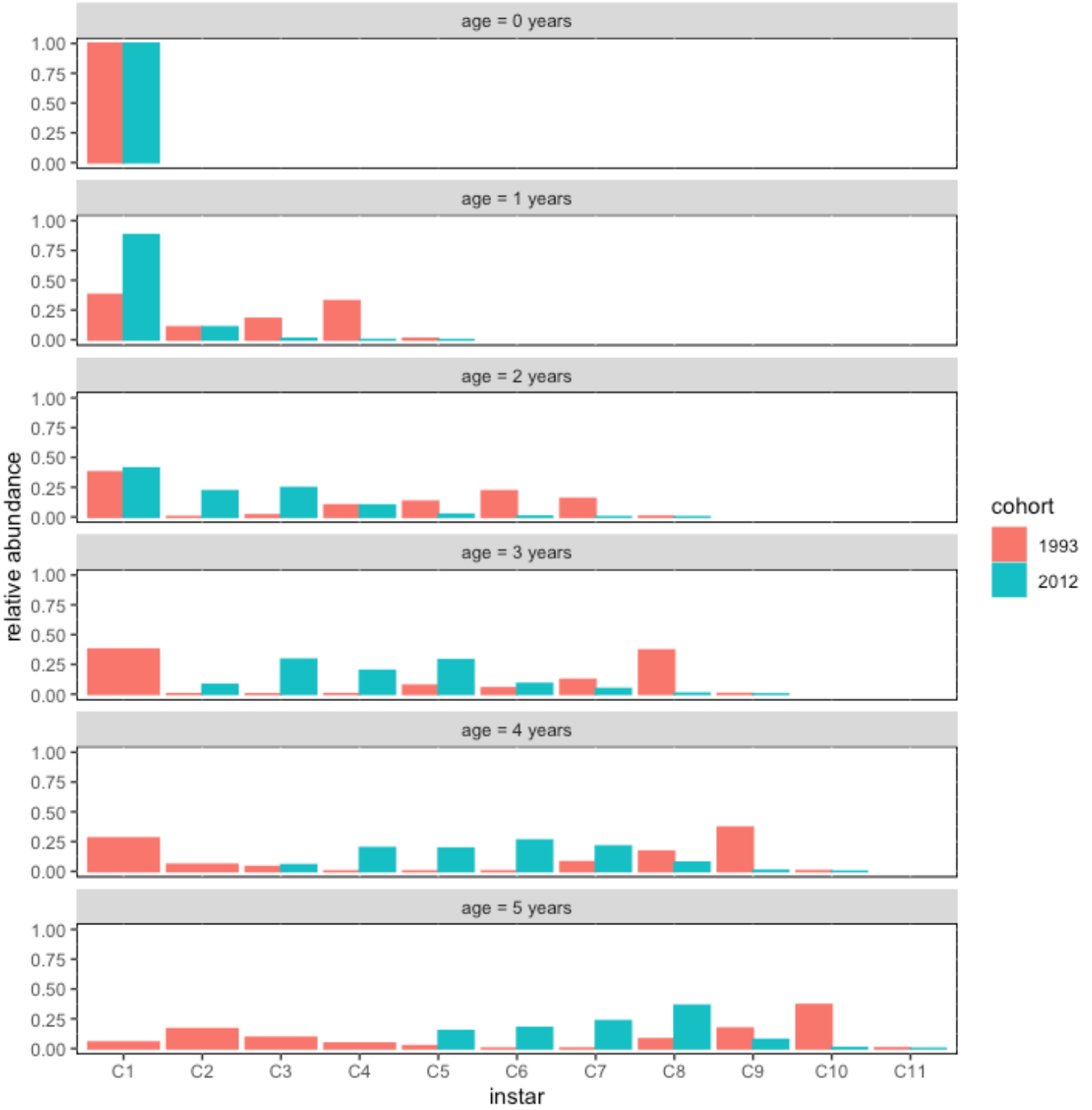


Cohort progression



Cohort Progression: Warm vs. Cold Years

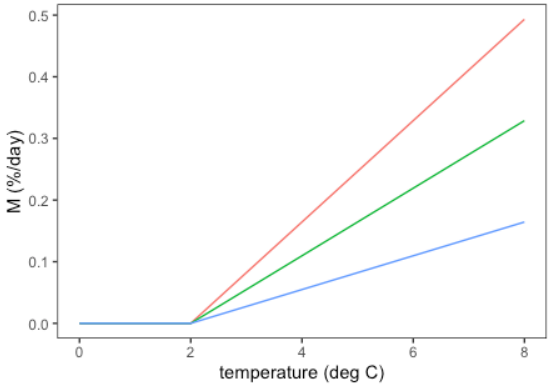
- no mortality

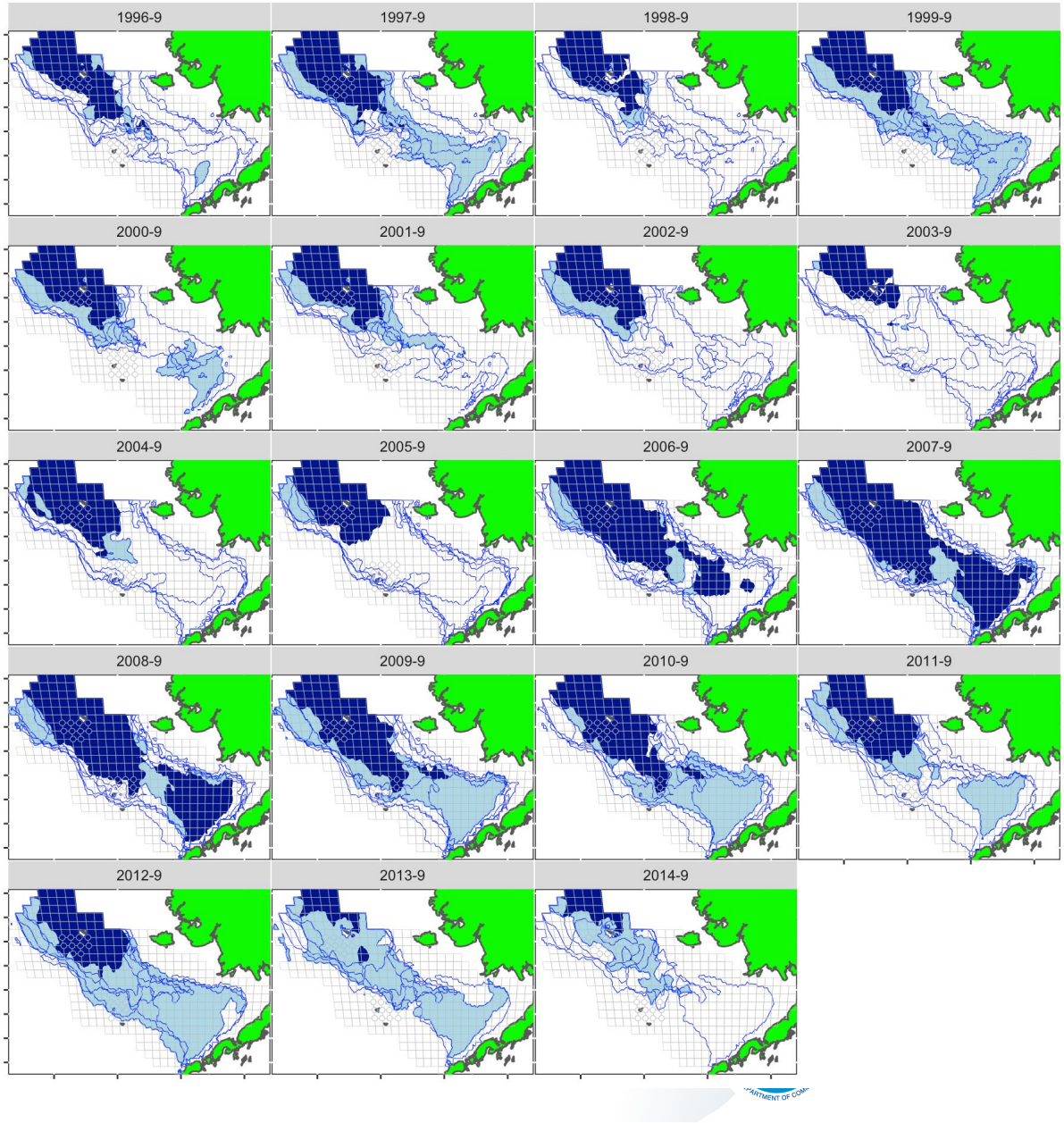


Cold pool extents: settlement to recruitment

by settlement year

- predation by cod excluded from cold pools?

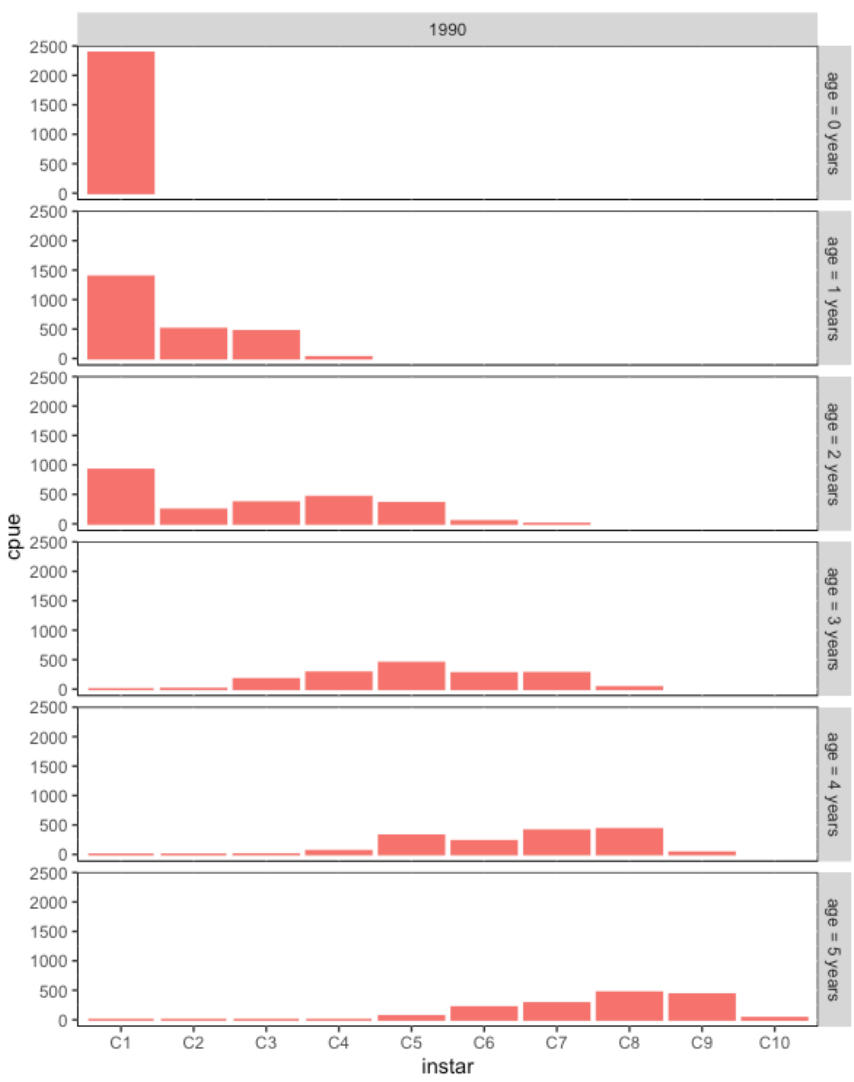




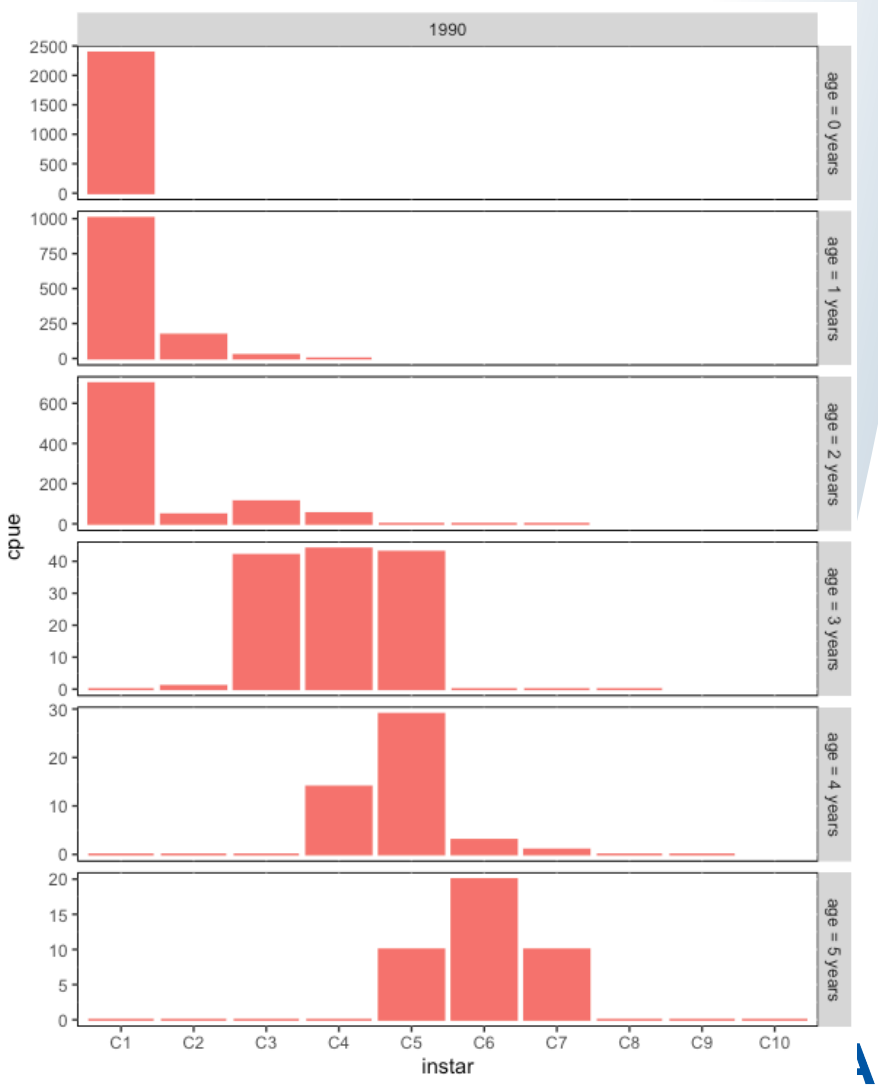
Example Cohort Progression

- C5: 16 mm CW
- C6: 21 mm CW
- C7: 30 mm CW

no "cod predation"

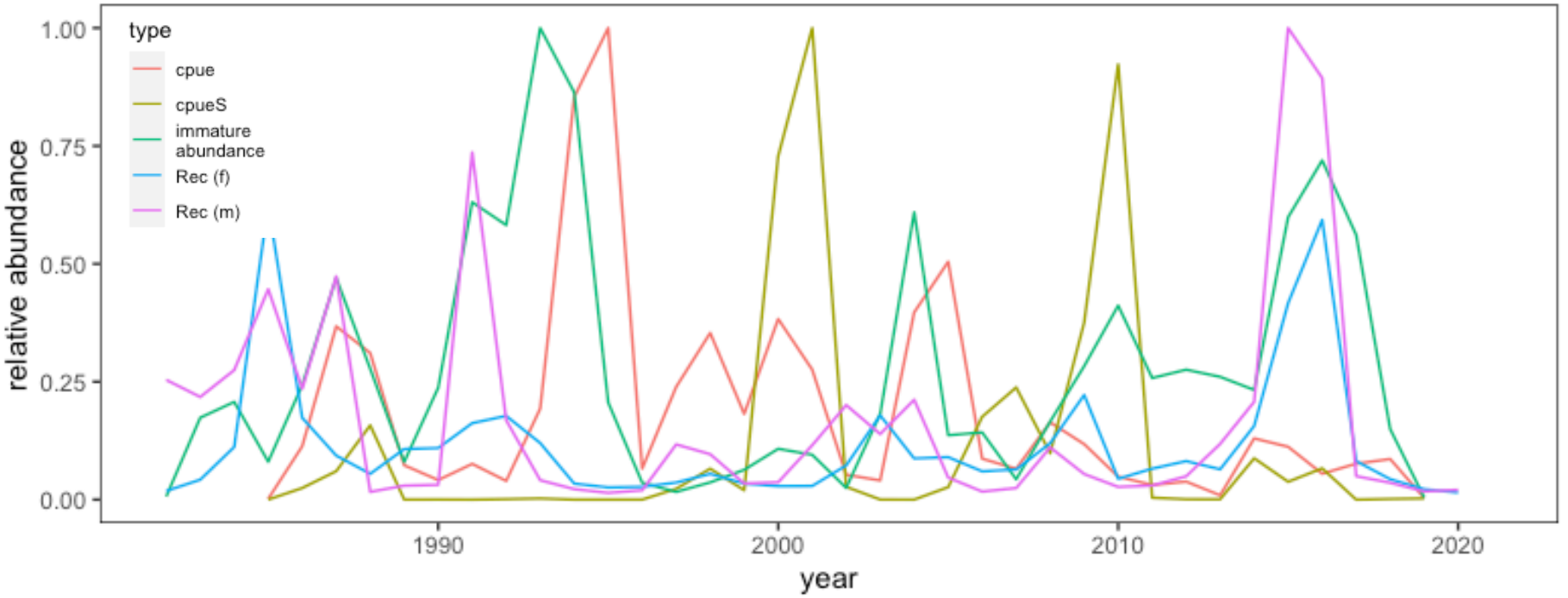


with "cod predation"



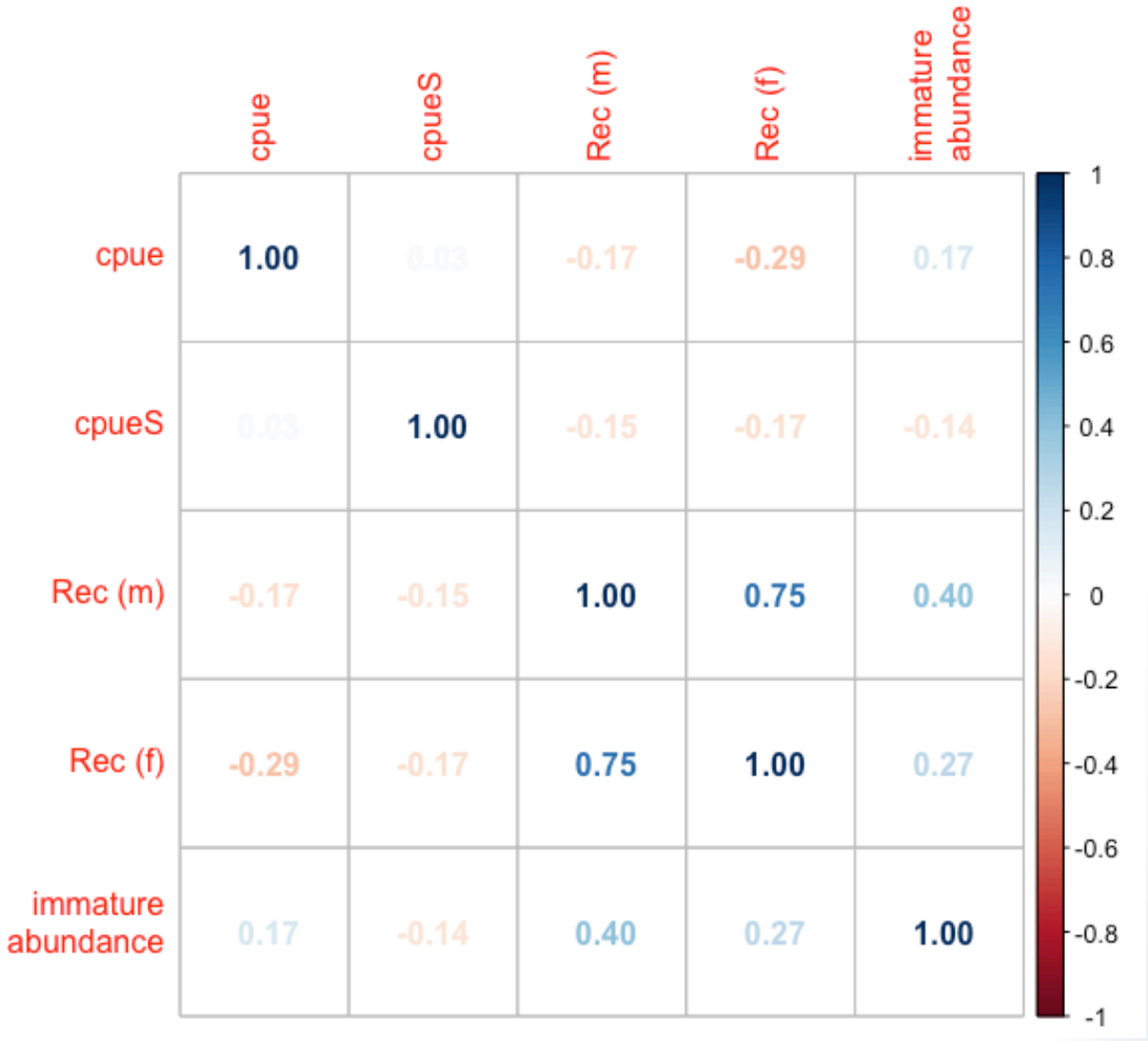
FISHERIES

Indices



NOAA FISHERIES

Indices



NOAA FISHERIES

Summary

- Bit disappointing in terms of correlation with recruitment
- What's missing?
  - better description of P. cod predation?
  - density dependence?
  - other mortality factors?
- Next steps?