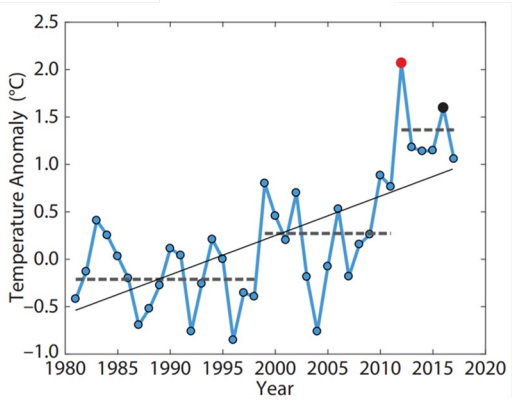
Climate impacts on ovigerous lobster behavior and the downstream effects on larval dispersal and settlement

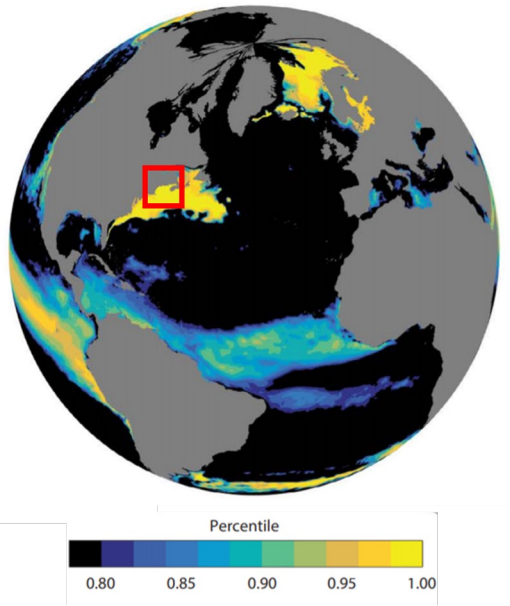
Andrew Goode and Everett Rzeszowski
University of Maine

Gulf of Maine Warming

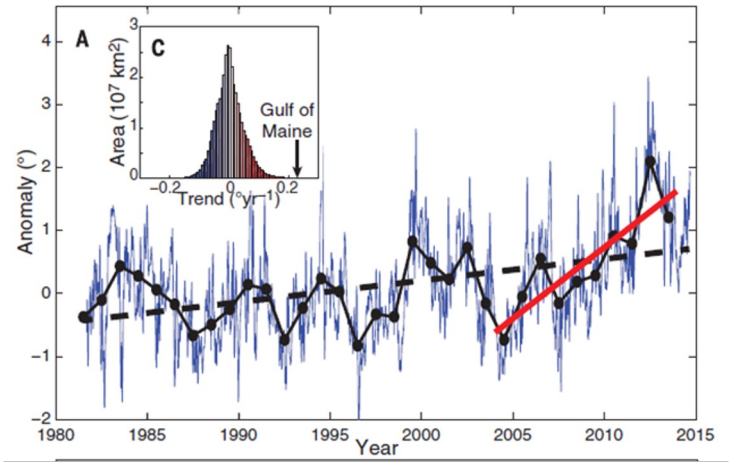
- Rapid, non-linear warming
- Thermal regime shift ~2008
- Climate scenarios predict continued warming

Why?

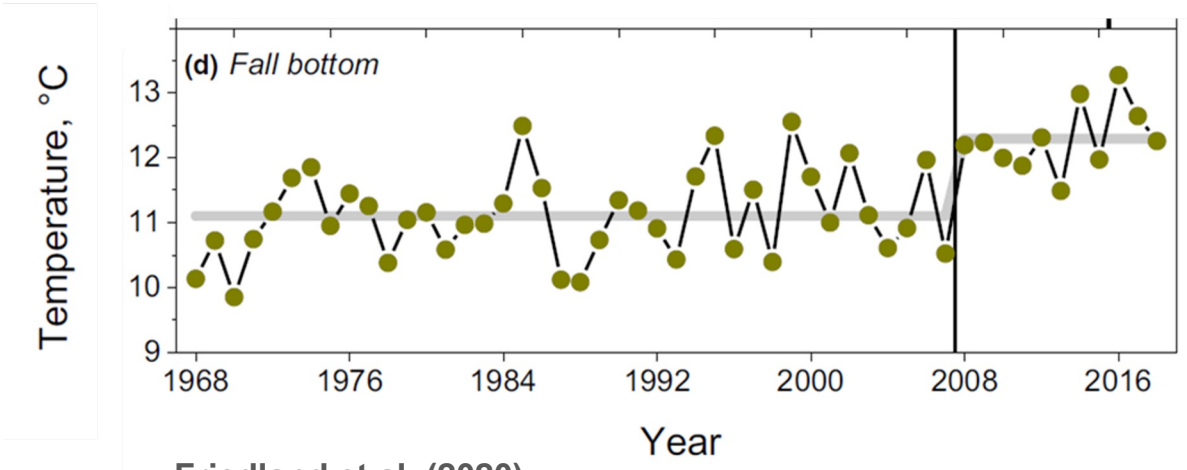




Pershing et al. (2018)



Pershing et al. (2015)

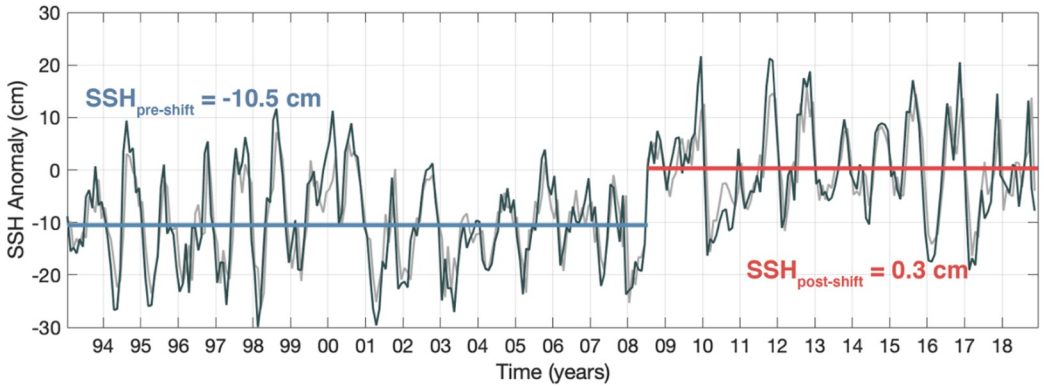


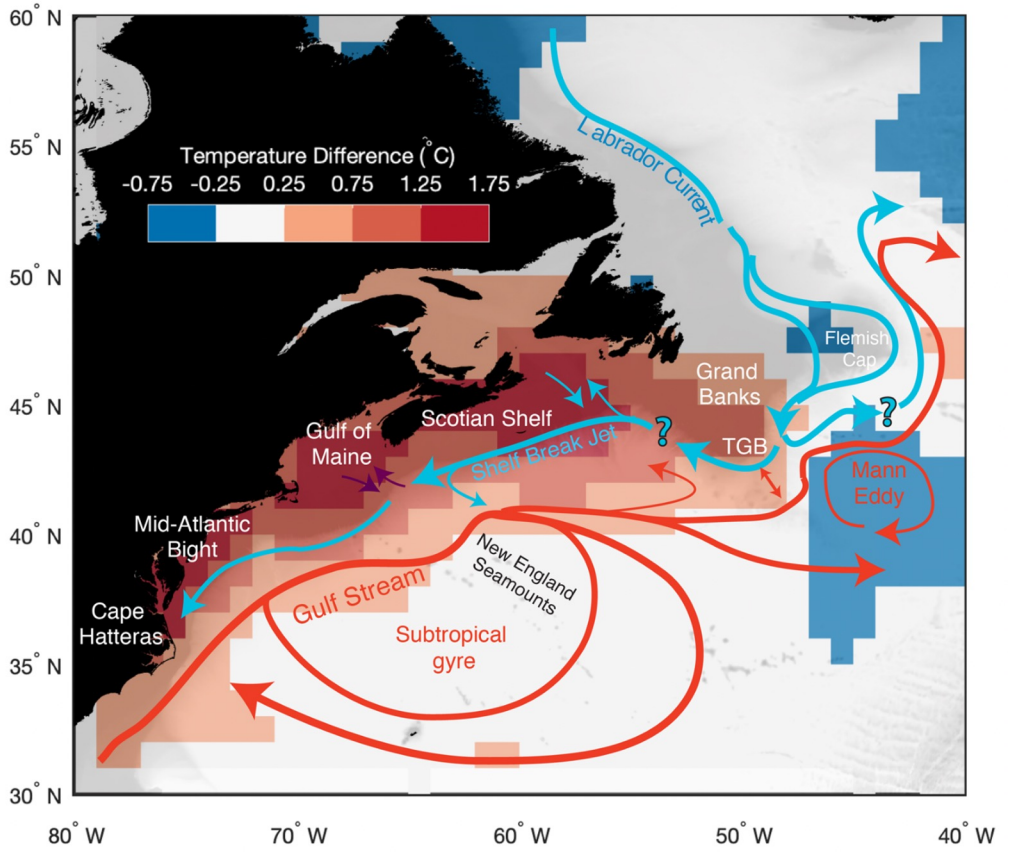
Friedland et al. (2020)

Gulf Stream Impingement

- As the Gulf Stream shifts northward it pinches off subarctic currents at the Tail of the Grand Banks

- This impacts the water masses entering the Gulf of Maine

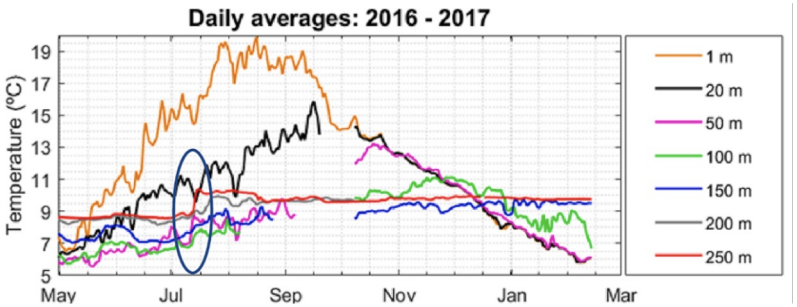




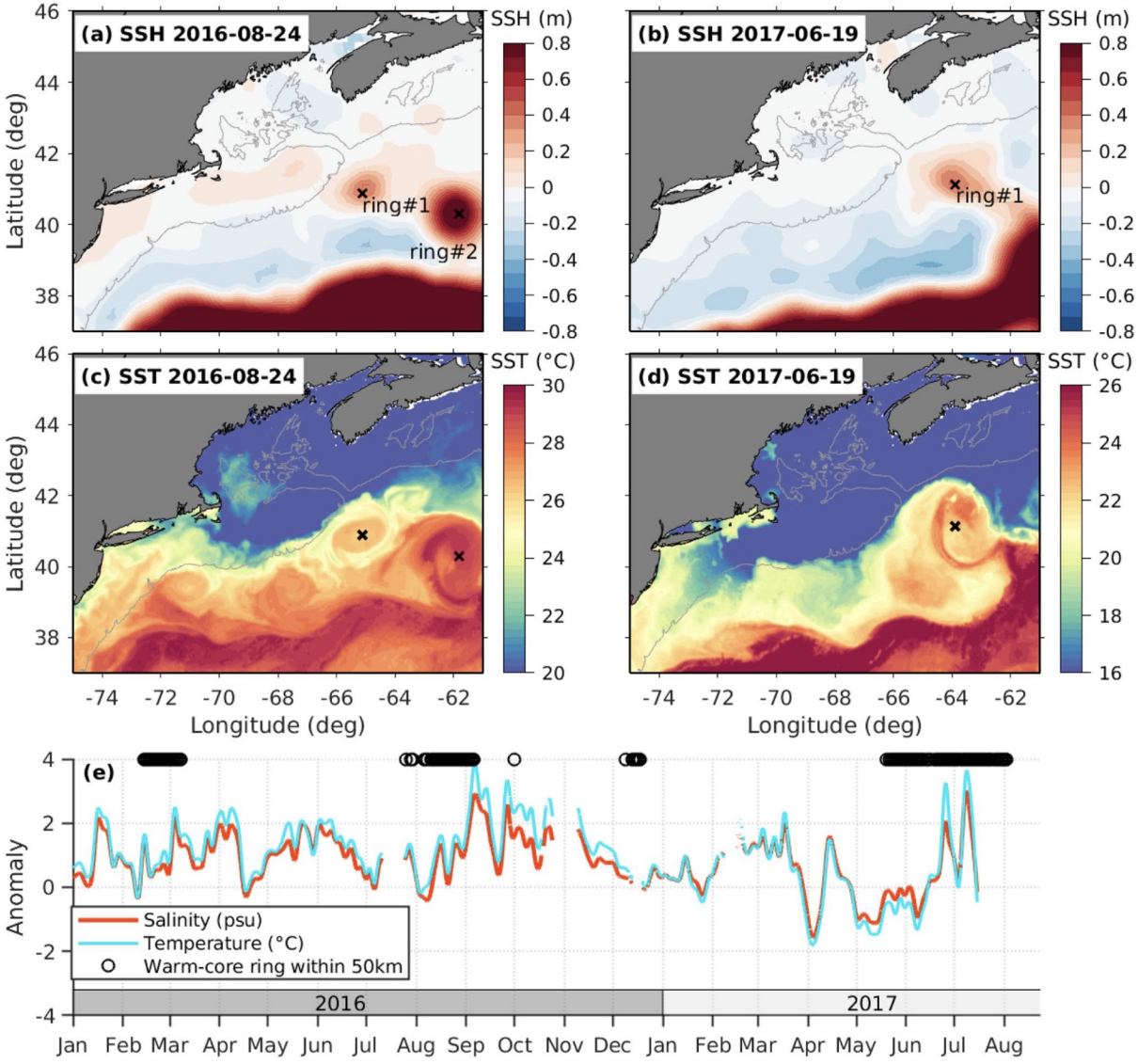
Changing circulation in the Northwest Atlantic with mean temperature difference between 2001-2007 and 2009-2017 (Top); SSH shift in 2008 at TGB, representing GS impingement (Left); Neto et al. 2021

Warm Water Intrusions

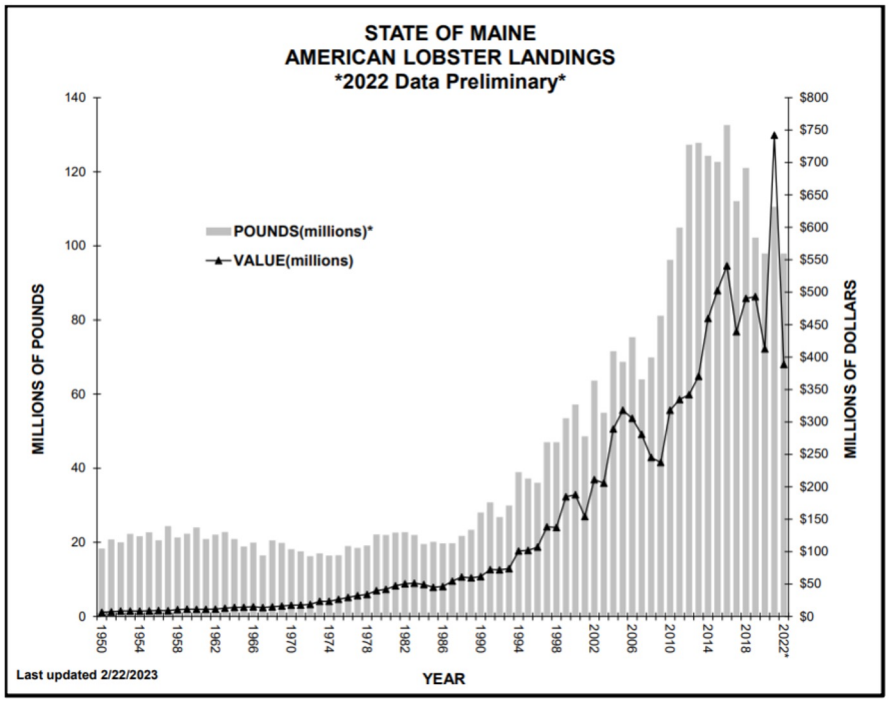
- Individual benthic warming events increase in frequency as Gulf Stream shifts.

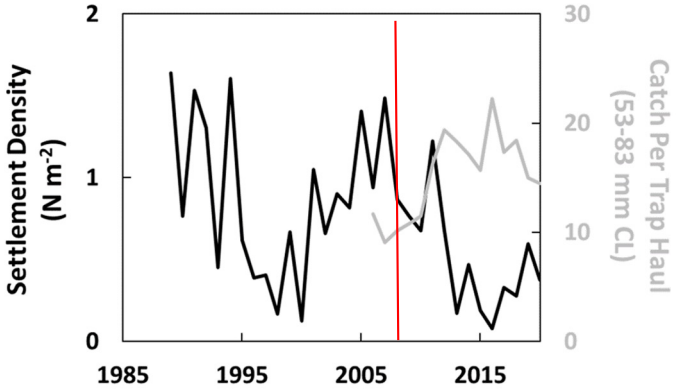


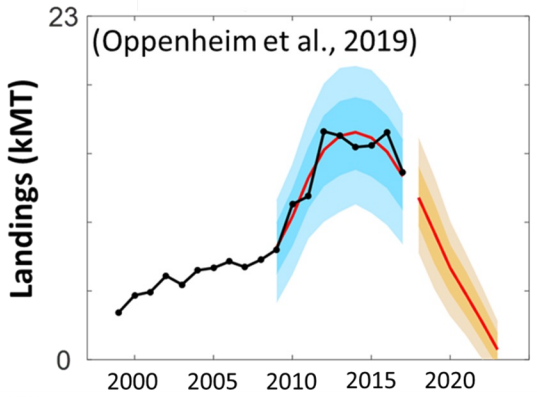
Gulf Stream warm core rings as seen in satellite images influence deep basin warming in the Gulf of Maine (Right, Du et al. 2021; Buoy M, Top, Townsend et al. 2023)

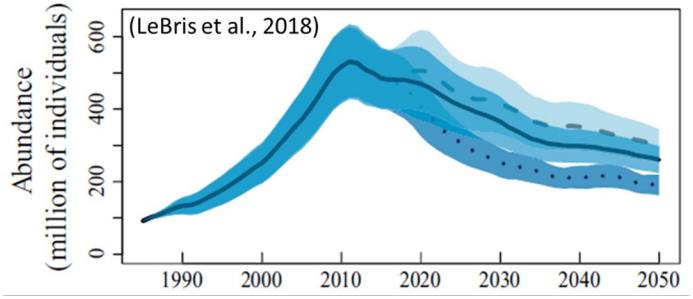


Fishery Changes



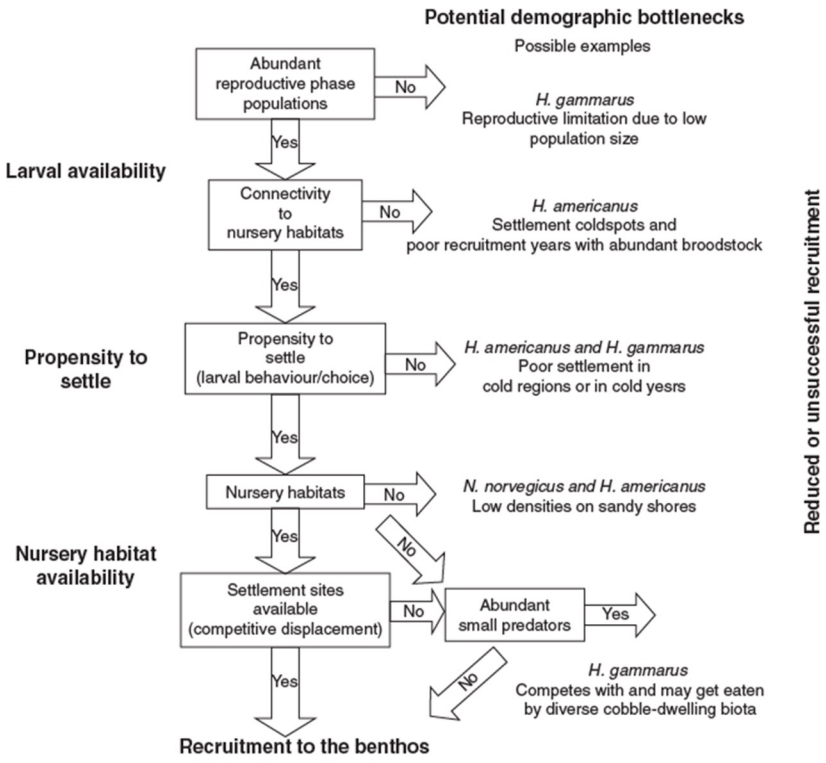




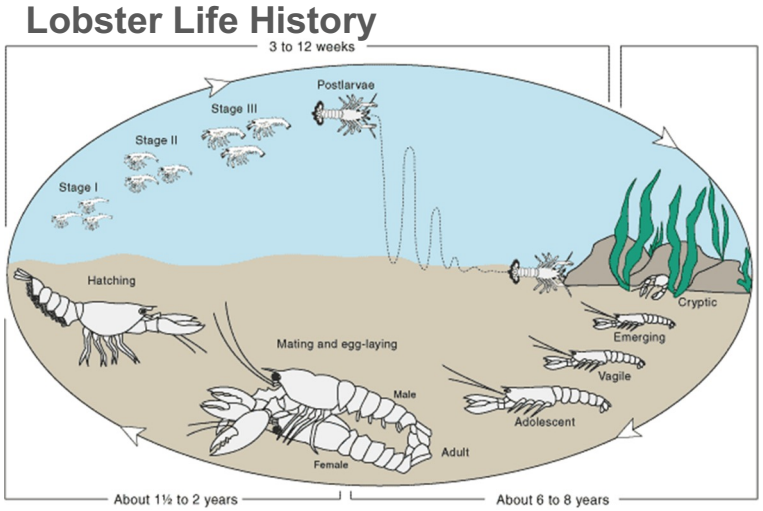


Historical Maine lobster landings (ME DMR; top)
Lobster Settlement density and predicted landings trends (right).

Implications:
Lobster Life History



Settlement Hierarchy; Butler et al. (2006)



Settlement driven demography:

- Larval availability, propensity to settle, nursery habitat availability

(sub)Adult behavior:

- Reproduction and distribution

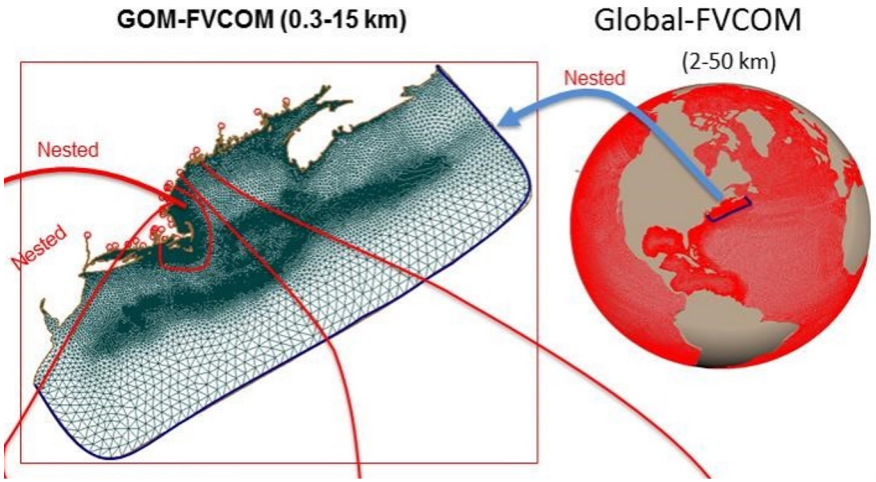
How does climate change impact these critical aspects of lobster life history?

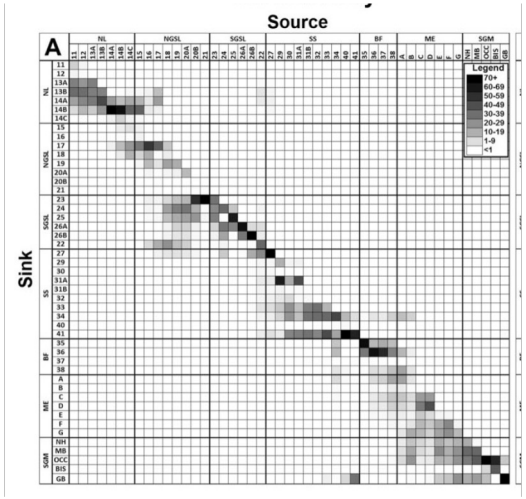
How?

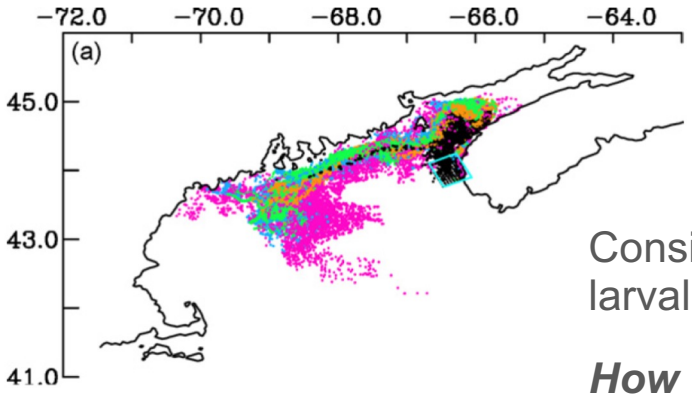
- Larval particle tracking using NECOFS (right)

Previous Work:

- Lobster particle tracking (Xue et al., 2008; Incze et al. 2010; Quinn, 2017)



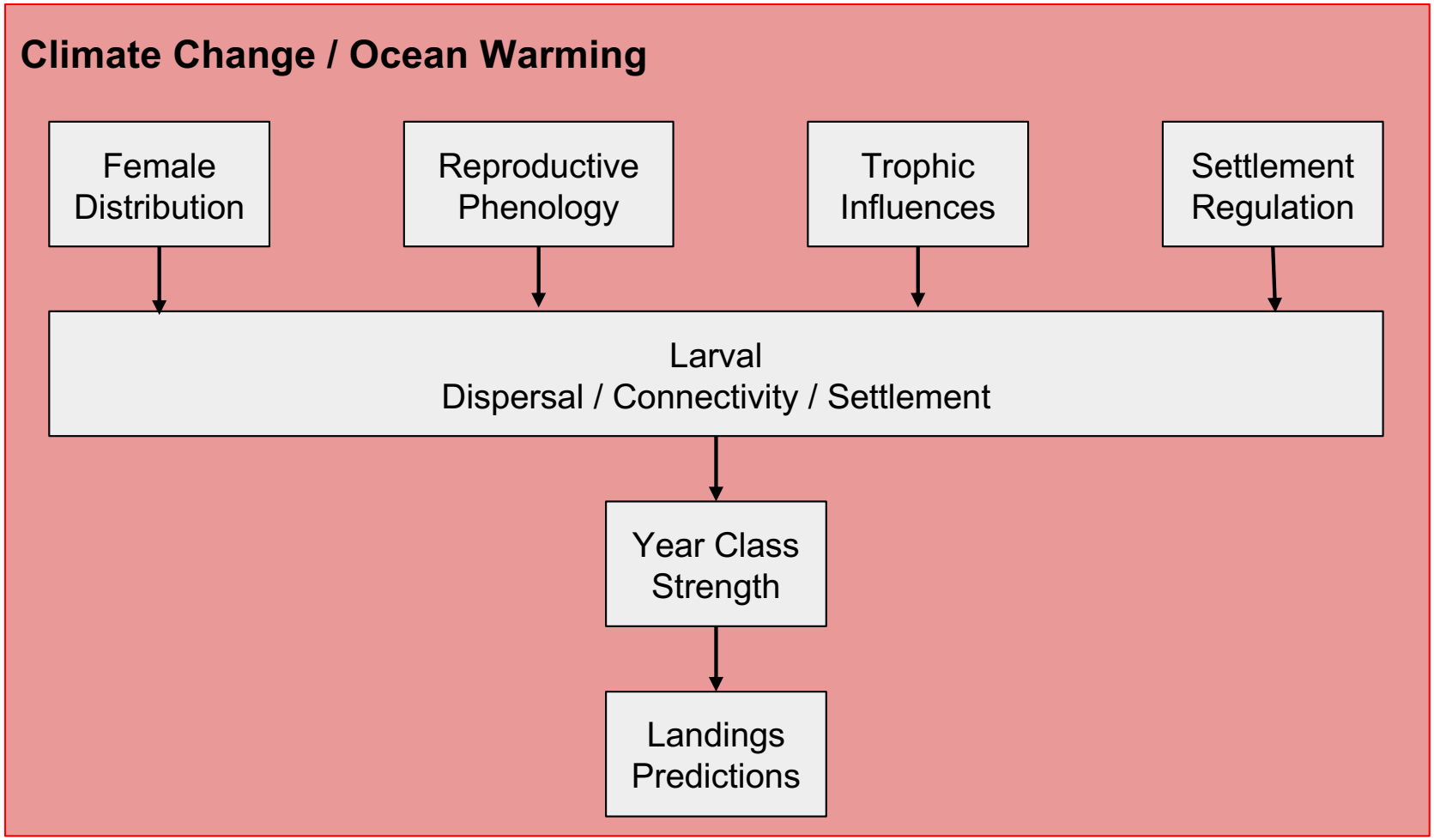




Consistent locations, release dates, and larval mortality

How does incorporating climate impacts to these parameters impact larval connectivity?

Integrated Research

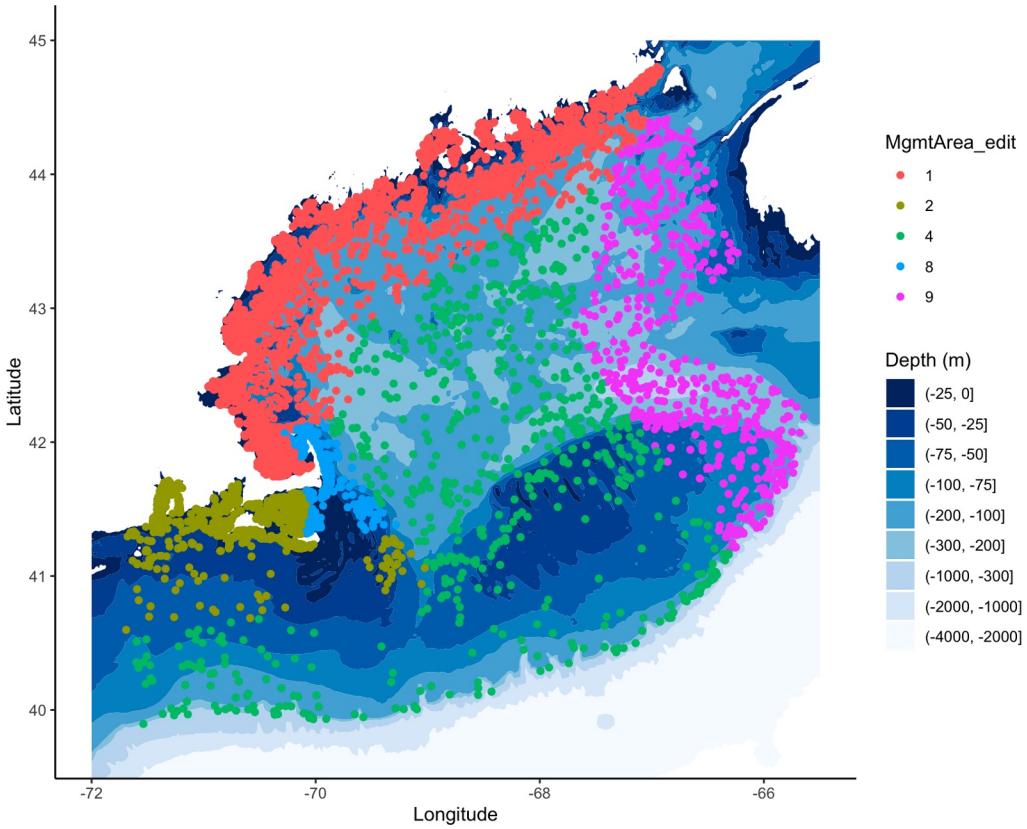


Female Distribution

Model Female Biomass in Spring Trawl Surveys from:

- MENH Inshore Trawl Survey
- MA Inshore Bottom Trawl Survey
- RI Coastal Trawl Survey
- NEFSC Bottom Trawl Survey

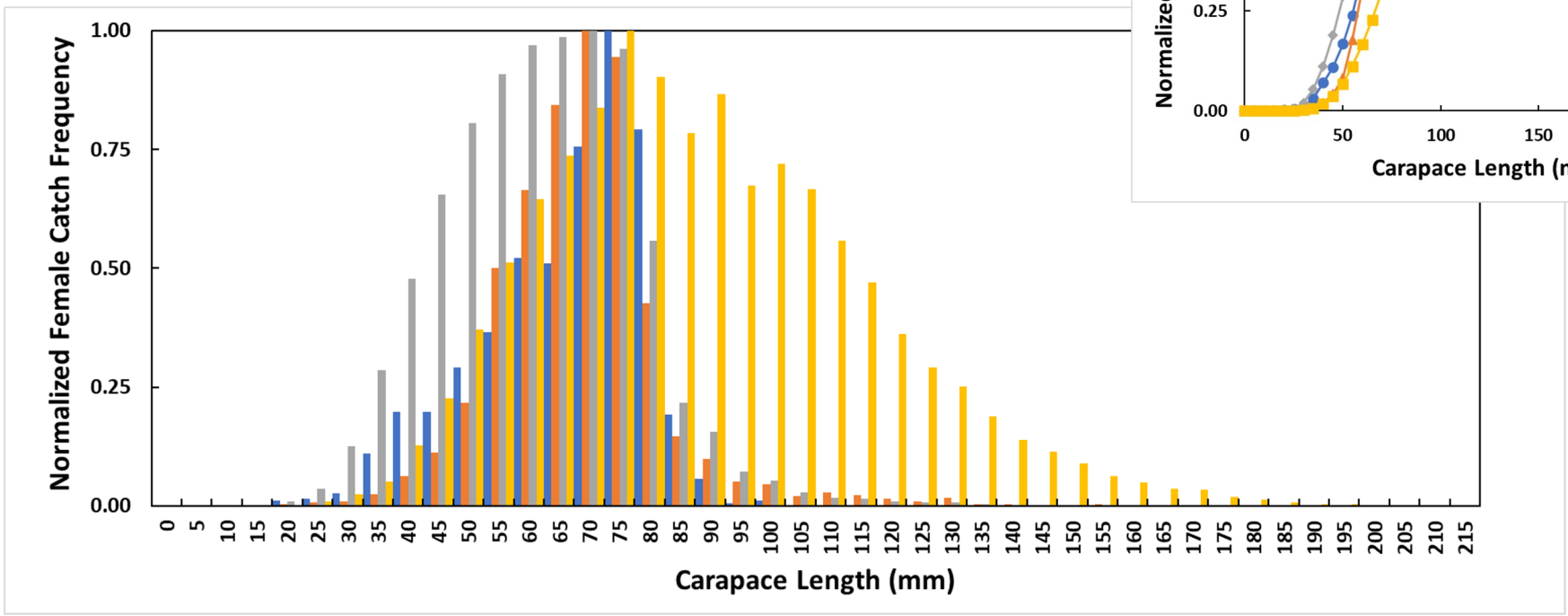
Abundance of Females> 75 mm CL

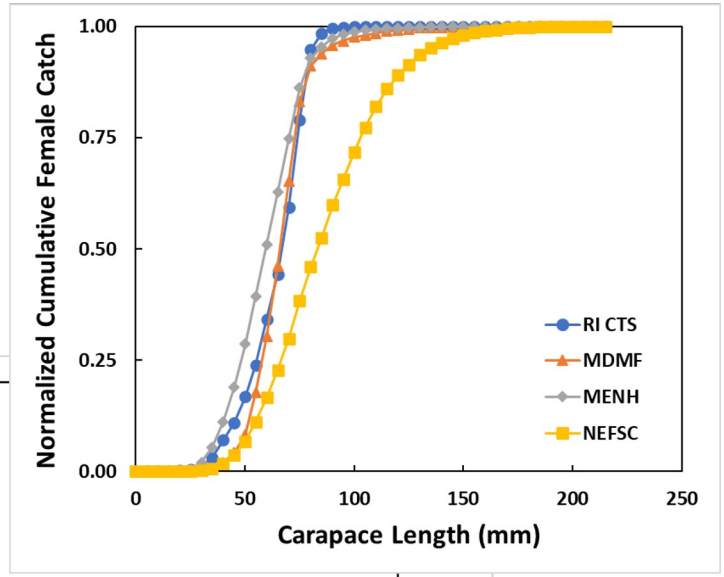


Female Distribution

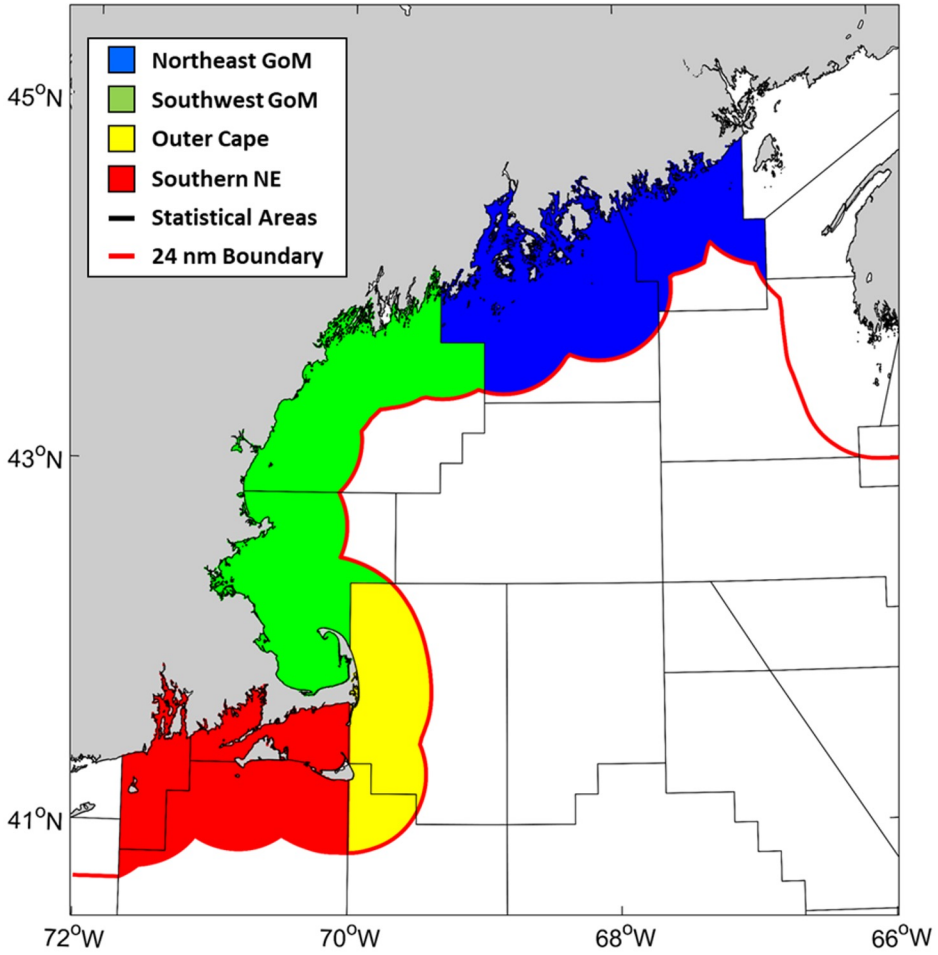
Standardization of catch

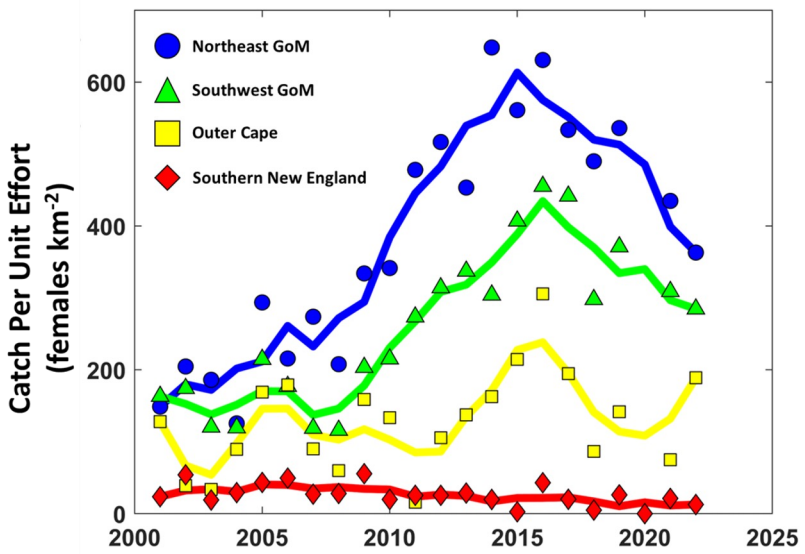
- Females km^{-2} ~ Catch / (Trawl length * Trawl Width)
- Catchability by trawl type?

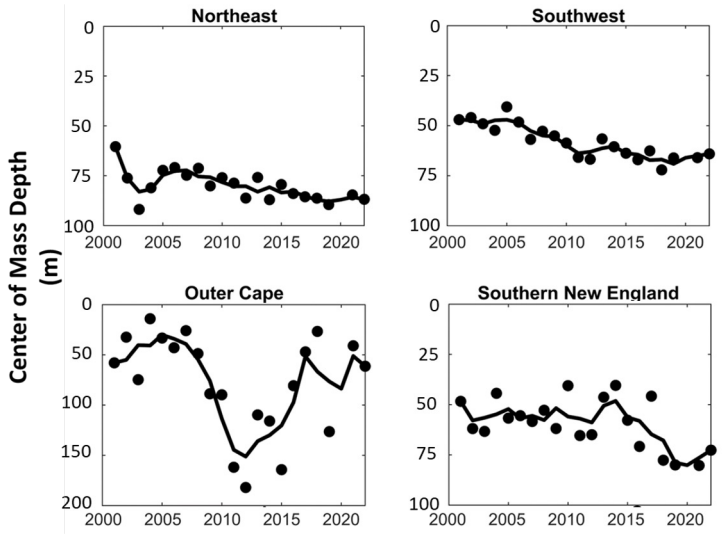




Female Distribution

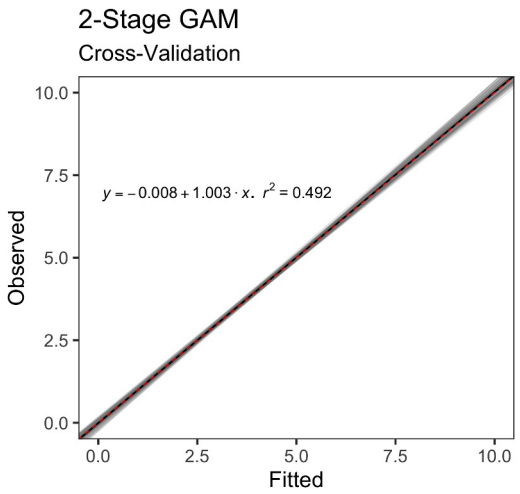


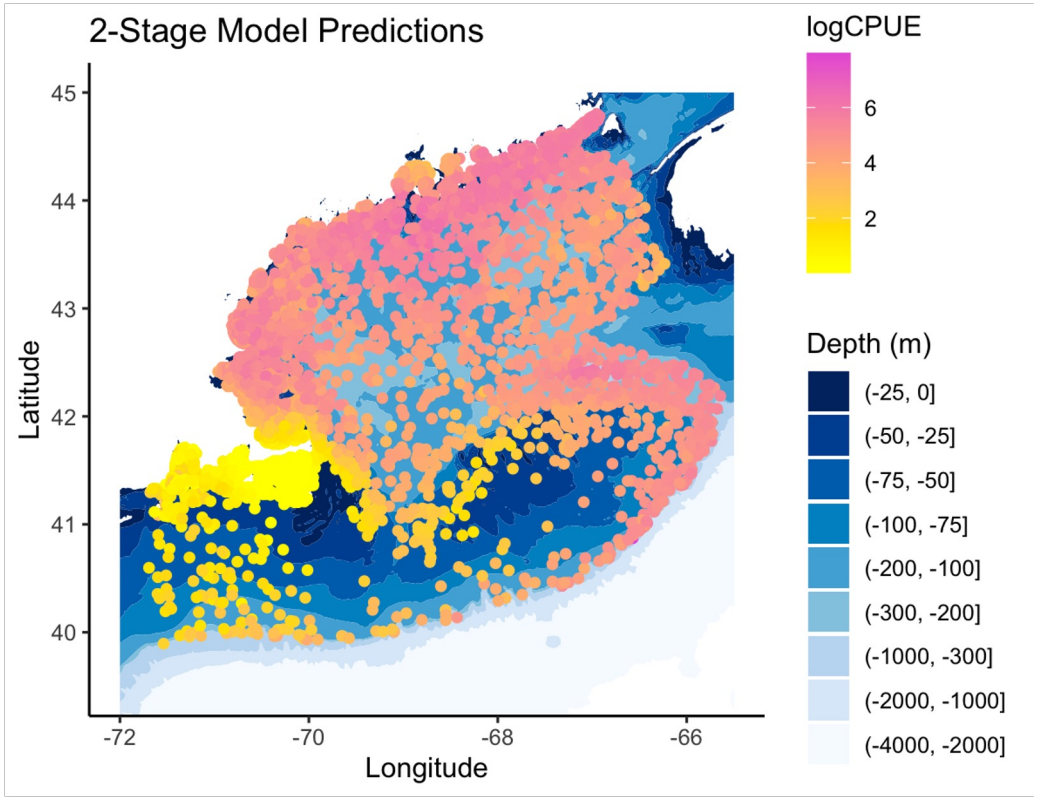




Modeling Female SSB Distribution

- 2 Stage GAMs describe changing female distributions and performed well.
  - Full data model
  - Annual models
  - Regime shift models

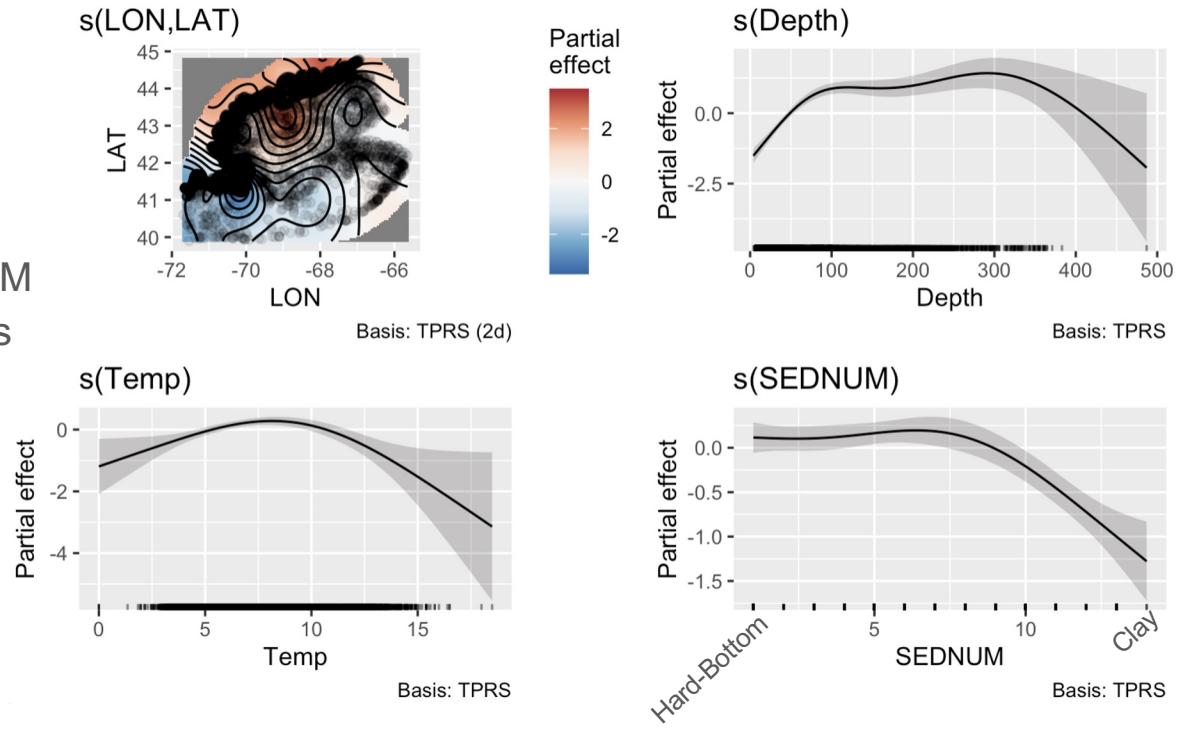




Mapped 2 Stage model predictions (Top).
Model cross-validation (Left).

Presence / Absence

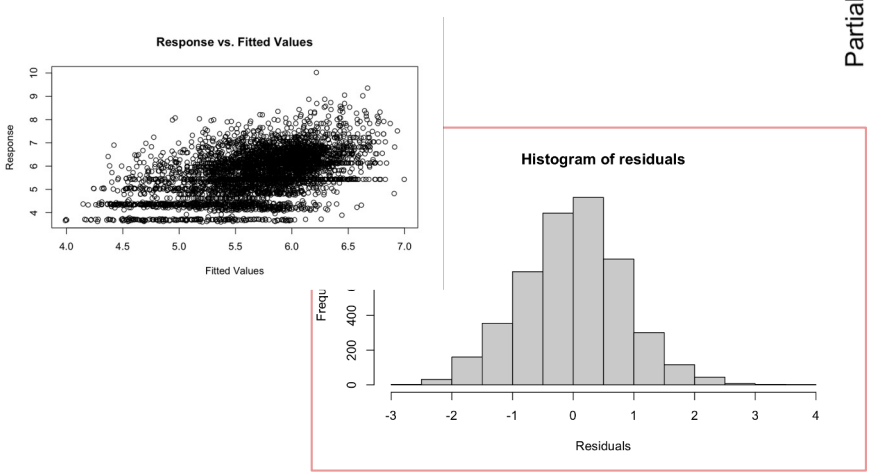
- Probability of Presence in a trawl sample:
  - Is higher in LMA 1; Central GOM
  - Increases 0 - 100 m; decreases >300m
  - Decreases >9°C
  - Decreases on clay sediment.

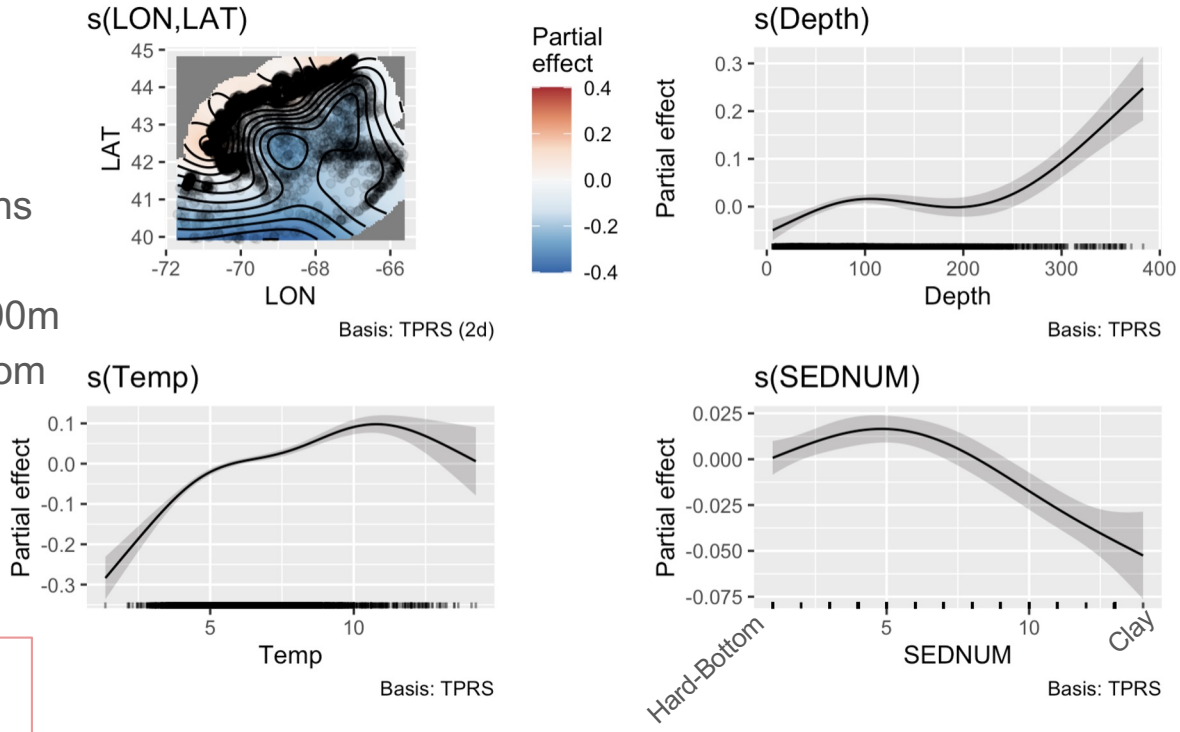


Partial effects of covariates included in the final presence / absence probability model.

CPUE

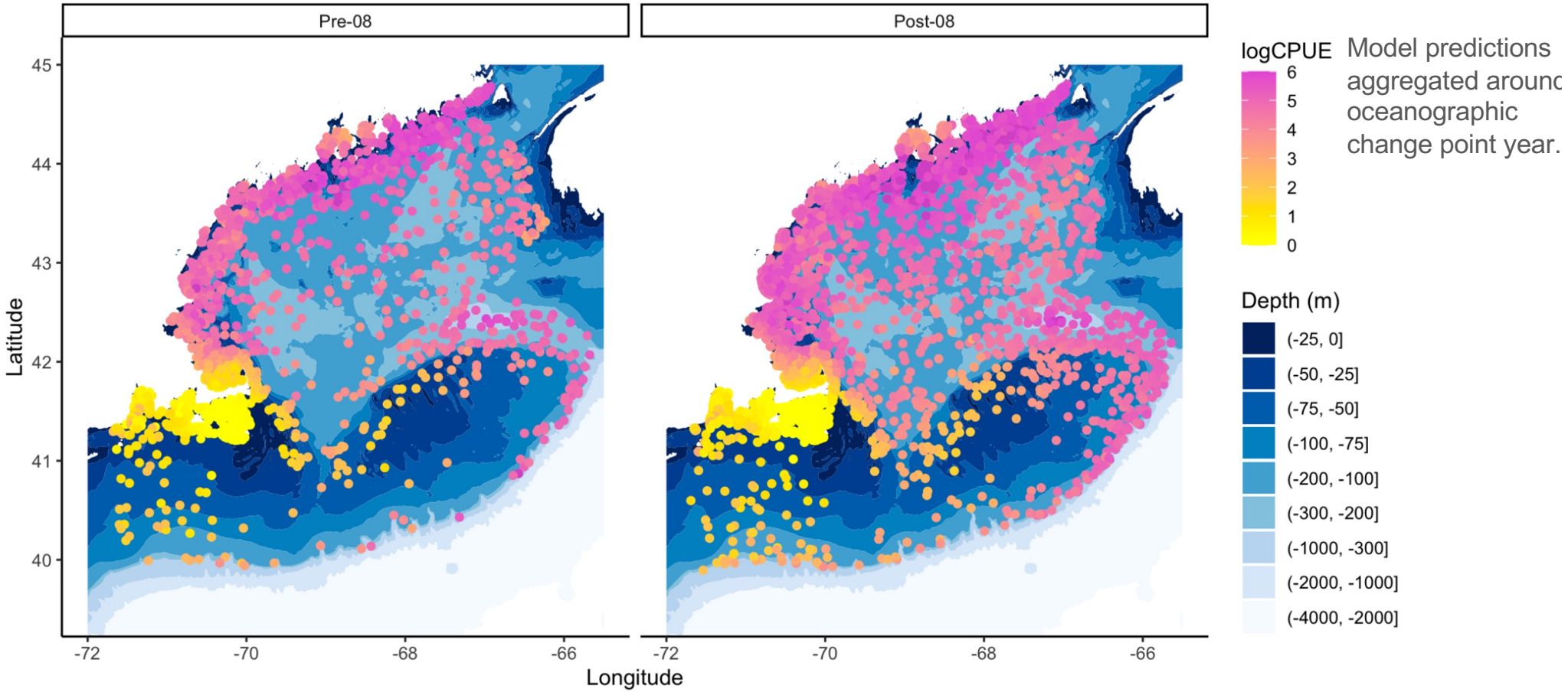
- CPUE is:
  - Higher in LMA 1 offshore regions
  - Increases from 0 - 10°C
  - Increases from 0 - 100 and >300m
  - Highest over sand / gravel bottom and decreasing over silt / clay.





Partial effects of covariates included in the final logCPUE model (Top). Response vs. fitted values and model stage residuals (Left).

Grouping Model Output



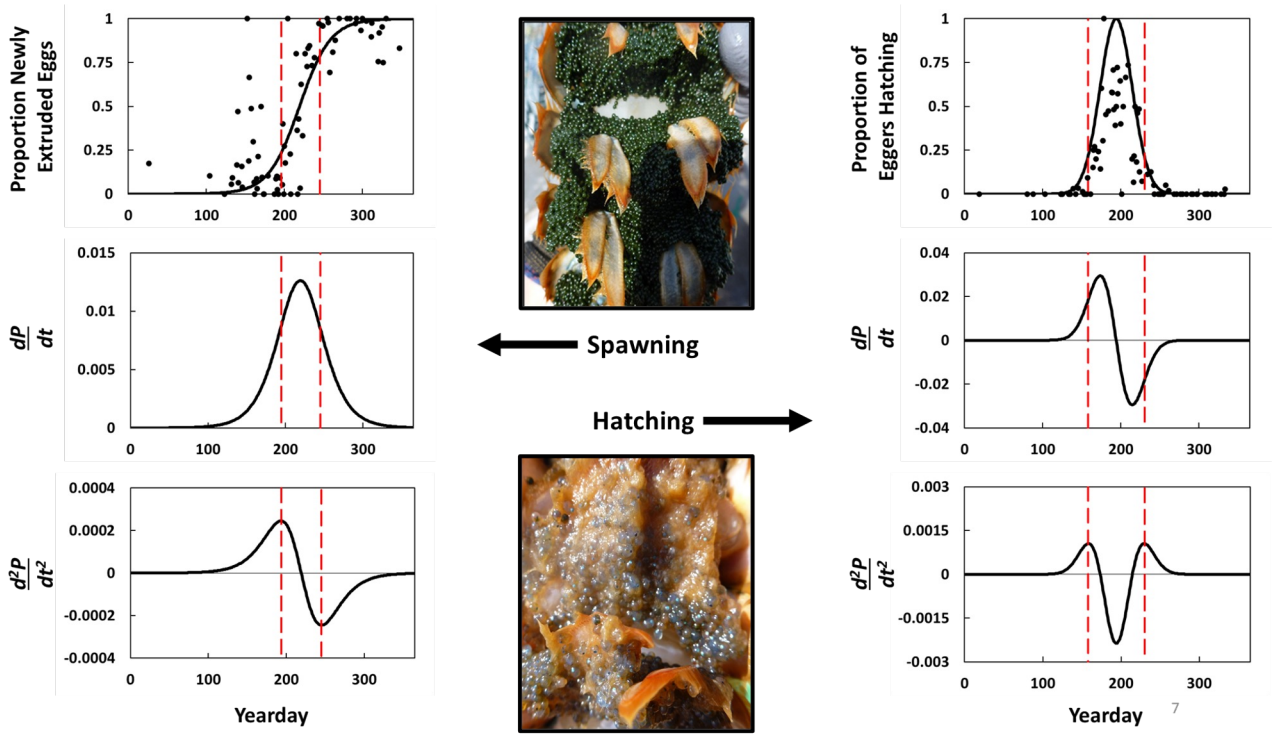
Model predictions aggregated around oceanographic change point year.

Reproductive Phenology

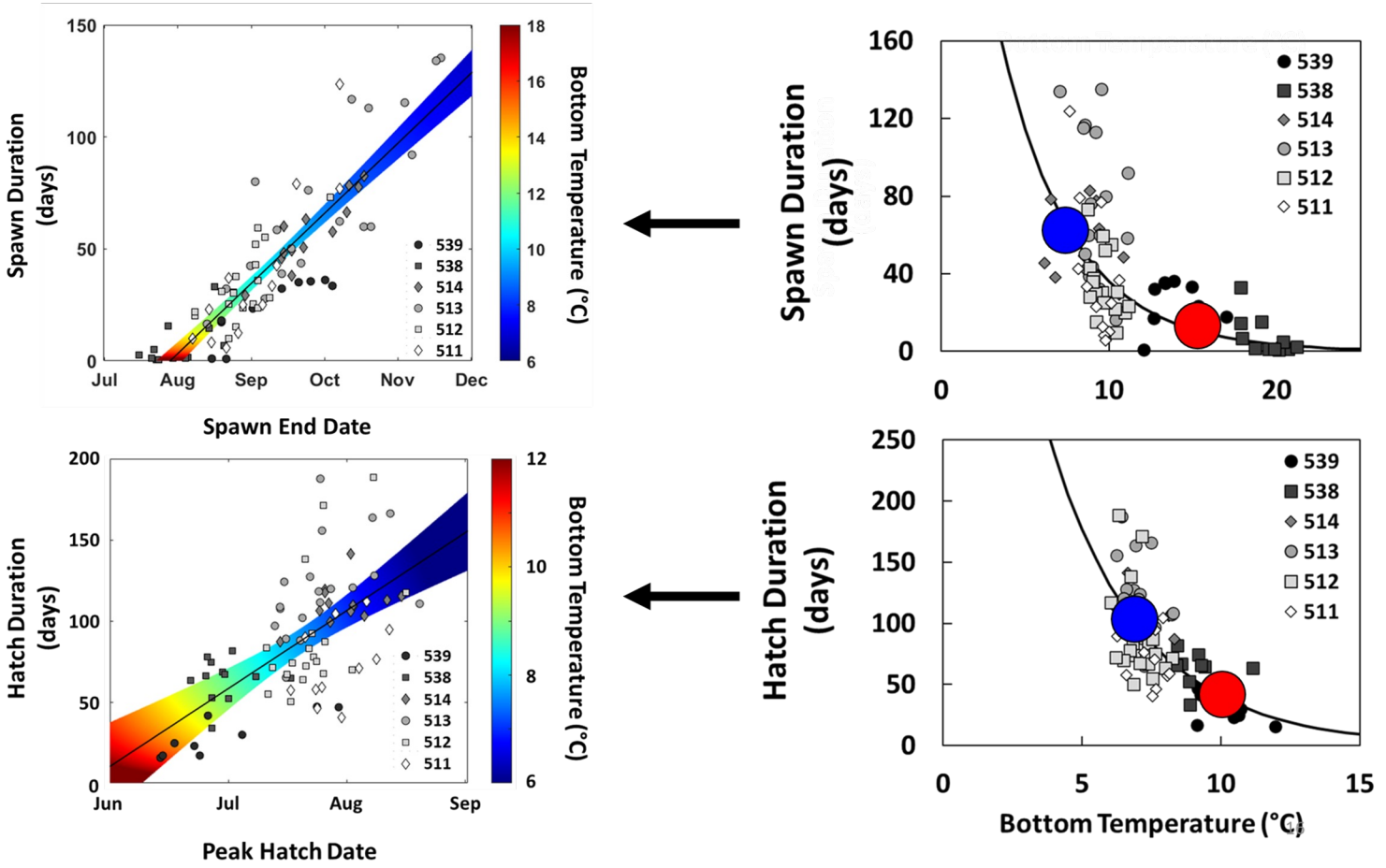
Ventless Trap and Sea Sampling Surveys

- ME DMR
- MA DMF
- RI DEM

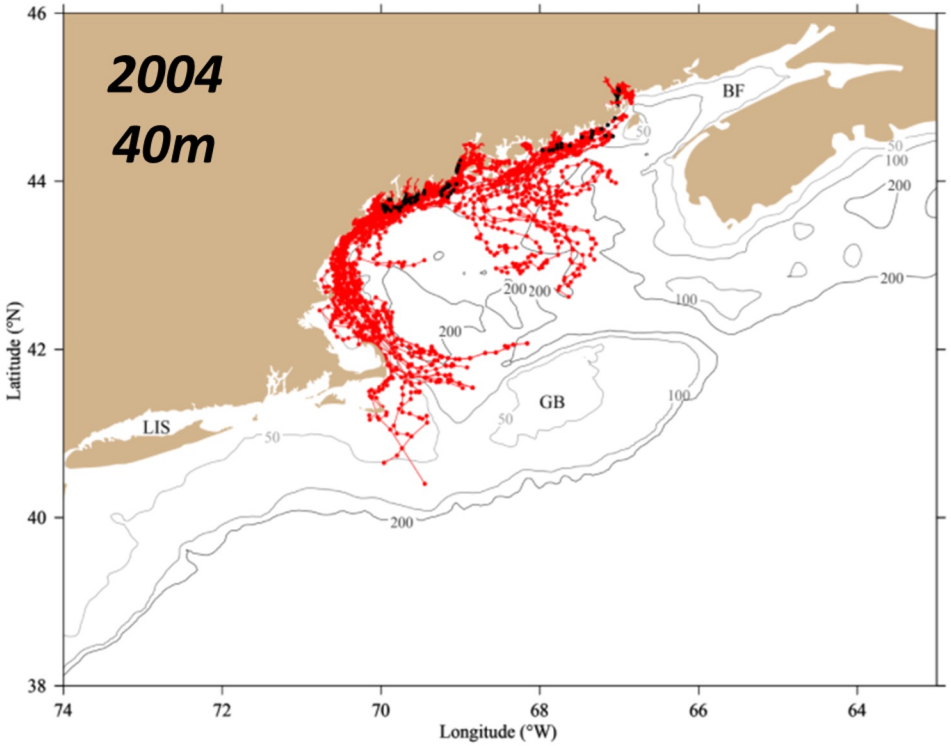
Proportion of ovigerous females spawning / hatching eggs

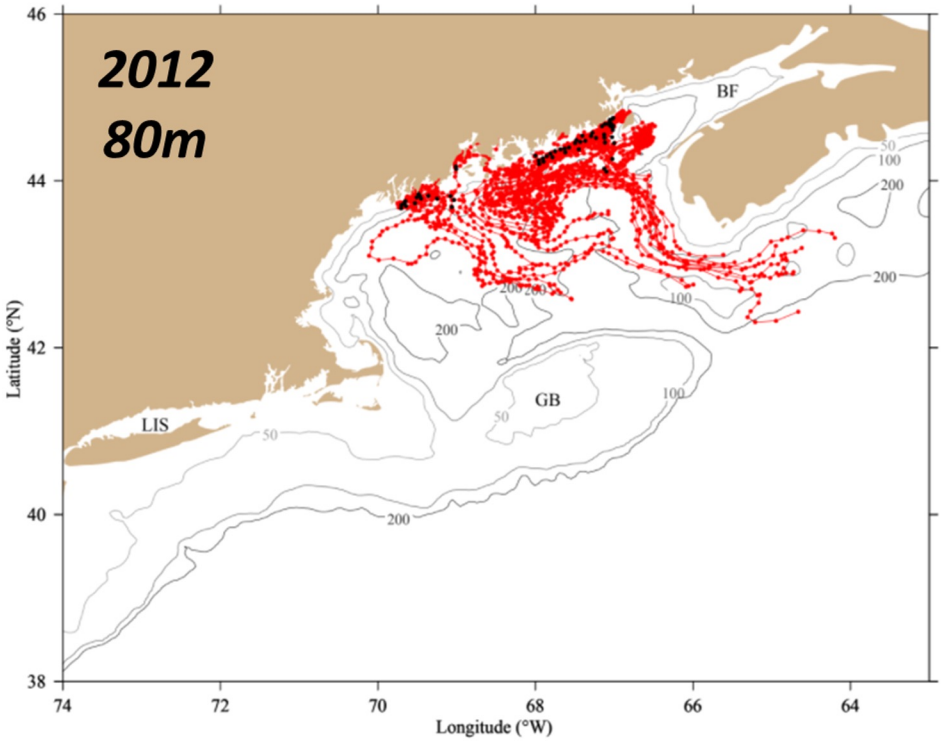


Reproductive Phenology

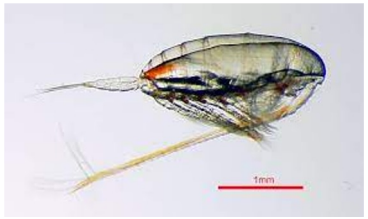


Implications to Larval Trajectories

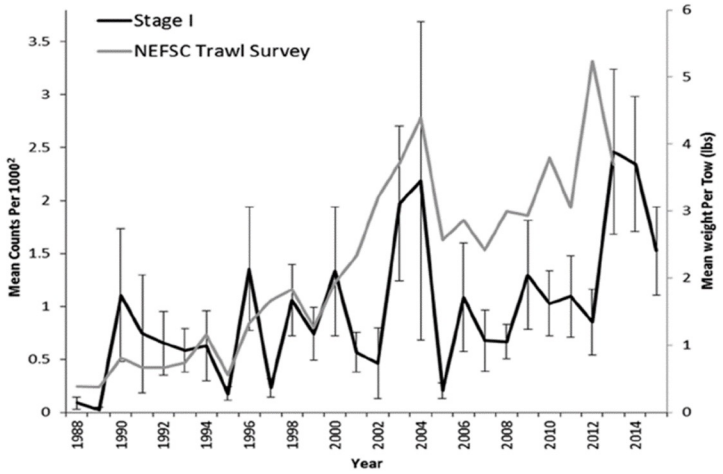




Trophic Influences

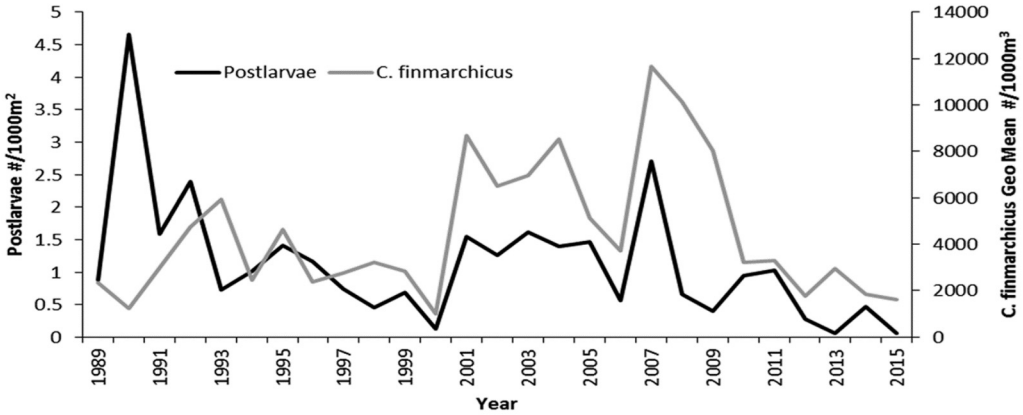


- Stage I larvae increase with increases in SSB



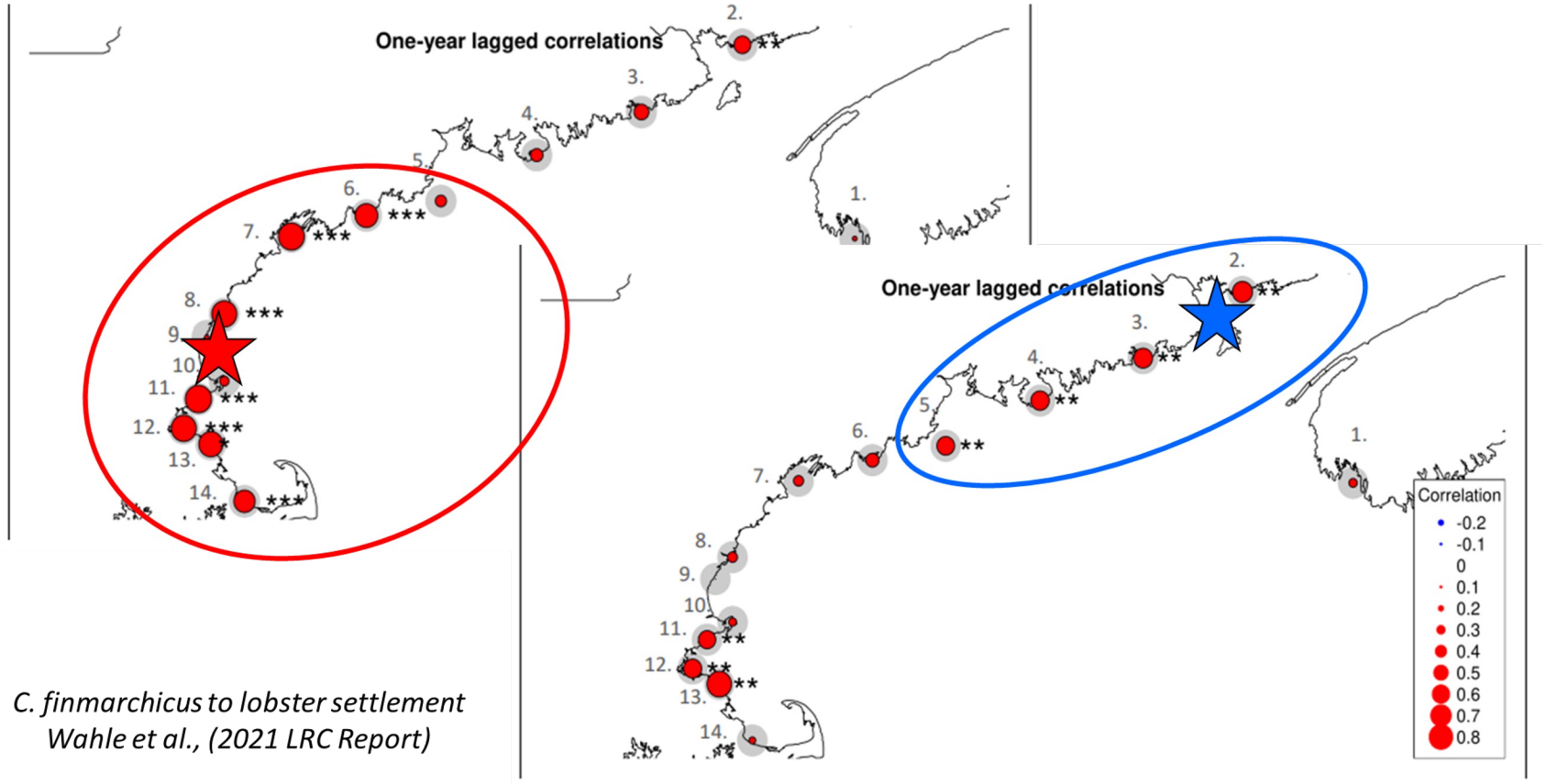
- Stage I increases but Stage IV decreases

- Postlarval abundance declines track similar declines in *Calanus finmarchicus*



Carloni et al. (2018)

Trophic Influences



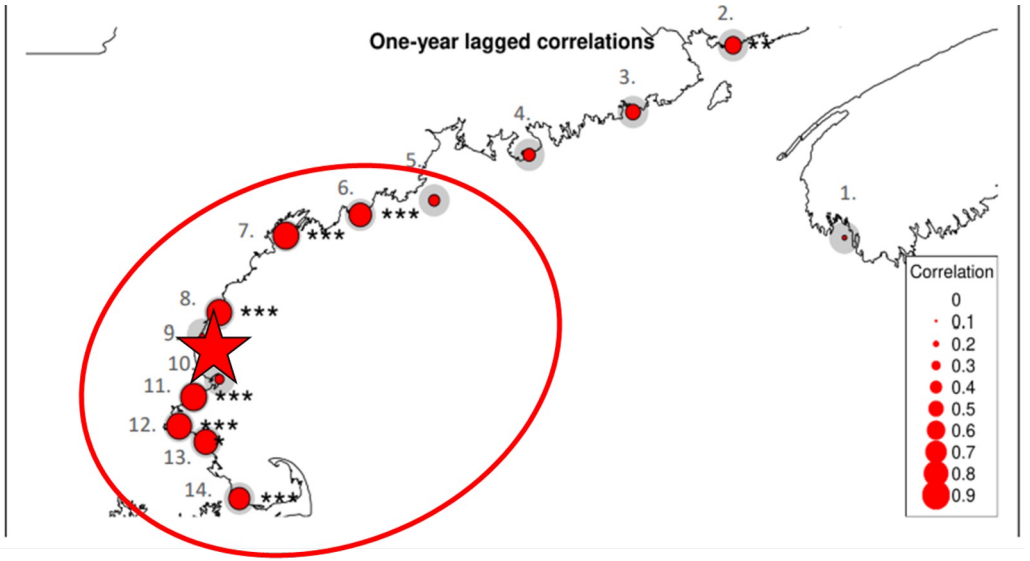
C. finmarchicus to lobster settlement
Wahle et al., (2021 LRC Report)

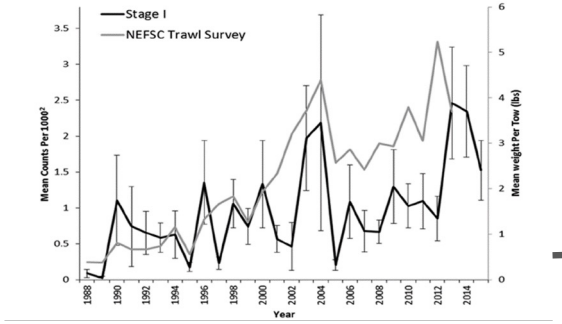
Trophic Influences

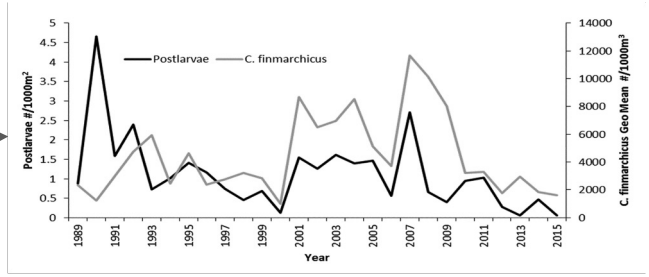
Training using particle tracks and Seabrook data

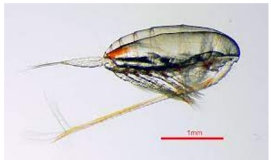
- Calanus-modified natural mortality to recreate SIV patterns
- Seabrook and PIV C.fin for

Stage	Z (day^{-1})
I	0.231
II	0.176
III	0.120
IV	0.065

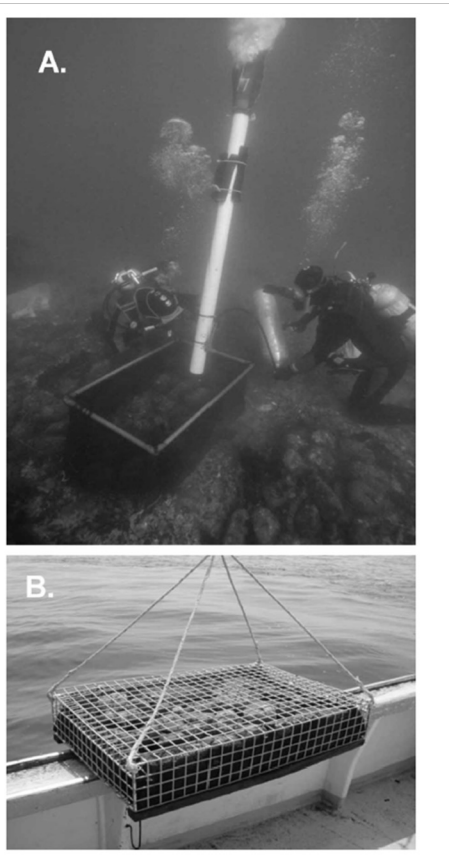








Settlement Regulation



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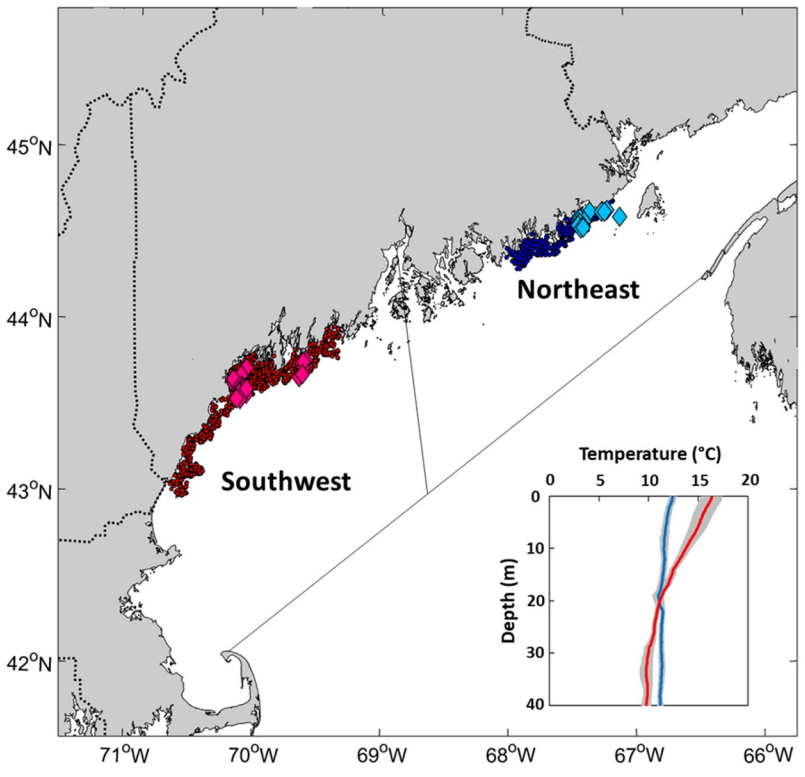
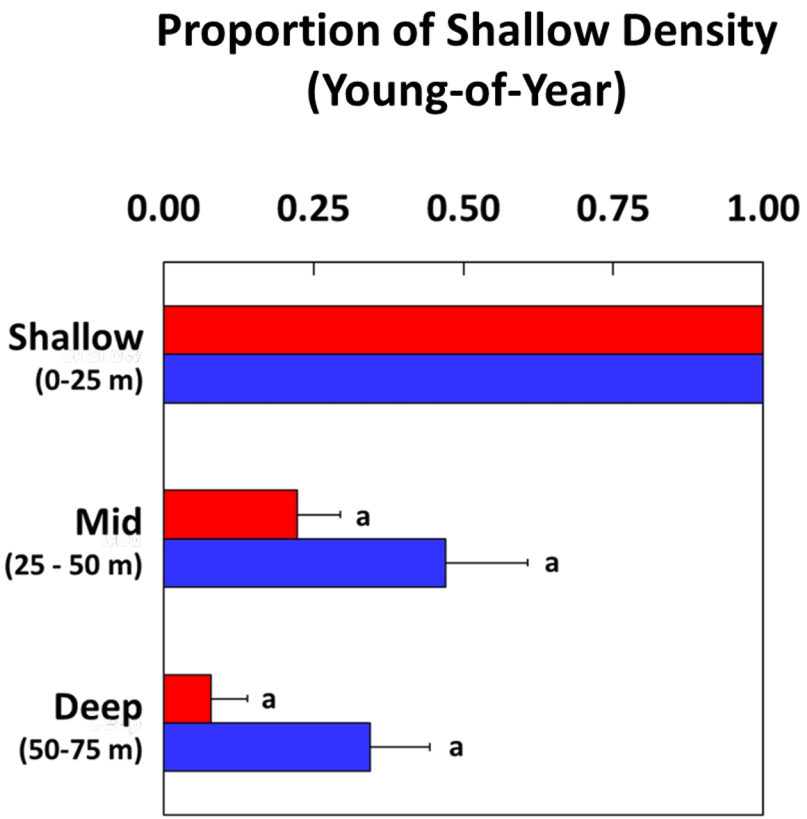


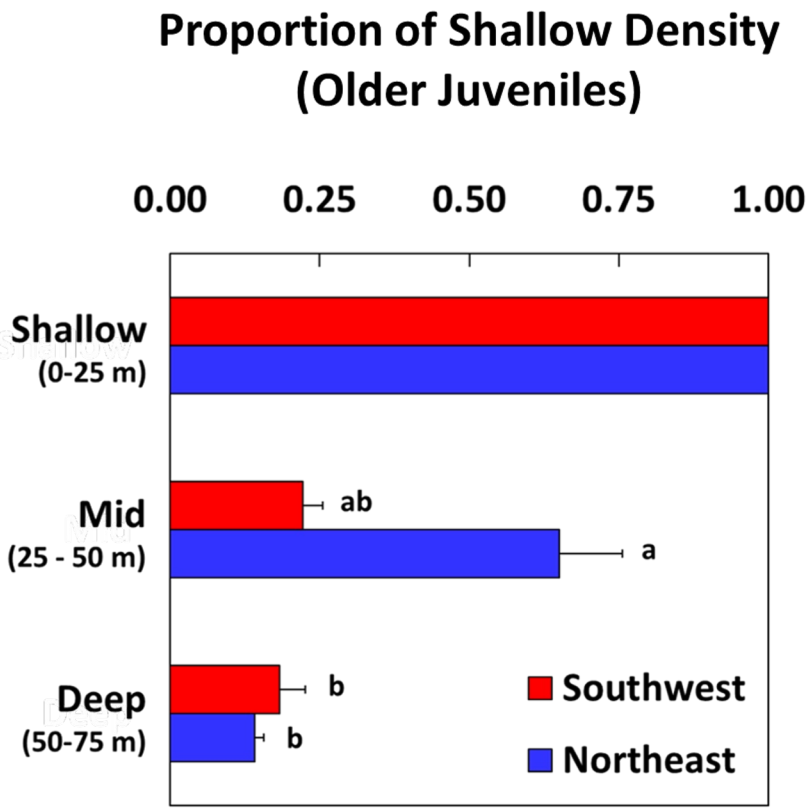
Gulf of Maine Oceanographic Regions

Ontogeny Stage	Carapace Length (mm)
Young of Year (YoY)	<13
Older Juvenile (OJ)	>13
Adolescent (Ad)	<53
Sub-adult (SA)	53-83
Adult (A)	>83

Collectors VTS

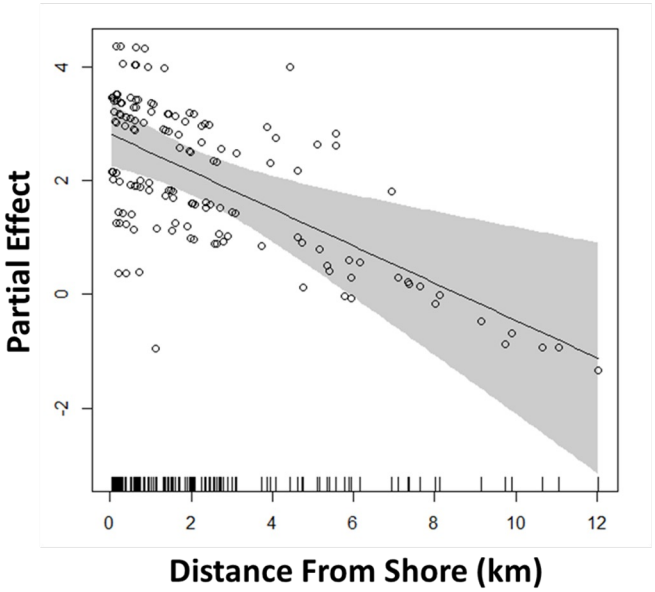
Settlement Regulation

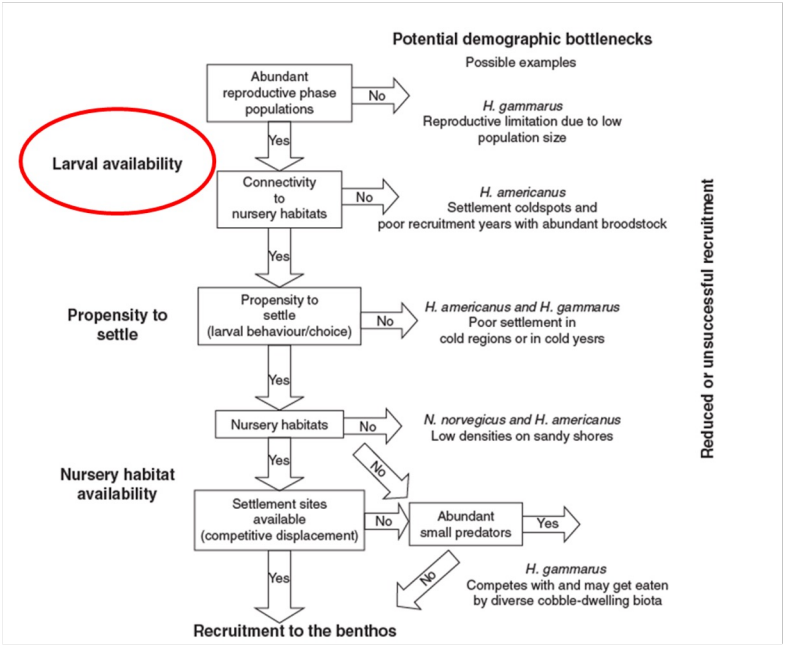




Settlement Regulation

YoY Presence GAM

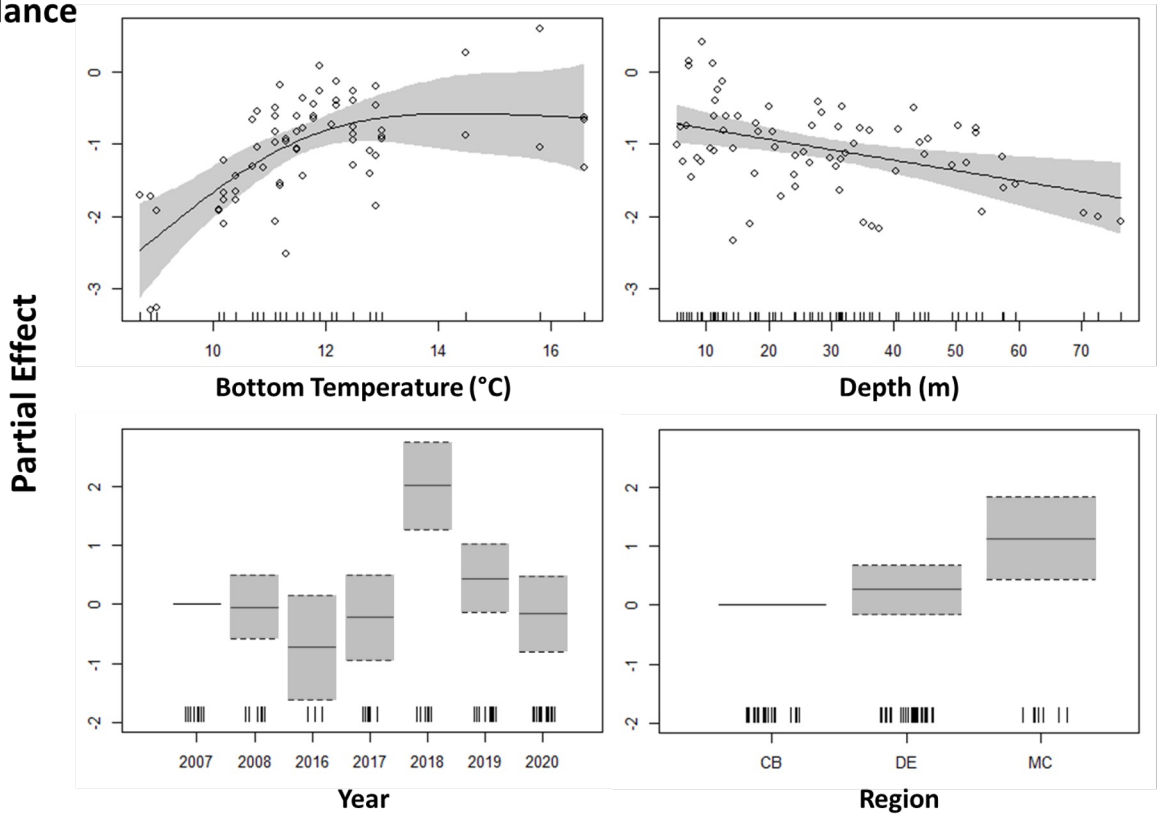




Settlement Hierarchy; Butler et al. (2006)

Settlement Regulation

YoY Abundance GAM



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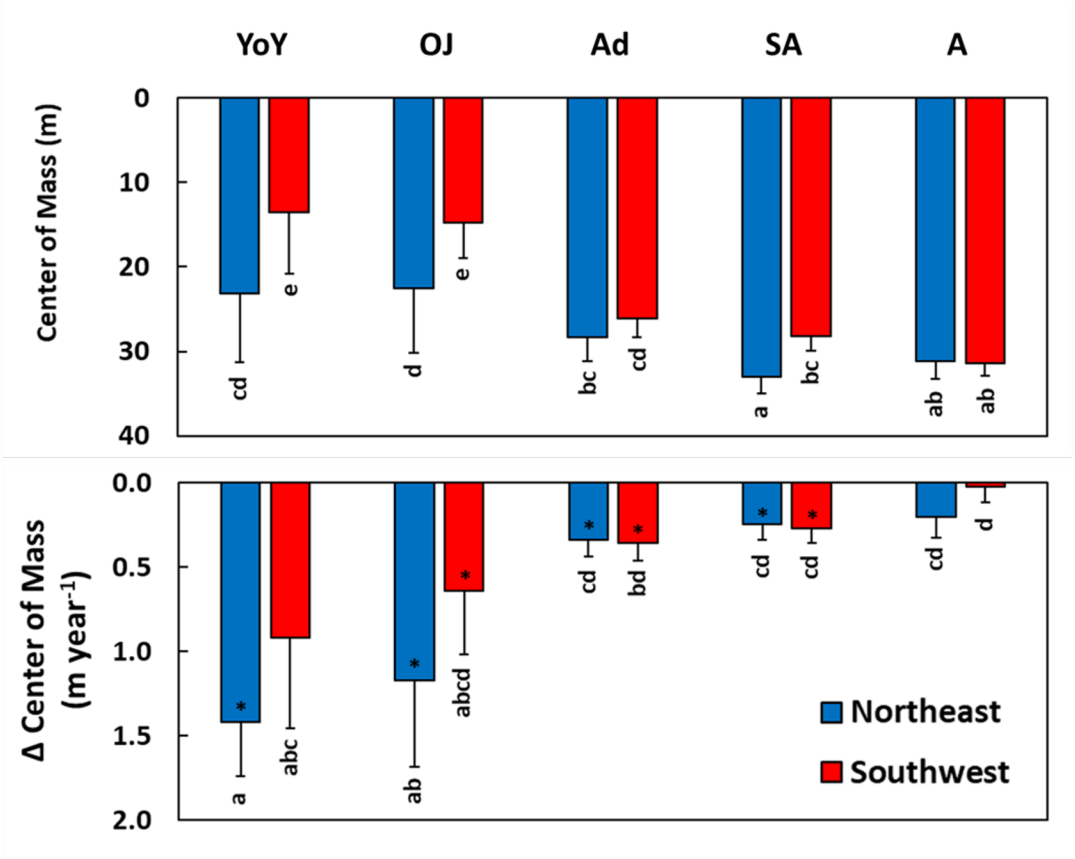

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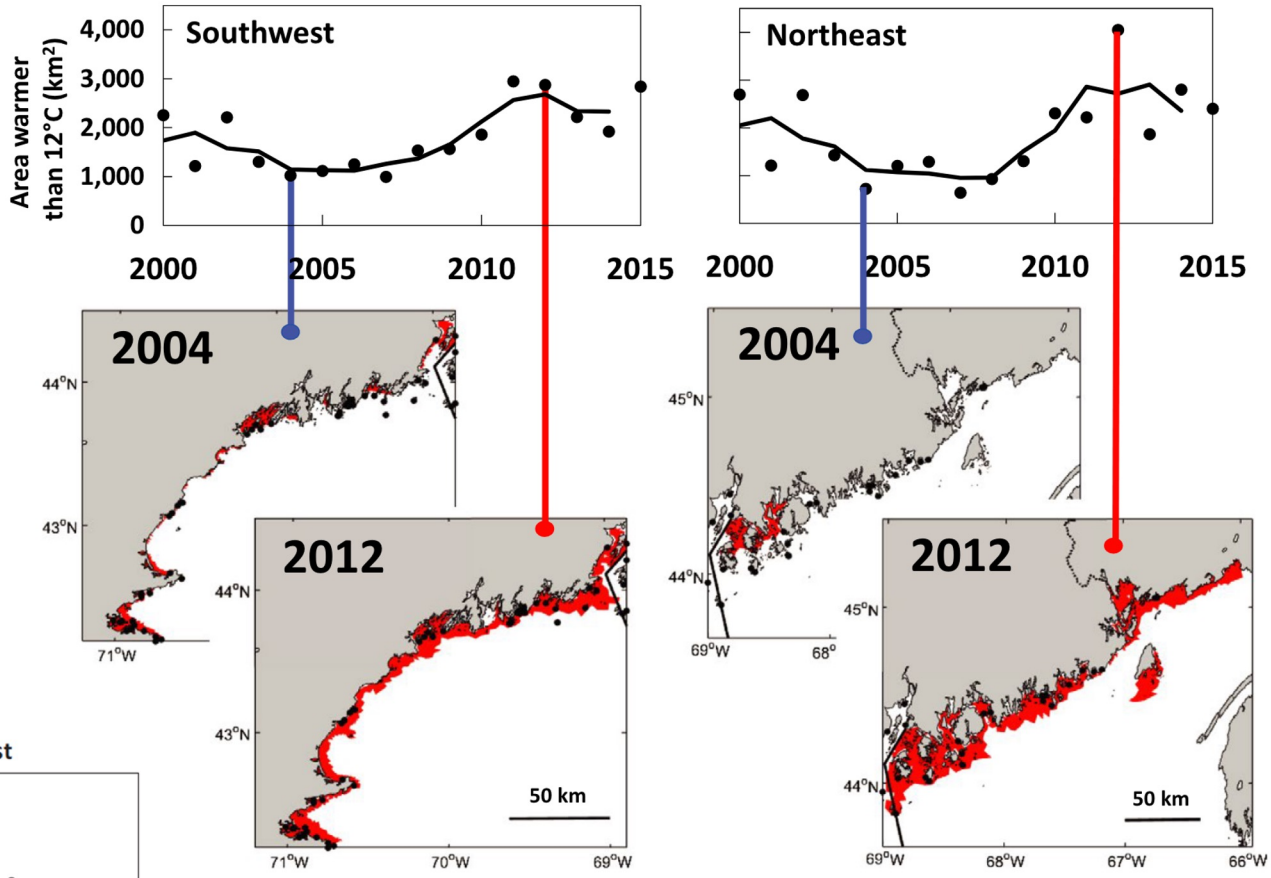
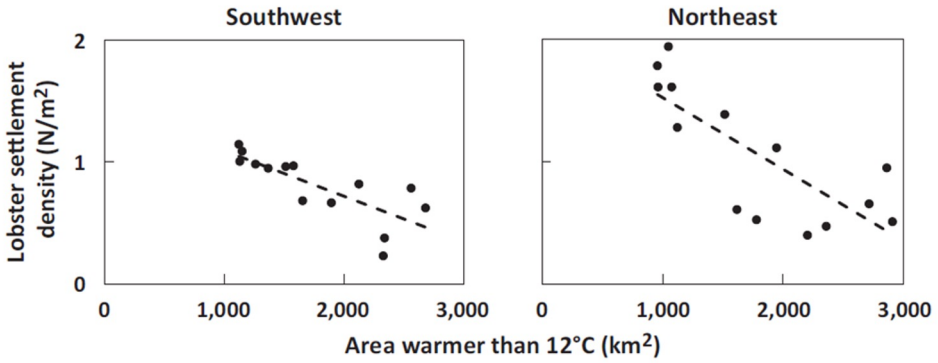
Collectors VTS

Settlement Regulation

- Warming above 12°C expands available thermal habitat for postlarval settlement.





Warmer conditions expand available settlement habitat (Top), possibly regulating the area over which larvae are dispersed (left). Goode et al. (2019)

Takeaways

SSB

- Changing HSIs in the central GOM makes habitat more accessible during Spring

Reproductive Phenology

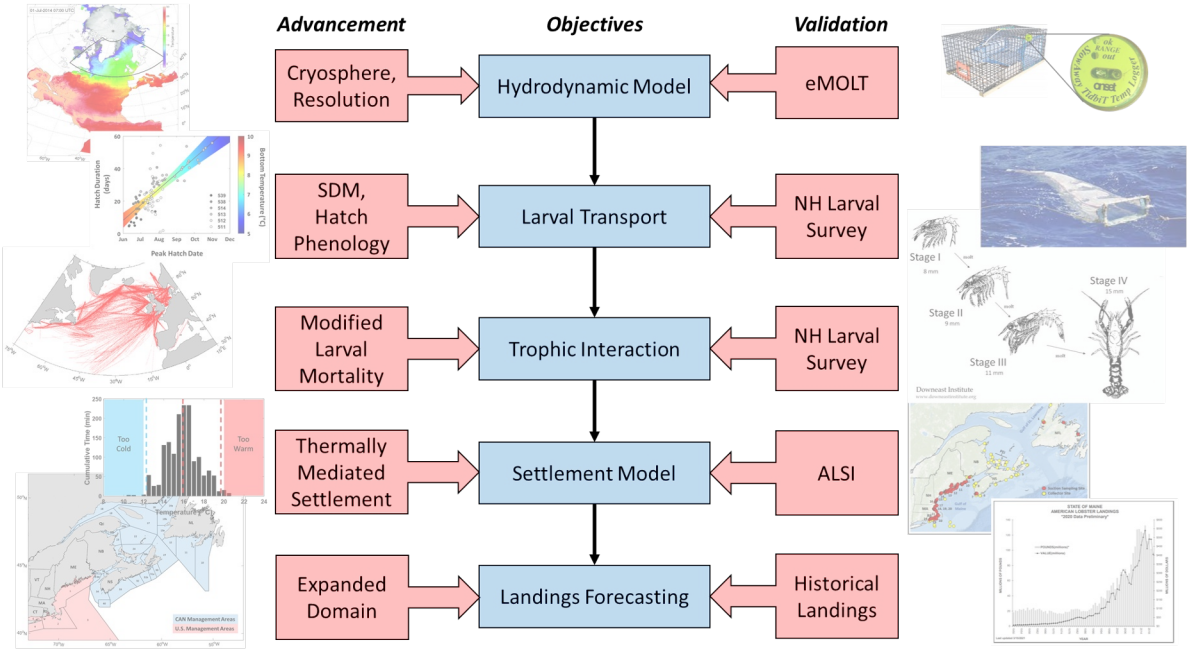
- Warming is shifting larval release earlier and over a shorter duration

Trophic Dynamics

- Regional *C. finmarchicus* patterns correspond to settlement
- Work being done to integrate patterns with larval model

Settlement Patterns

- Settlement deeper can potentially utilize colder temperatures than previously thought

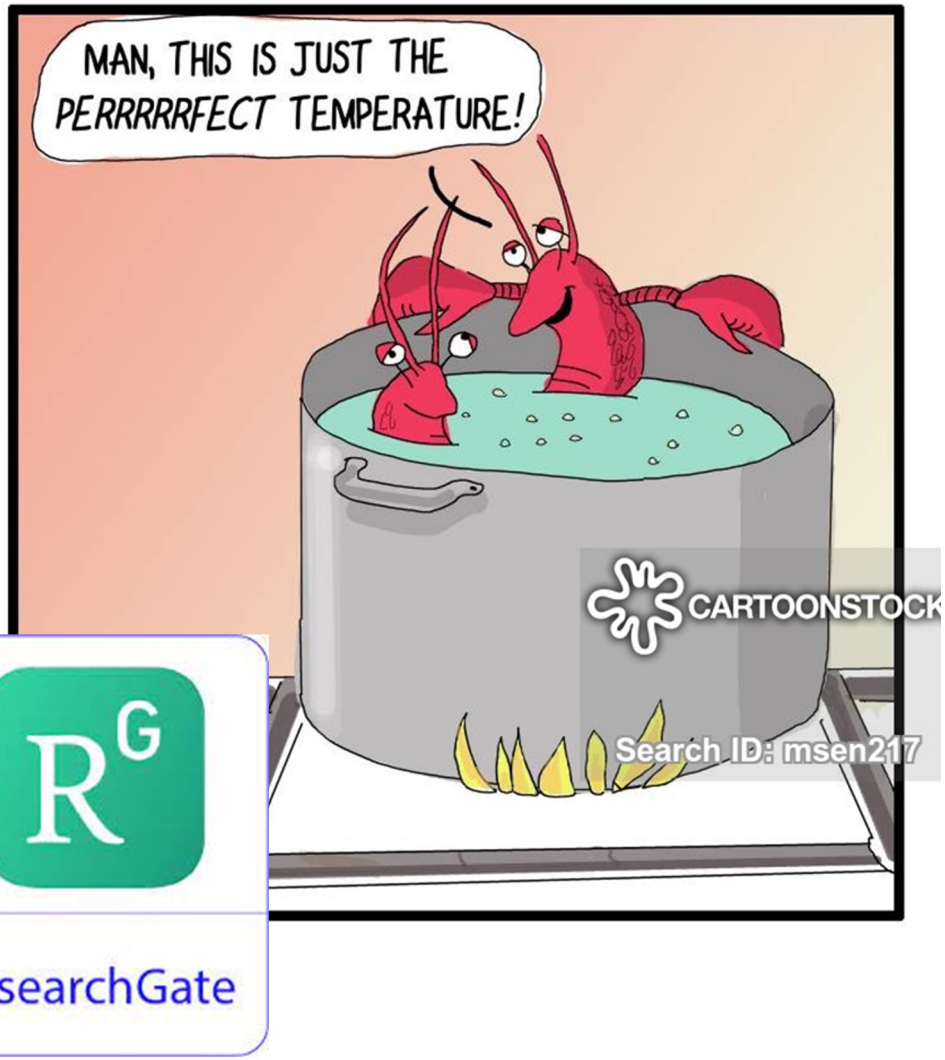


Integration = Difficult, but we're refining our inputs to make everything as applicable as possible

Questions?

Andrew Goode
https://www.researchgate.net/profile/Andrew-Goode

Everett Rzeszowski
https://www.researchgate.net/profile/Everett-Rzeszowski



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