

# Lobster Ecosystem Modeling + Monitoring



NNA Lobster Network All-Hands Meeting  
21 November 2024

Andrew Goode



1

## Overarching Research Goals / Objectives

### *Monitoring*

- Collaborate with The Lobster Institute, The Gulf of Maine Lobster Foundation, and NOAA to help expand benthic temperature monitoring by the Environmental Monitoring on Lobster Traps (eMOLT) program.

### *Modeling*

- Integrate multiple avenues of early lobster life history research to develop a Larval Life History Model to simulate drift, growth, mortality, and settlement of larval / Postlarval lobsters.

2

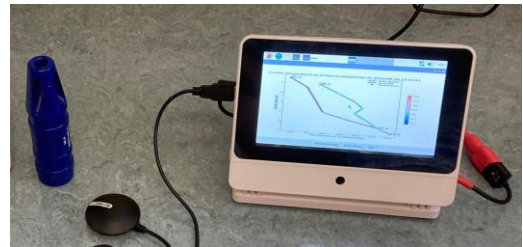
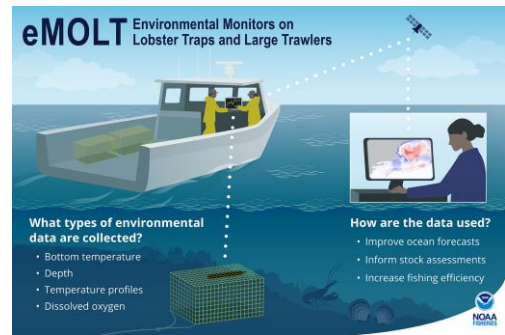
# Monitoring: eMOLT

## Why?

- Provides critical benthic temperatures and water column profiles necessary to tune the hydrodynamic models to real conditions in the Gulf of Maine

## How?

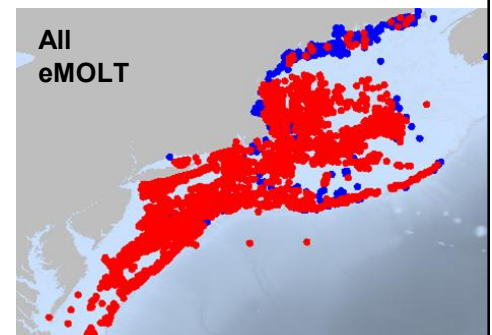
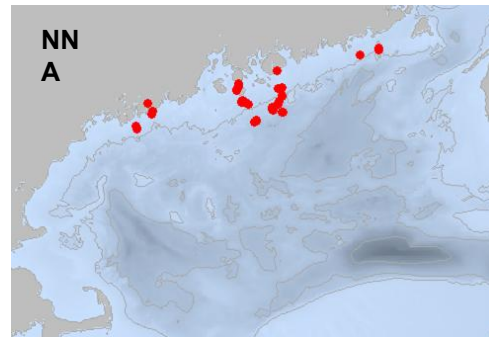
- *in situ* temperature-depth sensors, satellite transmission of data in near-real time



3

# eMOLT 2024

- In 2024 the NNA program and GOMLF added **10** new participating lobstermen to the eMOLT program ranging from Bucks Harbor to Kittery
  - 12 Temperature-Depth Sensors
  - 12 DO Sensors
- NNA Total: 18 new participants
- Add Pete's figure\*\*\*\*\*

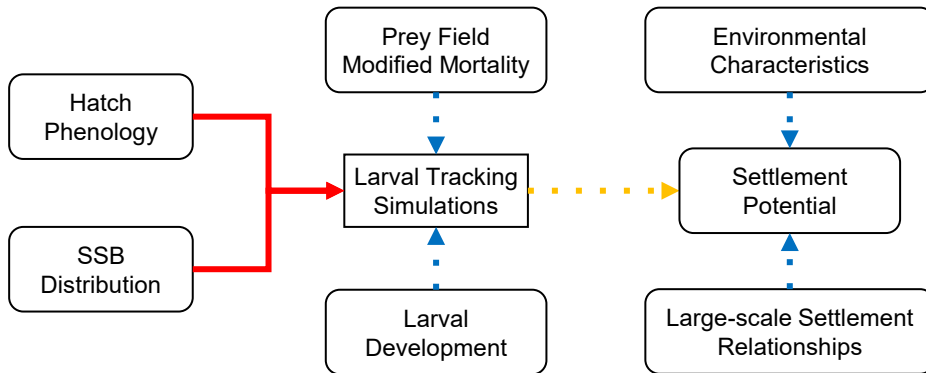


4

# Modeling

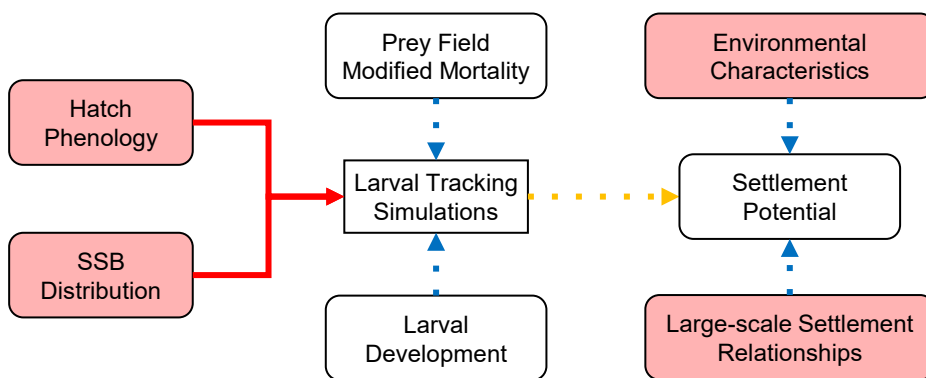
## Objective:

- Integrate HYCOM-NEMURO products to particle tracking simulations



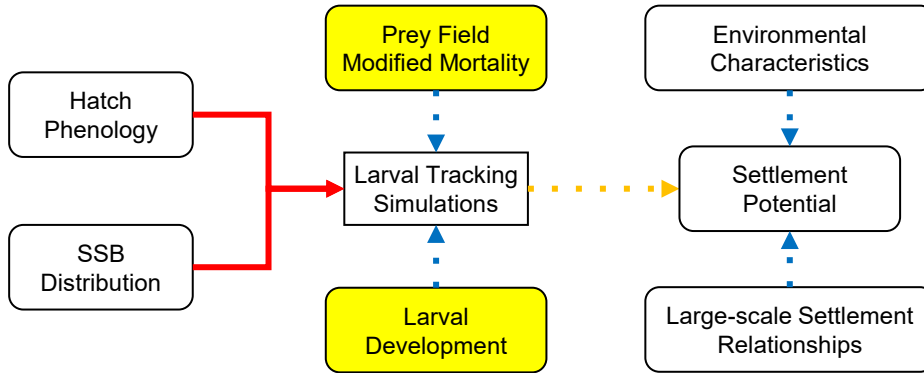
5

# Modeling: Previous All Hands Discussion



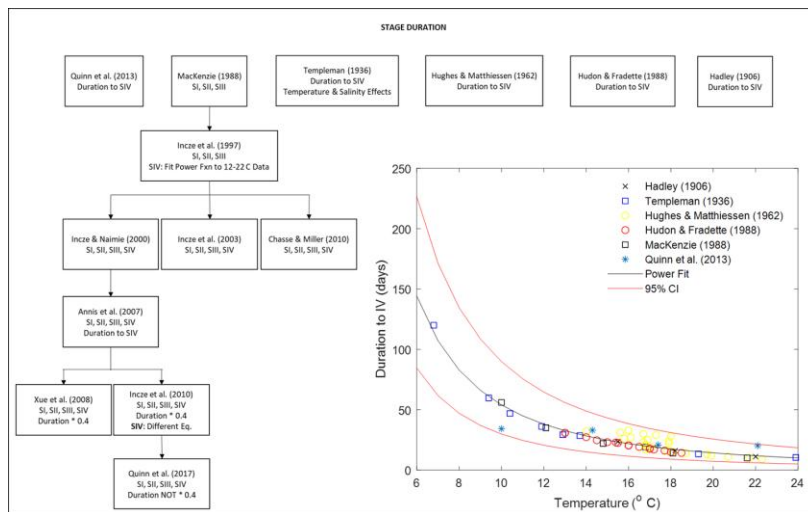
6

# Modeling: Today's Topic – development and mortality



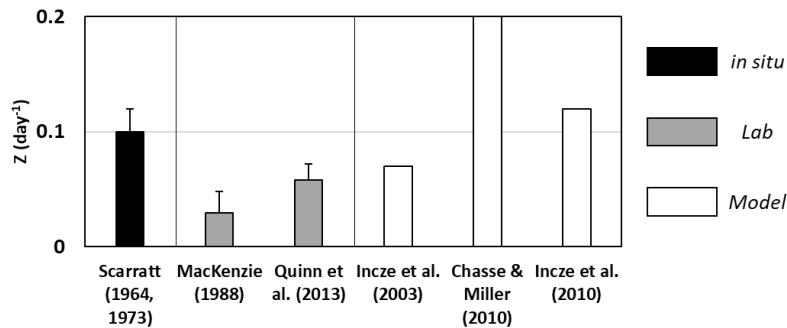
7

# Modeling: revisiting development and mortality



8

## Modeling: revisiting development and mortality



- What about temperature dependence?

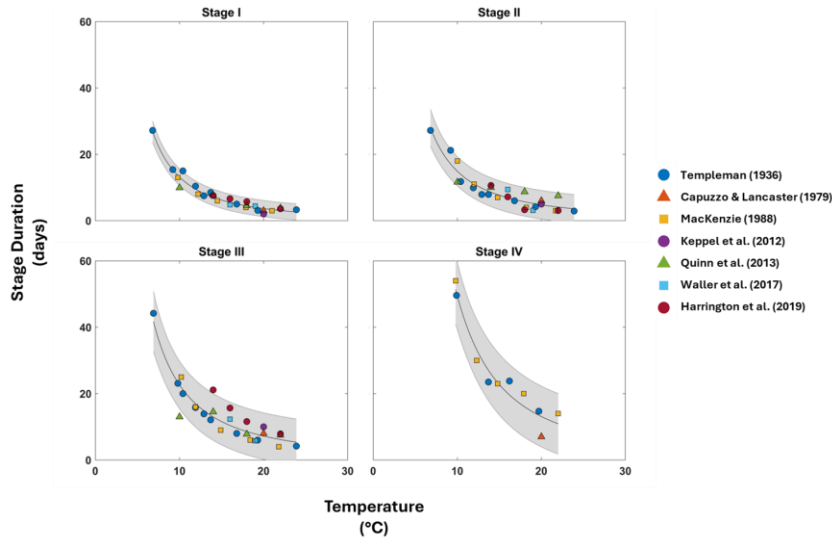
9

## Modeling: revisiting development and mortality

- Literature review of stage-specific temperature-dependent relationships to larval stage duration
- Revisit MacKenzie (1988) data for temperature-dependent, stage-specific larval mortality
- **Q:** *Can we refine these relationships with existing data, and what inferences can we gain from the two?*

10

# Larval development

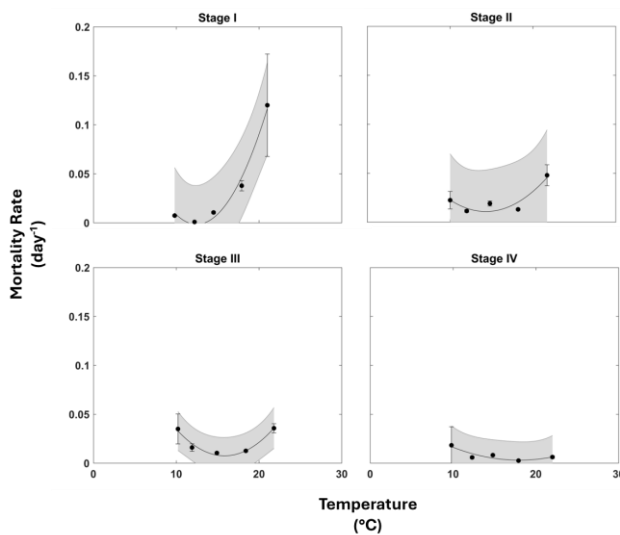


## Results

- Comparable equations to MacKenzie (1988)
- Improves eq. fit to results from 7 studies
  - Especially at low temperatures where the MacKenzie eqs. perform poorly

11

# Larval mortality

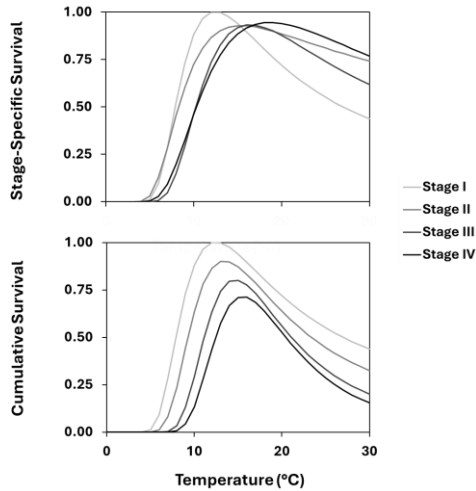


## Results

- MacKenzie (1988) data (Table 1), were able to generate daily mortality rates that varies with temperature.
- 2<sup>nd</sup> order polynomials with decreasing sensitivity to temperature with advancing larval stage

12

## Survival

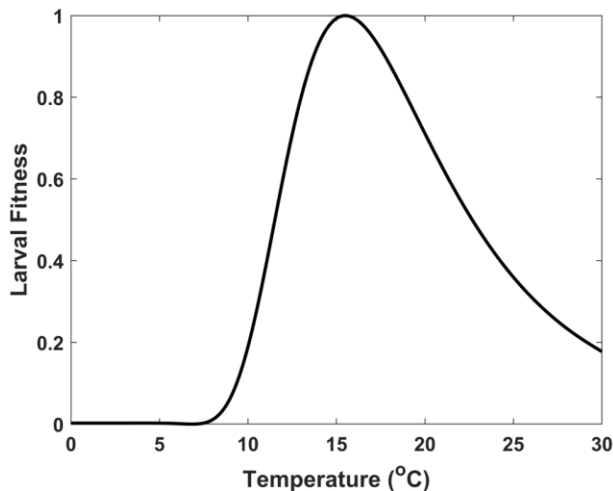


### Results

- Non-linear relationships between temperature and development/mortality create unique, non-linear functional relationships between larval survival and temperature.
- Cumulative survival is largely dictated by patterns established/experienced as a stage I larva.

13

## Fitness

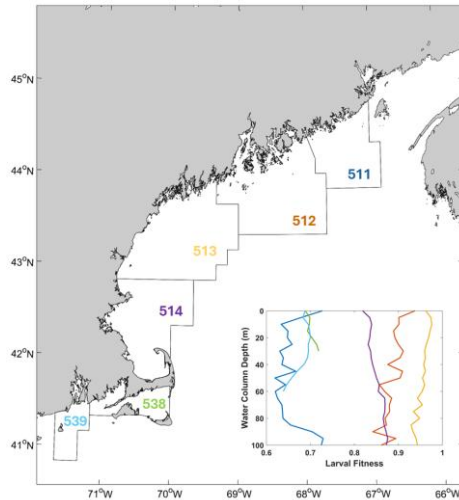


### New questions

- Can larval fitness (Survival / Max Survival) be used to investigate patterns of larval habitat suitability?
- How has larval habitat suitability changed over space/time?
- How do these patterns relate to lobster settlement patterns (the end result of successful survival and settlement to the early benthic stage)

14

## Fitness Over Space

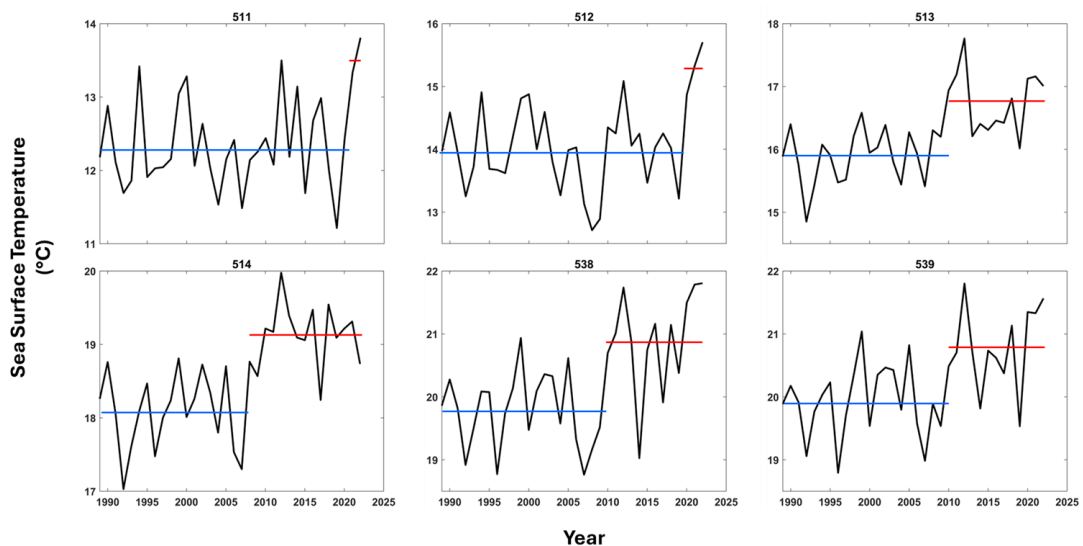


### Results

- Larval Fitness estimates show significant variation in larval habitat suitability across NOAA statistical areas.
  - Highest along Mid-coast ME
- Fitness changes inshore/offshore, but the patterns aren't the same everywhere

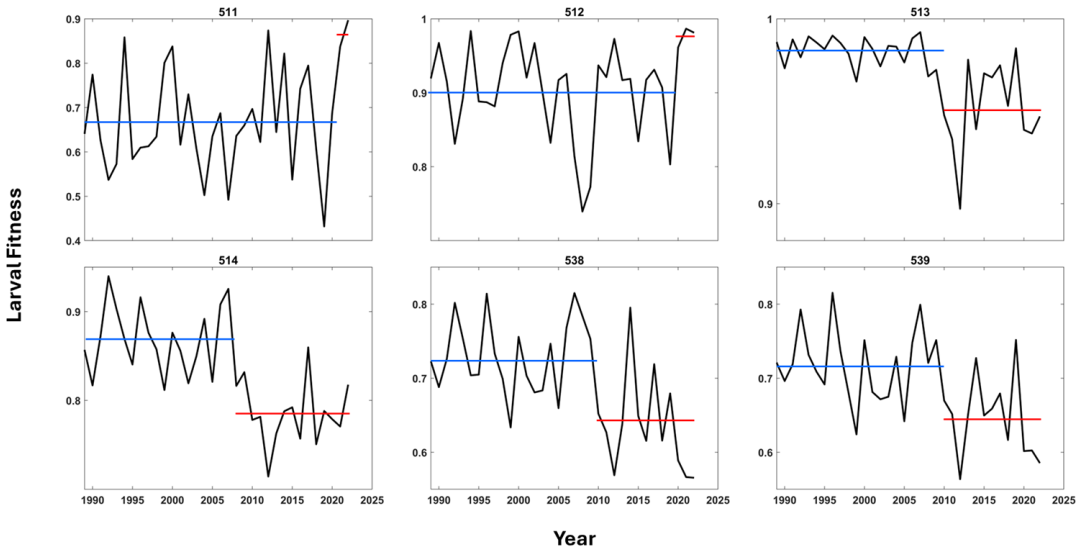
15

## SST Regime Shifts



16

## Larval Fitness Regime Shifts



17

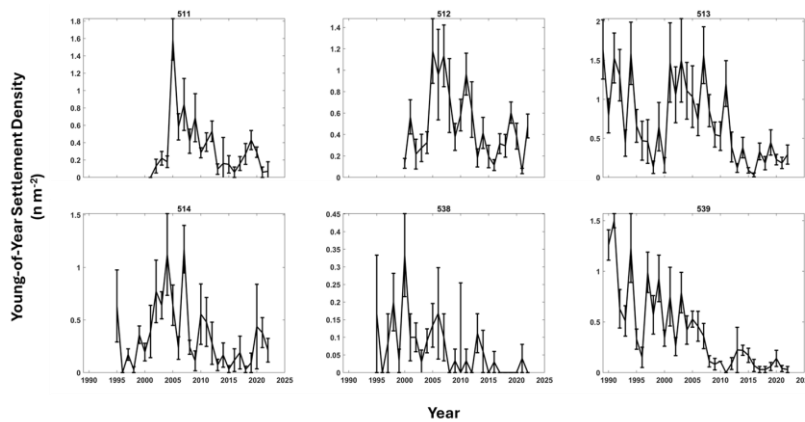
## Non-linear Responses Make a Difference

Statistical Area	Change Point	SST (°C)			Larval Fitness		
		Before	After	$\Delta$	Before	After	$\Delta$
511	2020-2021	12.3	13.6	1.27	0.66	0.87	0.21
512	2019-2020	14.0	15.3	1.34	0.90	0.98	0.08
513	2009-2010	15.9	16.8	0.86	0.98	0.95	-0.03
514	2007-2008	18.1	19.1	1.05	0.87	0.79	-0.08
538	2009-2010	19.8	20.9	1.13	0.73	0.64	-0.09
539	2009-2010	19.9	20.8	0.86	0.72	0.65	-0.07

- Rapid changes in the thermal environment have caused shifts in regional larval habitat suitability.
- Non-linear relationships to temperature cause heterogeneous responses to habitat suitability given similar changes in temperature

18

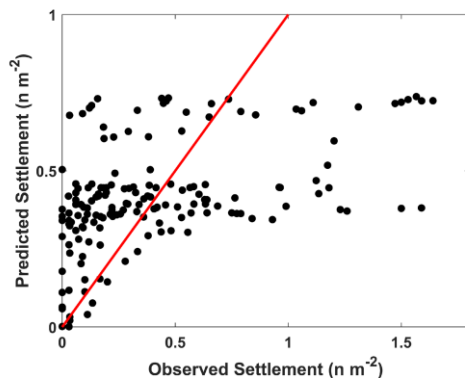
## Fitness and Post-larval Settlement



- Regional declines in settlement correspond to regime shift phenology of larval fitness
- How well do they relate?

19

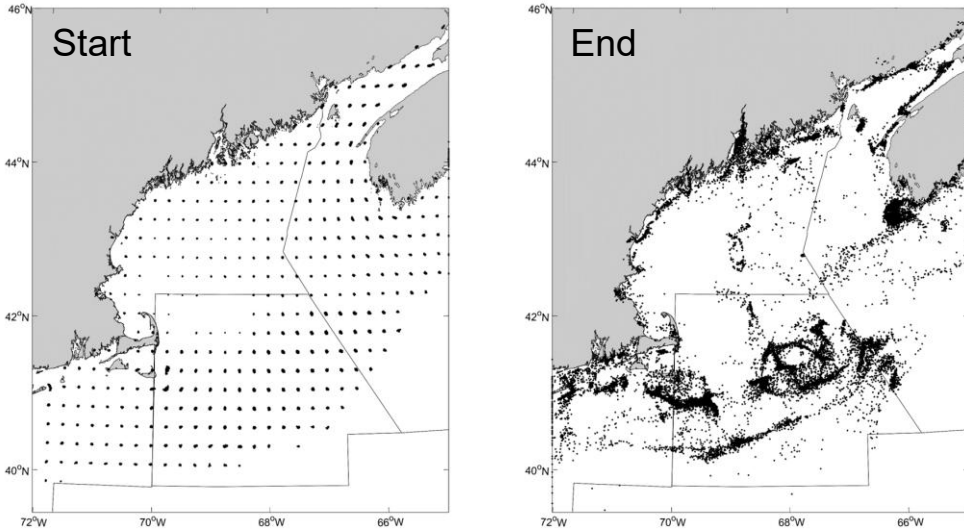
## Fitness vs Settlement



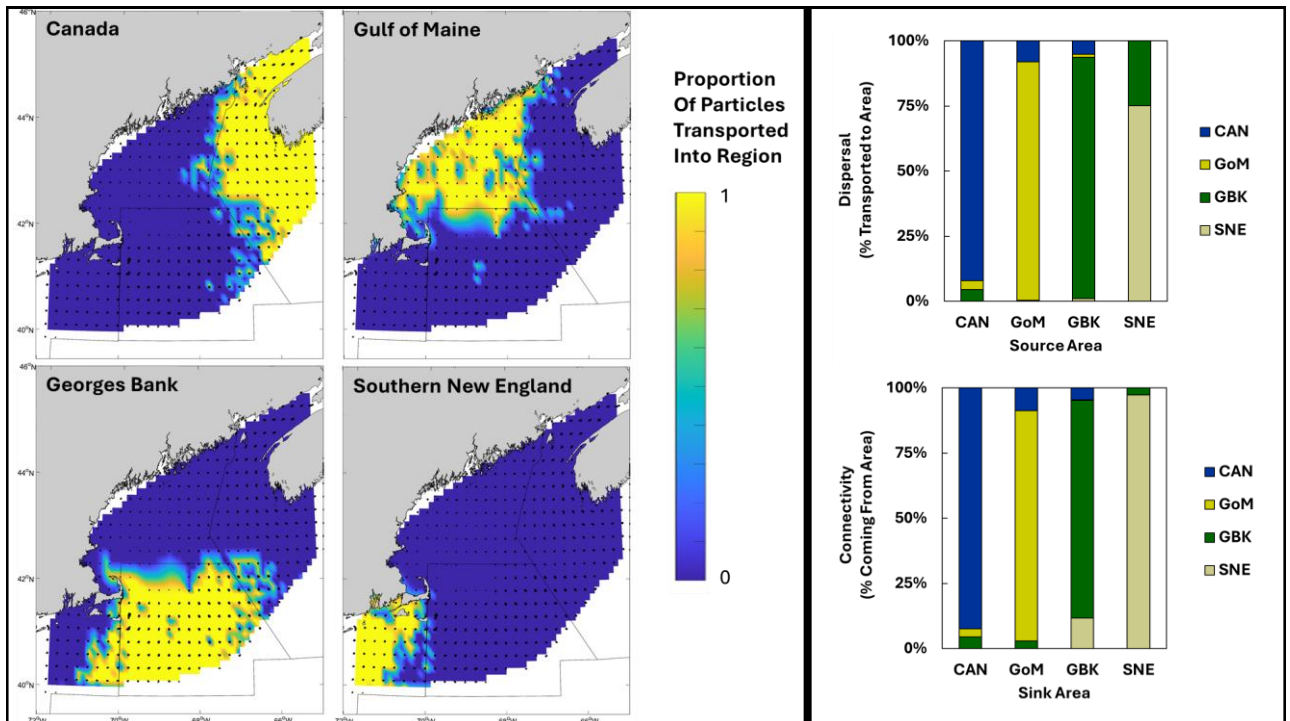
- Linear mixed effect model
  - Relationship between fitness and settlement rate varies over statistical areas due to spawner biomass, connectivity, benthic habitat suitability, etc.
  - Statistical area as random effects to slope and intercept to address regional patterns
- Model  $R^2 = 0.21$
- A significant part of the story that needs to be accounted for

20

# Tracking Simulations



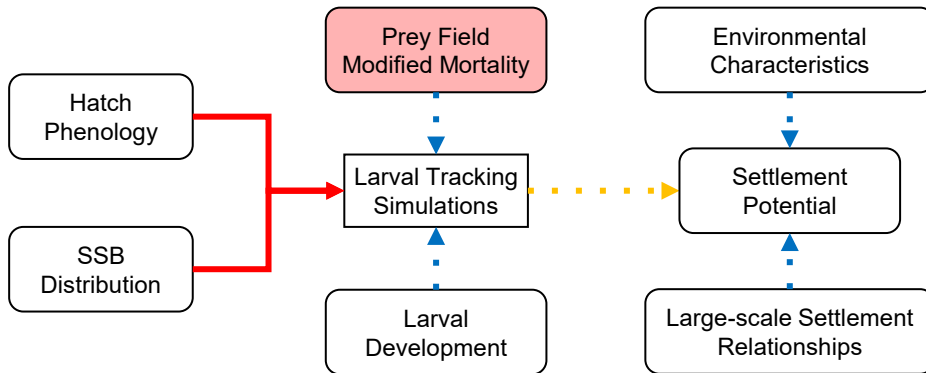
21



22

## Integration Needs

- HYCOM-NEMURO zooplankton abundances
- Tracking Using HYCOM



23

## Next Steps

- Integrate spawner biomass weighting, egg hatch phenology, revised temperature-dependent development and mortality to estimate annual larval supply and distribution.
- Use benthic thermal habitat, post-larval supply phenology, and large-scale settlement behavior dynamics to estimate annual post-larval supply.
- Relate supply to regional settlement
- Use zooplankton abundance to evaluate its ability to affect the relationship between post-larval supply and settlement density

24