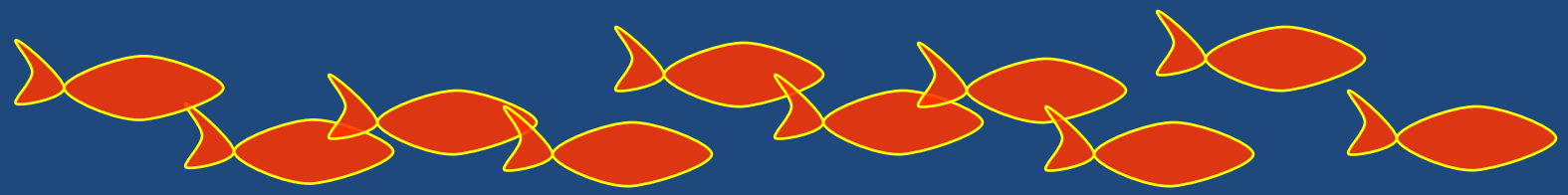
Spatially-Explicit Individual-Based Model of a Louisiana Tidal Marsh Community



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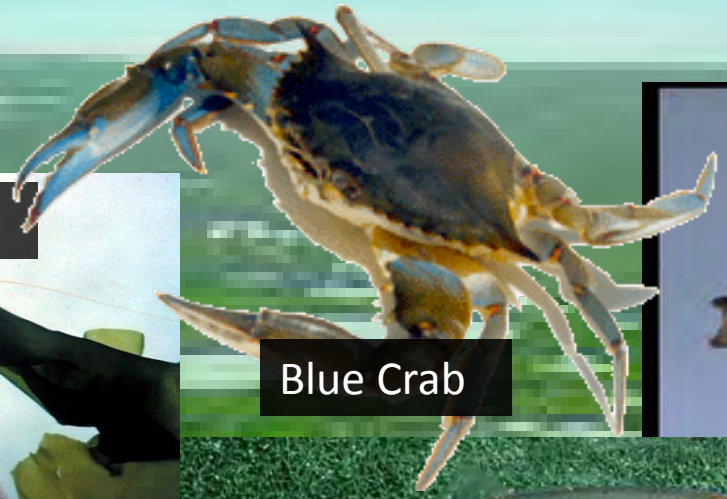
Tidal Marsh Community IBM



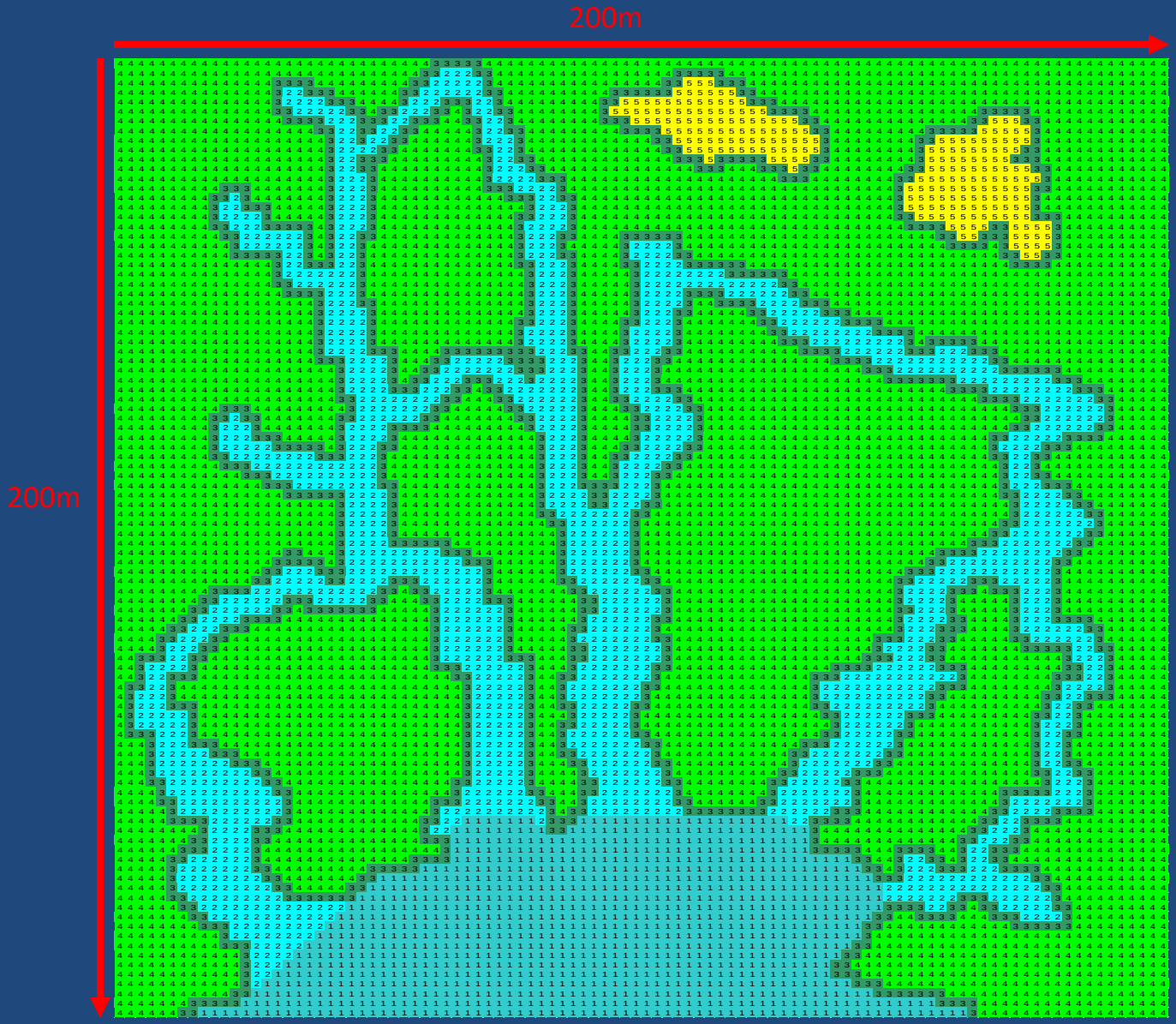
6-Species Community

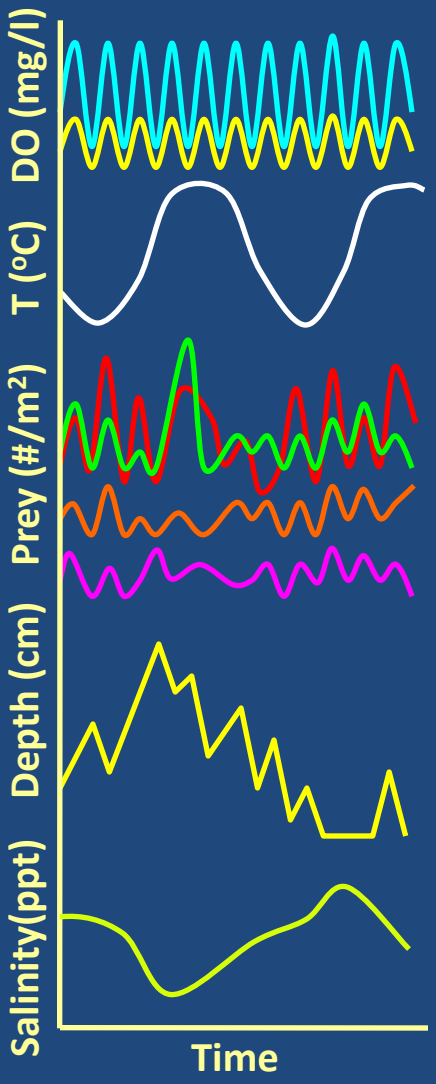
Bay anchovy *(Anchoa mitchilli)*

Tidal Marsh Community IBM

- 6-species food web
- 100 X 100 grid comprised of 4-m^2 cells (40,000 m^2)
- Hourly time step simulated over one year (360 days)
- Processes: feeding, growth, mortality, reproduction, movement
- Prey: zooplankton, benthos, model fish
- Movement, predation, consumption depend on individual size and fish numbers in habitat cells

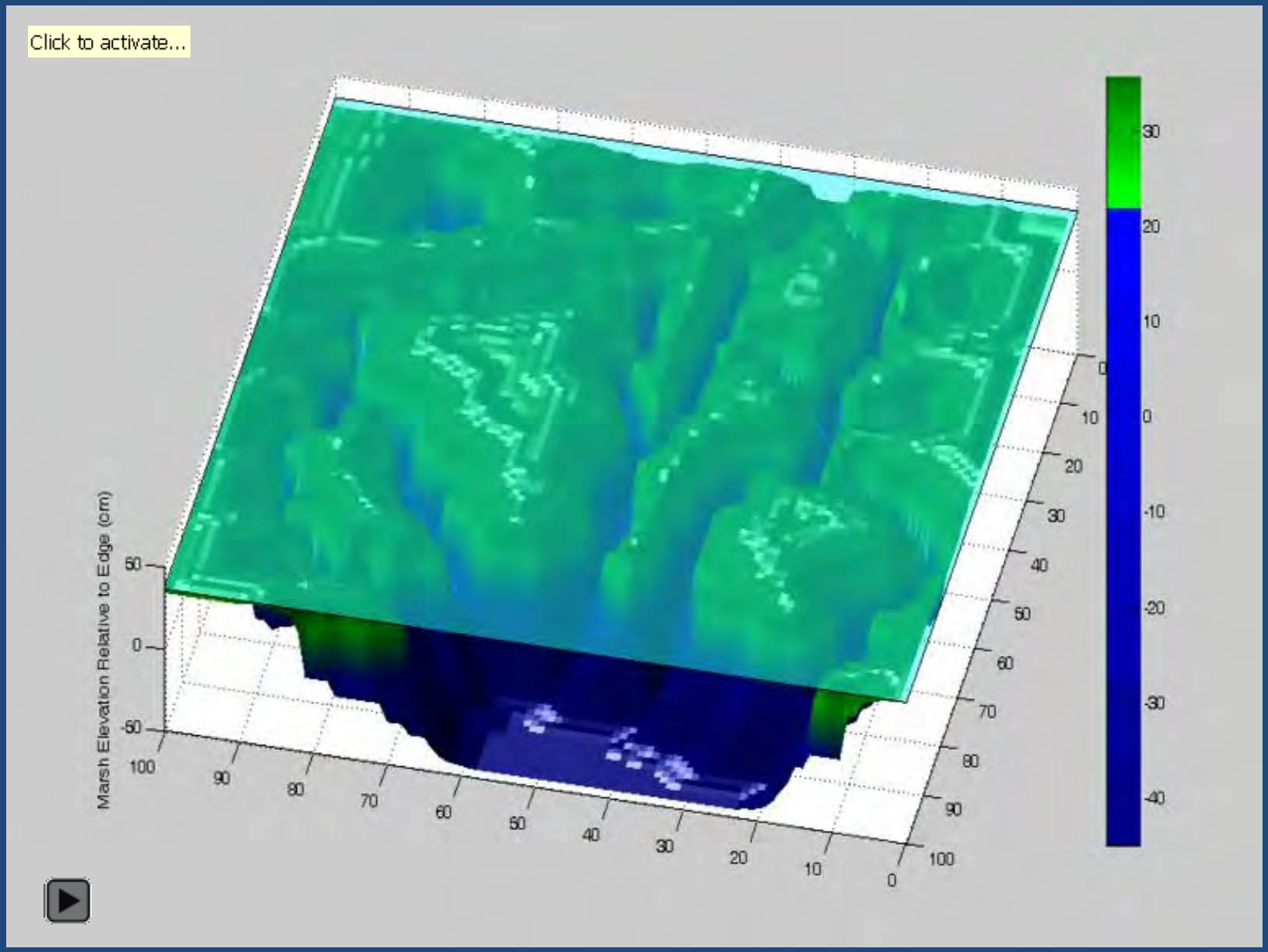
Tidal Marsh IBM





- Interior Marsh
- Marsh Edge
- Bay Channel
- Tidal Creek
- Marsh Pool

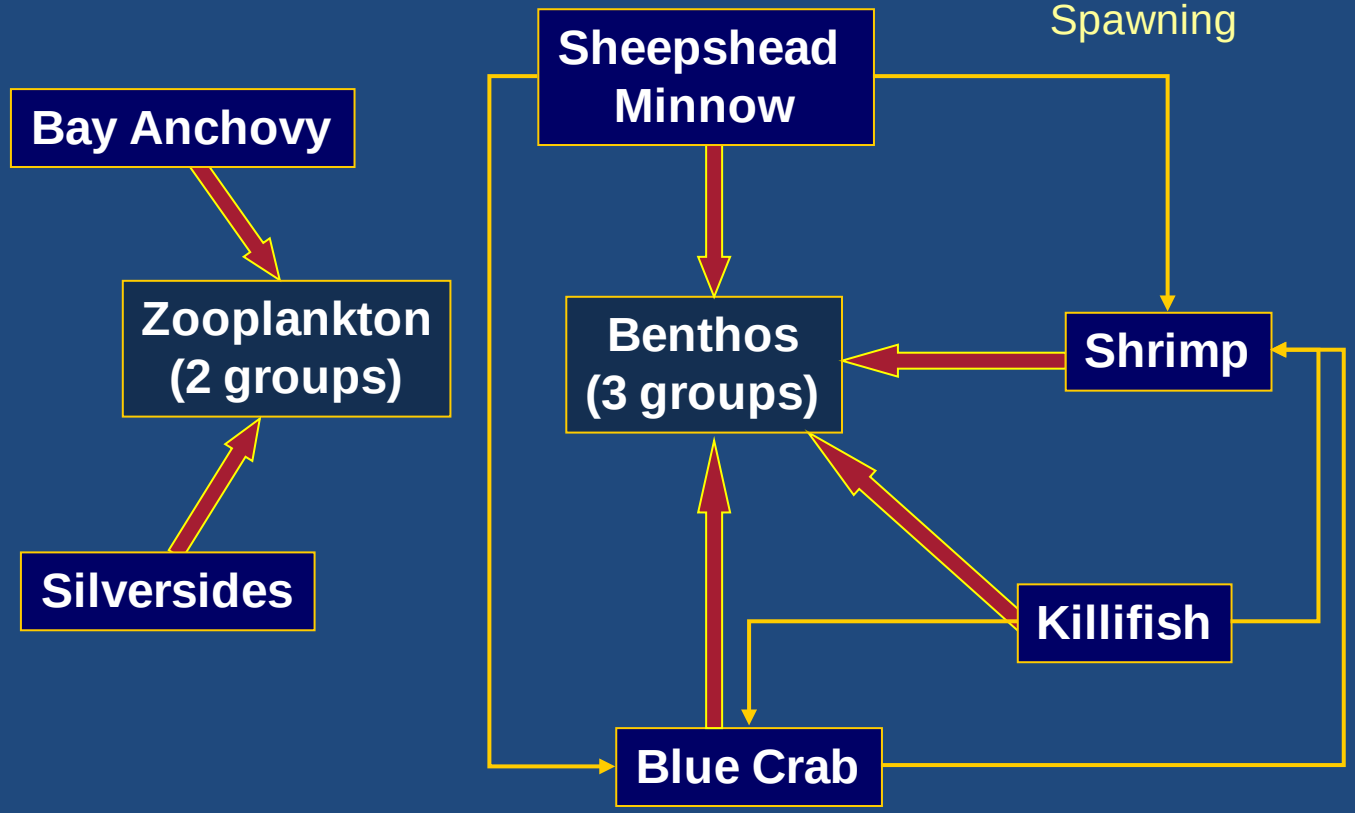
3-D Marsh Bathymetry with Tides



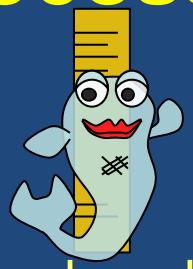
GOM Tidal Marsh IBM

Individual Processes
Growth
Movement
Mortality
Spawning

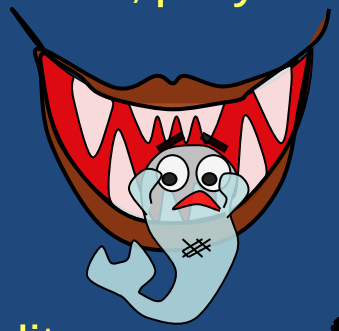
Conditions
Dissolved O_2
Temperature
Tidal stage
Prey density
Predator density
Individual size
Salinity



Individual Processes in IBM

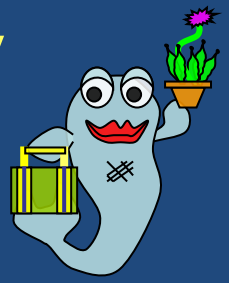


- Growth:
  - bioenergetics
  - consumption based on prey and predator sizes; prey densities



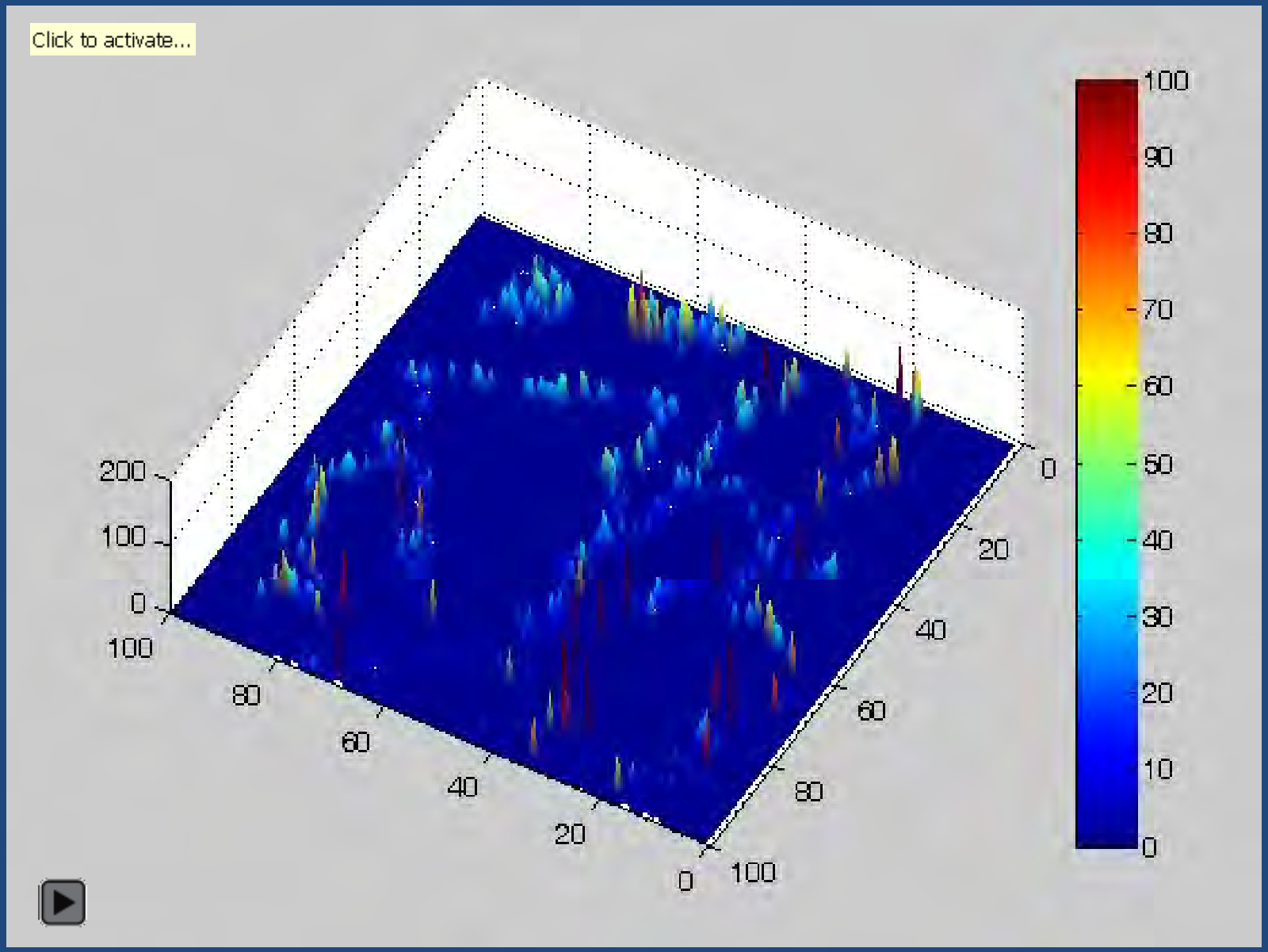
- Mortality:
  - predation; starvation; stranding; natural
- Spawning:
  - temperature and weight-dependent fecundity
  - fractional spawning with brood intervals

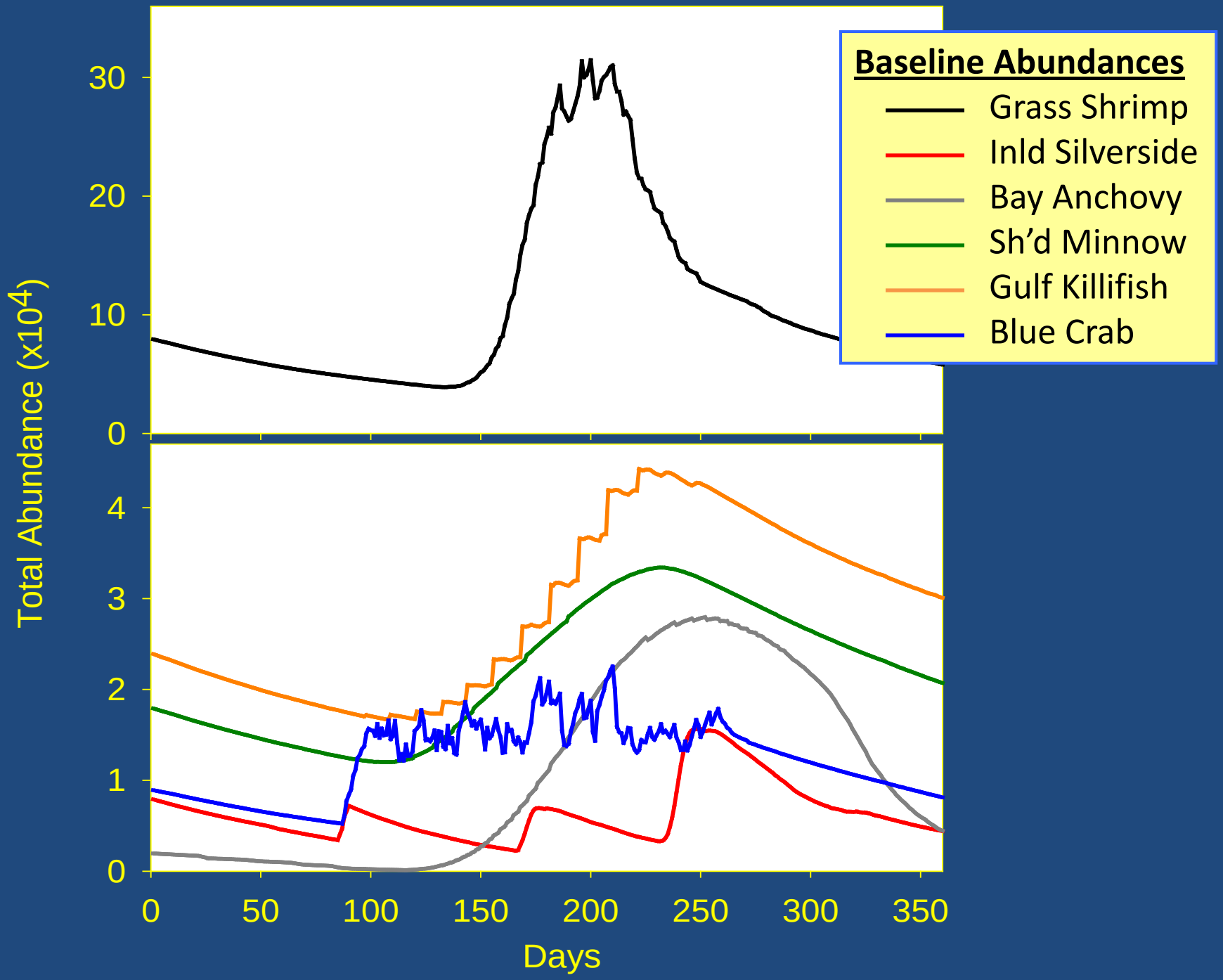
- Movement:
  - neighborhood depends on tidal stage and individual motility
    - motility size-based and species-specific
  - move to new cell with highest expected fitness
    - based on growth and survival potential during feeding
    - based on survival potential, DO, and crowding outside feeding



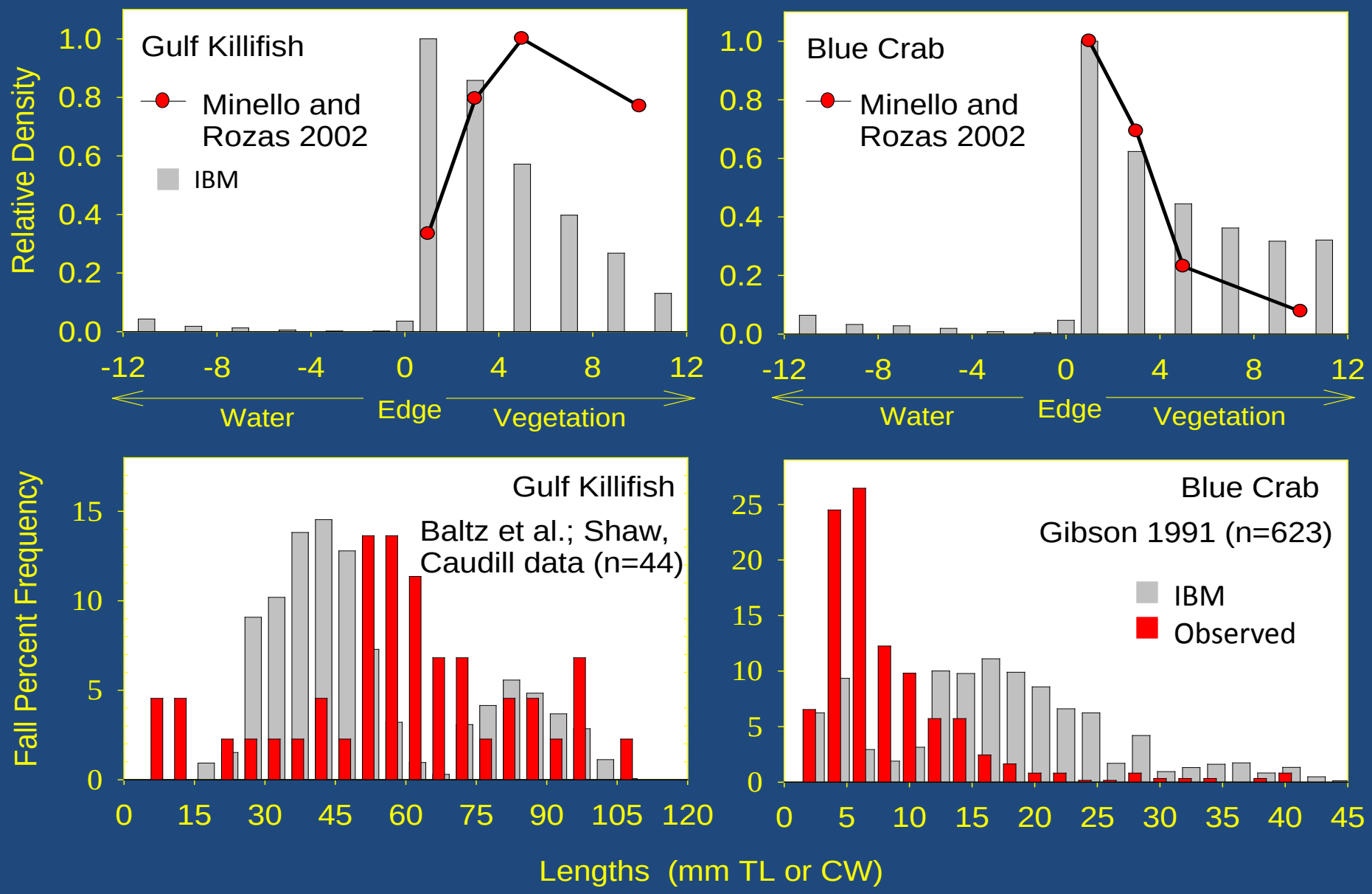
Grass Shrimp Distributions

Grass Shrimp Density (No. per m2)

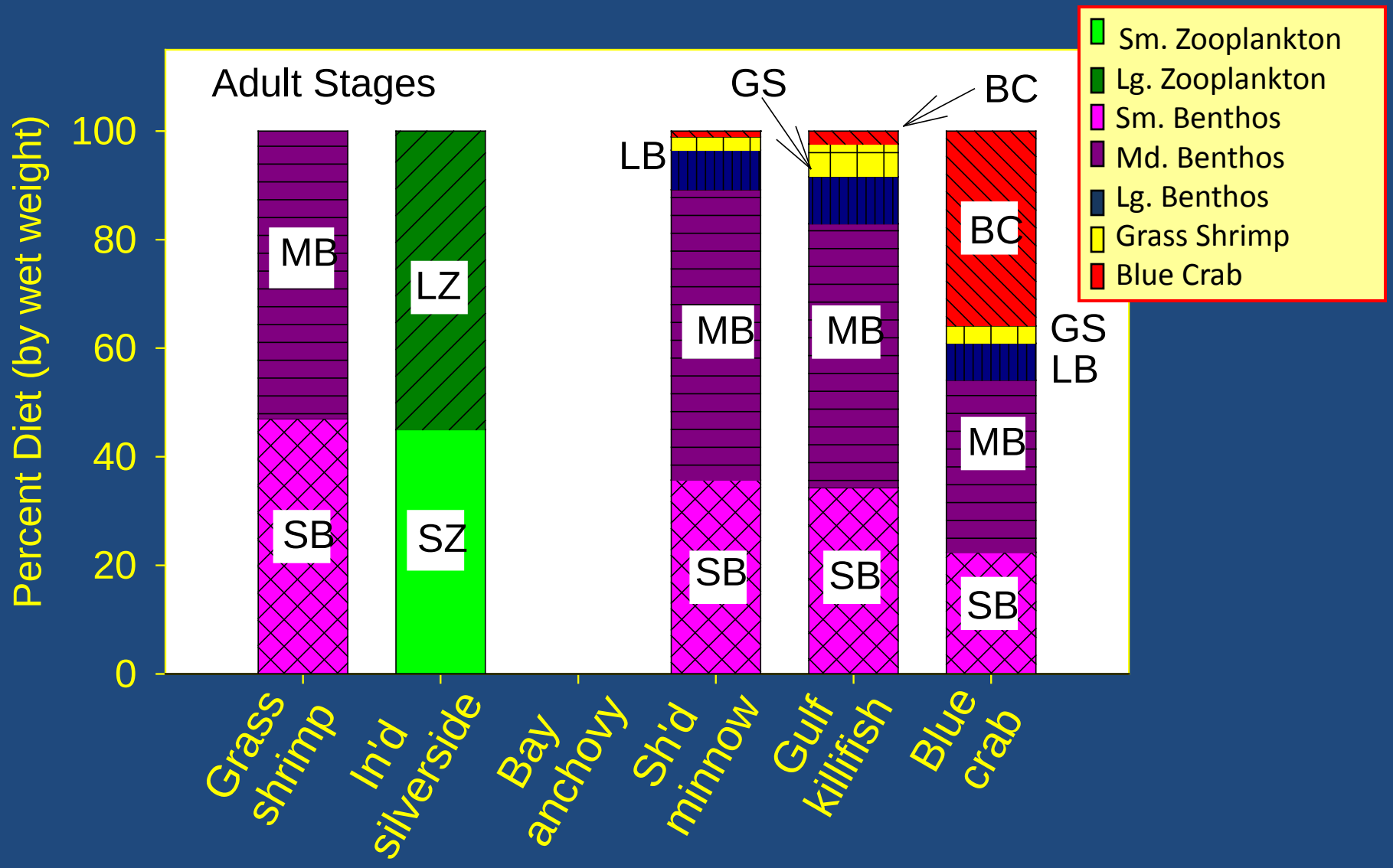



Baseline Abundances
Grass Shrimp
Inld Silverside
Bay Anchovy
Sh'd Minnow
Gulf Killifish
Blue Crab
Total Abundance (x10^4)
30
20
10
0
4
3
2
1
0
0
50
100
150
200
250
300
350
Days

Examples of Baseline Model Predictions Compared with Observed Data from Field Studies



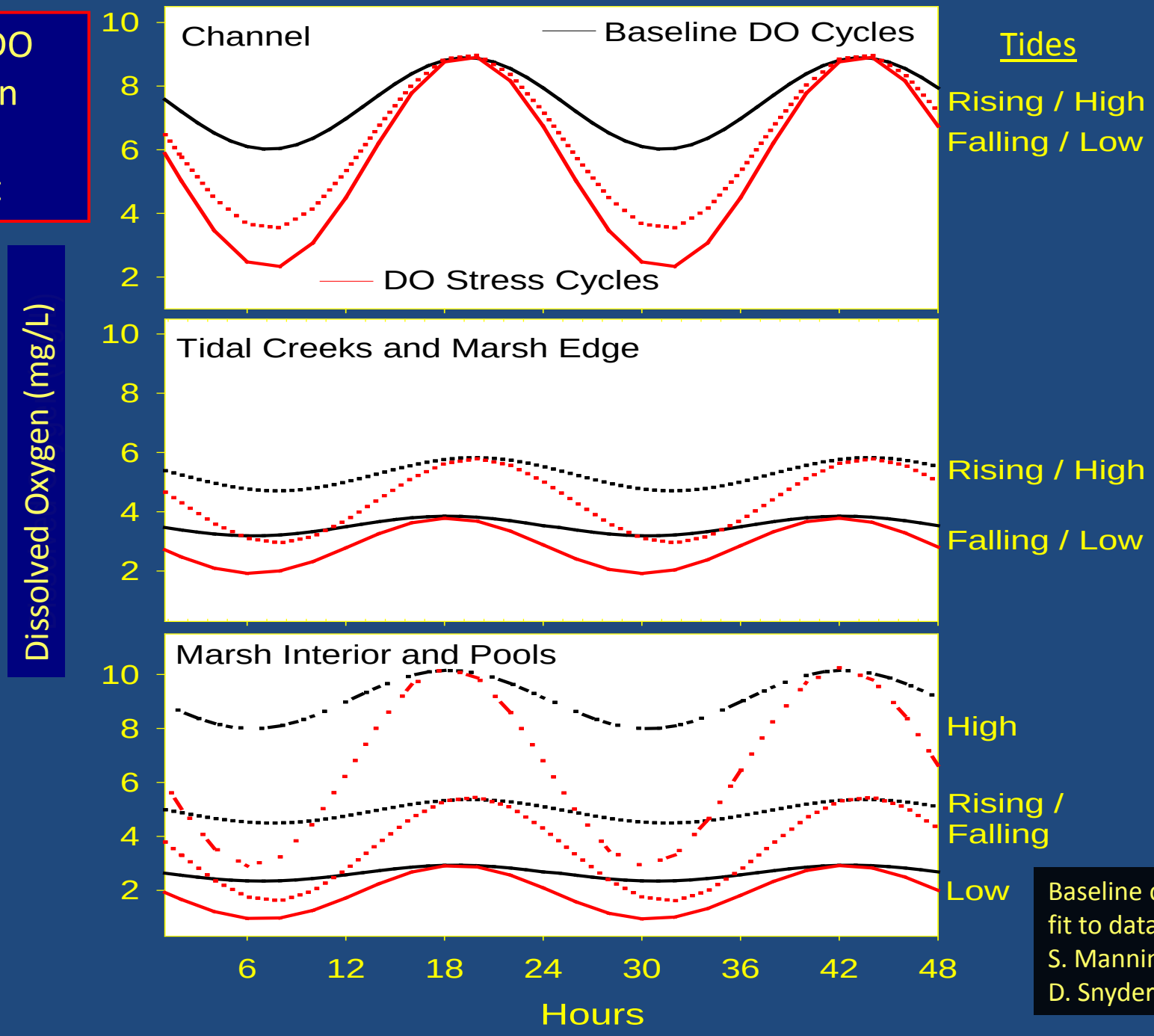
Baseline Results: Adult Diets



Population Responses Due to Cyclic DO Stress and Habitat Degradation

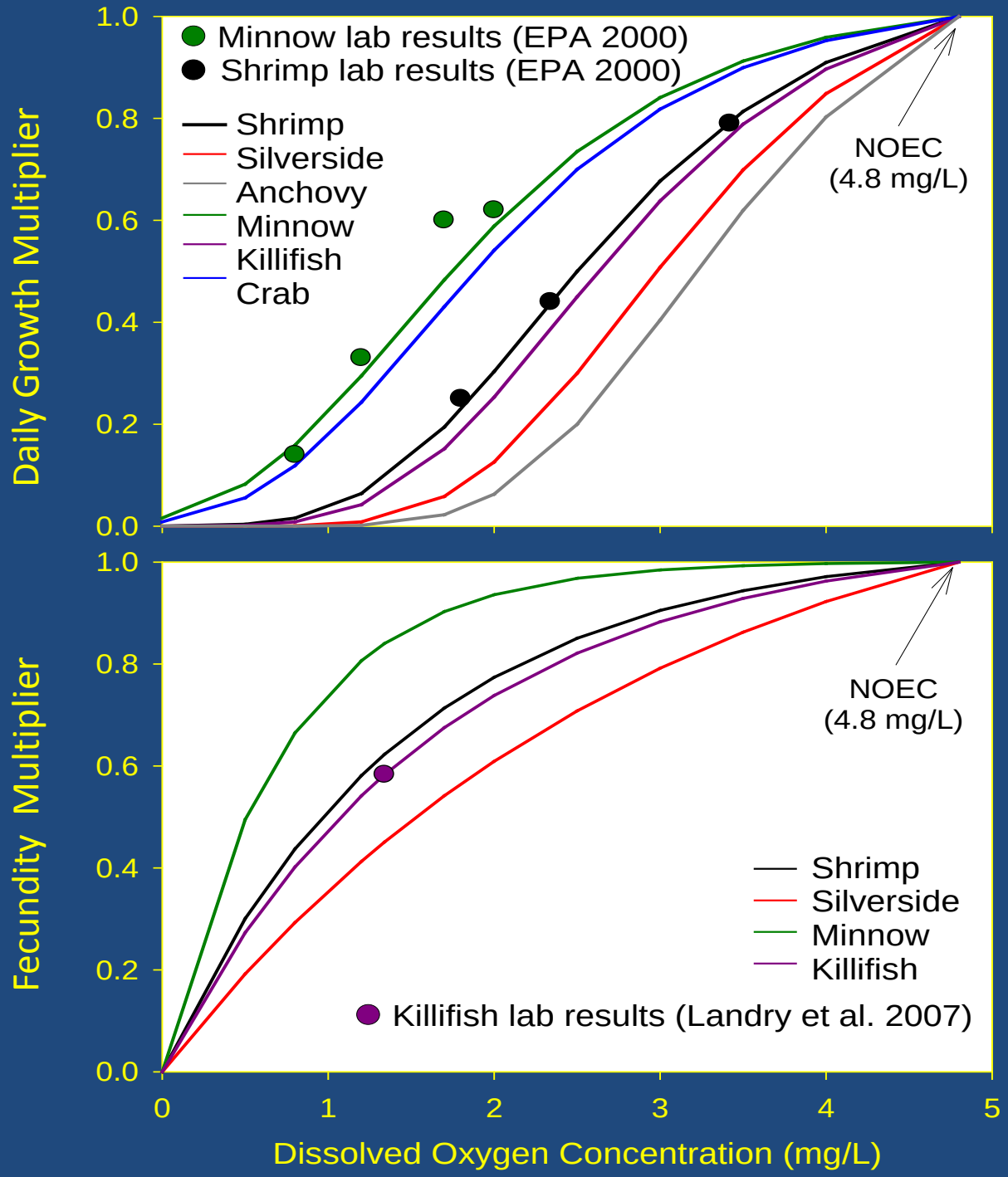
- 2 x 2 Factorial Design
  - Cyclic DO Stress and Habitat Degradation
- Changes in total annual production of species in the tidal marsh
- Evaluate how population responses are affected by individual-level exposure to DO, food web interactions and fine-scale spatial heterogeneity due to habitat degradation

Cyclic DO Stress in Marsh Habitat

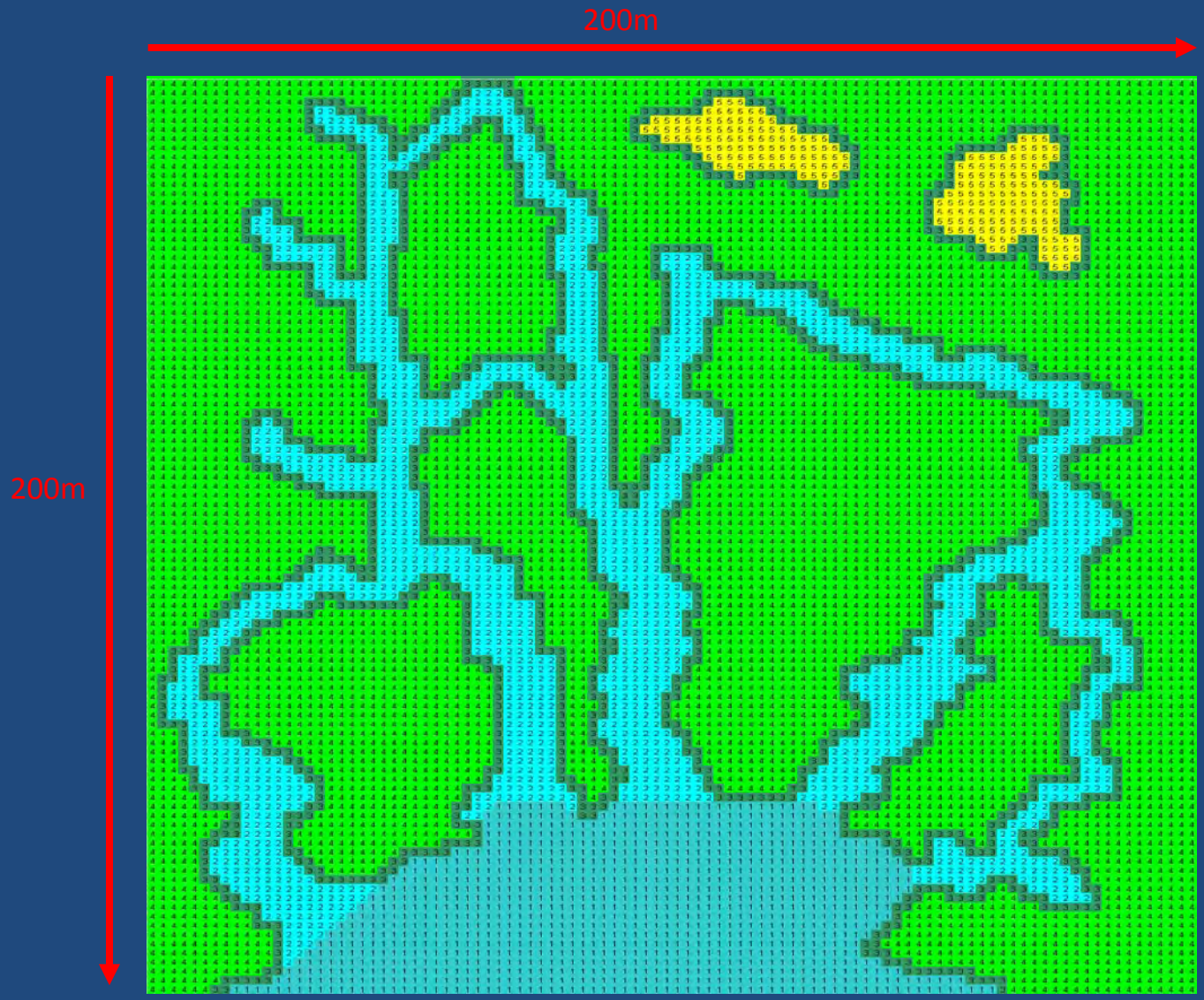


Baseline cycles fit to data from S. Manning and D. Snyder

Cyclic DO Stress on Individuals

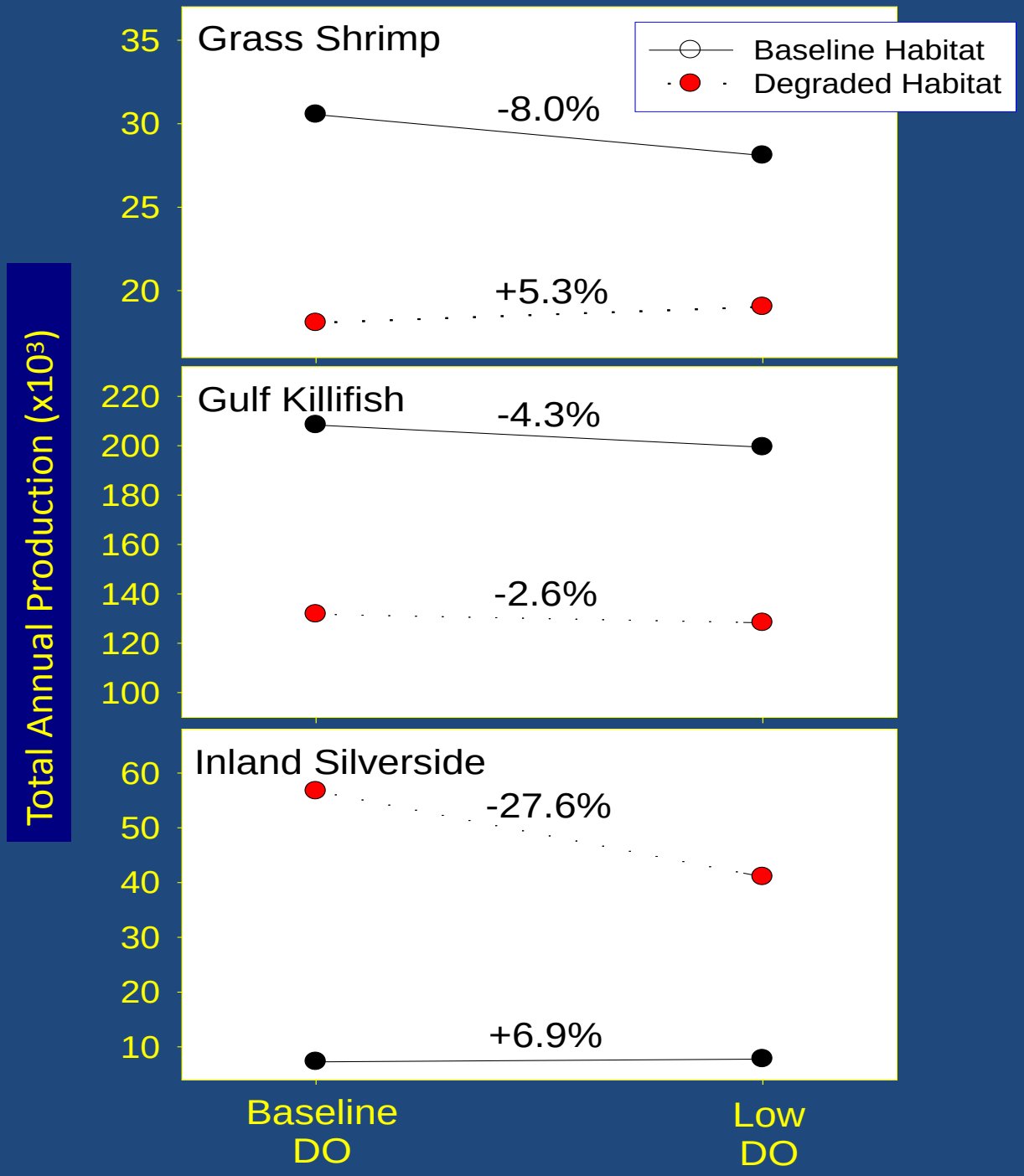


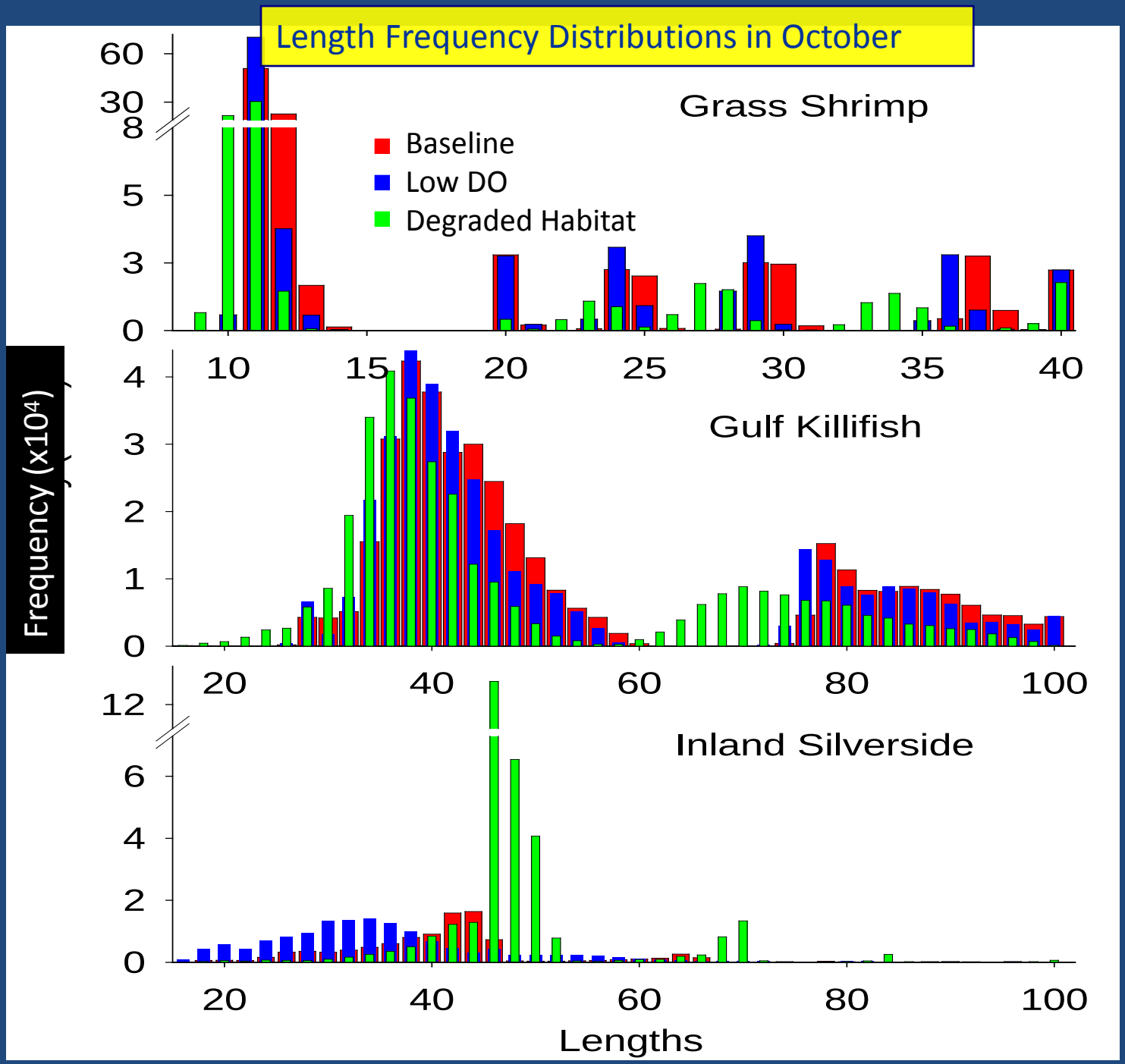
Habitat Degradation



Population Responses to Cyclic DO Stress and Habitat Degradation

- Lowered DO cycles usually reduced production by <10%
- Habitat degradation reduced shrimp and killifish by 30 to 40%
- Habitat degradation increased silverside production by 681%
- No strong evidence of interaction effects between stressors




Length Frequency Distributions in October
Grass Shrimp
Baseline
Low DO
Degraded Habitat
Gulf Killifish
Inland Silverside
Frequency (x10⁴)
Lengths
60
30
8
5
3
0
10
15
20
25
30
35
40
4
3
2
1
0
20
40
60
80
100
12
6
4
2
0
20
40
60
80
100

Population Responses to Habitat Degradation

		Baseline	Degraded Habitat	
Grass Shrimp	Recruit Size	0.03	0.02	↓ 33%
	Egg Production	18.1*	16.1*	↓ 11%
	# Eaten	4.22*	3.84*	↓ 9%
Gulf Killifish	Recruit Size	1.25	0.93	↓ 26%
	Egg Production	4.1*	3.2*	↓ 20%
Inland Silverside	Recruit Size	0.40	0.61	↑ 52%
	Egg Production	10.1*	25.4*	↑ 152%

* ($X10^6$)

Summary of Results and Conclusions

- Population responses to lowered DO were small (<10%)
- Population responses to habitat degradation were moderate (30-40%) to large (>600%) and mainly due to growth effects
  - good for zooplanktivores and bad for benthic feeders
- Little interaction between these applied stressors due to subtle population responses to lowered DO
- Only small indirect effects from food web interactions
  - effects increase with increased coupling between species and increased stress
- Simulation analysis to examine population responses to multiple stressors in a dynamic food web
  - evaluate population-level effects from individual-level responses to changing conditions

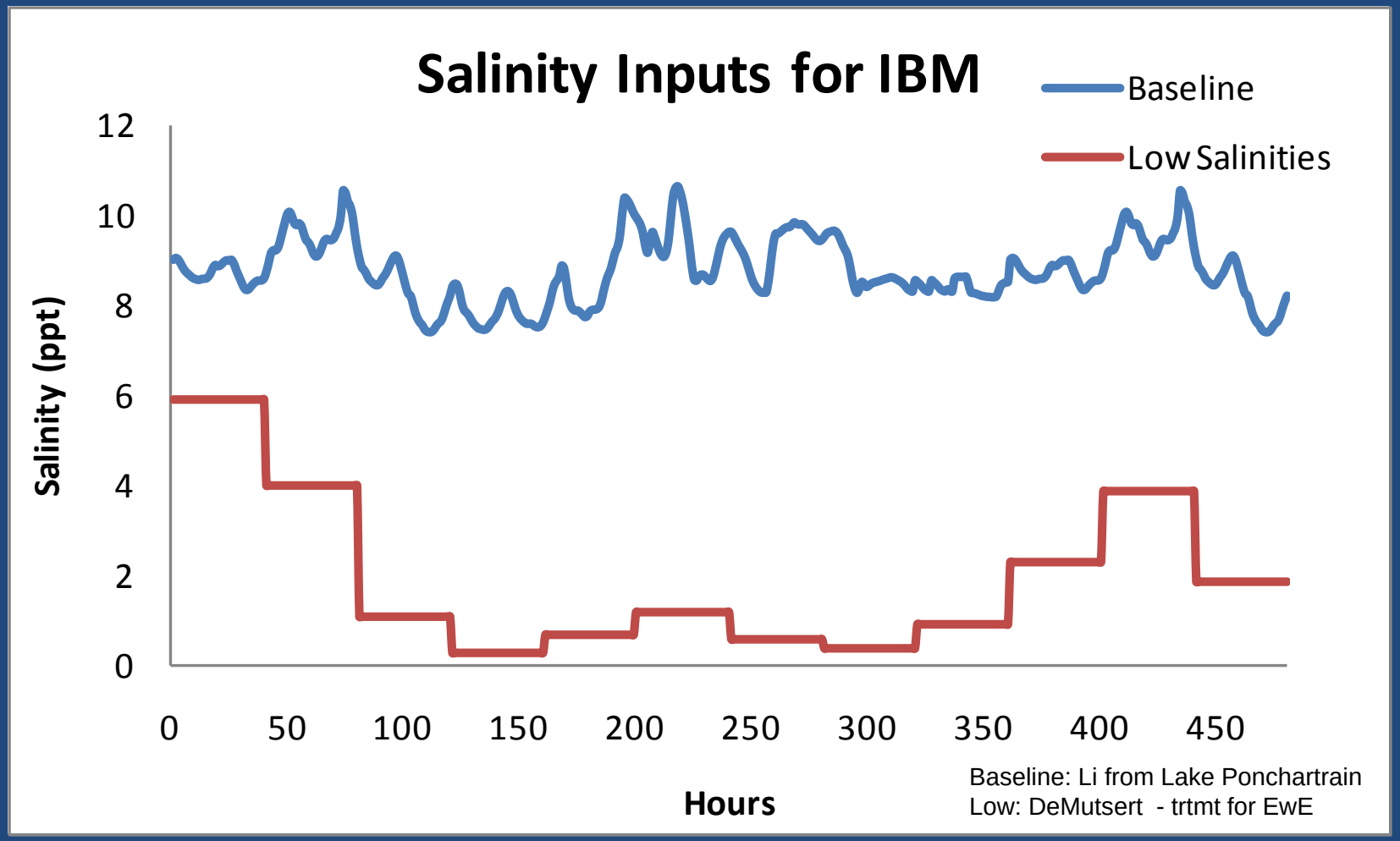
River Diversion Effects on the Tidal Marsh Community: In Progress

- Incorporate outputs from ADH models and/or regional data for diversions
  - temperature, DO, salinity, water levels
  - sediment transport and marsh building
- Further evaluate salinity effects on species
  - metabolic costs and growth
  - egg and larval mortality and/or development
- Simulation examines population responses to multiple stressors in a dynamic food web
  - evaluate population-level effects from individual-level responses to changing conditions on spatially-explicit map

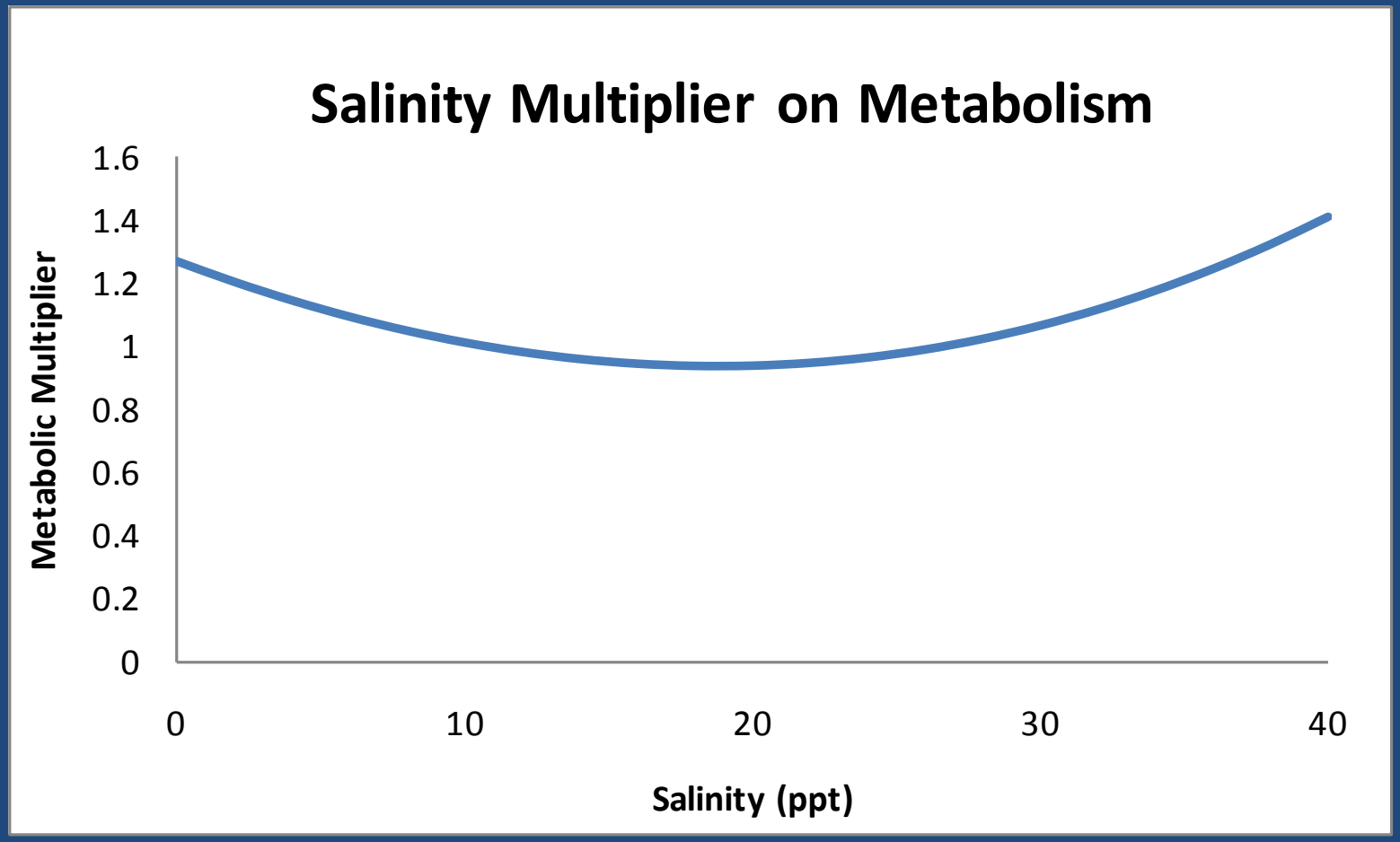
Population Responses Due to Decreased Salinity

- Single low salinity treatment
- Changes in total annual production of species in the tidal marsh
- Evaluate how population responses are affected by individual-level exposure to salinity, food web interactions and fine-scale spatial heterogeneity

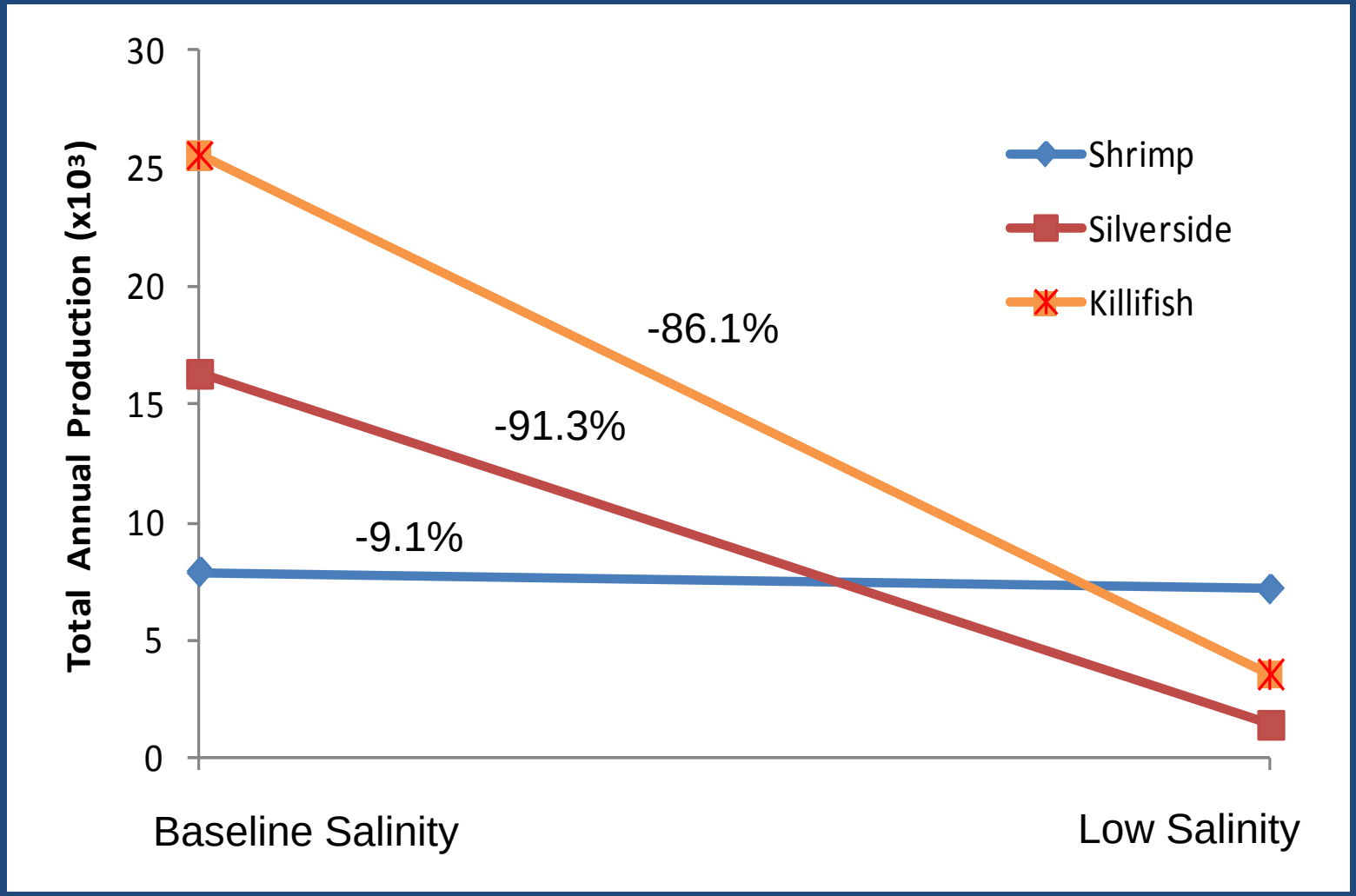
Salinity Simulations



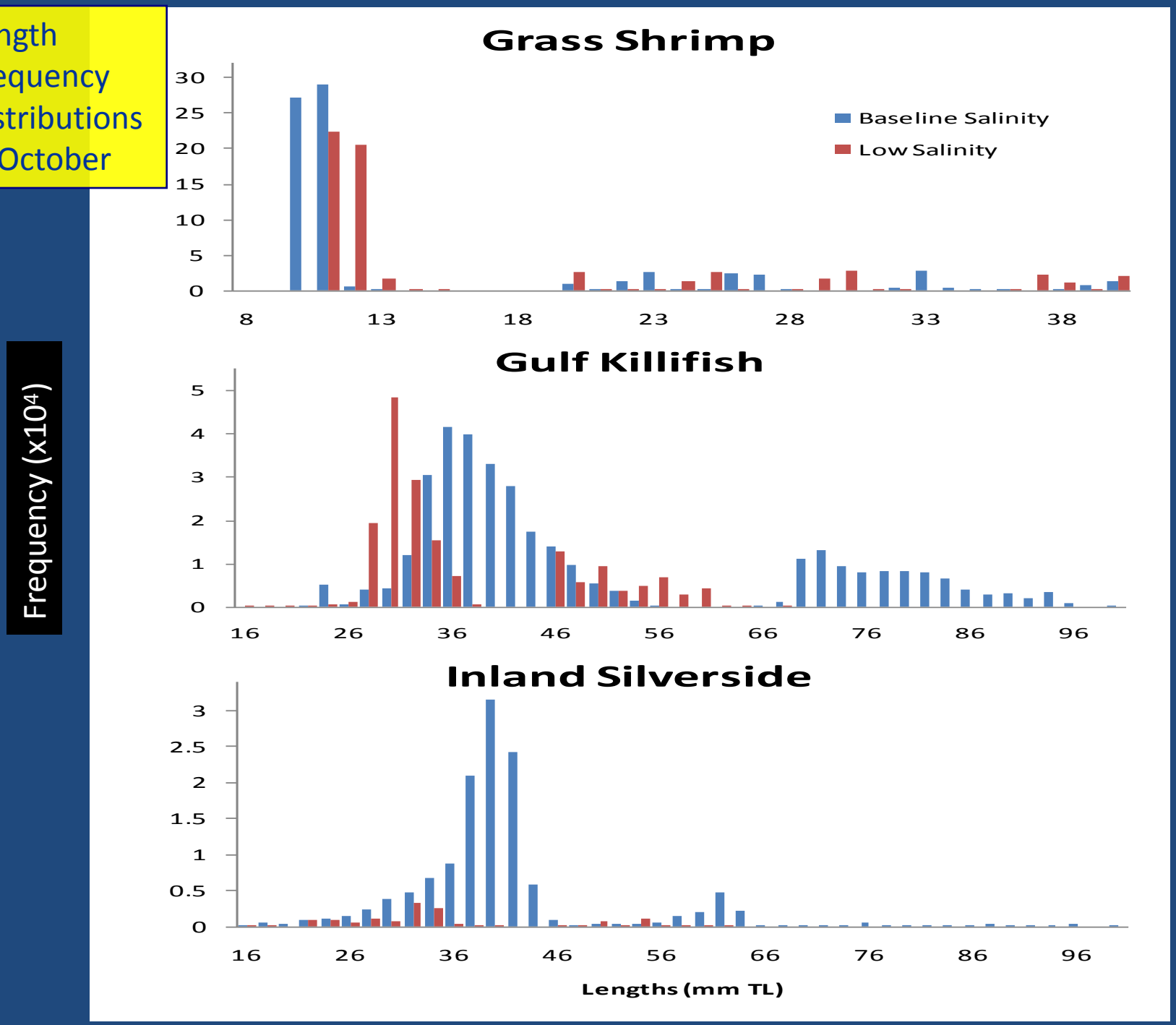
Salinity Stress on Individuals



Population Responses to Reduced Salinity



Length Frequency Distributions in October



Population Responses to Reduced Salinity

		Baseline Salinity	Low Salinity	
Grass Shrimp	Recruit Size	0.03	0.02	↓ 33%
	Egg Production	18.3*	16.7*	↓ 9%
	# Eaten	0.366*	0.301*	↓ 92%
Gulf Killifish	Recruit Size	1.02	0.51	↓ 50%
	Egg Production	3.5*	1.9*	↓ 45%
Inland Silverside	Recruit Size	0.39	0.19	↓ 51%
	Egg Production	9.7*	4.4*	↓ 55 %

* ($X10^6$)

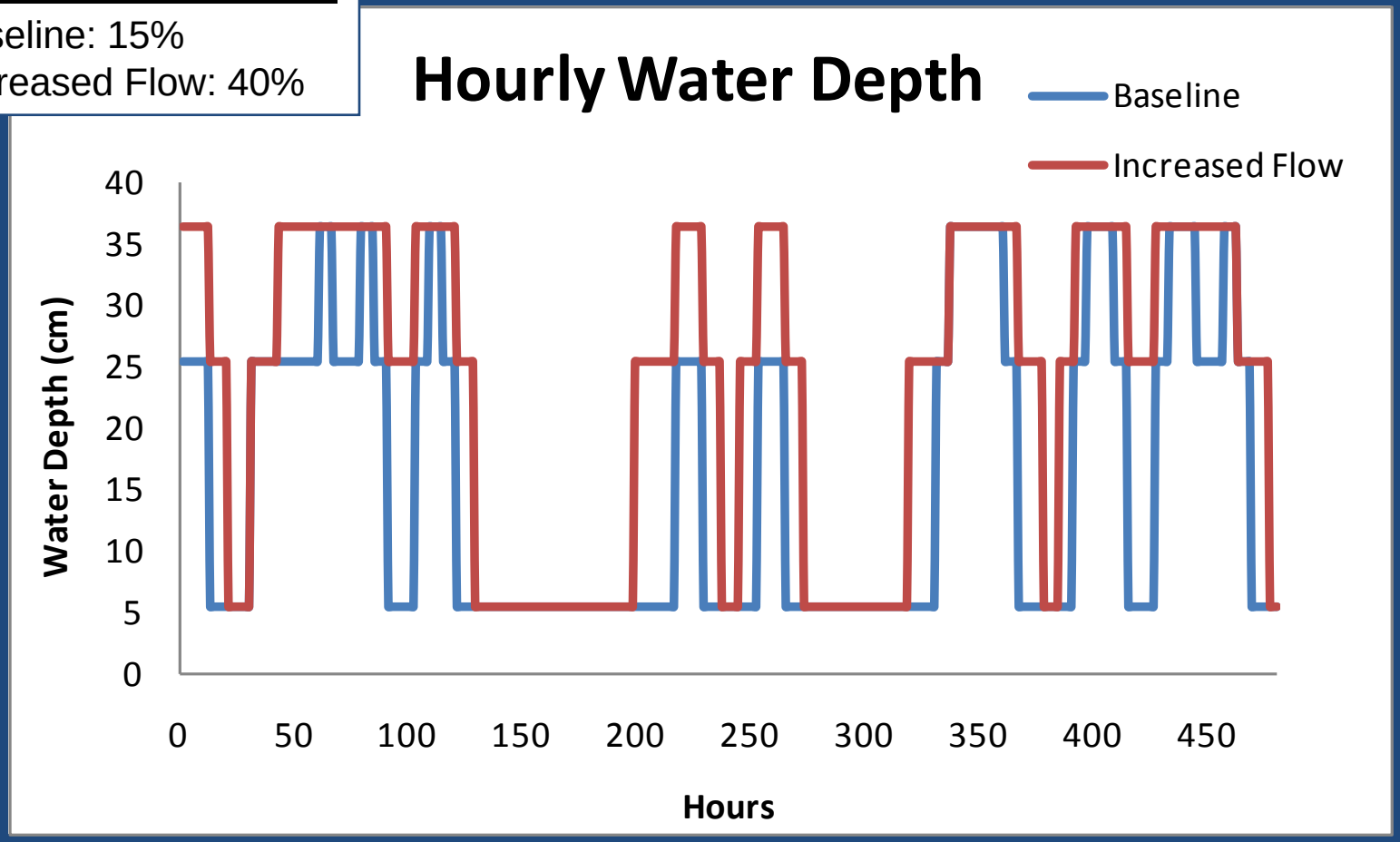
Summary of Results

- Population responses to low salinities were large and due to growth effects
  - metabolic costs for individuals

- Large indirect effect of food web interactions
  >> stress effect of salinity on grass shrimp
  - large decrease in shrimp predation
  - less predators and competitors

Water Levels and Marsh Flooding

% Time Marsh Flooded

Baseline: 15%

Increased Flow: 40%