Population Dynamics of Gulf Blue Crabs

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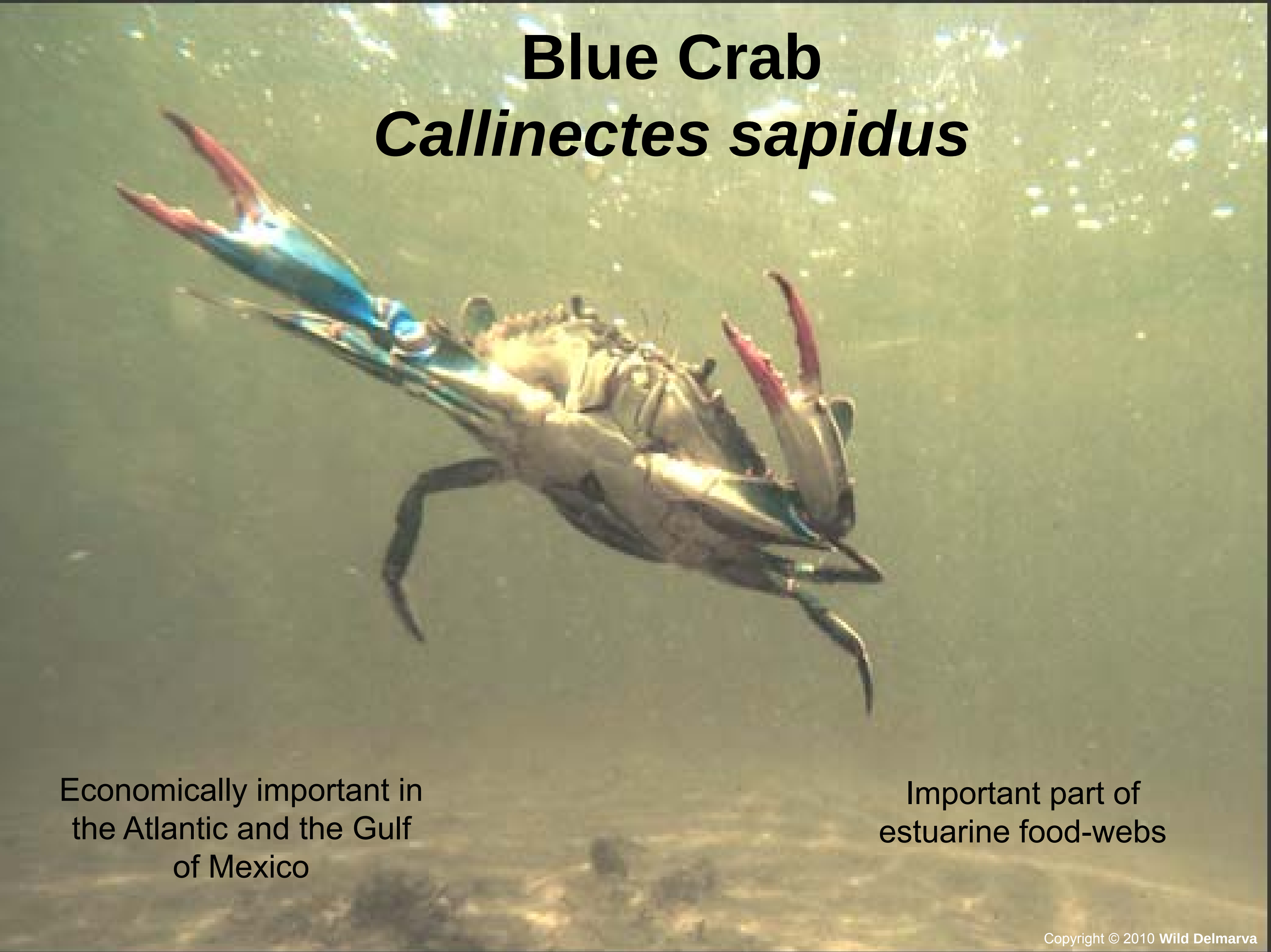
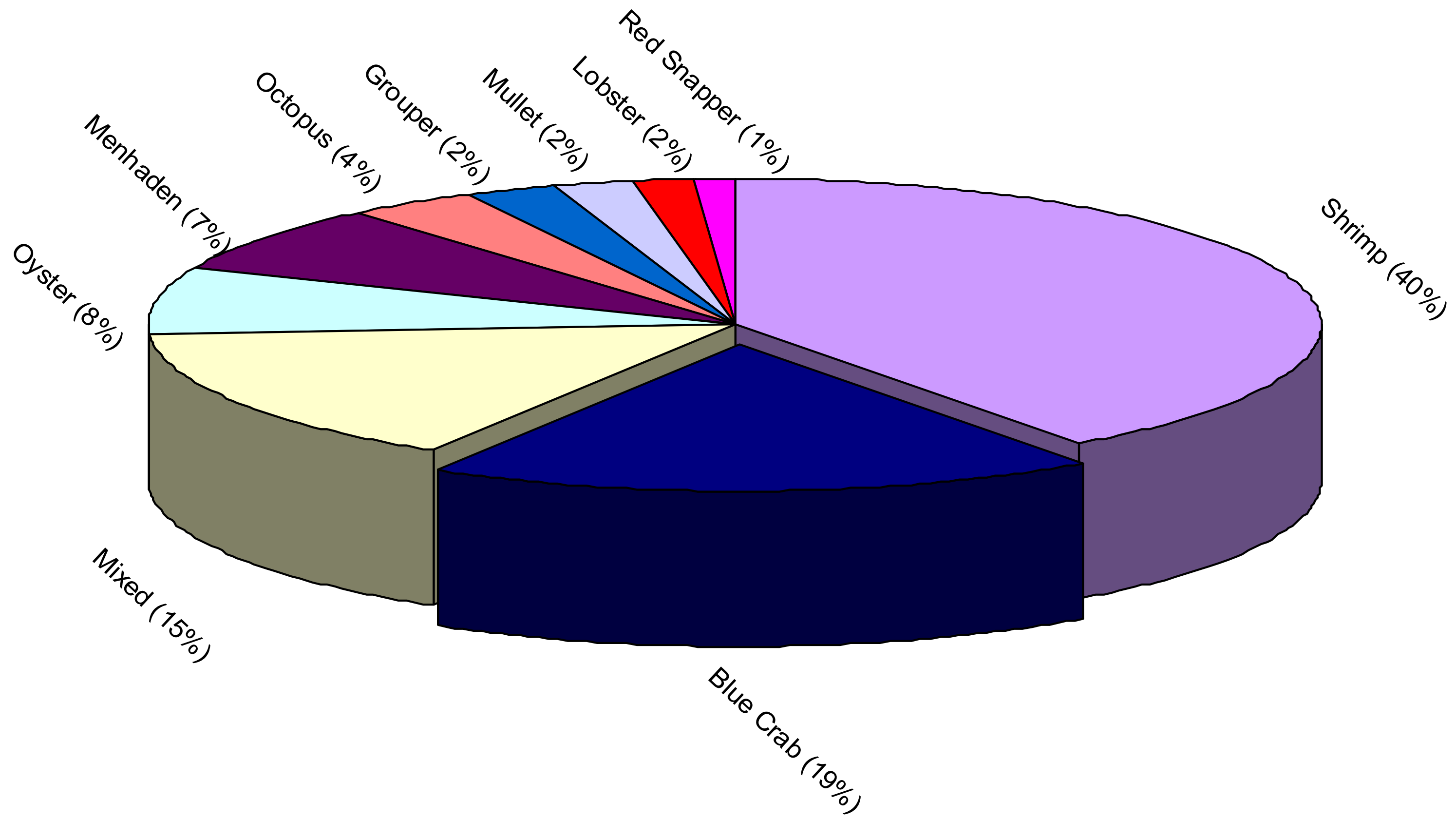

Blue Crab
Callinectes sapidus
Economically important in the Atlantic and the Gulf of Mexico
Important part of estuarine food-webs

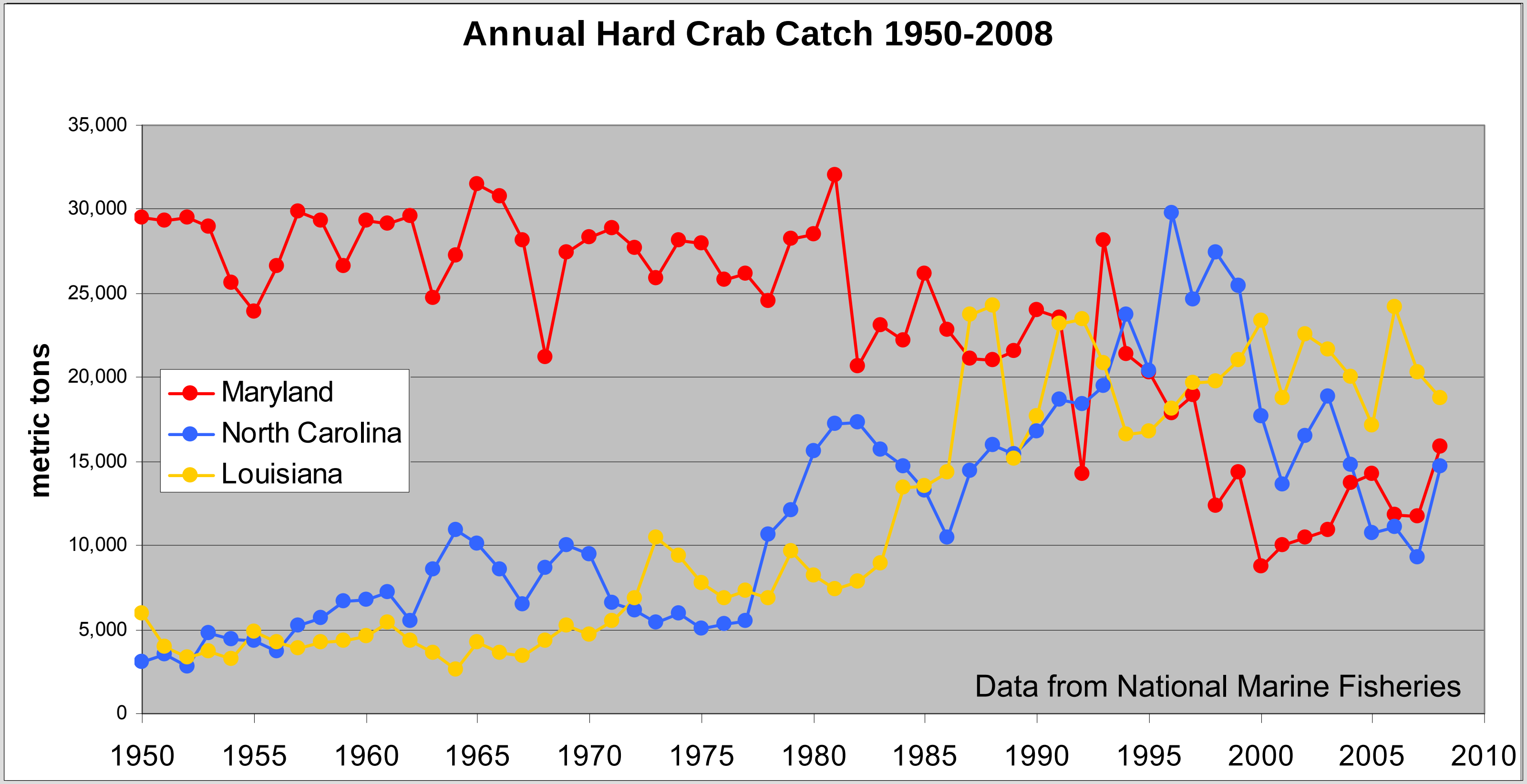
Blue Crabs Support a Large Fishery in Gulf of Mexico

2004 Gulf of Mexico Fishery Value by Species (data from Sea Around Us Project *www.seaaroundus.org)*



~200 million dollars in 2004, 2nd most valuable fishery.

Blue Crab Populations: Fluctuations & Crashes



Crashes:

1997 - Maryland
2000 - North Carolina
???? - Louisiana

Why do populations fluctuate?

- Biotic interactions

  - predation, competition

- Environmental stochasticity

  - climate, weather, storms, etc.

- Dispersal

  - movement between different populations

Why do populations crash?

- Habitat degradation
- Over-harvesting

Algae blooms as a result of run-off.

Commercial crabber.

Research Goals

1. Understand and predict population fluctuations

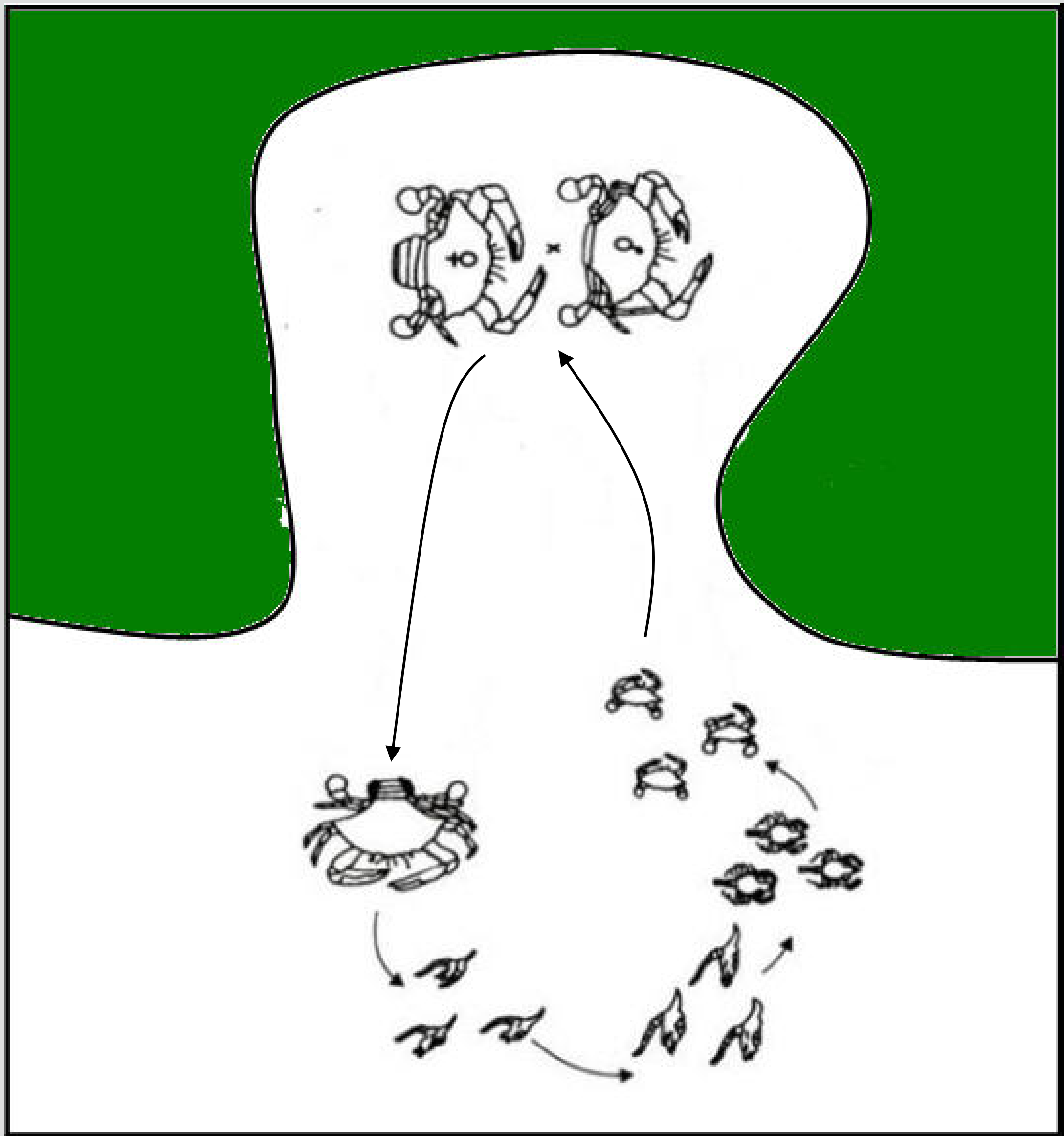
   → model population dynamics

   → tease apart biotic, environmental and dispersal effects on fluctuations

2. Prevent crashes by informing fisheries management decisions

Blue Crab Life Cycle

- **Juveniles** and **adults** live in estuaries
- Females spawn **larvae** into the ocean
- **Larvae** develop into **megalopae** and return to estuaries



Realistic Model for Gulf Blue Crabs

Adult populations in estuaries connected by larval dispersal.

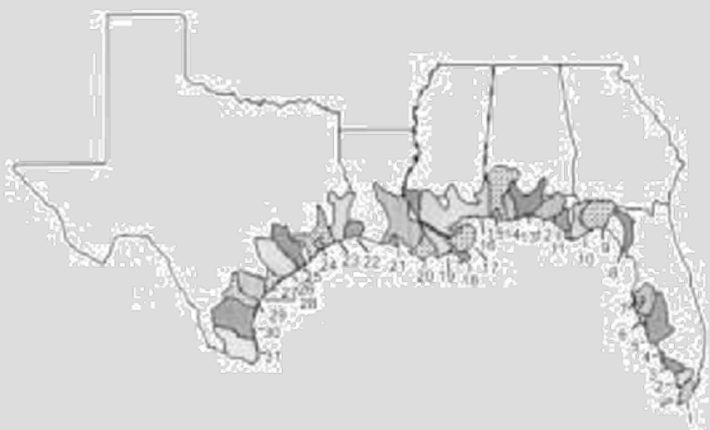
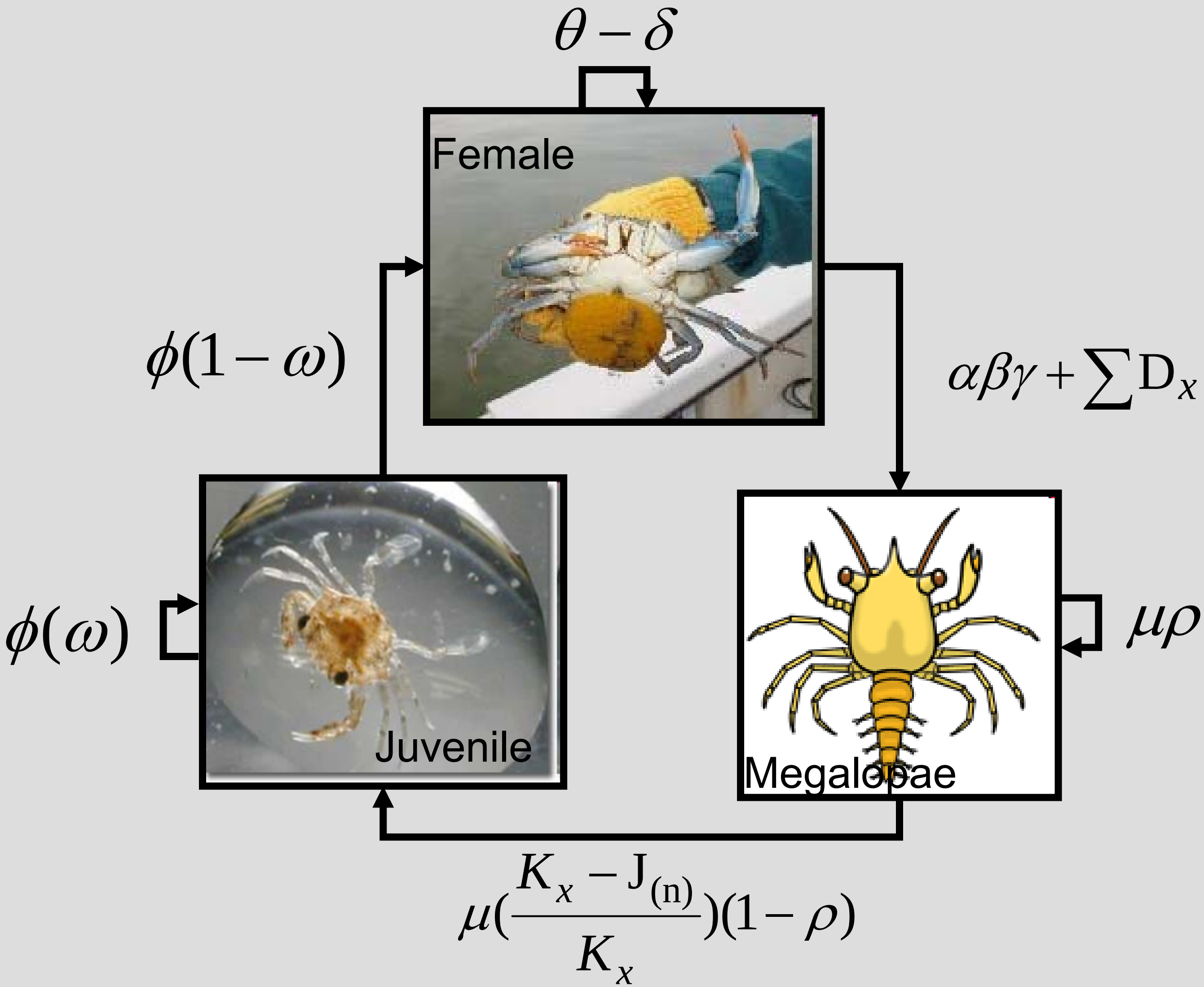


Figure 1. The major coastal watersheds in the Gulf of Mexico.

1 Florida Bay
2 South Ten Thousand Islands
3 North Ten Thousand Islands
4 Rookery Bay
5 Charlotte Harbor
6 Sarasota Bay
7 Tampa Bay
8 Suwanee River
9 Apalachee Bay
10 Apalachicola Bay
11 St. Andrew Bay
12 Choctawhatchee Bay
13 Pensacola Bay
14 Perdido Bay
15 Mobile Bay
16. Mississippi Sound
17 Breton/Chandeleur Sounds
18 Mississippi River
19 Barataria Bay
20 Terrebonne/Timbalier Bays
21 Atchafalaya/Vermilion Bays
22 Calcasiu Lake
23 Sabine Lake
24 Galveston Bay
25 Brazos River
26 Matagorda Bay
27 San Antonio Bay
28 Aransas Bay
29 Corpus Christi Bay
30 Upper Laguna Madre
31 Lower Laguna Madre

Local Population Model



$\alpha = \frac{\#eggs}{female}$

$\beta = P[spawn]$

$\gamma = P[settle]$

$\mu = P[meg\ survive]$

$\rho = P[stay\ meg]$

K=carrying capacity

$\varphi = P[juv\ survive]$

$\omega = P[stay\ \ juv]$

θ = female survival

δ = fishing mortality

D=connectivity matrix

time step = 2 days

Parameter Estimation

- There are estimates for many of the parameters

From literature and database developed by Tulane undergadauate Danielle Levy (LEAG-funded)

$$\alpha = \frac{\#eggs}{female}$$

$$\beta = \mathrm{P}[spawn]$$

$$\delta = \text{fishing mortality}$$

$$\theta = \text{female survival}$$

$$\rho = P[stay\ meg]$$

$$\mu = P[meg\ survive]$$

We still need estimates for:

- Megalopa & juvenile survival

$$K = \text{carrying capacity}$$

$$\varphi = P[juv\ survive]$$

$$\omega = P[stay\ juv]$$

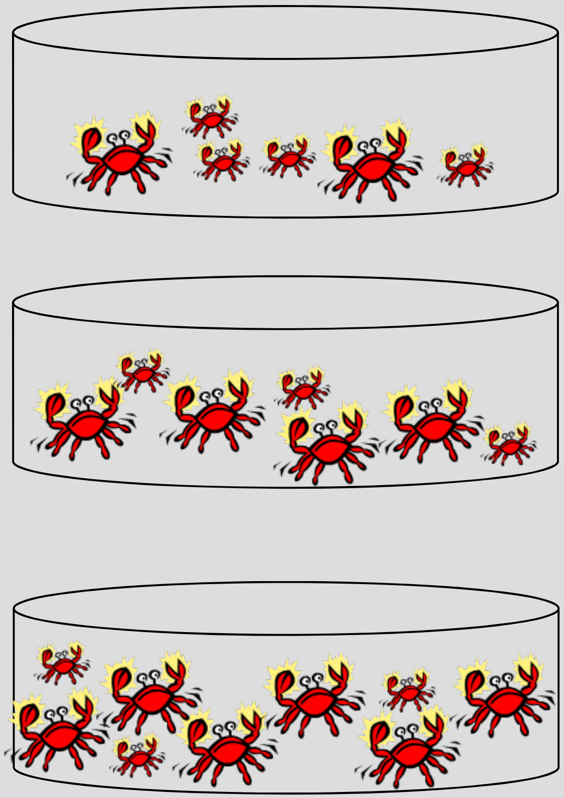
- Dispersal/Connectivity Matrix

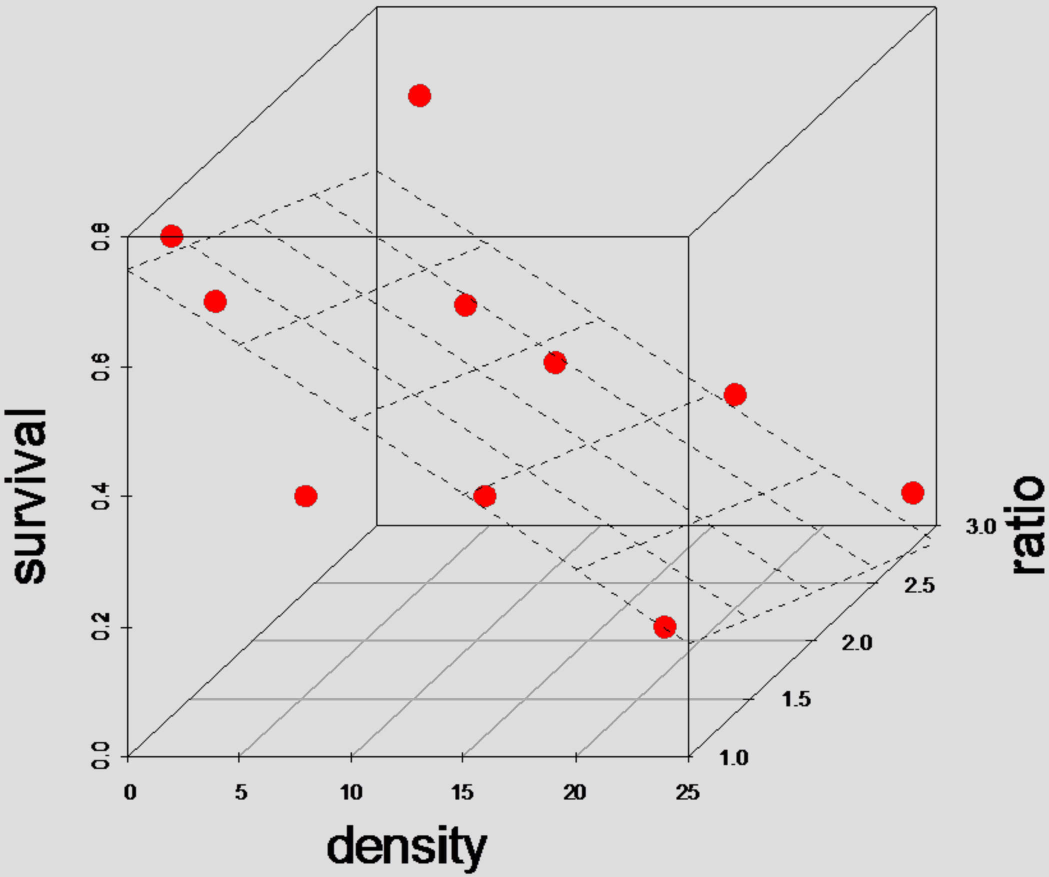
$$\gamma = \mathrm{P}[settle]$$

$$D = \text{connectivity matrix}$$

*Field Experiment: Estimating Survival of Megalopae and Juveniles

Survival as a function of density and size-ratio.





*Nicholas Brasier, undergraduate research project

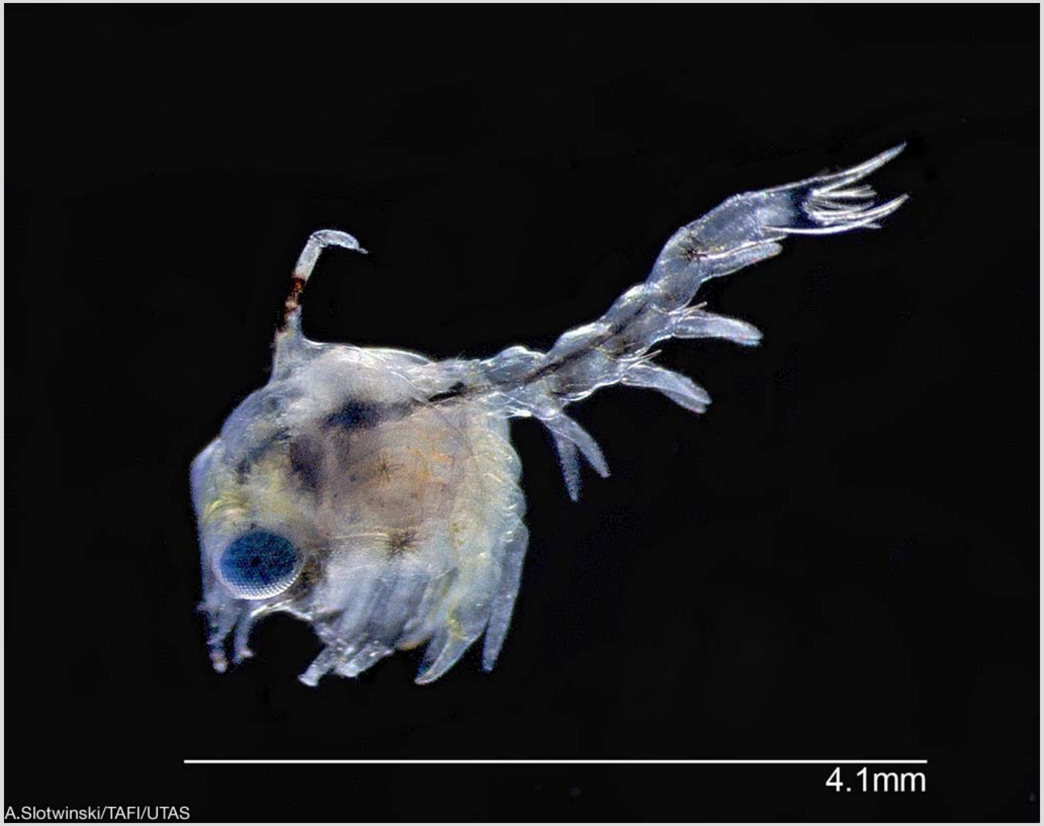
Estimating Dispersal

X Tagging unfeasible

- larvae very small
- billions of them
- high mortality rates

√ Particle-Tracking Models

- Use ocean circulation model output
- Track the trajectory of individual particles (larvae) within the ocean as a function of time



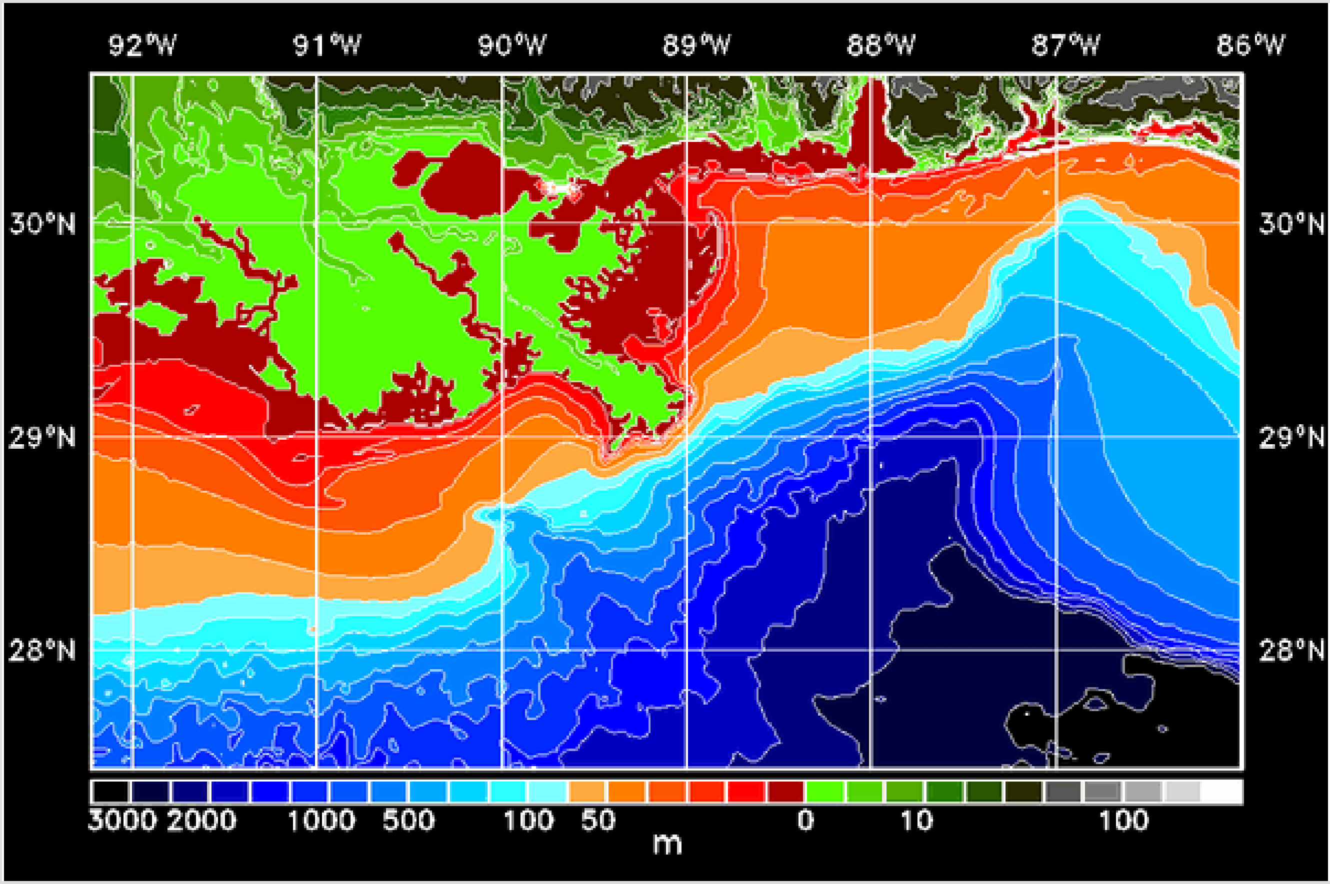
Northern Gulf of Mexico Nowcast-Forecast System

Dr. Dong Shan Ko, Naval Research Lab, Stennis Space Center

Based on the Navy's coarse (1/8°) global ocean model
- + tides
- + freshwater runoff
- + wind
- + sea height/temp

→ 1.9 X 1.9 km, 38 sigma (depth) resolution

→ Hourly 3D current velocities from 2006 to present



NGOMNFS Bathymetry Map

Basic Particle-Tracking Algorithm

- Each particle is moved by 3 currents (U,V,W). So a time t+1

$$(x_{t+1}, y_{t+1}, z_{t+1}) = (x_t + \mathrm{U}, y_t + \mathrm{V}, z_t + \mathrm{W})$$

- Currents U,V,W are found by tri-linear interpolation at each particle location.

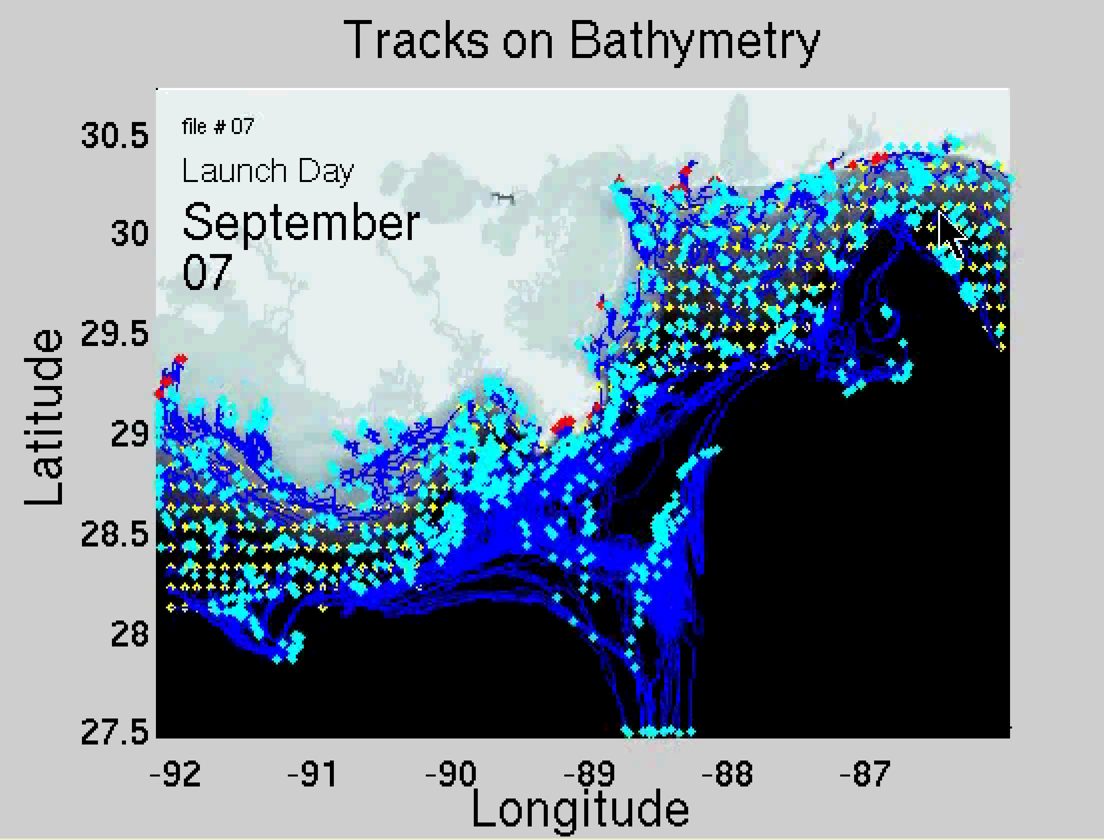
- 4th order Runga Kutta used for each update

- Larval behavior, diffusion, perpendicular shear also incorporated

Computational Statistics

- 3 years NGOMNFS data = 1TB
- Simulation time:
  - 5 minutes for 1 larvae
  - 1 week for 2000 larvae
  - We need at least 300*2000 simulations...

~ 5.7 years!!



Yellow diamonds: starting points
Red dots: larva recruits
Blue dots: larva dies

Courtesy of Dr. Redwood Nero, NOAA

High Performance Computing

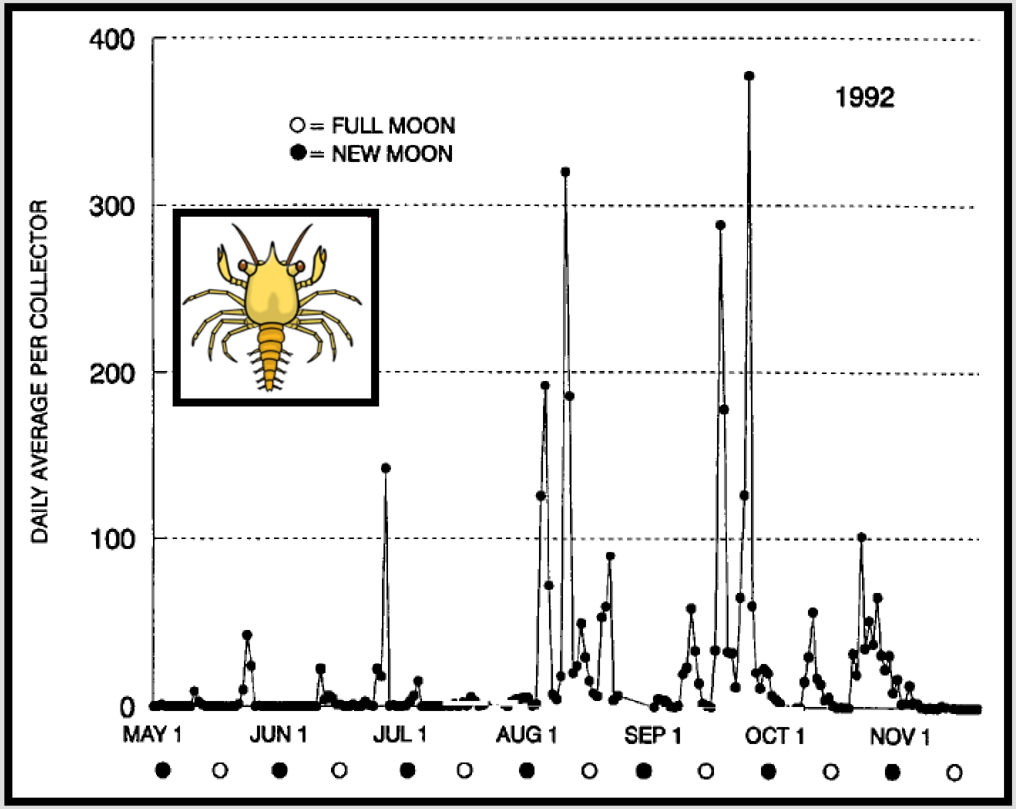
- ✓ Awarded 2 Months FTE of a LONI Institute Computational Scientist

Dr. Hideki Fujioka

Louisiana Optical Network Initiative (LONI) Institute
Tulane CCS

Validation: *Megalopal Collecting

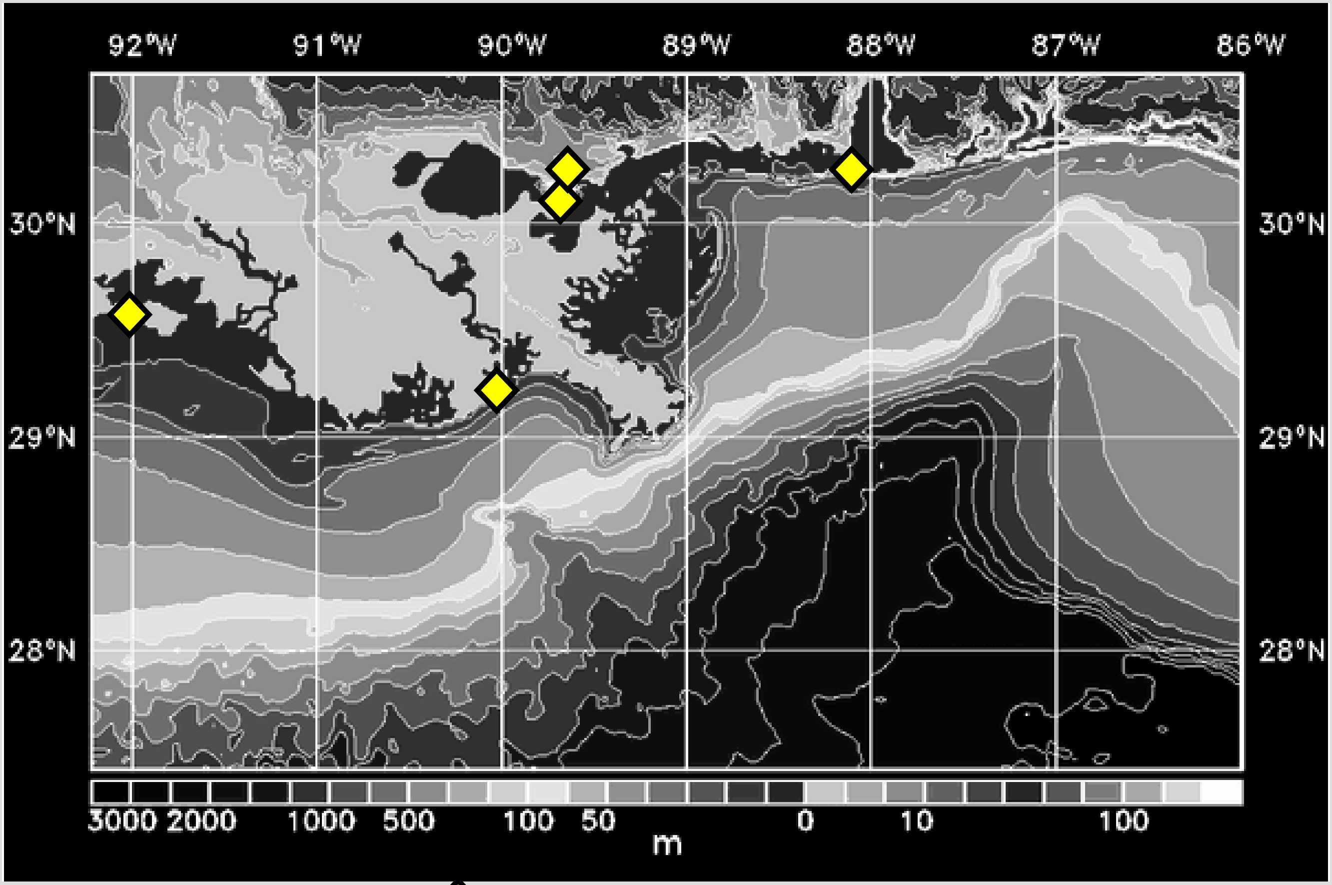
- Settlement of megalopa is episodic
- Can model predict episodes at different sites?



Megalopal settlement near Biloxi, MS in 1992.
Perry et al. 1995

*Research Assistants: Eileen Nalley, Susan Chiasson

Map of Megalopal Collecting Sites




megalopa collecting site

Chef's Pass

Rigolets Pass

Estimating Estuary Connectivity with Particle-Tracking Model

- Assume females spawn from nearest barrier island/shoal
- Use simulations to estimate the likelihood that larvae successfully disperse between each estuary (D)

Connectivity Matrix D

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \qquad a_{ij} = \mathrm{P}[\text{disperse from estuary } i \text{ to estuary } j]$$

Blue Crab Population Model as a Tool

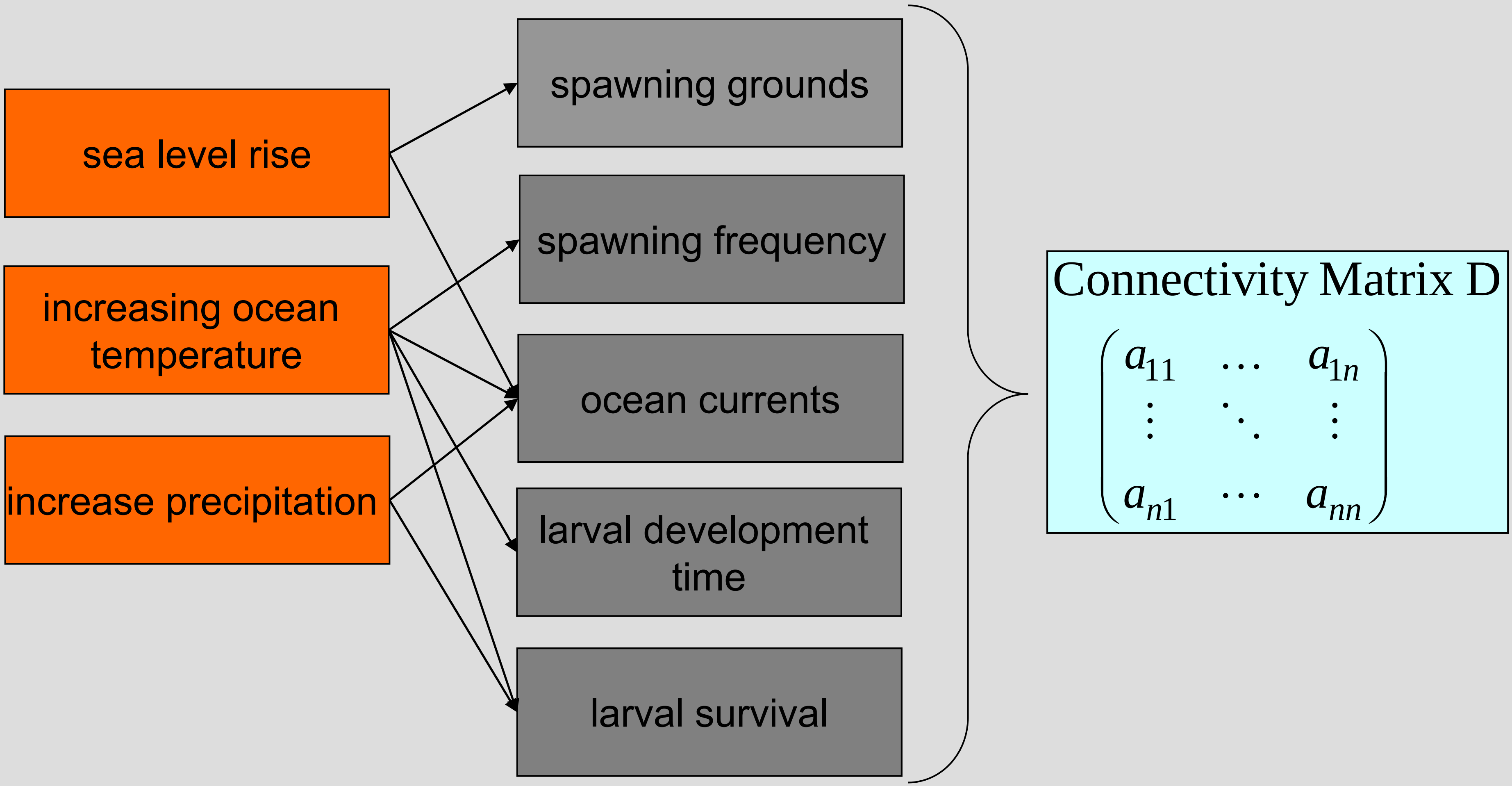
- Sustainable management of the fishery
  - Identify source populations
  - Account for class structure & spatial structure when setting catch limits

- This approach is applicable to populations of other estuarine species (i.e. shrimps, oysters, menhaden, etc.)

Future Directions

- Effects of climate change on connectivity and populations dynamics
  - NASA Climate and Biological Response: Research & Applications Proposal Caz Taylor & Erin Grey (Tulane), Woody Nero (NOAA), Dong-Shan Ko (NRL), Harriet Perry & Don Johnson (Gulf Coast Research Laboratory)
- Further refinement and testing of model parameters.
  - NSF Biological Oceanography Proposal Caz Taylor & Erin Grey (Tulane), Woody Nero (NOAA), Dong-Shan Ko (NRL), Harriet Perry & Don Johnson (Gulf Coast Research Laboratory)

Investigate Climate Change Effects on Connectivity



Acknowledgements

Collaborators

Hideki Fujioka, Tulane University & LONI
Woody Nero, NOAA
Dong-Shan Ko, Naval Research Lab
Richard Condrey, LSU
Carey Gelpi, LSU
Don Johnson, Gulf Coast Research Laboratory
Harriet Perry, Gulf Coast Research Laboratory

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Funding

Long-Term Estuary Assessment Group (LEAG)
Newcomb College Institute