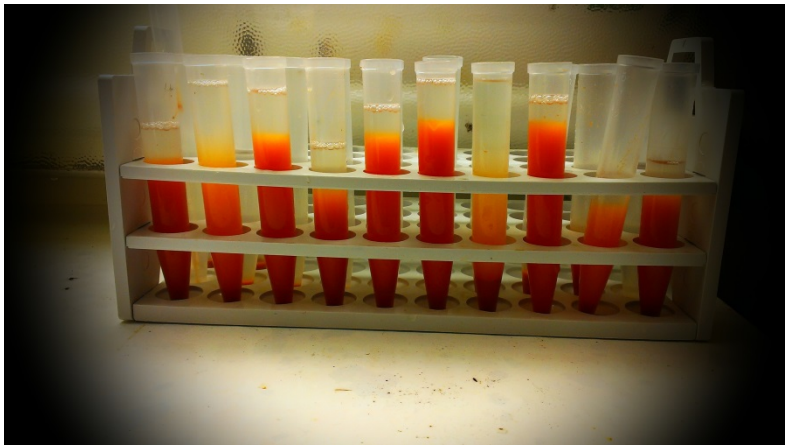
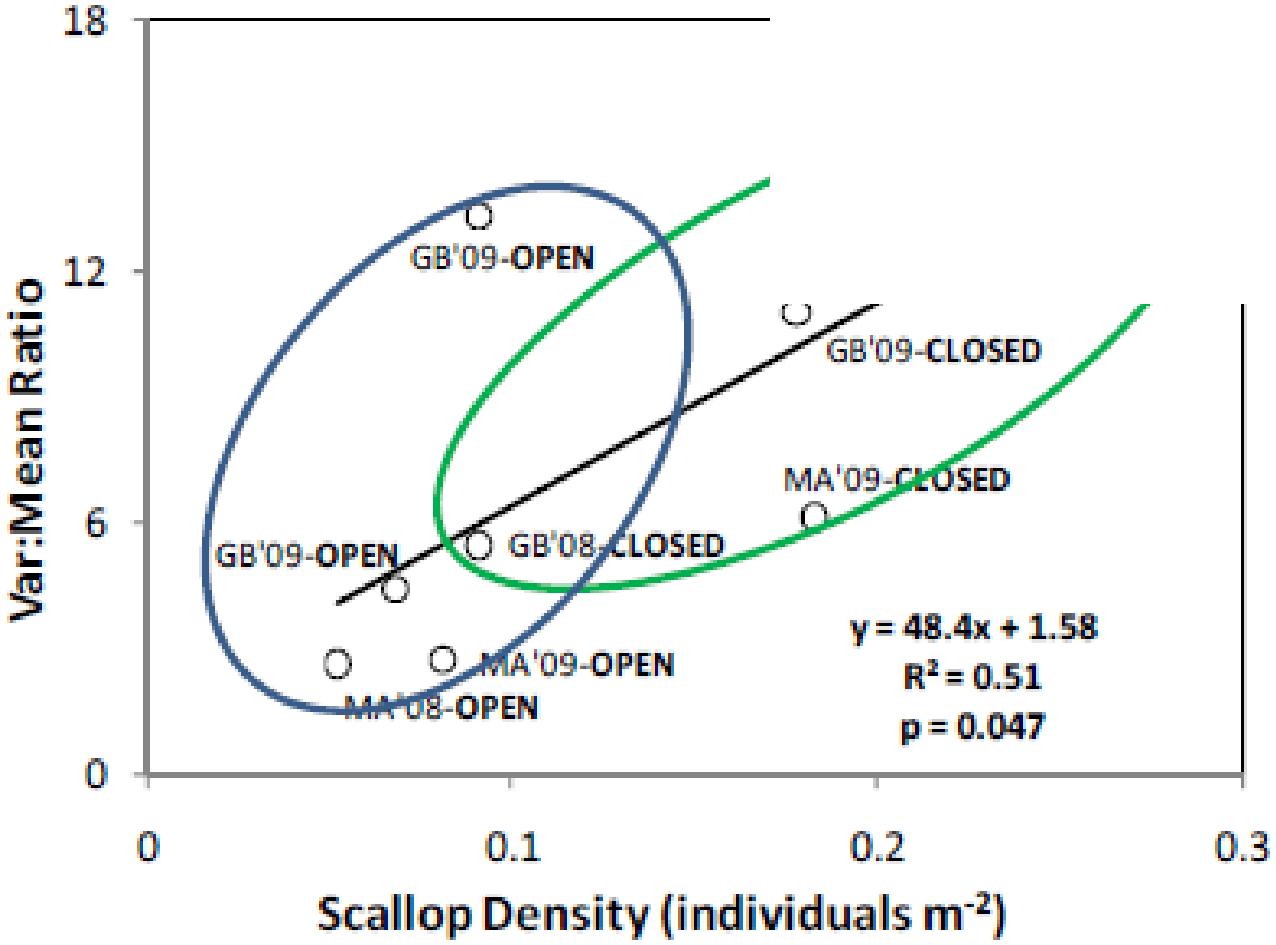
NOAA/RSA Projects

Developing Tools to Evaluate Spawning and Fertilization Dynamics of the Giant Sea Scallop

Skylar Bayer (UM), Wahle (UM), Gaudette (GMRI), Stokesbury (SMAST), Sieracki (Bigelow), Jumars (UM) + Maxwell (Harvester)

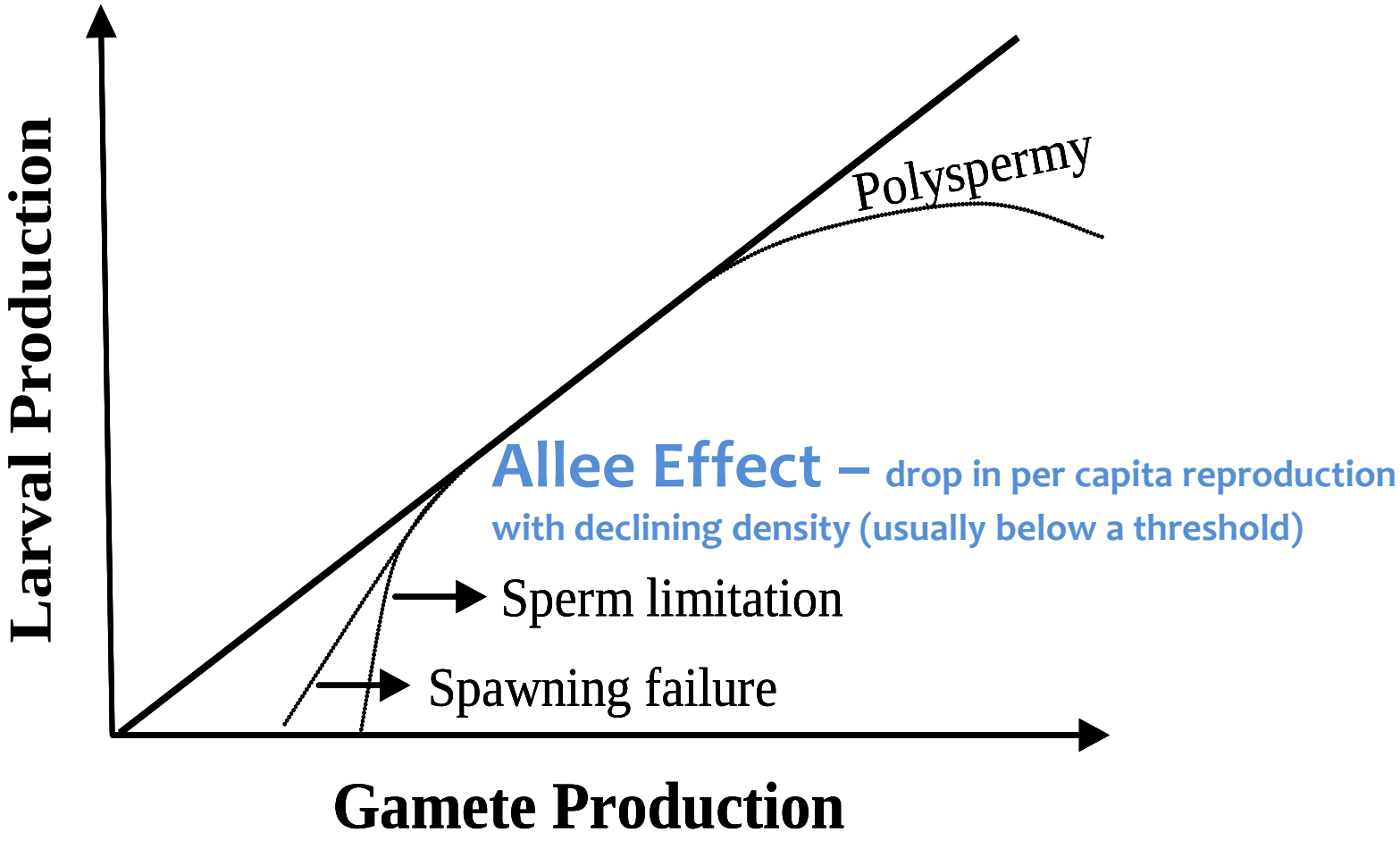


Scallops in areas open to fishing occur at lower density AND are less aggregated



From Stokesbury & Carey SMAST

Broadcast Spawners: Potential effects of variable population density on larval production



The Fertilization Plan

The Model

The Lab

Field Fertilization Assays:

- The Dock
- The Manipulated Field
- The Field

Modeling

Sperm advection-diffusion model

Fertilization ratio model

Movies

Modeling

Sperm advection-diffusion model

$$c(x,y) = \left(\frac{Q\bar{u}}{2\pi\alpha_y\alpha_z u_*^2 x^2} \right) * e^{-\left(\frac{y^2\bar{u}^2}{2\alpha_y^2 u_*^2 x^2} \right)}$$

Where

c = [sperm] at x, y positions down- and cross-stream from source

Q = spawning rate (cells s^{-1}) – *RSA Phase I*

$\bar{u}$ = average flow velocity (cm s^{-1})

u_* = shear velocity, an indicator of shear stress on the sea bed.

α = coefficient of particle diffusion in seawater

Modeling

Sperm advection-diffusion model

$$c(x,y) = \left(\frac{Q\bar{u}}{2\pi\alpha_y\alpha_z {u_*}^2 x^2} \right) * e^{-\left(\frac{y^2\bar{u}^2}{2{\alpha_y}^2{u_*}^2x^2} \right)}$$

Where

c = [sperm] at x, y positions down- and cross-stream from source

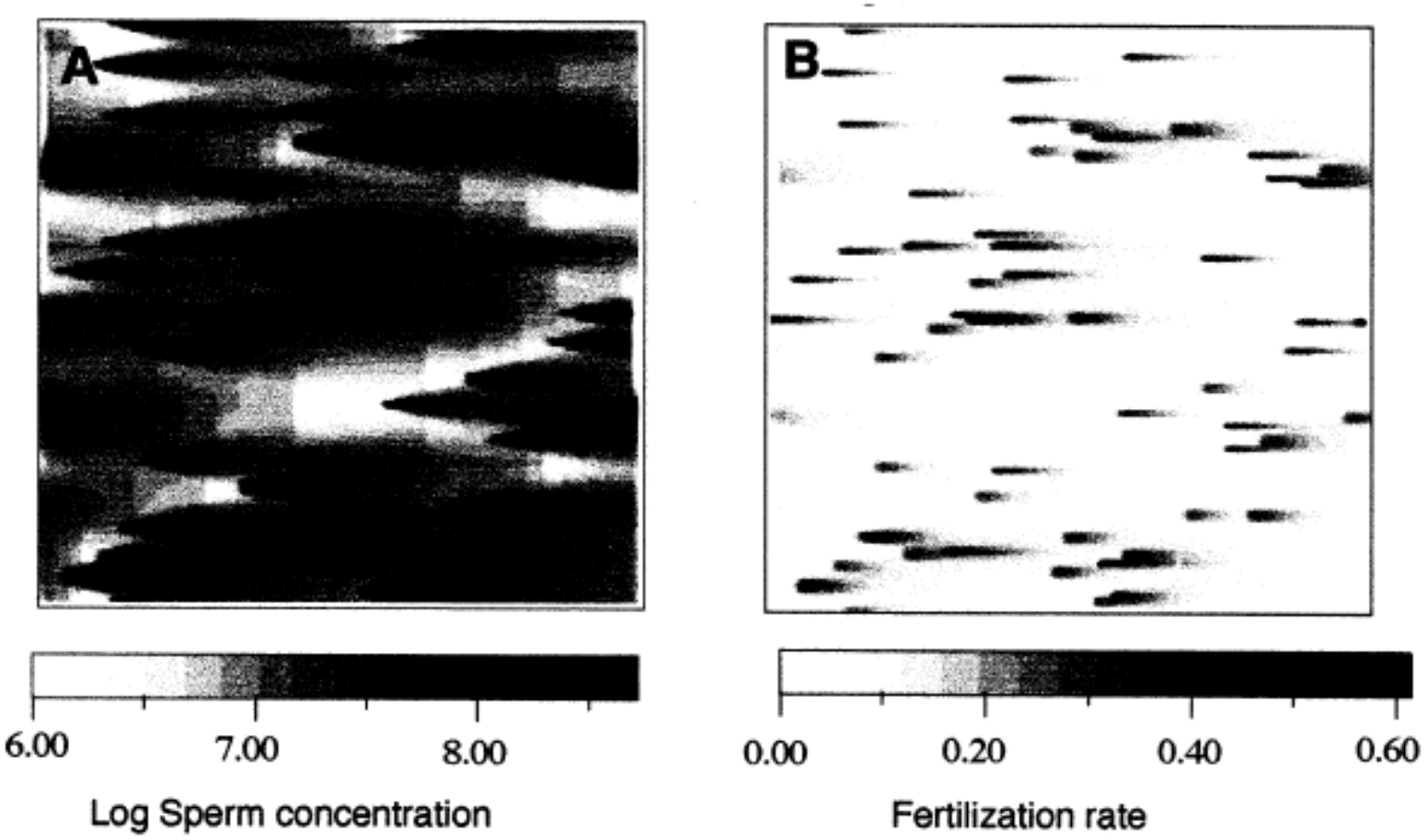
Q = spawning rate (cells s^{-1}) → dynamic function (based on Phase I data)

$\bar{u}$ = average flow velocity (cm s^{-1}) → dynamic function

α = coefficient of particle diffusion in seawater

u_* = friction velocity, an indicator of shear stress on the sea bed.

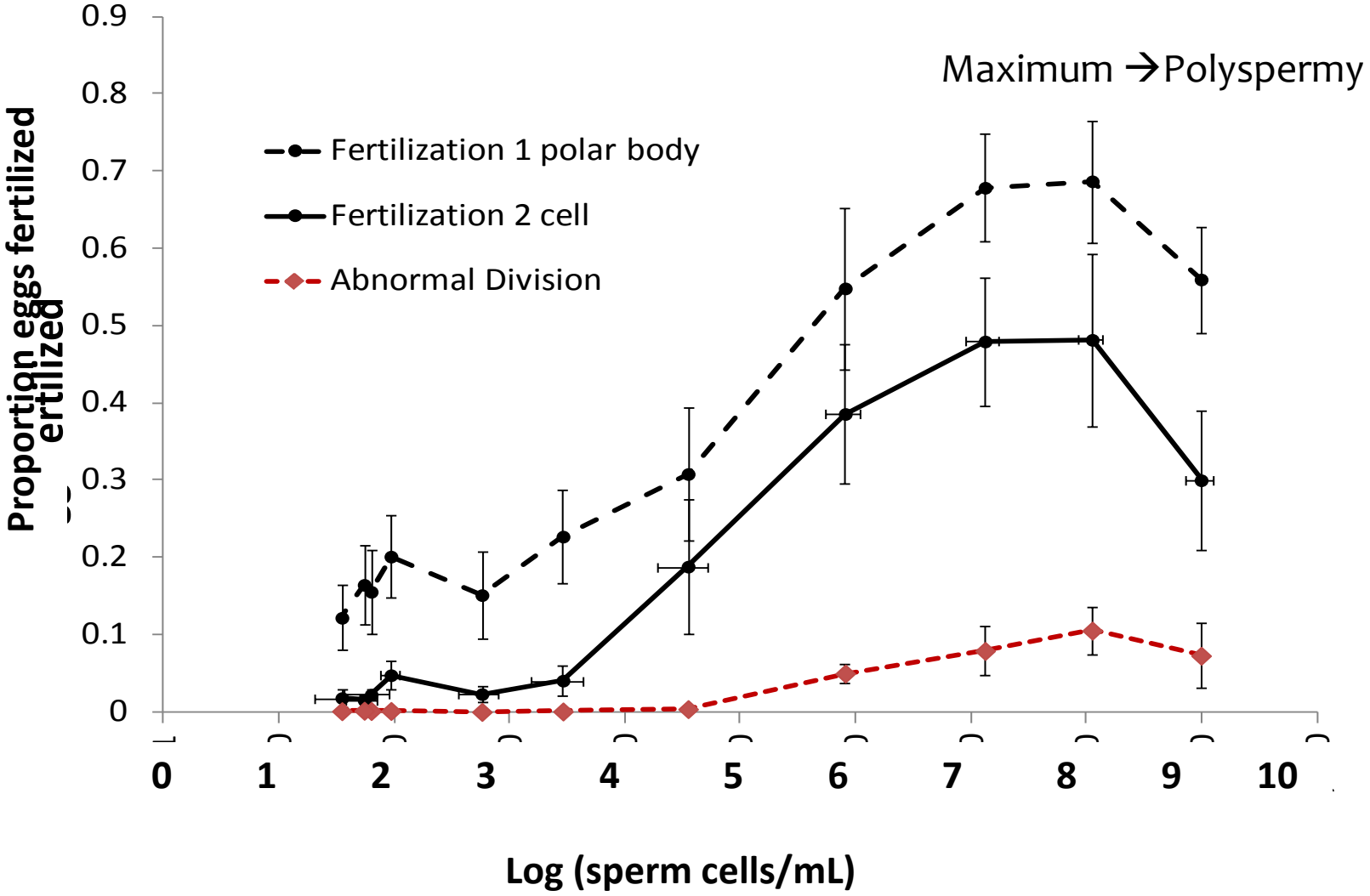
Goal: Modeling population level spawning & fertilization



From Claereboudt (1999) Ecological Modelling 121:221-233

Lab:

Sperm Dilution Series Experiment



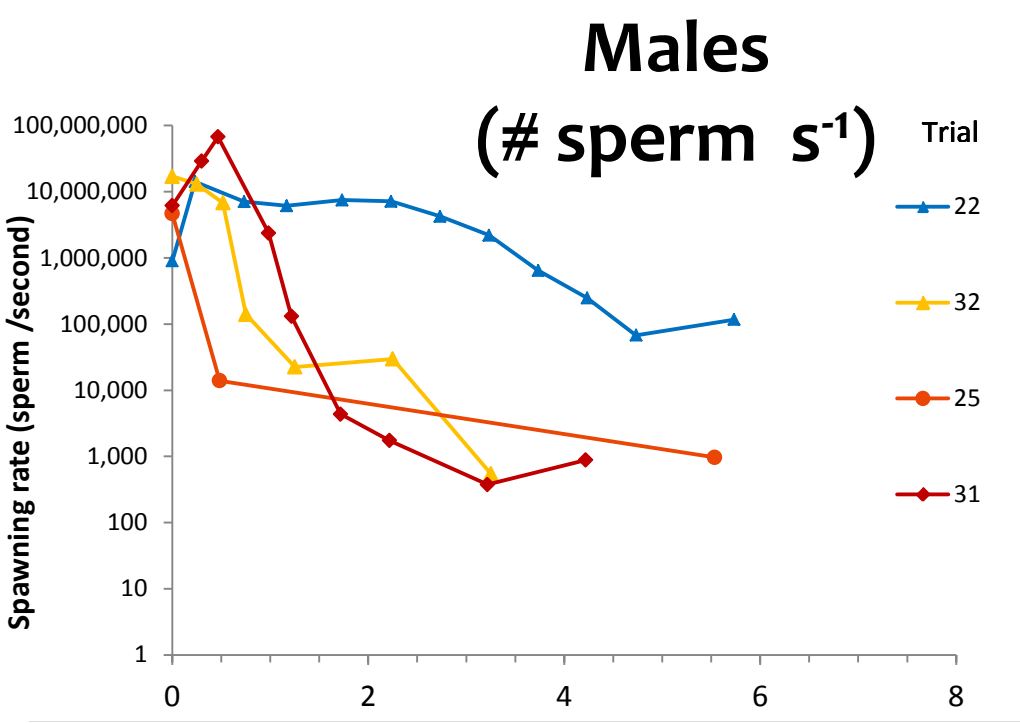
Lab :

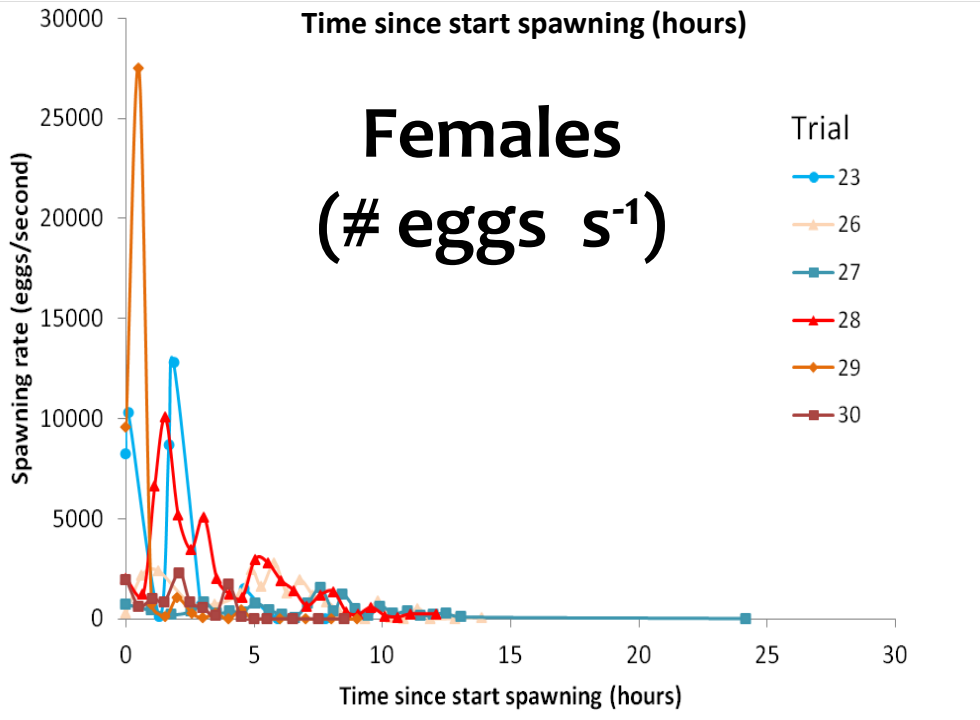
Spawning Rate Trials

- Male Max ~10^8 sperm s^{-1}
- Female Max ~10^4 eggs s^{-1}
- Spontaneous & temperature induced spawning rates highest in first few hours

Gamete Longevity Experiment

- Egg half-life >8h; <24 h
- Sperm half-life =
  - 2 h at 10^7 sperm ml^{-1}
  - 9 min at 10^6 sperm ml^{-1}



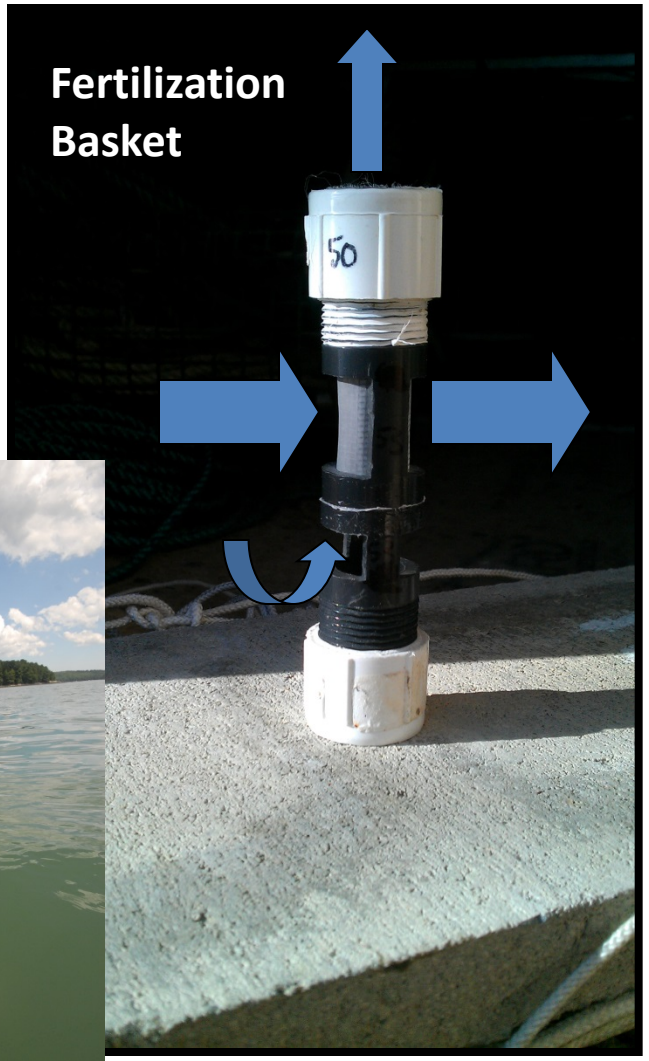


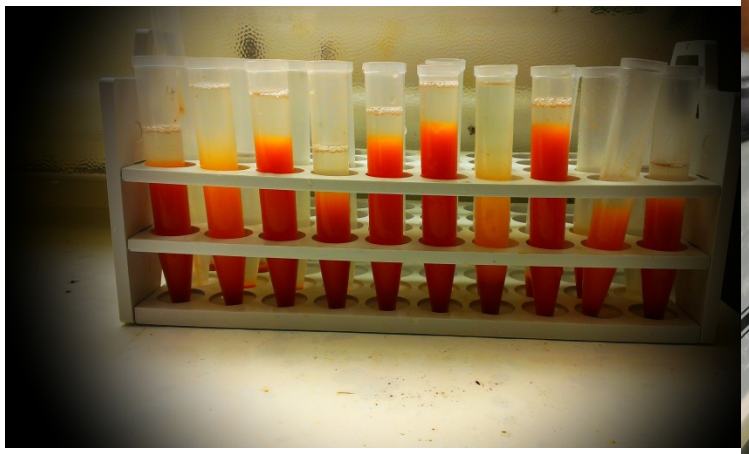
Field Fertilization Assays

Biological:

Fertilization basket trials

Density surveys

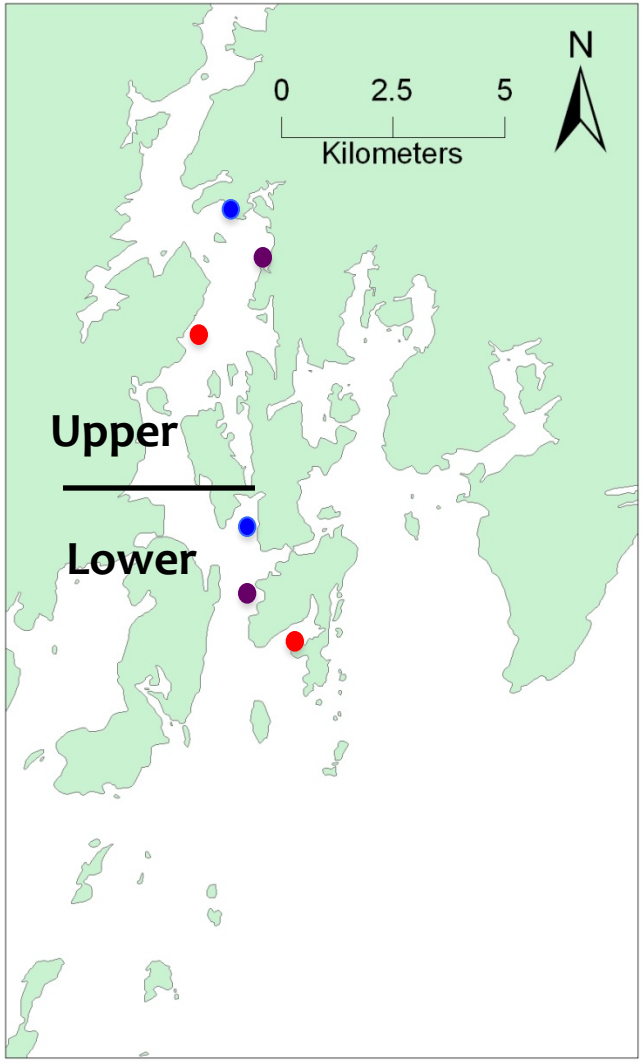


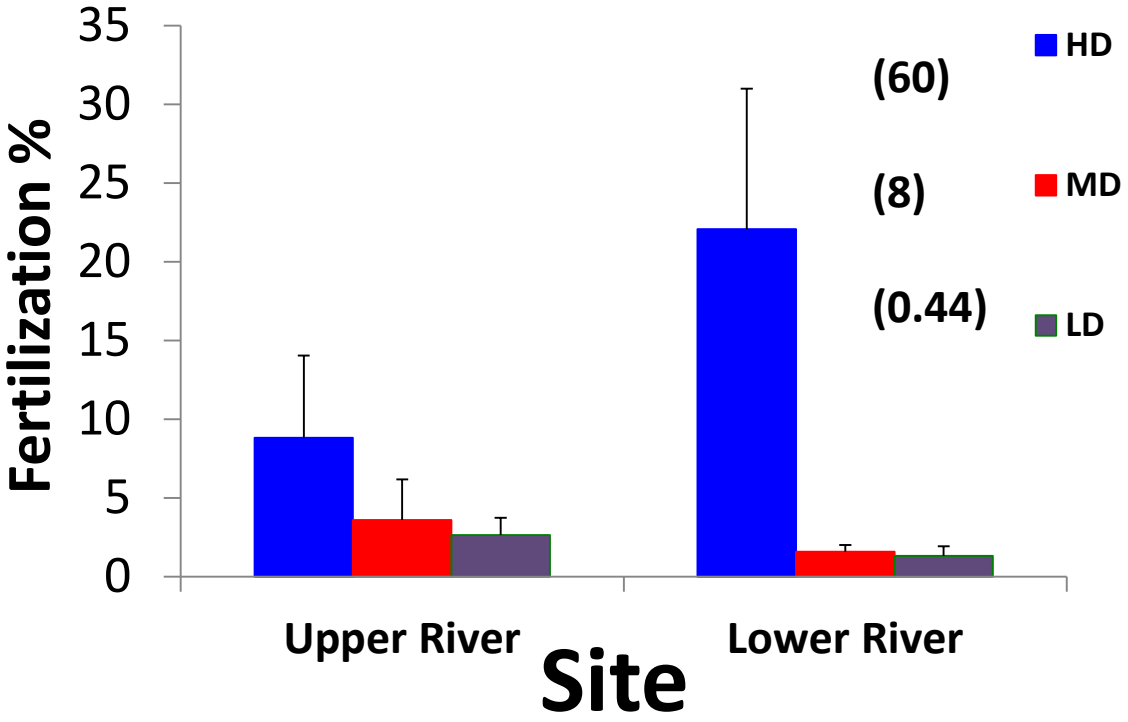


Question –

Does fertilization success correlate with density?

2013 Dockside Density Exp Results:





ANOVA results:

Site, NS

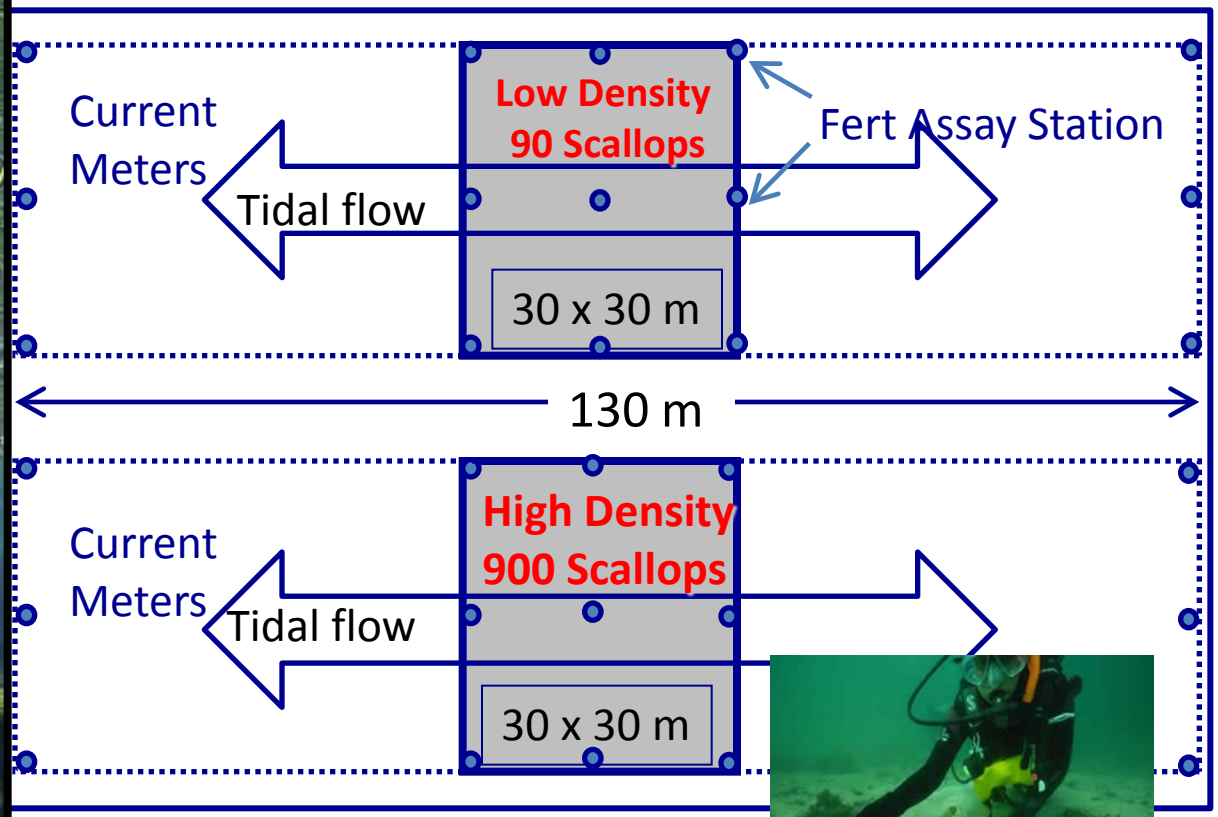
✓**Density, F= 9.103, p < 0.0001*****

✓**Site x Density, F= 3.982, p < 0.023***

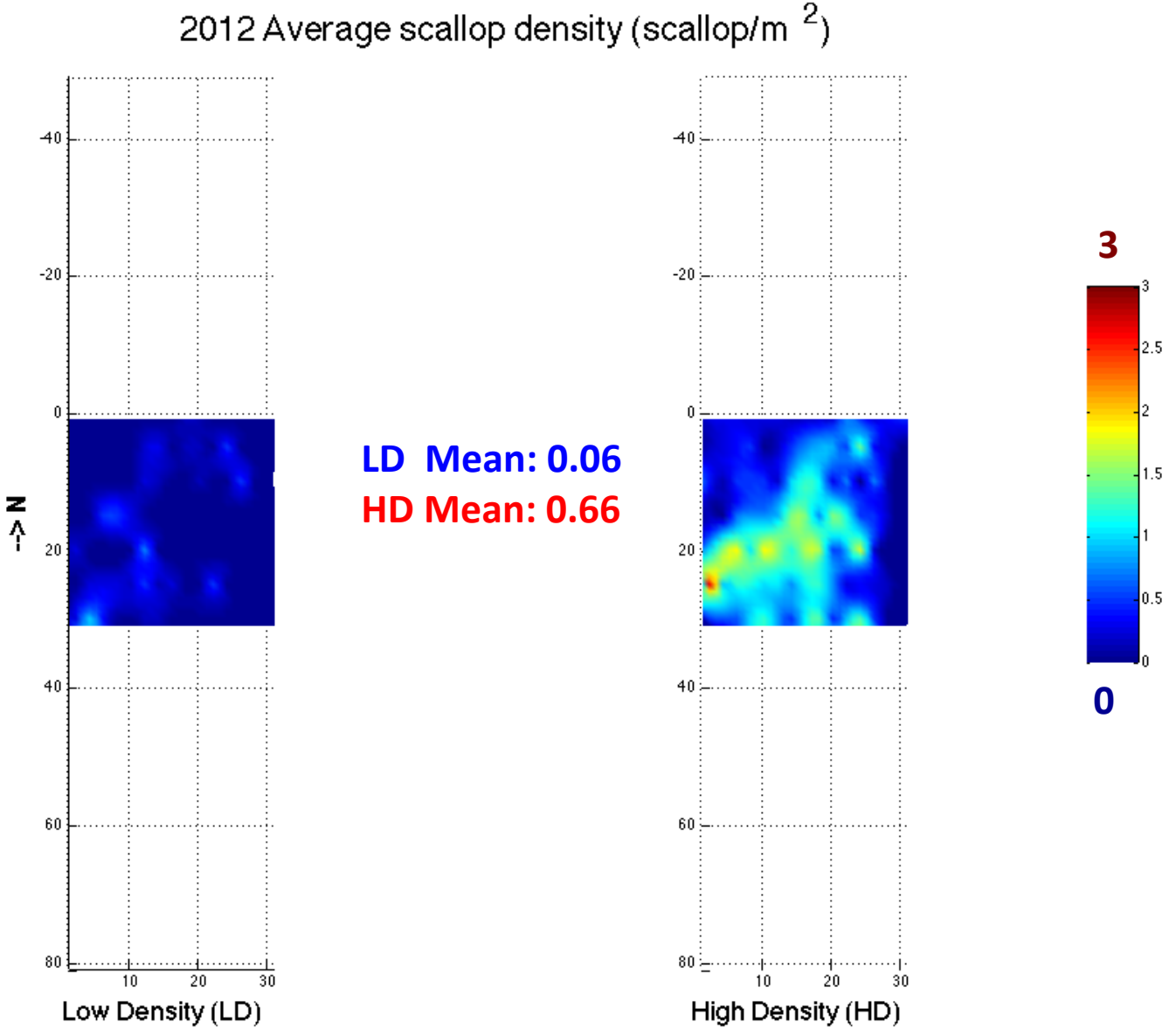
Question –

Can we try this experiment with a)observed densities and b) on a seabed?

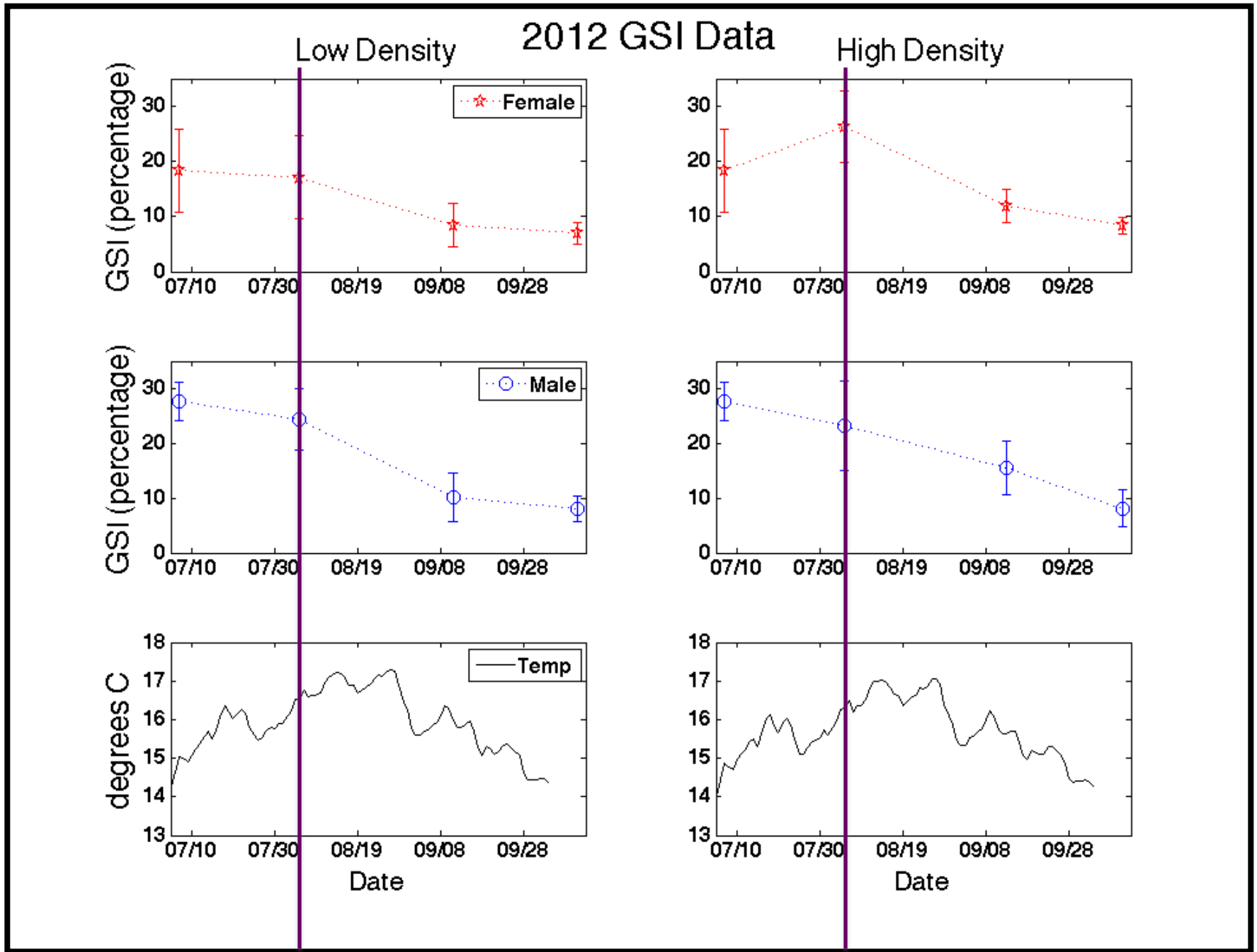
2012 Manipulated Field Populations



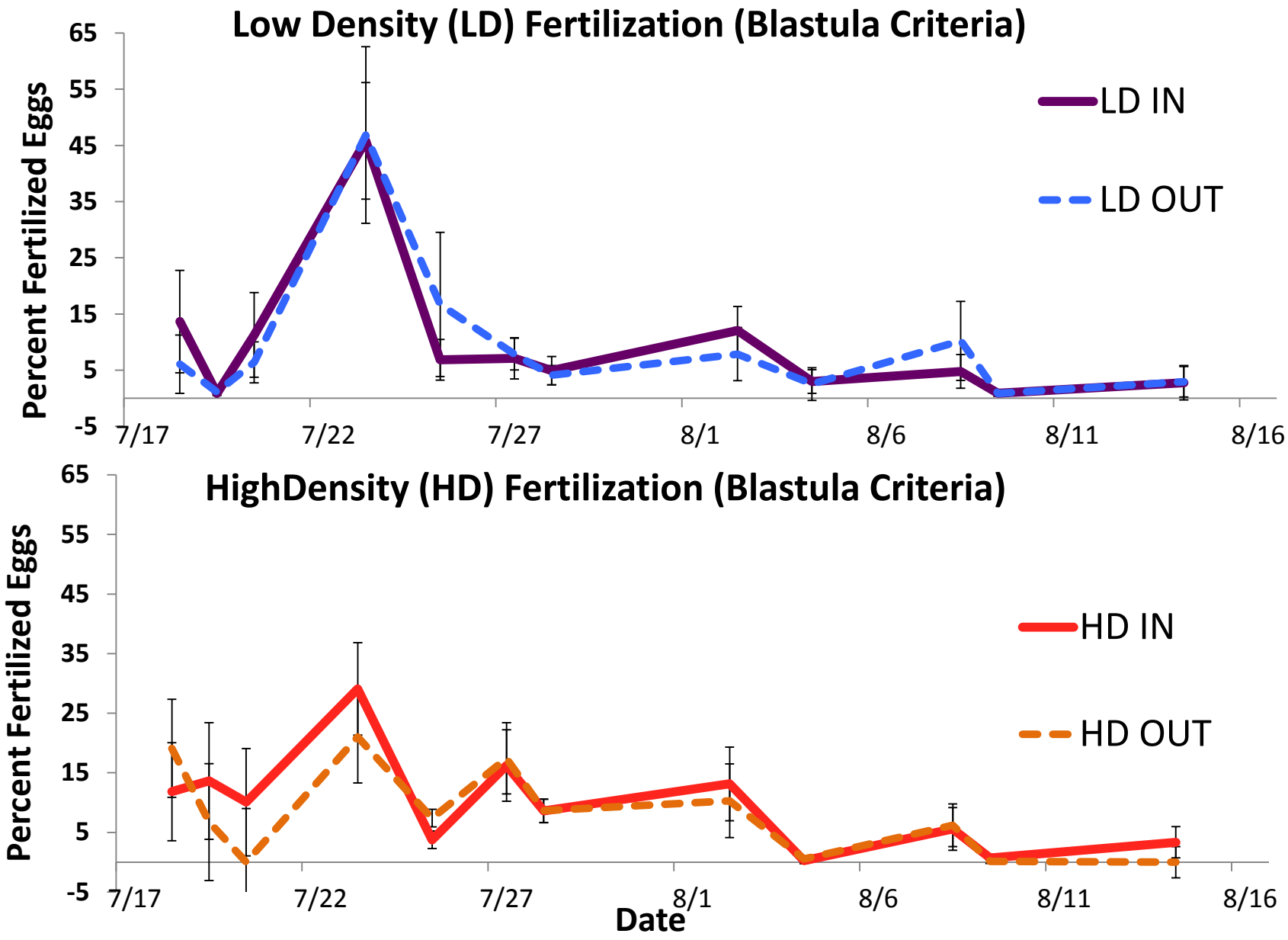
2012 Manipulated Field -- Density Surveys



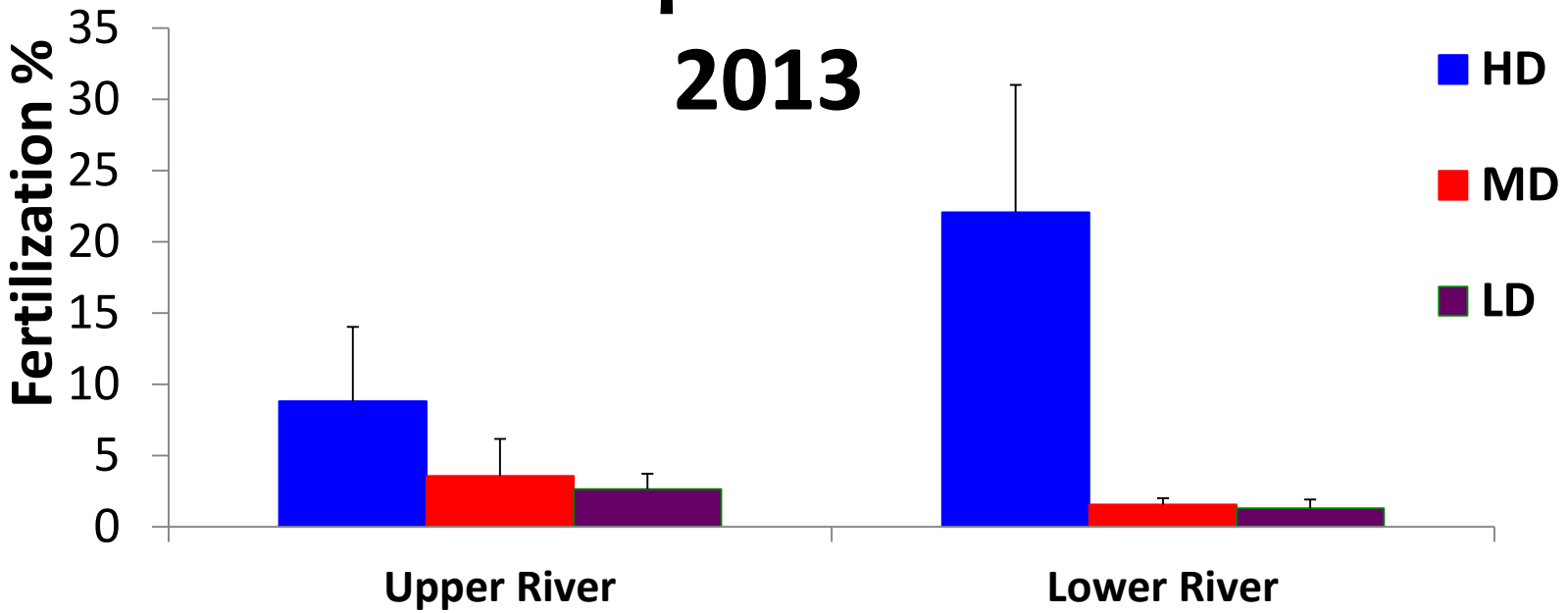
2012 Manipulated Field -- GSI

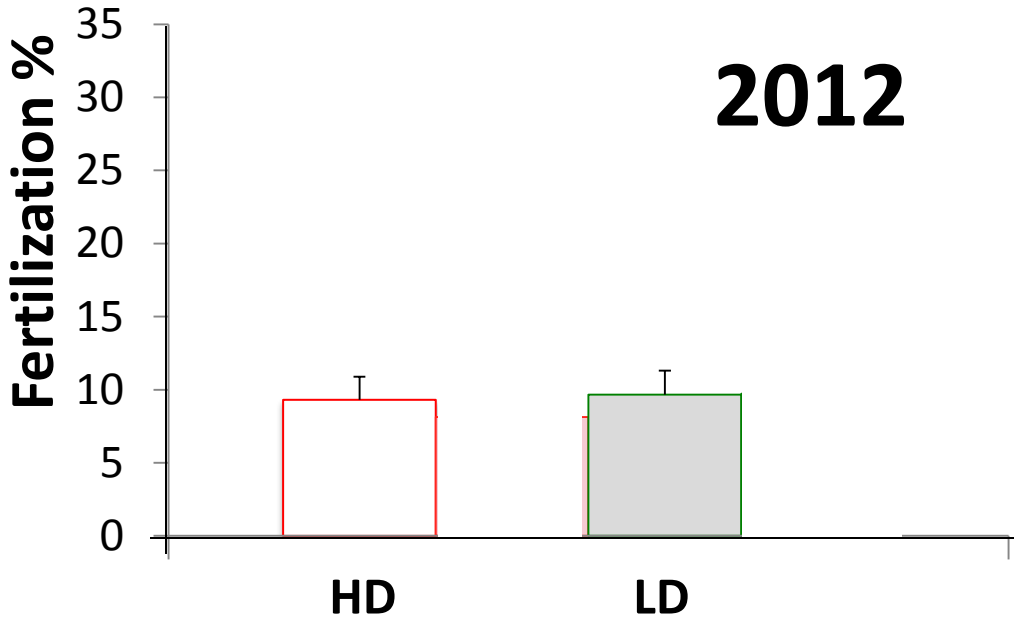


2012 Manipulated Field -- Fert Time Series



Dockside vs. Manipulated Field Fert

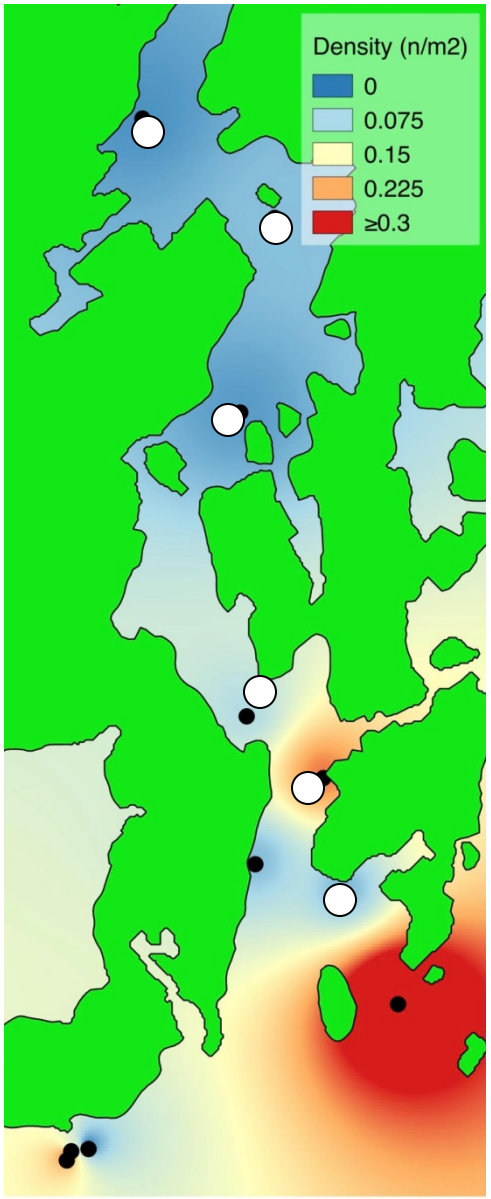




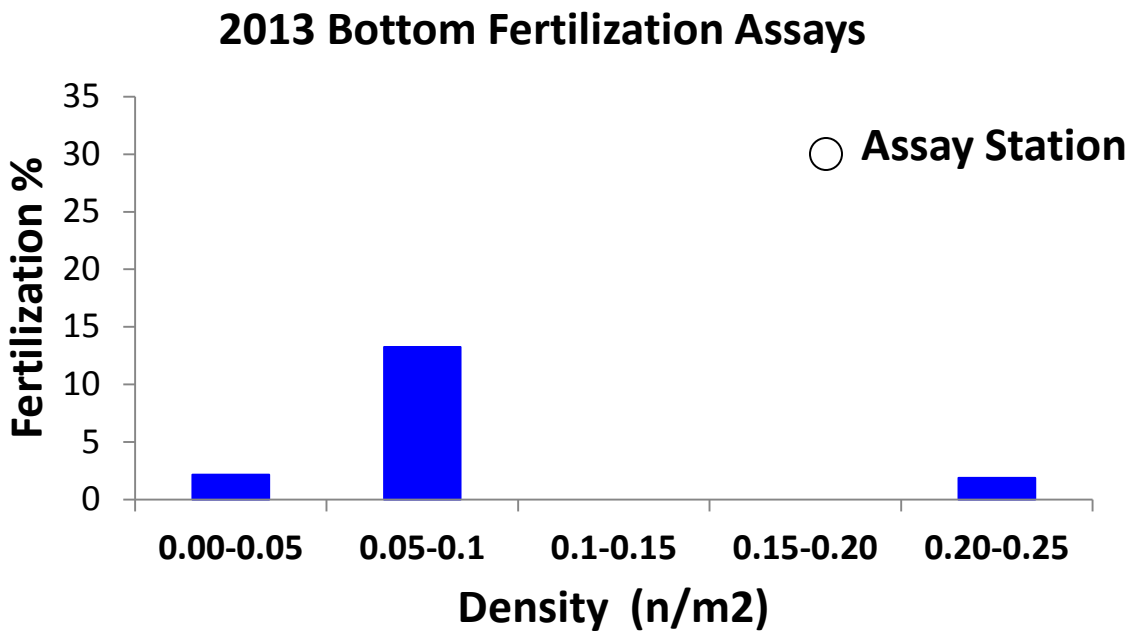
2013 Natural Populations:

Natural Population Surveys

● Survey Station



Natural Fertilization Results



Recap (1/2)

Lab Experiments:

- Pulse spawning
- Short half lives
- Dilution effects

- **Dockside Experiments:**
  - Density has significant effect on fert success (10th - 10s)

- **Manipulated Field Populations:**
  - NS difference between population fert success (10ths - 1s)
  - Captured spawning season (GSIs)

- **Natural Populations :**
  - Unclear relationship between density and fert success (100ths - 10ths)
  - Flow important?

Recap (2/2)

Model -- *in progress*

- Developing dynamic, spatial model with collected empirical biological data (half the battle)

- Next steps:
  - Turn Q into a function
  - Input time varying estuary flow
  - Individual spawner ---->Population spawners

Scallop RSA Project Finding Recap – Phase I

(2009-2011)

Wahle (UM), Gaudette (GMRI), Stokesbury (SMAST), Sieracki (Bigelow) + Maxwell (Harvester)

- Spawning typically sustained for several hours; maximal rates last <1 h.
-
- Male max spawning rates ~10^8 sperm s^{-1}; Female max ~ 10^4 eggs s^{-1}

- Egg half-life ~8-12 h. Tractable for field fertilization assays.

- Sperm half-life <1 h, depends on sperm concentration

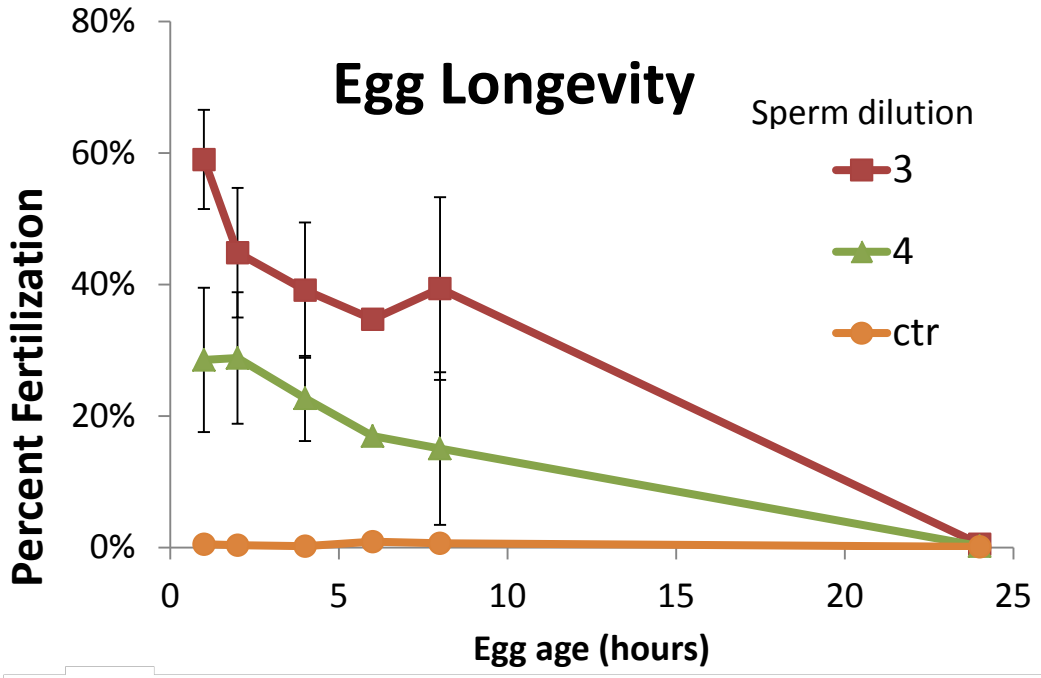
- Flume expts reveal distance, flow, spawning rate effects on fertilization rates.

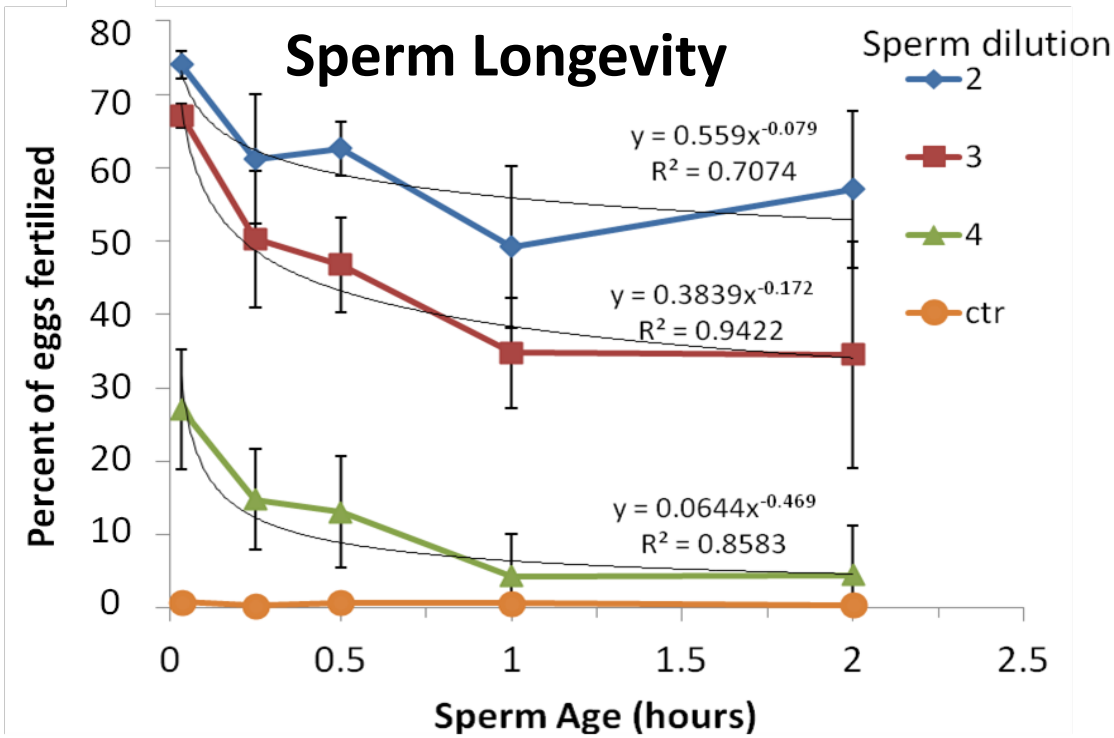
- SMAST surveys – Scallop densities generally higher AND more aggregated in closed areas.

Phase I:

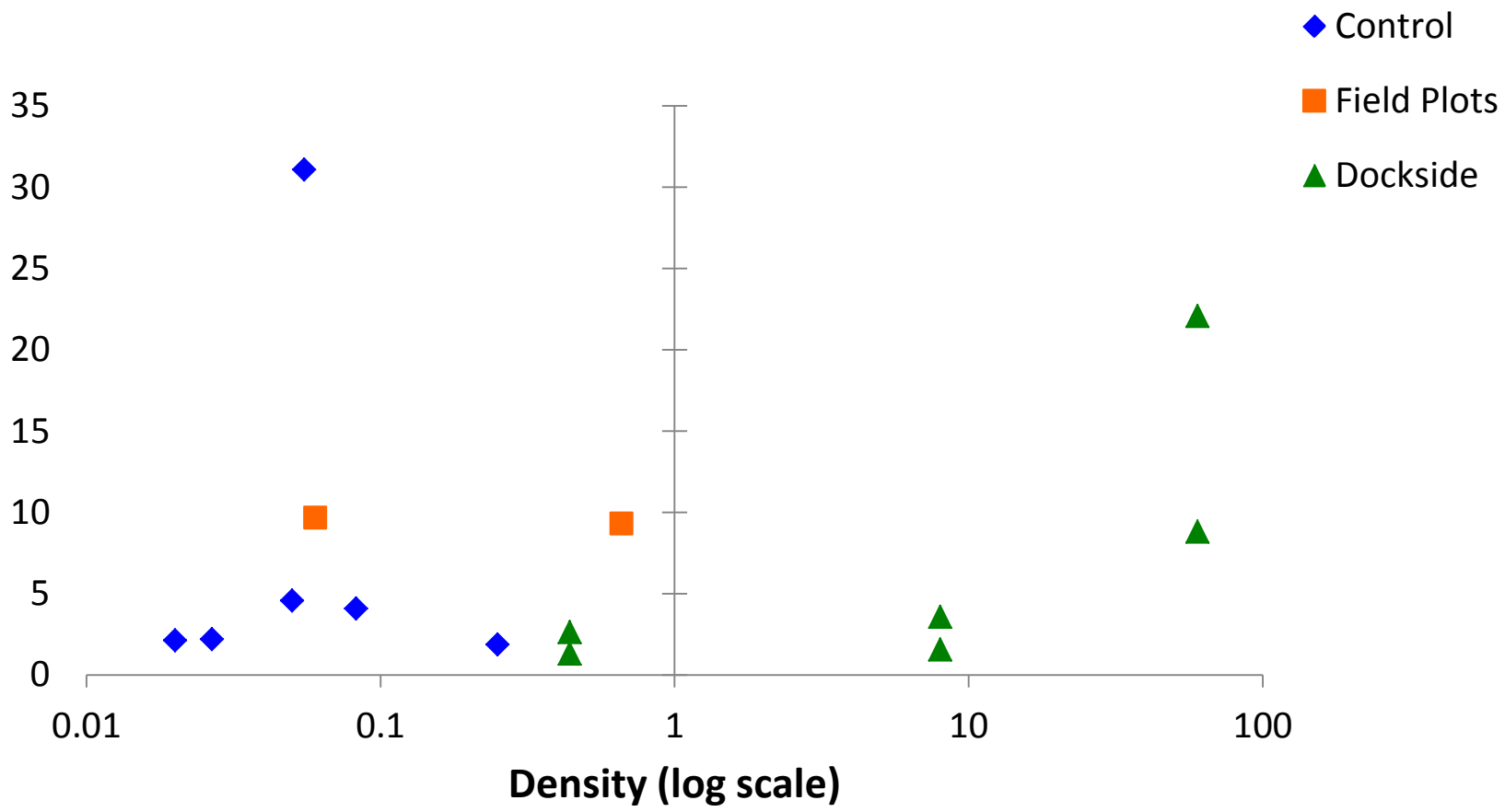
Objective 1 – *Gamete Longevity Experiment*

- Egg half-life >8h; <24 h
- Sperm half-life =
  - 2 h at 10^7 sperm ml^{-1}
  - 9 min at 10^6 sperm ml^{-1}

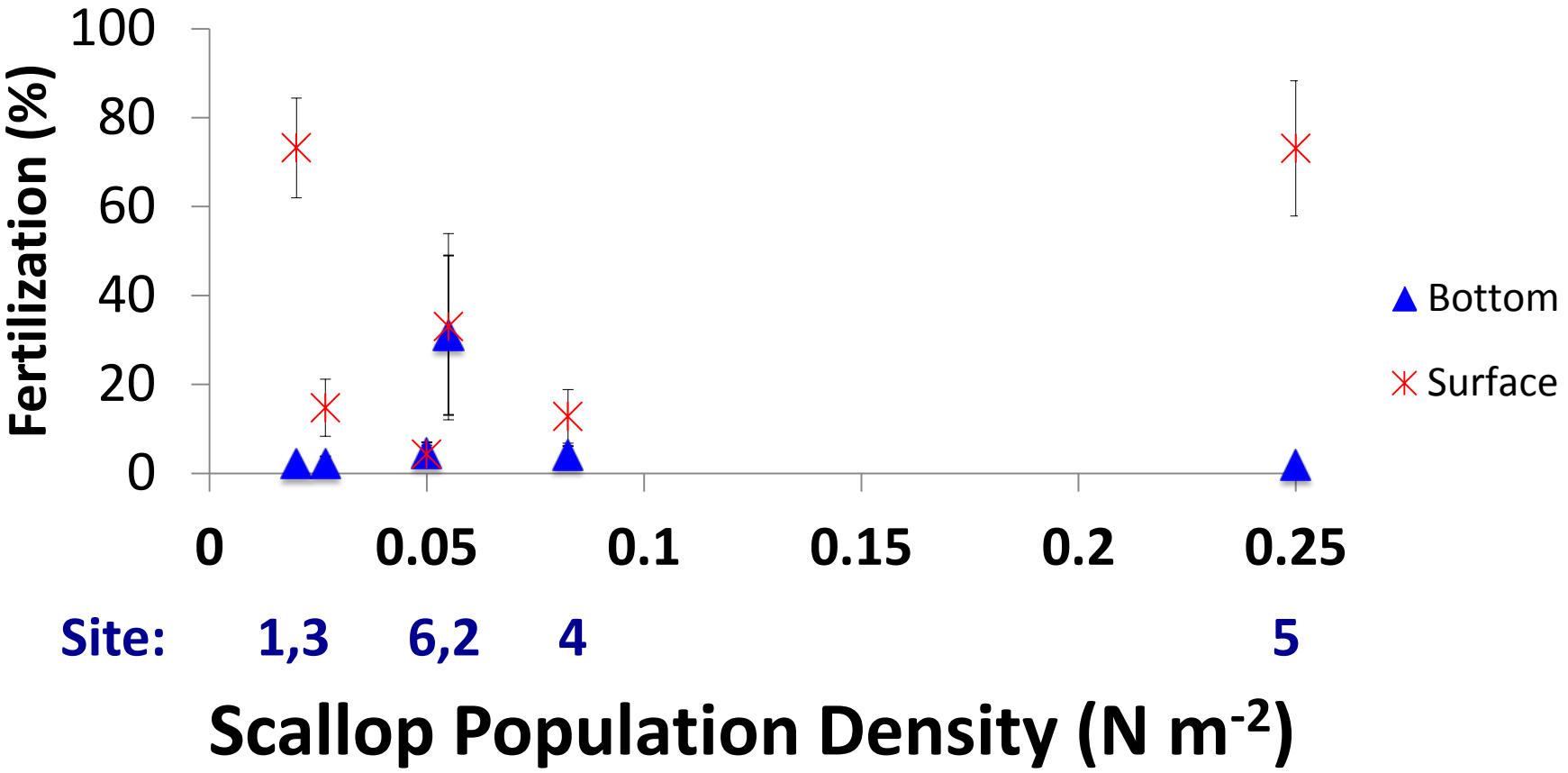




2013 Lantern Net Density Exp Results:

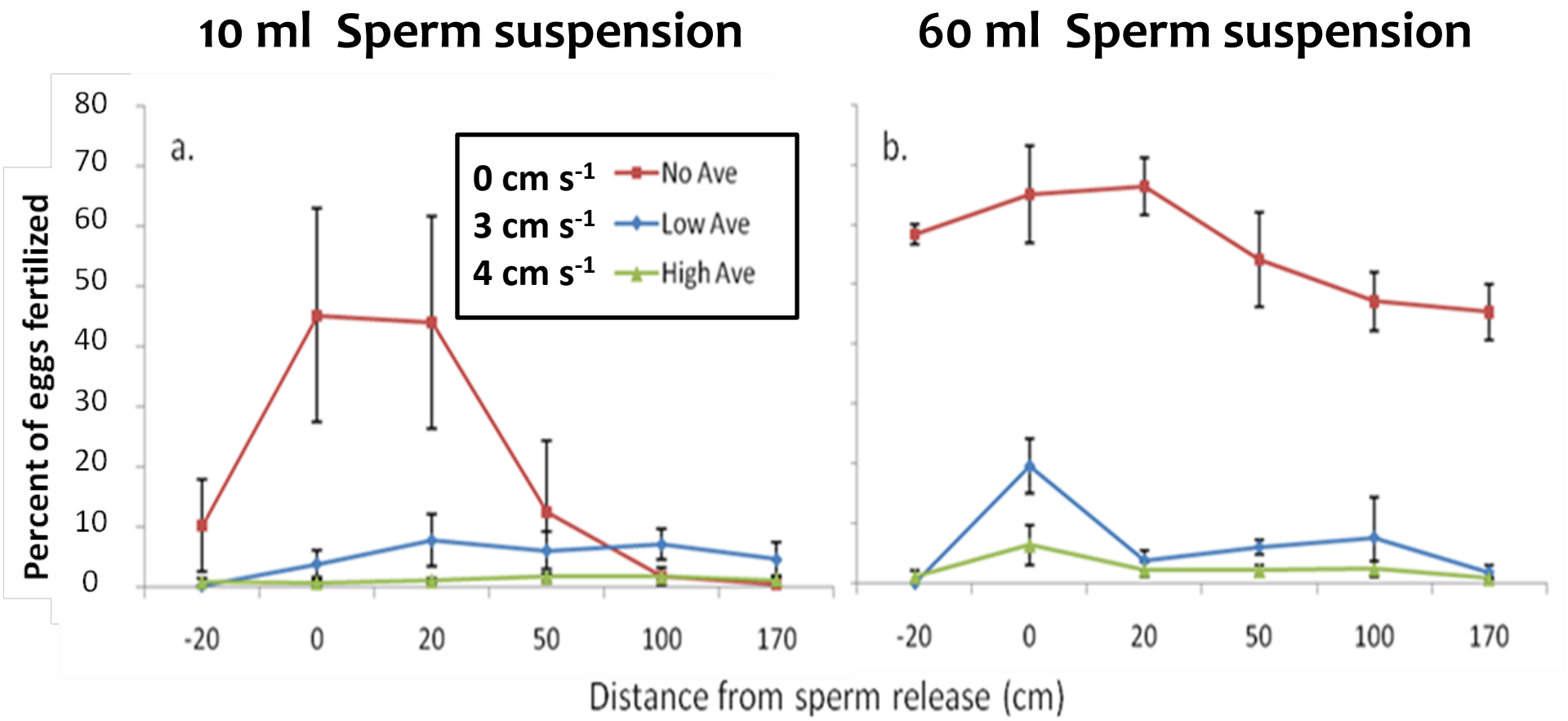


2013 Local Populations:



Fertilization (%) of eggs deployed at bottom and surface (2 m below surface) at stations 1-6. N=4 trials (7/26/13, 7/30/13, 7/31/13, 8/3/13), Error bars are standard error.

Phase I: Objective 2 – *Flume Experiments*

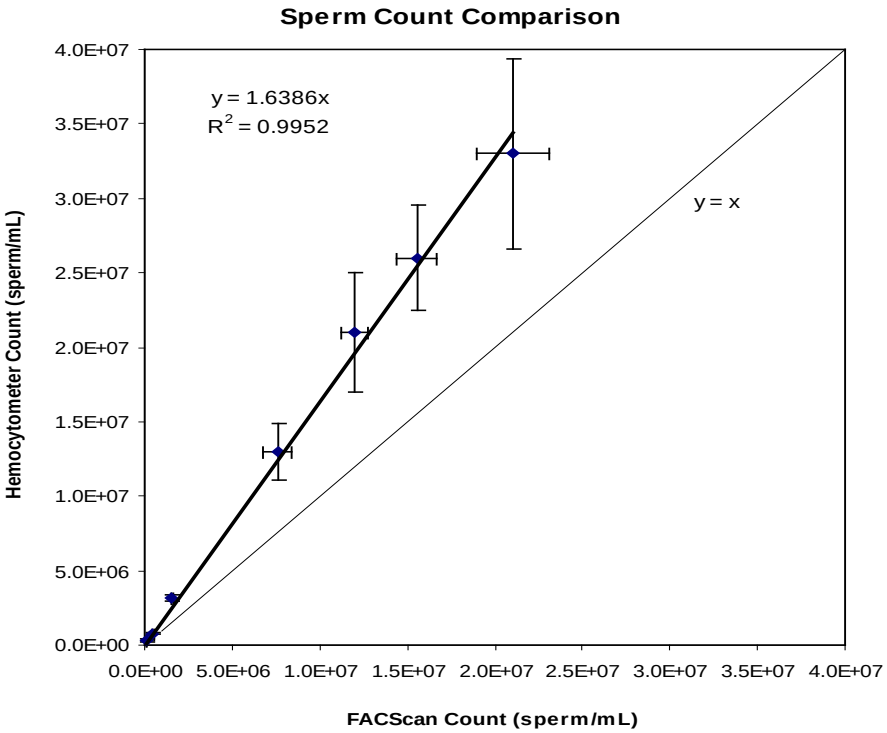


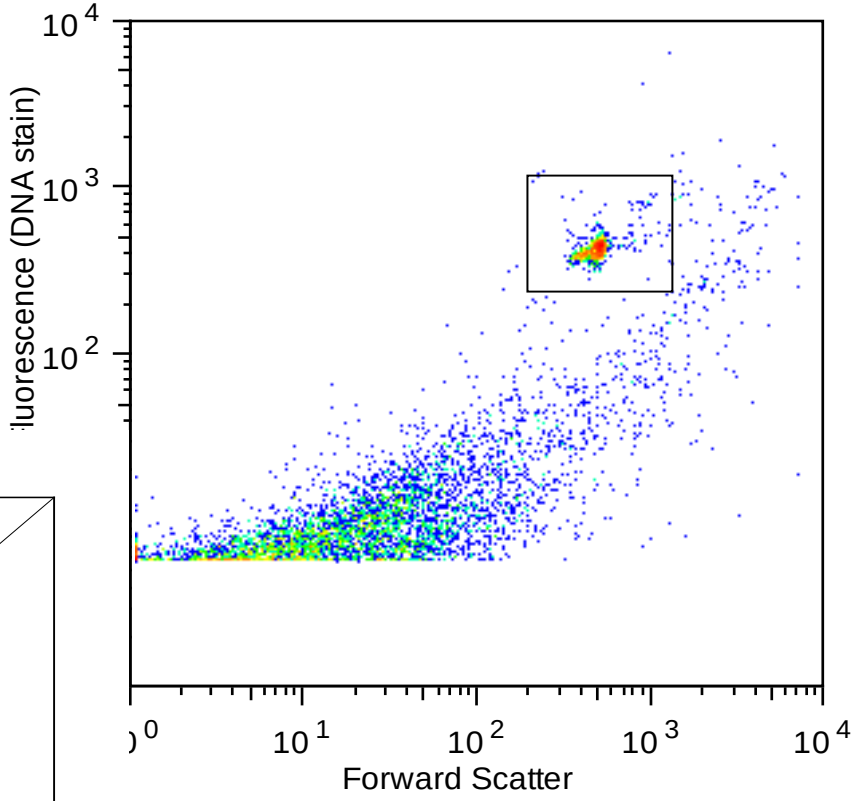
Phase I:

Objective 1 -

Flow Cytometry

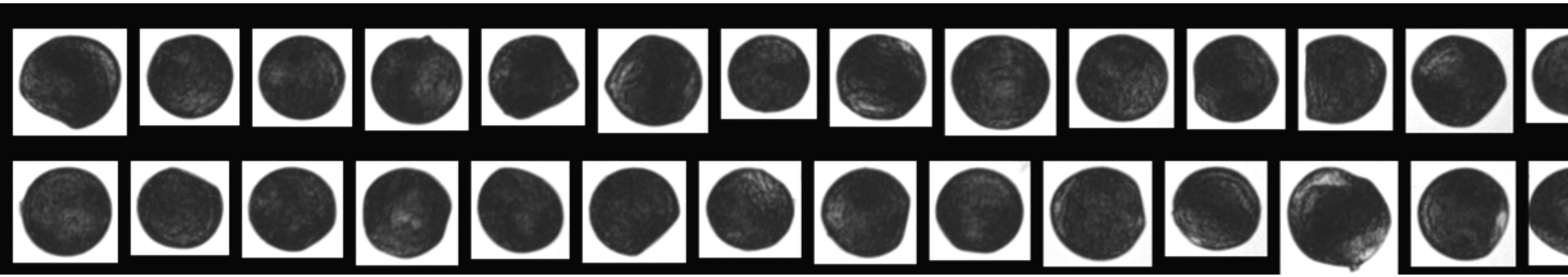
Sperm Counts



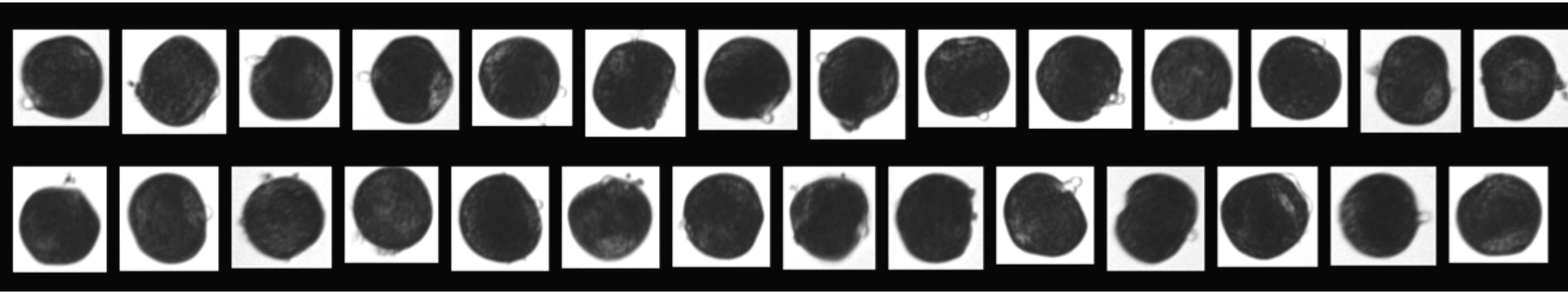


Imaging Flow Cytometry – Embryo staging

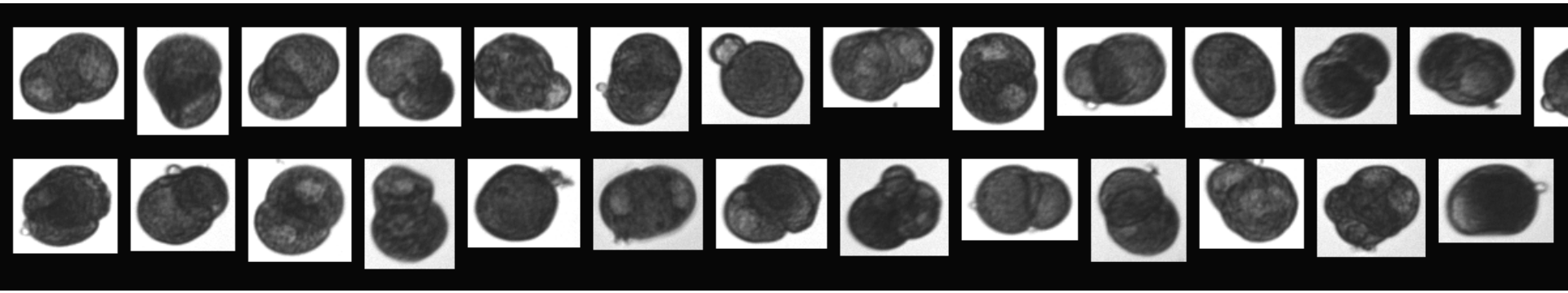
A. Unfertilized



B. 1 Polar Body

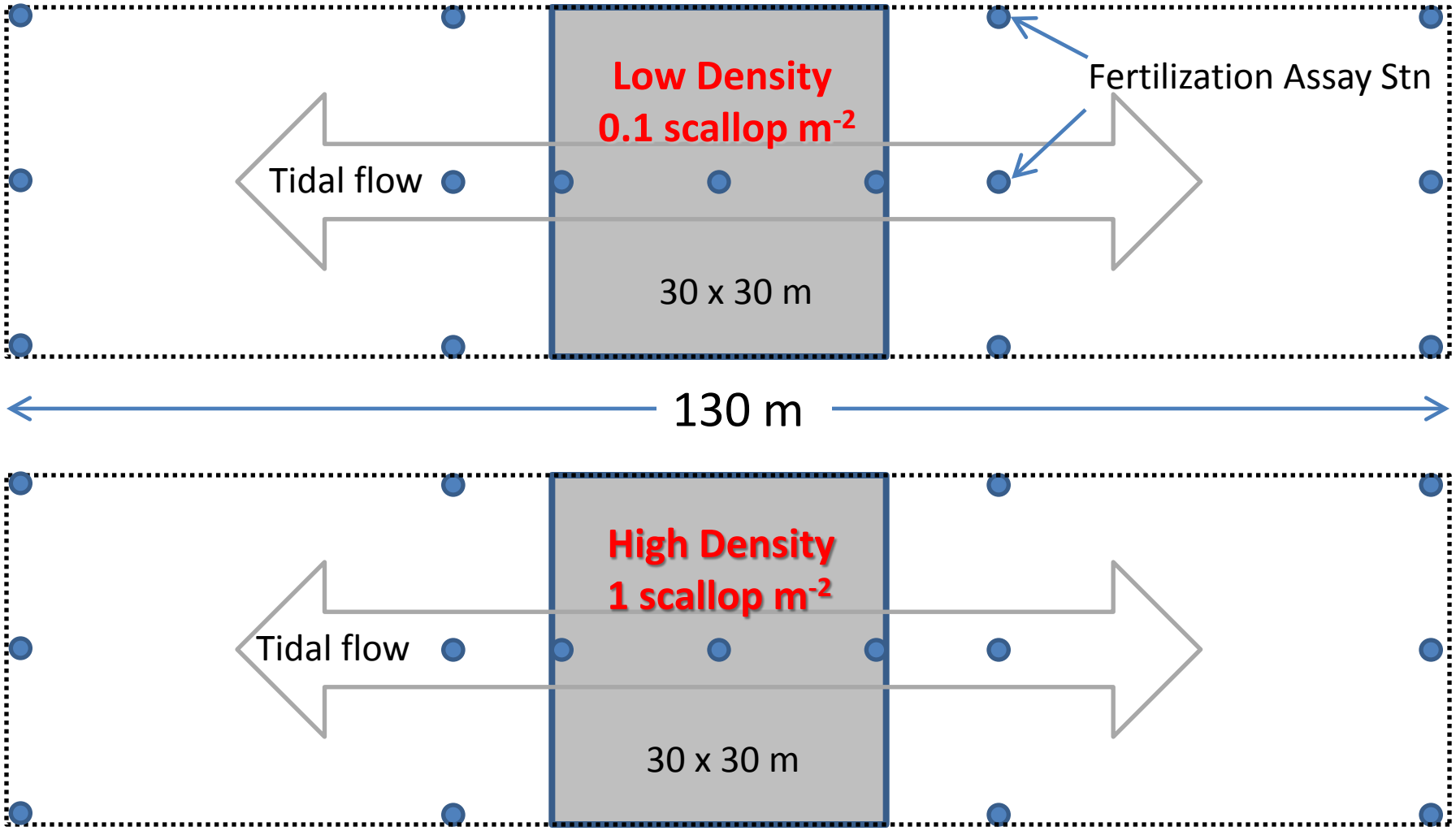


C. 2-Cell

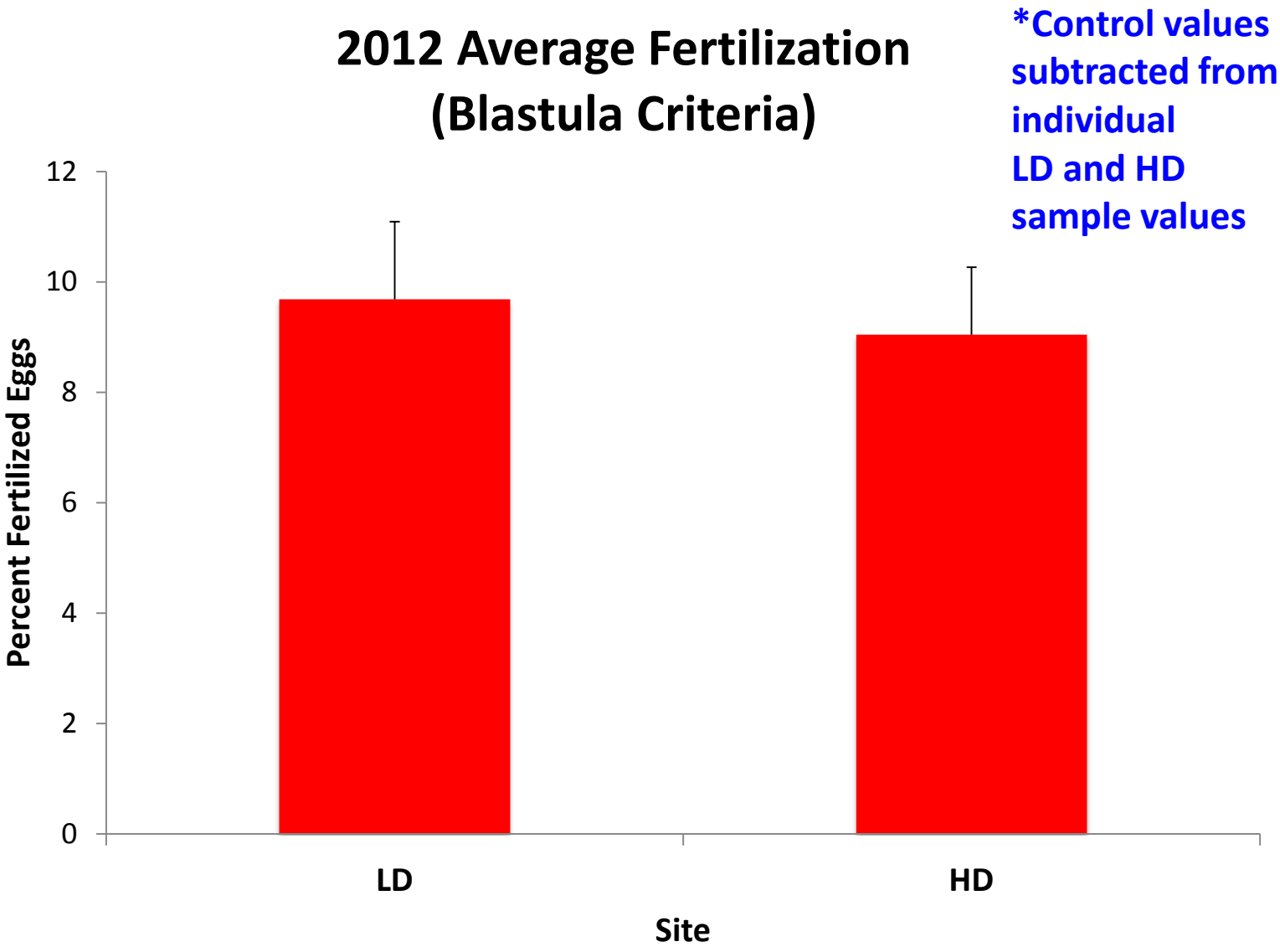


Phase II

Objective 2 – *Fertilization Assays in Field Populations*



2012 Preliminary Results– Fertilization Sites



2012 Preliminary Results– Spatial Results

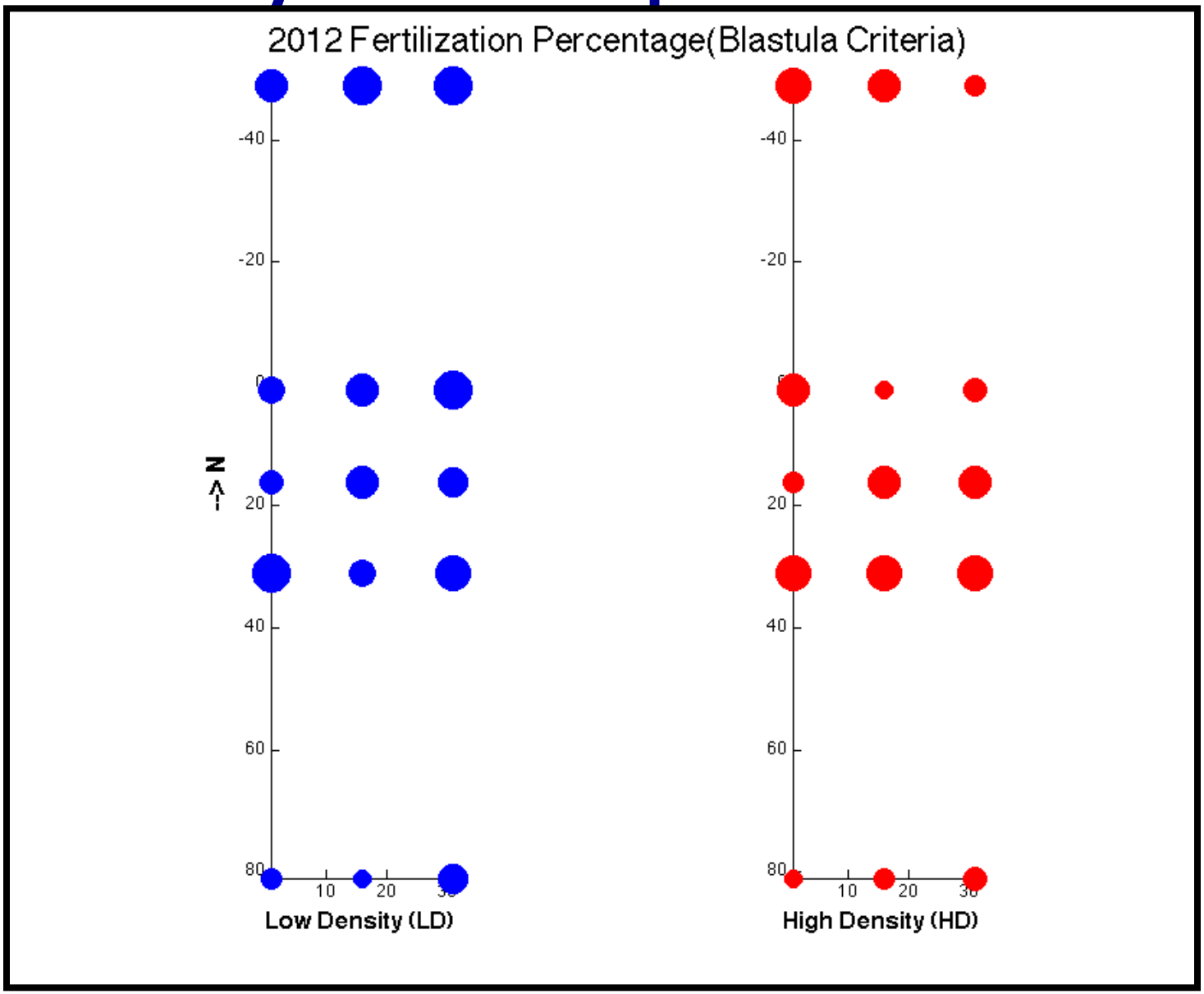
Fertilization Success

80%

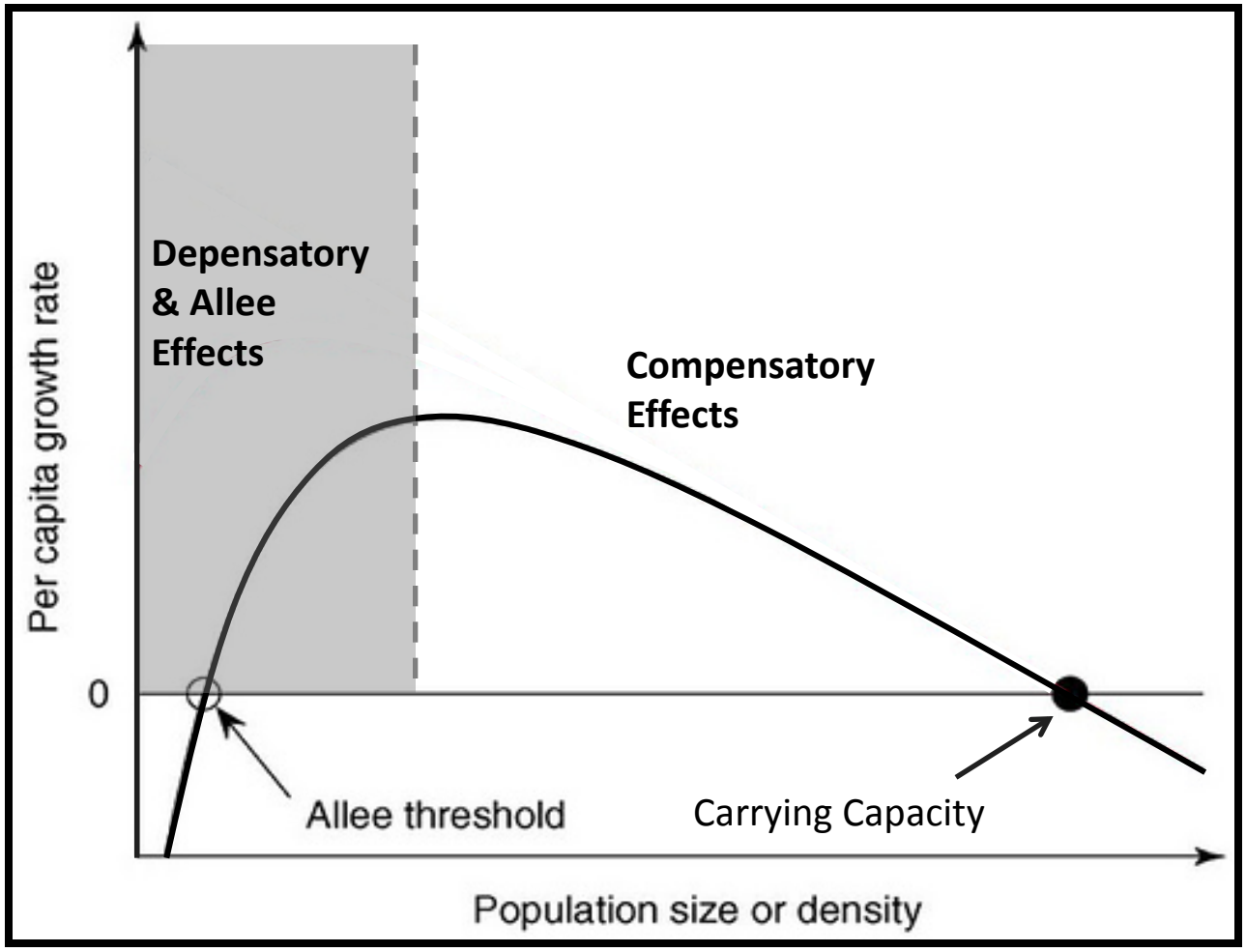
20%

10%

5%



Broadcast Spawners: Potential effects of variable population density on larval production



Allee Effect –

drop in per capita reproduction with declining density (usually below a threshold)

Recap

2012:

- **Preliminary data suggests no density treatment effect on fertilization success**

- **Highest fertilization rates at the beginning of the spawning season (tailing off over the course of the season)**

- **Locations highly synchronous and similar with respect to fertilization rates**

Time-Integrated Fertilization Assays: Green sea urchin

From Gaudette, Wahle & Himmelman (2006) L&O 51:1485–1496

- Spawning patterns in small and large aggregations in nature
- Environmental correlates

Field Fertilization Unit

Pemaquid Point Urchin MPA