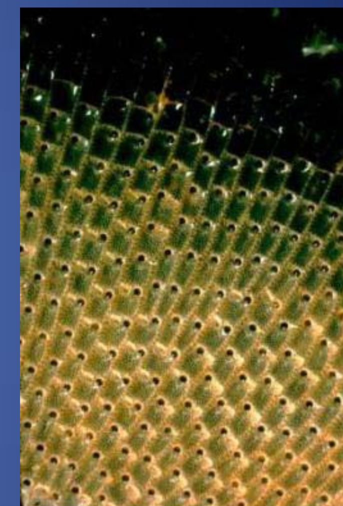
Interaction of Climate Change, Landuse and Invasive Species: Tests of Contrasting Management Scenarios for Coastal Communities

Robert B. Whitlatch, University of Connecticut
Richard W. Osman, Smithsonian Environmental Research Center

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # RD-83383801







- Marine sessile invertebrate community
- Multiple taxa, diverse life histories, economically important species
- Found worldwide in all habitats



Non-native species have become a dominant component of southern New England's fouling community over the past ~30 yrs

Why should we care about non-native marine species?

They can have detrimental effects on native species that may ultimately result in local reductions of native biodiversity

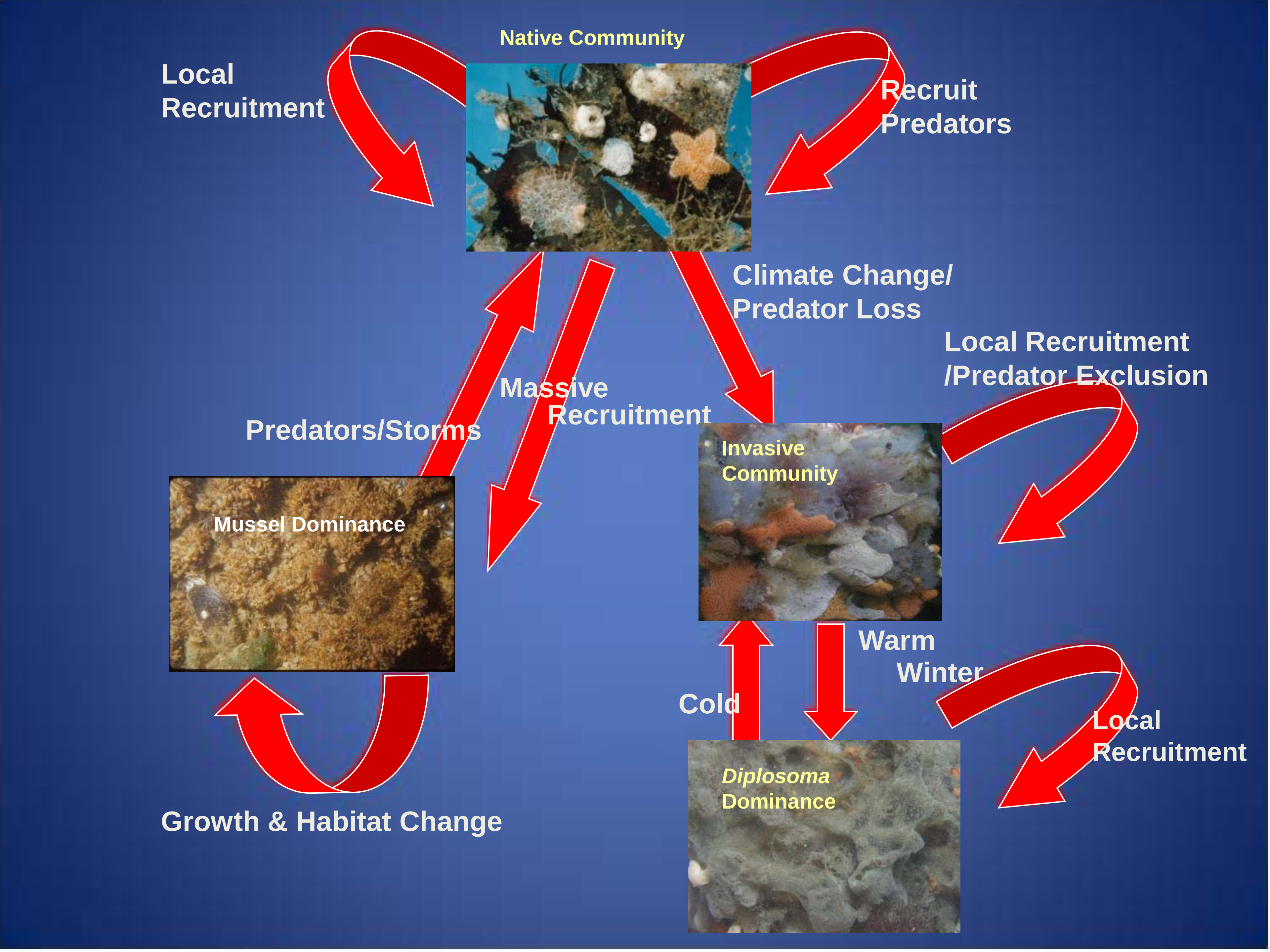
They can greatly modify habitats and reduce ecosystem services

They can have impacts on economically or commercially important species (e.g., green crabs preying on soft-shell clams, fouling species overgrowing mussels, oysters and scallops)

They can have impacts on human-made structures (e.g., species clog intake pipes, foul boat hulls)

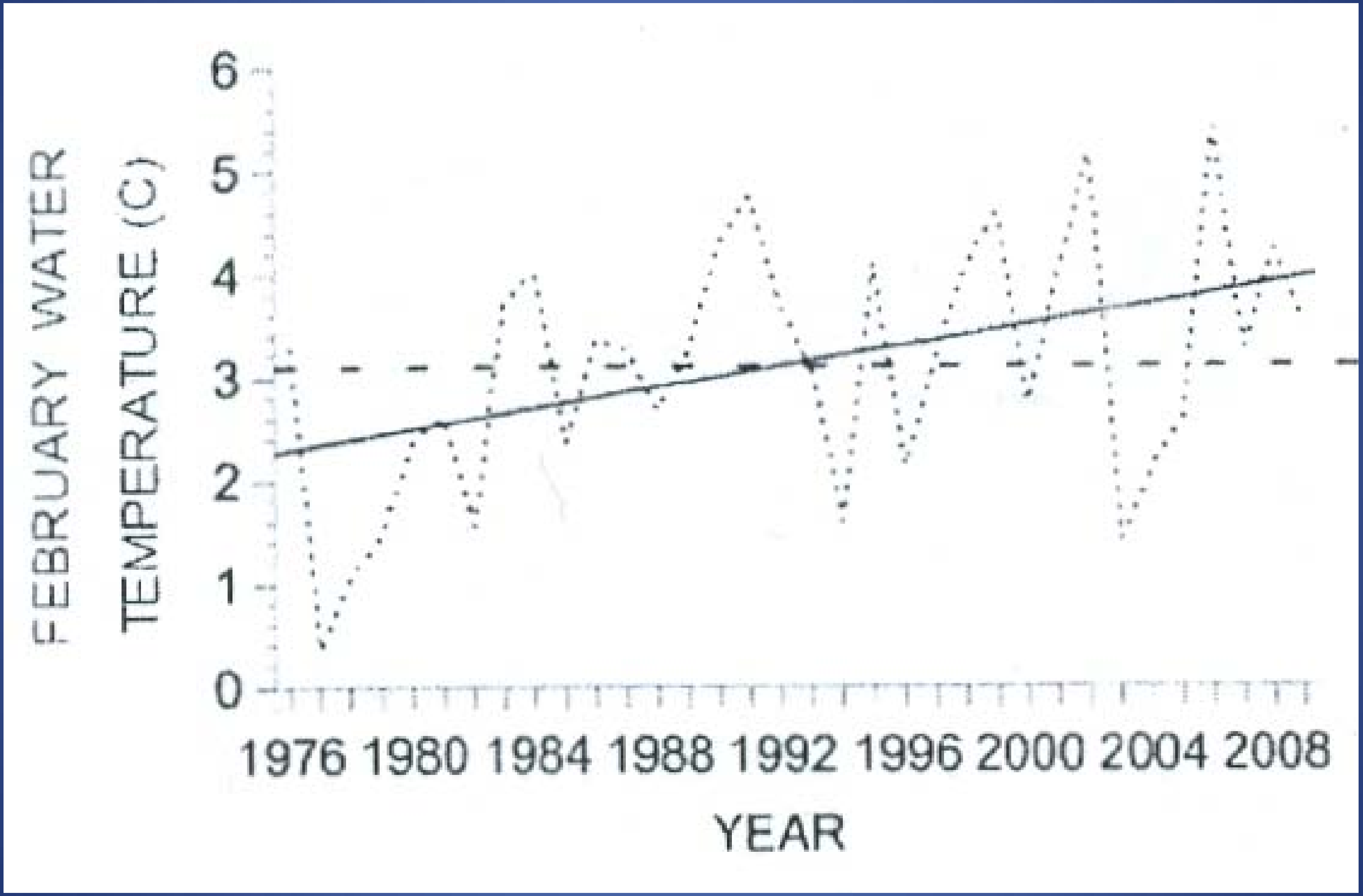
Marine biofouling results in world-wide damages of ~$50 billion annually

Marine biofouling regularly contributes ~20-80% of the total production costs of marine aquaculture operations


Native Community
Local Recruitment
Recruit Predators
Climate Change/ Predator Loss
Local Recruitment /Predator Exclusion
Massive Recruitment
Predators/Storms
Invasive Community
Mussel Dominance
Warm Winter
Cold
Local Recruitment
Diplosoma Dominance
Growth & Habitat Change

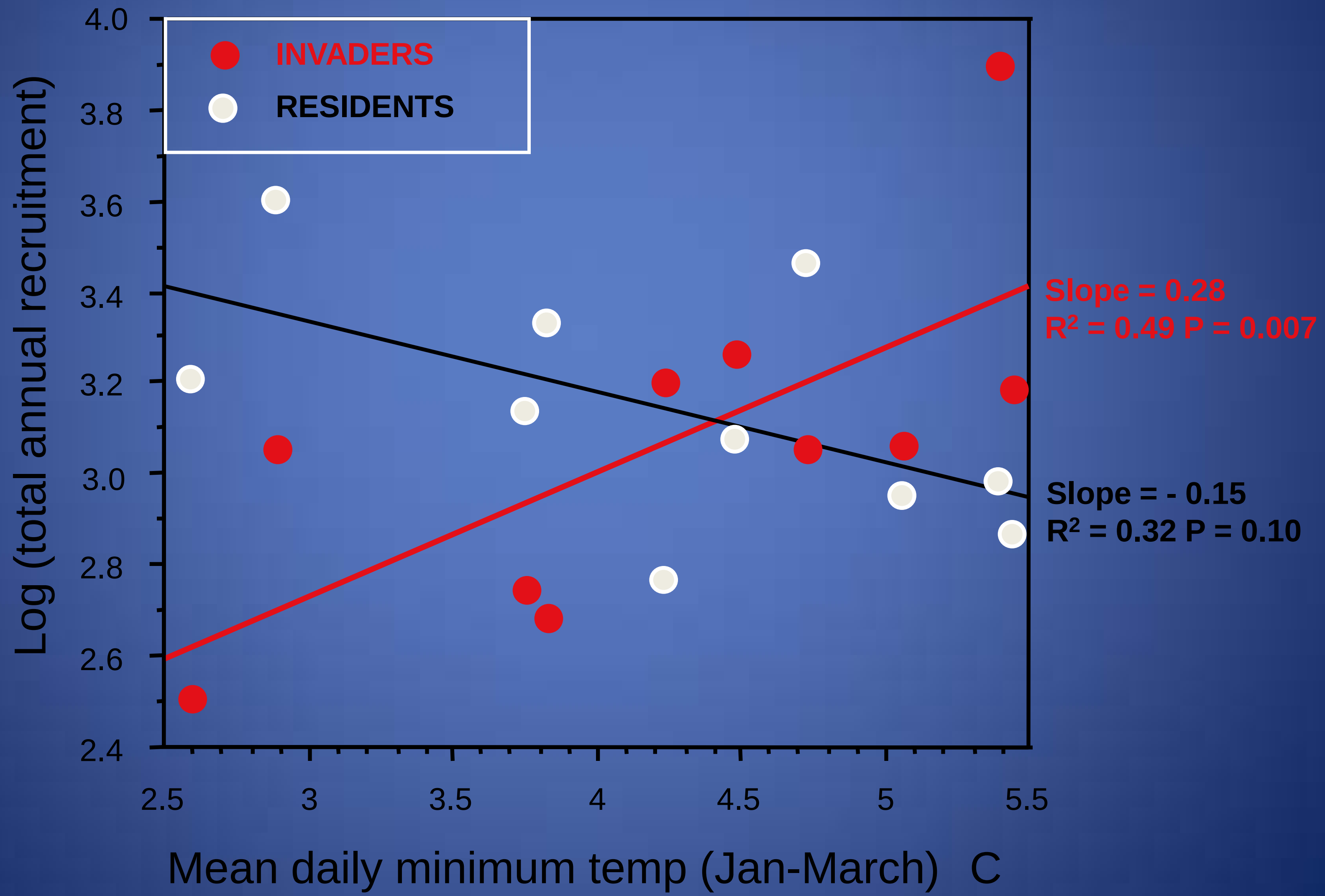
Long term changes in Long Island Sound environmental conditions

Eastern Long Island Sound: seasonal water temperatures – 1976-2009

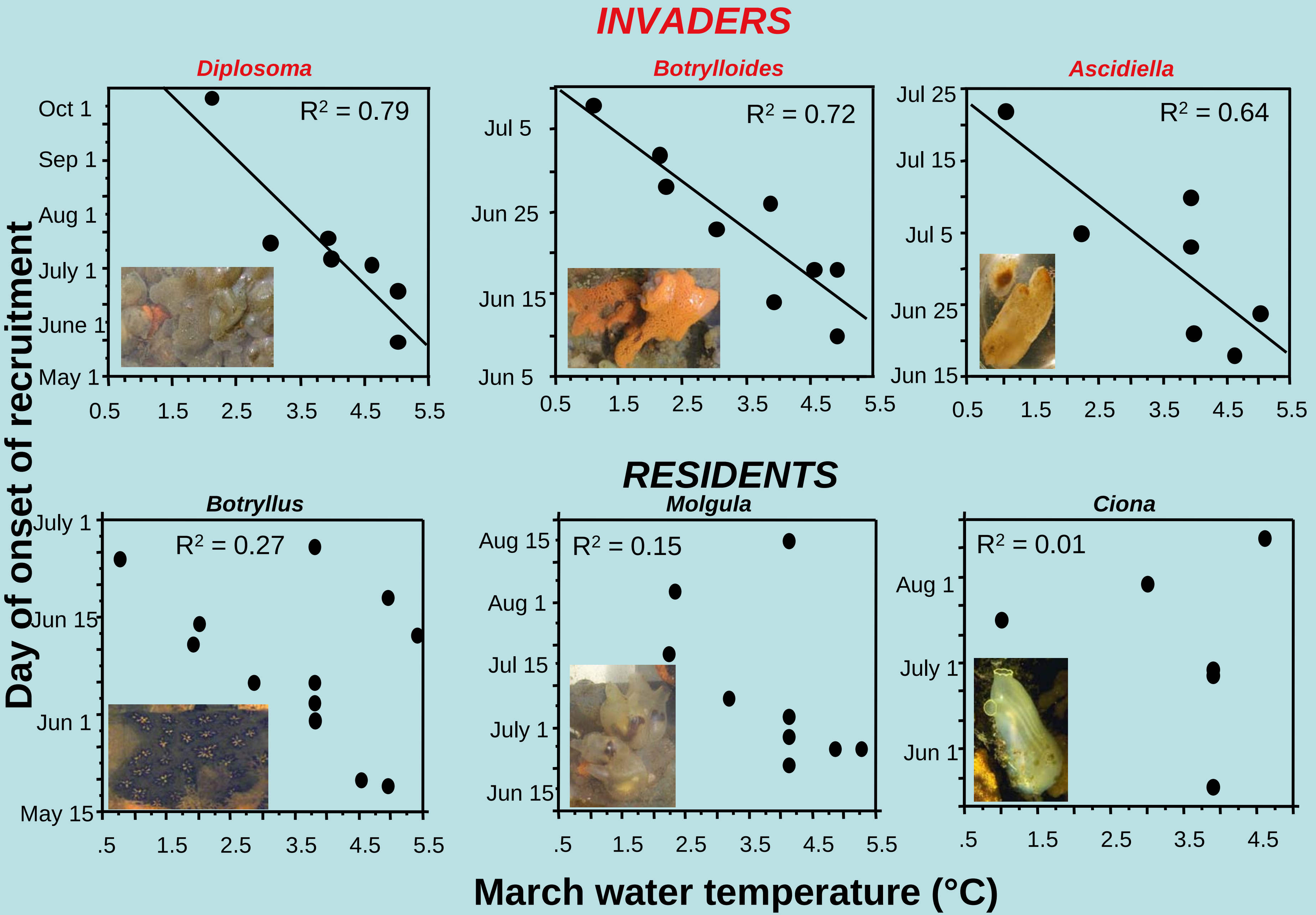


Data courtesy of Millstone Environmental Laboratory

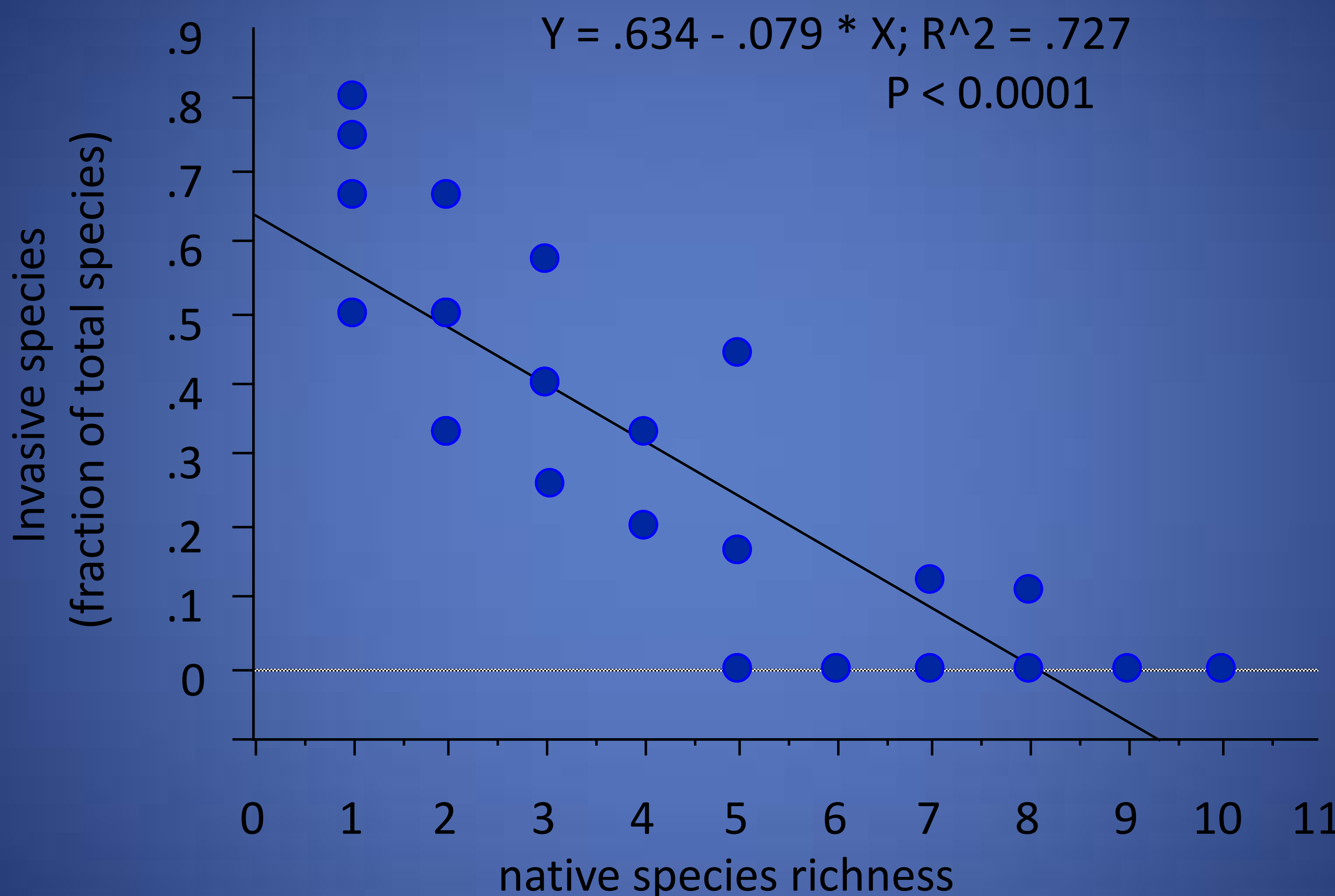
Rising winter temperatures (1991-2008): 1. Increases in the recruitment abundance of recent invaders. 2. Decreases in recruitment abundance of resident species



Timing of recruitment in relation to inter-annual variations in seawater temperatures: non-native vs resident species



In coastal Connecticut waters there tends to be an inverse relationship between the occurrence of invasive species and resident species



Native biodiversity is important! Habitats with higher diversity of resident species appear less vulnerable to invasion

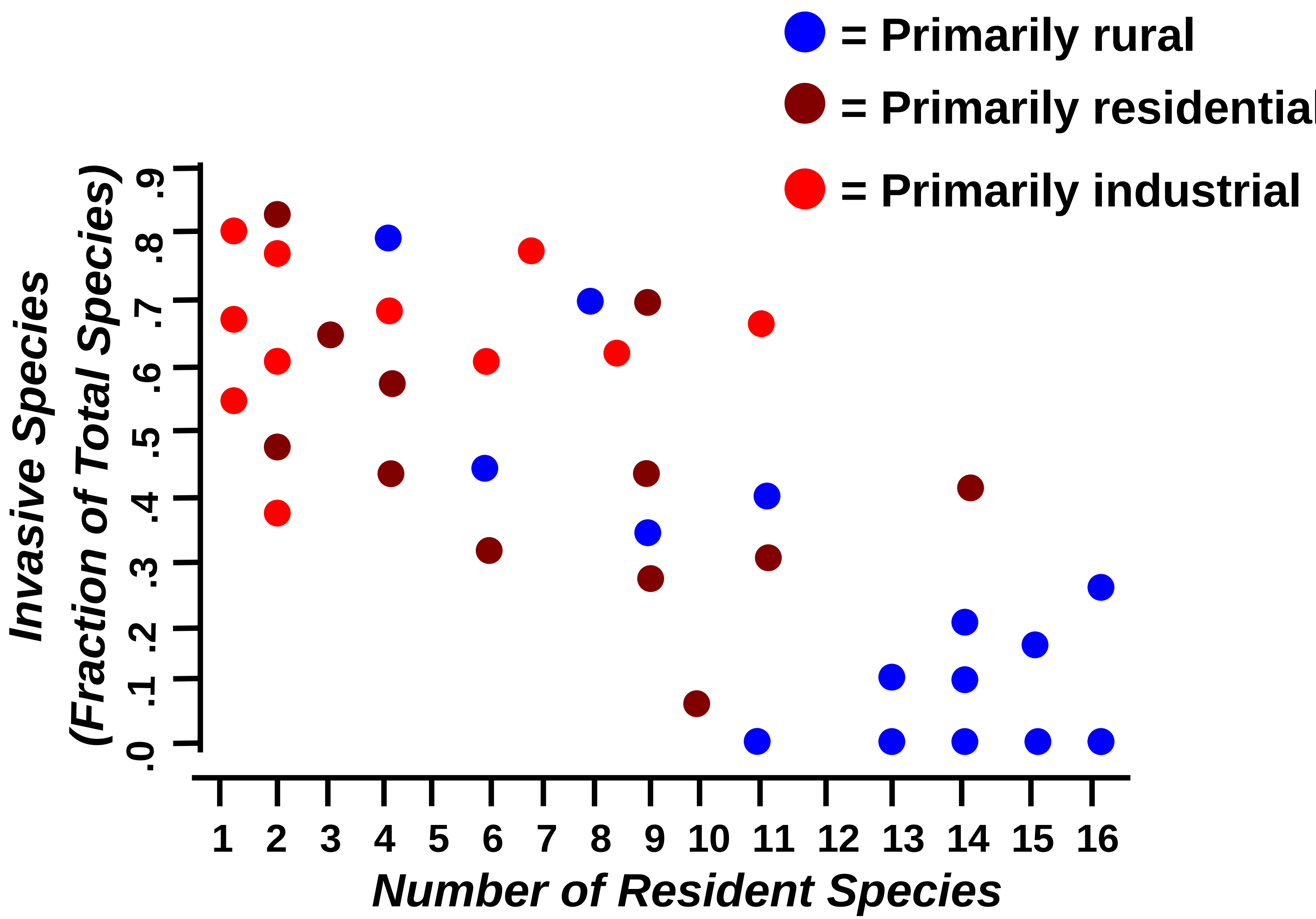
Variations in Land Use Along the Connecticut Coastline

Primarily Industrial

Primarily Residential

Primarily Rural

Correlation between resident species richness and the fraction of exotic species in areas of different coastal land use



Project Goal #1 – Work with environmental managers and other stakeholders on different management scenarios for land use planning in the context of climate change and invasive species (*interaction with clients*)

1. Established a Project Management Advisory Board:
   Mark Tedesco – Director – US EPA Long Island Sound Office; ***Paul Stacey*** – Former Director of Planning and Standards, Bureau of Water Protection and Land Reuse – CT DEP; ***Gary Wikfors*** – Scientist – NOAA, NMFS, Milford, CT ***Adam Whelchel*** – Director of Conservation Science – The Nature Conservancy, CT Chapter; ***Beth Doran*** – Director – Long Island Resource Center – CT DEP; ***Susan McNamara*** – Executive Director – Long Island Sound Foundation; **Ron Rozsa** – CT DEP Office of LIS Programs

2. **Conducted workshops with various managers and stakeholders** – Discussed management priorities and needs; broaden network with the managers/stakeholders; discuss project goals and outputs and how they can assist with management goals

3. **Met with local shellfish, planning and conservation commissions** – Towns of Groton, New London, Stonington, East Lyme/Waterford – discuss local management needs and goals of the project.

Project Goal #1 (cont)

4. Outreach Activities

Aquakids host Molly McKinney with PI Whitlatch

Interviews:

Connecticut National Public Radio

New London Day

Boston Globe

Featured segment on *AquaKids* Episode 18

– aired in Connecticut 24 Jan 2009

-- aired nationally – week of 19 Jan 2009

Project Goal #2: Conduct mesocosm experiments examining the interactions of climate change (temperature increase) and land-use (nutrients) and the interactions between them in altering the ability of invasive species to Influence native communities

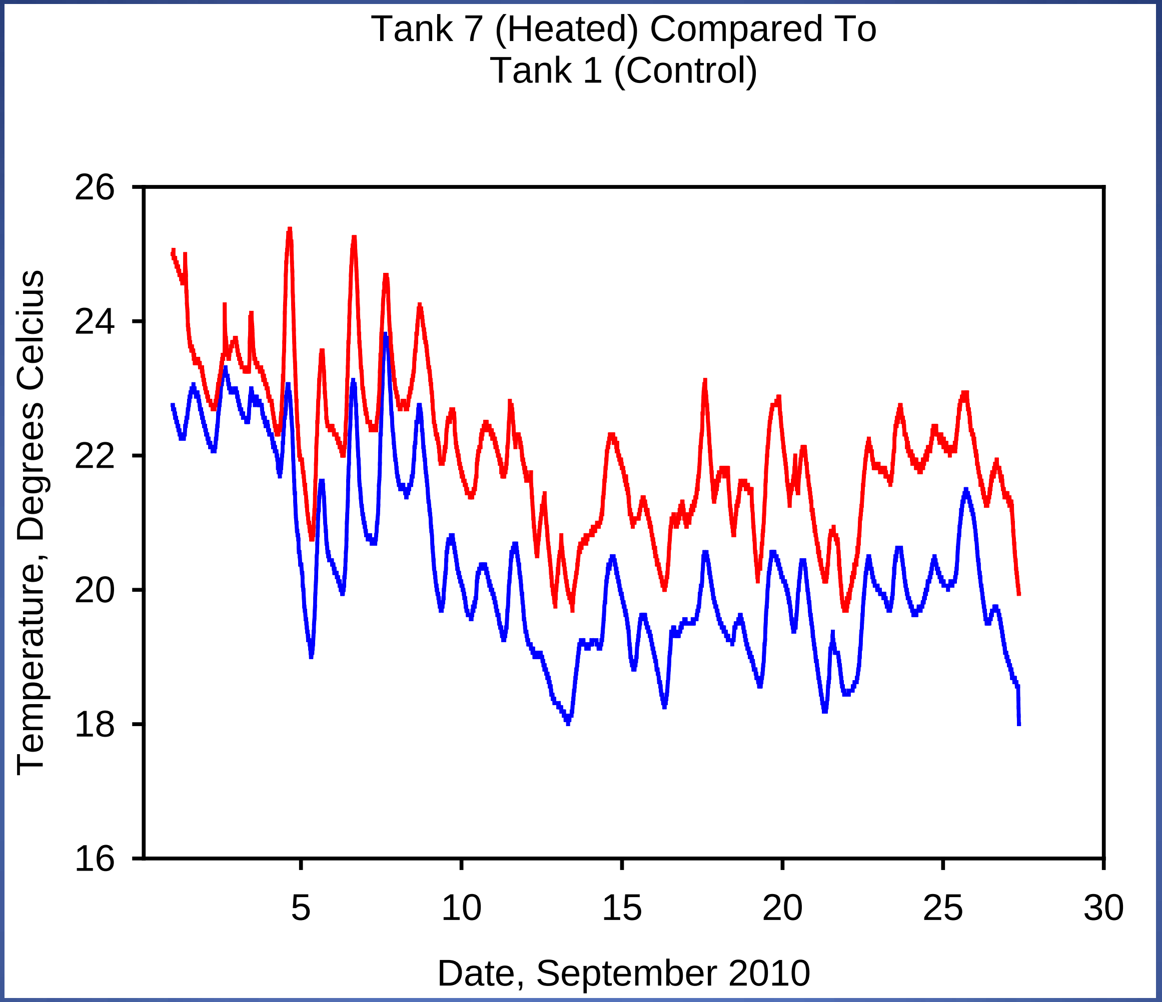
Large-scale mesocosm facility located at UCONN's Avery Point Campus. Each insulated tank is 2.5 m in diameter and 1.3 m tall. The facility is run as a flow-through system

A bird's eye view of one of the tanks

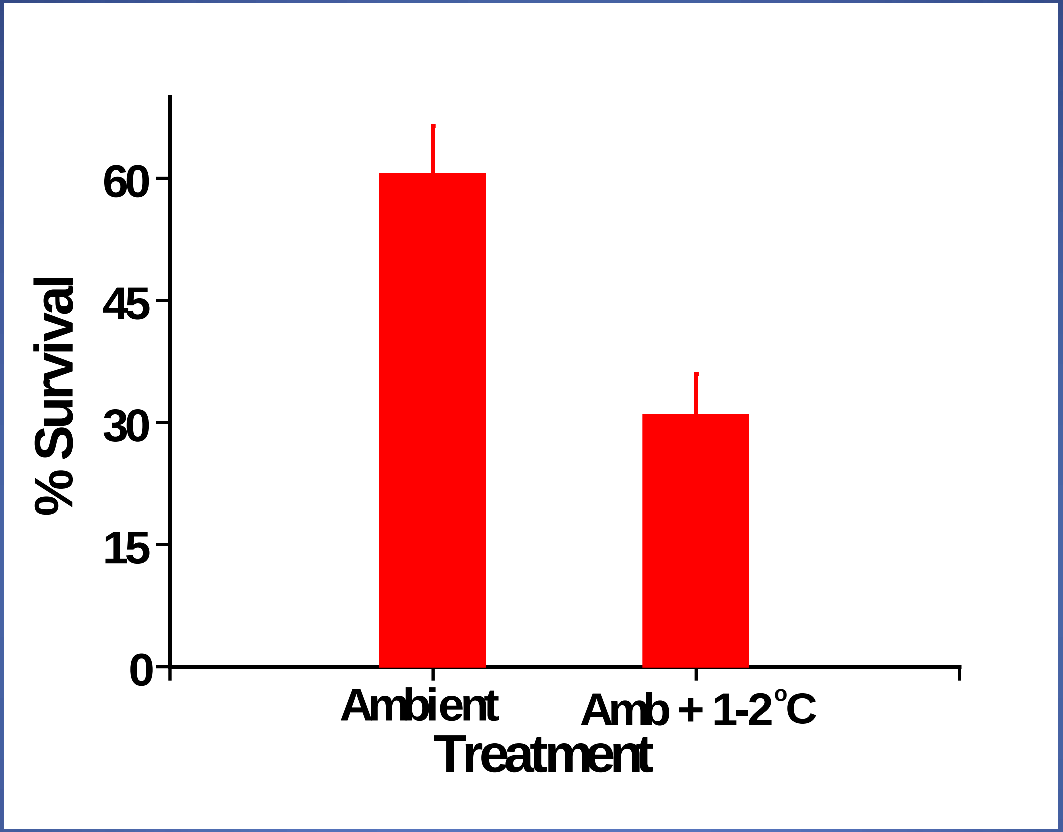
A fish's eye view of some of what is in the tanks

Environmental Monitoring and Controller System

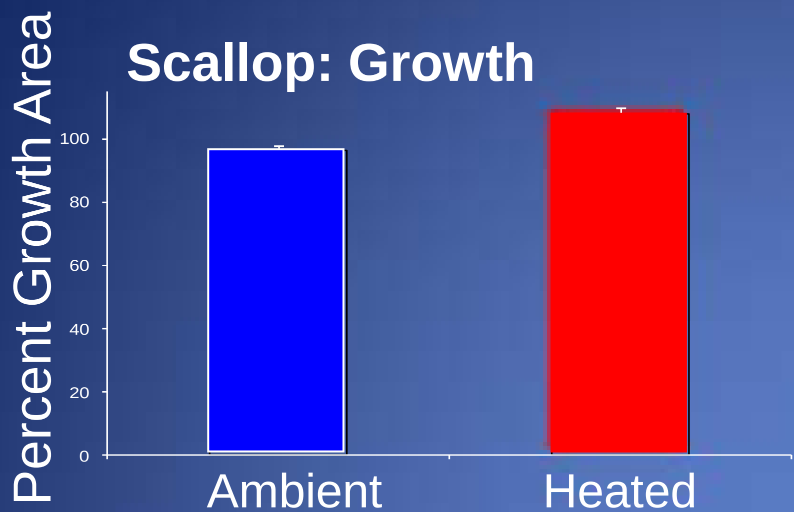
Environmental parameters (ie., temperature, nutrients) are maintained by an automated monitoring and control system using LABVIEW and National Instruments data acquisition modules (ie., high impedance A/D converters which convert voltages from various environmental probes to digital units)

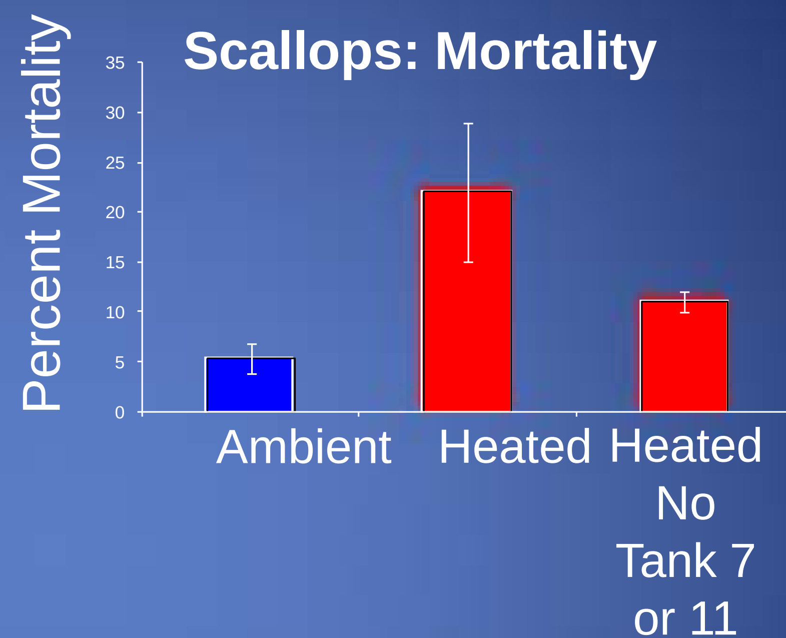


Example of a one-month time-series showing temperature variations in an ambient (blue) mesocosm tank versus a heated (red) mesocosm tank.

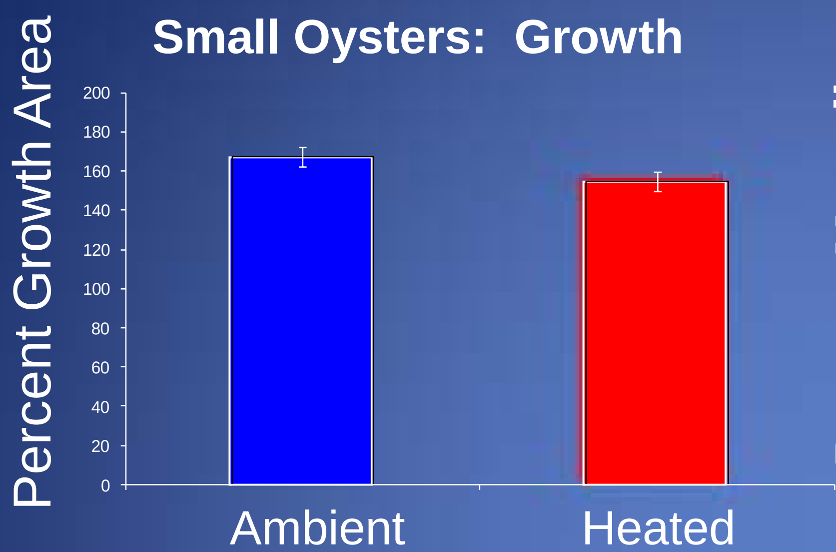


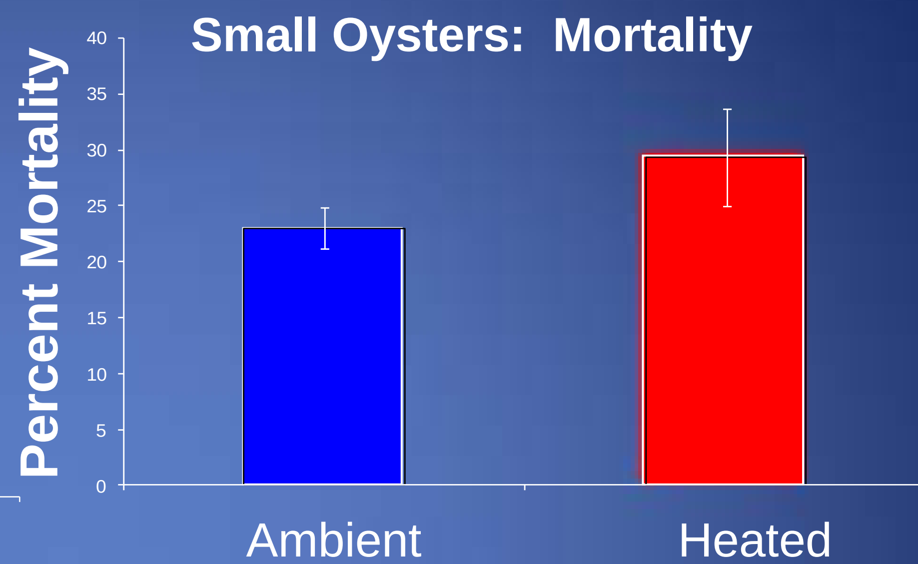
Eelgrass (*Zostera* marina) survival in response to experimentally-induced seawater warming over a three month period (July-Sept 2009)



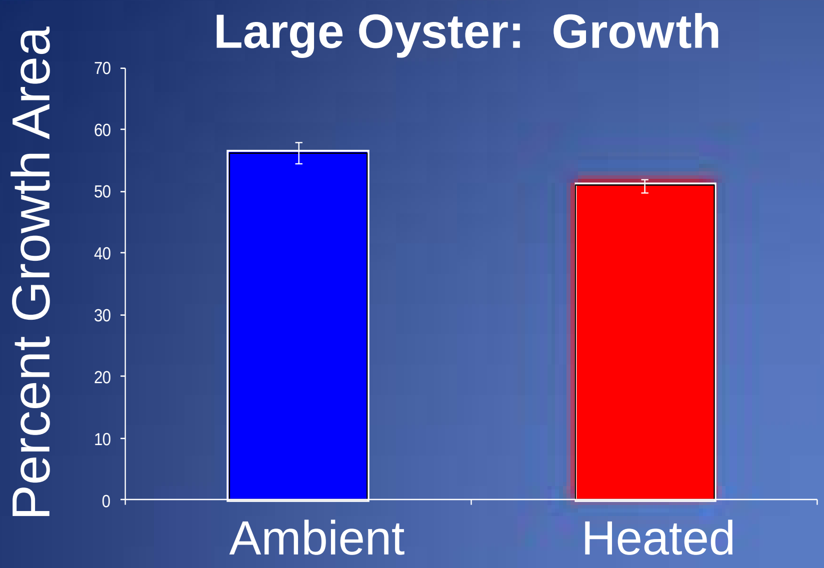


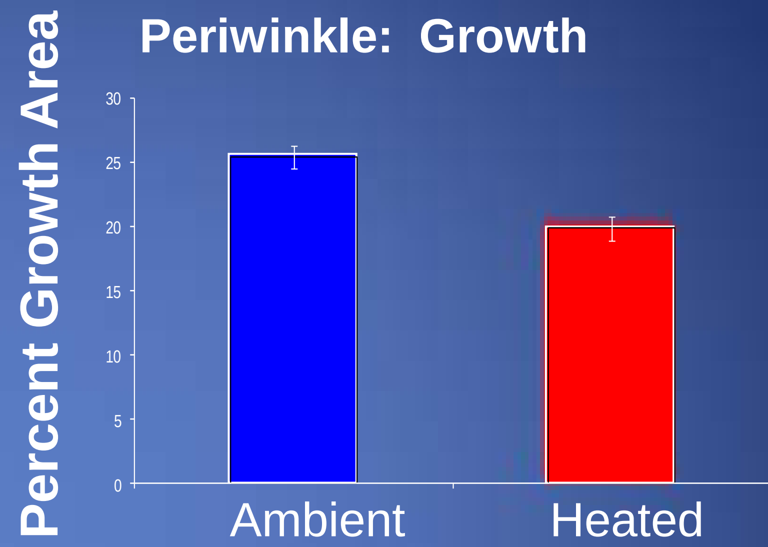
Scallops in heated tanks (mean = 107.95 1.88 S.E.) grew significantly more than scallops in ambient water tanks (96.27 1.53) (F = 6.704, df = 10, n = 475, p < 0.001), however, scallop mortality was significantly higher in heated tanks (heated: 22.03 6.99, ambient: 5.33 1.52, t = -2.333, df = 10, n = 12, p = 0.042). This trend held when two heated tanks that had unusually high mortality (2x the mean heated tank mortality) were removed from the analysis (Heated No Tank 7 or 11: 11.04 1.02, t = -2.667, df = 8, n = 10, p = 0.028).





Small oysters in ambient water tanks (167.50 4.99) grew significantly more than small oysters in heated tanks (154.78 5.11) (F = 13.173, df = 10, n = 317, p < 0.001). Small oyster mortality was higher in heated tanks, though not significantly so (heated: 29.33 4.34, ambient: 23.00 1.84, t = -1.688, df = 9, n = 11, p = 0.126).



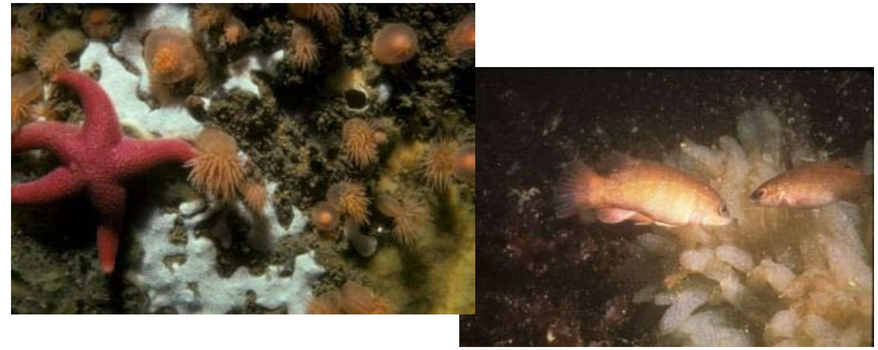


Large oysters in ambient water tanks (56.32 1.73) grew significantly more than large oysters in heated tanks (50.98 1.13) (F = 6.706, df = 10, n = 576, p < 0.001).

There was no mortality in large oysters.

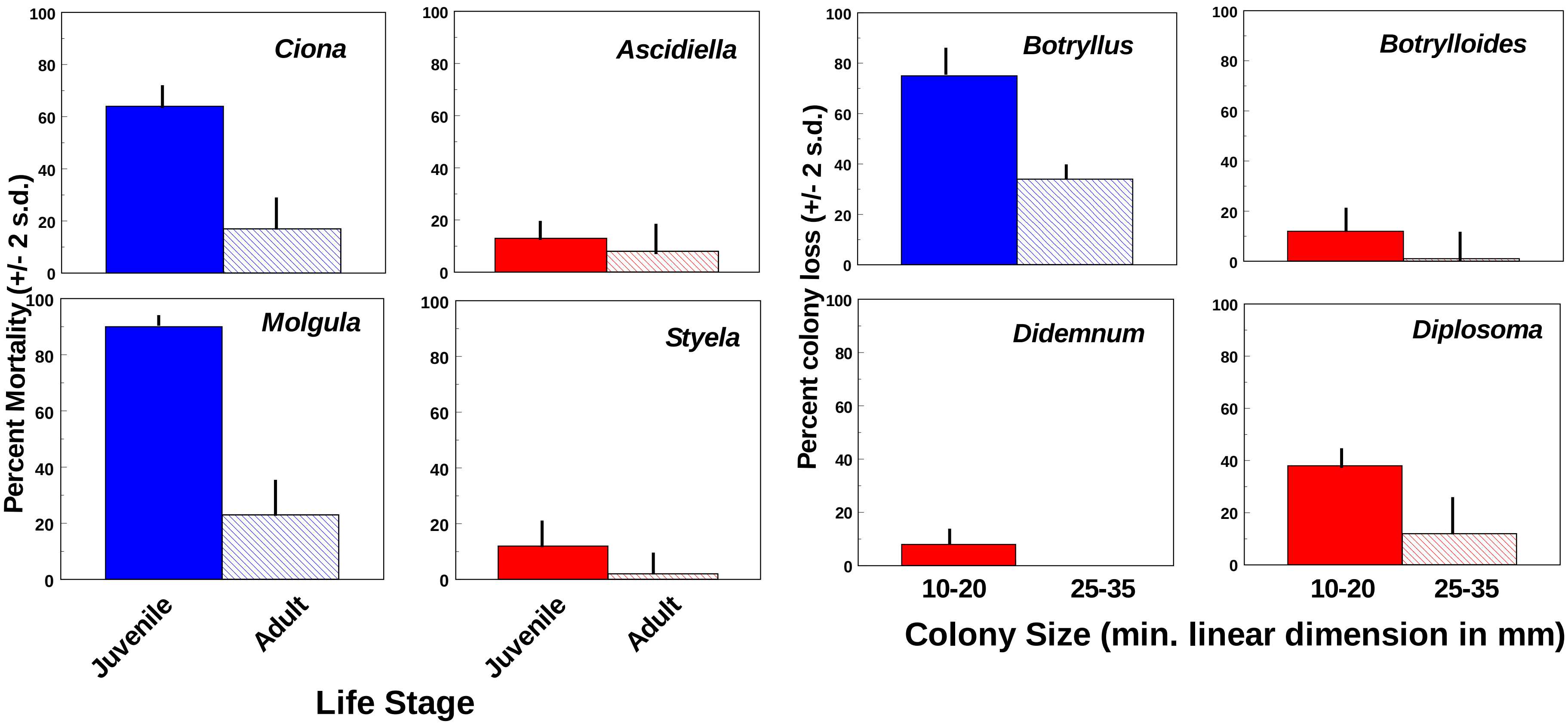
Periwinkles in ambient water tanks (25.41 0.86) grew significantly more than periwinkles in heated tanks (19.86 0.90) (F = 3.864, df = 10, n = 329, p < 0.001). Because periwinkles regularly escaped during the experiment from both ambient and treated tanks, no analysis was performed on their apparent 'mortality.'

Project Goal #3 – Survivorship of predators and their effectiveness in controlling invasive species in different land use conditions



Effects of macro-predators (seastars, fish, crabs) feeding on juvenile and adult ascidian life stages (7 day expt.)

Solitary forms *Colonial forms*



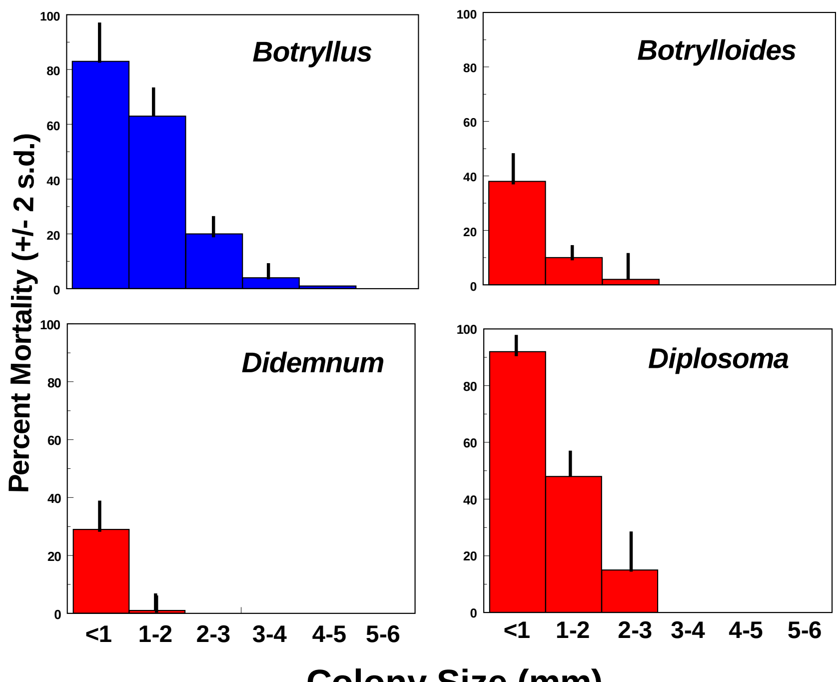
Goal #3 (cont.)

Anachis and *Mitrella* feeding on a 1 day *Botrylloides* recruit

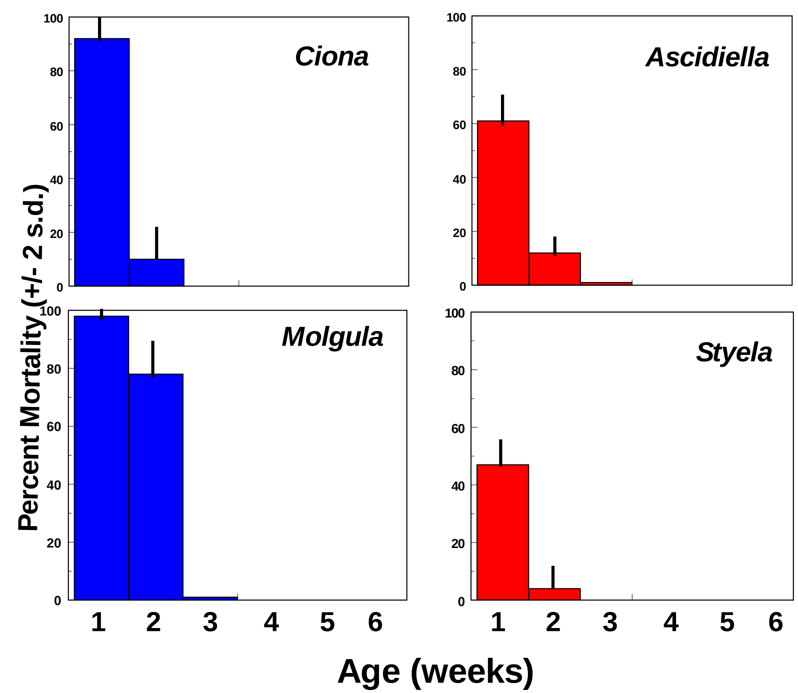
Effects of predation micropredators (snails, small crabs):

Percent mortality of ascidian post-recruits (7 Day experiments using different colony sizes or different ages of native and non-native ascidians

Colonial forms



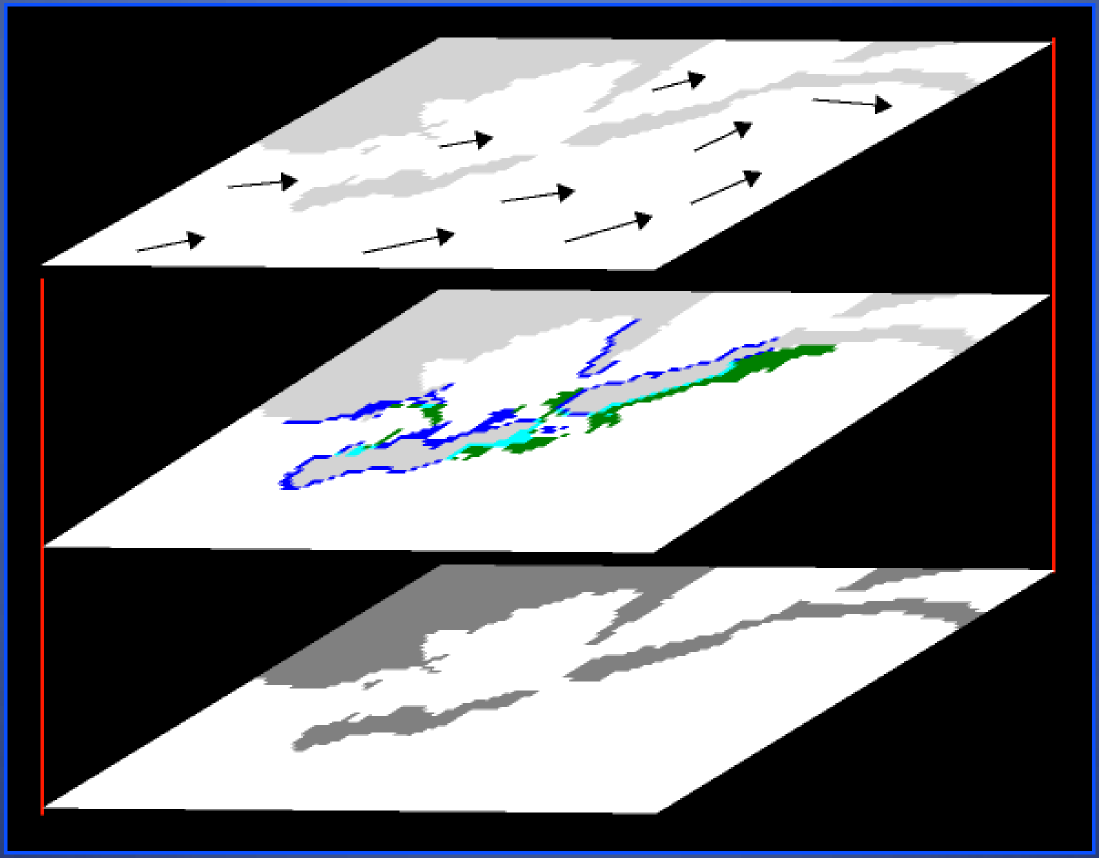
Solitary forms



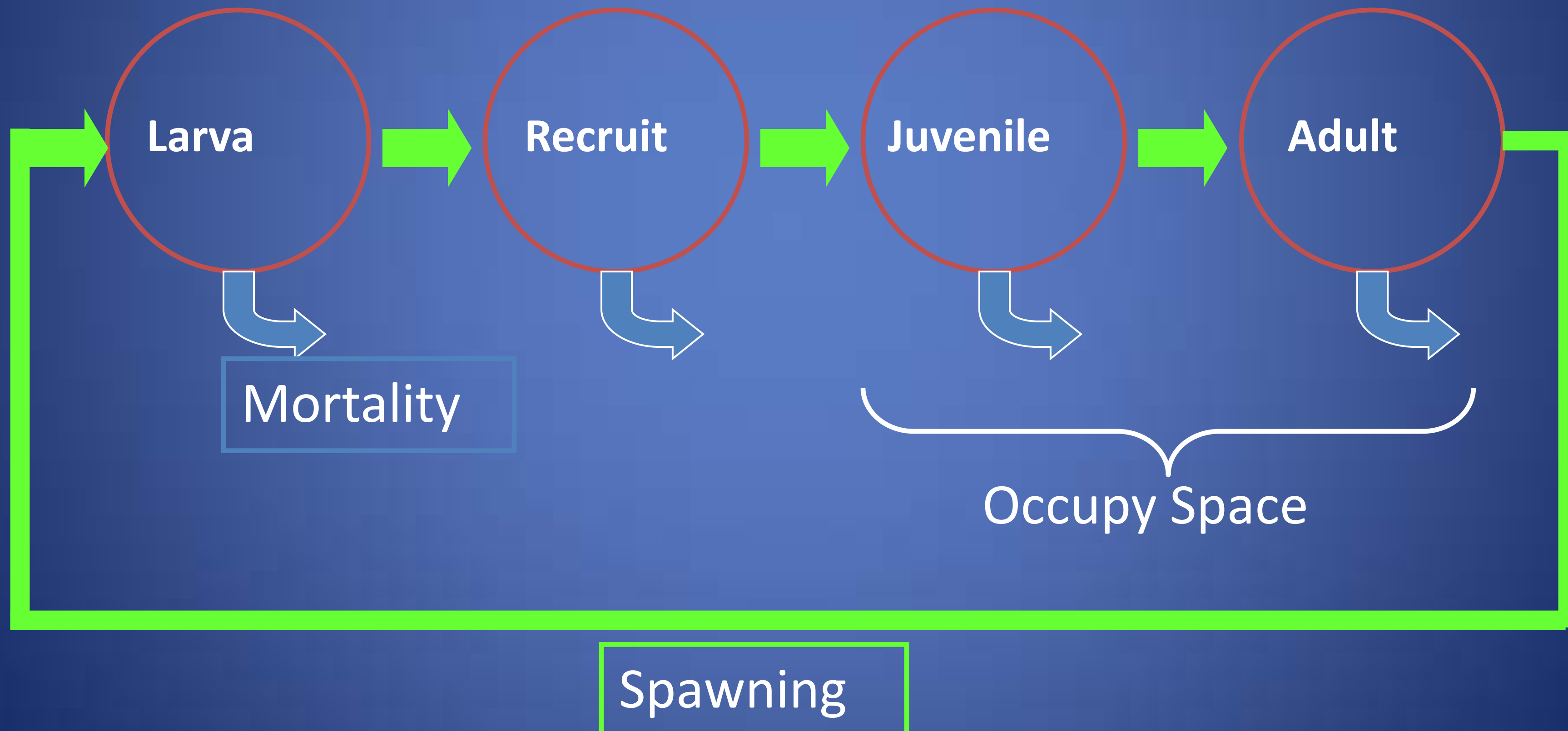
Goal #4. Develop predictive models to assess potential alternative management strategies to evaluate multiple stressors at different spatial and temporal scales in different types of coastal systems

- **Spatially explicit, individual-based model driven by hydrodynamic model**

Model Layers

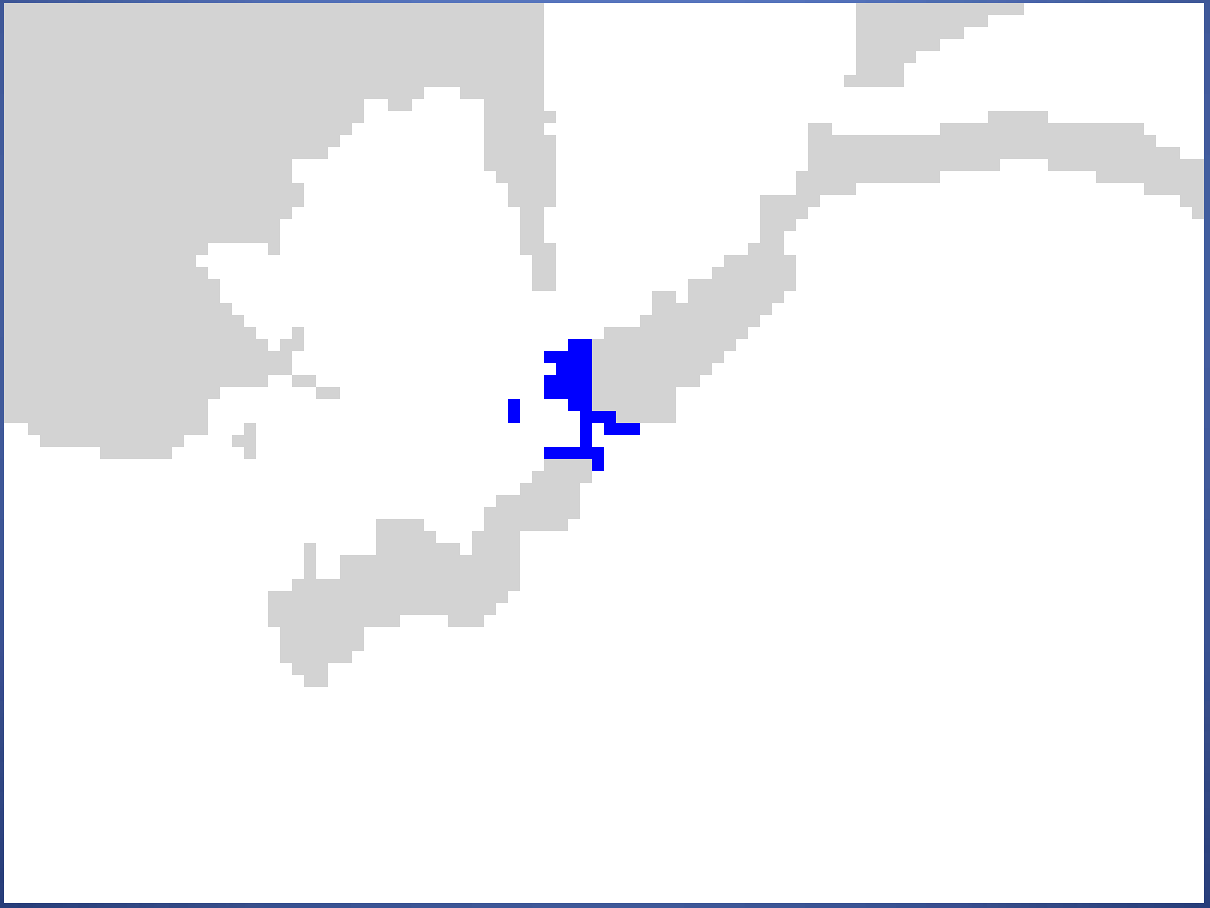


Two Phase Life History



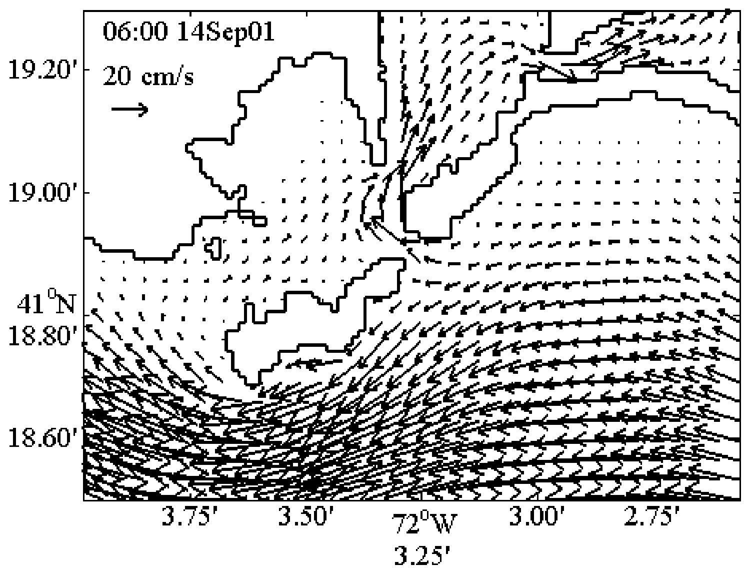
Example of Model Larval Sources

Source Area: A seagrass bed in a channel

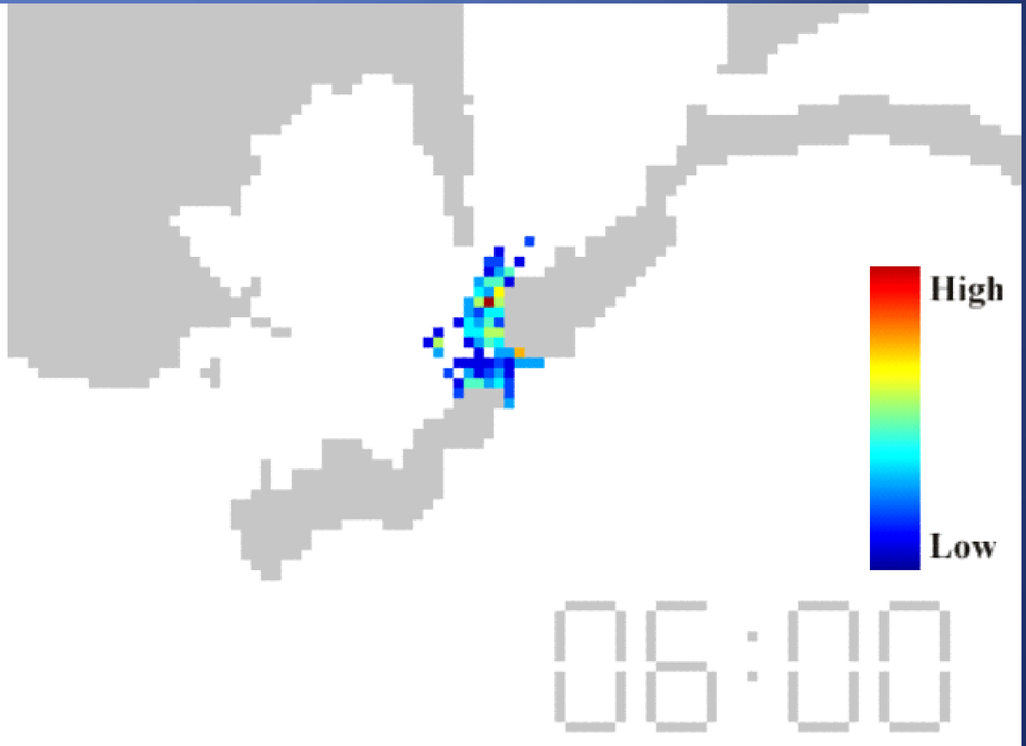


Habitat + Hydrodynamics -> Larval Distribution

Source: Seagrass bed in a Channel Region

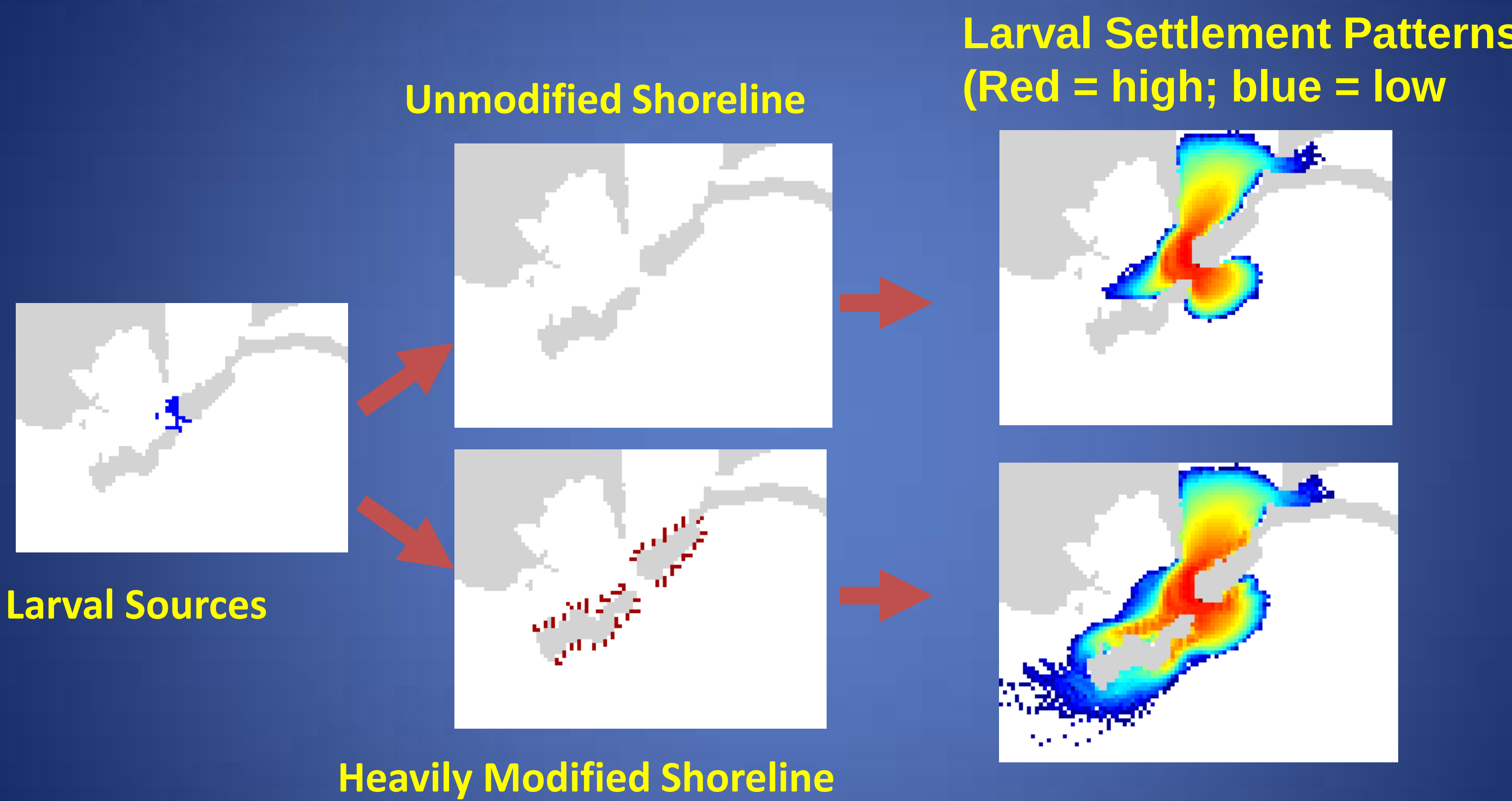


Hydrodynamic Model

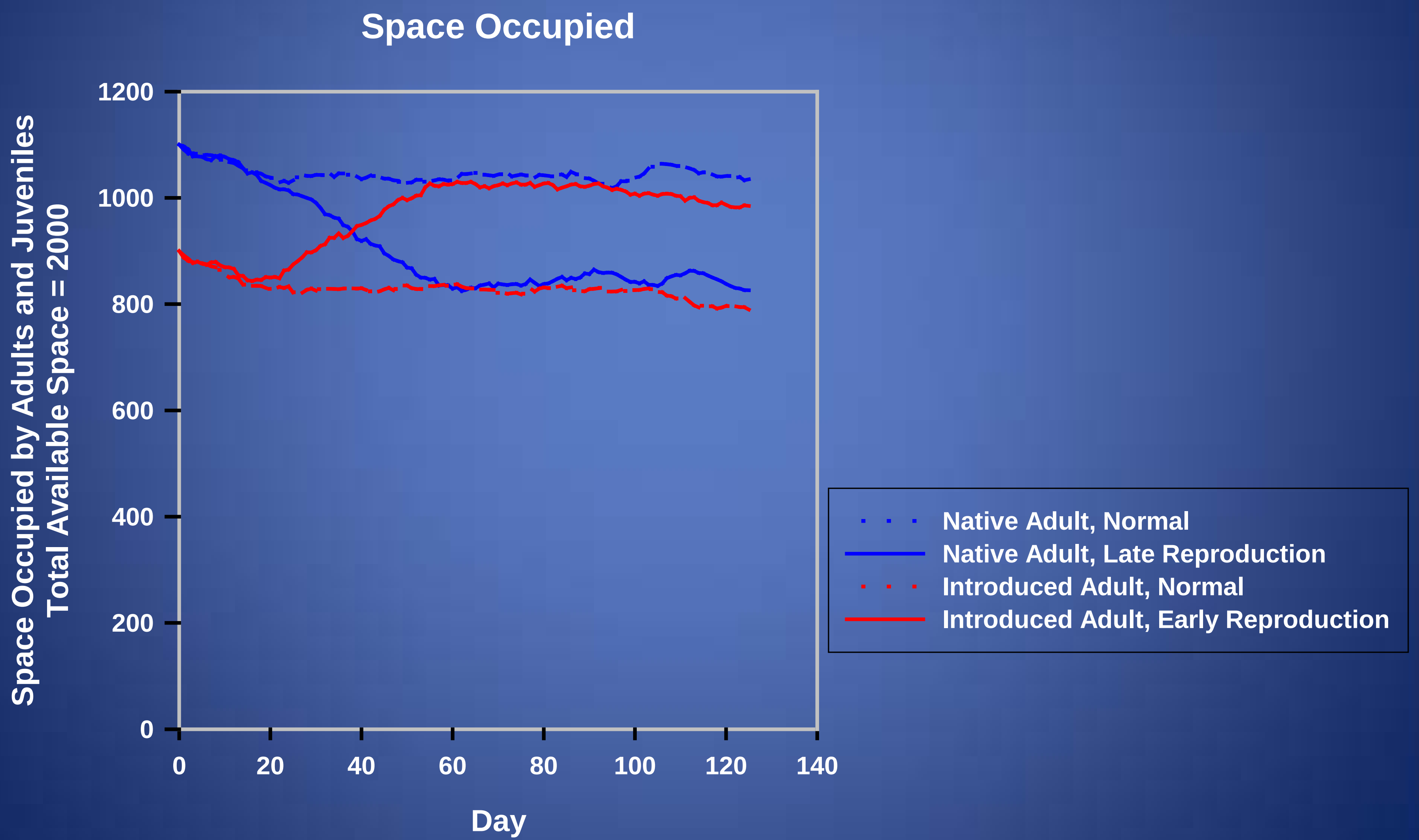


Estimated Larval Density

Example: Habitat Arrangements



Modeling Invasive Species Benefits From Climate Change, Favoring Early Reproduction



Modeling Invasive Benefits From Disturbances and Climate Change

Lessons Learned:

Very important to include input by managers/stakeholders in the early stages of the project

Managers often are dealing with the most current 'brush fire' and often are in a rapid response mode (a reality lesson, but also a challenge to the scientist)

Critical importance of long-term environmental data bases and associated population/community data

Challenges:

The most recent sea squirt alien, Didemnum vexillum, in eastern Long Island Sound (~25 m depth) – potential new alternative state?

Concerns about "new" stressors – coastal acidification, power infra-structure disturbances – and how they interact with climate change and land use patterns