The Influence of Connectivity and Host Behavior on PaV1 Disease in Caribbean Lobster

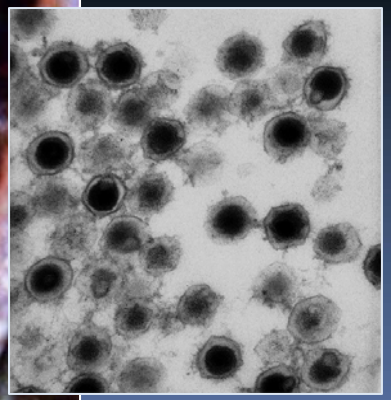
Donald Behringer[1],Mark Butler[2], Jeffrey Shields[3], Claire Paris[4], Jessica Moss[3] and Robert Cowen[4]

[1]Fisheries and Aquatic Sciences, University of Florida, Gainesville, FL, USA

[2]Department of Biological Sciences, Old Dominion University, Norfolk, VA, USA

[3]Virginia Institute of Marine Science, Gloucester Pt, VA, USA

[4]RSMAS, University of Miami, Miami, FL, USA



Funding:

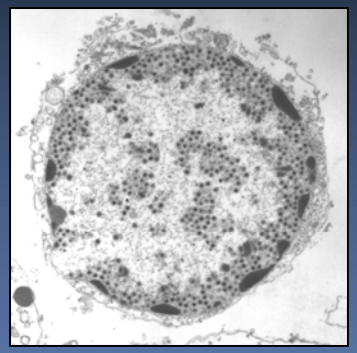
NSF

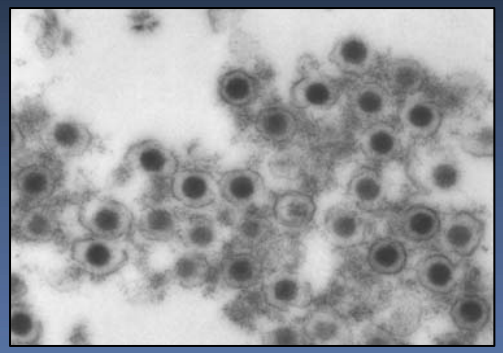
WWF

A Viral Disease in Caribbean Spiny Lobster

Overview

- We first discovered the disease in 1999 and named the virus:
  PaV1 (*Panulirus argus* virus 1)
- First viral disease described in any species of lobster in the world
- Probably not a new disease; similar disease condition has been observed periodically in the past and prevalence stable in FL Keys
- Probably not a human health threat
- A potential threat to lobster fisheries & mariculture because:
  (1) it is pathogenic and lethal in > 90% juvenile infections, less so in adults
  (2) appears to be widespread





Visible Signs of Advanced PaV1 Infection

Morphological

- Milky white hemolymph
- Discoloration of carapace

Behavioral

- Lethargy
- Lack of molting and grooming
- Isolation

Diagnostics

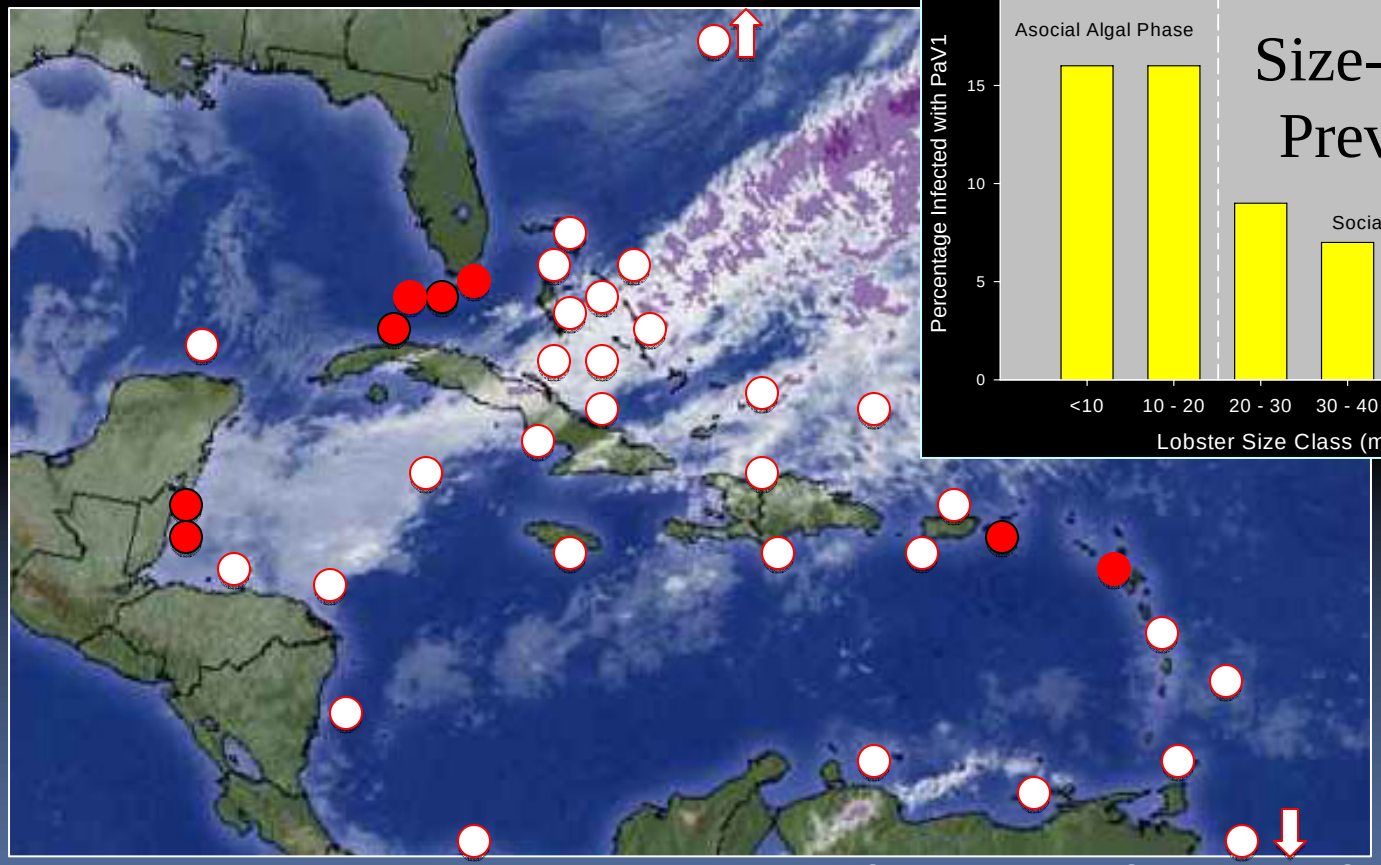
- PCR or histopathology

Gross signs only visible in juvenile lobsters, not adults but

adults infected - carriers?

PaV1 Distribution & Prevalence

- Widely distributed in Florida Keys & Caribbean
- Prevalence declines with size
- Local prevalence (around FL Keys) varies: 0 – 50%



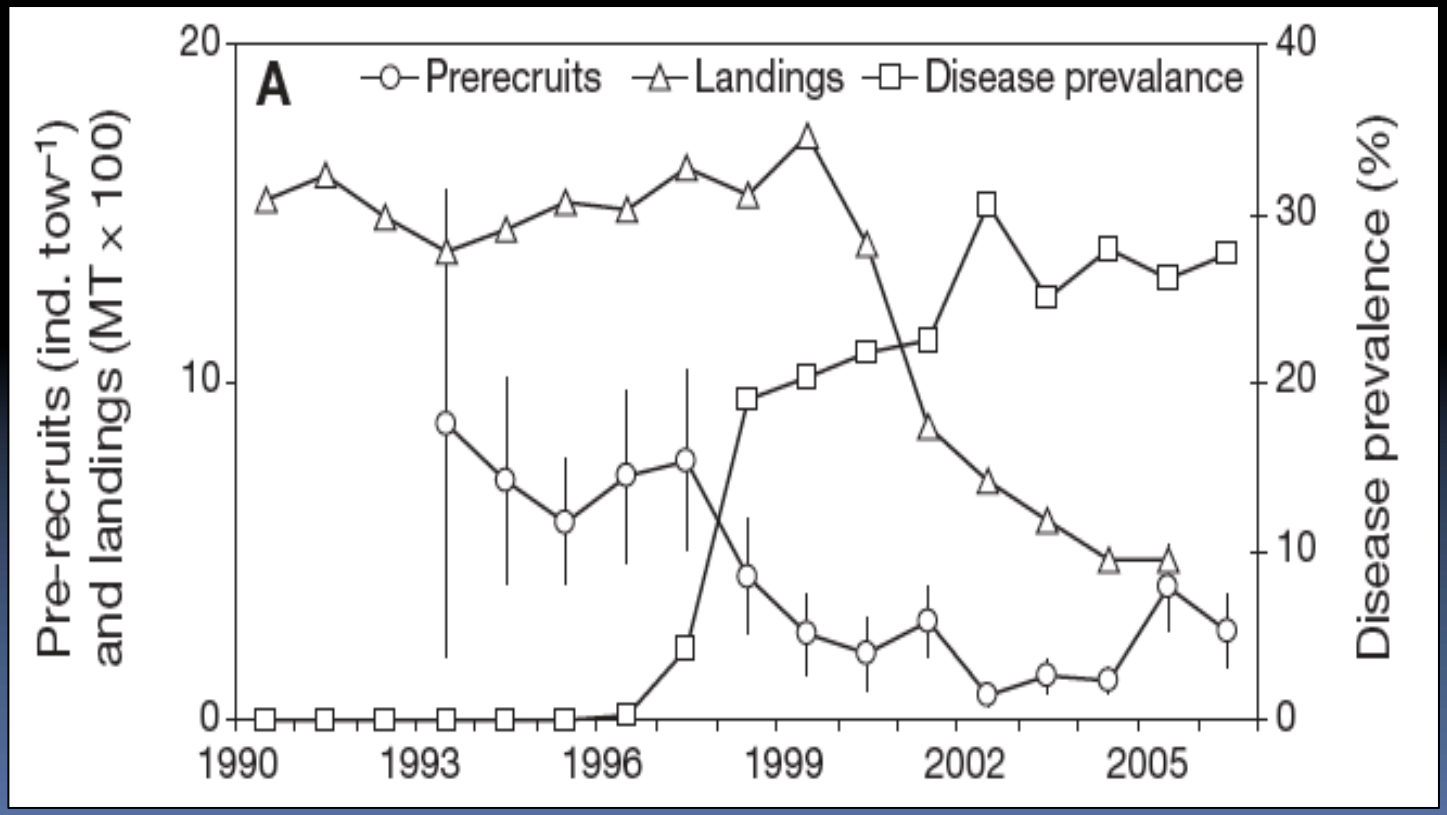
Sites we are sampling PaV1 infections confirmed so far

Distinguishing disease impacts from larval supply effects in a lobster fishery collapse

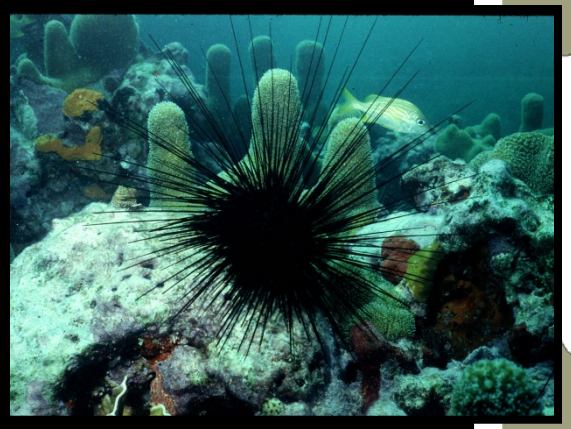
Richard A. Wahle[1,*], Mark Gibson[2], Michael Fogarty[3]

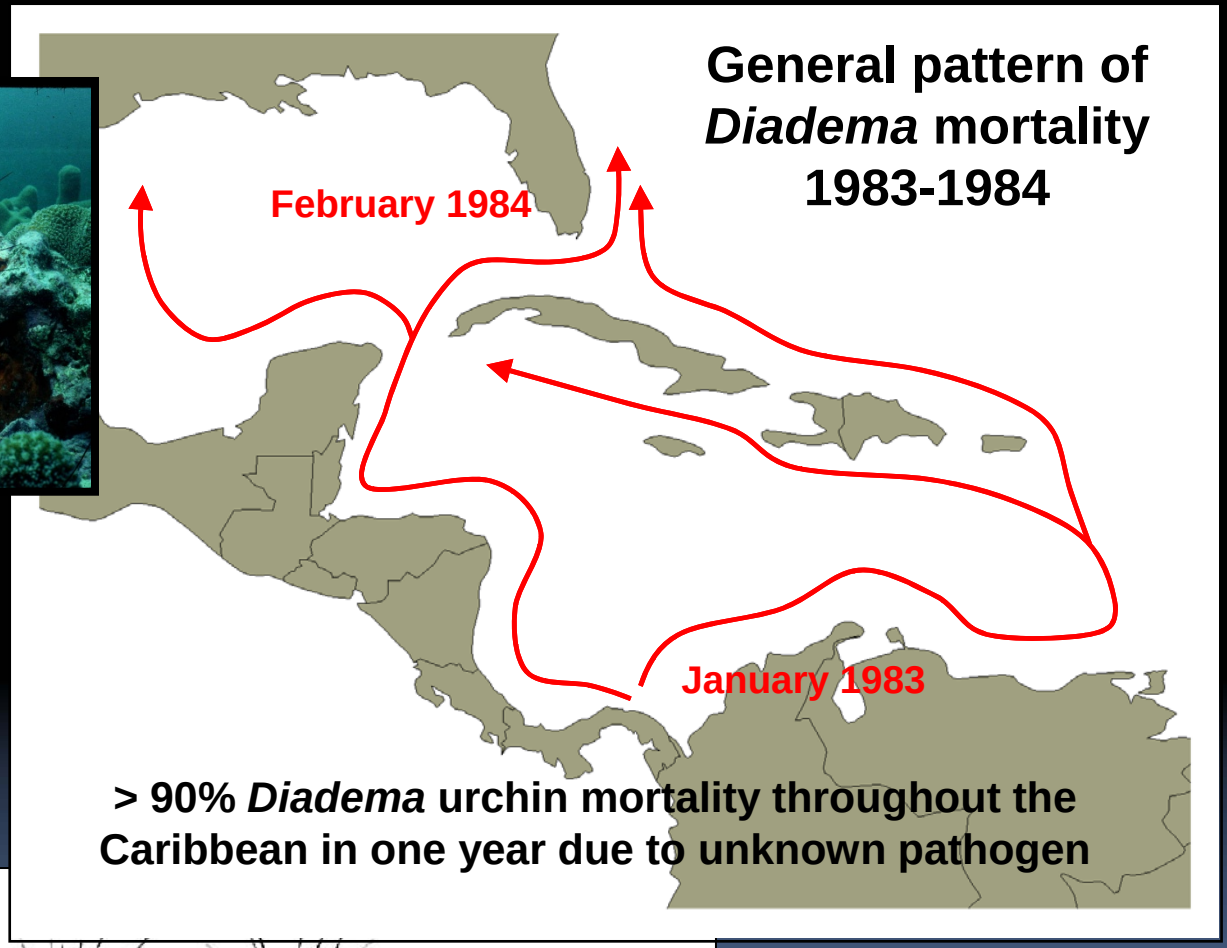
2009 MEPS

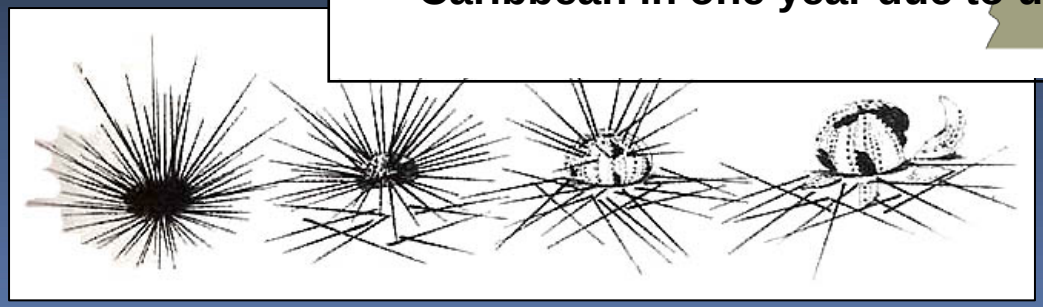
Shell Disease in Southern New England



Diadema Disease Epizootic







Rates of Disease Spread: Terrestrial vs. Marine

"…in measuring degree of connectivity in marine ecosystems…it is a very large assumption, and completely untested, that marine pathogens will be captured by the same barriers and processes that restrict fish and invertebrate gene flow… due to great longevity, rafting ocean currents and diverse vectoring..."

McCallum et al. 2003 Ecol Letters

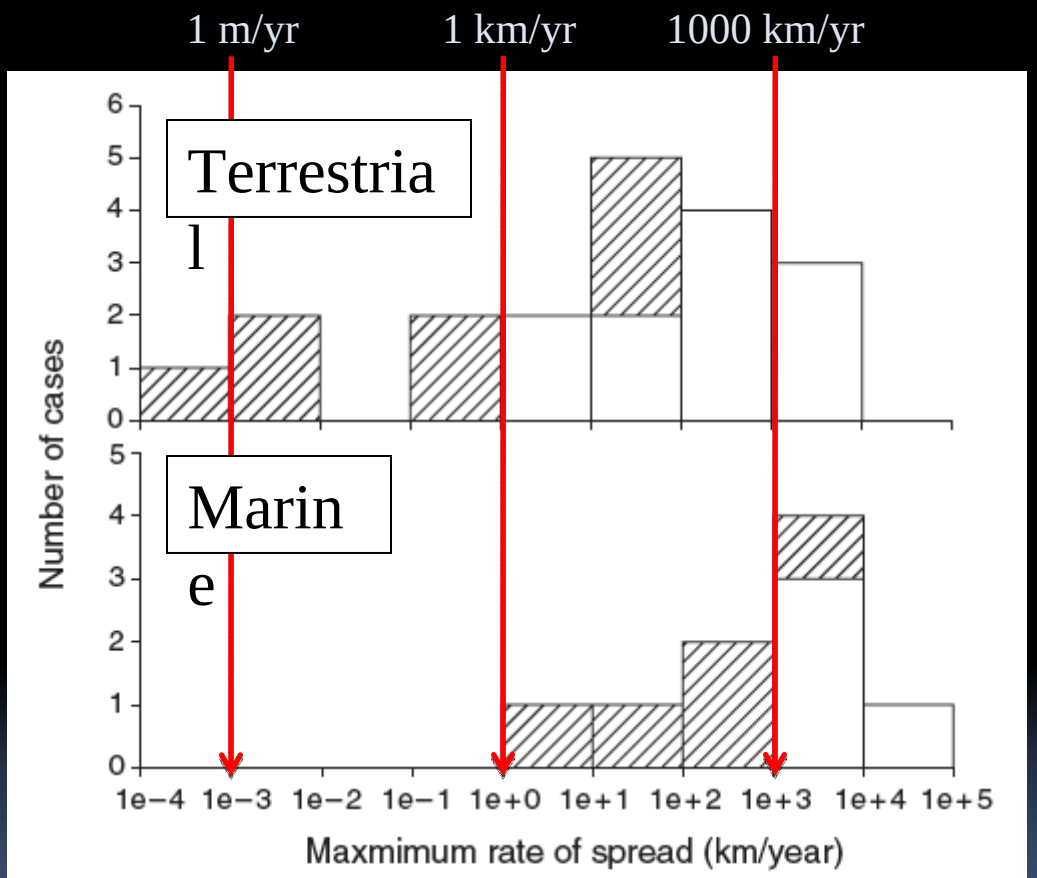


Figure 1 Maximum rates of spread of pathogens in terrestrial (top) and marine (bottom) environments. Rates of spread for pathogens with highly mobile vertebrate hosts are shown unshaded and rates of spread for pathogens with sessile (or nearly sessile) non-vertebrate hosts are shown with diagonal hatching.

"Other" Modes of Pathogen Dispersal?

Lethal marine snow: Pathogen of bivalve mollusc concealed in marine aggregates

M. Maille Lyons and J. Evan Ward
Department of Marine Science, University of Connecticut, 1080 Shennecossett Rd., Groton, Connecticut 06340

Roxanna Smolowitz and Kevin R. Uhlinger
Marine Biological Laboratory, 7 MBL St., Woods Hole, Massachusetts 02543

Rebecca J. Gast
Biology Department, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543

2005 L&O

Prevalence and diversity of Lyme borreliosis bacteria in marine birds☆

David Duneau[a,b], Thierry Boulinier[c], Elena Gómez-Díaz[a], Aevar Petersen[d], Torkild Tveraa[e], Robert T. Barrett[f], Karen D. McCoy[a,*]

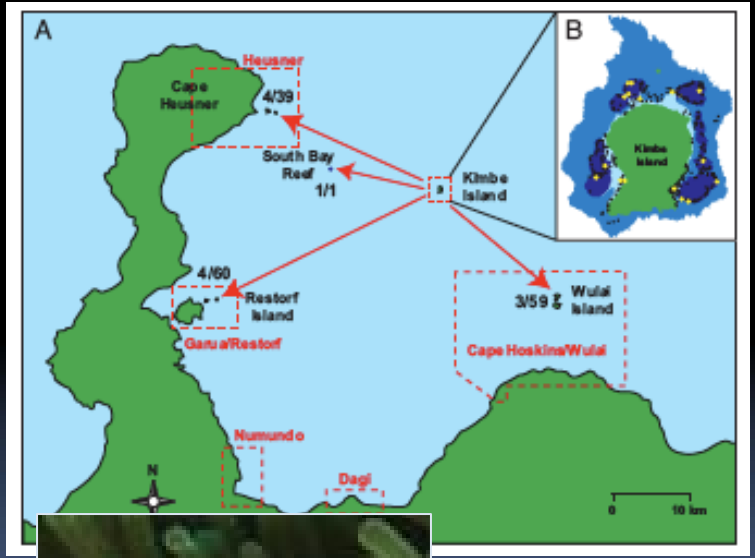
2008 Infect Gen Evol

- Marine aggregates
- Ballast water
- Airborne particles
- Marine vectors

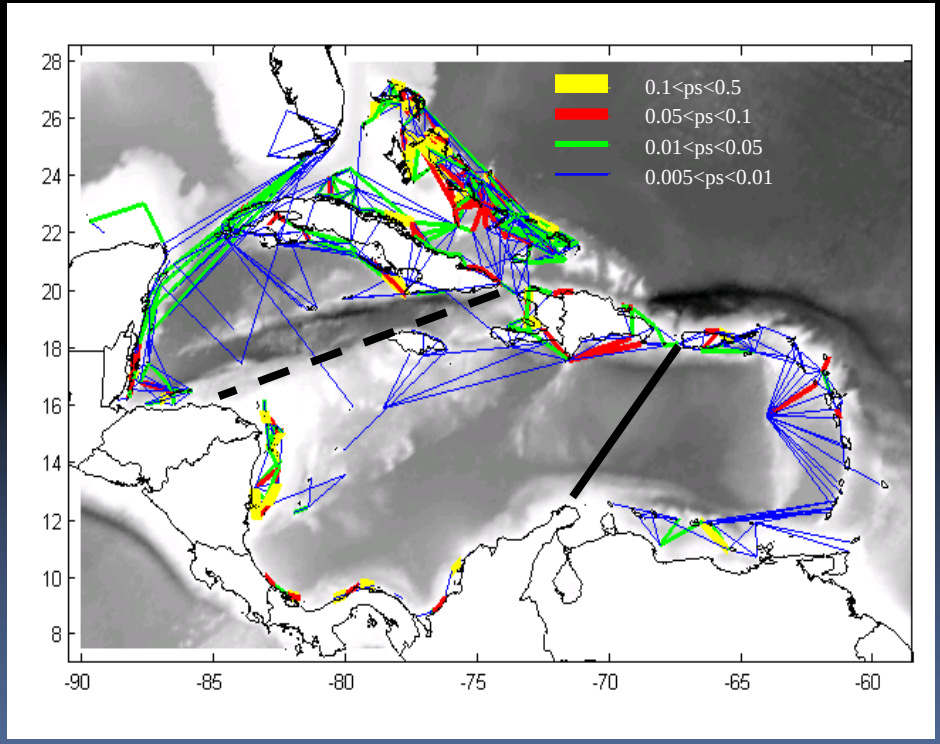
Non-passive Dispersal of Pathogens?

Modeling and empirical studies of connectivity in larval fish and other taxa demonstrate that *behavior* is crucial to understanding dispersal and population connectivity…

…what if larvae are infected and thus function like marine vectors?



Planes et al 2009
PNAS



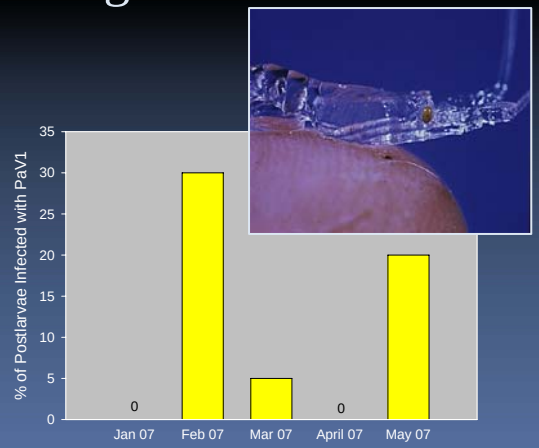
Cowen et al. 2005 Science

Evidence For Dispersal of Disease by Larvae

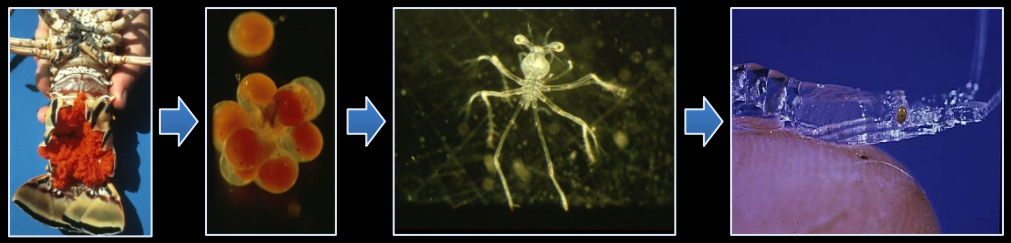
The PaV1 virus infecting Caribbean spiny lobster appears to be vertically transmitted and dispersed via infected larvae

(Butler, Behringer, Shields, Paris & Cowen – in progress)

- Postlarvae in Florida are infected and vary in viral prevalence & haplotypes
- Virus is widely distributed in Caribbean, but virions infective < 3d in water
- Viral haplotypes, no hypermutation after 6 mos – biogeographic sources?
- Naturally PaV1 infected females with eggs
- Vertical transmission from females to eggs confirmed; testing larvae now



Ramifications



- Larvae may serve as vectors of PaV1, providing a mechanism for pathogen connectivity among distant host populations.

Project Objectives

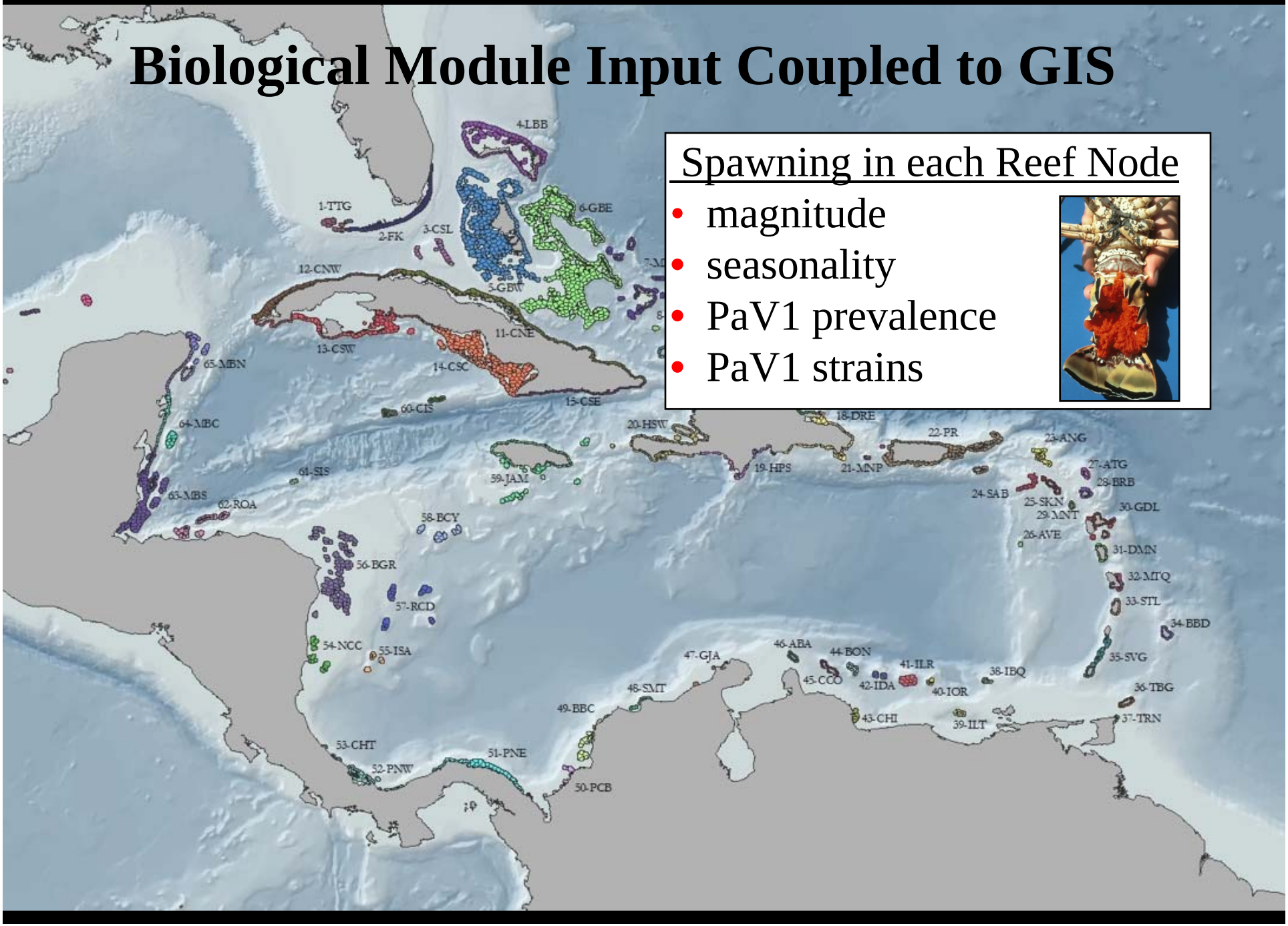
- Modify existing biophysical larval dispersal model to incorporate PaV1 disease dynamics and haplotype variation:

-Hind cast potential sources of PaV1 virus

-Role of exogenous input of PaV1 vs local disease dynamics

-Hypothetical effects of pathogen dispersal potential on spread of marine diseases

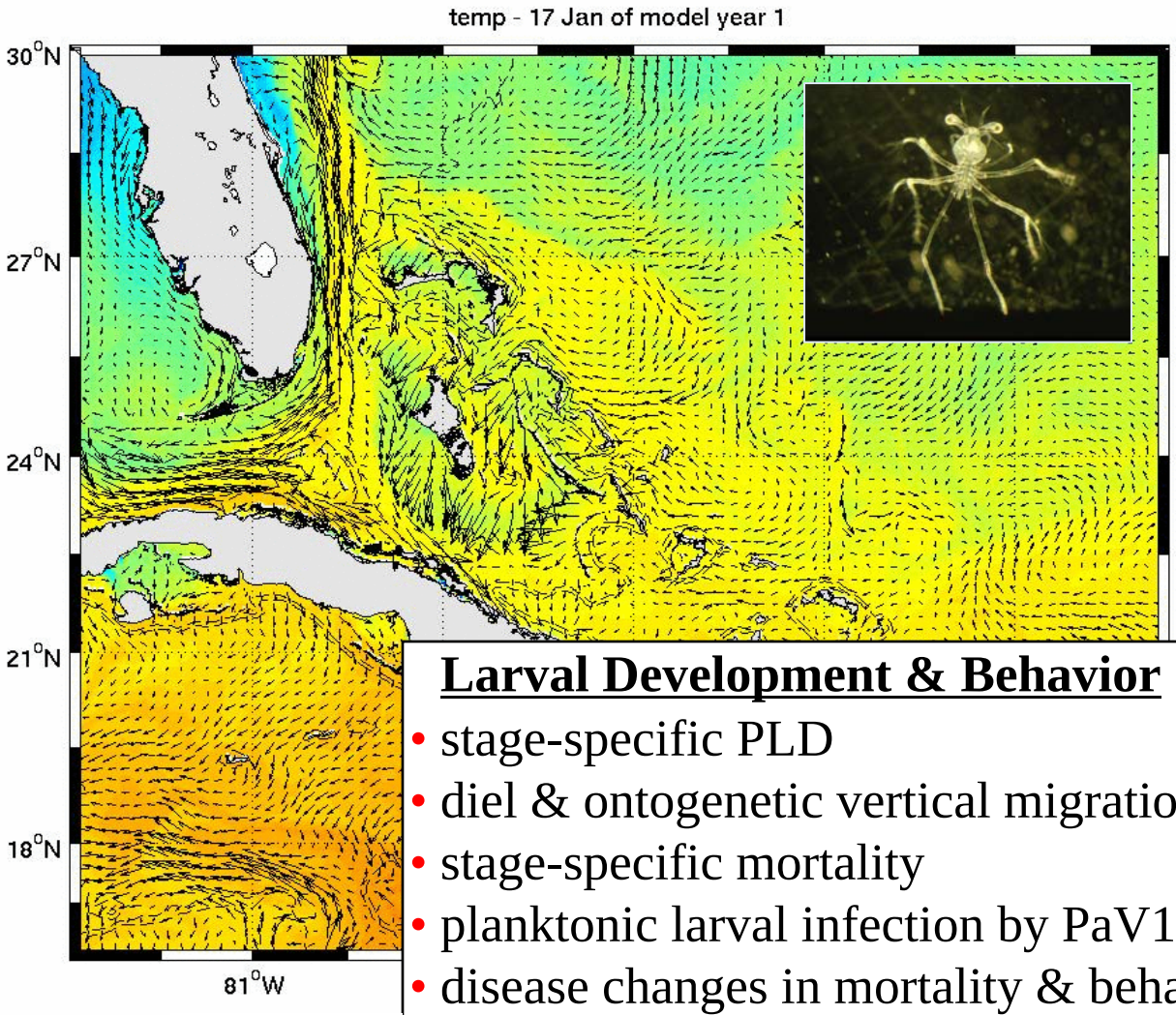
Biological Module Input Coupled to GIS



Spawning in each Reef Node

- magnitude
- seasonality
- PaV1 prevalence
- PaV1 strains

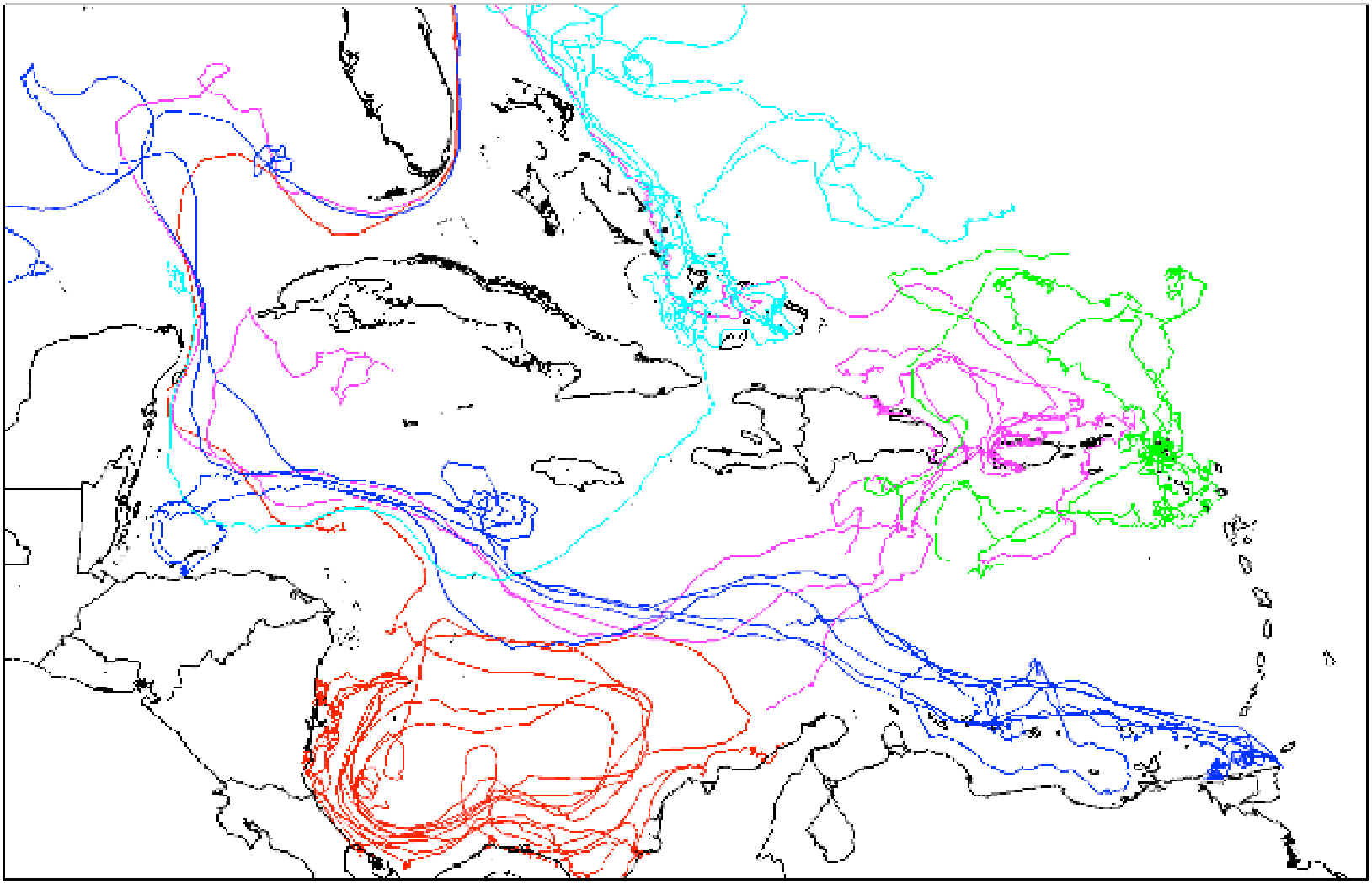
Biological Module Coupled to HYCOM/ROMS



Larval Development & Behavior

- stage-specific PLD
- diel & ontogenetic vertical migration
- stage-specific mortality
- planktonic larval infection by PaV1?
- disease changes in mortality & behavior?
- postlarval coastal attraction

Example Spiny Lobster Larval Trajectories… PaV1 too?



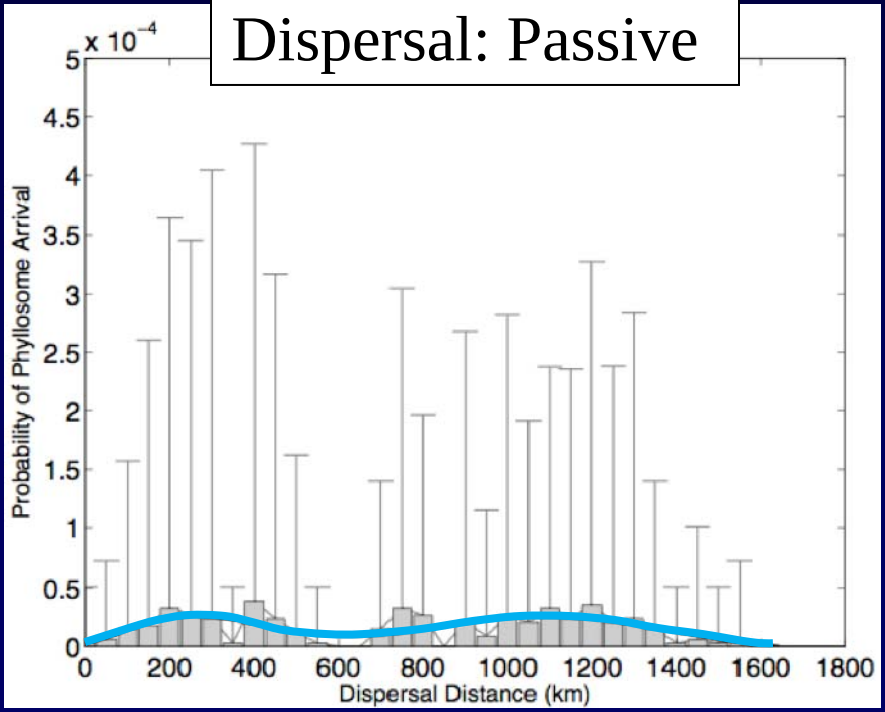
The Caribbean is a kaleidoscope of hydrodynamic environments, thus dispersal of even long-lived lobster larvae depends on location

Behavior & Larval Dispersal: Implications for PaV1

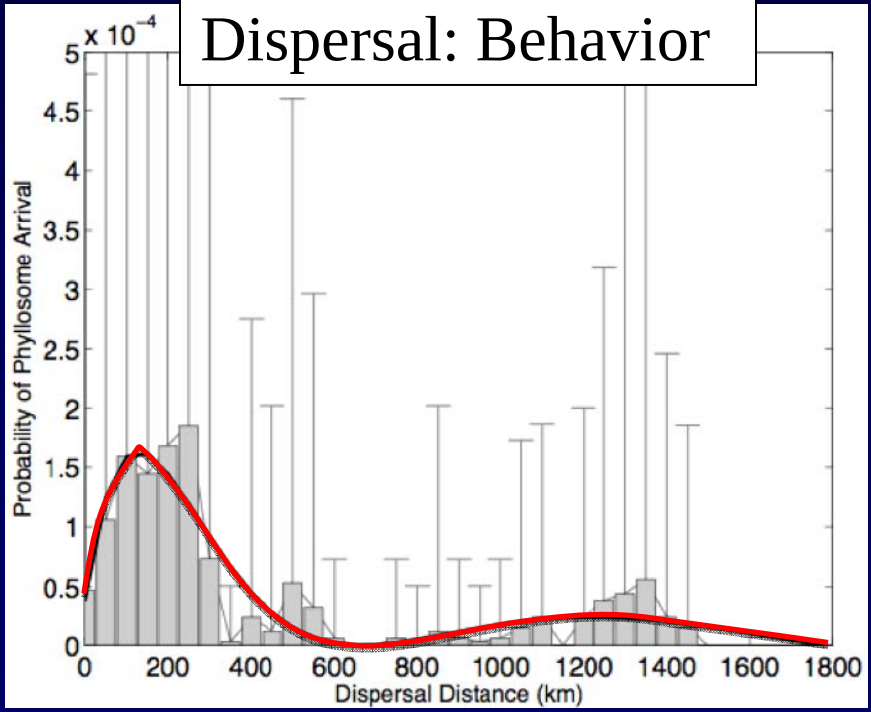
Larval Behavior:

- Increases recruitment by ~2.5x compared to passive transport
- Reduces mean dispersal to about 20% (~200km) of passive dispersers
- Increases asymmetry of dispersal kernel by enhancing "local" retention

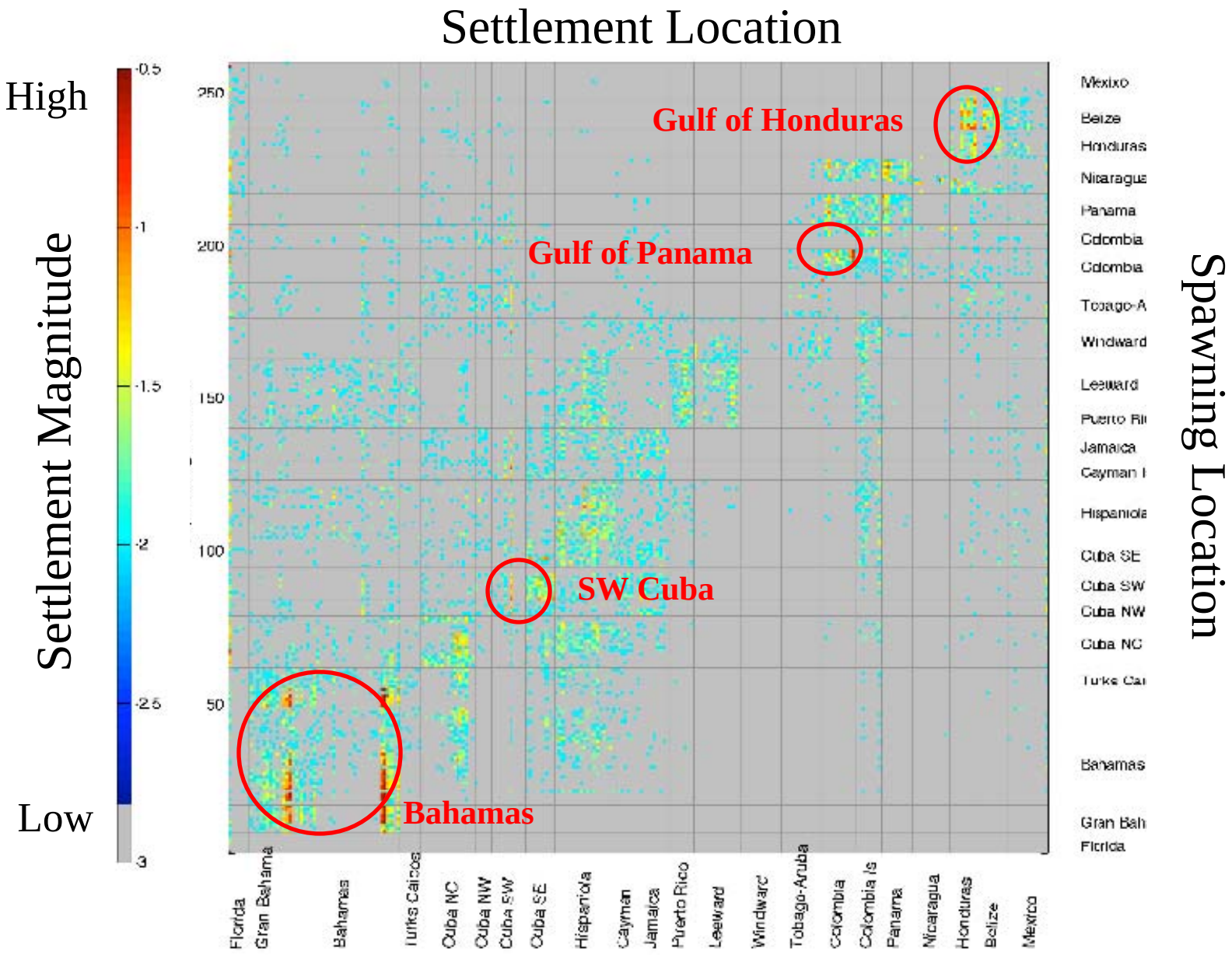
Dispersal: Passive



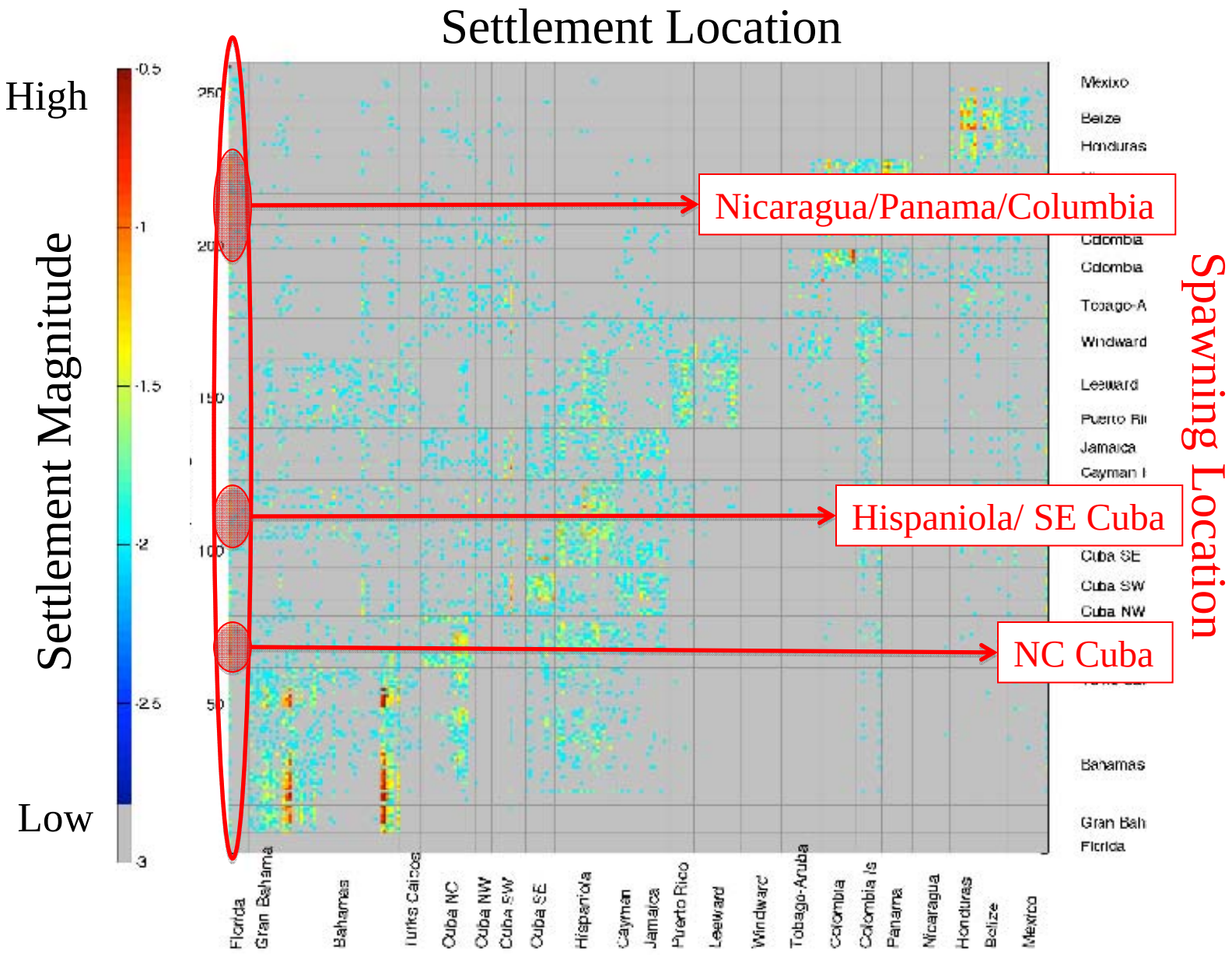
Dispersal: Behavior



Regions in Caribbean with Likely Larval & PaV1 Retention

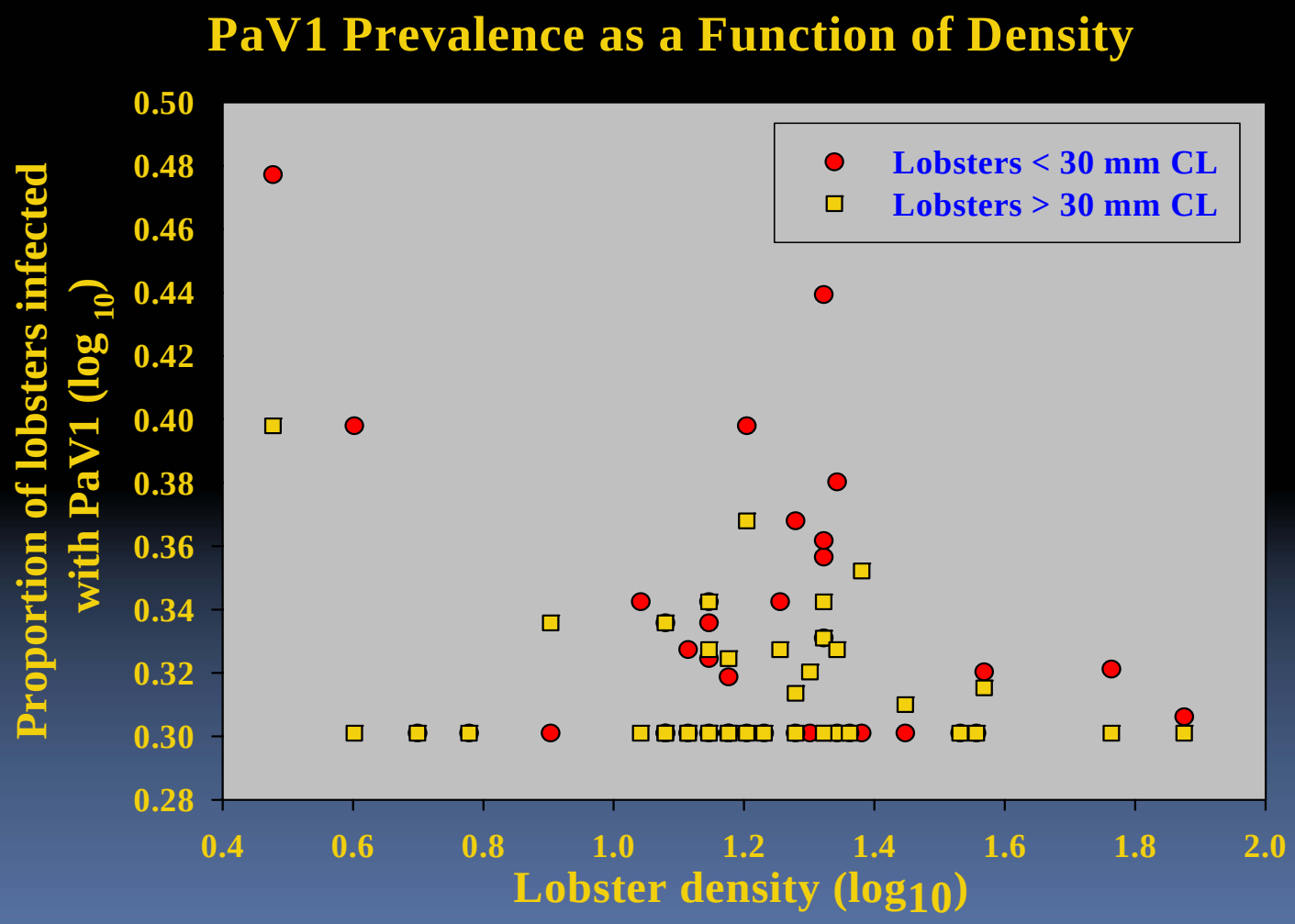


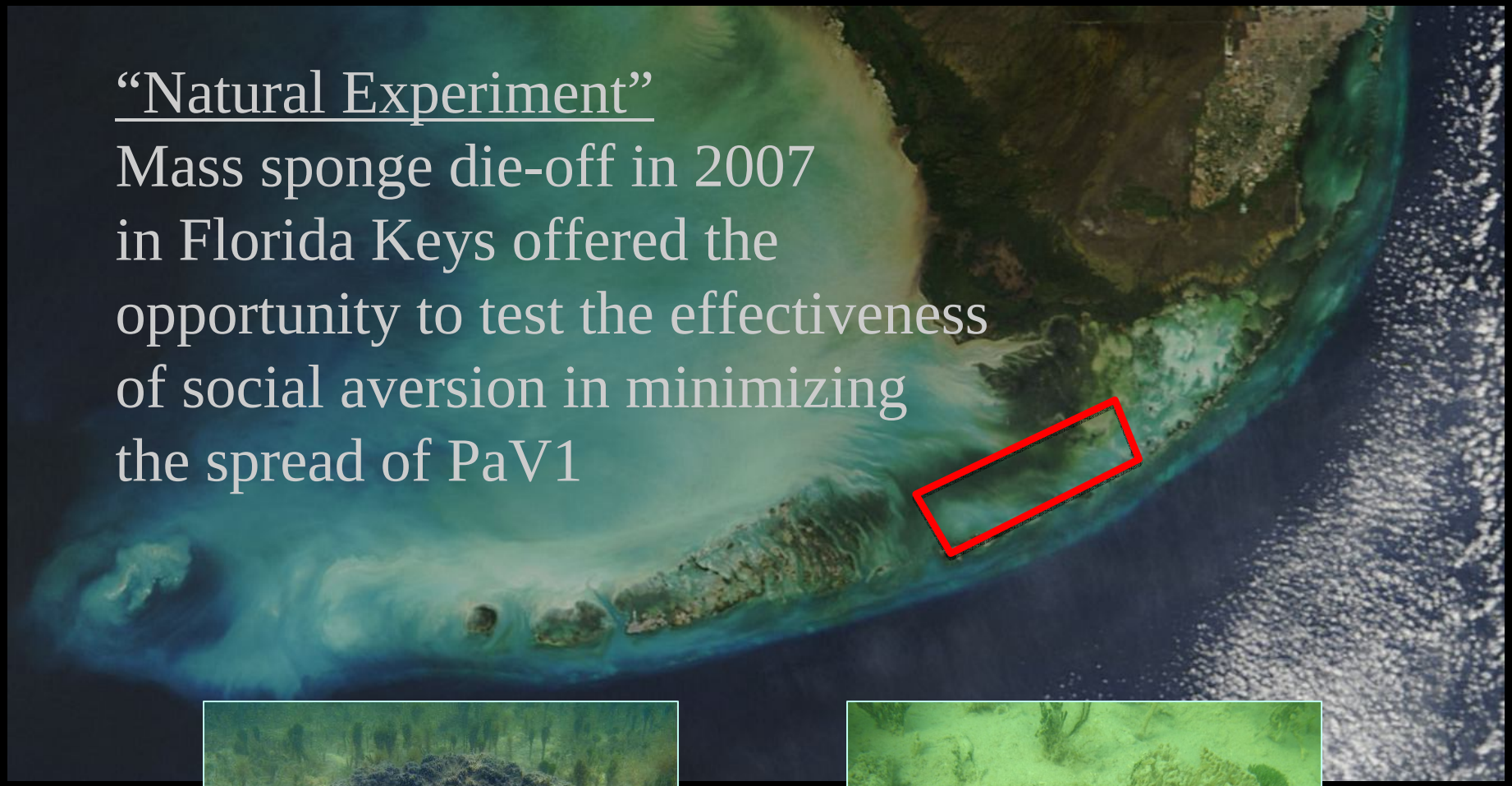
Where Do Florida's Lobster Larvae (and PaV1?) Come From?



- Healthy, normally social lobsters avoid diseased conspecifics
- First report of such behavior in wild for any animal species

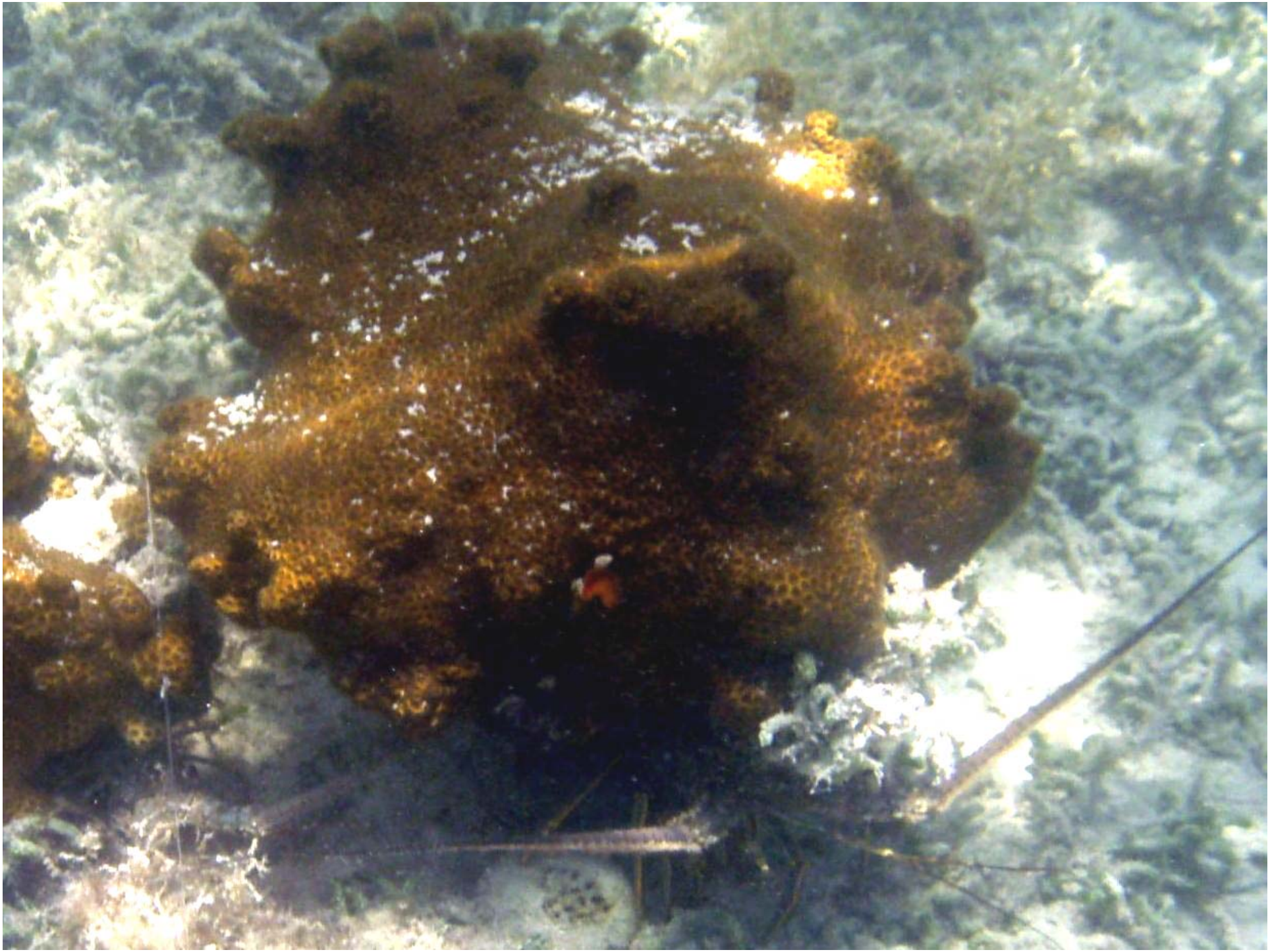
- In nature, no relationship between local lobster density and disease prevalence despite the social nature of spiny lobsters and high rates of PaV1 transmission





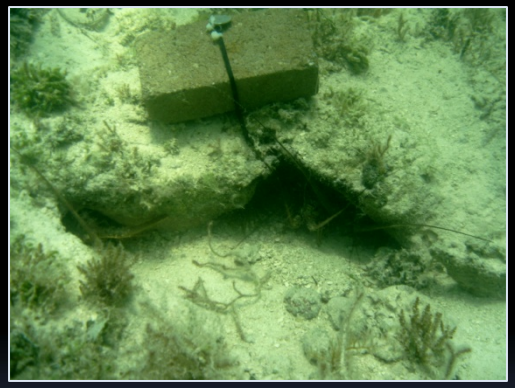
"Natural Experiment"

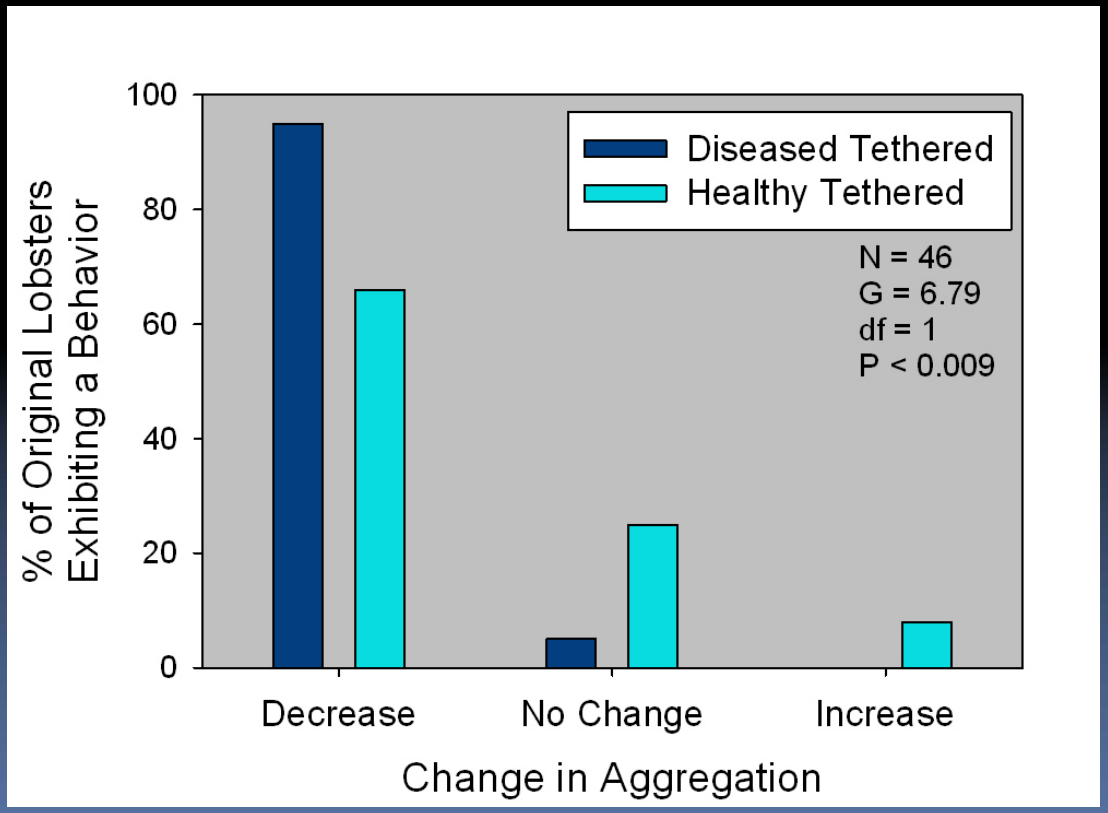
Mass sponge die-off in 2007 in Florida Keys offered the opportunity to test the effectiveness of social aversion in minimizing the spread of PaV1



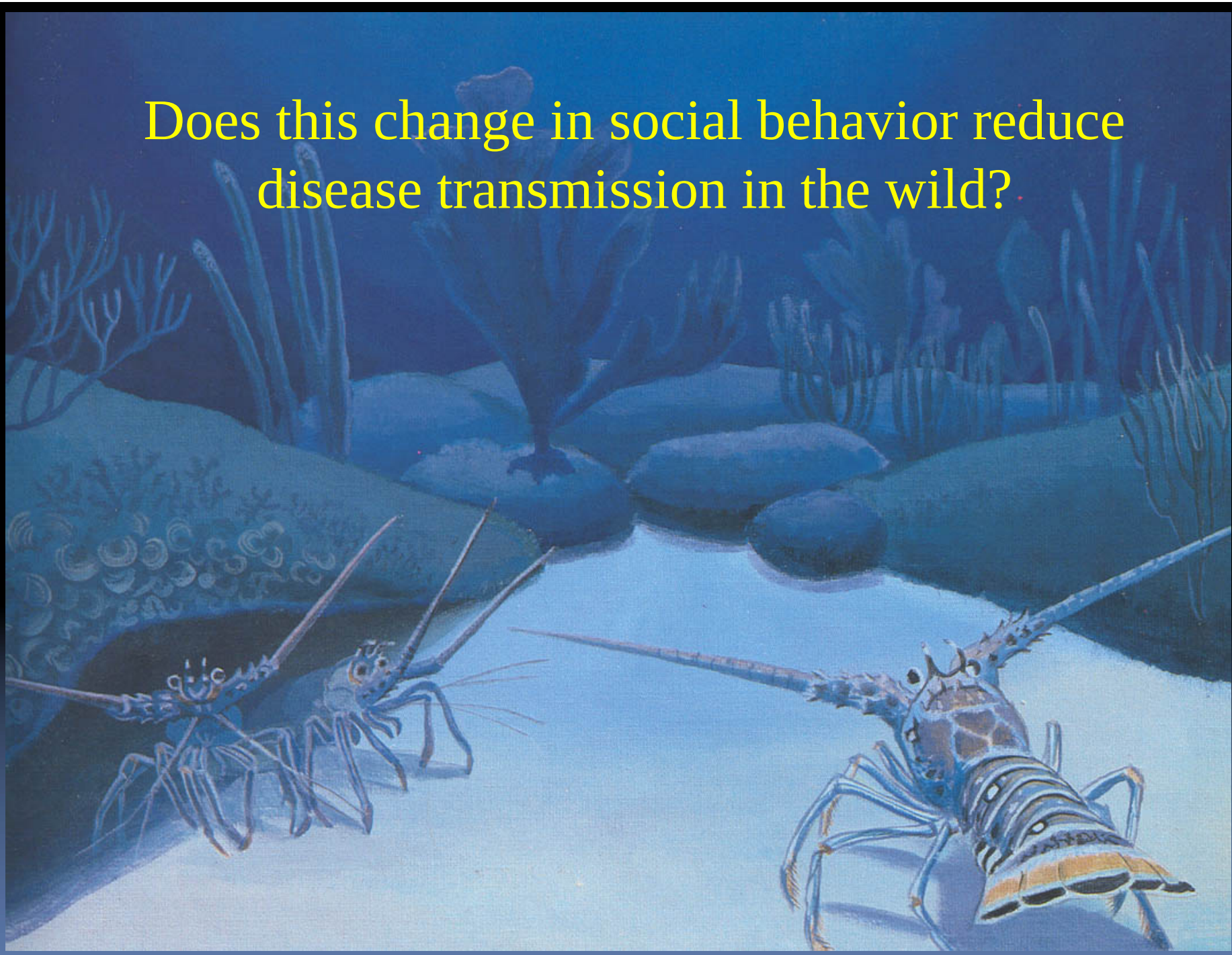
Field Test of Disease Avoidance After Sponge Die-off

- Introduce a single tethered lobster (healthy or diseased) to an existing "super-aggregation" of lobsters in a den remaining after sponge die-off
- After 24 hrs observe changes in aggregation

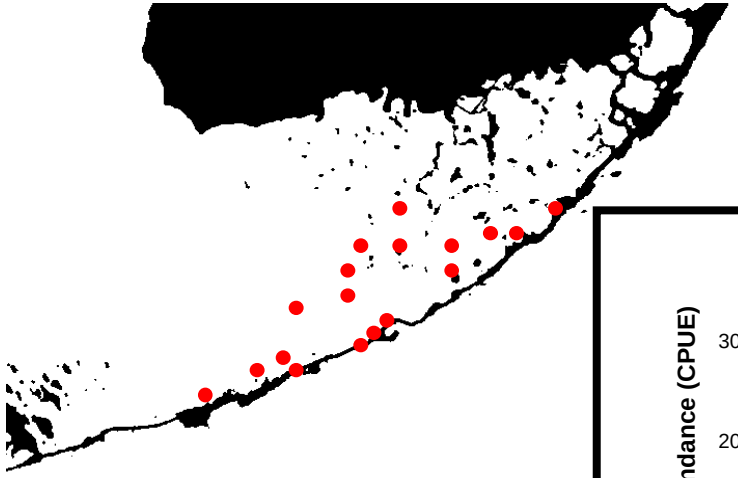




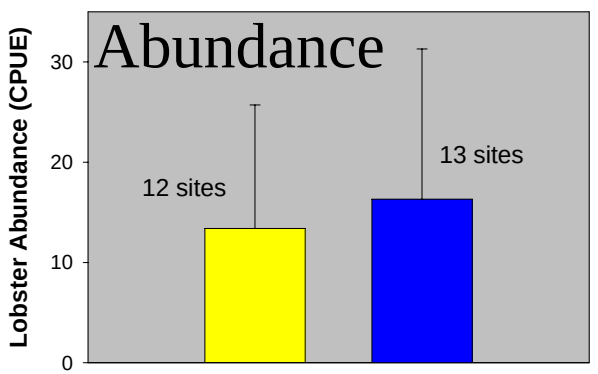
Does this change in social behavior reduce disease transmission in the wild?

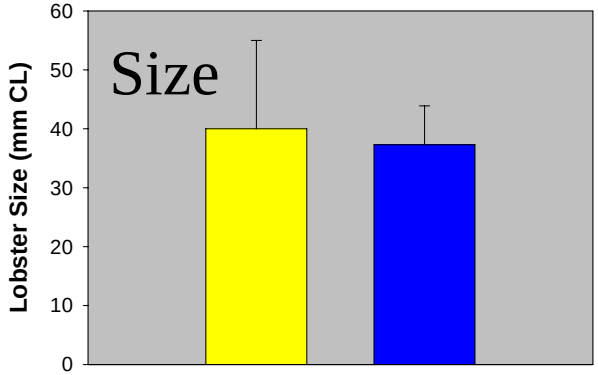


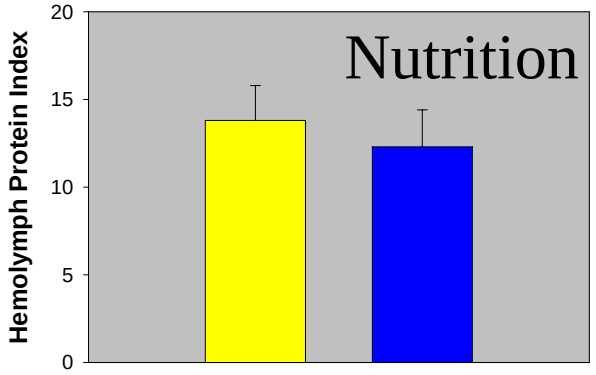
2008 post sponge die-off lobster surveys

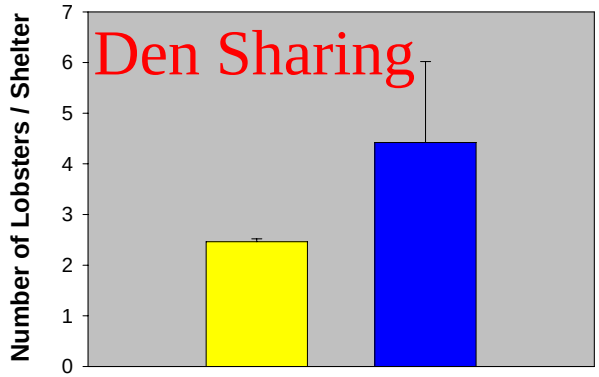


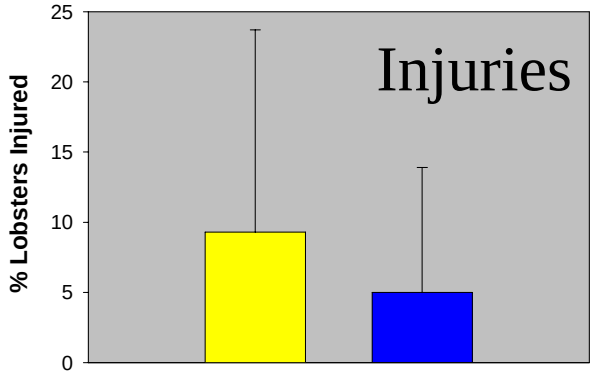
- **Survey locations**











Concluding Remarks

- The emergence of diseases is a serious phenomenon for many marine taxa, yet we know little about disease connectivity
- The PaV1 disease in Caribbean spiny lobsters is probably not a human health risk, but it is a potential threat to lobster populations because it is pathogenic, often lethal, and widespread
- Dispersal of PaV1 around the Caribbean may occur via infected larvae, but larval behavior probably plays a large role in dispersal
- Host behavior (i.e., avoidance of diseased conspecifics) also limits the spread of PaV1 among juvenile lobsters in nursery habitat, even when shelter is severely limited by sponge die-offs