Toward a Truly Sustainable Caribbean Lobster Fishery: Consideration of the Science on Larval Connectivity, PaV1 Disease, and Maximum Size Limits

Dr. Mark Butler

Professor & Eminent Scholar

Old Dominion University

Norfolk, Virginia USA

Scientific Collaborators & Funding

Larval Dispersal and Connectivity:

- Dr. Claire Paris & Andy Kough (University of Miami)

Lobster Virus Research:

- Dr. Donald Behringer (University of Florida)

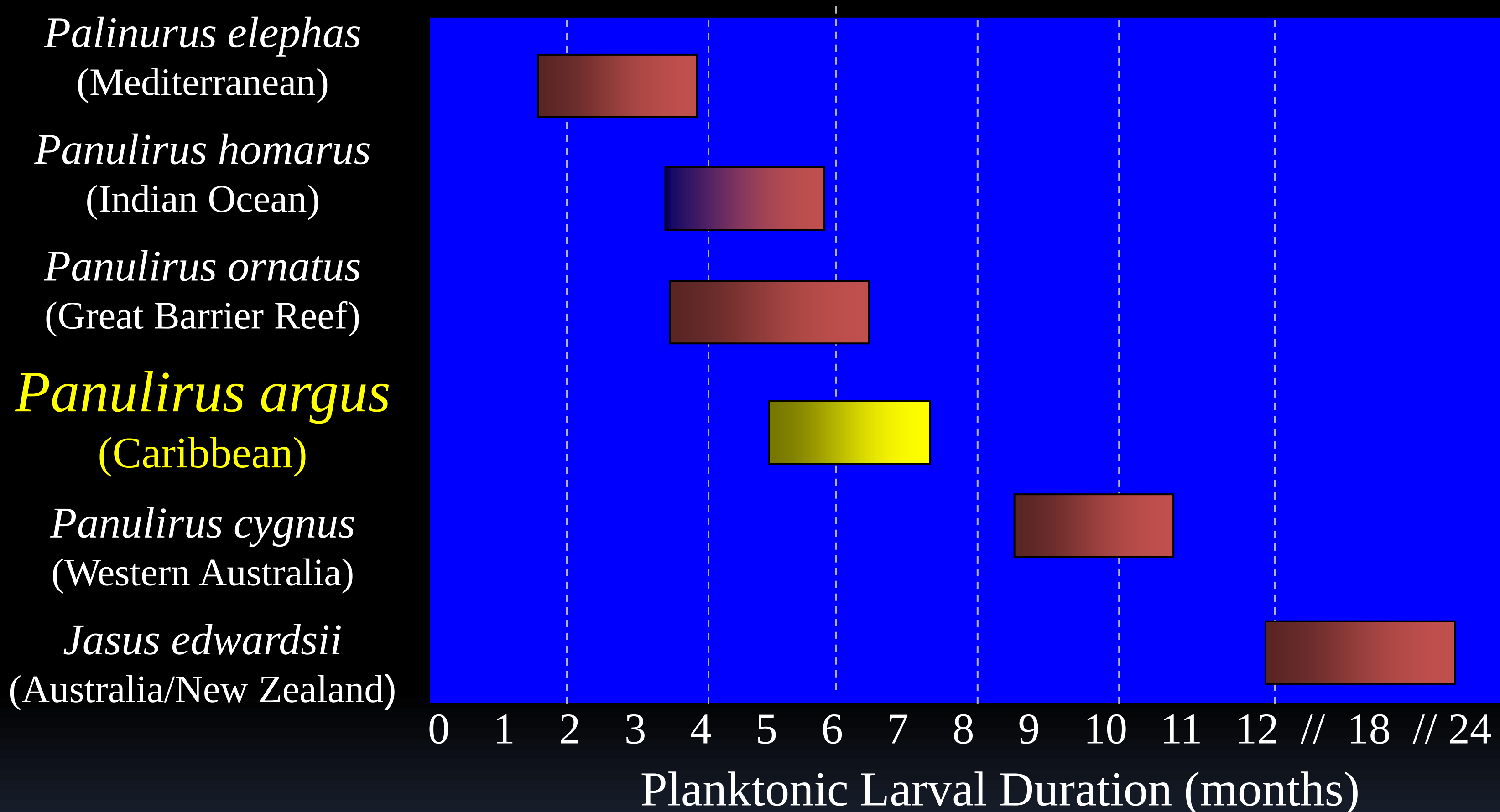
Funding:

- US National Science Foundation
- World Bank Global Environment Fund
- Florida Sea Grant

Caribbean-scale Management
and the Rebuilding of Spiny Lobster Stocks:

- Larval Dispersal & Connectivity
  - Focus on Source Populations & Key Network Nodes
- Robust Approach to Enhancing Spawning Stocks
  - NTRs and Maximum Size Limits
- Vigilance & Minimization PaV1 Virus Transmission

Spiny Lobsters Have Long Planktonic Larval Durations (PLD)



THE COMPLETE DEVELOPMENT OF LARVAL CARIBBEAN SPINY LOBSTER
PANULIRUS ARGUS (LATREILLE, 1804) IN CULTURE

Jason S. Goldstein, H. Matsuda, T. Takenouchi, and Mark J. Butler IV

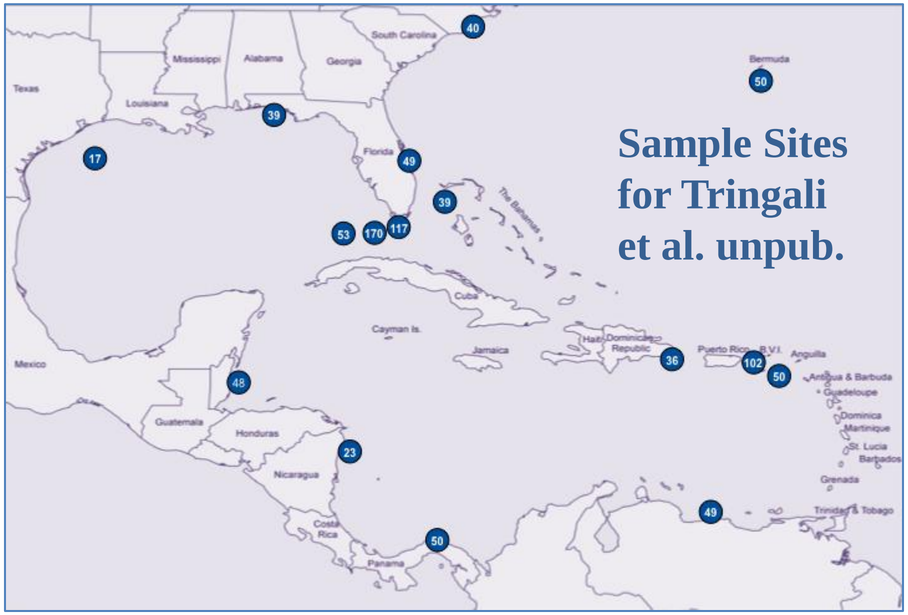
Journal Crustacean Biology 2008

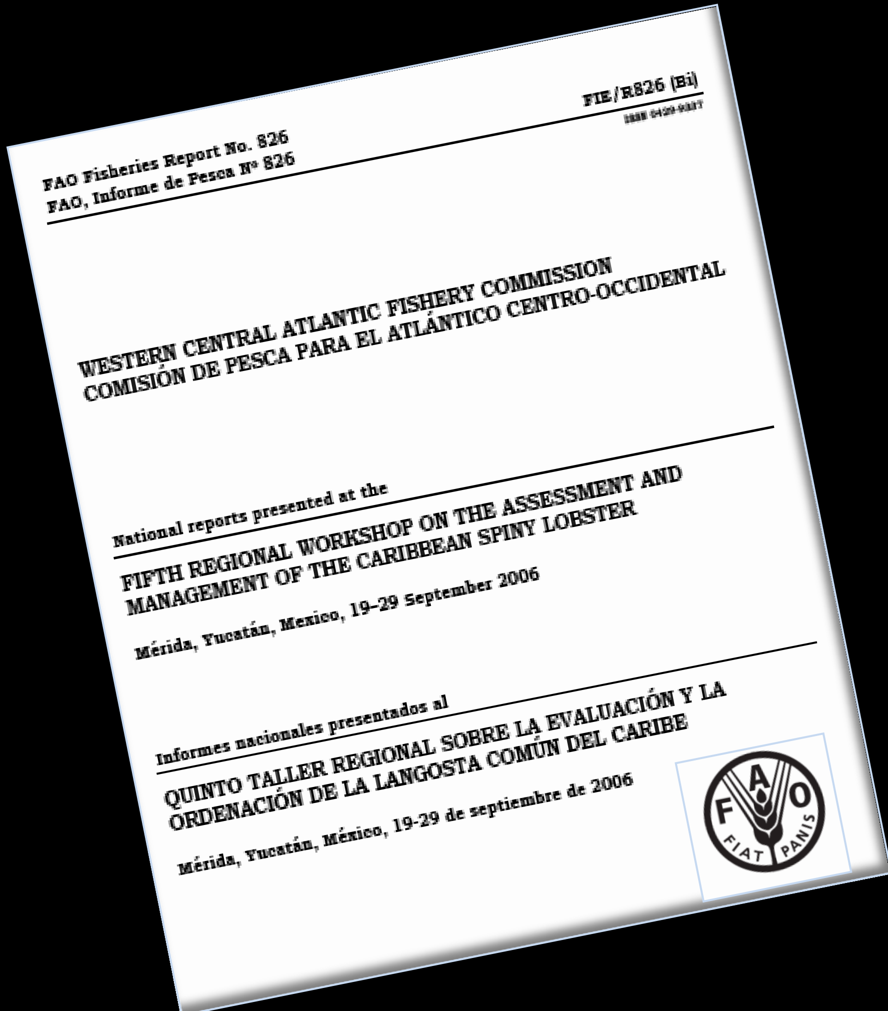
Assessments of Lobster Genetic Structure in Caribbean

- No evidence of isolation-by-distance
  (high gene flow & long dispersal distances)
- High levels of single and multi-locus disequilibrium
  (lobsters differ little genetically around the Caribbean)
- High demographic connectivity whose details (sources, sinks) are unresolvable by presently available genetic techniques

Population Genetic Studies
<u>of *P. argus* in the Caribbean</u>

Menzies & Kerigan 1979
Menzies 1980
Silberman et al. 1994
Diniz et al. 2004
Tringali et al. 2008
Naro-Machiel et al. 2011
Truelove et al. 2012





FAO Fisheries Report No. 826
FAO, Informe de Pesca Nº 826

FIE/R826 (Bi)

WESTERN CENTRAL ATLANTIC FISHERY COMMISSION
COMISIÓN DE PESCA PARA EL ATLÁNTICO CENTRO-OCCIDENTAL

National reports presented at the

FIFTH REGIONAL WORKSHOP ON THE ASSESSMENT AND MANAGEMENT OF THE CARIBBEAN SPINY LOBSTER

Mérida, Yucatán, Mexico, 19–29 September 2006

Informes nacionales presentados al

QUINTO TALLER REGIONAL SOBRE LA EVALUACIÓN Y LA ORDENACIÓN DE LA LANGOSTA COMÚN DEL CARIBE

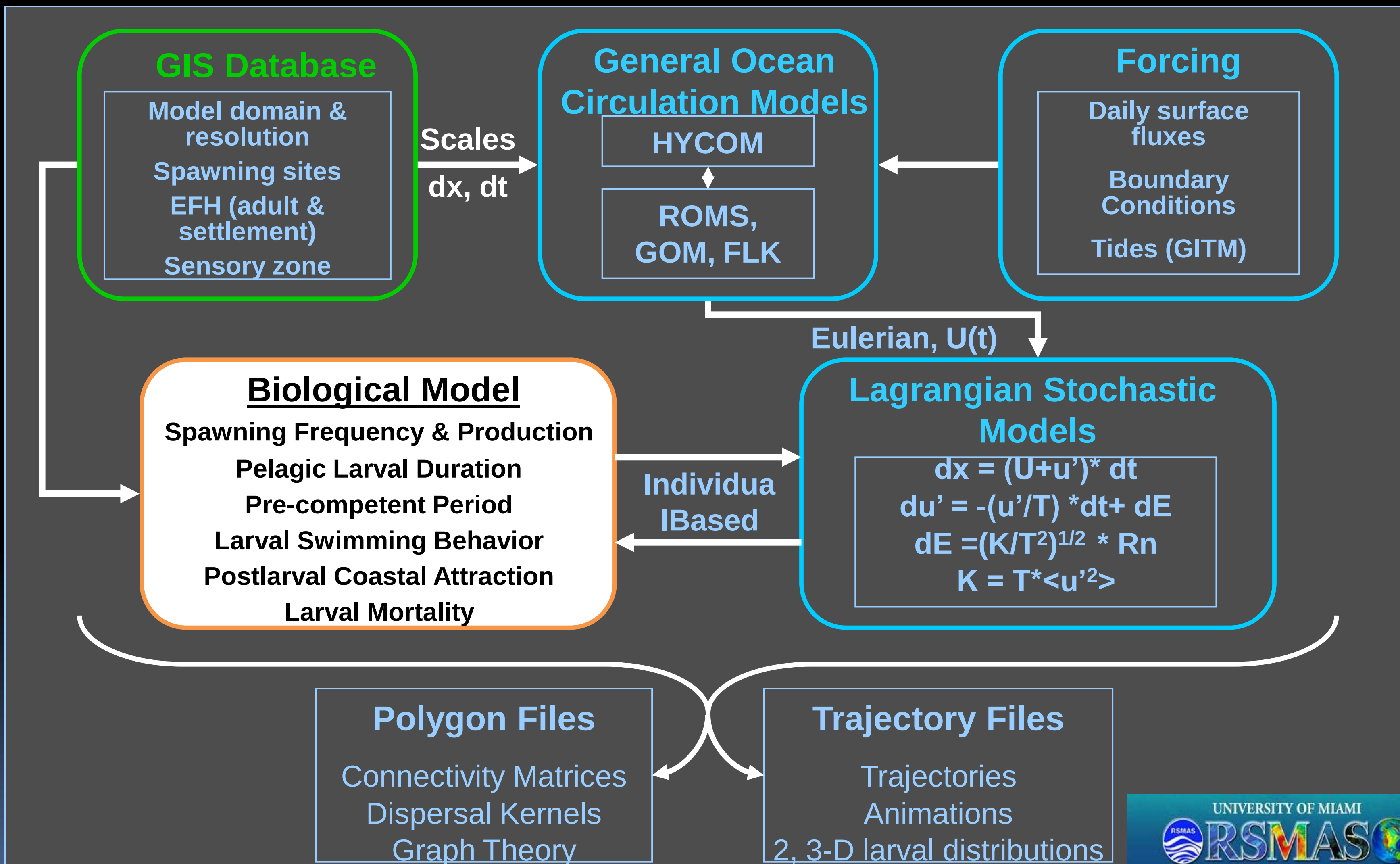
Mérida, Yucatán, México, 19-29 de septiembre de 2006

The Damsel of the Sanct Grael
- Dante Gabriel Rossetti

How can we determine the sources and destinations of trillions of tiny, actively swimming planktonic larvae during their 5 – 7 month long journey in the sea?

- Use genetic tools to discern how “related” the lobsters are among locations in the Caribbean
- Use of elemental tags & recovery downstream
- Use computer simulation modeling to “recreate” observed ocean conditions and lobster biology for prediction of larval dispersal

Our Approach: Biophysical Modeling of Lobster Dispersal & Population Connectivity



UNIVERSITY OF MIAMI RSMAS ROSENSTIEL SCHOOL OF MARINE & ATMOSPHERIC SCIENCE

Behavior Matters for Larval Dispersal

Modeling and empirical data for marine taxa with PLDs of 2-24 wks indicates that larval dispersal is often more limited than previously believed due to *larval behavior*

Local Replenishment of Coral Reef Fish Populations in a Marine Reserve

Glenn R. Almany,[1]* Michael L. Berumen,[1,2] Simon R. Thorrold,[3] Serge Planes,[4] Geoffrey P. Jones[1]

Science 2007

Scaling of Connectivity in Marine Populations

R. K. Cowen,[1]* C. B. Paris,[1] A. Srinivasan[2]

Science 2006

Local retention, dispersal and fluctuating connectivity among populations of a coral reef fish

J. Derek Hogan · Roger J. Thiessen · Peter F. Sale · Daniel D. Heath

Oecologia 2011

Complex larval connectivity patterns among marine invertebrate populations

Bonnie J. Becker*, Lisa A. Levin, F. Joel Fodrie†, and Pat A. McMillan

PNAS 2007

Behavior constrains the dispersal of long-lived spiny lobster larvae

Mark J. Butler IV[1,*], Claire B. Paris[2], Jason S. Goldstein[3], Hirokazu Matsuda[4], Robert K. Cowen[2]

MEPS 2011

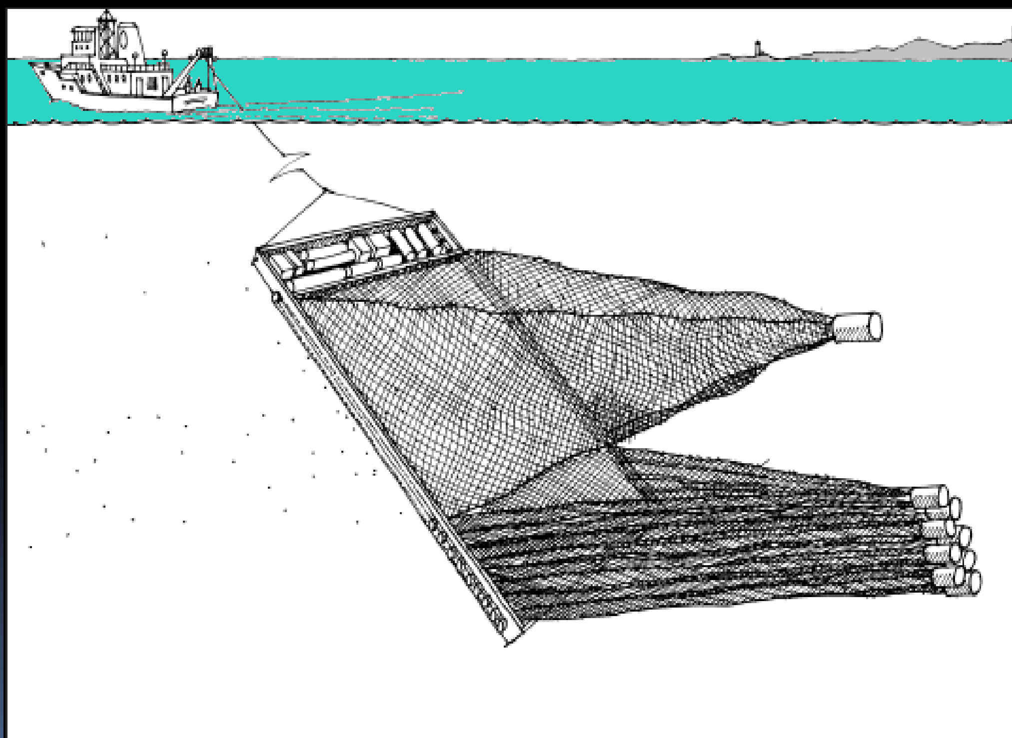
Etc., Etc., Etc…

P. argus larvae are not passive particles … their swimming behavior changes daily and ontogenetically

- Their depth in water column changes daily & weekly
- Currents also change in direction & speed with depth
- Therefore, we must include larval behavior in models & can not use just surface currents to predict larval dispersal

Biological Input: Larval Vertical Migration

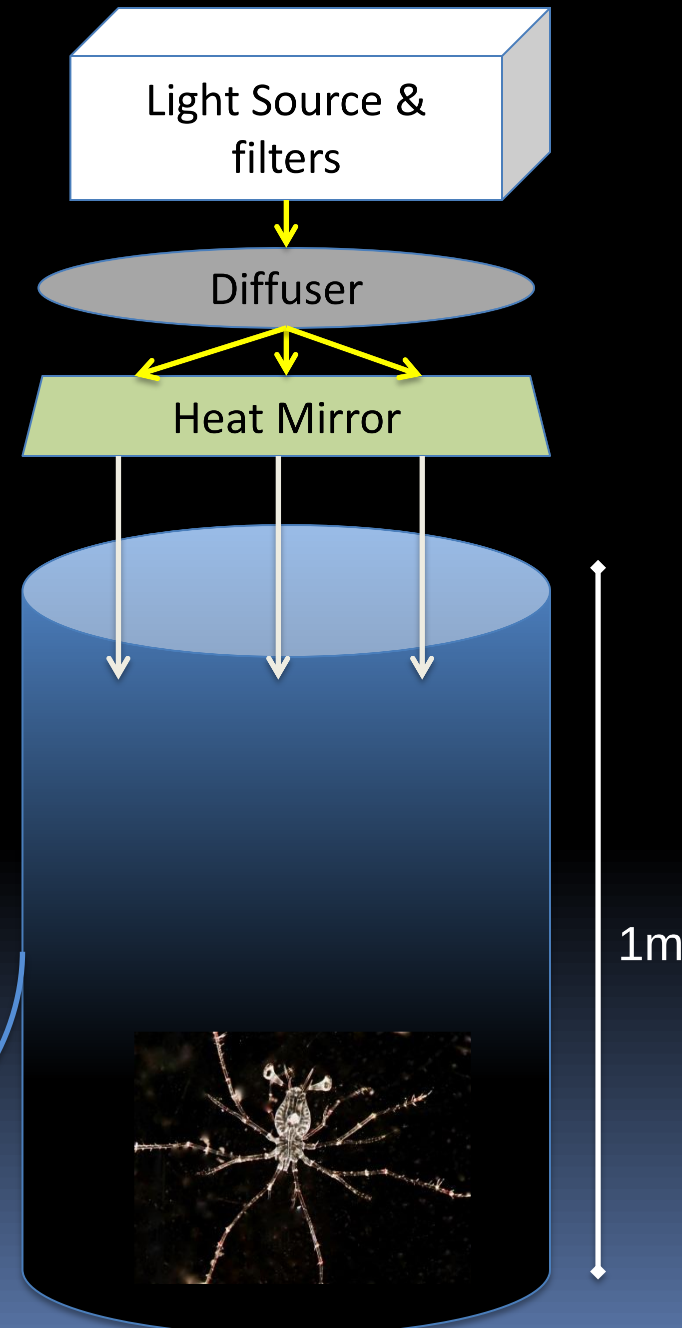
- Plankton sampling at multiple depths with MOC net (multiple open & close net)
- Monthly cruises Miami - Bimini: 2 years, 17 stations, & 10 depths

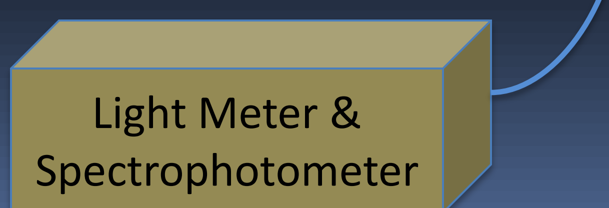


Compliments of Robert Cowen

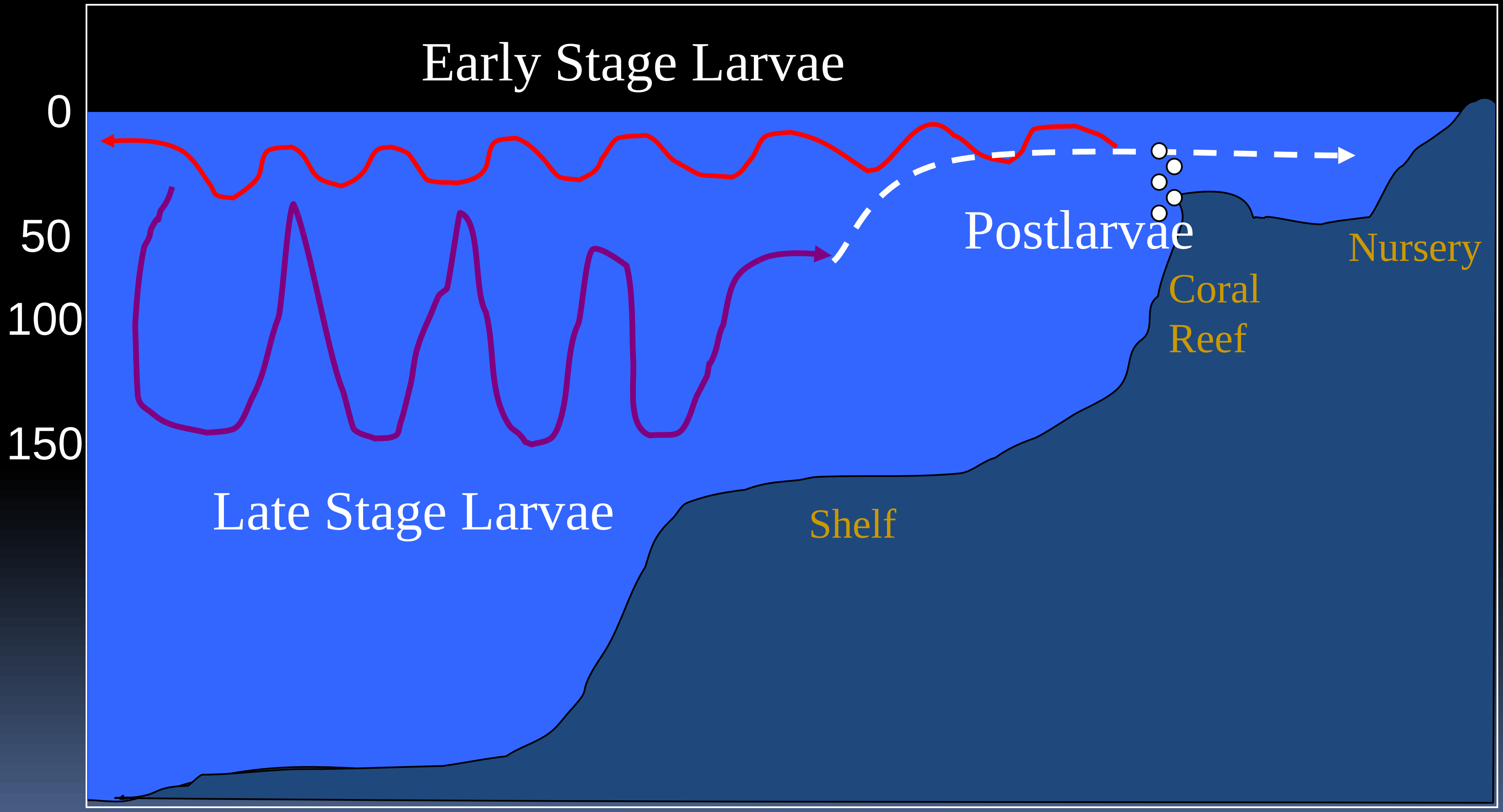
Biological Input: Laboratory Studies of Larval Behavior

- Test swimming response of laboratory reared larvae of different ages and exposed to light intensities and wavelengths during the day and the night representing: 0m, 25m, 50m & 100m depths

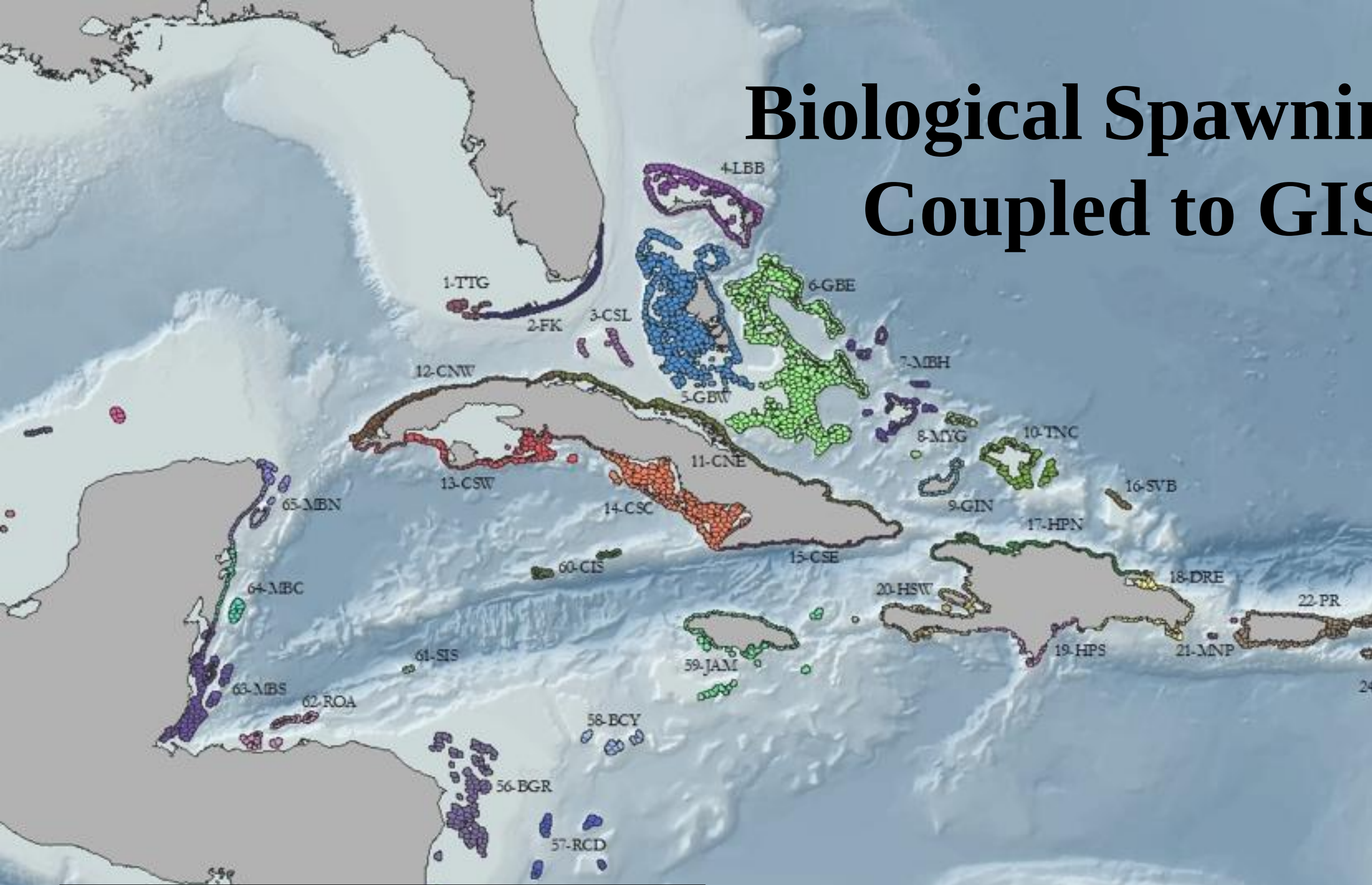




Model Depiction of Larval Behavior Based on Empirical Studies



Biological Spawning Module Coupled to GIS Seascape



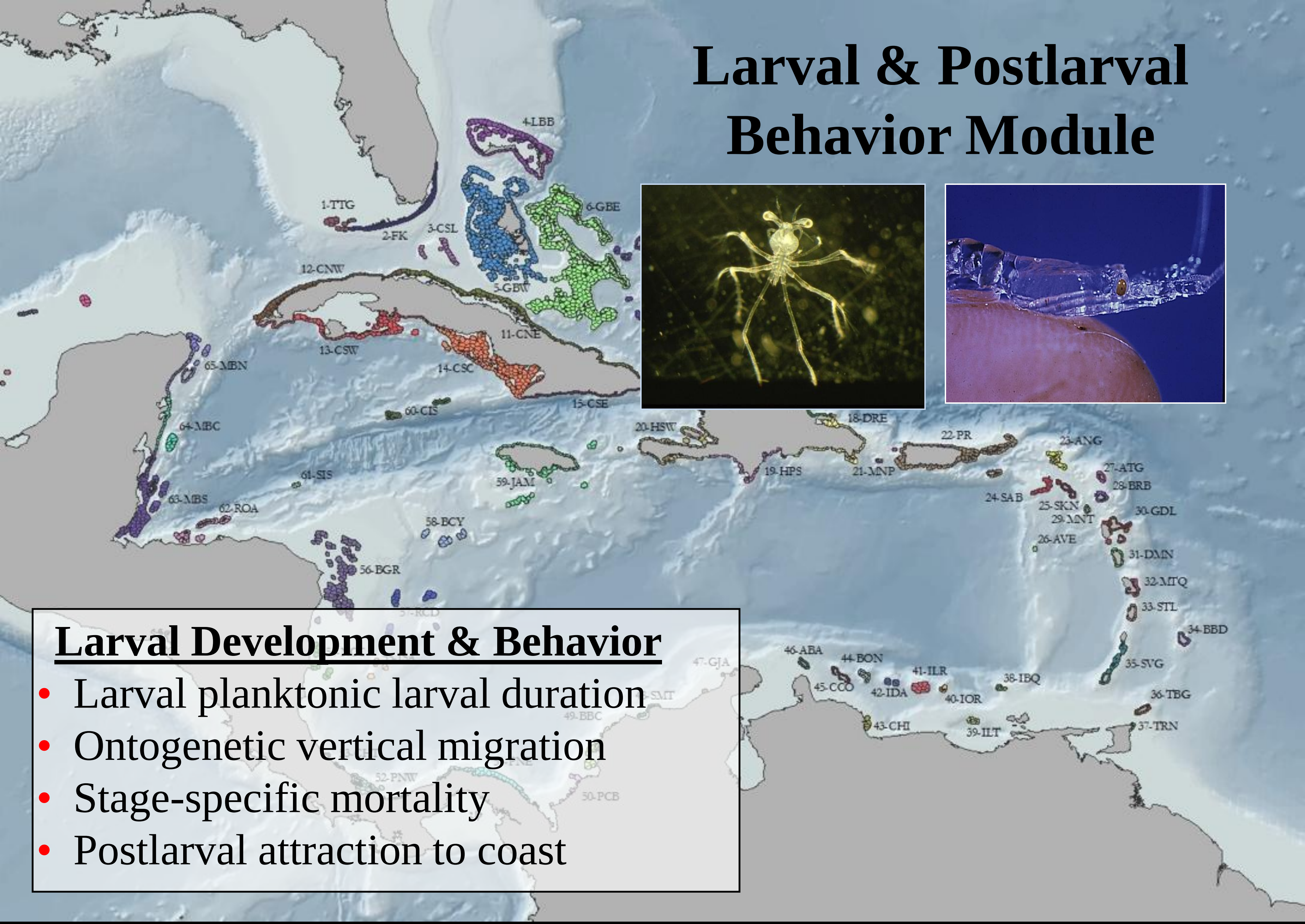
<u>Data from:</u>

- Literature
- English & Spanish surveys of fishery managers in region

<u>Spawning in each Reef Polygon includes:</u>

- magnitude & seasonality of spawning
- PaV1 virus prevalence in adult females

Larval & Postlarval Behavior Module

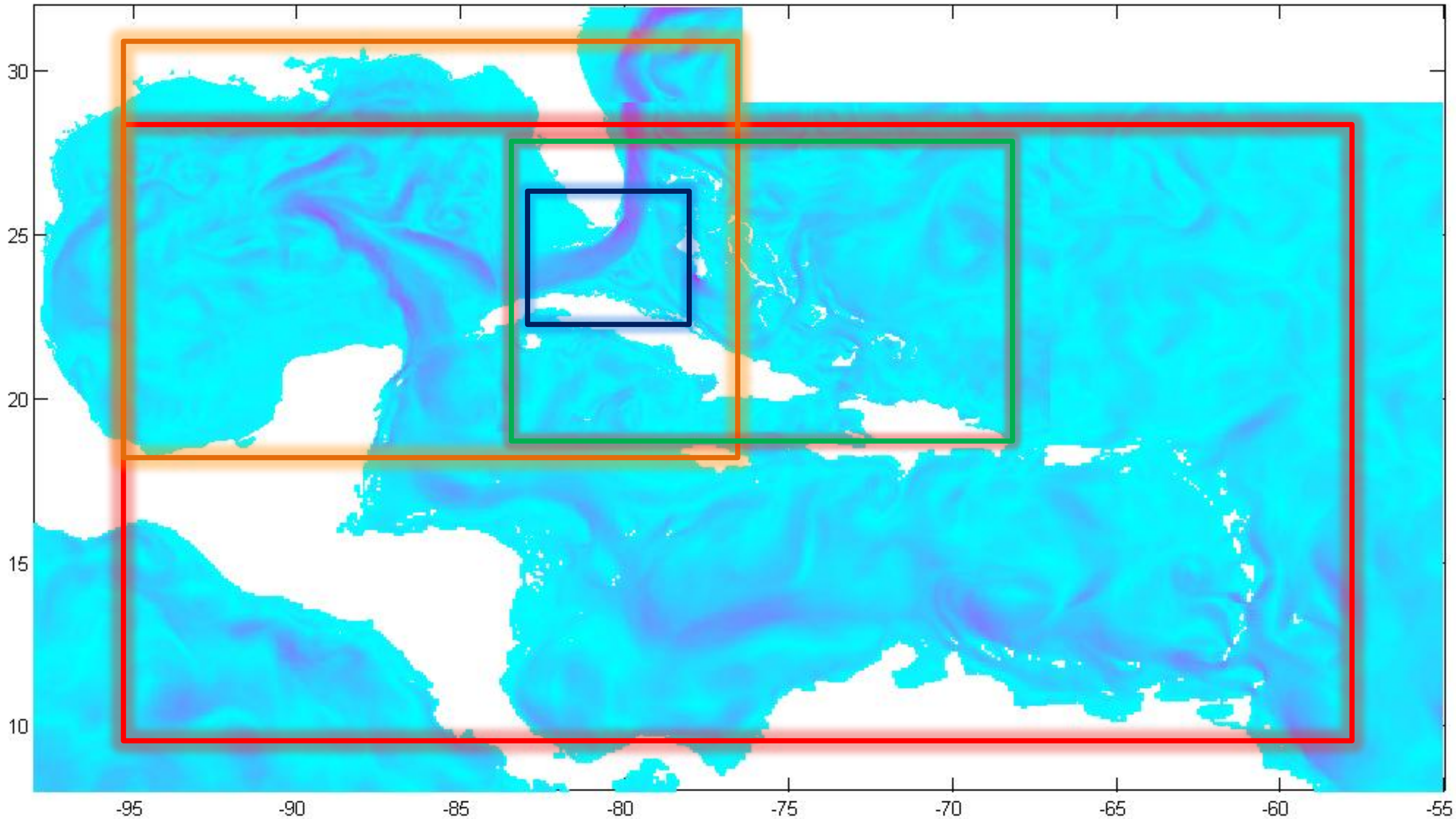


<u>Larval Development & Behavior</u>

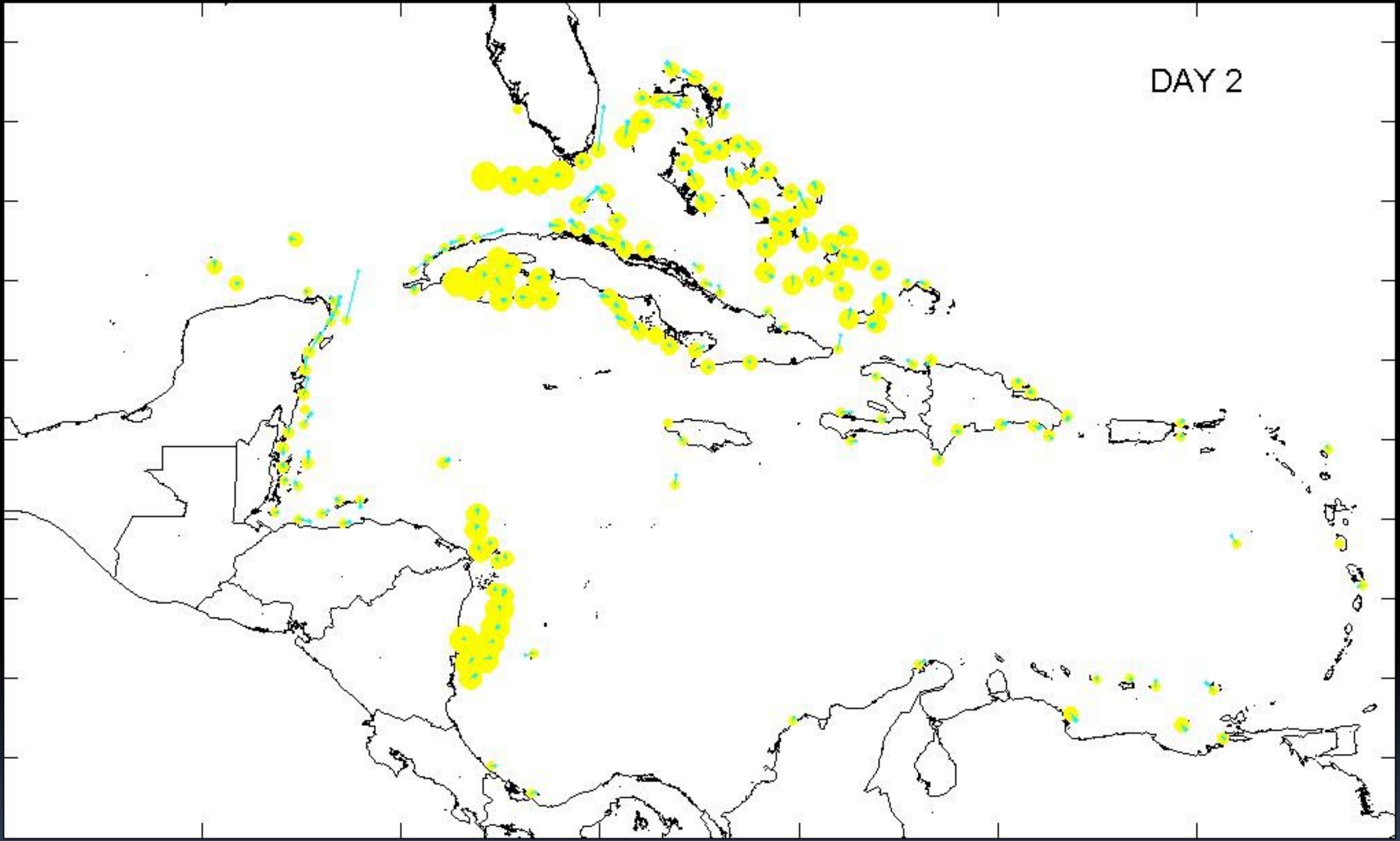
- Larval planktonic larval duration
- Ontogenetic vertical migration
- Stage-specific mortality
- Postlarval attraction to coast

3-Dimensional Larval Dispersal by Integrating Multiple Ocean Circulation Models

- HYCOM GLOBAL (Caribbean; ~7 km resolution)
- GOM-HYCOM (Gulf of Mexico; ~ 4 km resolution)
- ROMs (Bahamas; ~ 4 km resolution)
- FLK-HYCOM (Florida Keys; ~900 m resolution)

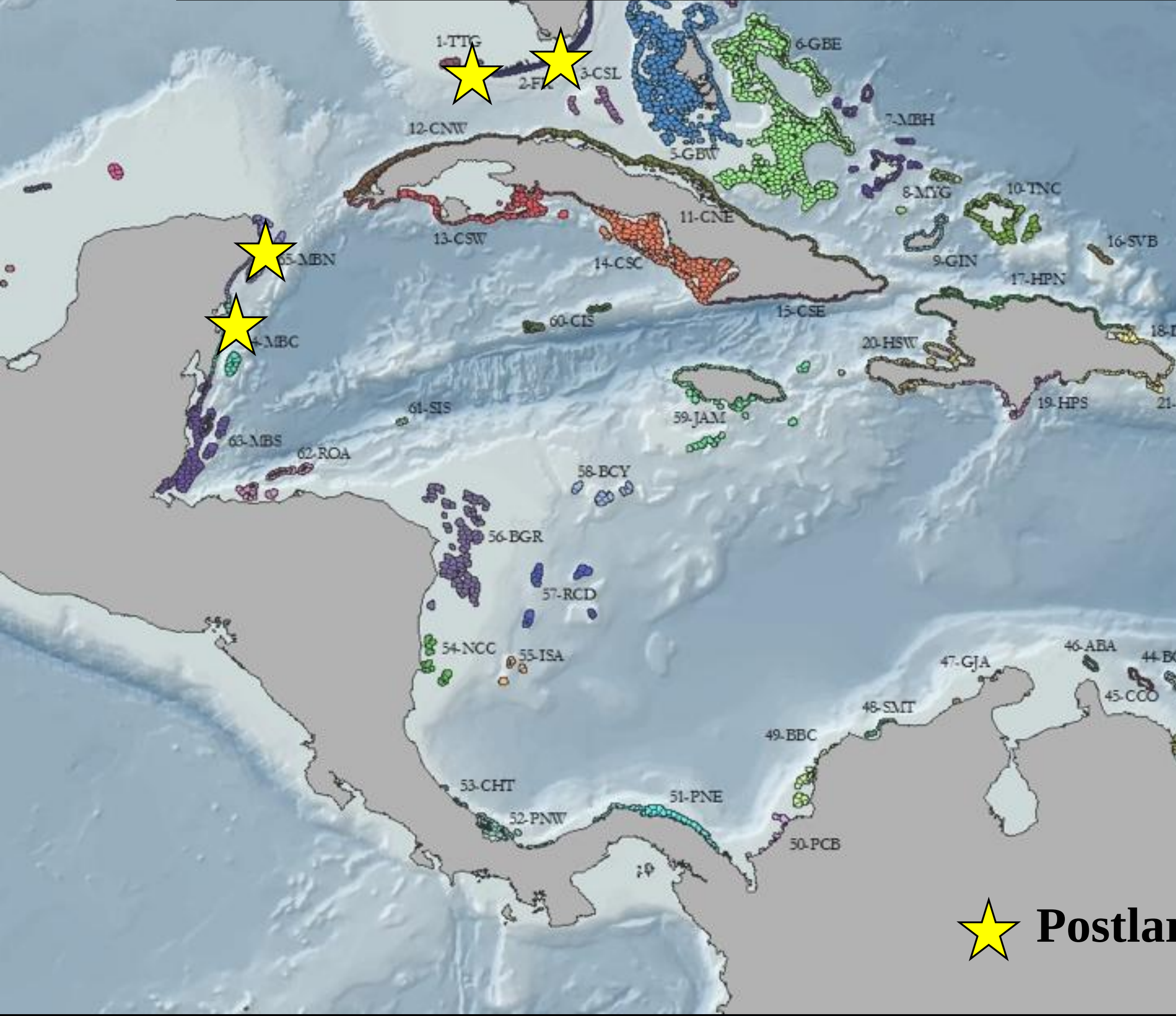


An Example Model Run



- Yellow circles & sizes are larval release sites and magnitude
- Modeled larvae change color with age
- Settlement sites and magnitude of settlement are shown by green circles

<u>Model Validation</u>:
Predicted vs. Observed Postlarval Supply

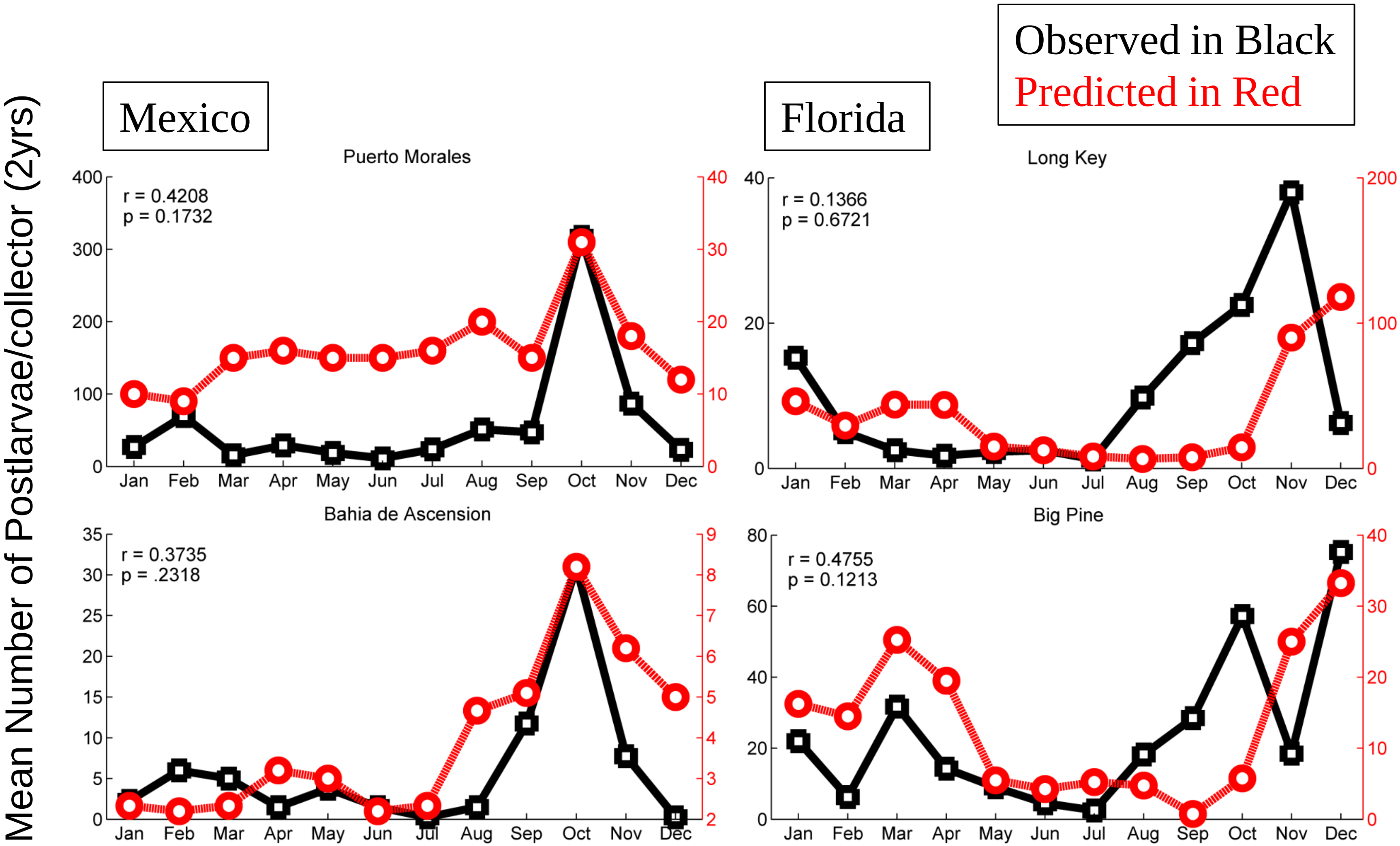


- 4 sampling stations
- Monthly for 2 years

★ **Postlarval Sampling Stations**

Model Validation Results

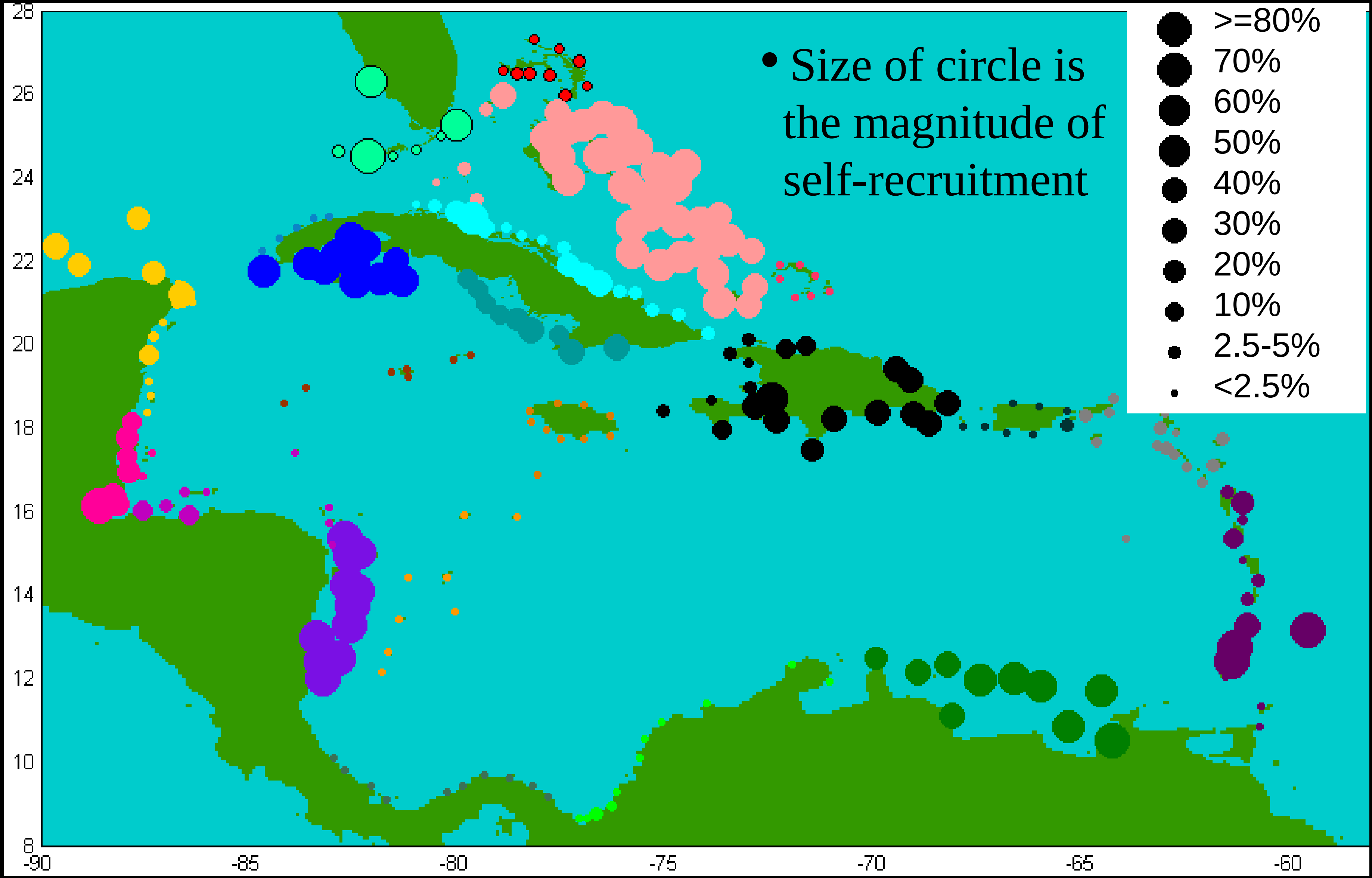
Predicted vs. Observed Postlarval Settlement



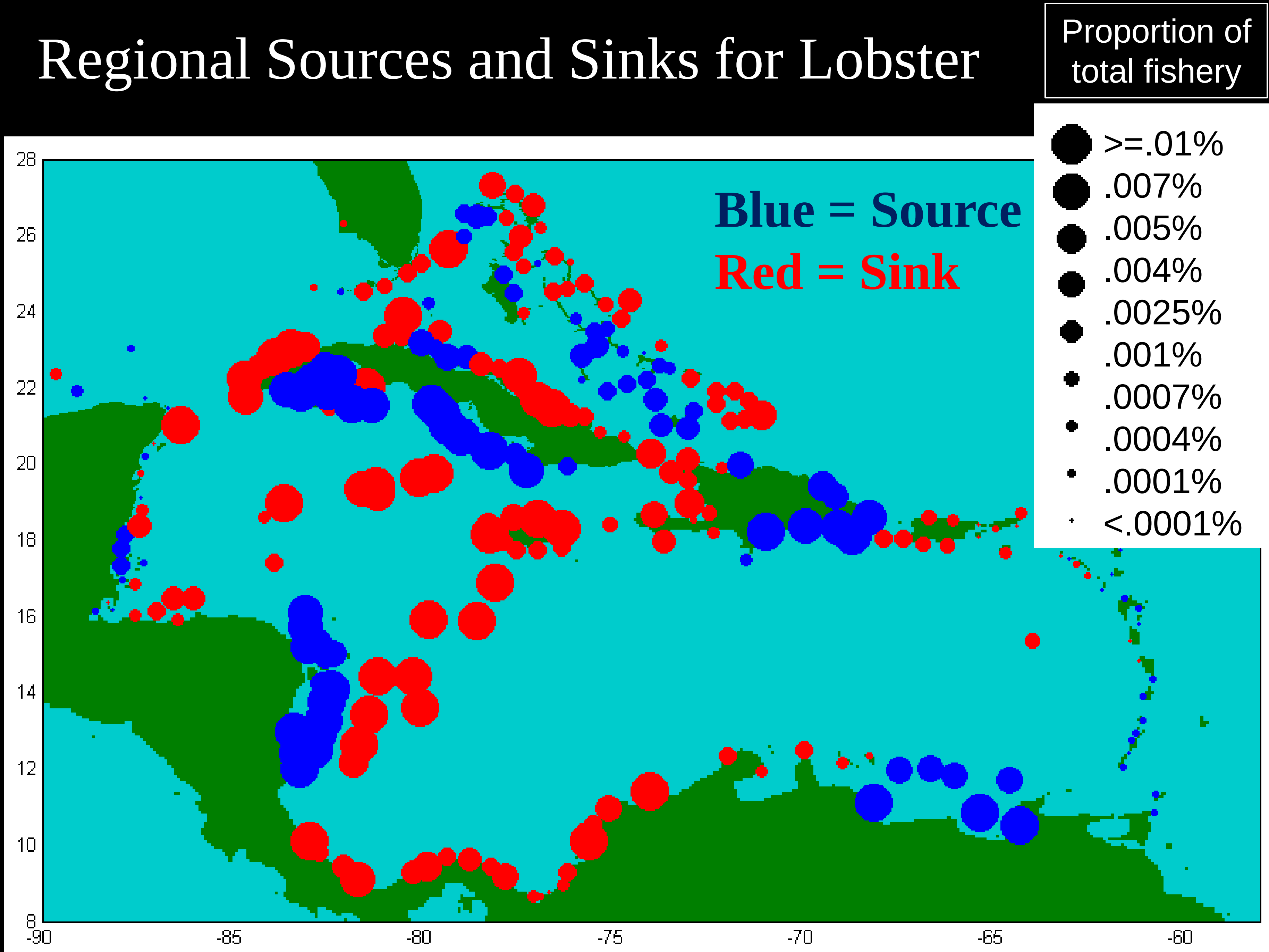
From Kough et al. 2013

Regional Patterns of Self-recruitment

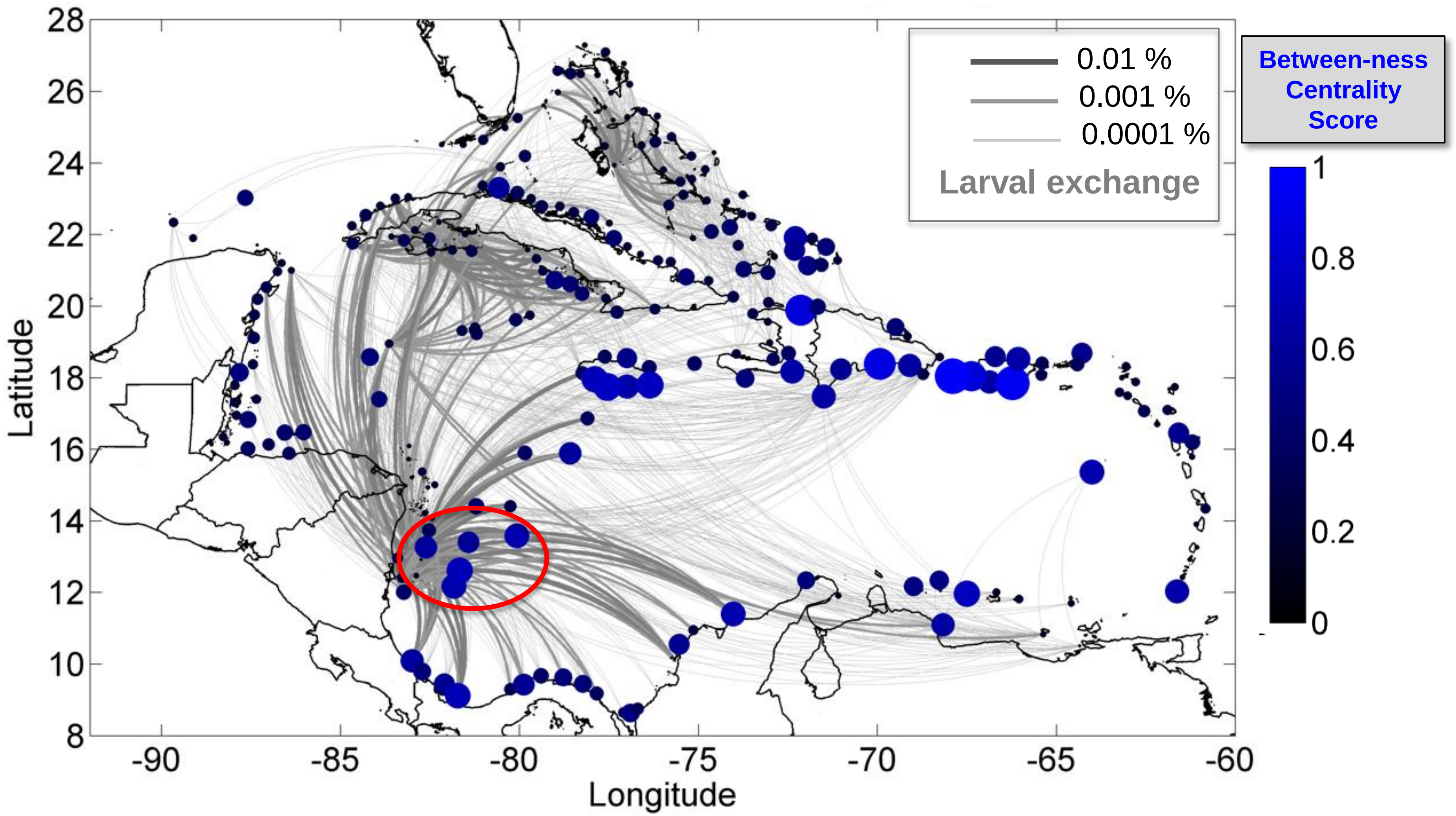
Proportion of regions recruits



Regional Sources and Sinks for Lobster

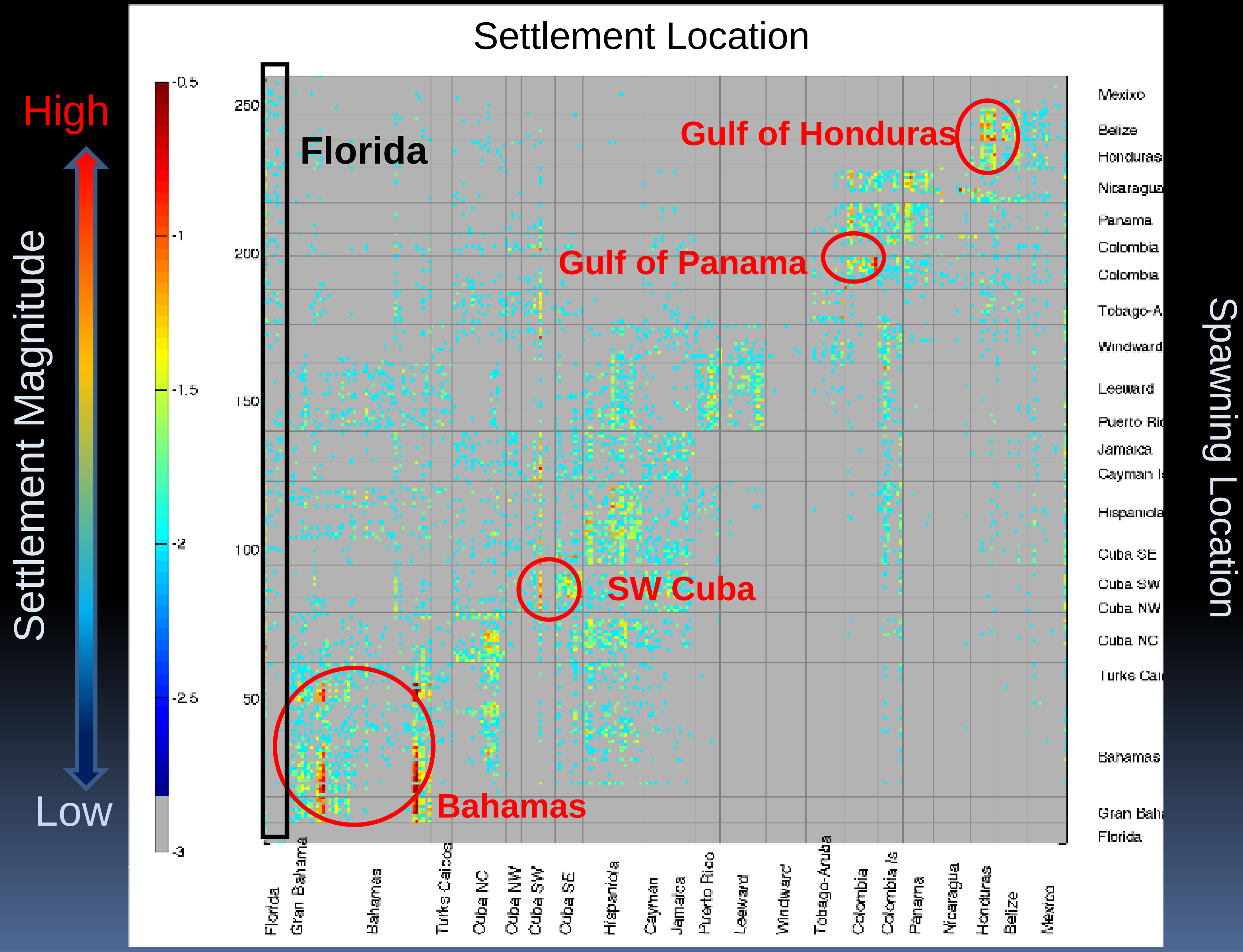


Exchange of *P. argus* Larvae and Between-ness Centrality of Spawning Locations



From Kough et al. in review

Connectivity Matrix for *P. argus* in the Caribbean



Modeling Implications:
Larval Connectivity & Multinational Stock Management

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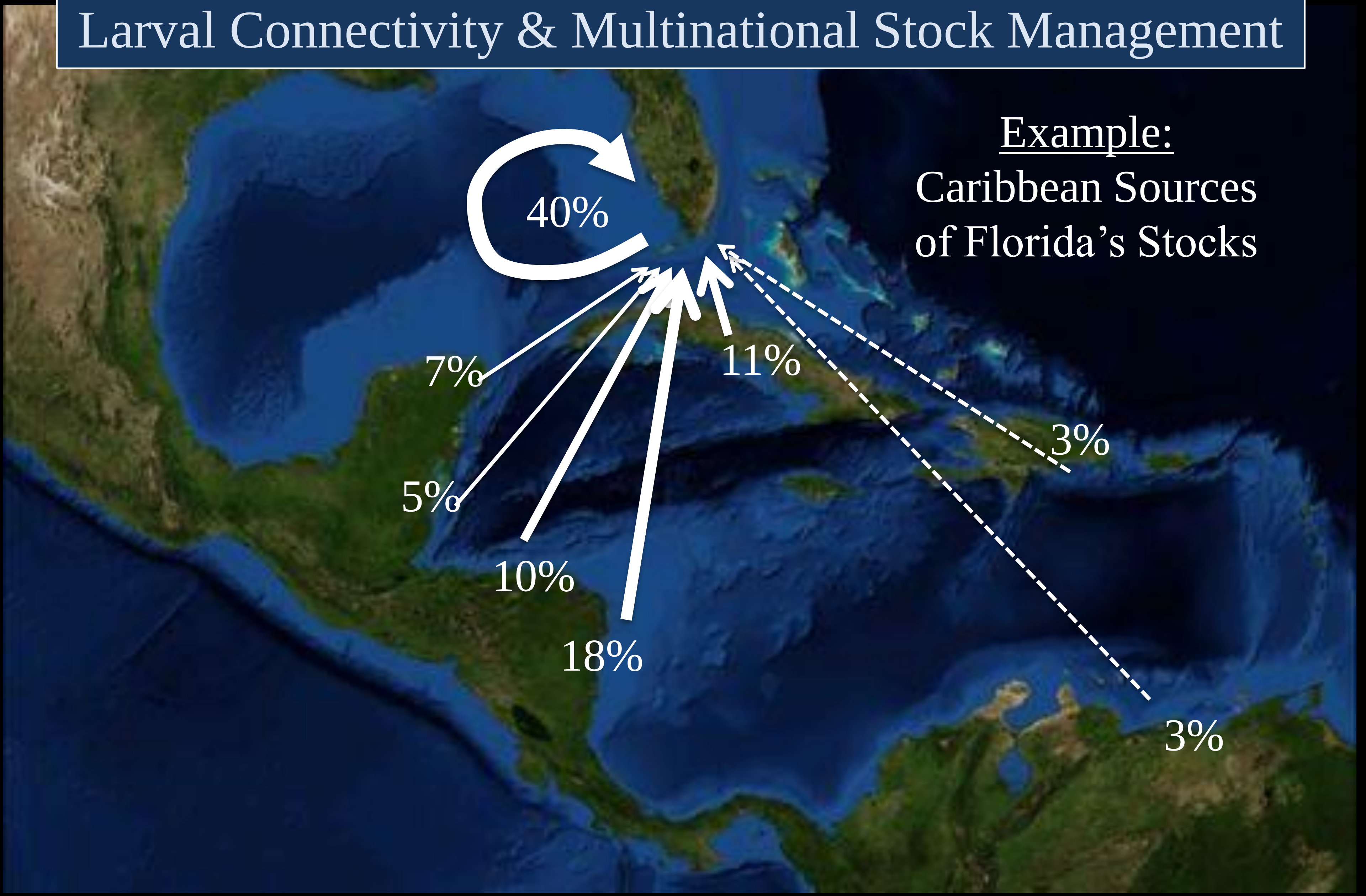


Other Implications for Management

OPEN ACCESS Freely available online — PLOS ONE

Larval Connectivity and the International Management of Fisheries

Andrew S. Kough[1]*, Claire B. Paris[1], Mark J. Butler IV[2]

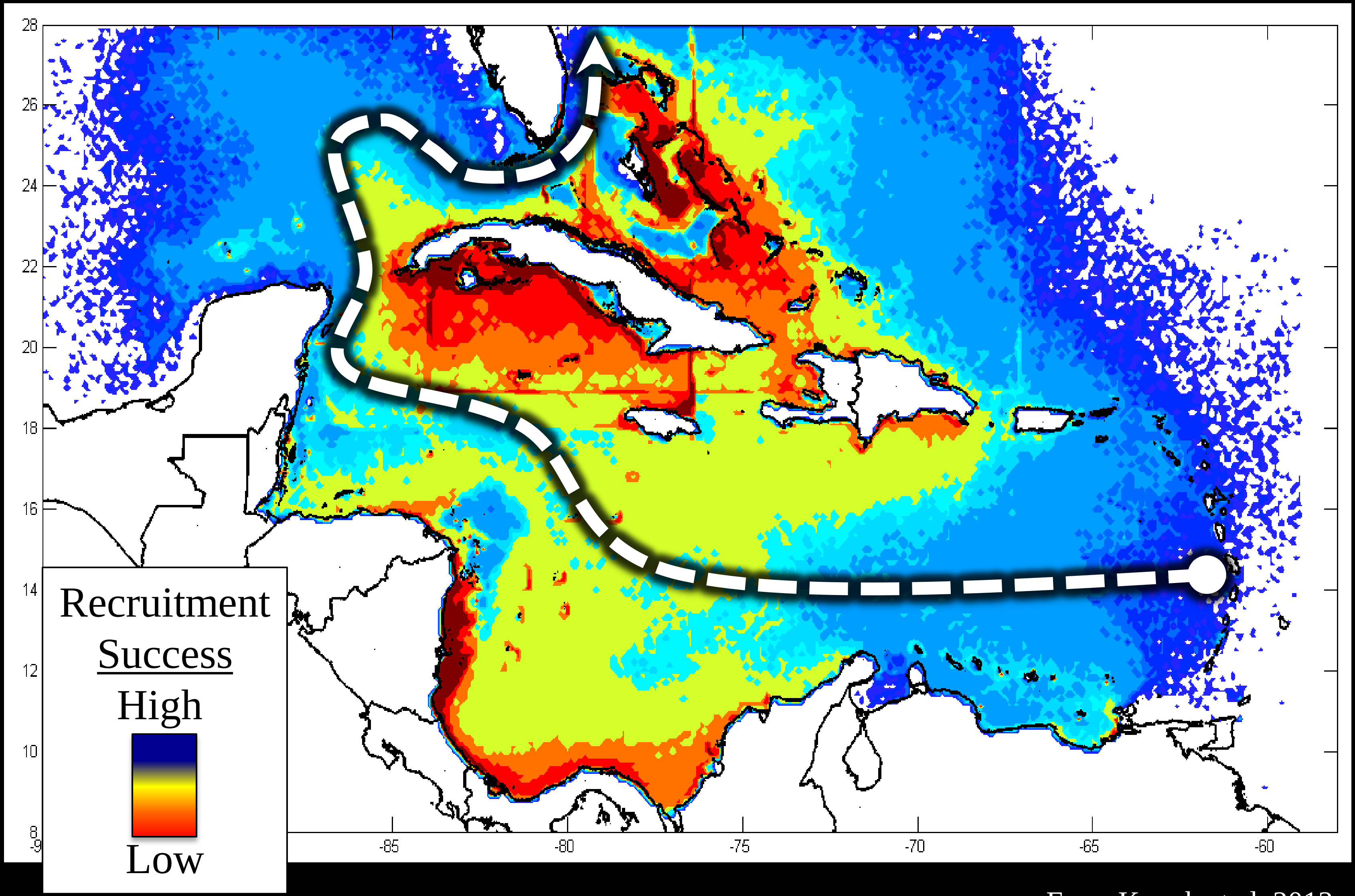
1 Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Miami, Florida, United States of America, **2** Department of Biological Sciences, Old Dominion University, Norfolk, Virginia, United States of America

PLOS ONE 2013

- More targeted international collaborative management, rather than uniform regulations
- Management based on “larval credits” (similar to carbon credits)
- Consideration of “pelagic MPAs” for larvae

Pelagic Larval Nurseries?

Logarithmic Probability Distribution of Successfully Recruiting Larvae in Model



From Kough et al. 2013

Caribbean-scale Management and the Rebuilding of Spiny Lobster Stocks:

- Larval Dispersal & Connectivity
  - Focus on Source Populations & Key Network Nodes
- Robust Approach to Enhancing Spawning Stocks
  - NTRs and Maximum Size Limits
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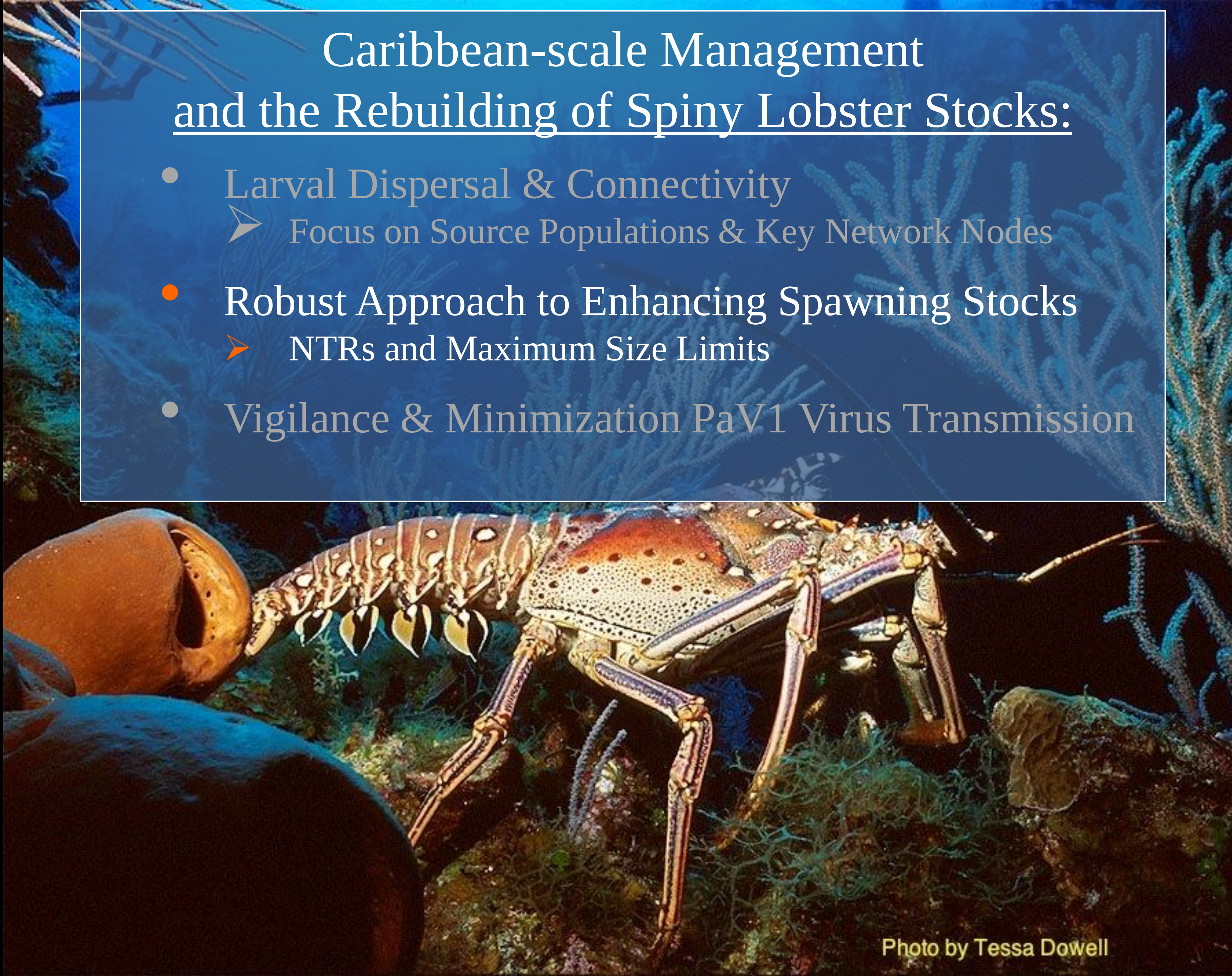
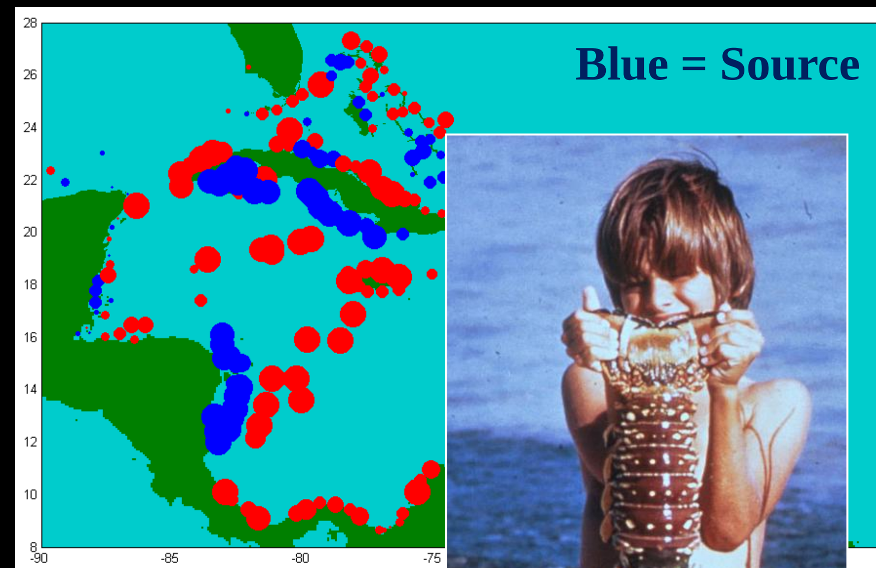


A Robust Approach to Enhancing Lobster Spawning Stocks

- Focus on rebuilding lobster spawning stocks in important source populations

- Healthy spawning stocks require both large females and large males, because:
  - Exponential female size: clutch size relationship
  - Large females produce multiple clutches per year
  - Sperm limitation without large males

- Demands management options that are scientifically sound, publically acceptable, & logistically feasible: a new option to consider



Integrating No-Take Reserves & Maximum Size Limits

Problem with No-Take Reserves Alone:

- Too few & too small to protect sufficient numbers of large reproductive lobsters to rebuild spawning stock biomass

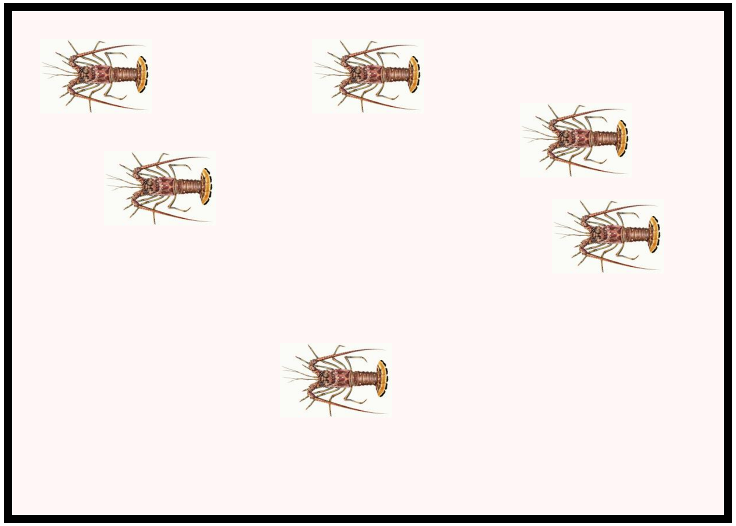
Problem with Maximum Size Limits Alone:

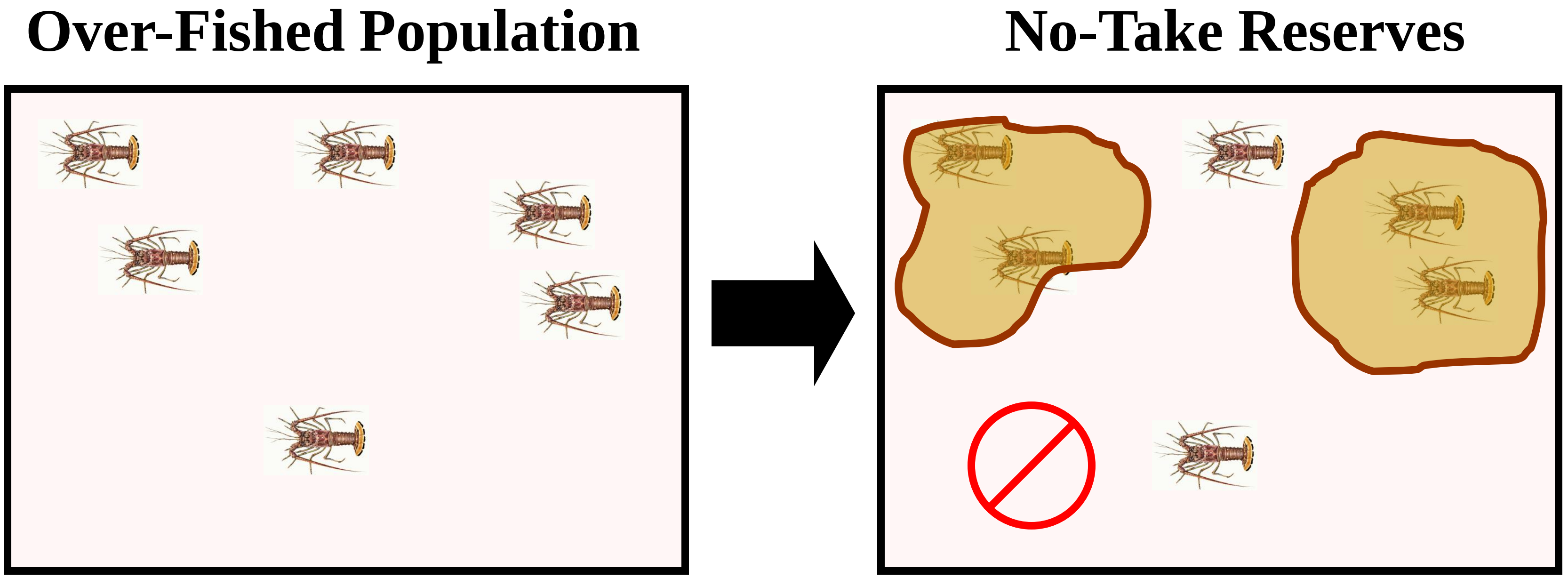
- Fishing mortality in most areas is too high to permit the build up of large reproductive lobsters and thus spawning stocks

But … No-Take Reserves & Maximum Size Limits Together:

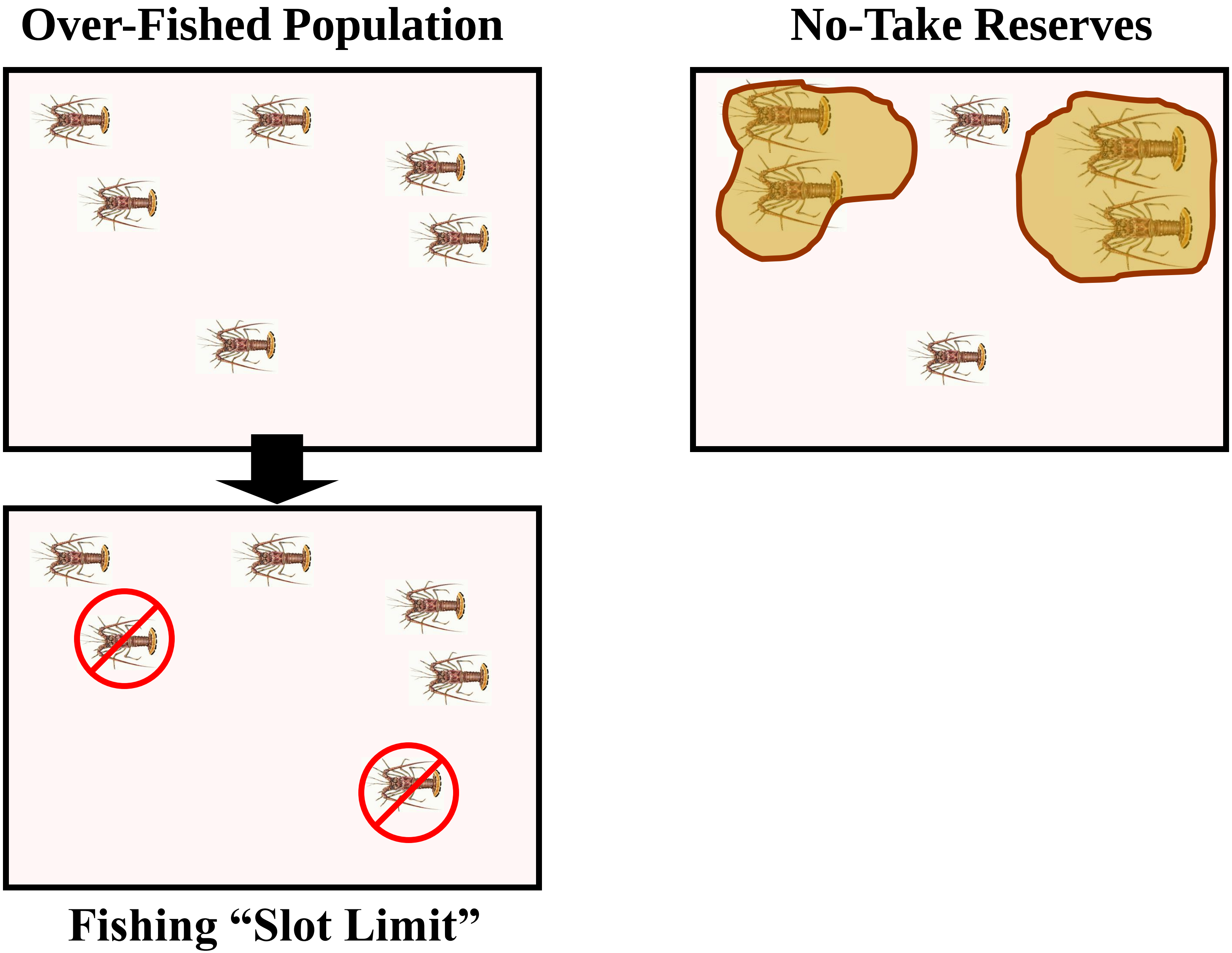
- Potentially permit the build-up of large lobsters within reserves and as they emigrate ("spill-over") into fished areas they are protected, rebuilding spawning stocks over larger area

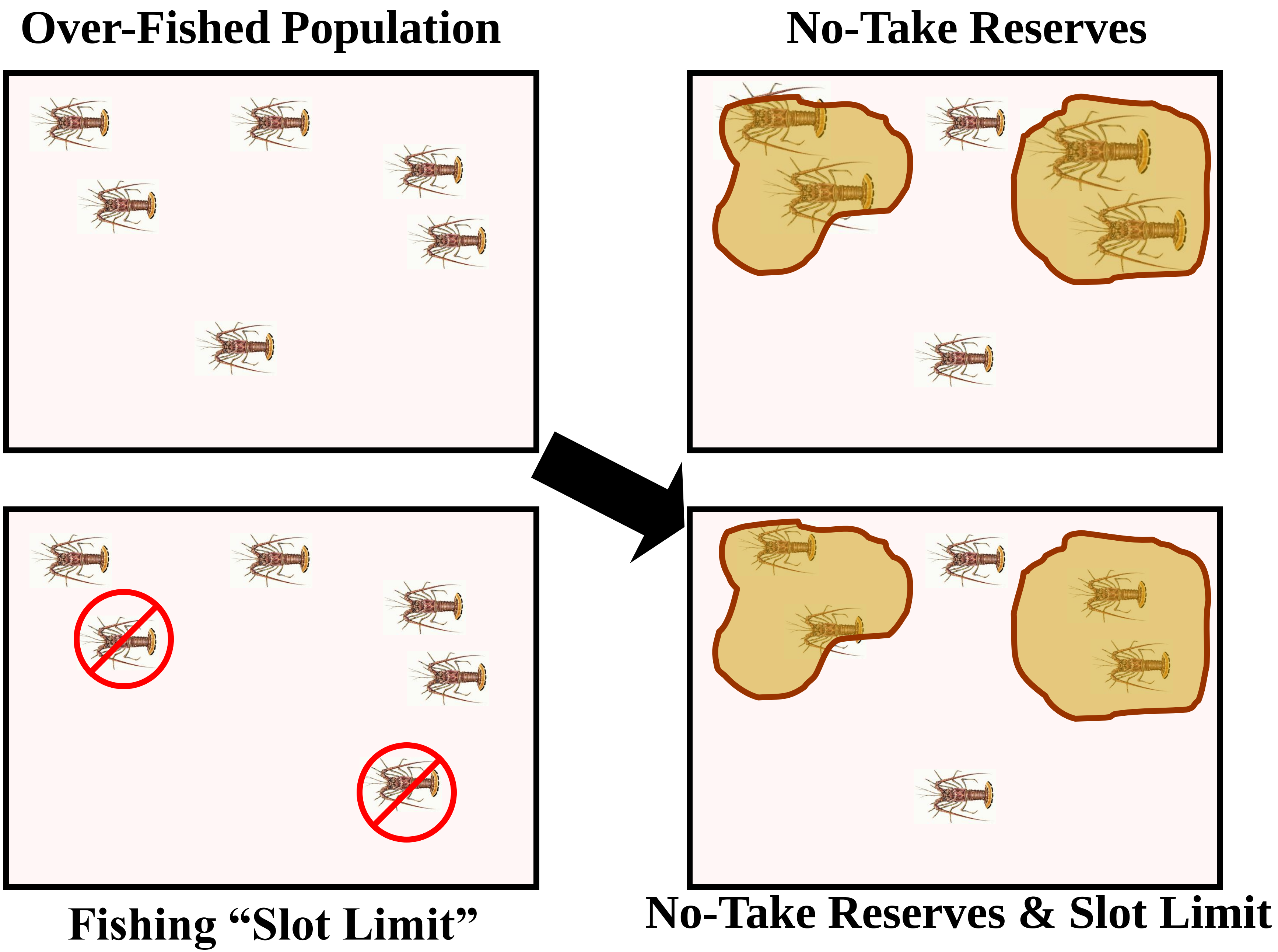
Over-Fished Population





Over-Fished Population
No-Take Reserves

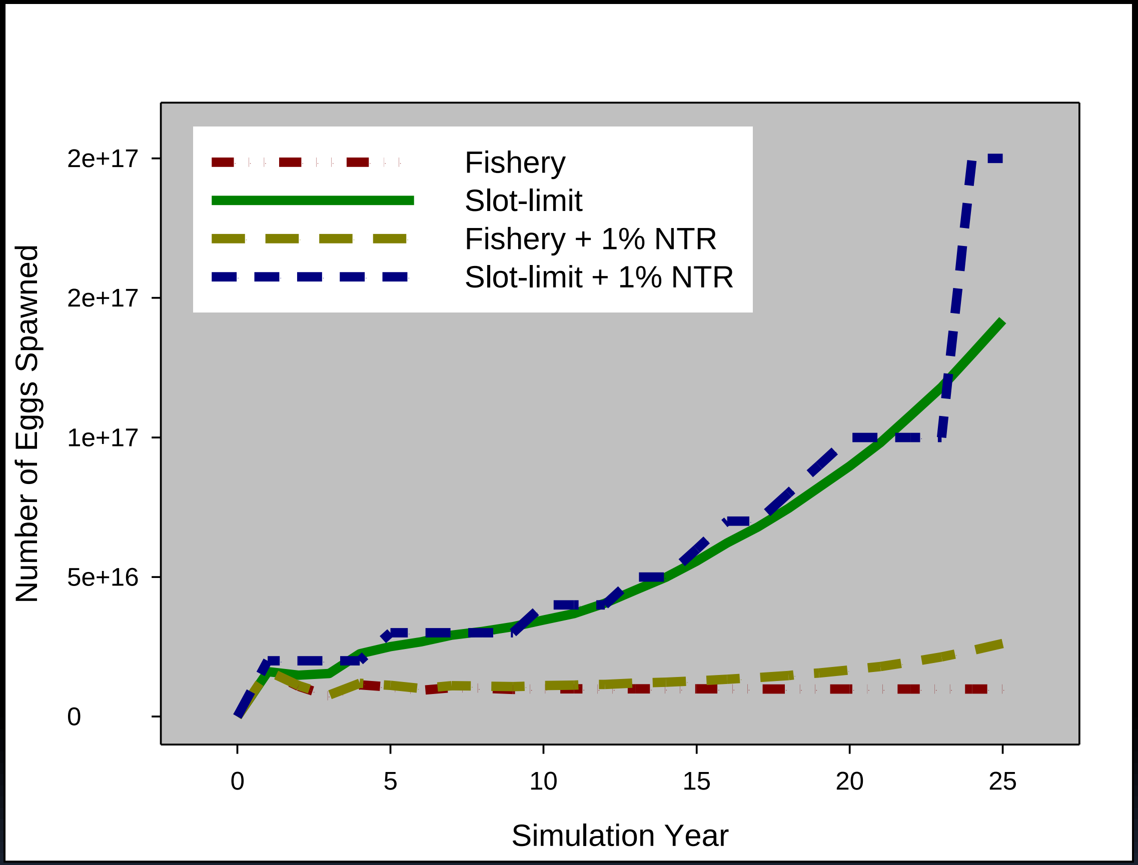

Over-Fished Population
No-Take Reserves
Fishing “Slot Limit”


Over-Fished Population
No-Take Reserves
Fishing “Slot Limit”
No-Take Reserves & Slot Limit

Preliminary Results: Linking NTRs with Slot Limits

- Used stage-based population model with data on fishing effort and lobster population dynamics in Florida

- Protection of just 1% of the area within NTRs along with a slot limit on landings (e.g., minimum & maximum size limit) increased egg production over other management strategies



Coral Reefs 2009

Ongoing Research for Rebuilding Spawning Stocks

Harvest Slot Limits & No-Take Reserves

- Please complete the electronic or paper versions of our survey and return it ASAP to me
- We will use that information and WECAF data in two ways:
  - Stage-based, metapopulation spatial model to evaluate the effectiveness of this approach under varying fishing pressures & no-take zone coverage
  - Analysis of manager and fisher acceptance of these potential regulations

OLD DOMINION UNIVERSITY

Survey on Harvest Slot Limits and No Take Fishing Areas for the Caribbean Spiny Lobster

Overview:

This survey is part of a PhD research project looking at the management of spiny lobster fisheries in the Caribbean. In particular, we are interested in the potential use of harvest slot limits and no take fishing areas as a way of increasing the number of large breeding lobsters and fisheries landings throughout the Caribbean. This survey is directed toward senior national fisheries personnel and information from this survey will be used to gauge perceptions around these two management tools. Please note for the purposes of this survey, 'harvest slot limit' refers to combined minimum and maximum size limits that create an intermediate catchable size.

Participation in this study is completely voluntary. Questions that you do not wish to answer may be skipped and you may quit at any time without penalty. Any information that you provide will be treated as confidential and you will not be personally identified in any reports. This research has no known risks and has been approved by the Old Dominion University, College of Sciences Committee for Review of Human Subjects.

We estimate that it will take 10-15 minutes to complete. Thank you for your participation. If you have any questions or concerns regarding this survey or would like to learn more about the project please contact:

Ms. Gaya Gnanalingam (ggnan001@odu.edu) or Dr. Mark Butler (mbutler@odu.edu).
Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23529 USA

Personal Information

Name: Country:

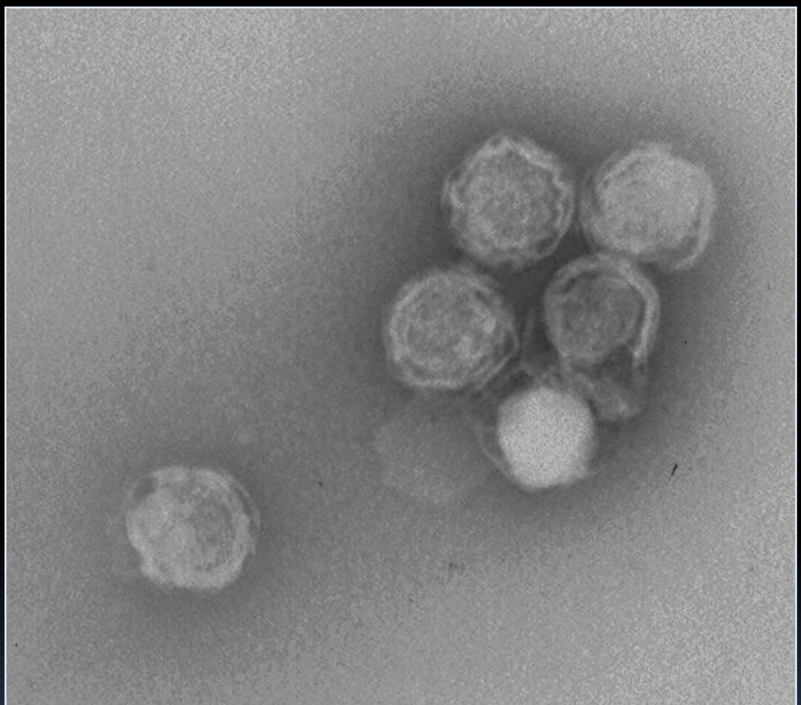
Position: Length of Time in Role:

Organisation:

Research Update:
A Lethal Viral Disease Infecting Caribbean Spiny Lobster

Caribbean Spiny Lobster

(Panulirus argus)

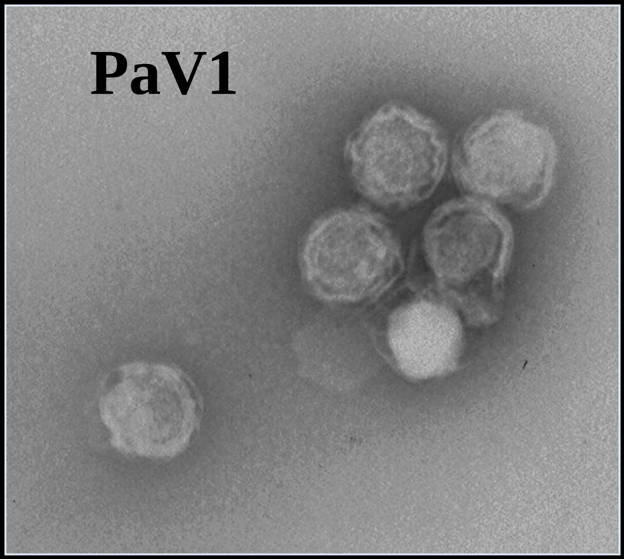


PaV1 virus

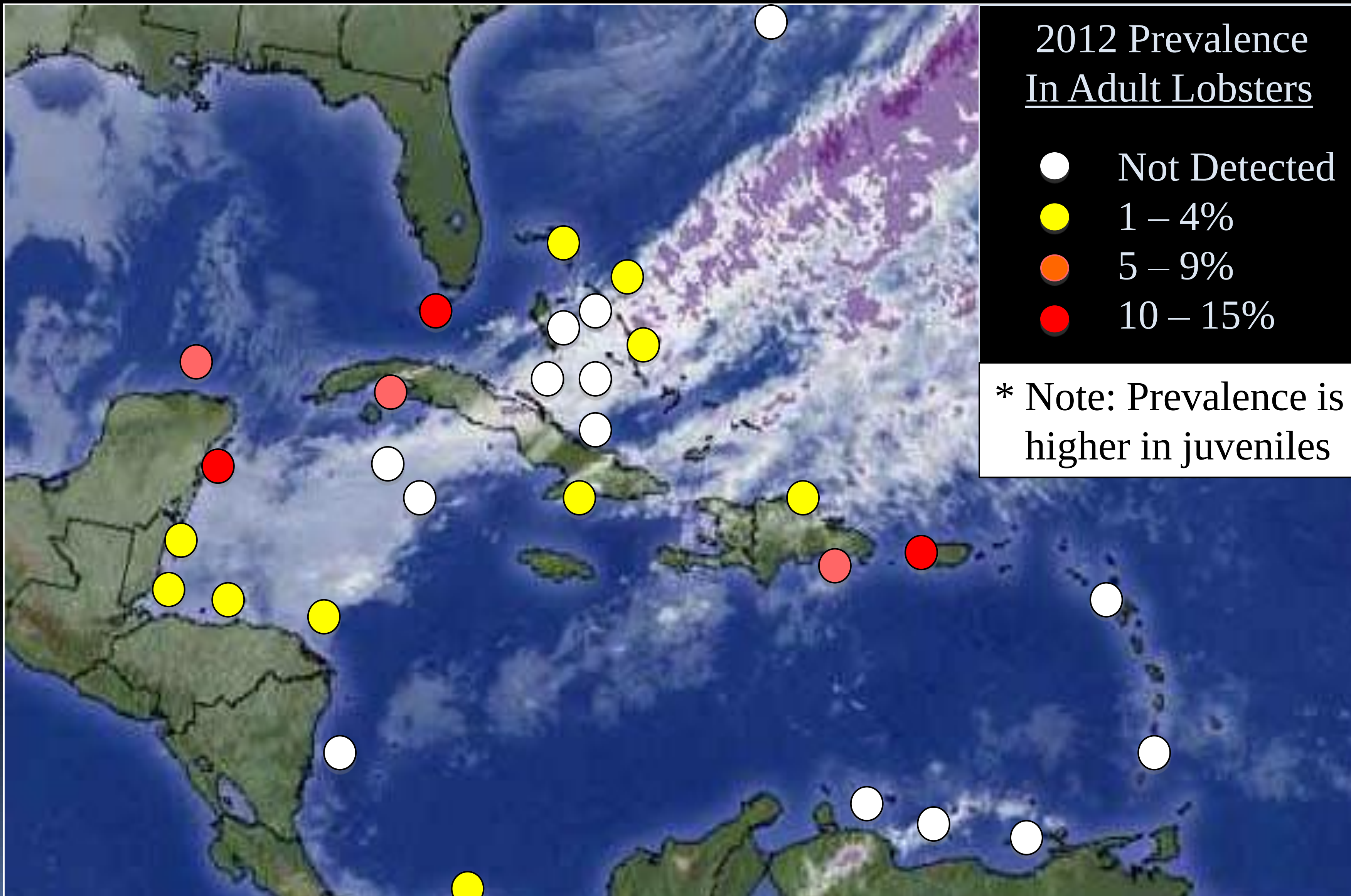
(*Panulirus argus* Virus 1)

PaV1 Viral Disease in Caribbean Spiny Lobster

- Discovered by our research team in 1999 in Florida; we developed histological & molecular diagnostics
- First virus known in any lobster
- Postlarvae & juveniles susceptible; lethal > 90% juveniles; adults are asymptomatic but may be carriers
- Transmitted through contact and in seawater over short distances
- Virus kills ~ 25% of new recruits in Florida; same elsewhere?
- Unlikely human health risk



Caribbean PaV1 Prevalence in Adult Lobsters*



Locally, the spread of the virus is reduced by "natural quarantine" - the avoidance of diseased lobsters by healthy lobsters

Behringer, Butler, & Shields. 2006. Nature
Behringer & Butler. 2010. Behav Ecol Sociobiol
Dolan, Butler & Shields. 2014. Ecology
Butler, Behringer, & etc. In press. PLOS ONE

Crustacean Fisheries Impacted by Disease

- American Clawed Lobster – shell disease
- Norway Clawed Lobster - *Hematodinium*
- American Blue Crab – *Hematodinium*
- European Edible Crab - *Hematodinium*
- King Crab – *Hematodinium*
- Snow Crab – *Hematodinium*
- Tanner Crab – *Hematodinium*
- Dungeness Crab - microsporidian
- Various Shrimps – White Spot

ETC., ETC., ETC…

Crustacean Fisheries Impacted by Disease

- Caribbean Spiny Lobster – PaV1?

PaV1 Disease & Lobster Management

- **Be Vigilant; need to monitor PaV1 distribution & prevalence**
  - molecular (PCR) screening of lobster tissues

- **Prohibit activities that potentially increase the spread of PaV1**
  - No transfer of live lobster among countries
  - No transport of live lobster among regions within countries
  - Limit the stock-piling of live lobsters prior to shipment or release
  - No discarding of diseased lobsters in the sea

- **Currently no national or international regulations, programs, or funding in place to safeguard against PaV1 outbreaks**

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Thank you for the opportunity
to speak with you at WECAFC.
Questions?