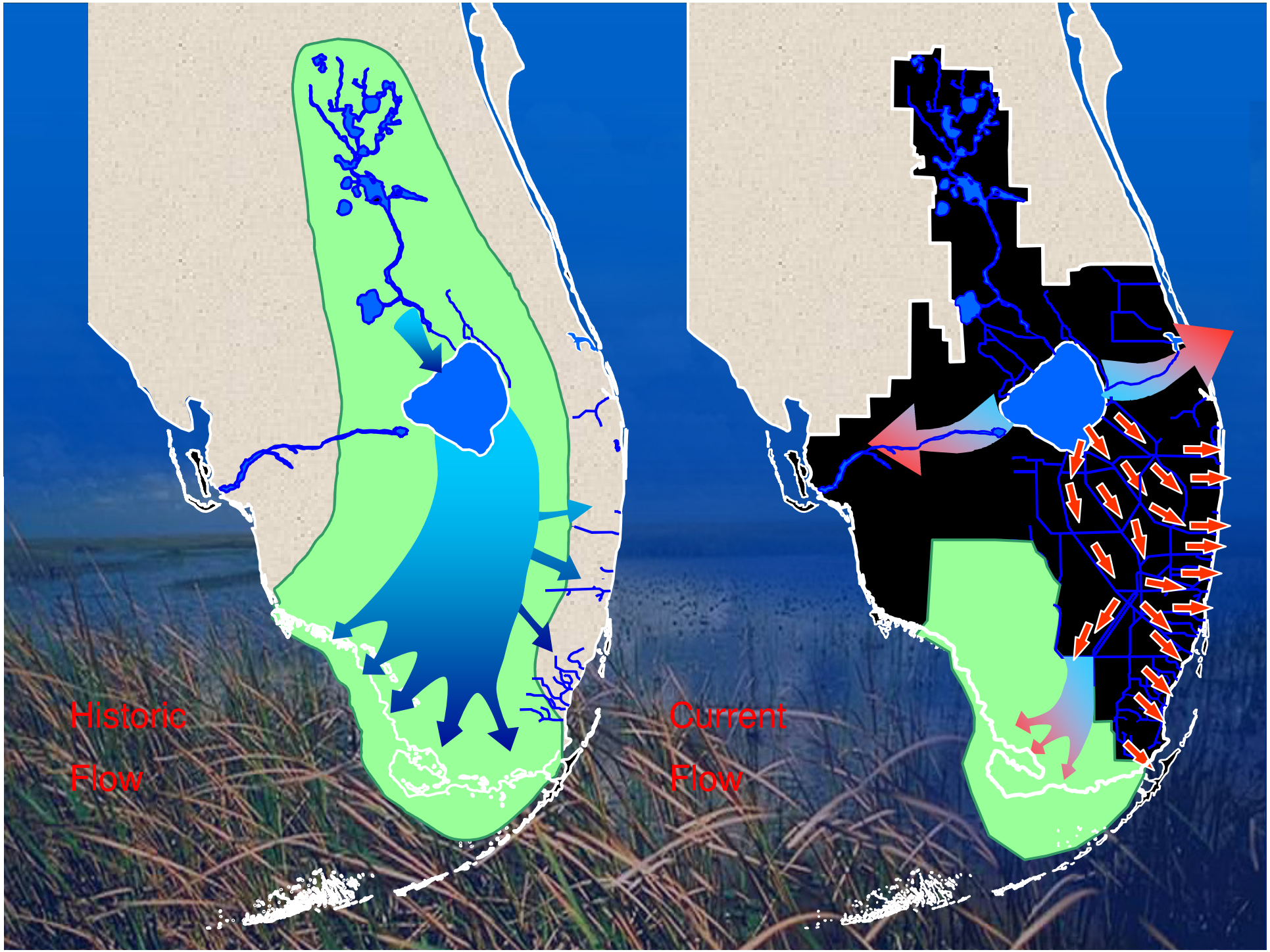
Eastern Oysters (*Crassostrea virginica*) as an Indicator for Restoration of Everglades Ecosystems

Aswani K. Volety, Michael Savarese, Greg Tolley, Lesli Haynes, Amanda Booth; Coastal Watershed Institute, Florida Gulf Coast University

William Arnold; Florida Wildlife Research Institute

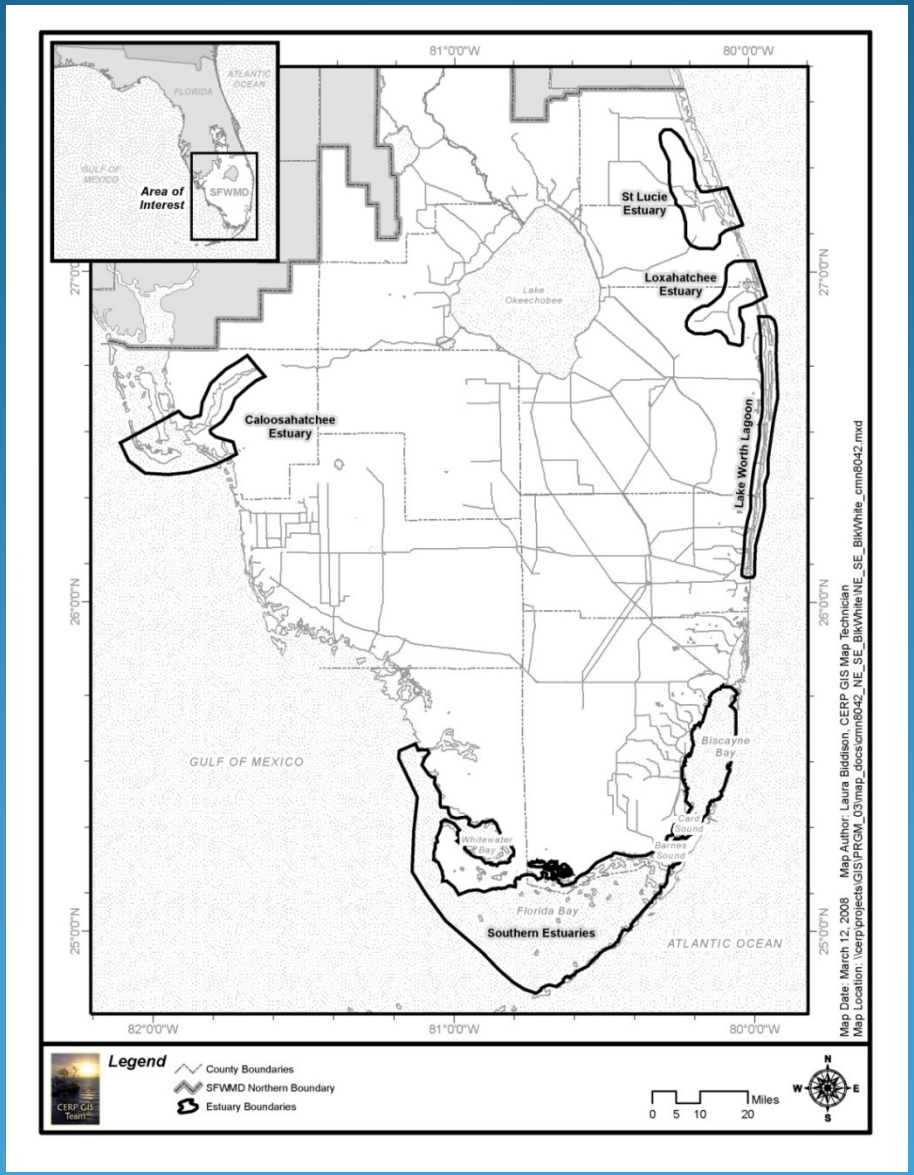
Patricia Goodman, Patricia Sime, Peter Doering; South Florida Water Management District

Florida Gulf Coast University


Historic
Flow
Current
Flow

Getting The Water Right

Northern Estuaries



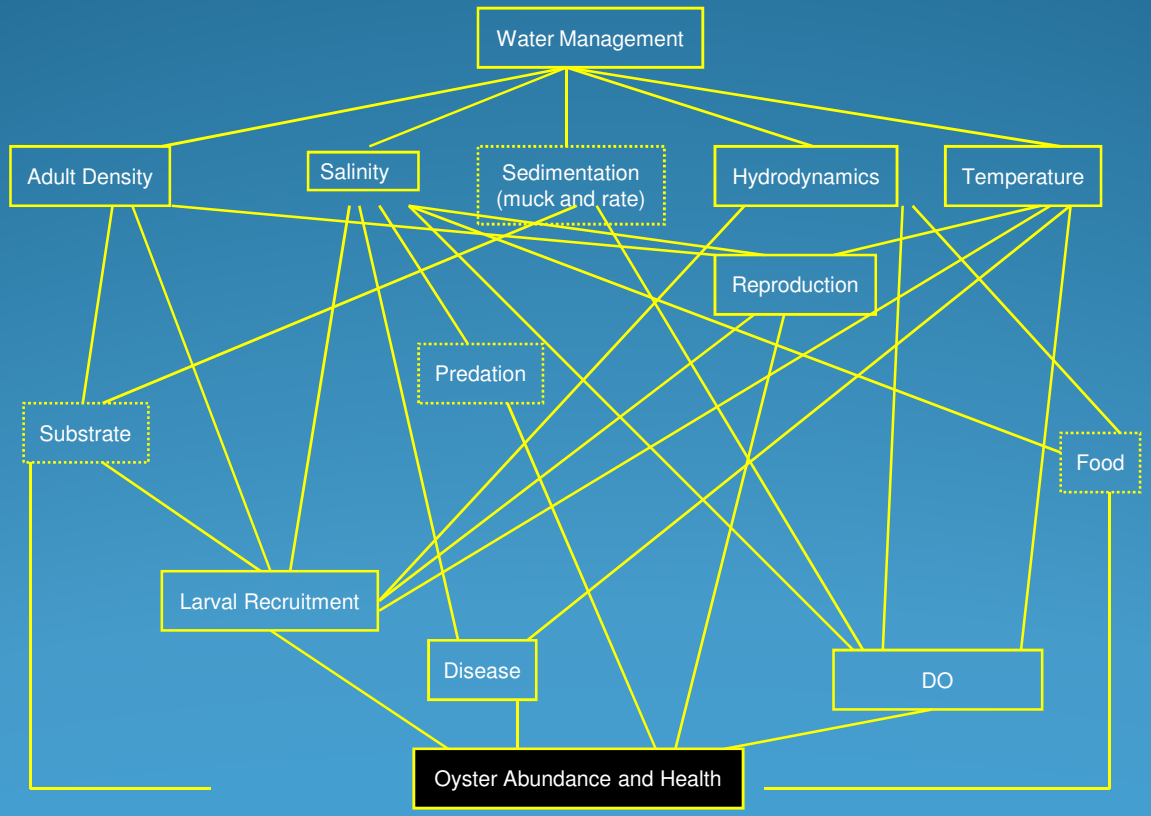
Applicability of the oyster indicator species to CERP

- Oyster life cycle is typical of other estuarine species.
- Oyster reefs provide habitat, shelter, and food for over 300 species.
- Oyster reefs contribute to benthic-pelagic coupling.
- Oysters are primary consumers.
- Productivity and community structure are directly linked to hydrology .
- Secondary habitat and food source for 2 and 3 carnivores.
- Oyster-reef survival, distribution, and aerial extent are key indicators (performance measures) in most RECOVER Conceptual Ecological Models and in CERP Interim Goals;

Advantages of the oyster indicator

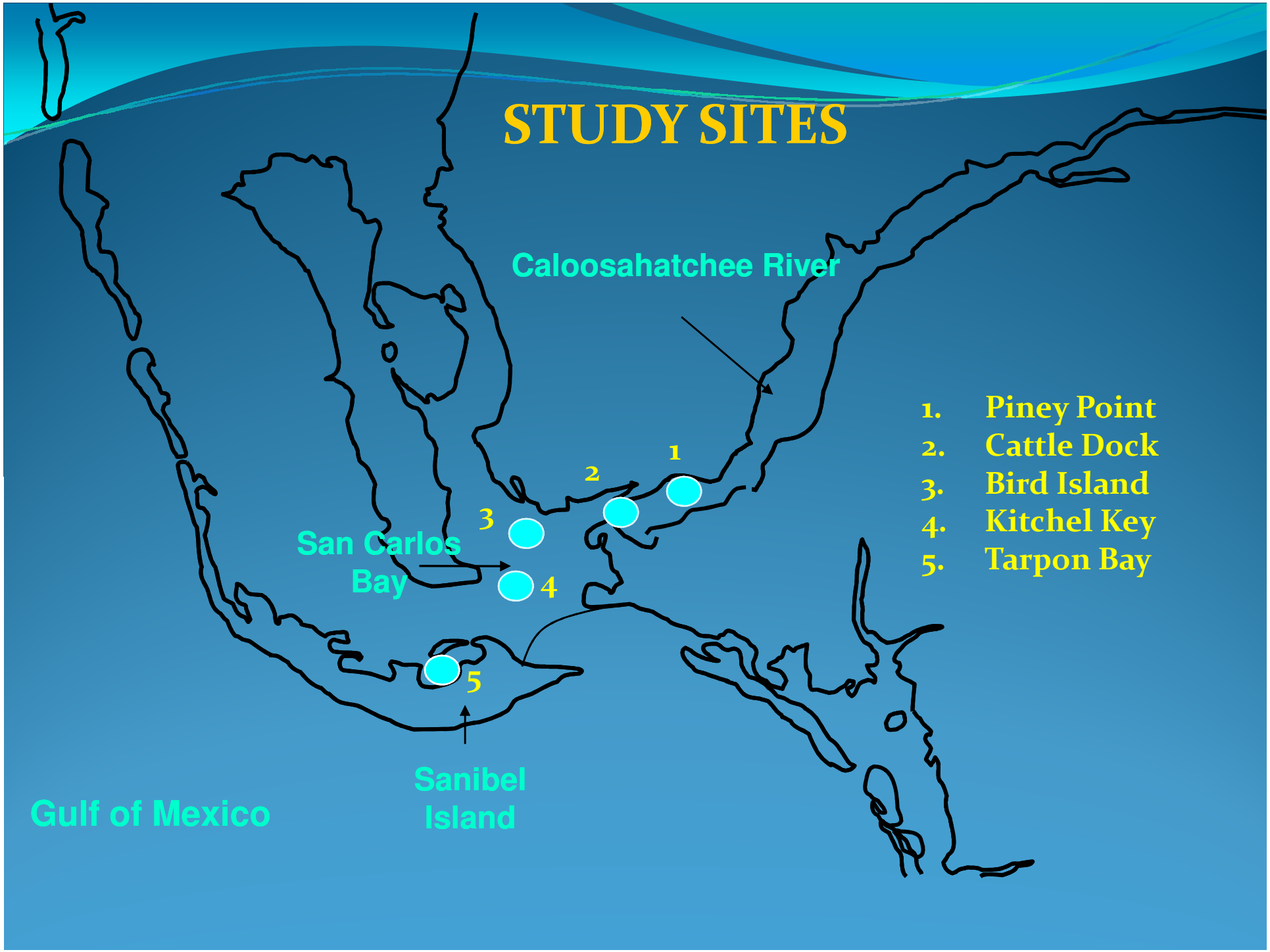
- The indicator is feasible to implement and is scientifically defensible
- The indicator is sensitive to System Drivers (Stressors)
- The indicator is integrative
- Goals and Performance measures are established in the RECOVER MAP for the indicator and the following metrics are being monitored

Conceptual model – Eastern oyster



Performance measures

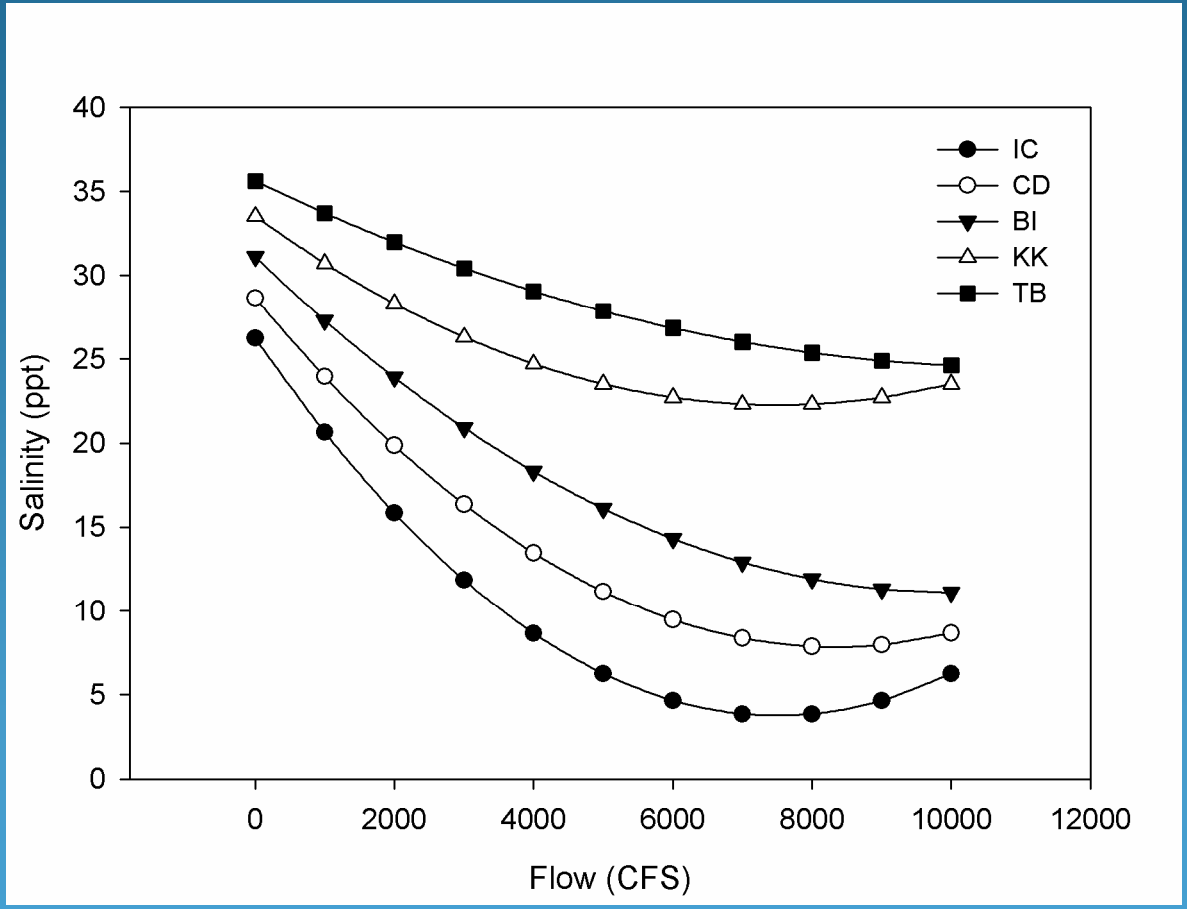
- Number of live oysters per square meter;
- Number of acres of oyster reefs;
- Condition index of live oysters;
- Disease prevalence and intensity of *Perkinsus marinus* in oysters;
- Larval / spat recruitment
- Reproduction.
- Growth and survival


STUDY SITES
Caloosahatchee River
1
2
3
4
5
San Carlos Bay
Sanibel Island
Gulf of Mexico
1. Piney Point
2. Cattle Dock
3. Bird Island
4. Kitchel Key
5. Tarpon Bay

Parameters measured

- Temperature, salinity, D. O.
- Flow (CFS; SFWMD)
- Condition Index
- *Perkinsus marinus* intensity and prevalence
- Gonadal Index
- Spat Recruitment
- Growth
- Survival (including predation)
- Living density

Salinity vs. Flow (1999-2007 data)



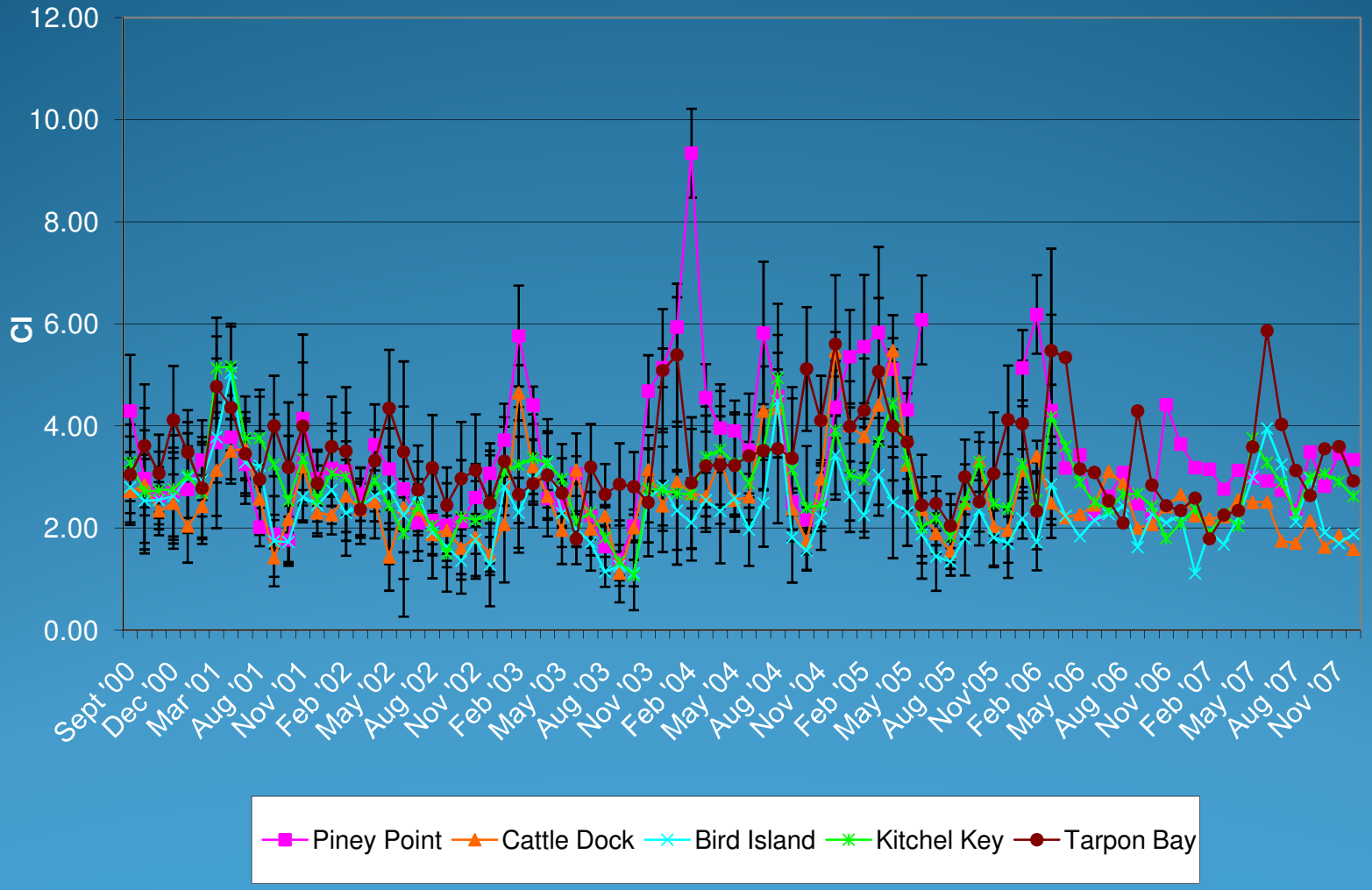
Condition Index

Quantify the ability of an area to support oyster growth (i.e., suitable water quality, food availability). CI quantifies the overall health.

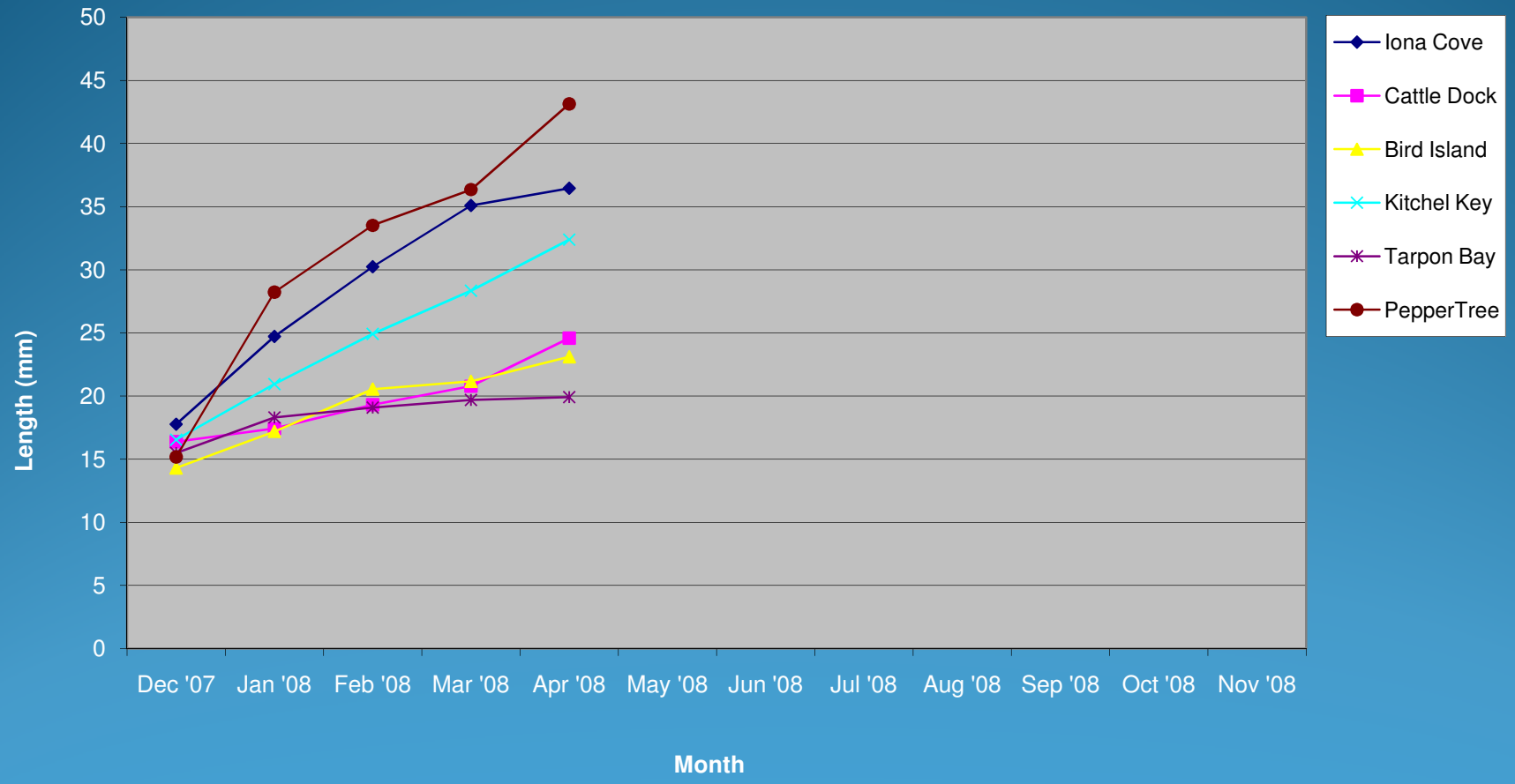
Growth and Survival

Juvenile survival and growth analyses yield results related to short-term survival and long term potential to support oyster reefs

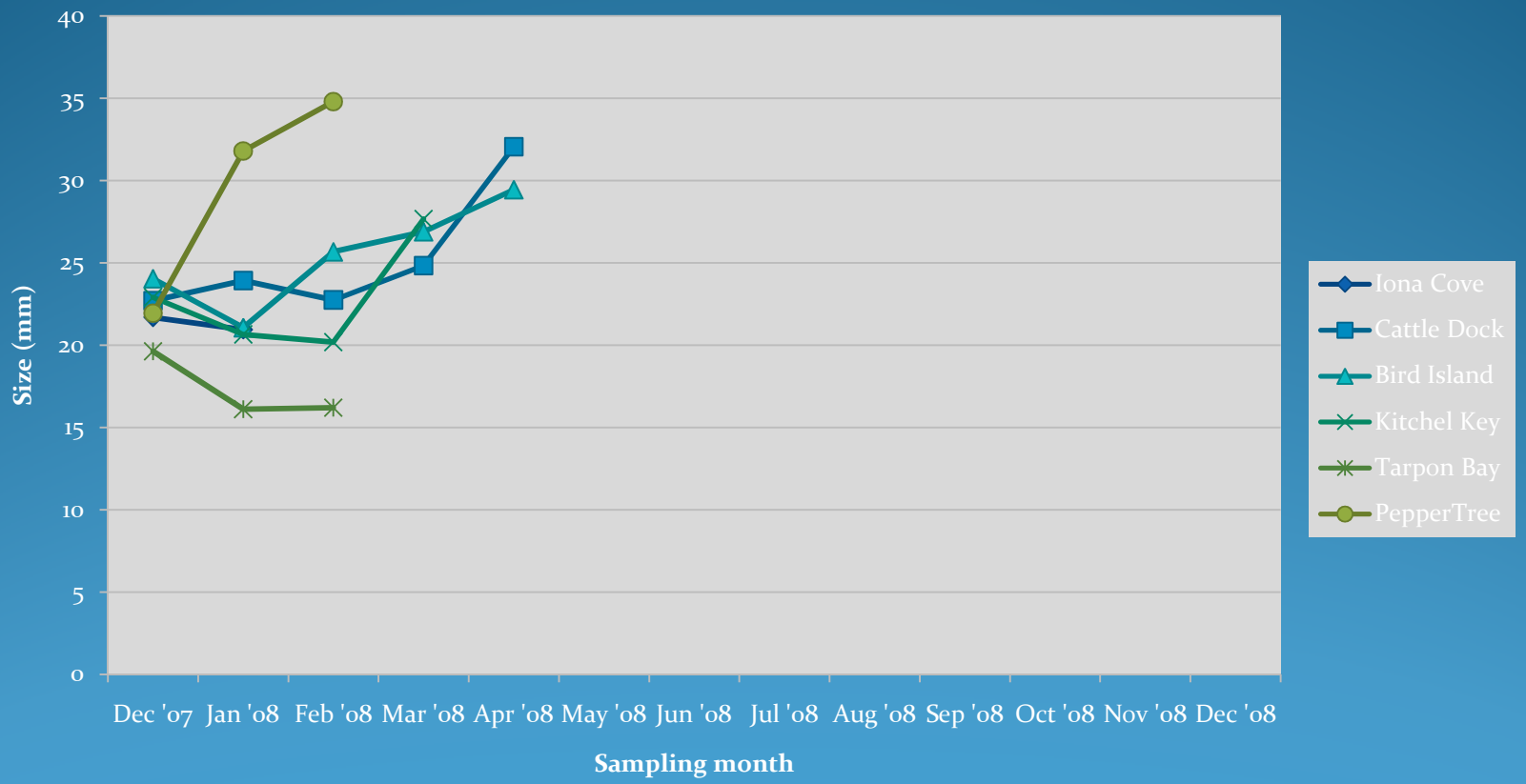
Condition Index



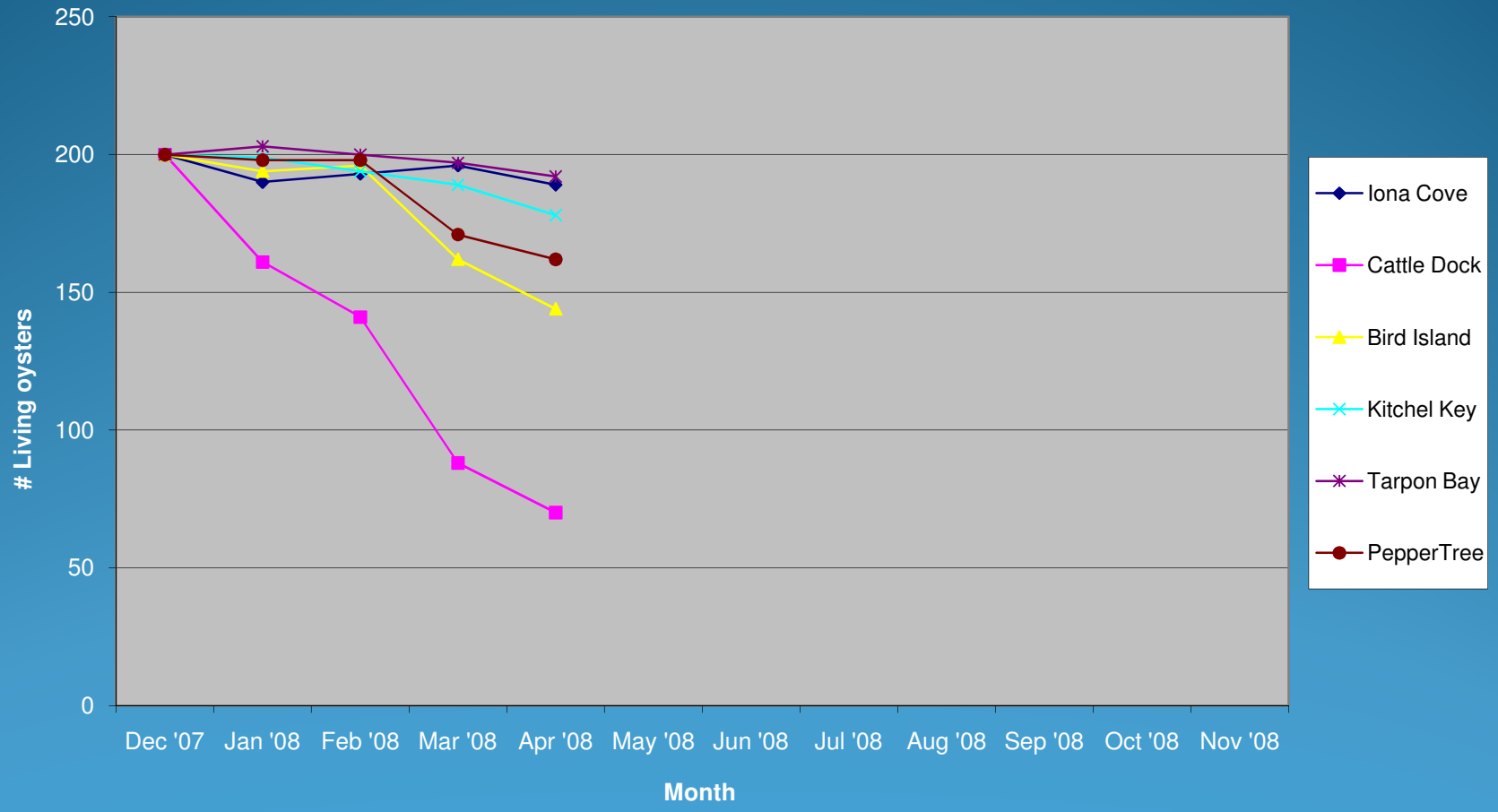
Juvenile Growth – closed bag



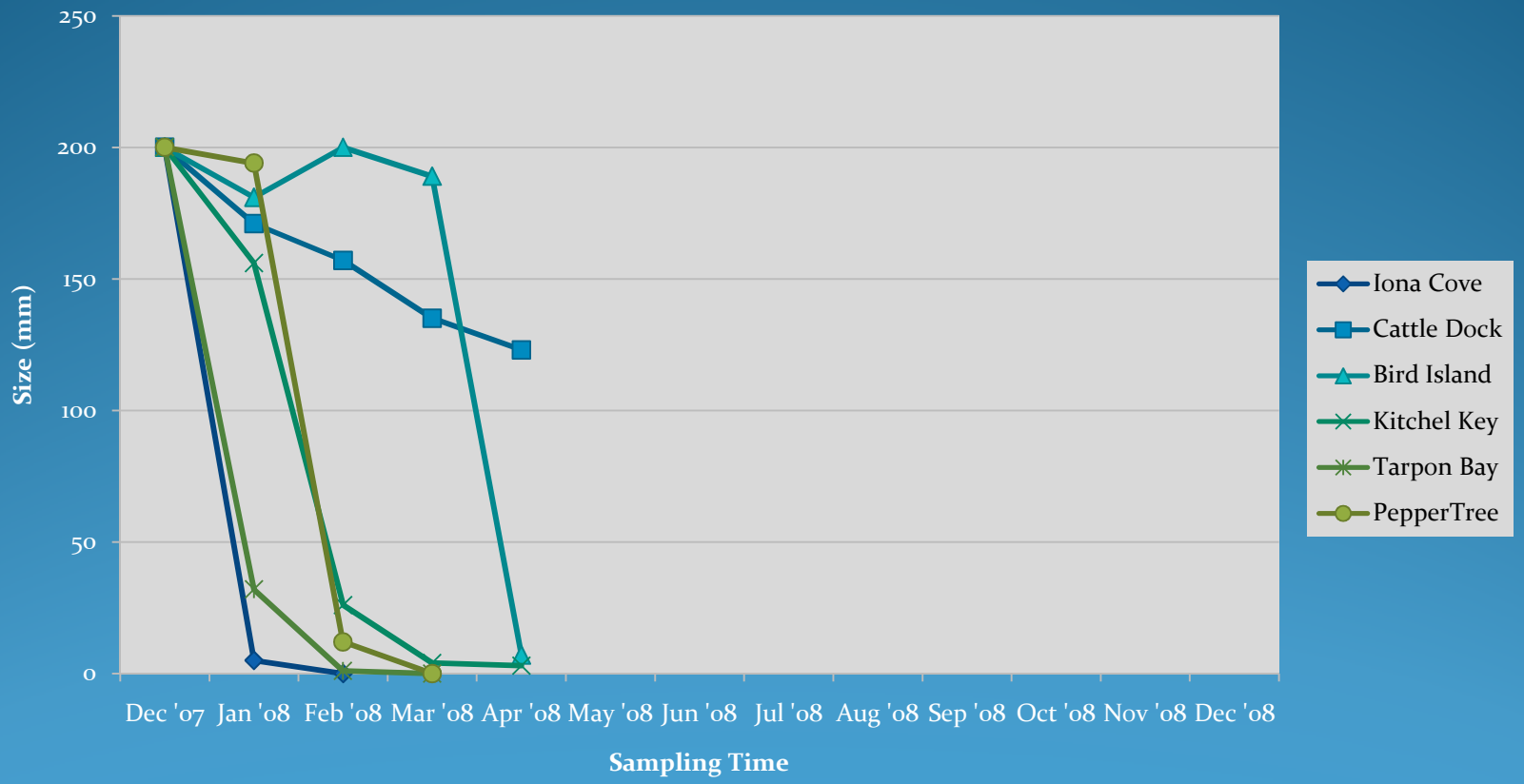
Juvenile growth - closed



Juvenile survival – closed bag

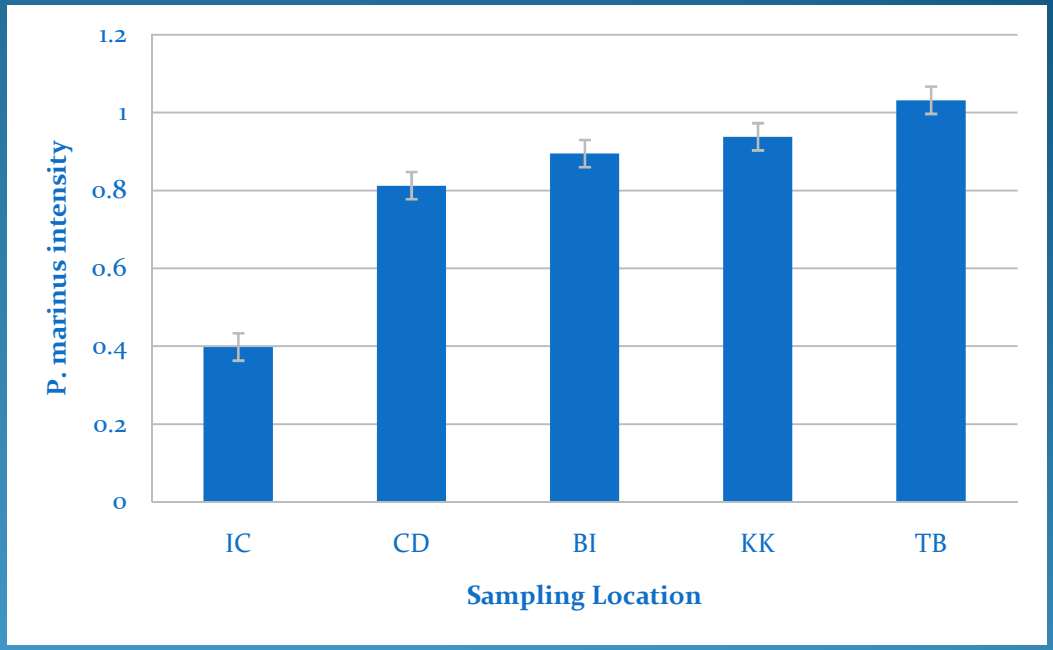


Juvenile survival – open bag

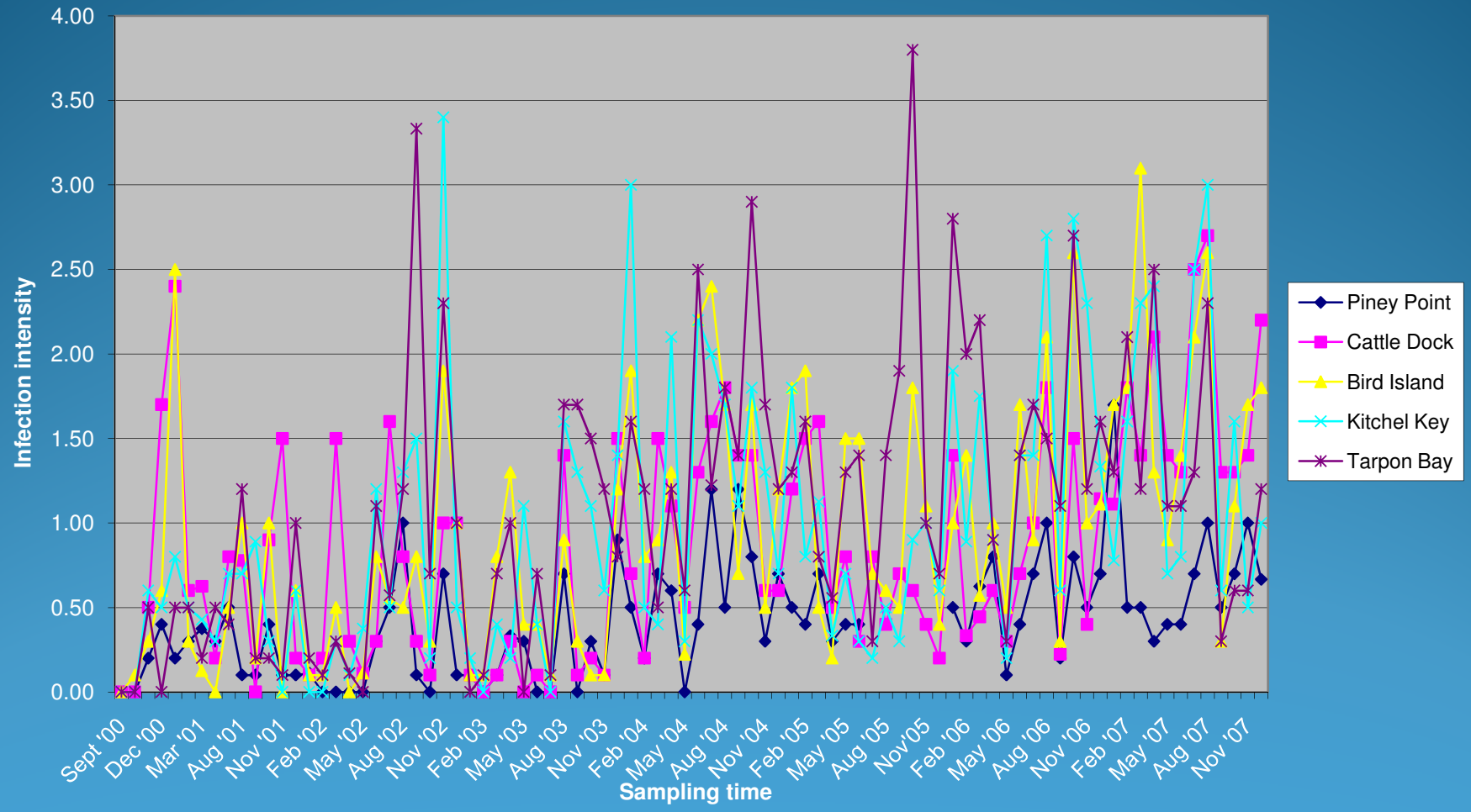


Survival: Disease

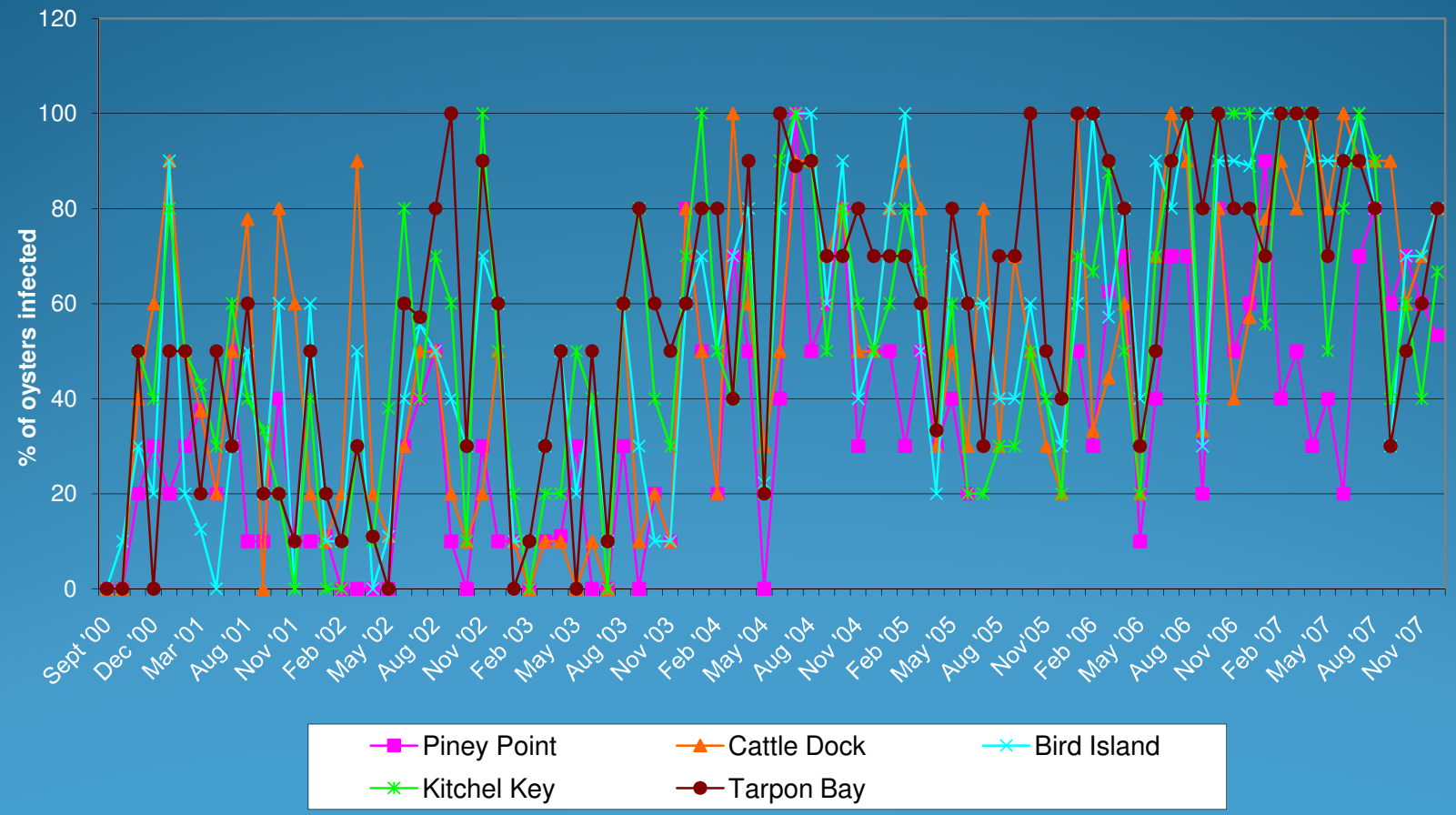
Juvenile survival and disease analyses yield results related to short-term survival



P. marinus intensity



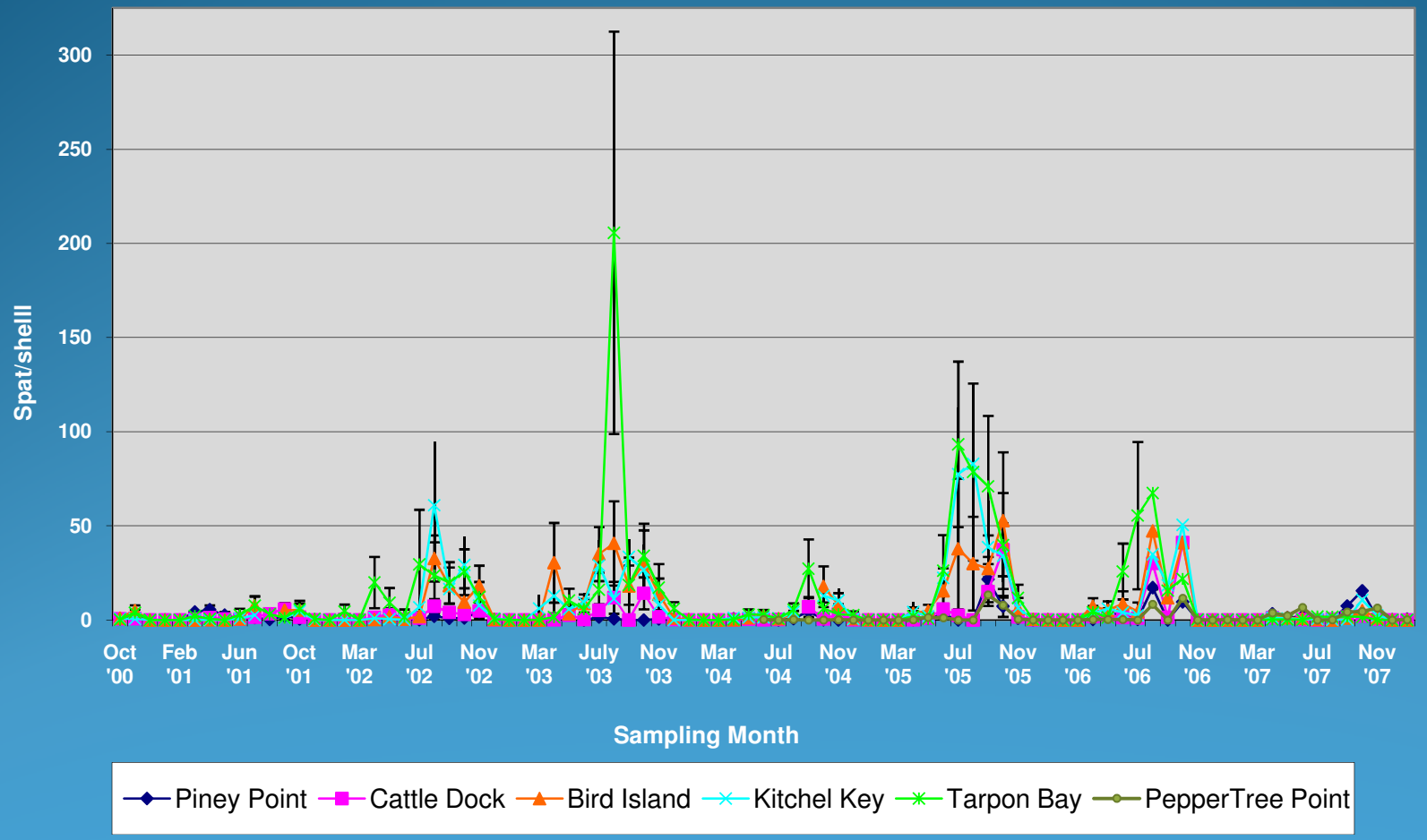
P. marinus prevalence



Reproduction

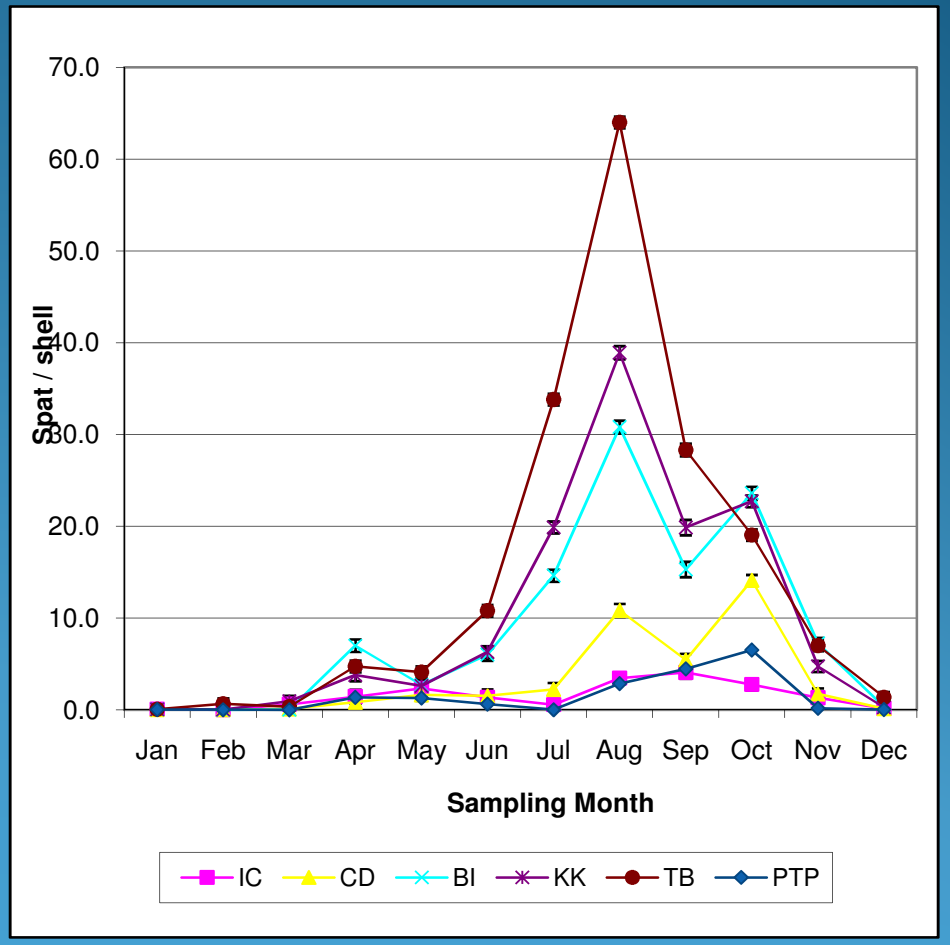
- Effects of water quality and substrate on long-term viability of reef
- Gonadal index: reproductive stage and qualitative estimate of fecundity
- Recruitment: estimates for next year class
- Management implications: timing of freshwater inflows

Spat Recruitment

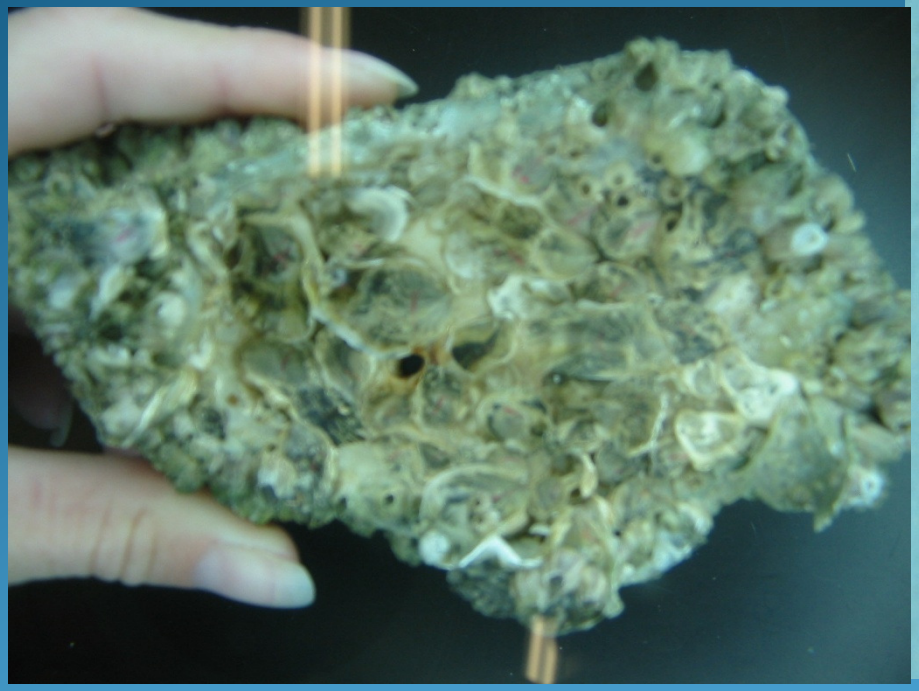


Spat Recruitment – Caloosahatchee River

- Oysters spawn between May – October.
- Large freshwater releases flush larvae downstream or create unfavorable salinity conditions.



Spat Recruitment



Reproduction

- Effects of water quality and substrate on long-term viability of reef
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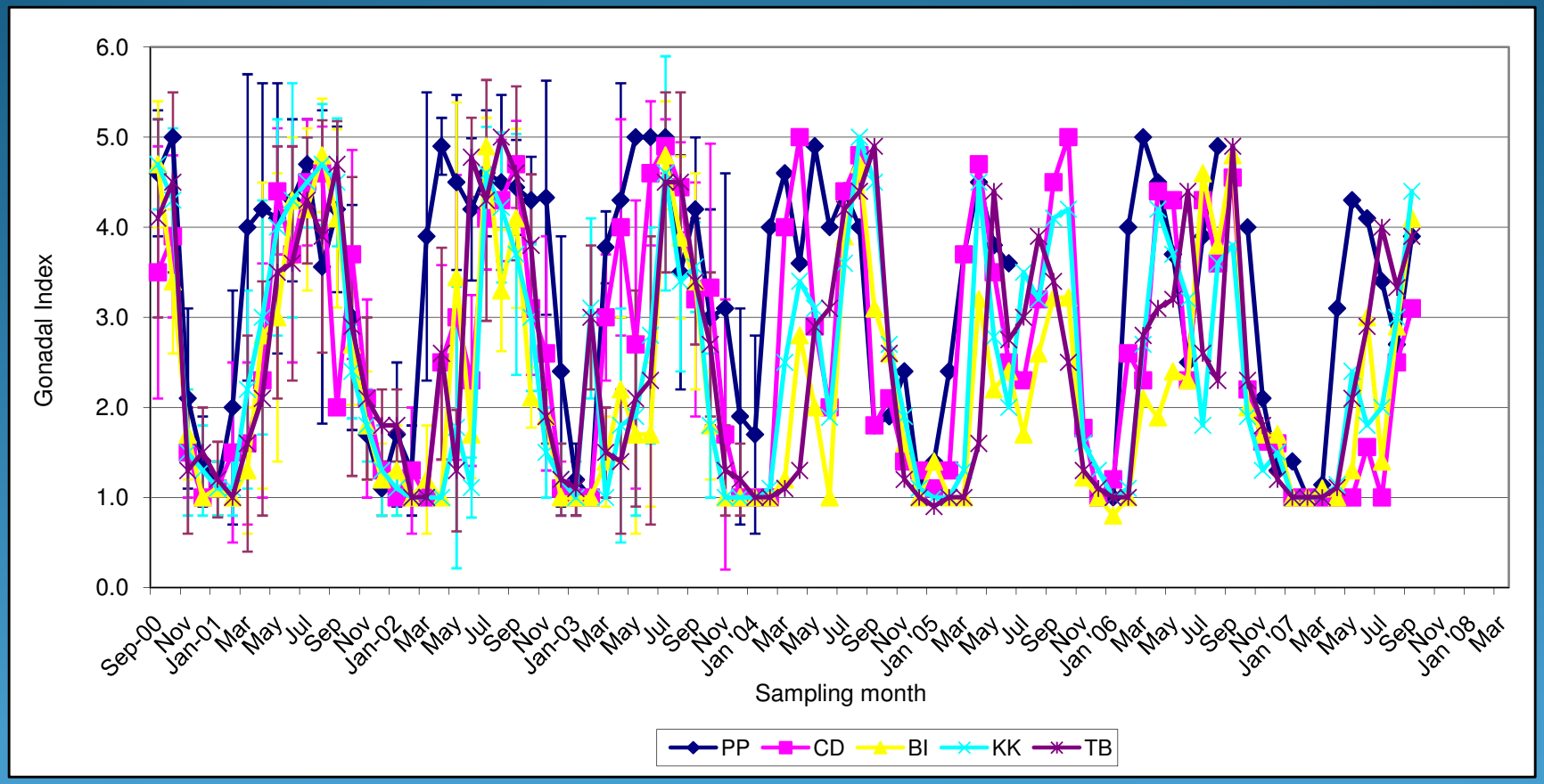
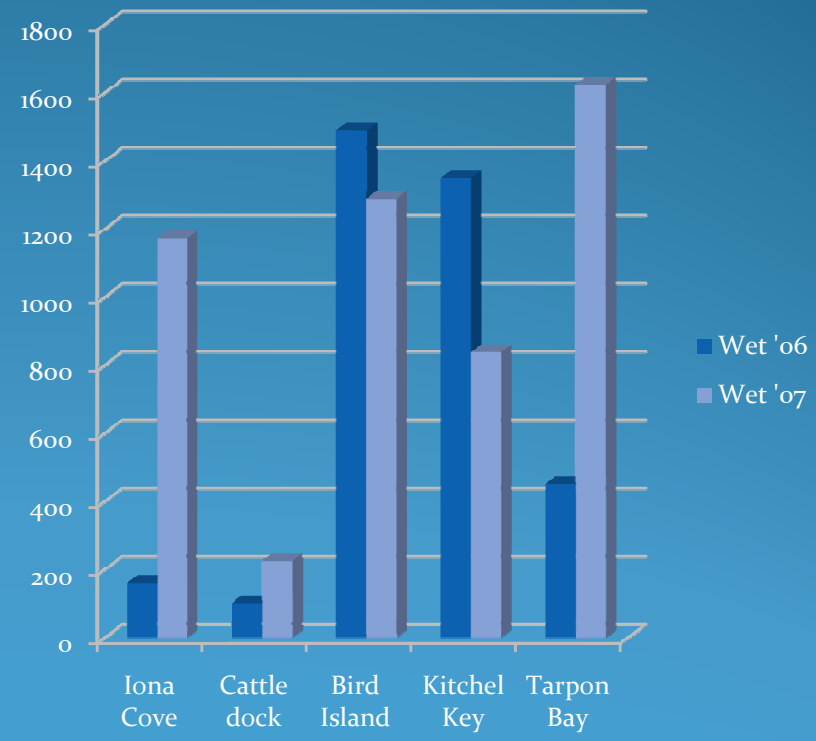
Gonadal Index



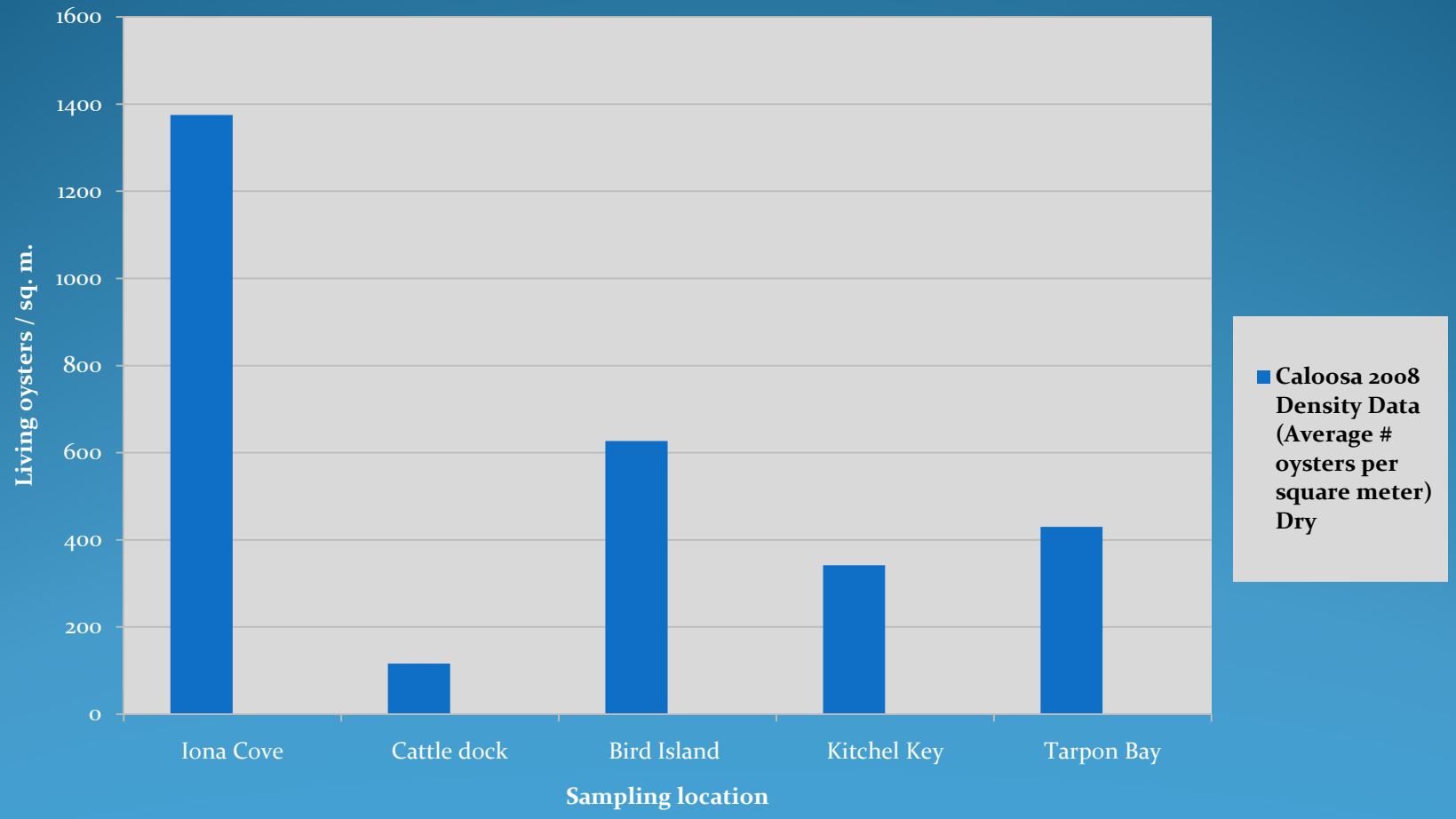
Living Density

Dry Season

Wet Season



Living Density (2008)



Approach

- What do we do with the data?
- The measurements we make will answer why and not just what is happening.
- Enables us to engage in adaptive management.
- In addition to scientific evaluation of the cause and effect relationship, we need to communicate the results with resource managers and public
- Stoplight Indicator (Success (Green), Caution (Yellow) and Failure (Red).
- Caloosahatchee Estuary as an example

Stoplight Indicator

- A communication tool that uses MAP performance measures to grade an estuary's response to anthropogenic or restoration inputs (Average of component score + trend score).
- Questions or decision rules are developed for each performance measure and translated as suitability curves.
- Suitability curve address:
  - (1) Have we reached the restoration target, and
  - (2) are we making progress toward targets?
- Finally, results are translated into a stoplight display (red, yellow, green)

Component Scores – Decision rules

1. What is the current living density, in individuals per meter square, of oysters in the Caloosahatchee estuary.

a.	0 - 200	Score: 0	Red
b.	> 200 - 800	Score: 0.5	Yellow
c.	> 800 - 4000	Score: 1.0	Green

2. What is the current condition index of the oysters in the Caloosahatchee estuary? Use the yearly average.

a.	0 – 1.5	Score: 0	Red
b.	> 1.5 – 3.0	Score: 0.5	Yellow
c.	> 3.0 - 6.0	Score: 1.0	Green

3. What is the current gonadal condition of oysters in the Caloosahatchee estuary? Use the yearly average.

a.	0 – 1	Score: 0	Red
b.	>1 - 2	Score: 0.5	Yellow
c.	>2 - 4	Score: 1	Green

Component Scores – decision rules

4. What is the current spat recruitment of oysters (spat / shell) in the Caloosahatchee estuary?

a. 0 - 5	Score: 0	Red
b. > 5 - 20	Score: 0.5	Yellow
c. > 20 – 200	Score: 1.0	Green

5. What is the current growth of juvenile oysters in mm/month?

a. 0 – 1	Score: 0	Red
b. > 1.0 - 2.5	Score: 0.5	Yellow
c. > 2.5 - 5	Score: 1.0	Green

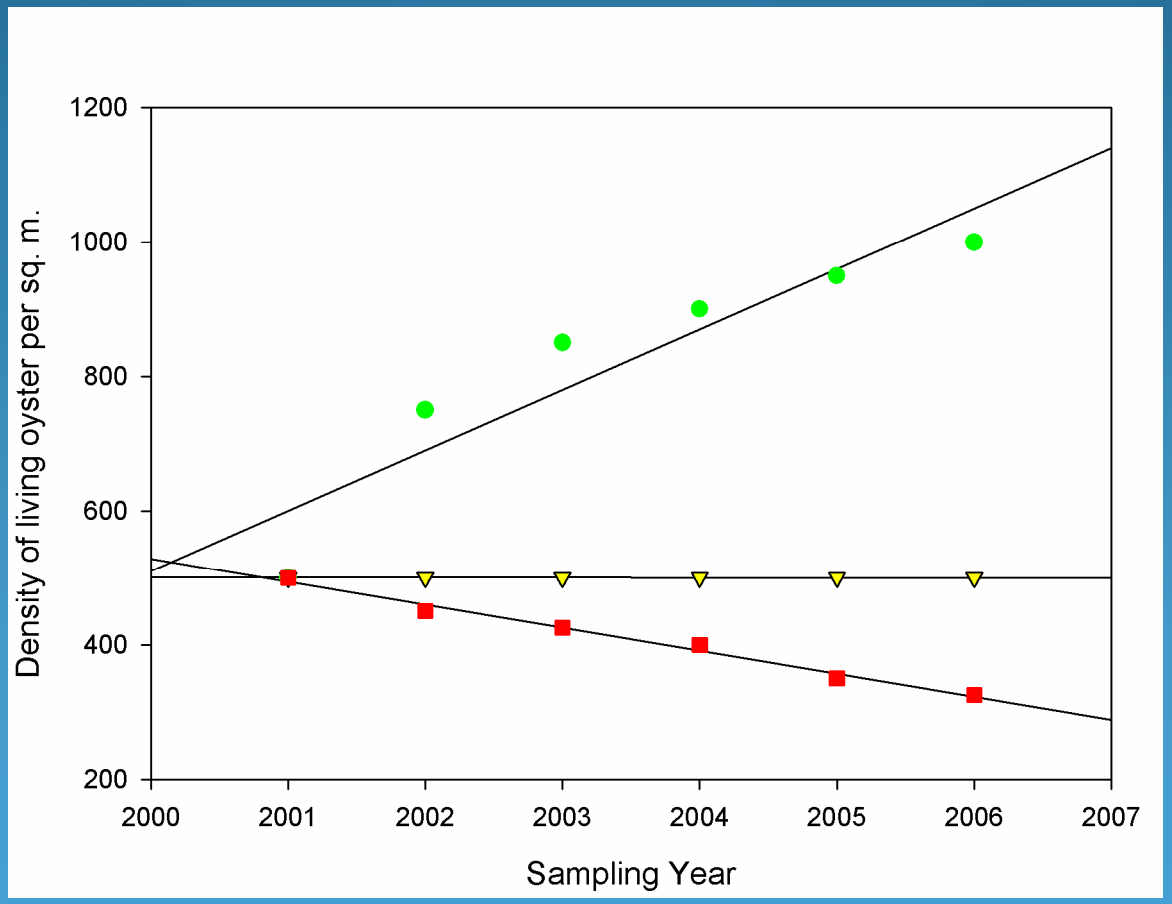
6. What is the prevalence of *Perkinsus marinus* (% of infected oysters) in oysters from the Caloosahatchee estuary? Use the yearly average.

a. 0 - 20	Score: 1	Green
b. > 20 – 50	Score: 0.5	Yellow
c. > 50 - 100	Score: 0	Red

7. What is the intensity of *Perkinsus marinus* (scale 0-5) in oysters from the Caloosahatchee estuary? Use the yearly average.

a. 0 - 1	Score: 1	Green
b. > 1 - 3	Score: 0.5	Yellow
c. > 3 – 5	Score: 0	Red

Trend score


1200
1000
800
600
400
200
Density of living oyster per sq. m.
2000
2001
2002
2003
2004
2005
2006
2007
Sampling Year

Trend score – decision rule

Trend question		
a. - slope	Score: 0	Red
b. no slope	Score: 0.5	Yellow
c. + slope	Score: 1.0	Green

Translation of component score and trend score into an index score

	Index Score	**Stoplight Color**
0.0-0.3	0	Red
>0.3-0.6	0.5	Yellow
>0.6-1.0	1.0	Green

Caloosahatchee estuary

Component	Parameter Value	Parameter Value Stoplight	Index Score	Trend	Trend Stop light	Trend score	Average Component Score	Component Stoplight
Oysters								
Living Density (per sq. m.)	1029		1			0.5	(1+0.5)/2=0.75	
Condition Index	2.96		0.5			0.5	(0.5+0.5)/2=0.5	
Spat Recruitment per shell	6.43		0.5	±		0.5	(0+0.5)/2=0.5	
Juvenile growth (mm/month)	2		0.5	±		0.5	(0.5+0.5)/2=0.5	
Perkinsus marinus prevalence	49.5		0.5	-		0	(0.5+0)/2=0.25	
Perkinsus marinus intensity	0.83		1	-		0	(1+0)/2=0.5	
Geometric mean of oyster component scores (0.75 x 0.5 x 0.5 x 0.5 x 0.25 x 0.5)$^{1/6}$ = 0.477								
Final Eastern Oyster Index score = 0.5								

St. Lucie Estuary

Component	Parameter Value	Parameter Value Stoplight	Index Score	Trend	Trend Stop Light	Trend Score	Average Component Score	Component Stoplight
Living Density (per sq. m.)	95.3		0	+		1	(1+0)/2=0.5	
Condition Index	2.7		0.5	±		0.5	(0.5+0.5)/2=0.5	
Spat Recruitment per shell	1.4		0	-		0	(0+0)/2=0	
Juvenile growth (mm/month)	3.2		1	±		0.5	(1+0.5)/2=0.75	
Perkinsus marinus prevalence	5.7		1	+		0	(1+0)/2=0.5	
Perkinsus marinus intensity	0.04		1	±		0.5	(1+0.5)/2=0.75	
Geometric mean of oyser component scores $(0.5*0.5*0*1*0.5*1)^{1/6}=0$								
Final Eastern Oyster Index Score = 0								

Loxahatchee Estuary

Component	Parameter Value	Parameter Value Stoplight	Index Score	Trend	Trend Stop Light	Trend Score	Average Component Score	Component Stoplight
Living Density (per sq. m.)	168		0	+		1	(1+0)/2=0.5	
Condition Index	3.1		1	±		0.5	(1+0.5)/2=0.75	
Spat Recruitment per shell	3.8		0	+		1	(0+1)/2=0.5	
Juvenile growth (mm/month)	2.8		1	±		0.5	(1+0.5)/2=0.75	
Perkinsus marinus prevalence	28.7		0.5	+		0	(0.5+0)/2=0.25	
Perkinsus marinus intensity	0.22		1	+		0	(1+0)/2=0.5	
Geometric mean of oyster component scores $(0.5*0.75*0.5*0.75*0.25*0.5)^{1/6}=0.03$								
Final Eastern Oyster Index Score = 0.03								

Lake Worth Lagoon

Component	Parameter Value	Parameter Value Stoplight	Index Score	Trend	Trend Stop Light	Trend Score	Average Component Score	Component Stoplight
Living Density (per sq. m.)	172		0	-		0	(0+0)/2=0	
Condition Index	3.4		1	+		1	(1+1)/2=1	
Spat Recruitment per shell	3.1		0	±		0.5	(0+0.5)/2=0.25	
Juvenile growth (mm/month)	2.5		0.5	±		0.5	(0.5+0.5)/2=0.5	
Perkinsus marinus prevalence	41.6		0.5	+		0	(0.5+0)/2=0.25	
Perkinsus marinus intensity	0.32		1	+		0	(1+0)/2=0.5	
Geometric mean of oyster component scores $(0*1*0.25*0.5*0.25*0.5)^{1/6}=0.0$								
Final Eastern Oyster Index Score = 0.0								

Summary

- Freshwater releases from Lake Okeechobee decrease salinities at the samples sites by 3-6 ppt.

- Juvenile oysters at upstream locations with intermediate salinities showed higher growth, with the exception of Cattle Dock, a location that receives output from Cape Coral (water quality?)

Summary

- Oysters in the Caloosahatchee Estuary spawn continuously between April – October.
- High levels of freshwater flows during summer (spawning) months may flush out oyster larvae or reduce salinities to unfavorable levels.
- High salinities in 2007 resulted in poor spat recruitment and higher disease levels (as well as low survival due to predation?)

Summary

- **Flows between 500 – 3000 CFS from Lake Okeechobee will result in optimum salinities at sampling locations (15 – 25 ppt).**
- **Stoplight indicator communication toll was developed. Can be adapted for other estuaries**
- **Caloosahatchee estuary is at "Caution"**

Future directions

- Integration of the data with HSI
- Inclusion of other factors influencing oyster responses
- Newer techniques that will enhance the sample size and power of analyses
- Addition / changing sampling locations
- Looking at why the indicator species is responding and not what it is doing.
- Adaptive management

Acknowledgements

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- **Technical / Field Help**: Lesli Haynes, Amanda Bridges, Erin Dykes and numerous graduate and undergraduate students.