Life History of the Caribbean Spiny Lobster *Panulirus argus*

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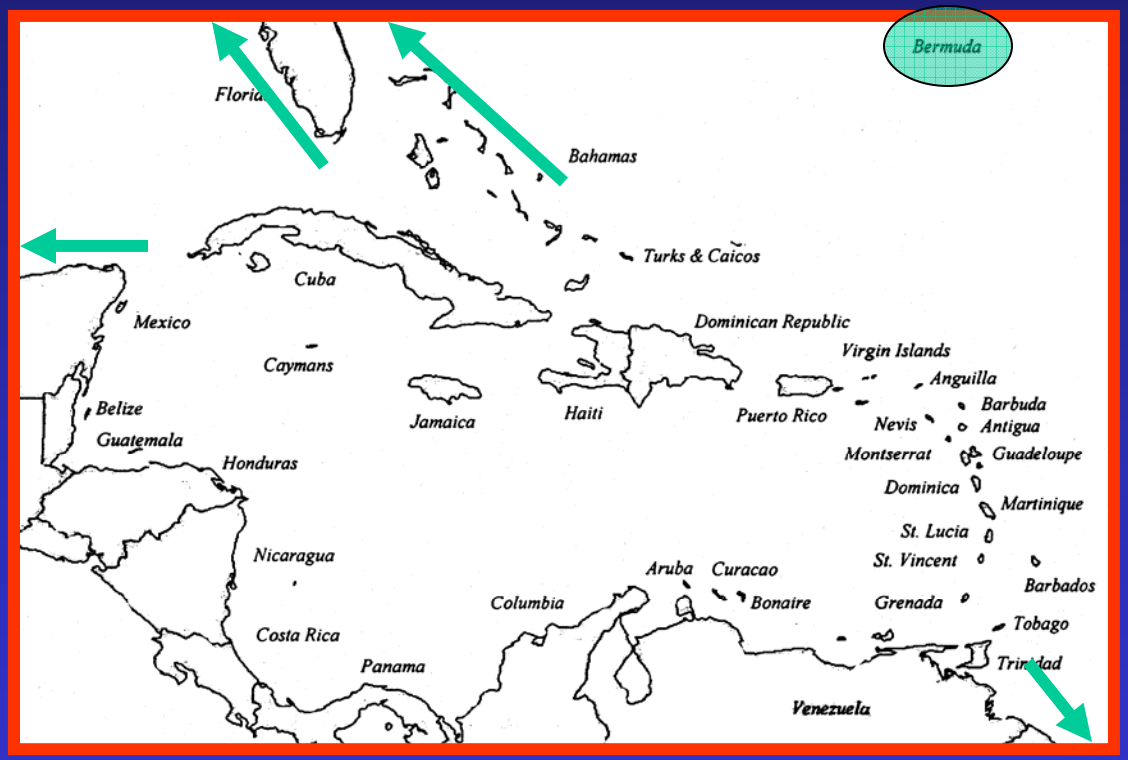
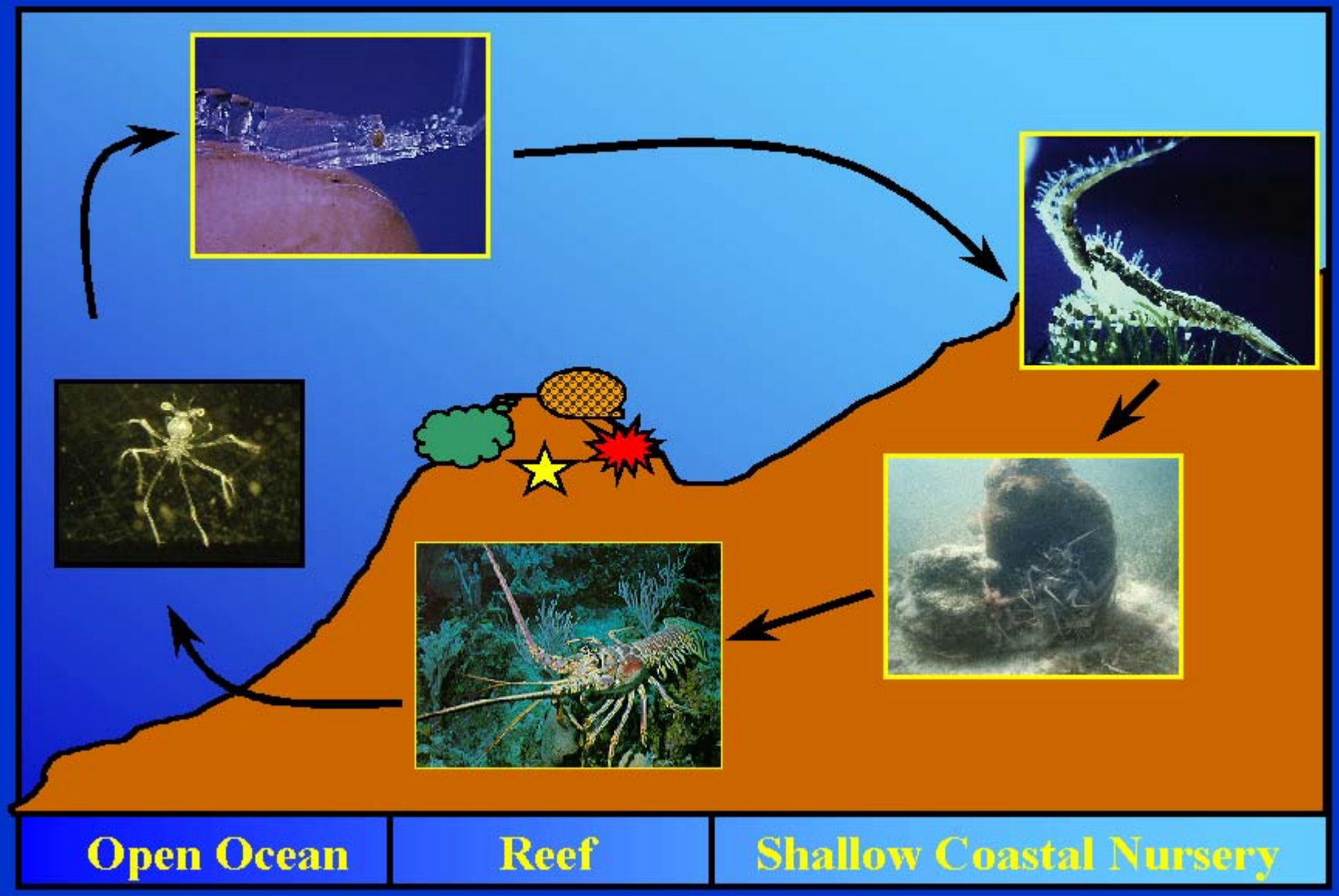
Stock Distribution & Definition

Range: Brazil to North Carolina,
Bermuda and the Gulf of Mexico

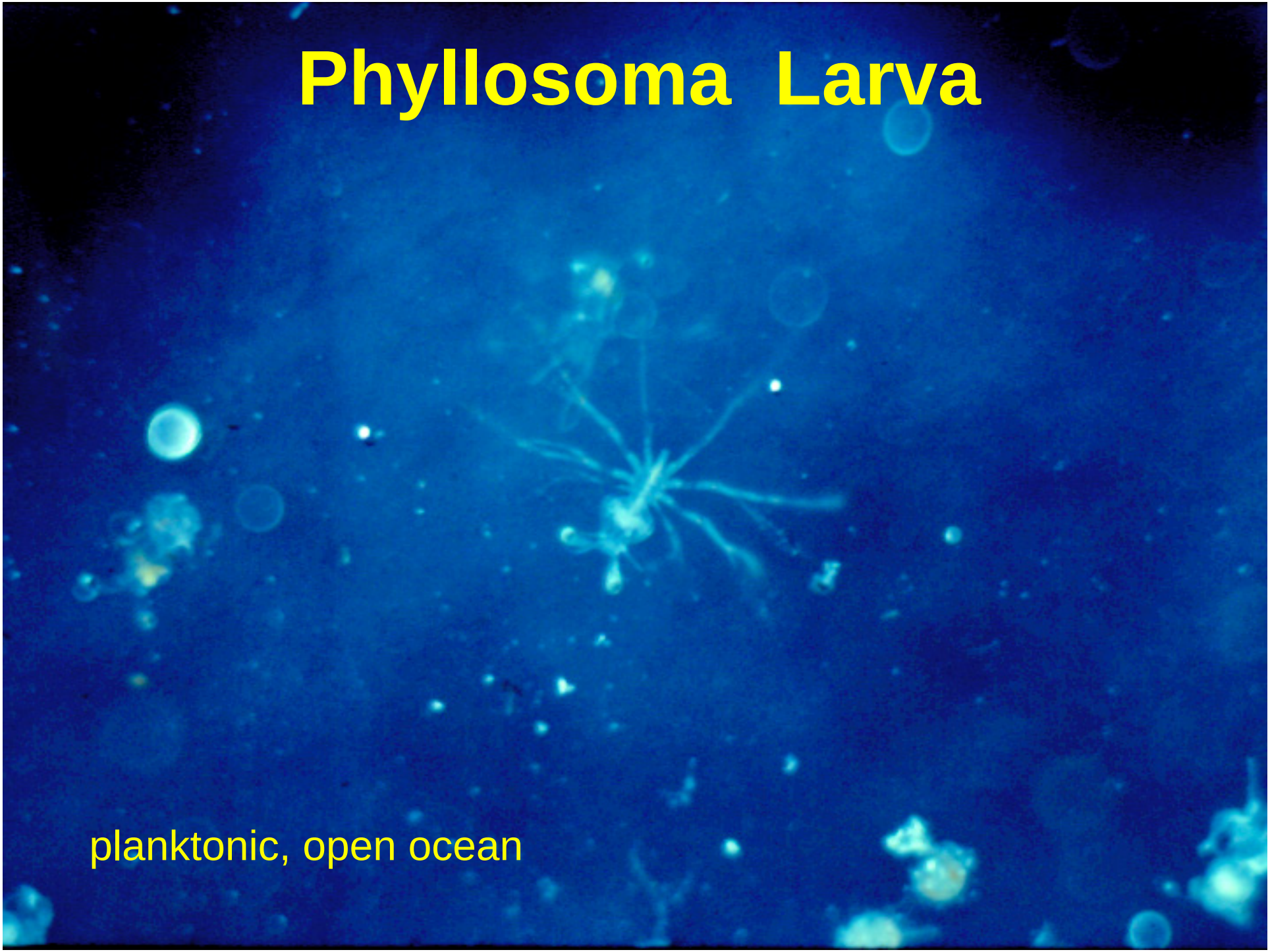


Panulirus argus is a single, pan-Caribbean stock
(Silberman et al. 1994)

Caribbean Spiny Lobster Life Cycle

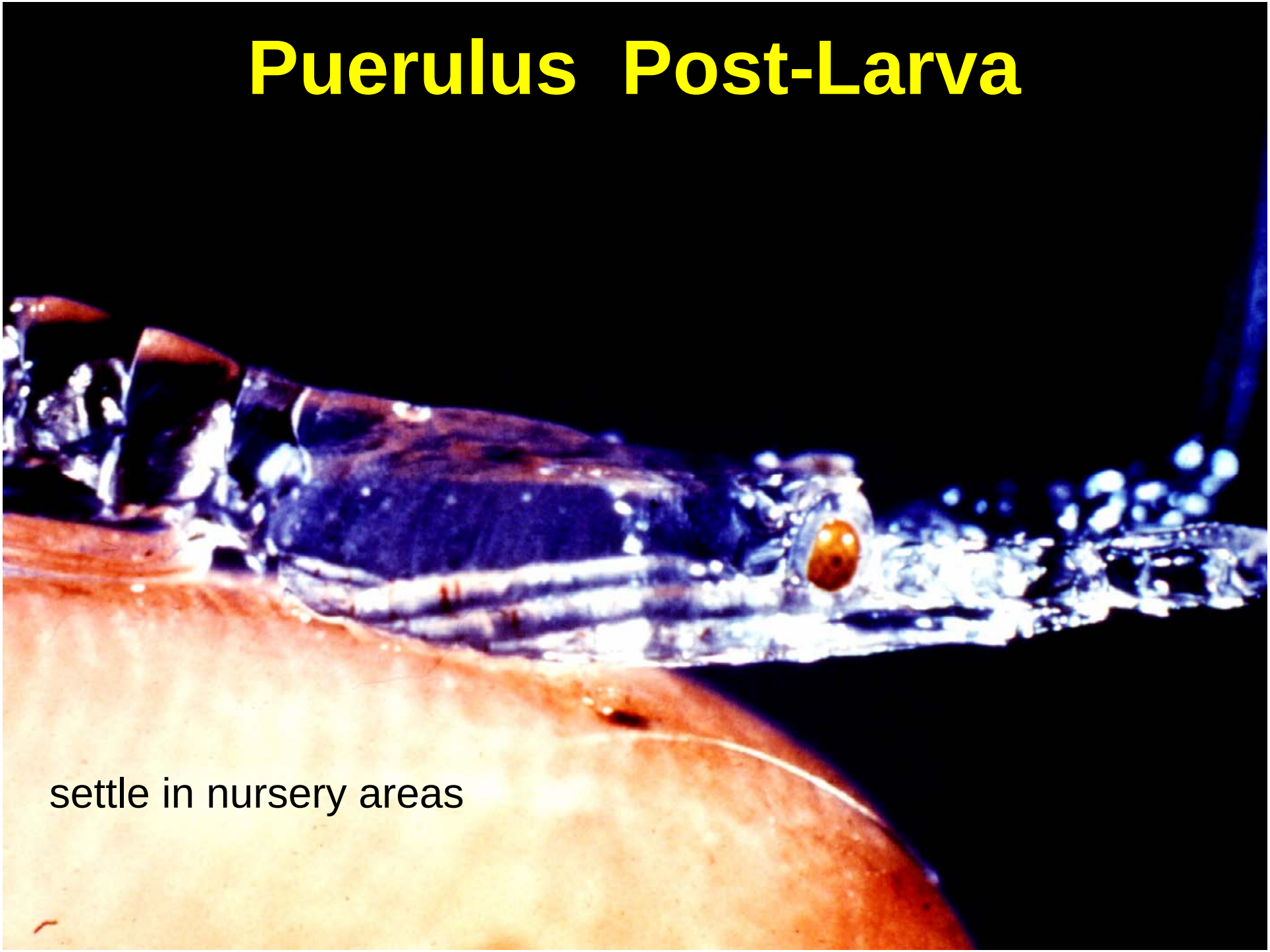


Phyllosoma Larva

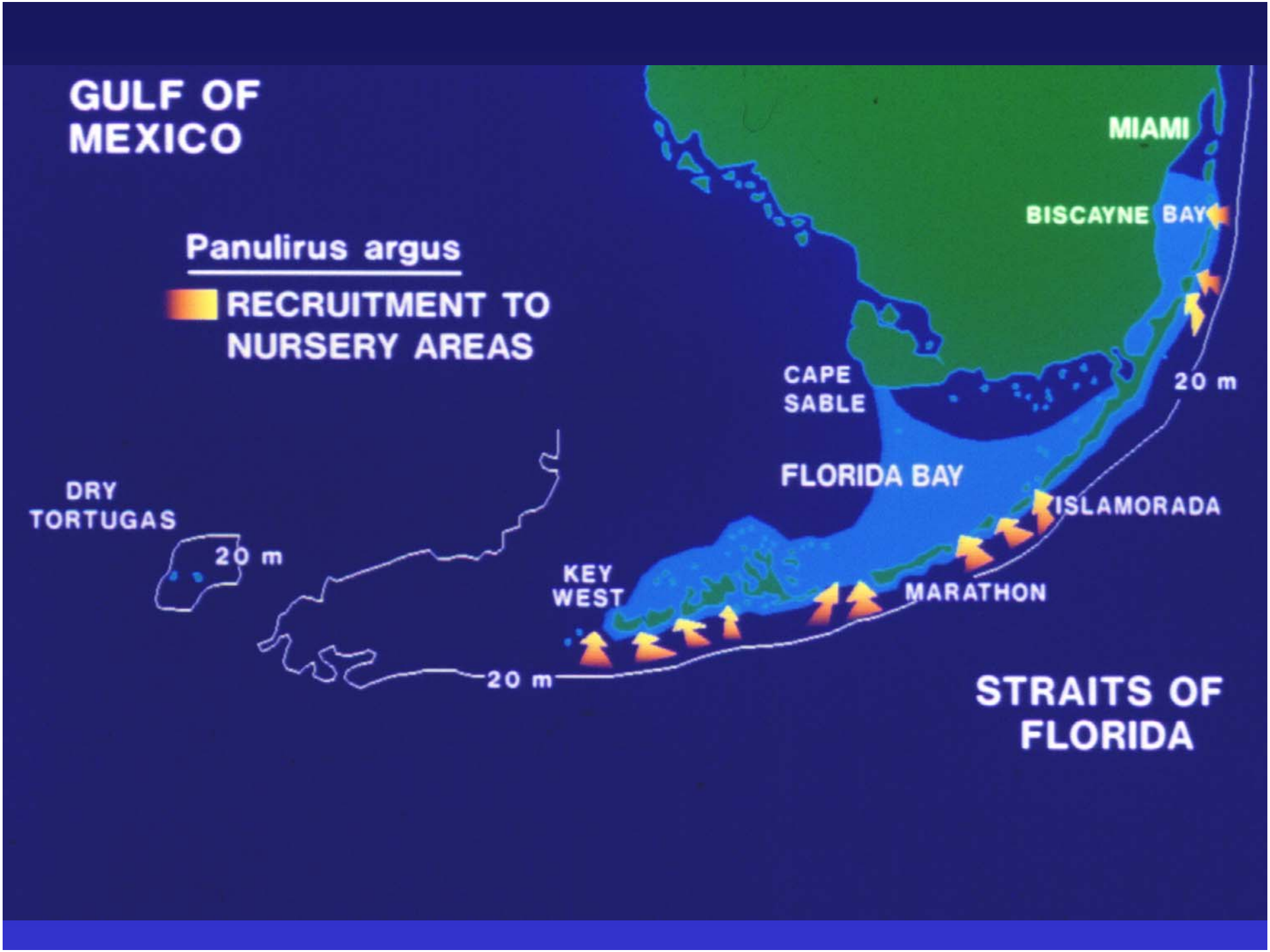


planktonic, open ocean

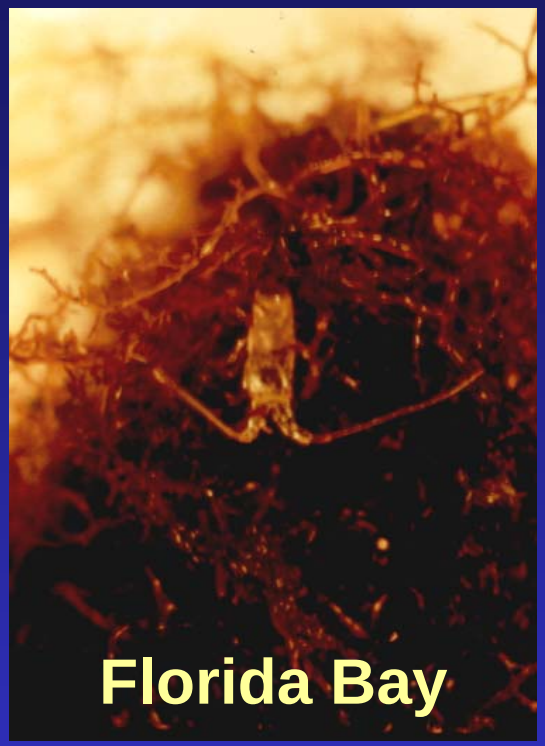
Puerulus Post-Larva



settle in nursery areas


GULF OF MEXICO
Panulirus argus
RECRUITMENT TO NURSERY AREAS
MIAMI
BISCAYNE BAY
CAPE SABLE
20 m
FLORIDA BAY
ISLAMORADA
DRY TORTUGAS
20 m
KEY WEST
MARATHON
20 m
STRAITS OF FLORIDA

Settlement Habitat

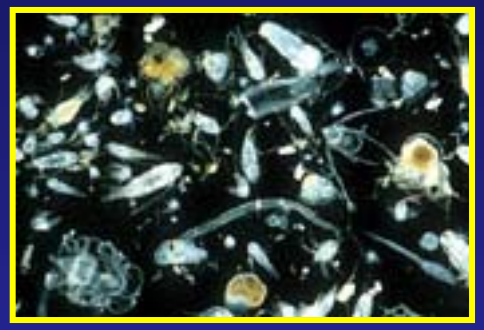


Post-Algal Phase Habitat

Juvenile Habitat

Adult Habitat

Food



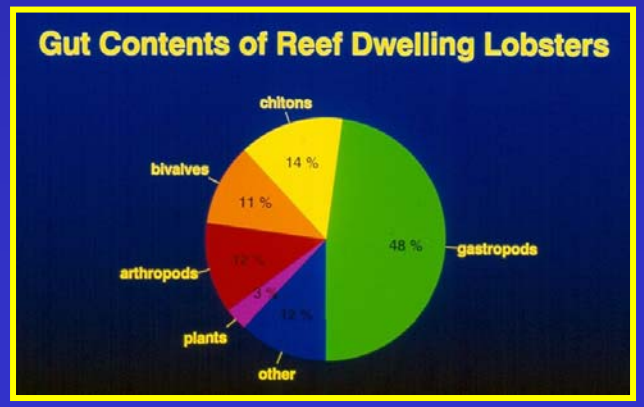
Phyllosomes

- soft-bodied plankton & fish larvae

Pueruli

- non-feeding

Juveniles and Adults



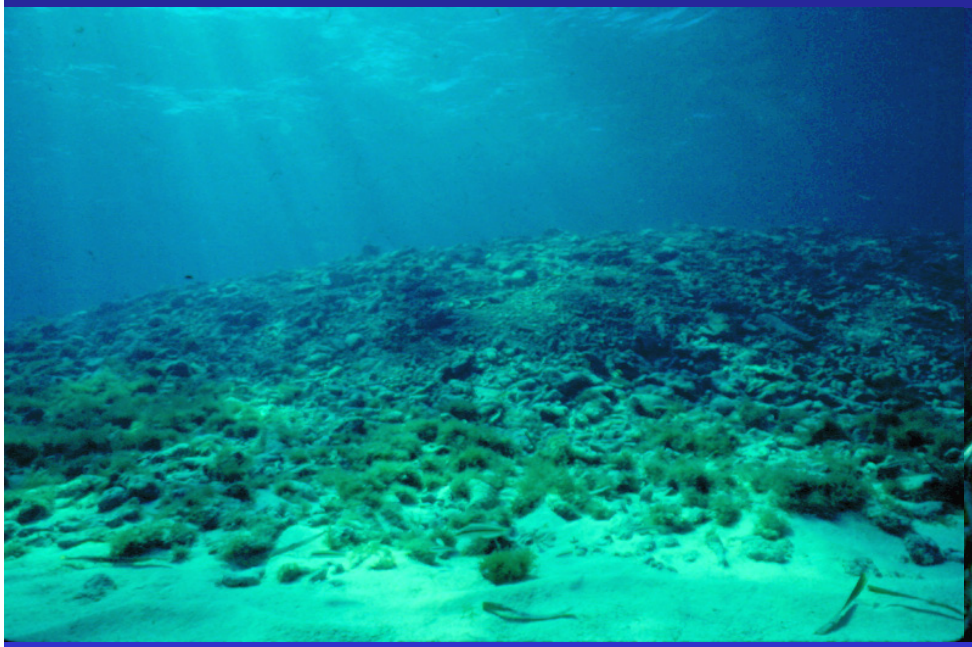
- molluscs

- crustaceans

Foraging

- nocturnal
- wherever prey is abundant

rubble



seagrass

Natural Mortality

- most reliable estimates for M range from 0.3-0.4 per year

  (from FAO, 2001)

- M = 0.2-0.3 for juveniles < 50 mm CL, unexploited area, Grand Bahama

  (Waugh, 1981)

Country	Sex	Method	M	Author
Bahamas	Γ+E	?	0.36	Ehrhardt
Brazil	Γ+E	Pauly (1980)[3]	0.30	Ivo (1996)
Colombia	Γ	Empirical formula[2]	0.54	Gallo *et al.* (1998)
	E		0.51	
	Γ+E		0.62	
Cuba	Γ+E	Tagging	0.26	Buesa (1972)
	Γ+E	Tagging	0.44	Cruz *et al.*, (1986a)
	Γ+E	Empirical formula[2]	0.34	Cruz *et al.* (1981)
Florida, USA	Γ+E	Pauly (1980)[3]	0.42	Powers and Sutherland (1989)
Florida, USA	Γ+E	Longevity	0.30	Muller *et al.* (1997)
Jamaica	Γ	Pauly (1980)[3]	0.59	Haughton (1988)
	E		0.67	
	Γ+E		0.62	
Nicaragua	Γ	Empirical formula[2]	0.41	Estimated during the 1998 working group session
	E		0.50	
	Γ+E		0.45	
Virgin Is.	Γ	Tagging	0.46	Olsen and Koblic (1975)
	Γ		0.43	
	E		0.52	
Turks & Caicos	Γ+E	Depletion model[4]	0.36	Medley and Ninnes (1997)

[1]The working group used as an average value for longevity of 13.9 years from Ivo (1996), in conjunction with the model for natural mortality of Hoenig (1983) where the relation between Z and longevity (T_m) is: $Z = 1.46 - 1.01\ T_m^{1.01}$.

[2]Cruz *et al* (1981) developed an empirical equation to estimate crustacean natural mortality based on mortality and growth parameters and mean water temperature from a number of data sets, similar to Pauly's equation used for finfish:

$M = 0.0277 - 0.0004 * L_\infty + 0.5397 * K + 0.0119 * T$

Where L_∞ = CL (mm), K = Growth rate ($year^{-1}$) and T = Temperature (°C). Using this equation, M values for the region range between 0.3 and 0.35 $year^{-1}$.

[3]Pauly's (1980) method was developed for finfish and is unreliable for crustaceans, which may explain the generally higher values obtained through this method. Where possible, these values should be re-estimated using Cruz *et al.* (1981) method.

[4]The depletion model provides an estimate independent of growth models and size data.

Morphometrics

Carapace length

Total length

Tail length

Tail width

Total weight

By sex

Sexes combined

(from Matthews et al., 2003)

Variables	Sex[1]	Regression Equation[2]
Carapace Length : Total Length	B	TTL=2.67*CL+13.30
	M	TTL=2.51*CL+22.19
	F	TTL=2.80*CL+6.32
Tail Length : Total Length	B	TTL=1.56*TL-5.72
	M	TTL=1.57*TL-5.26
	F	TTL=1.57*TL-7.89
Tail Length : Carapace Length	B	CL=0.58*TL-7.13
	M	CL=0.62*TL-10.95
	F	CL=0.56*TL-5.07
	M<73mm	CL=0.58*TL-5.66
	M>73mm	CL=0.62*TL-9.48
Carapace Length : Total Weight	B	$TTWT=0.001989*CL^{2.80327}$
	M	$TTWT=0.002229*CL^{2.77012}$
	F	$TTWT=0.001839*CL^{2.82810}$
Total Length : Total Weight	B	$TTWT=0.00003671*TTL^{3.00056}$
	M	$TTWT=0.00002080*TTL^{3.10922}$
	F	$TTWT=0.00005812*TTL^{2.91274}$
Tail Length : Total Weight	B	$TTWT=0.00008379*TL^{3.08710}$
	M	$TTWT=0.00005494*TL^{3.17957}$
	F	$TTWT=0.00001059*TL^{3.03328}$
Total Weight : Carapace Length	B	$CL=9.1975*TTWT^{0.35673}$
	M	$CL=9.0640*TTWT^{0.36100}$
	F	$CL=9.2734*TTWT^{0.35359}$
Total Weight : Total Length	B	$TL=30.0684*TTWT^{0.33327}$
	M	$TL=32.0479*TTWT^{0.32162}$
	F	$TL=28.4571*TTWT^{0.34332}$
Total Weight : Tail Length	B	$TL=20.9218*TTWT^{0.32393}$
	M	$TL=21.8696*TTWT^{0.31451}$
	F	$TL=20.4409*TTWT^{0.32968}$

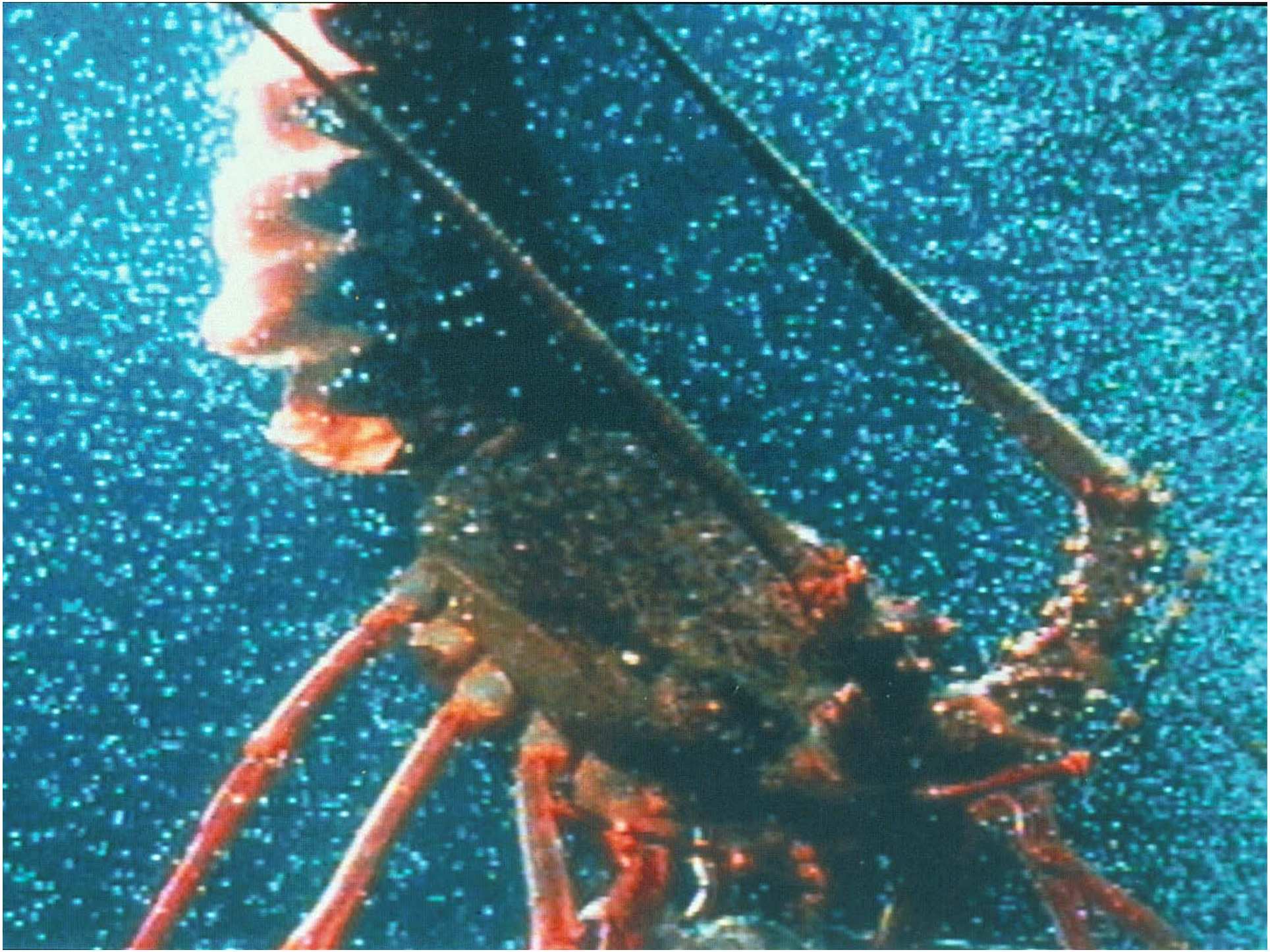
[1] B = both sexes included, M = male, F = female
[2] TTWT = total weight, TTL= total length, CL= carapace length, TL = tail length, TW = tail width.

Reproduction

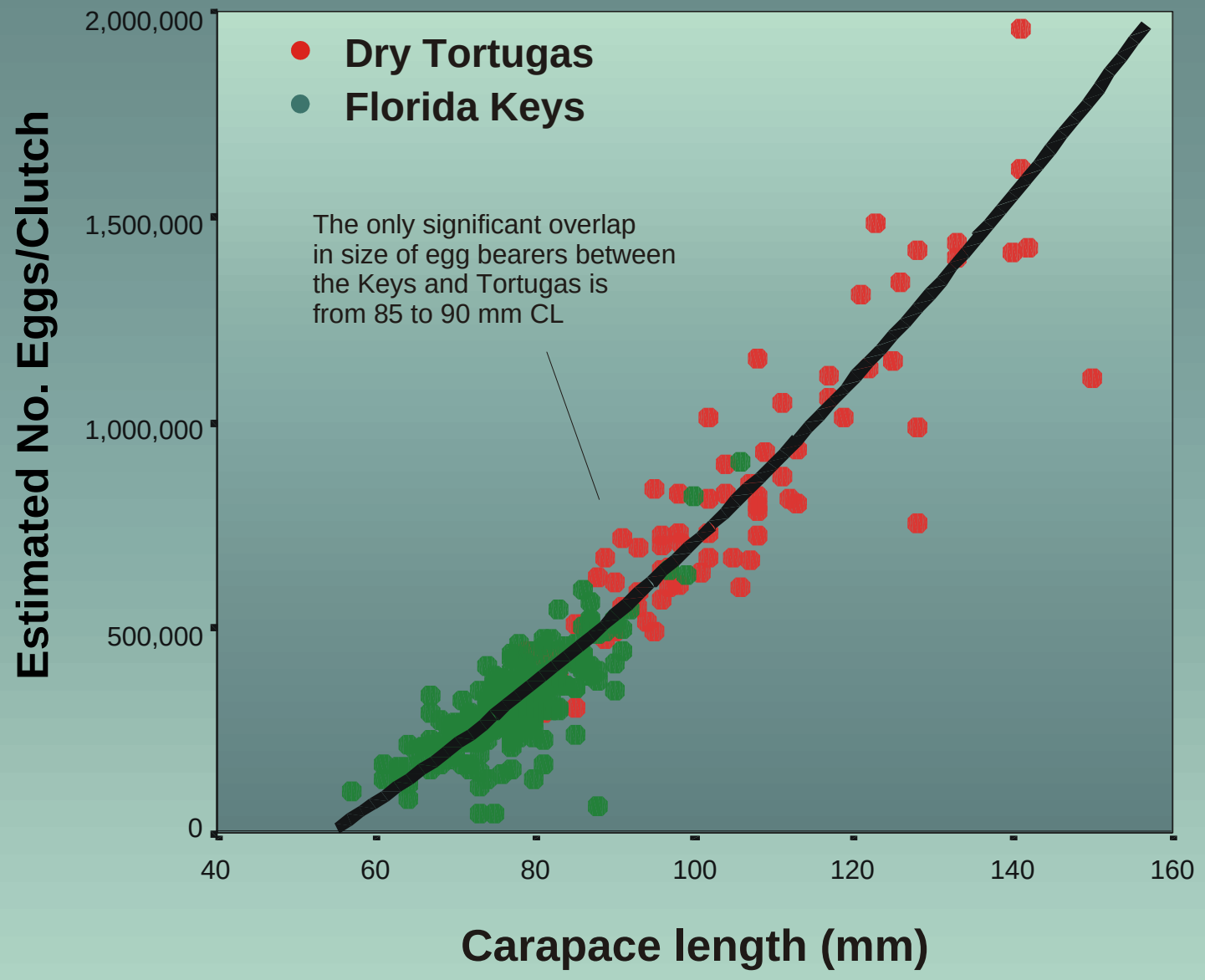
Could Egg Production of Caribbean Spiny Lobster be Limited by Males?

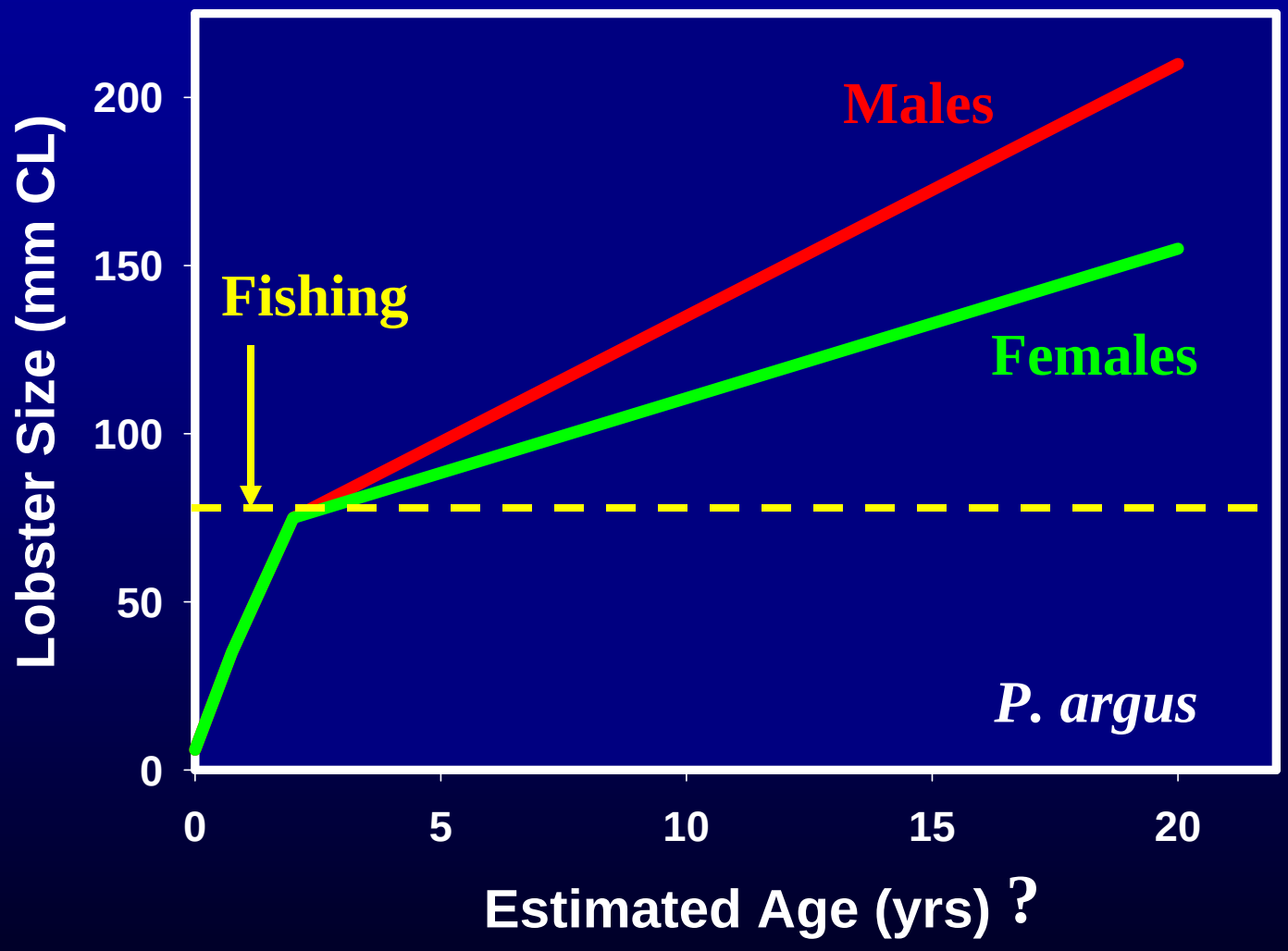
Mark Butler[1] & Alison MacDiarmid[2]

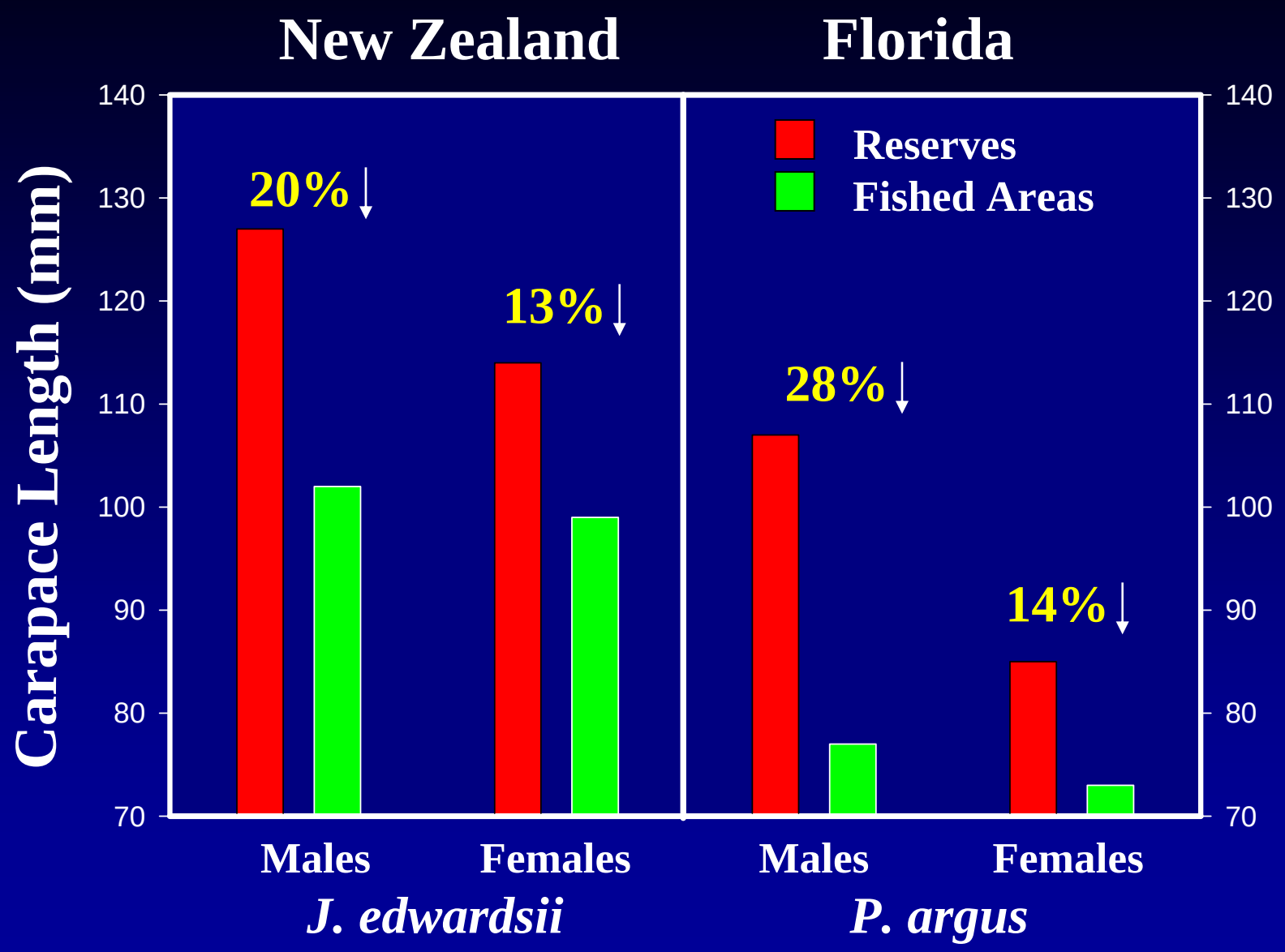
[1] Old Dominion University, Norfolk, Virginia USA
[2] National Institute of Water & Atmospheric Research, Wellington, New Zealand



From: Bertelsen, Hunt, Muller (2000)




Lobster Size (mm CL)
200
150
100
50
0
Males
Fishing
Females
P. argus
0
5
10
15
20
Estimated Age (yrs) ?


New Zealand
Florida
Carapace Length (mm)
140
130
120
110
100
90
80
70
20%
13%
28%
14%
Reserves
Fished Areas
Males
Females
Males
Females
J. edwardsii
P. argus

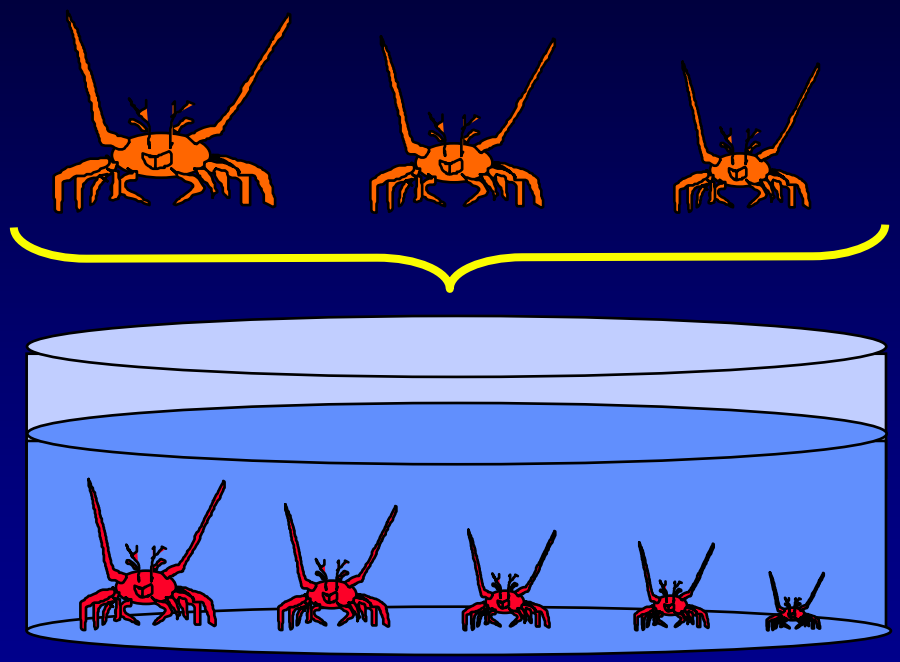
Does male lobster size matter when it comes to reproductive success?

Male Size Effects on Mating & Reproduction

Design of Laboratory Experiment

Protocol:

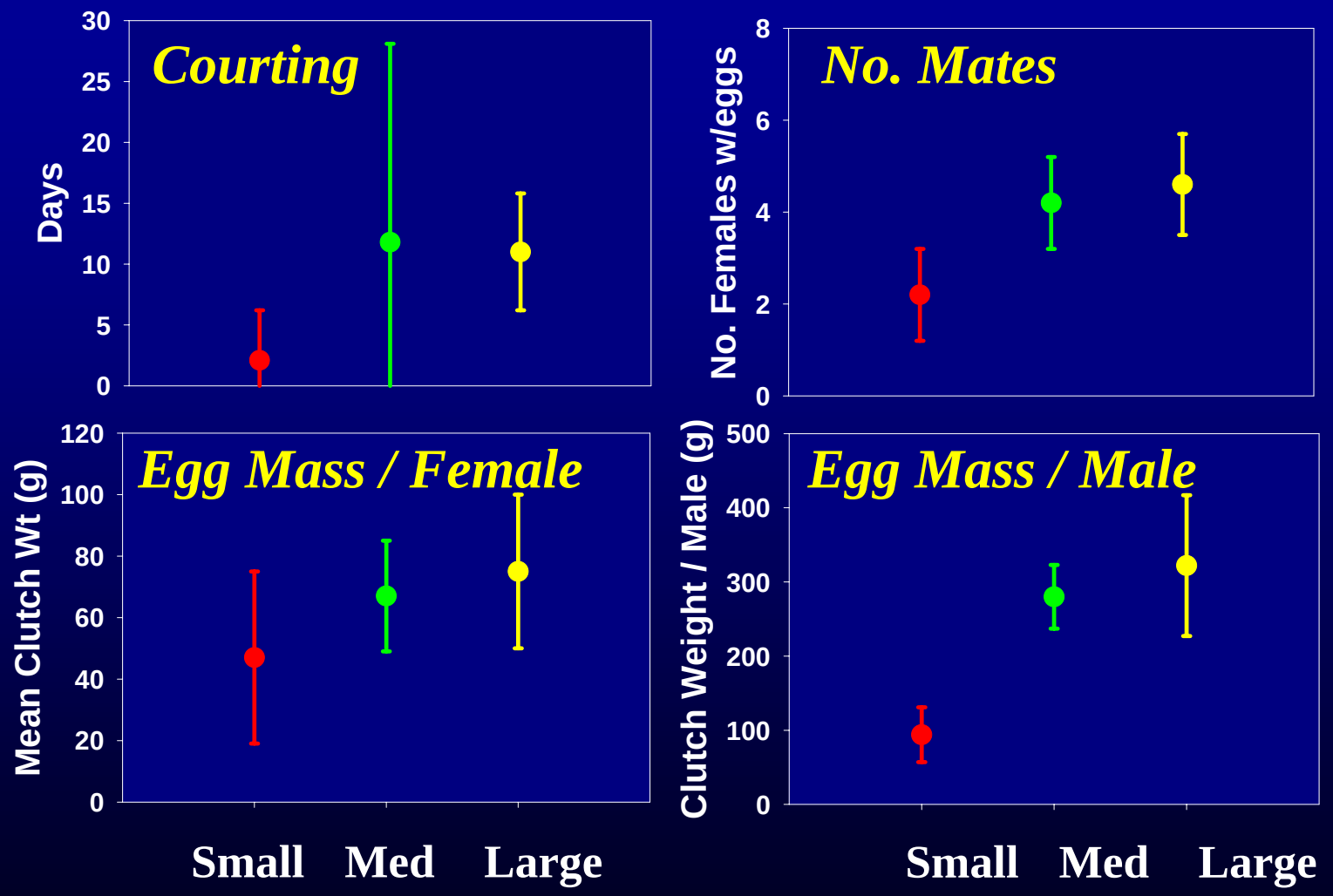
- **1 Male per tank:**
  - large, medium, or small
- **5 Females per tank:**
  - from large to small
- **4 - 5 replicates /trt**



Behavioral Response: **First day courting, No. days courting, First day mating**

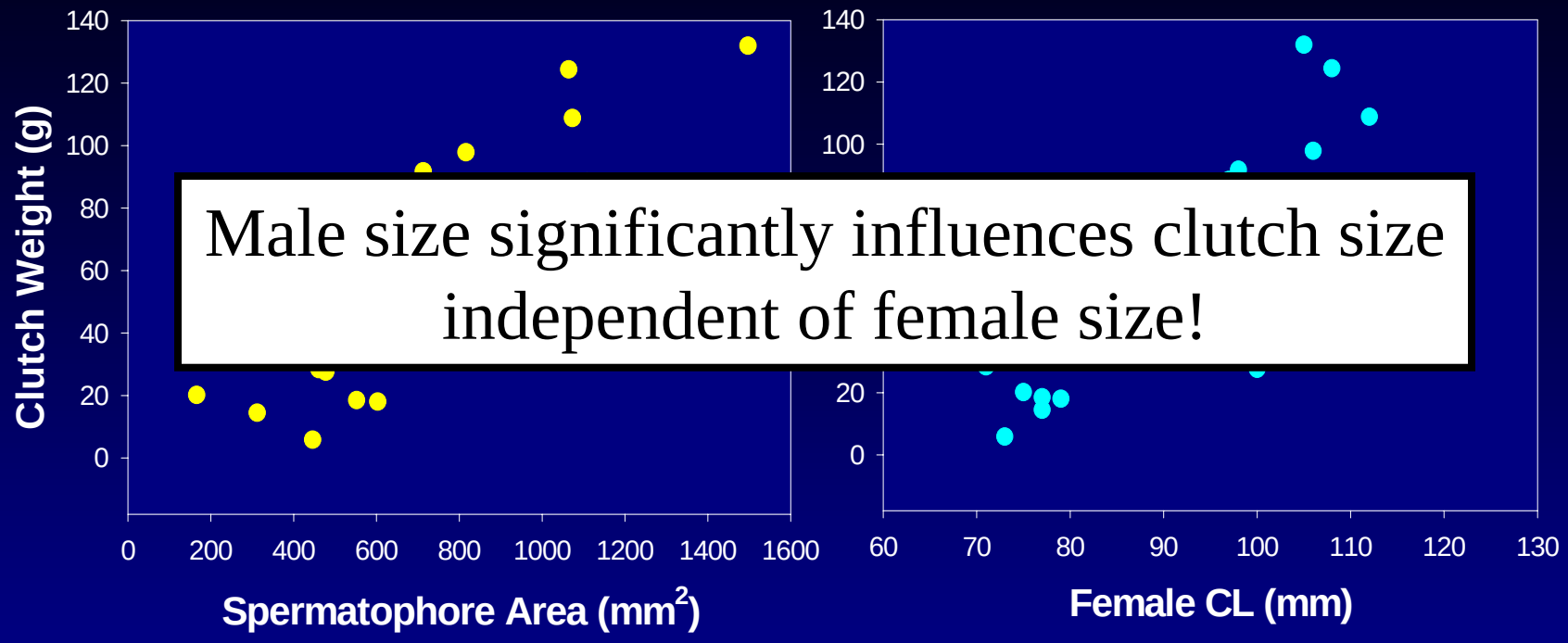
Reproductive Response: **No. & size of females w/eggs, No. eggs/female, No. eggs/male**

Laboratory Results



Male Size

Laboratory Results: *Panulirus argus*



Male size significantly influences clutch size independent of female size!

Multiple Regression Results: $R^2 = 0.74$; $P = 0.0002$

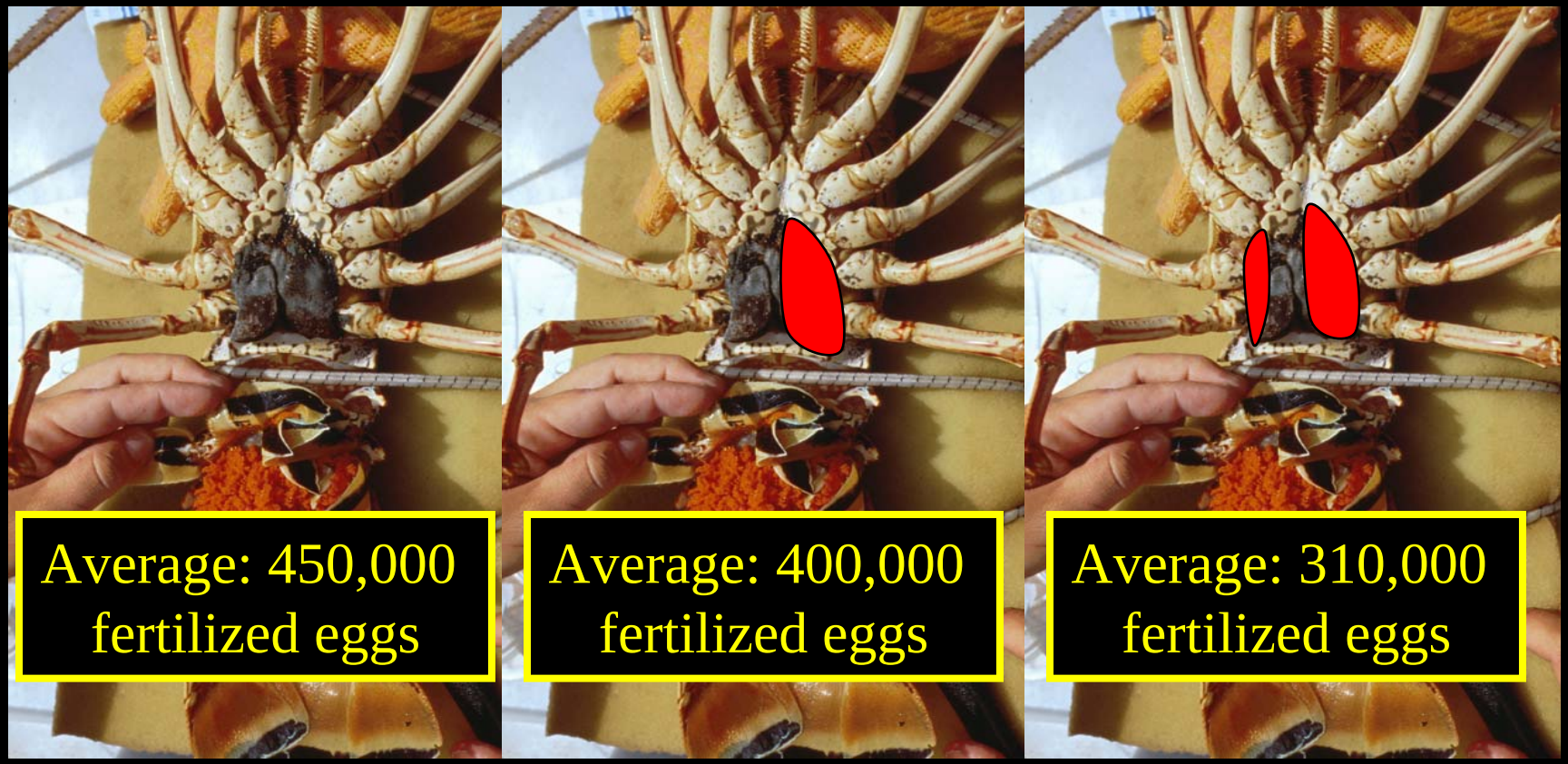
Variable	P - value	% Variance Explained
Spermatophore Area	< 0.0001	46%
Female CL	0.0002	28%

Large males produce large spermatophores ("tar spot"), does this matter to fertilization success?

Spermatophore Reduction Experiment

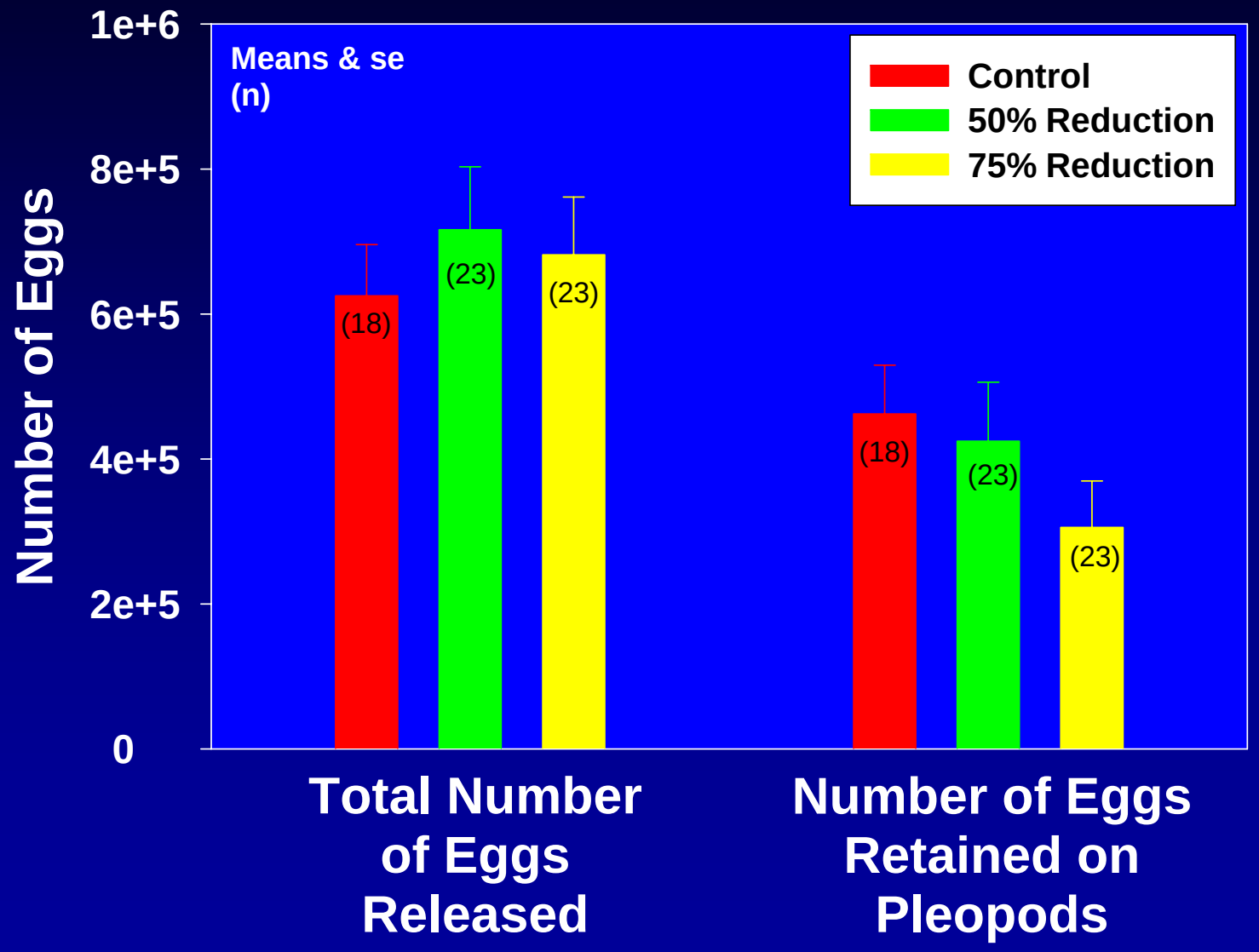
<u>Protocol:</u> Manipulate the size of existing spermatophores on large & small females and then measure reproductive success.

Control | **50% Reduction** | **75% Reduction**



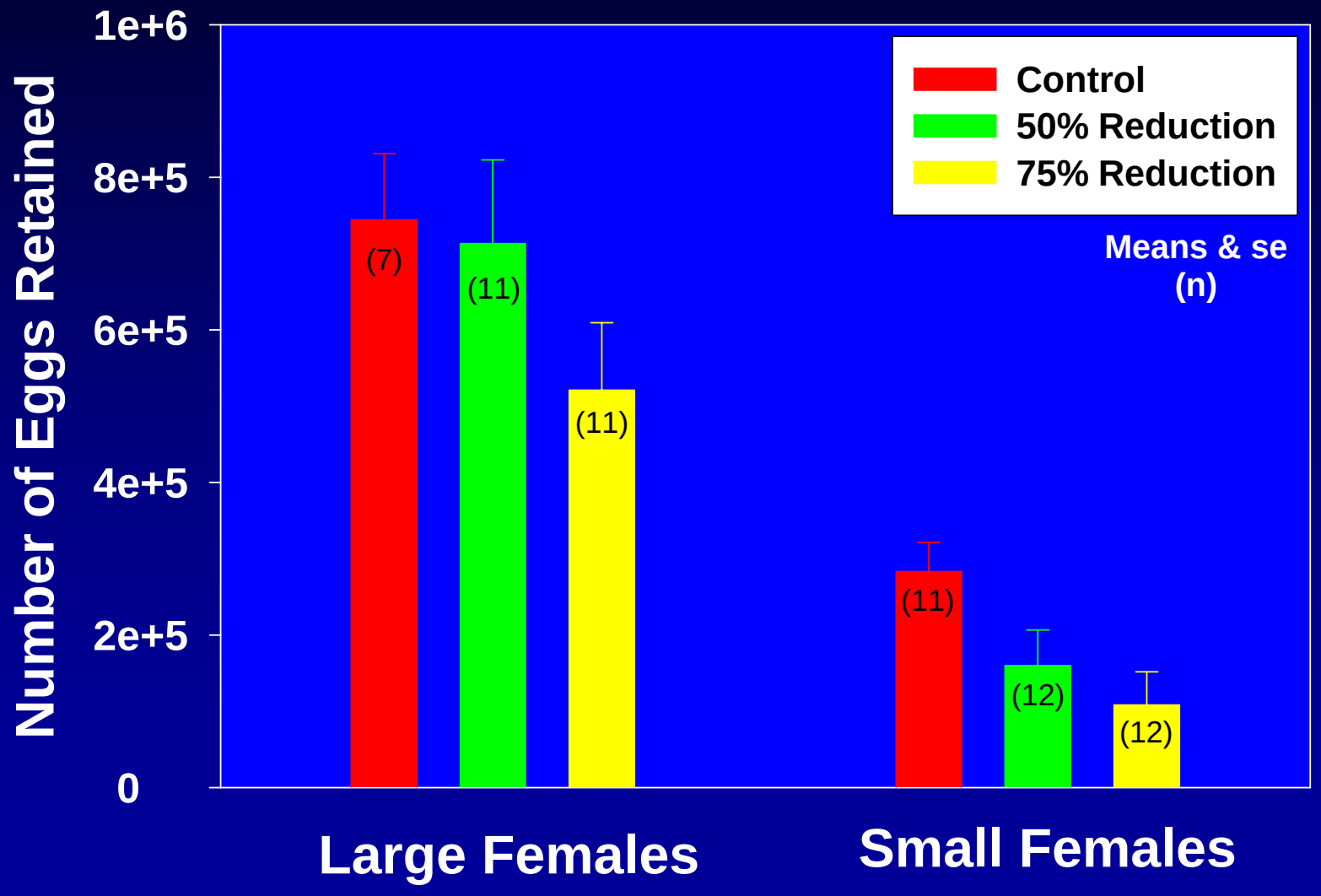
Spermatophore Reduction Experiment

All Females Combined



Spermatophore Reduction Experiment

By Female Size Class



Does male lobster size or number of matings affect sperm abundance?

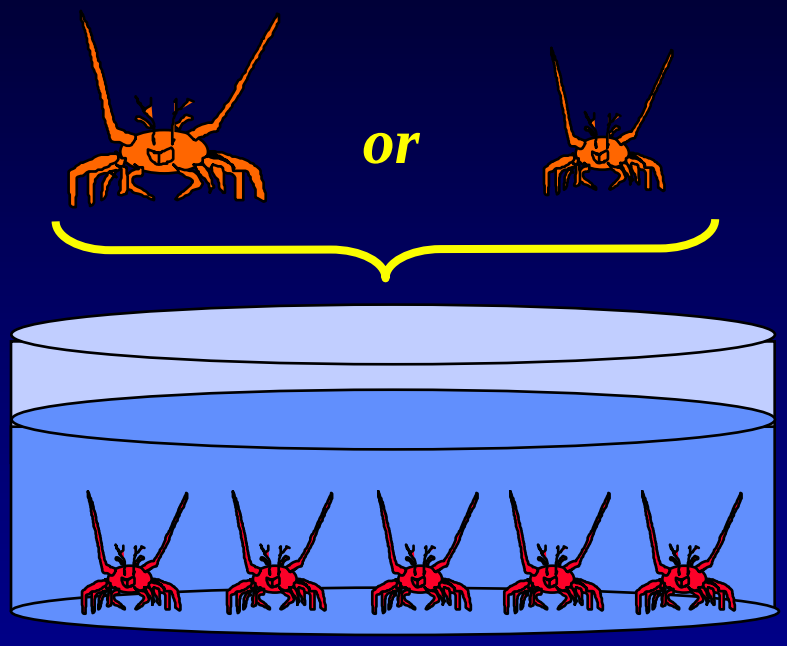
Sperm Depletion & Recharge Experiment

Protocol:

(1) Repeatedly mate large or small males with numerous females; n = 7 per male trt.

(2) Remove spermatophores from females & count sperm.

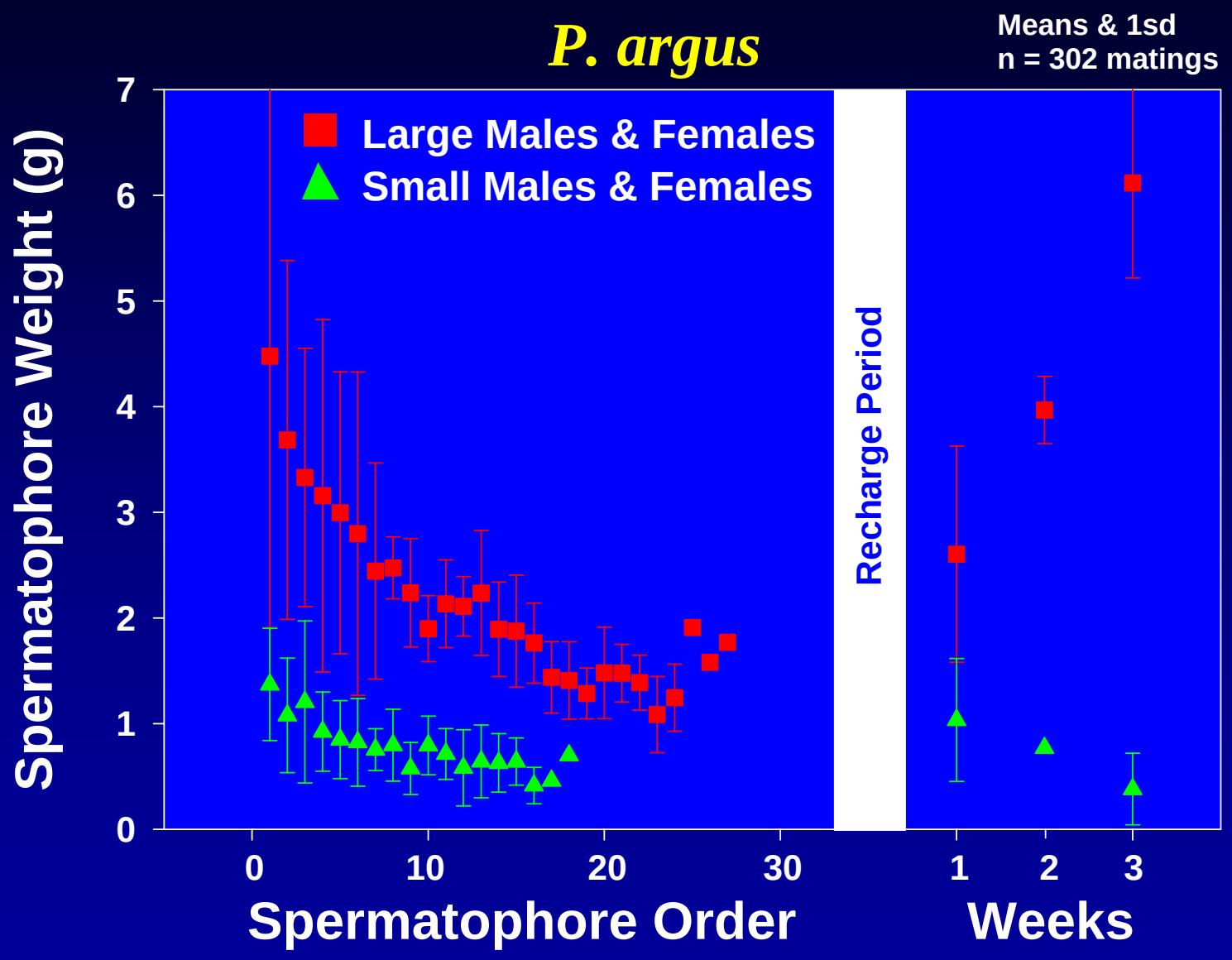
(3) 1, 2, or 3 week recharge period, then repeat procedure.



Response Variables:

- **number & weight of spermatophores**
- **sperm count per spermatophore**
- **clutch size of selected matings**

Sperm Depletion & Recharge Experiment



Is there field evidence for sperm limitation in Florida?

Sperm:Egg Ratio

34.6 (± 8.4)

Sperm:Egg Ratio

21.6 (± 5.4)

Summary

- **Striking differences between these representative species of spiny lobster with respect to reproductive life histories, specificity of mate selection, maternal effect on larval characteristics, and consequences of lost mating opportunities.**
- **Potential for sperm limitation of fertilization success in both lobster species that largely depends on male size, as well as the number of prior matings.**
- **Can fisheries reduce reproductive success via sperm limitation? Possibly, but differences in mating behavior when lobsters of different size are present complicate a straight-forward answer - modeling is needed.**

Modeling Population-level Consequences

Questions

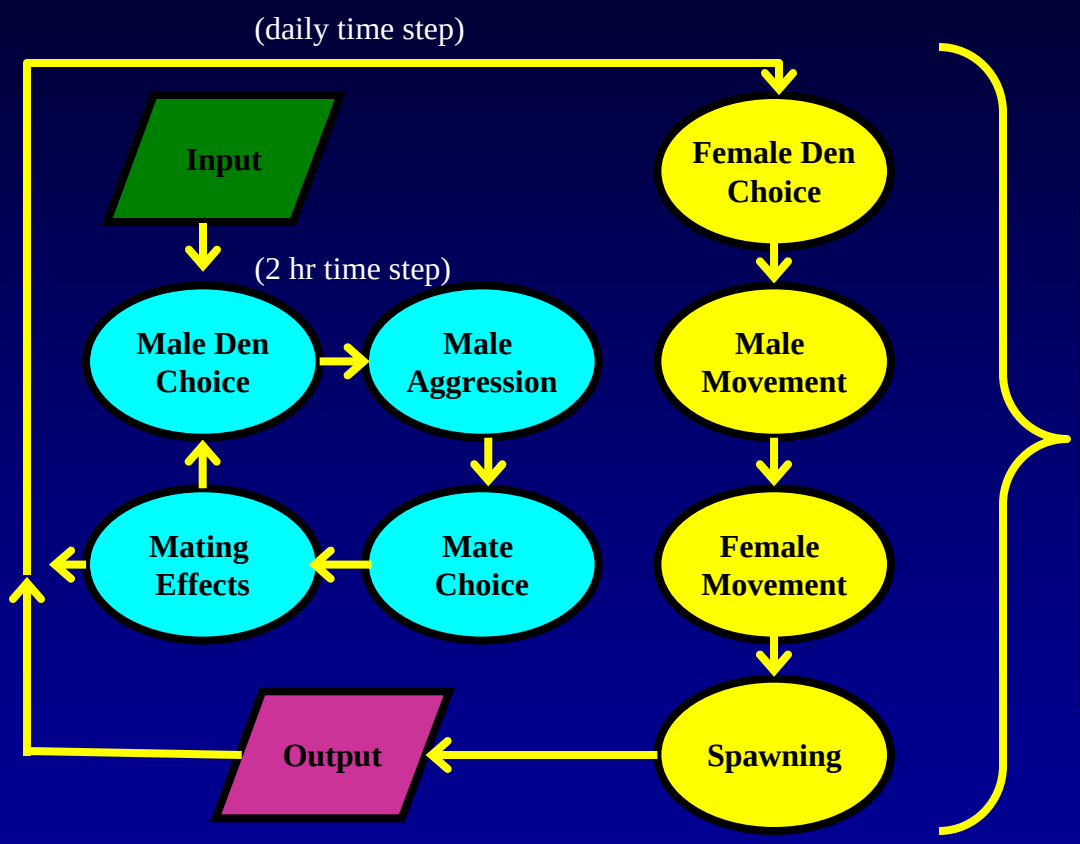
(1) Given our understanding of spiny lobster mating behavior and reproductive dynamics, what is the projected egg or larval production of populations that differ in male and female size structure?

(2) How much of this effect is due to male size?

Simulation Scenarios:

- **Fished and Unfished Populations**
- **Populations that vary independently in male & female size and density distributions (e.g., alternative fishery size limits)**

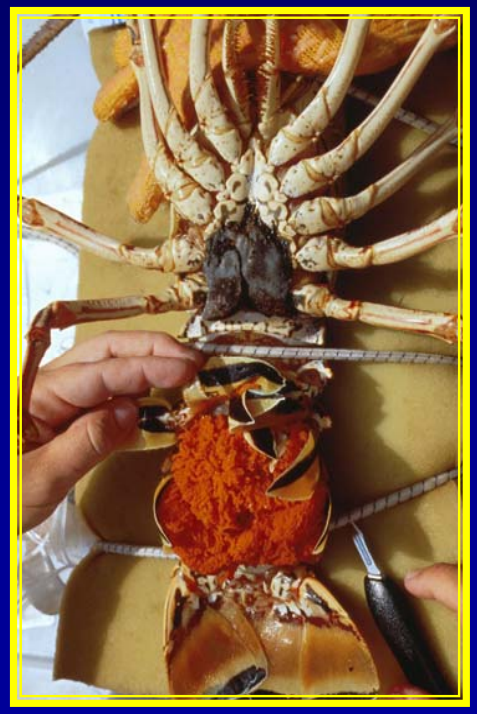
Work In Progress!



Reproductive Dynamics

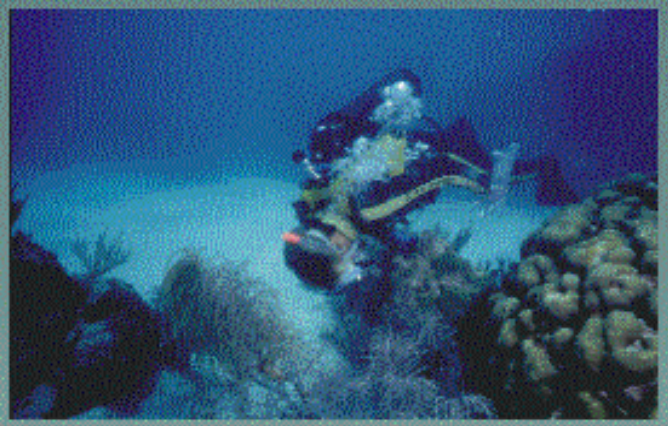
Spatial Landscape

Questions?

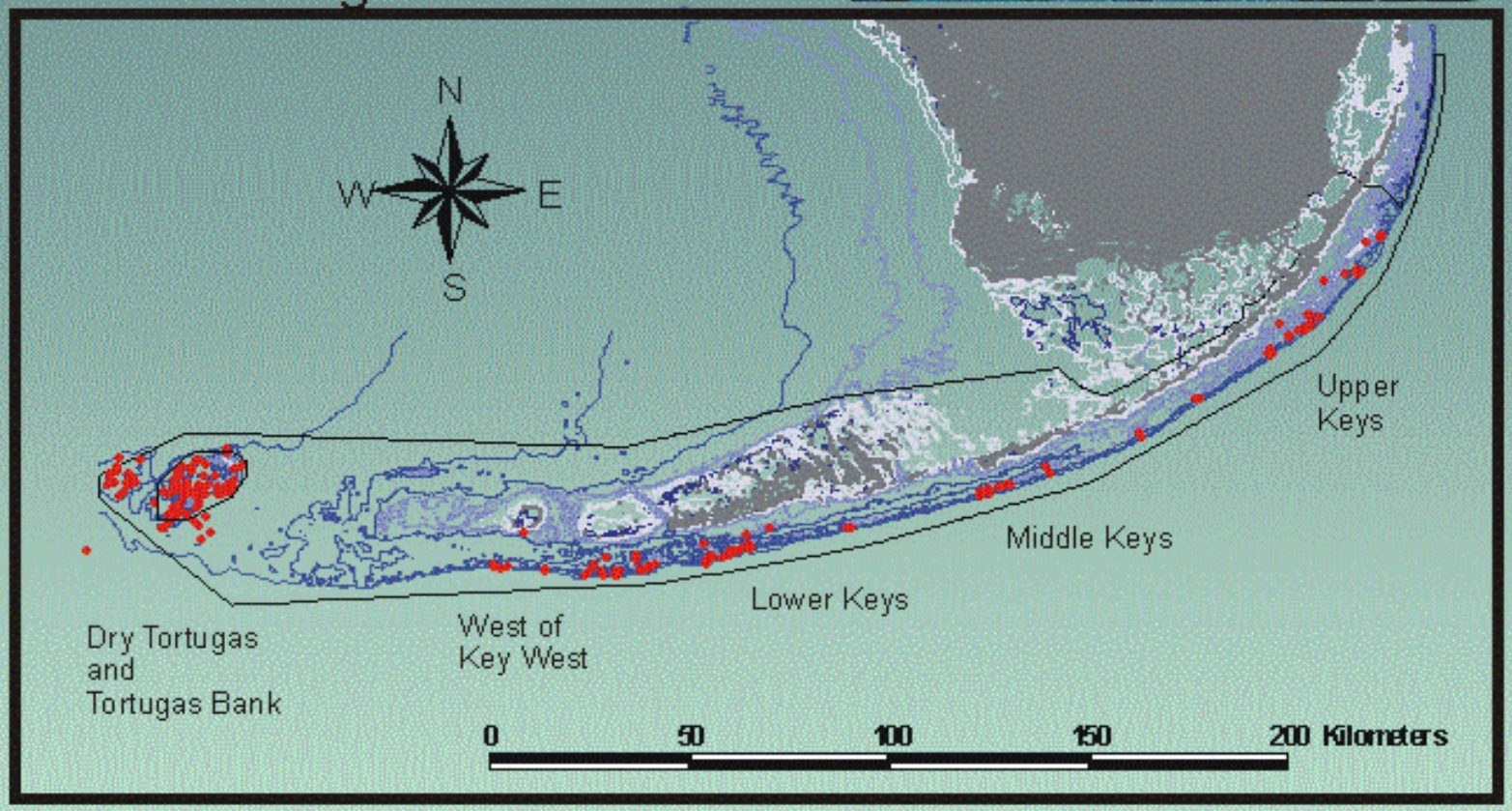


Project Overview

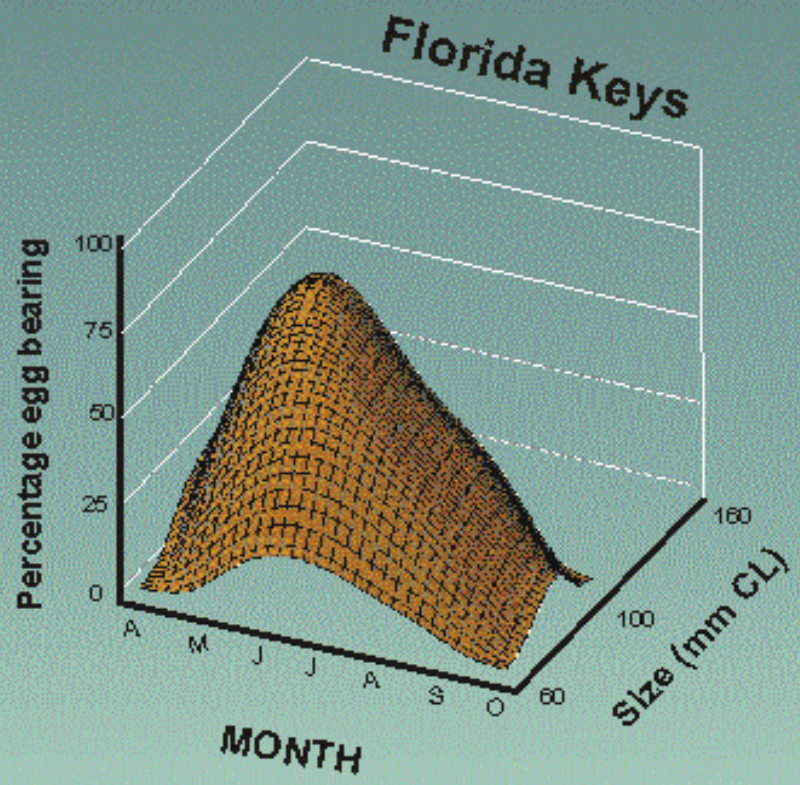
Diver surveys: 288
Size range: 15 - 184 mmCL
Egg masses observed: 404
Lobsters observed: >3,600
Depth range: surface to 28 meters

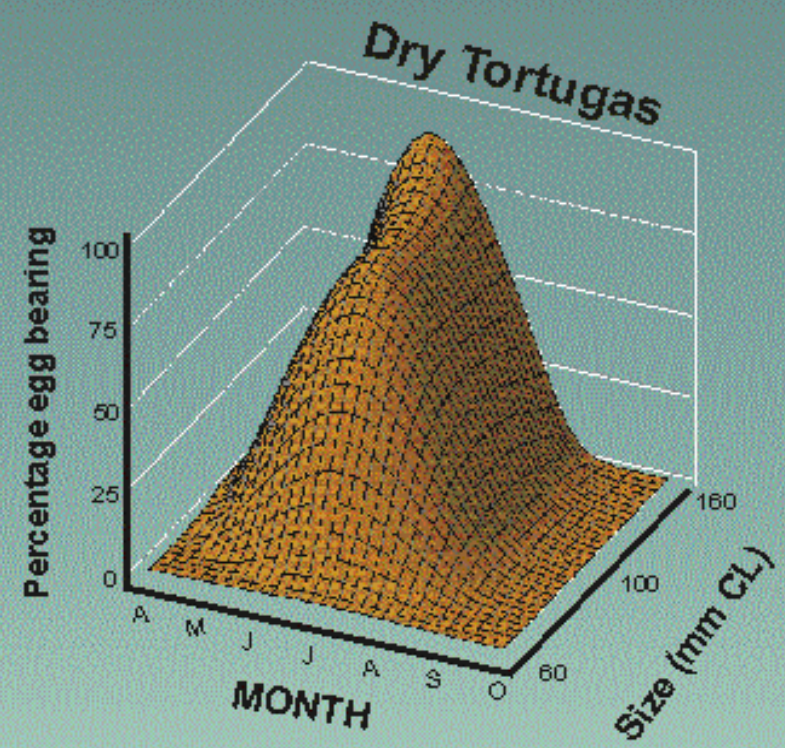


Areal coverage

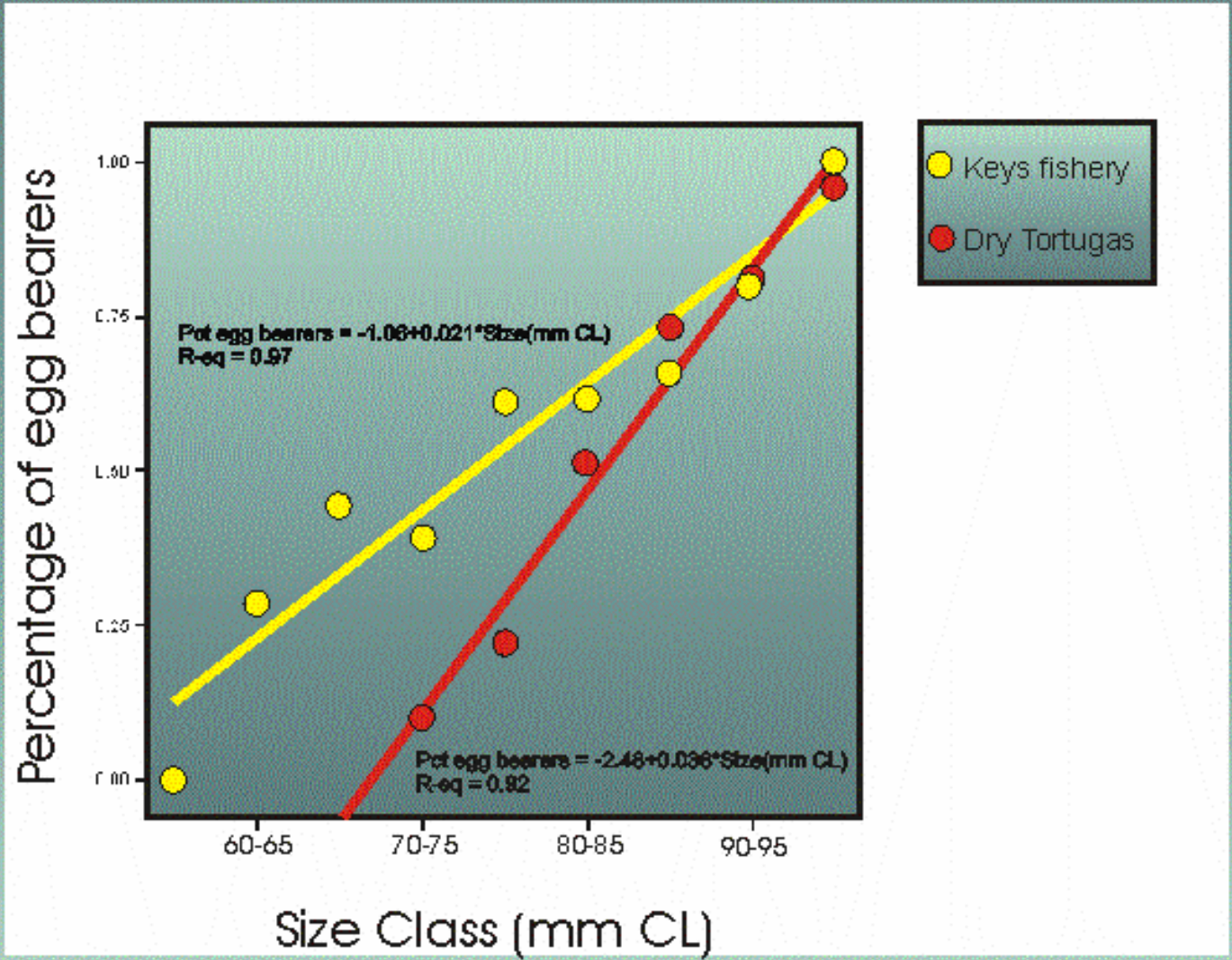


Percent of egg bearers by month and size-class

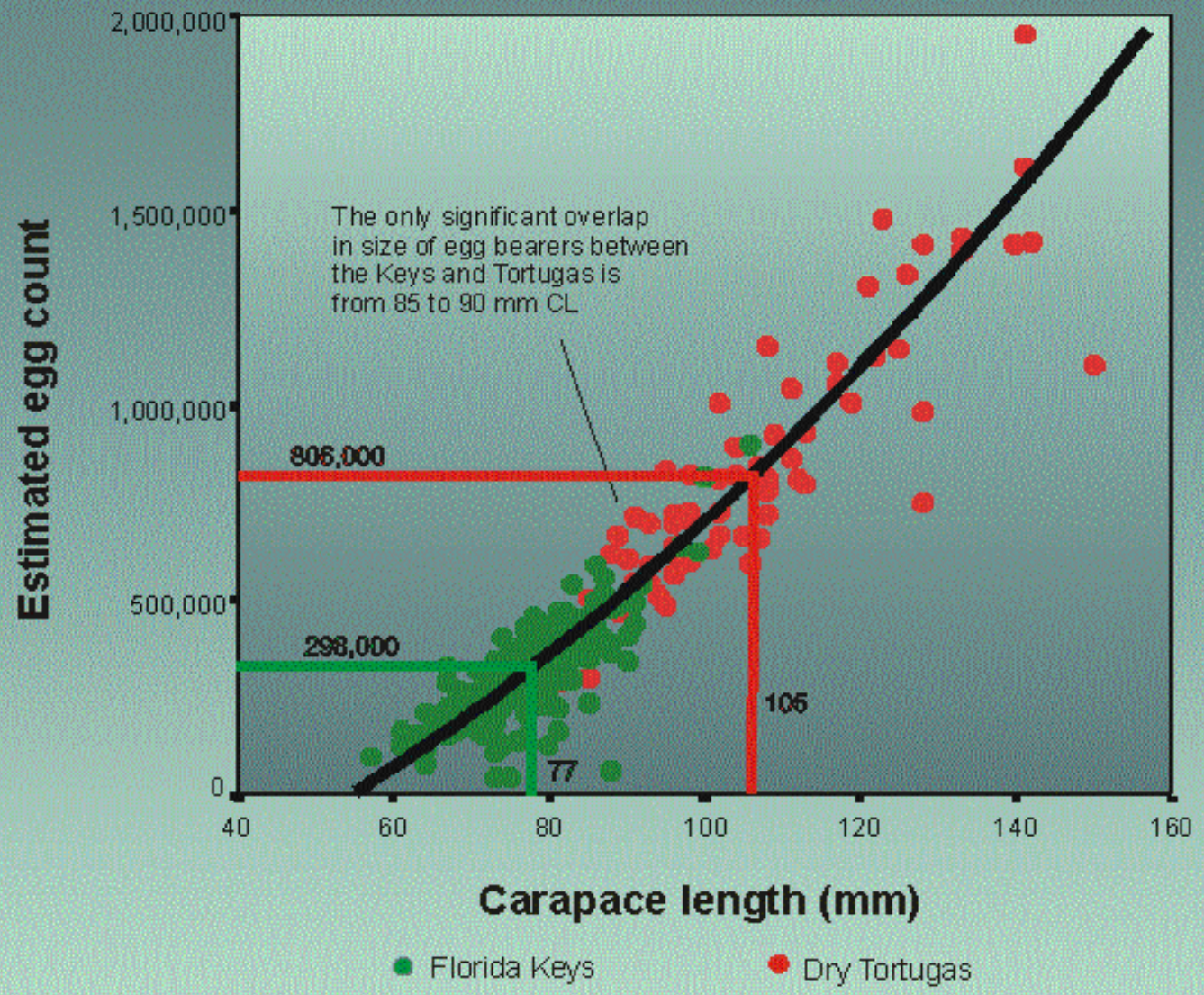




Percentage of egg bearers during Apr-Jun



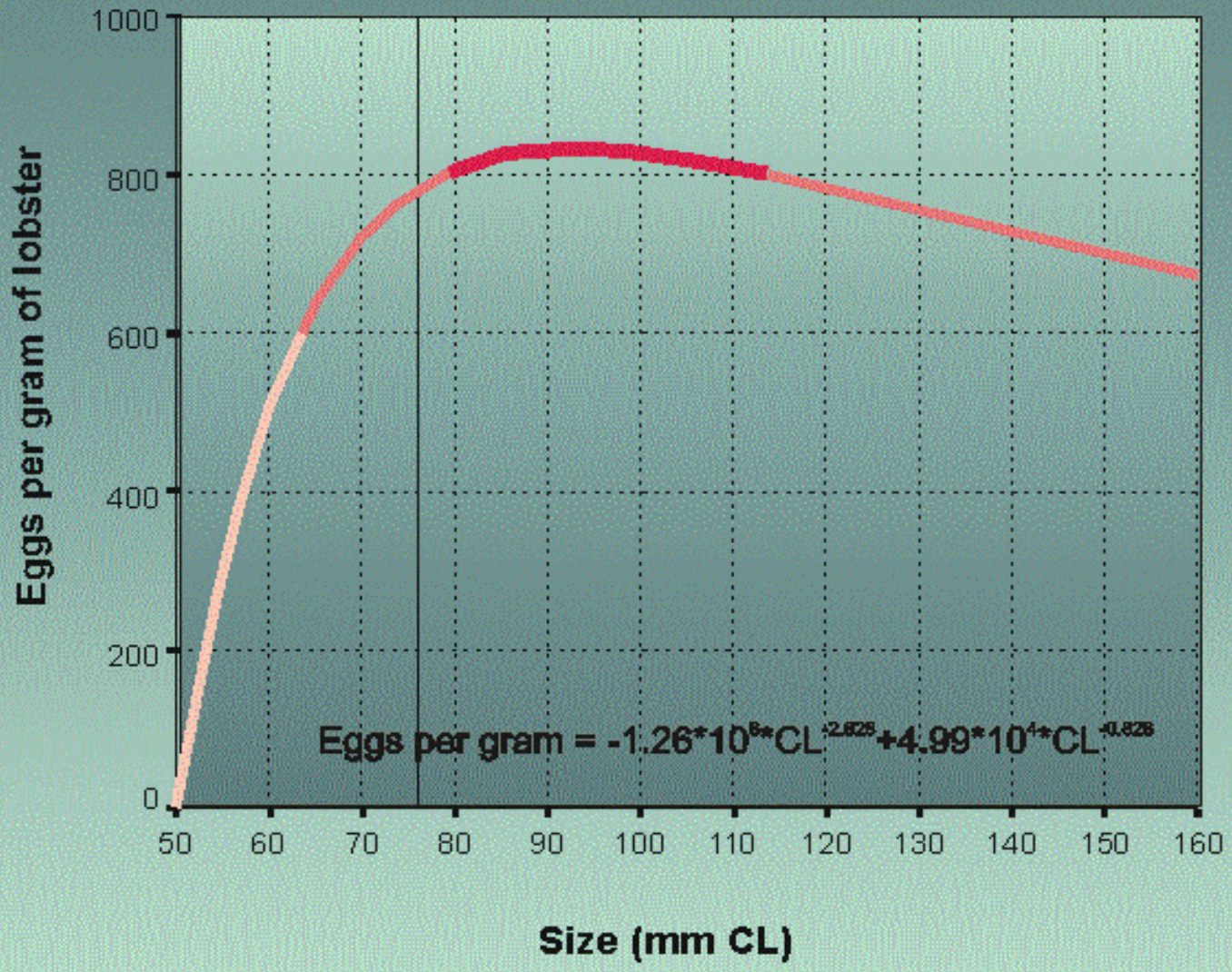
Egg count by carapace length for Florida Keys fishery and Dry Tortugas sanctuary lobsters

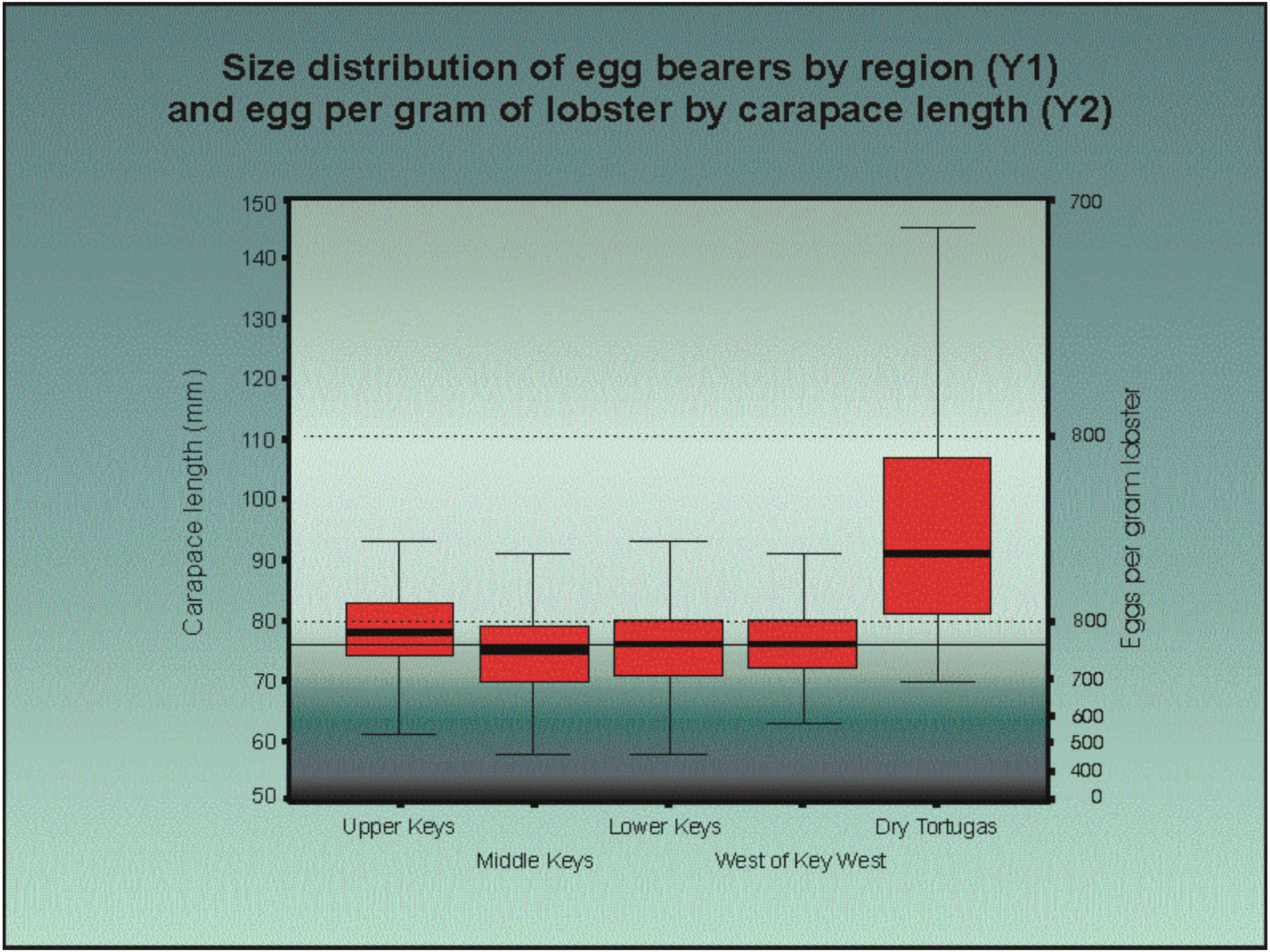


Predicted number of eggs produced per gram of lobster

Ratio of the (1) egg fecundity curve by (2) mass vs cl equation

$$Egg\ count = -231{,}212 + 91.88\ CL^2 \qquad Mass_{gr} = 0.00184 * CL_{mm}^{2.82}$$




Size distribution of egg bearers by region (Y1)
and egg per gram of lobster by carapace length (Y2)
Carapace length (mm)
150
140
130
120
110
100
90
80
70
60
50
Eggs per gram lobster
700
800
800
700
600
500
400
0
Upper Keys
Middle Keys
Lower Keys
West of Key West
Dry Tortugas