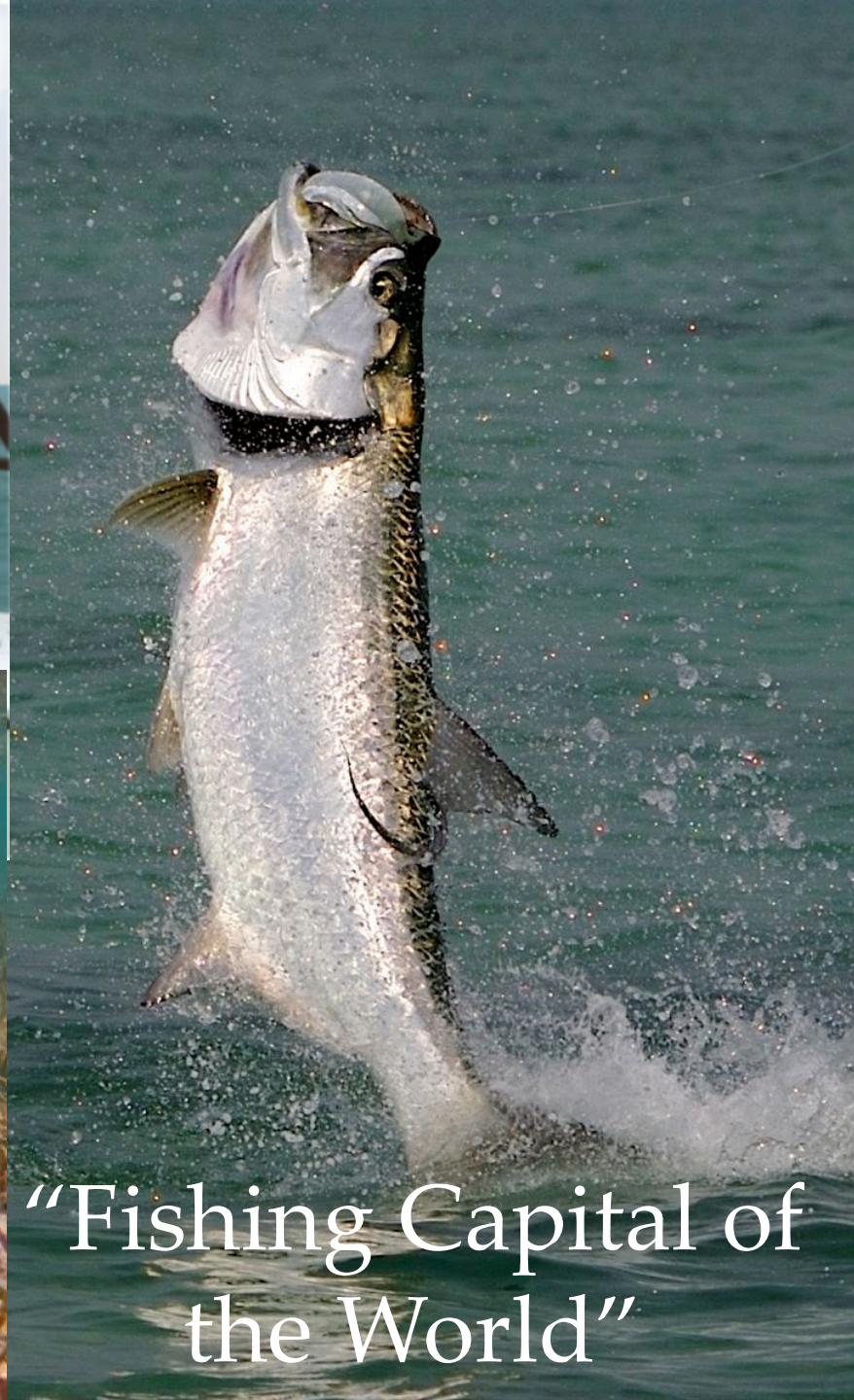
Assessing Reef Fish Changes & Marine Reserve Dynamics in Florida

Jerald S. Ault & Steven G. Smith



"Fishing Capital of the World"

Major Threats to Sustainability

- Fishing pressures
- Habitat loss & degradation
- Prey-base reductions
- Water quality – flow changes
- Recruitment collapse
- Climate changes
- Multiple interacting effects

Competition for Finite Resources

2X in 13 years!!

11 1:14 PM

Pressures

Fish Habitat Degradation & Loss

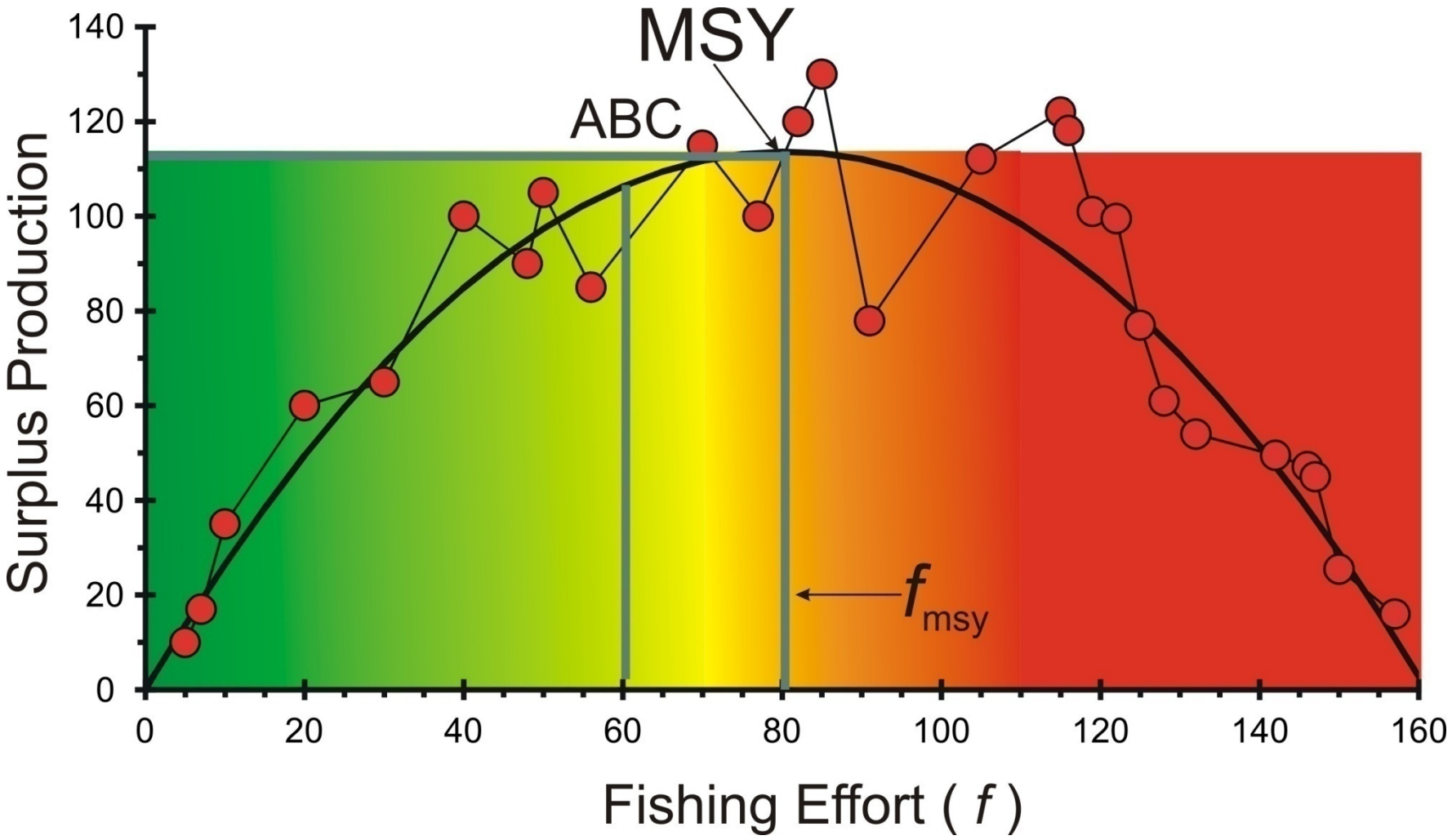
The Nature of Sustainability

Key management concern

- Sustainability of multispecies reef fisheries and their habitats

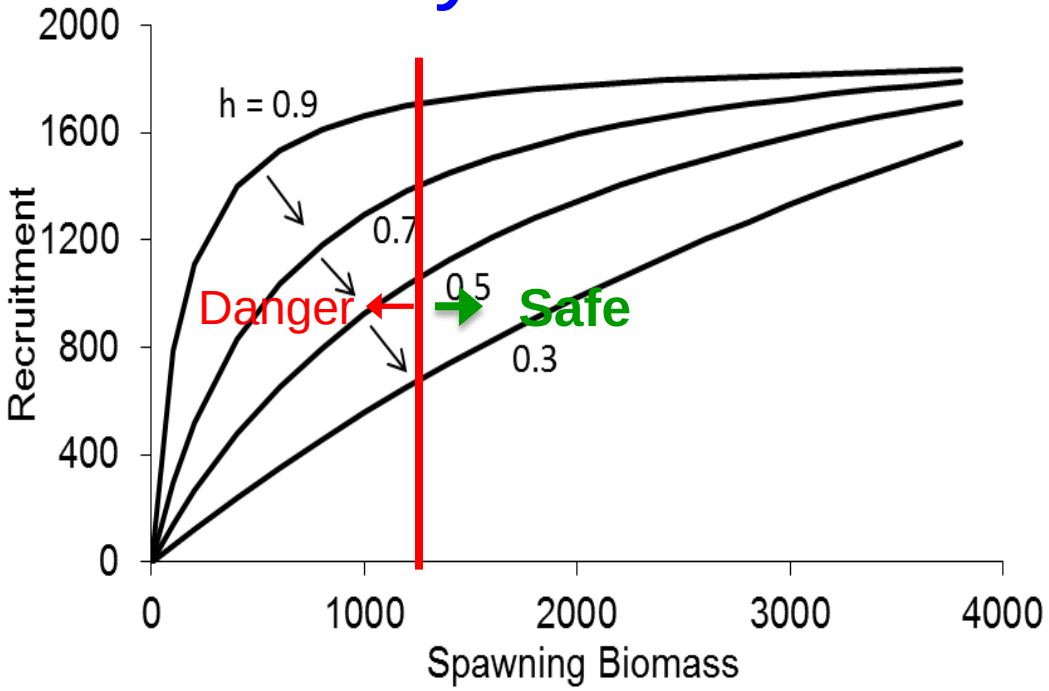
"Sustainability"

Ability of exploited stock to maintain sufficient reproductive capacity to produce yields at suitable levels into the indefinite future.

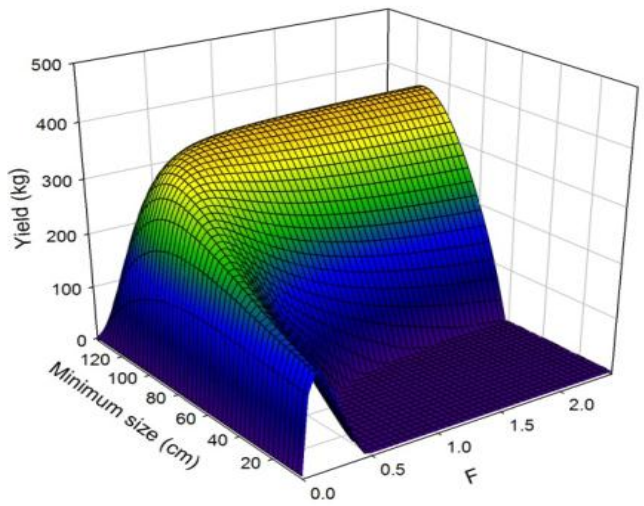

MSY
ABC
f_{msy}
Surplus Production
Fishing Effort (f)
0
20
40
60
80
100
120
140
160

Sustainability Thresholds

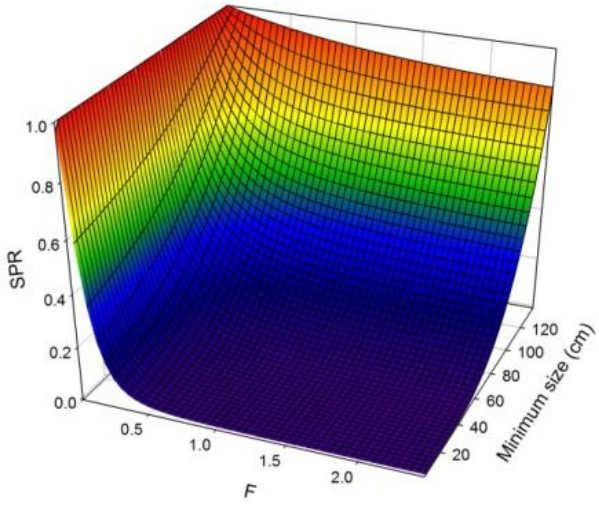
"Steepness"



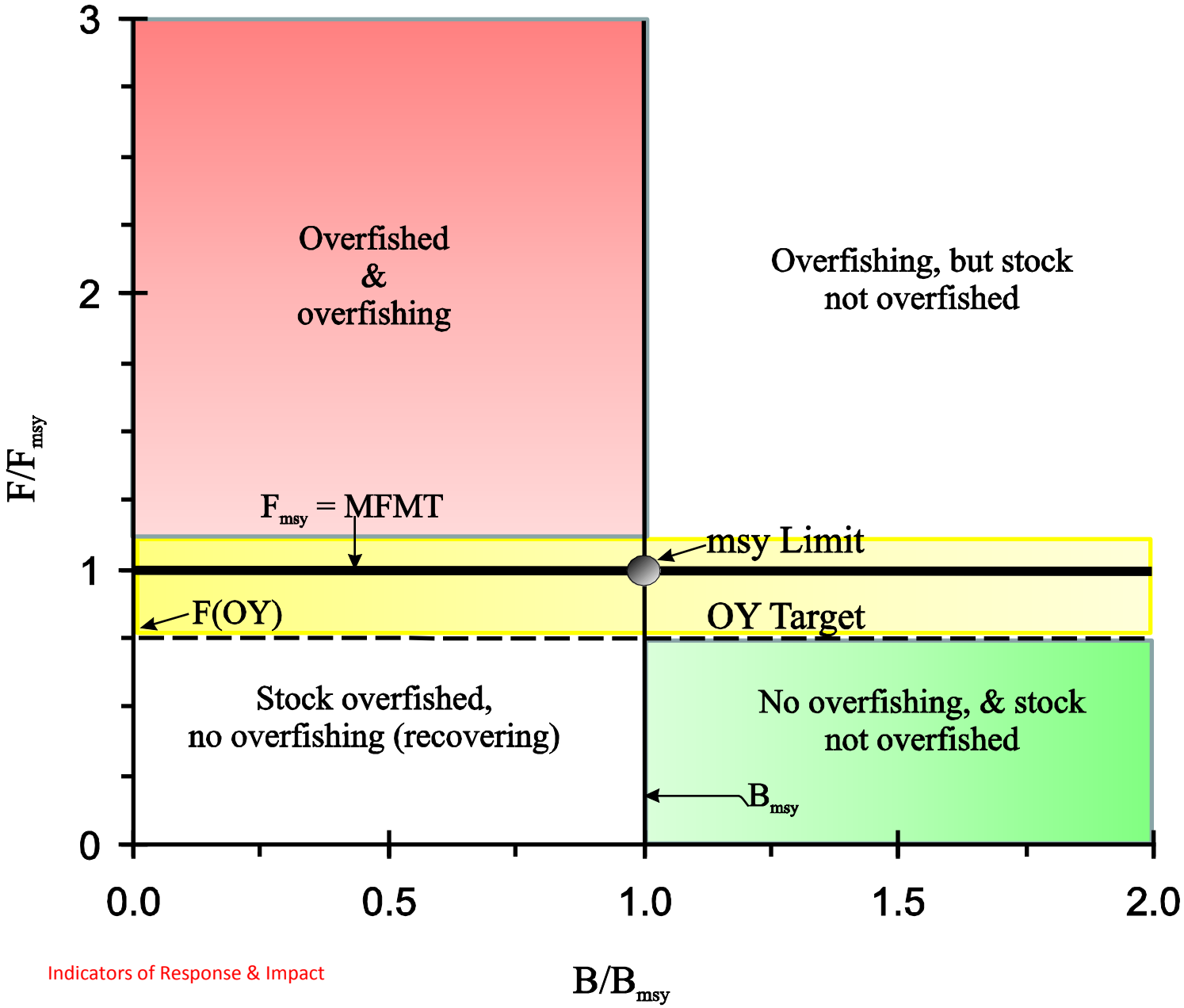
Fishery Yields



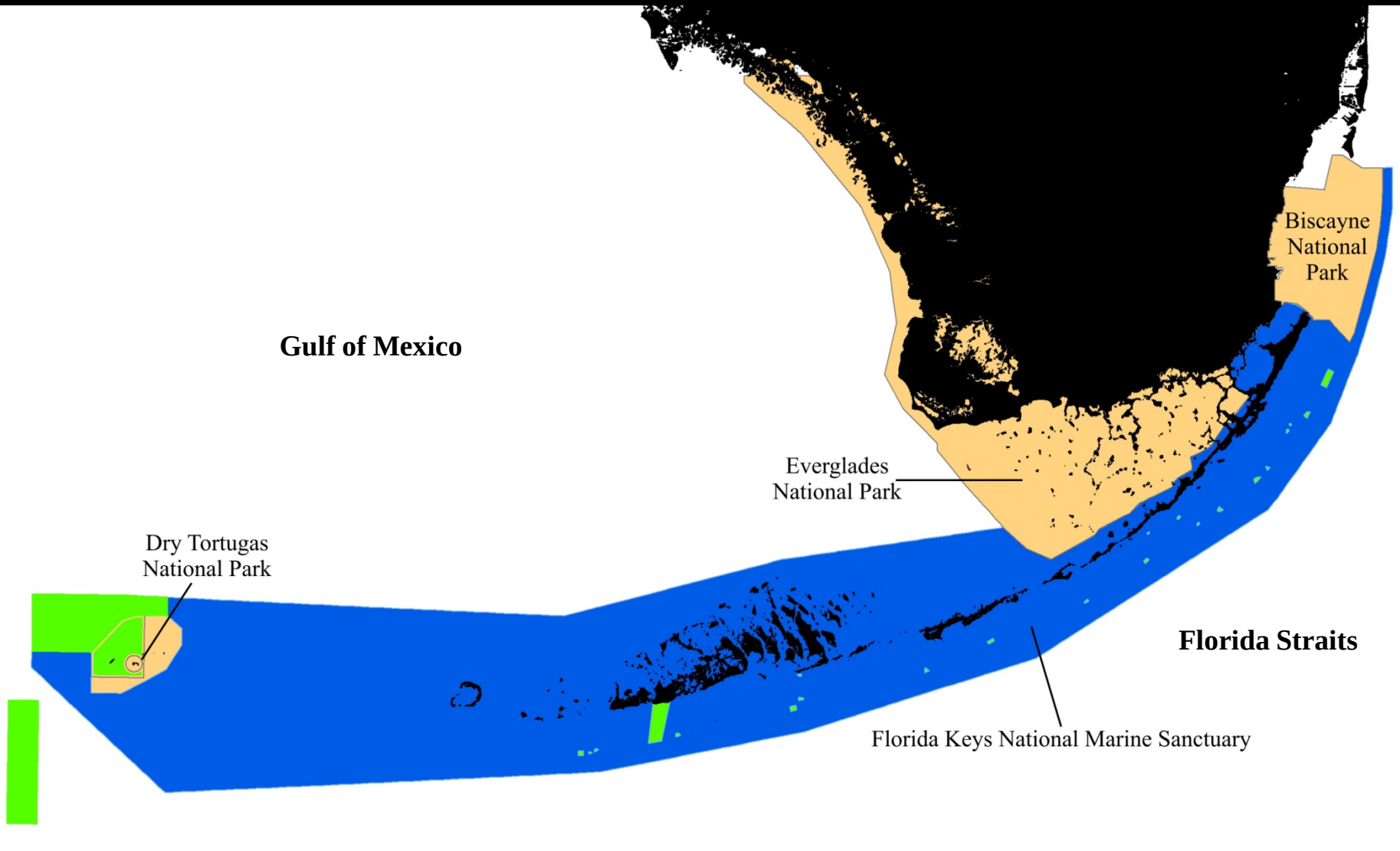
Spawning Stock Biomass



Limit-Control Rule Indicator



The Managed Florida Keys-Dry Tortugas Coral Reef Ecosystem



Fisheries Research 109 (2011) 25–41

Contents lists available at ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Multispecies survey design for assessing reef-fish stocks, spatially explicit management performance, and ecosystem condition

Steven G. Smith[a,*], Jerald S. Ault[a], James A. Bohnsack[b], Douglas E. Harper[b], Jiangang Luo[a], David B. McClellan[b]

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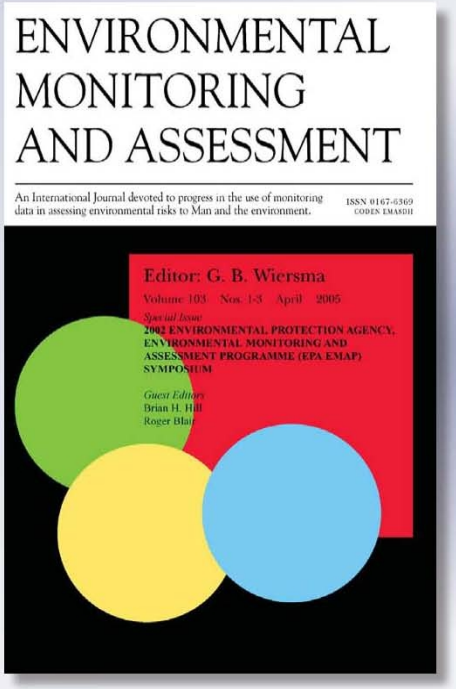
Probability sampling of stony coral populations in the Florida Keys

Steven G. Smith, Dione W. Swanson, Mark Chiappone, Steven L. Miller & Jerald S. Ault

Environmental Monitoring and Assessment
An International Journal Devoted to Progress in the Use of Monitoring Data in Assessing Environmental Risks to Man and the Environment

ISSN 0167-6369
Volume 183
Combined 1-4

Environ Monit Assess (2011)
183:121-138
DOI 10.1007/s10661-011-1912-2



Springer

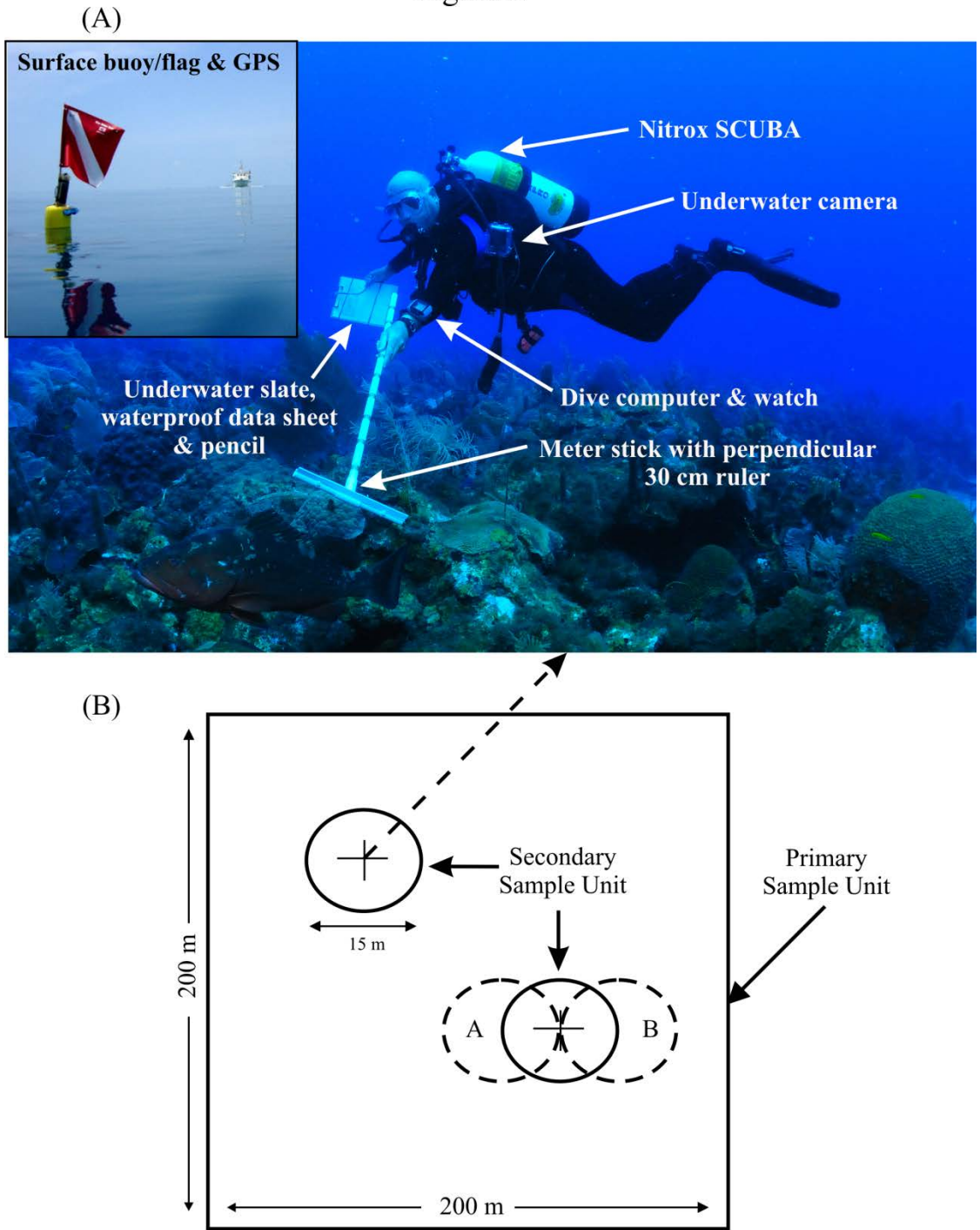
National Park Service
U.S. Department of the Interior

Natural Resource Program Center

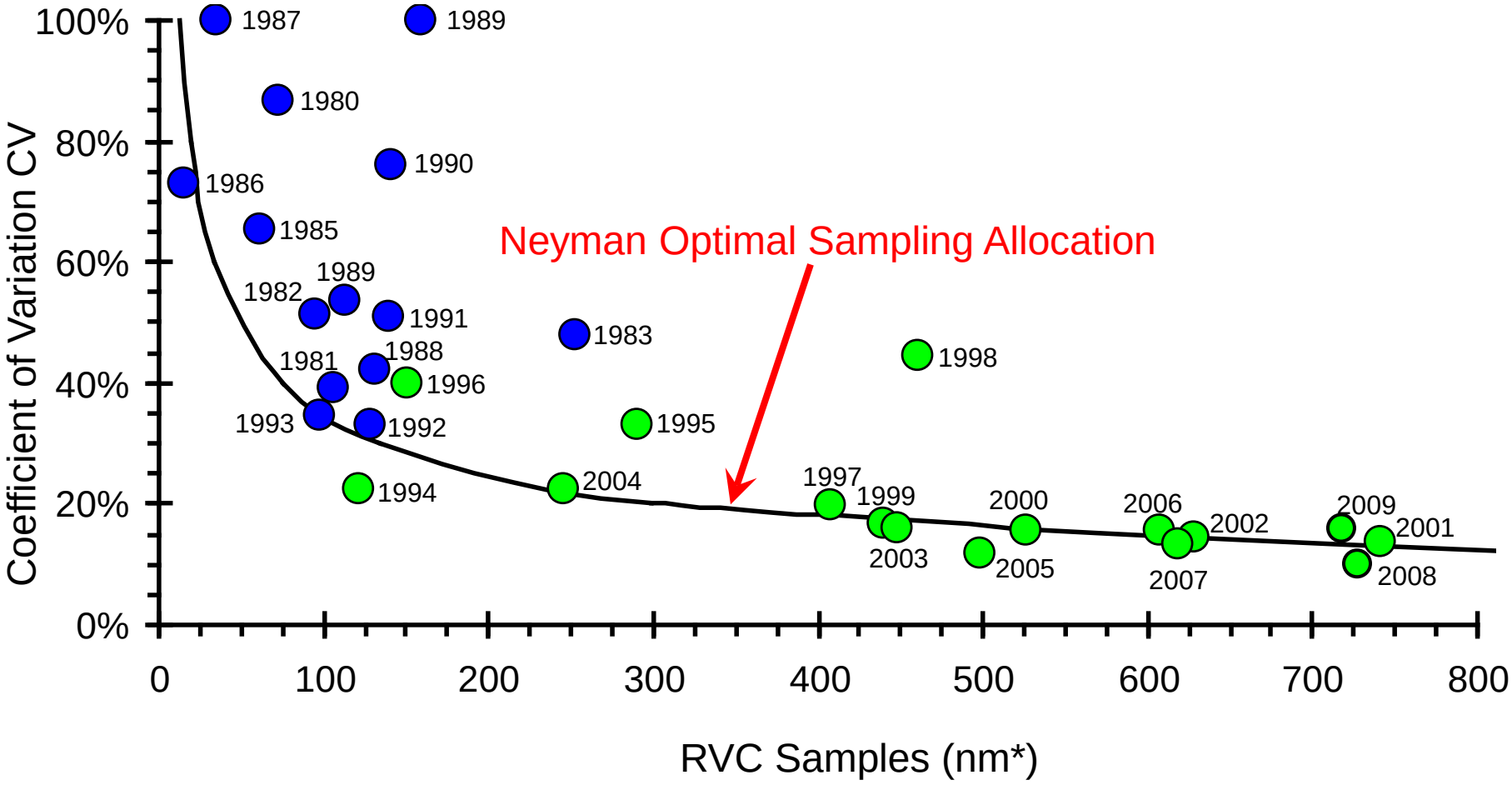
A Cooperative Multi-agency Reef Fish Monitoring Protocol for the Florida Keys Coral Reef Ecosystem

Natural Resource Report NPS/SFCN/NRR—2009/150

Figure 2


(A)
Surface buoy/flag & GPS
Nitrox SCUBA
Underwater camera
Underwater slate, waterproof data sheet & pencil
Dive computer & watch
Meter stick with perpendicular 30 cm ruler
(B)
Secondary Sample Unit
Primary Sample Unit
15 m
200 m
200 m
A
B

Florida Keys
Sampling Design Efficiency 1979-2010



Smith, Ault et al. 2011. Fisheries Research 109(1): 25-41.

A retrospective (1979–1996) multispecies assessment of coral reef fish stocks in the Florida Keys

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Manuscript accepted 16 December 1997.
Fishery Bulletin 96(3):395–414 (1998).

ICES Journal of Marine Science, 62: 417–423 (2005)
doi:10.1016/j.icesjms.2004.12.001

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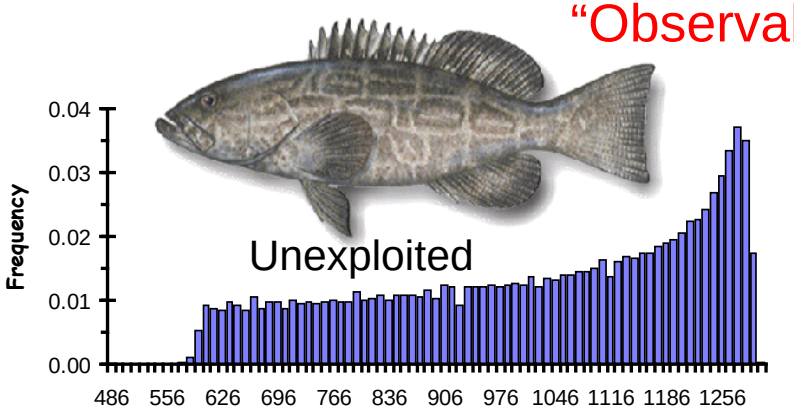
Evaluation of average length as an estimator of exploitation status for the Florida coral-reef fish community

Jerald S. Ault, Steven G. Smith, and James A. Bohnsack

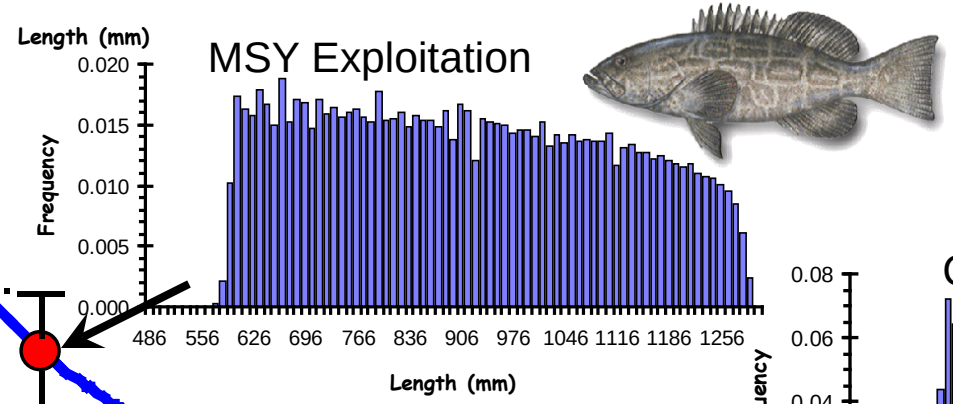
Ault, J. S., Smith, S. G., and Bohnsack, J. A. 2005. Evaluation of average length as an estimator of exploitation status for the Florida coral-reef fish community. – ICES Journal of Marine Science, 62: 417–423.

“Observable” Assessment Indicator Variables



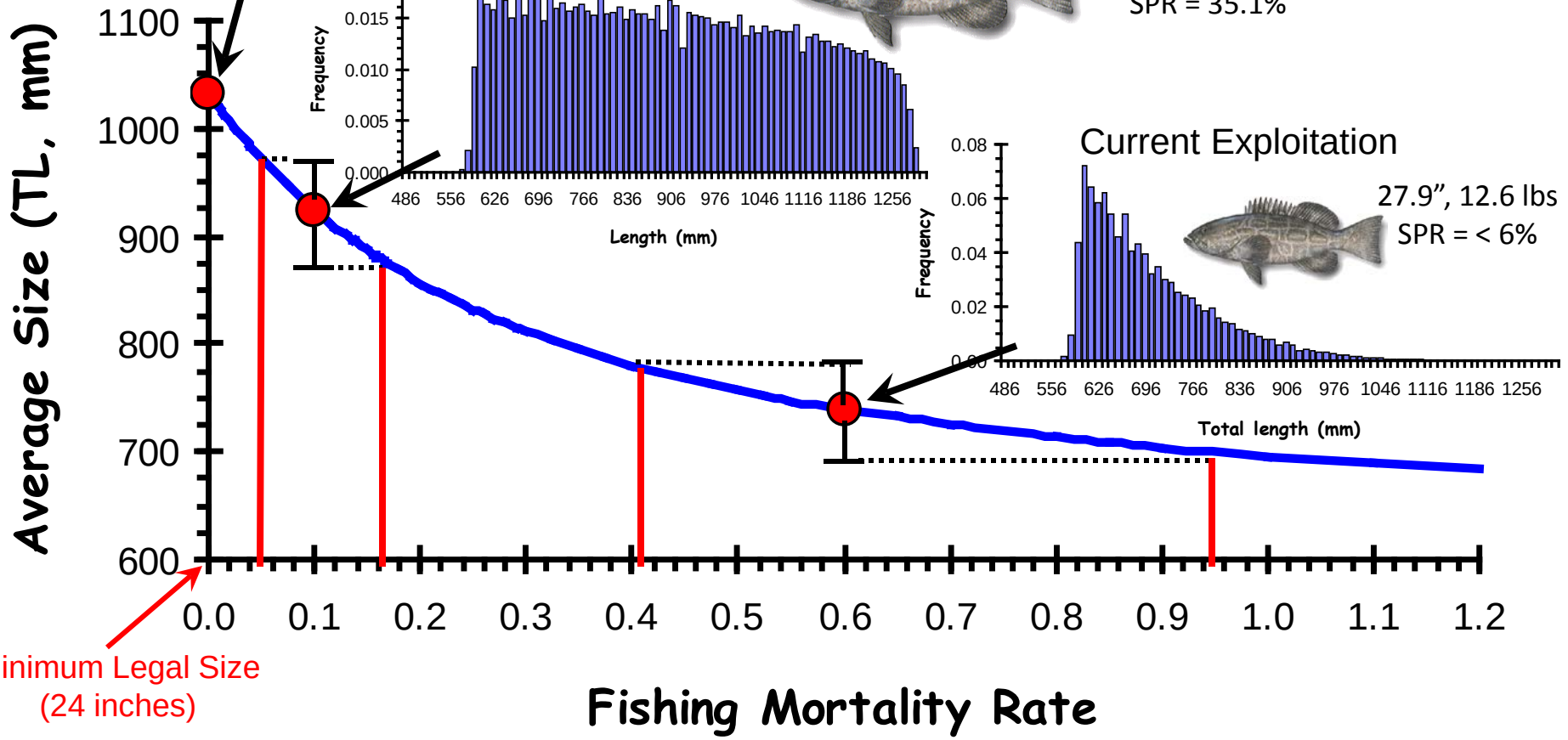
40.6”, 42.8 lbs
SPR = 100%

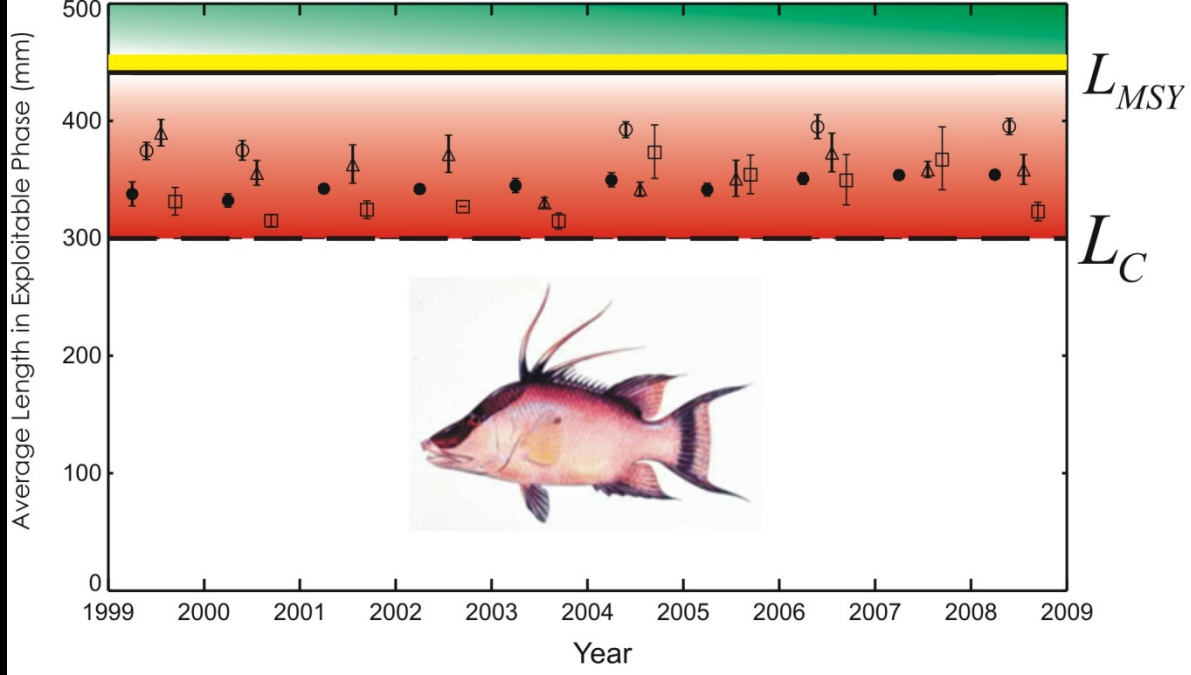
$$\bar{L}(t) = \frac{F(t)\int_{a_c}^{a_\lambda} N(a,t)\, L(a,t)\, da}{F(t)\int_{a_c}^{a_\lambda} N(a,t)\, da}$$

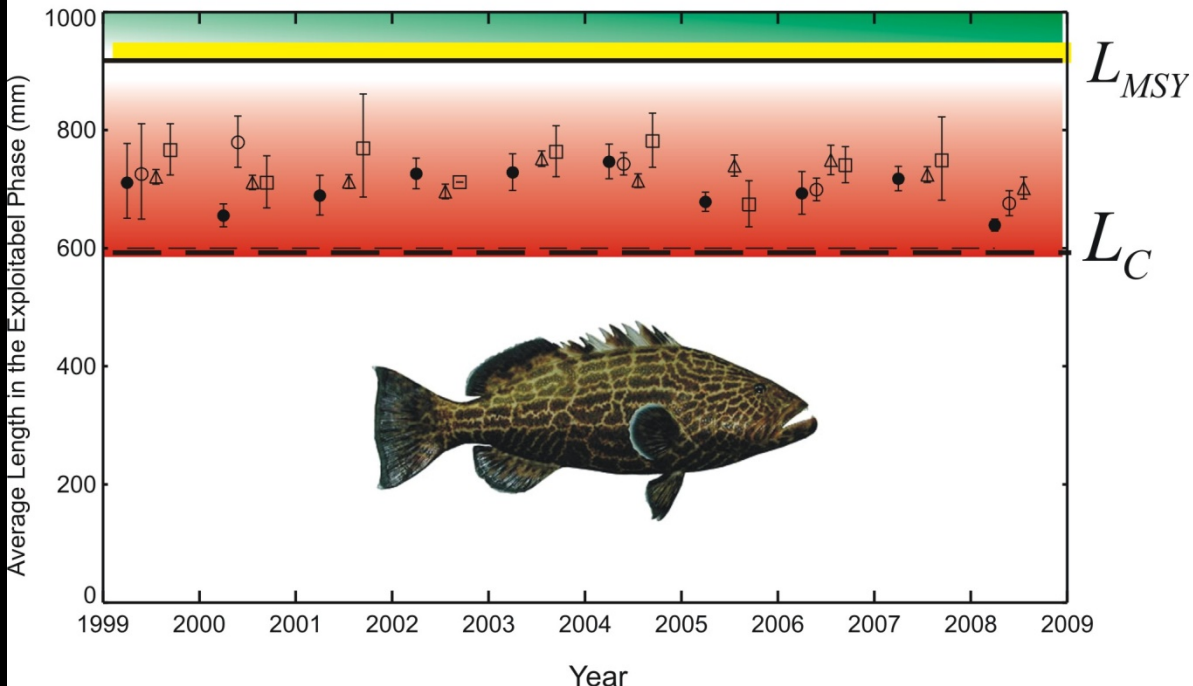


36.4”, 30.1 lbs
SPR = 35.1%

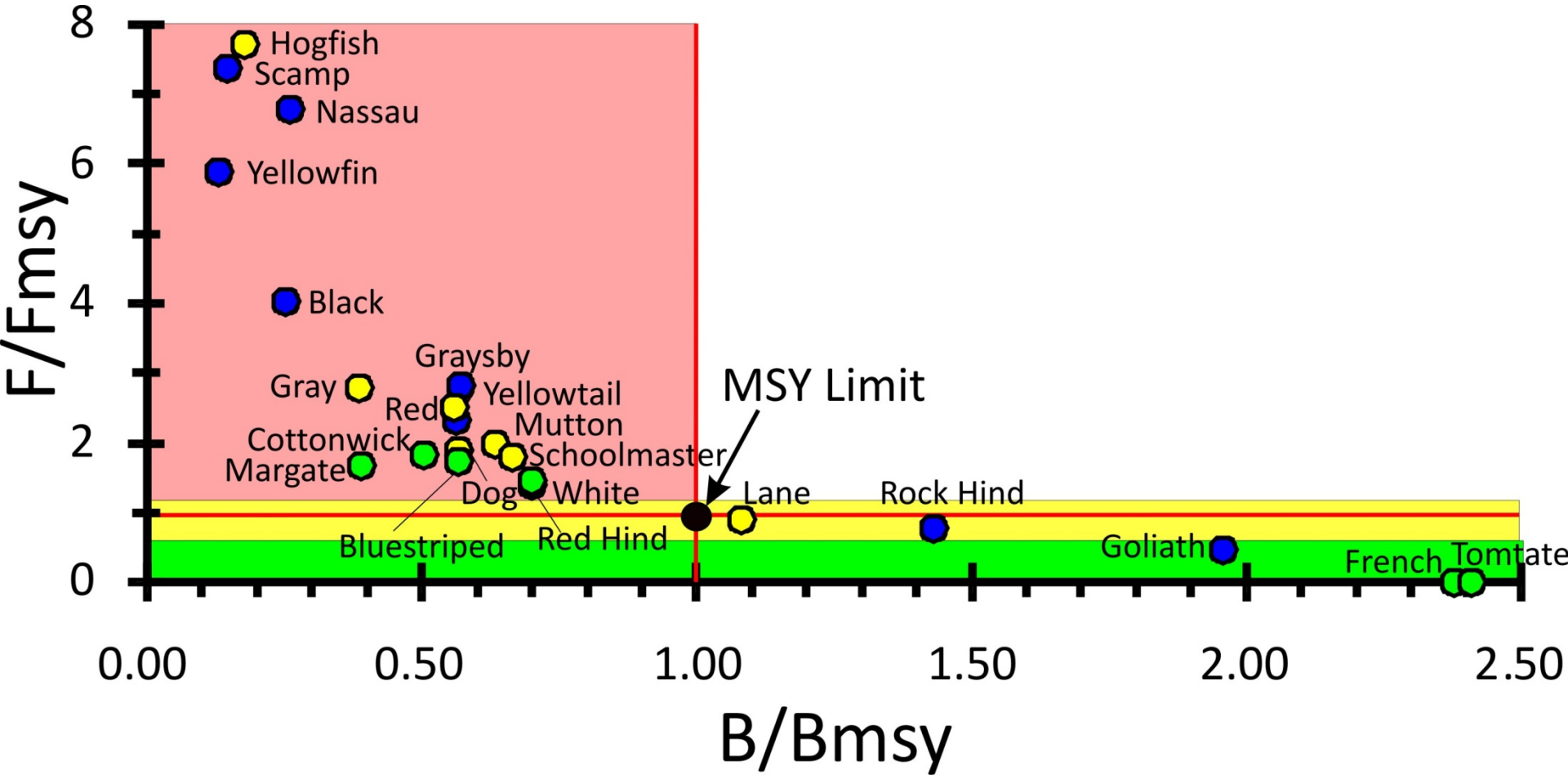
27.9”, 12.6 lbs
SPR = < 6%




Average Length in Exploitable Phase (mm)
500
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year
L_{MSY}
L_C


Average Length in the Exploitabel Phase (mm)
1000
800
600
400
200
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year
L_{MSY}
L_C

Florida Keys – Dry Tortugas
Limit-Control Rule Indicator



Ault et al. 1998. Fishery Bulletin 96(3): 395-414.
Ault et al. 2005. ICES J. Marine Science 62: 417-423.
Ault et al. 2009. International Coral Reef Symposium 11: 989-993.

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ISSN 0025-1909 | EISSN 1526-5501 | 04 | 5008 | 1031

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Designing Marine Reserves for Fishery Management

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Optimal Design of Marine Reserves

OBJECTIVE FUNCTION

$$Min\left\{\mu_q^+ q^+ + \sum_{s\in S}\left(\mu_s^+ p_s^+ + \mu_s^- p_s^-\right) + \left(\mu_f^+ f^+ + \mu_f^- f^-\right) + \left(\mu_c^+ c^+ + \mu_c^- c^-\right) + \left(\mu_a^+ a^+ + \mu_a^- a^-\right) + \sum_{r\in R}\left(\mu_{ar}^+ a_r^+ + \mu_{ar}^- a_r^-\right)\right\}$$

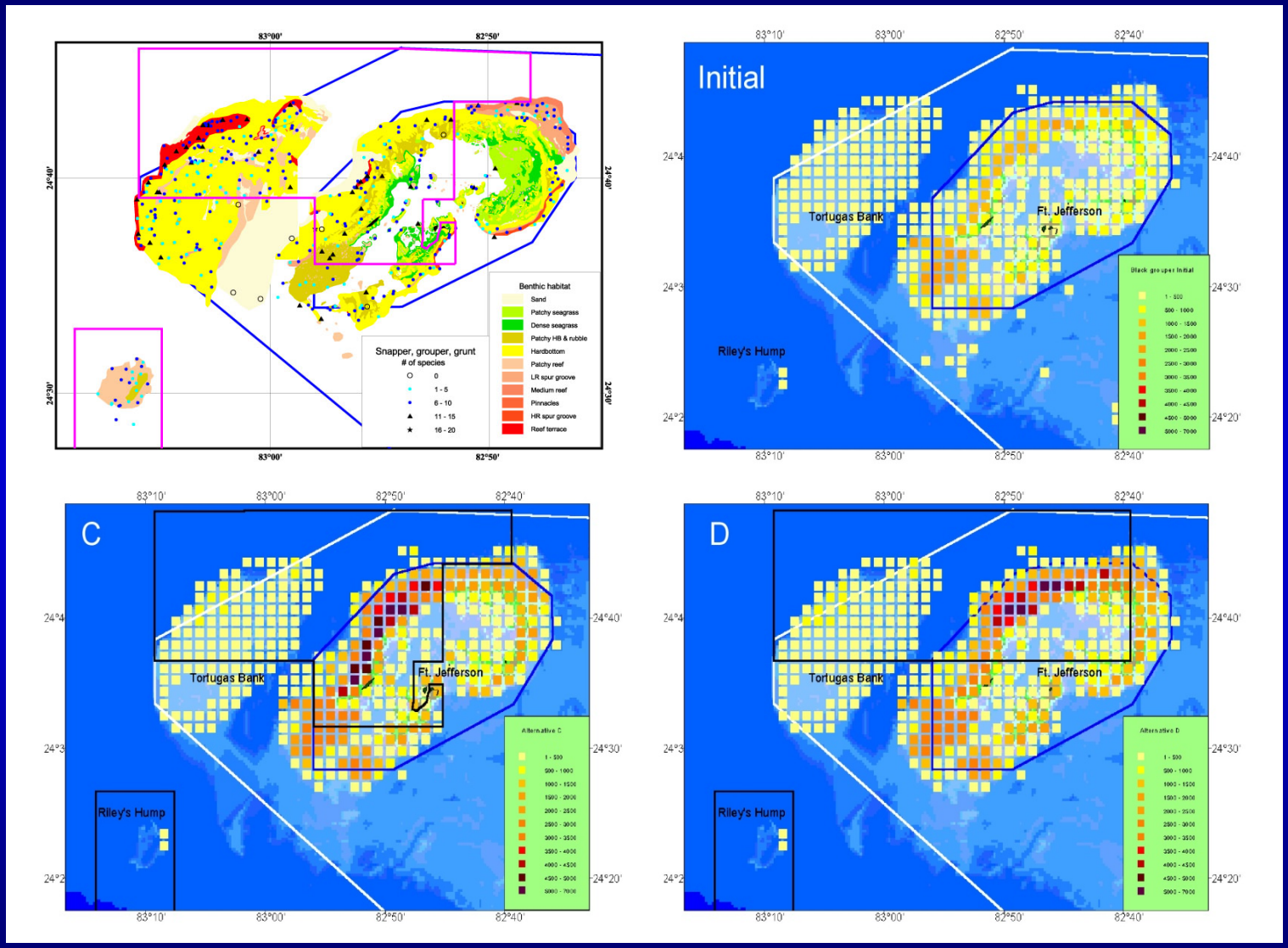
Reserve shape	SPR over all species	fishing effort	Reef area	Total Reserve area	Regional Reserve area

CONSTRAINTS -- SUBJECT TO:

(C1) Reserves non-overlapping
(C2) Pre-specified number of reserves
(C3) Fixed proportion of SPR protected
(C4) Maximum number of fishing vessels displaced by reserves
(C5) Target area of coral reef area protected
(C6) Target total area protected
(C7) Distribution of reserves among regions of ecosystem
(C8) Each reserve contiguous, compact, and desirably shaped

Meester, Mehrotra, Ault and Baker. 2004. Management Science 50: 1031-1043

Designing Marine Reserves for Fishery Management

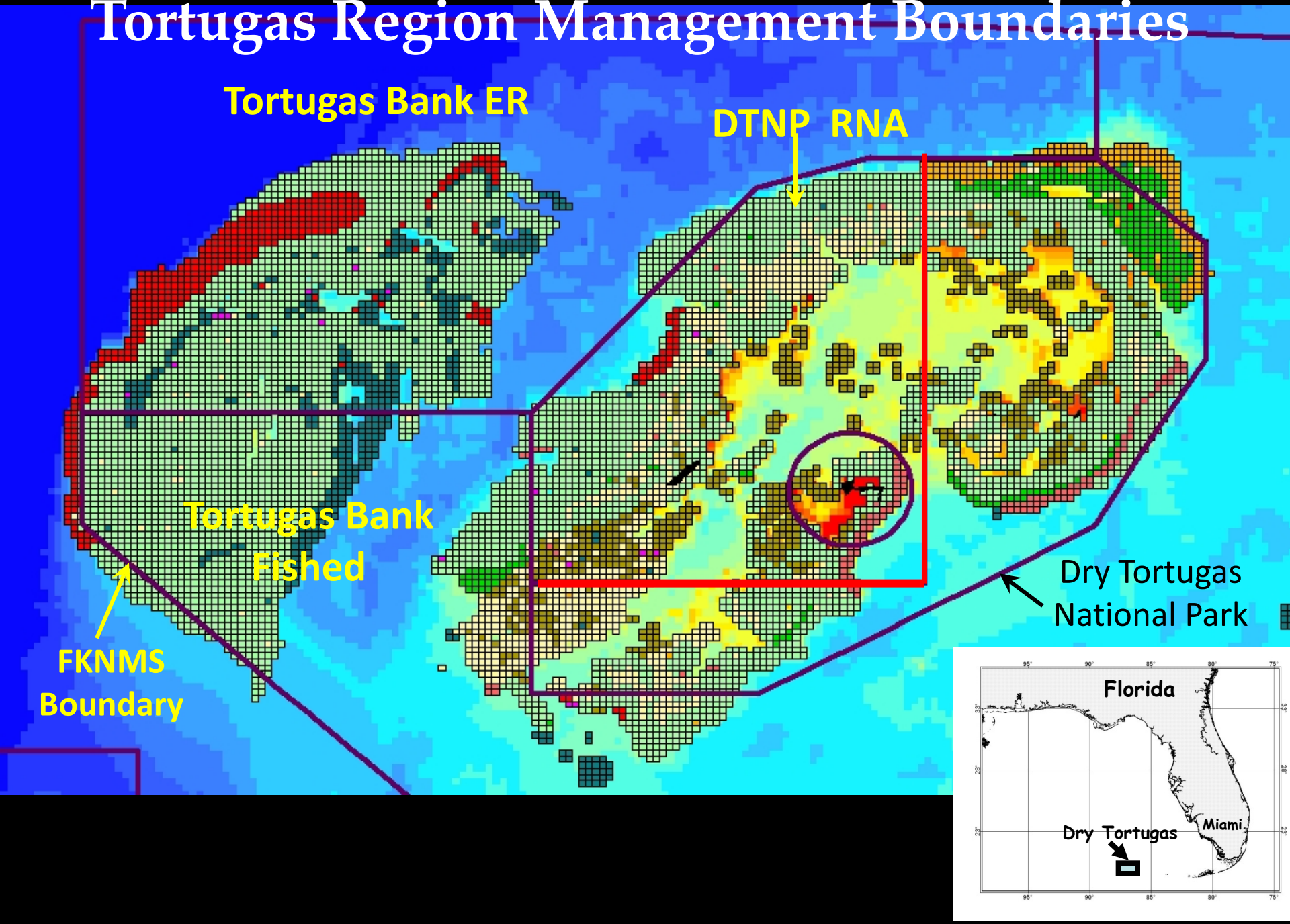


Integrated methodologies:

(1) Integer Goal Programming for network design;

(2) Simulation to assess shape and size effects.

Tortugas Region Management Boundaries



Fisheries Research 144 (2013) 28–37

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Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Assessing coral reef fish population and community changes in response to marine reserves in the Dry Tortugas, Florida, USA

Jerald S. Ault[a,*], Steven G. Smith[a], James A. Bohnsack[b], Jiangang Luo[a], Natalia Zurcher[a], David B. McClellan[b], Tracy A. Ziegler[g], David E. Hallac[d], Matt Patterson[e], Michael W. Feeley[e], Benjamin I. Ruttenberg[b], John Hunt[f], Dan Kimball[c], Billy Causey[g]

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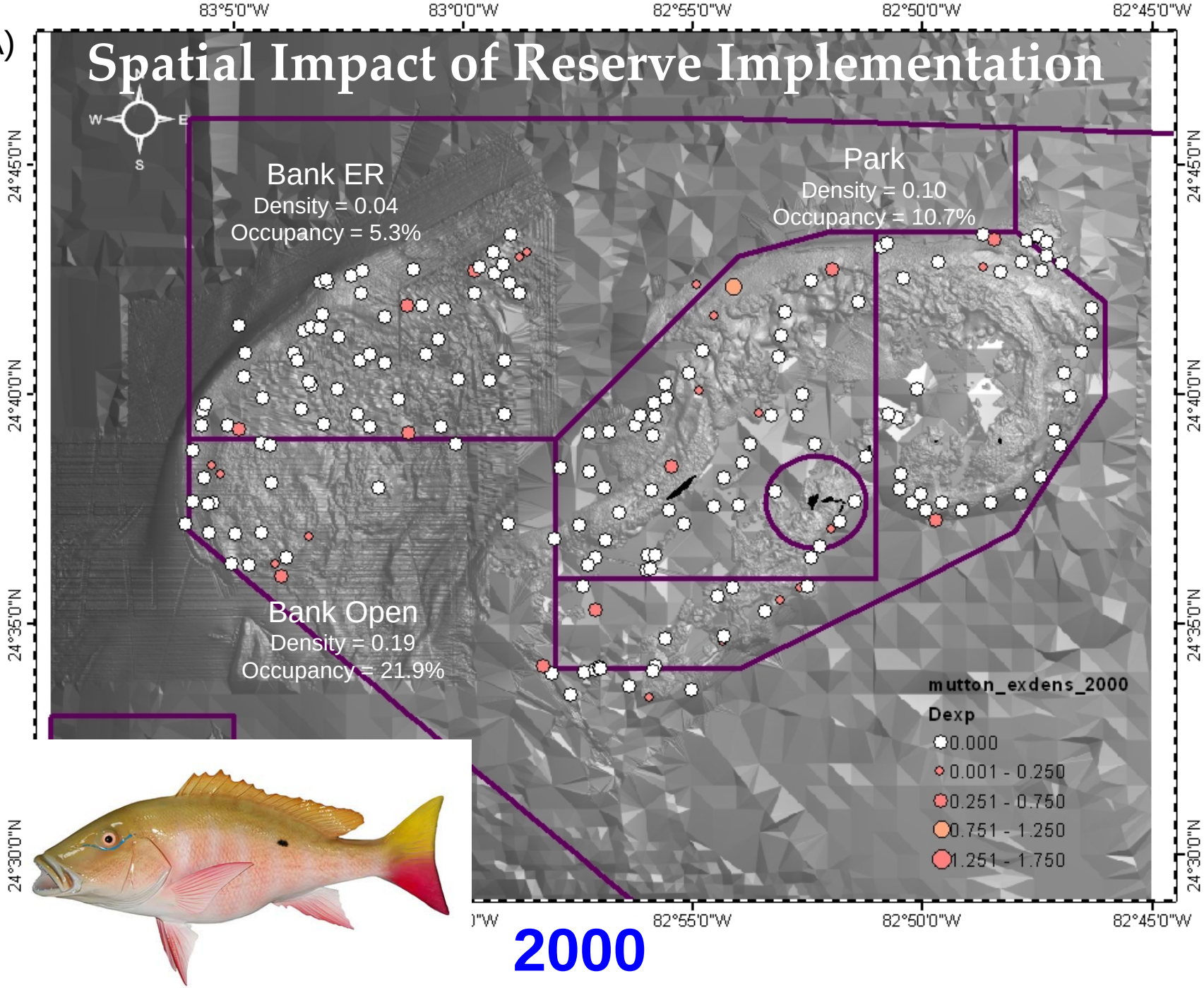
[d] Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190, United States
[e] National Park Service, South Florida-Caribbean Network, 18001 Old Cutler Road Suite 419, Palmetto Bay, FL 33157, United States
[f] Florida Fish and Wildlife Conservation Commission, 2796 Overseas Highway, Suite 119, Marathon, FL 33050, United States
[g] Florida Keys National Marine Sanctuary, 33 East Quay Road, Key West, FL 33040, United States

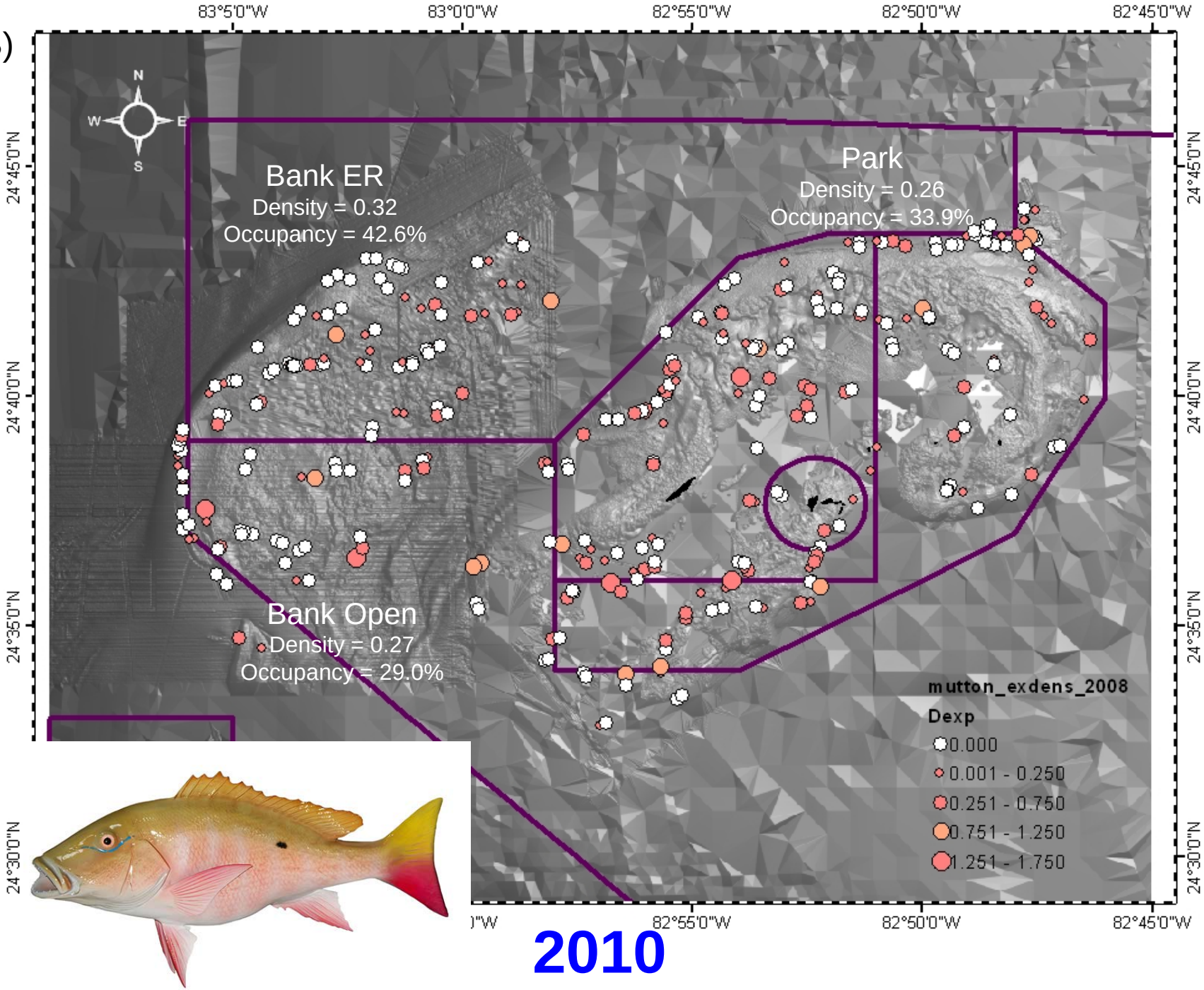
(A)

Spatial Impact of Reserve Implementation



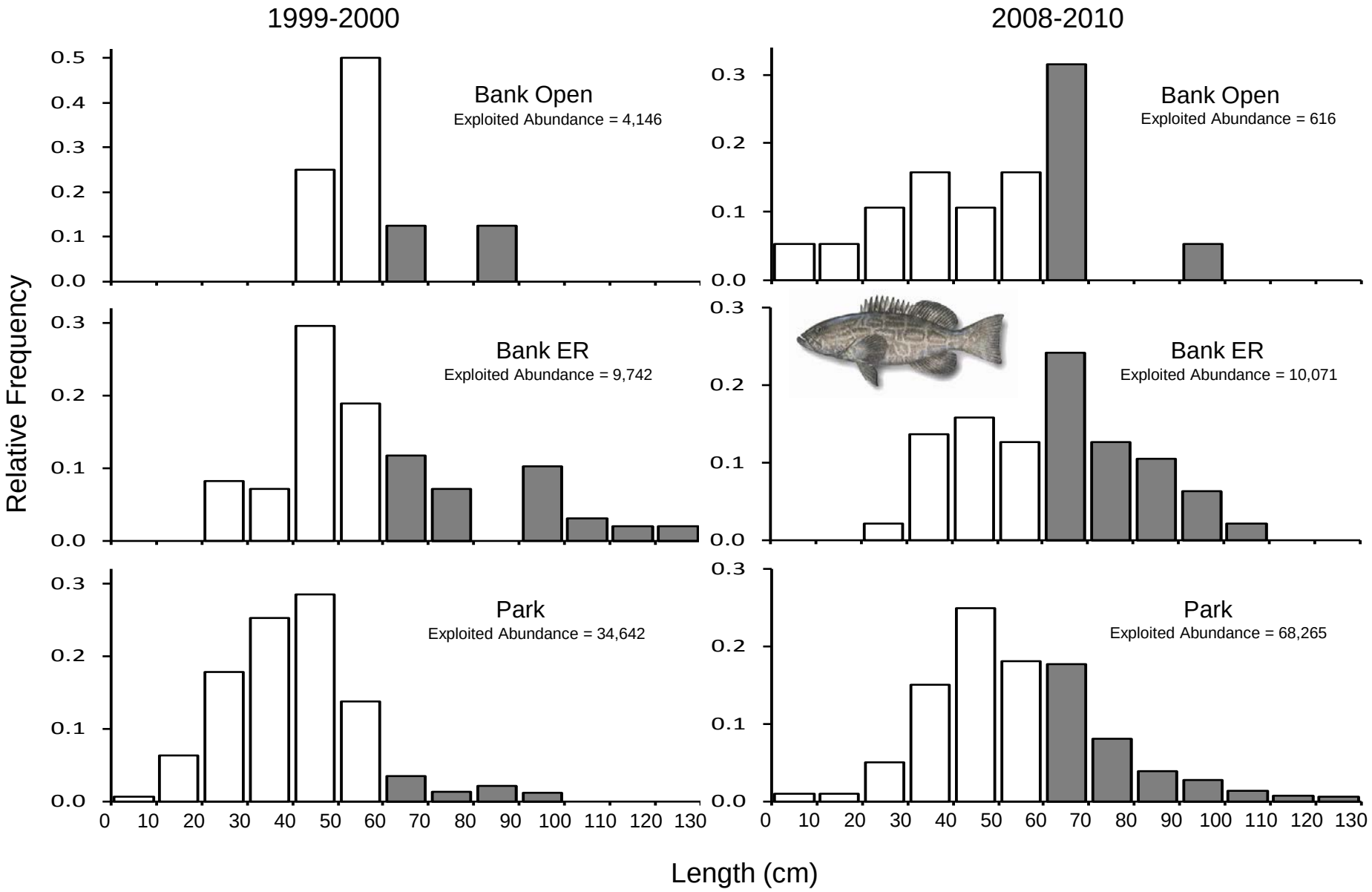
2000

(B)


83°5'0"W
83°0'0"W
82°55'0"W
82°50'0"W
82°45'0"W
24°45'0"N
24°40'0"N
24°35'0"N
24°30'0"N
N
W
E
S
Bank ER
Density = 0.32
Occupancy = 42.6%
Park
Density = 0.26
Occupancy = 33.9%
Bank Open
Density = 0.27
Occupancy = 29.0%
mutton_exdens_2008
Dexp
0.000
0.001 - 0.250
0.251 - 0.750
0.751 - 1.250
1.251 - 1.750

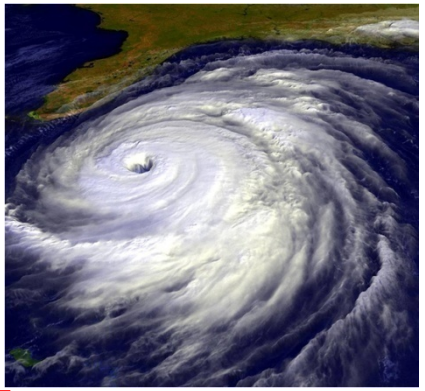
2010

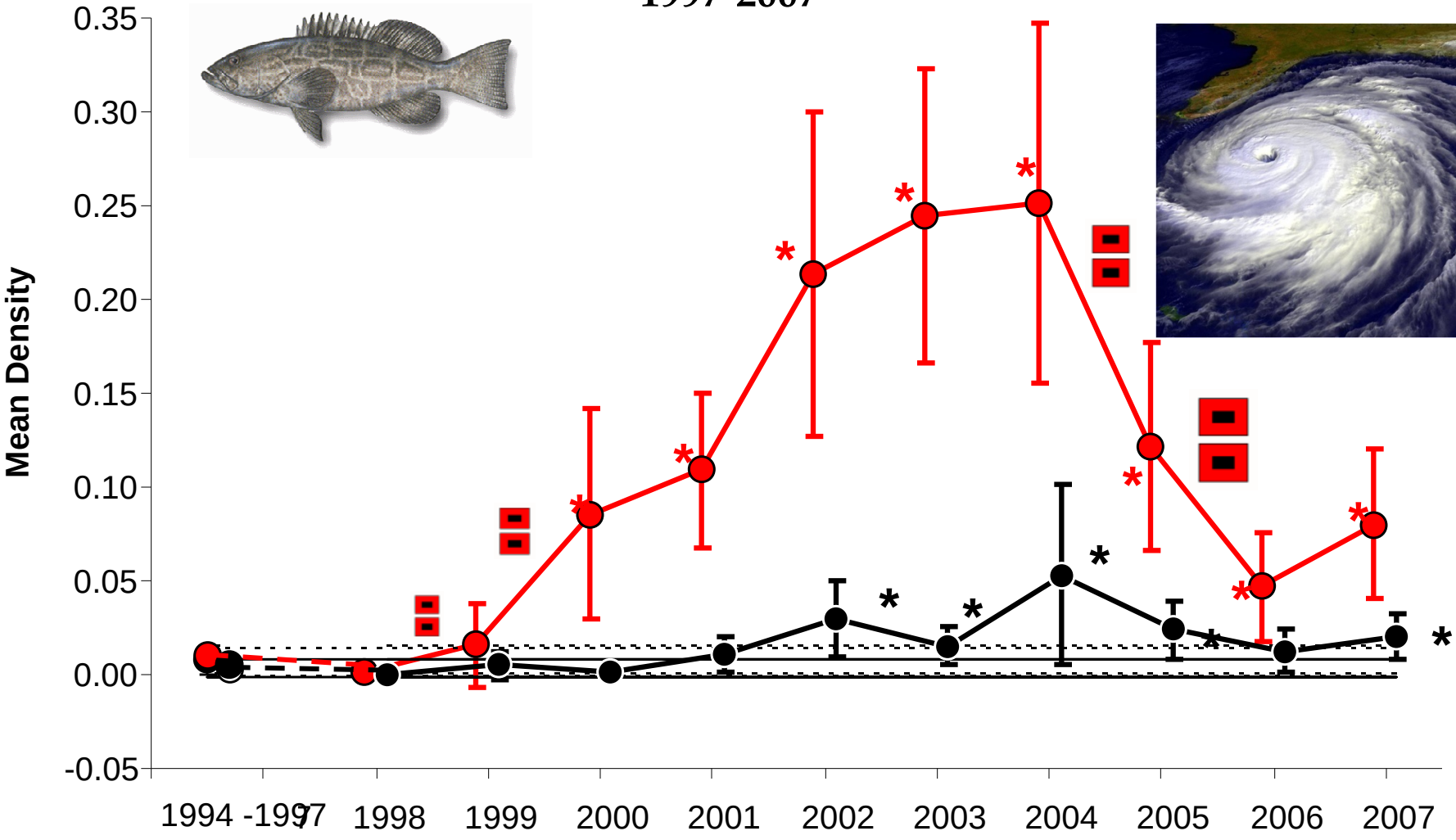
Response of Tortugas MPAs to Protection



Florida Keys National Marine Sanctuary

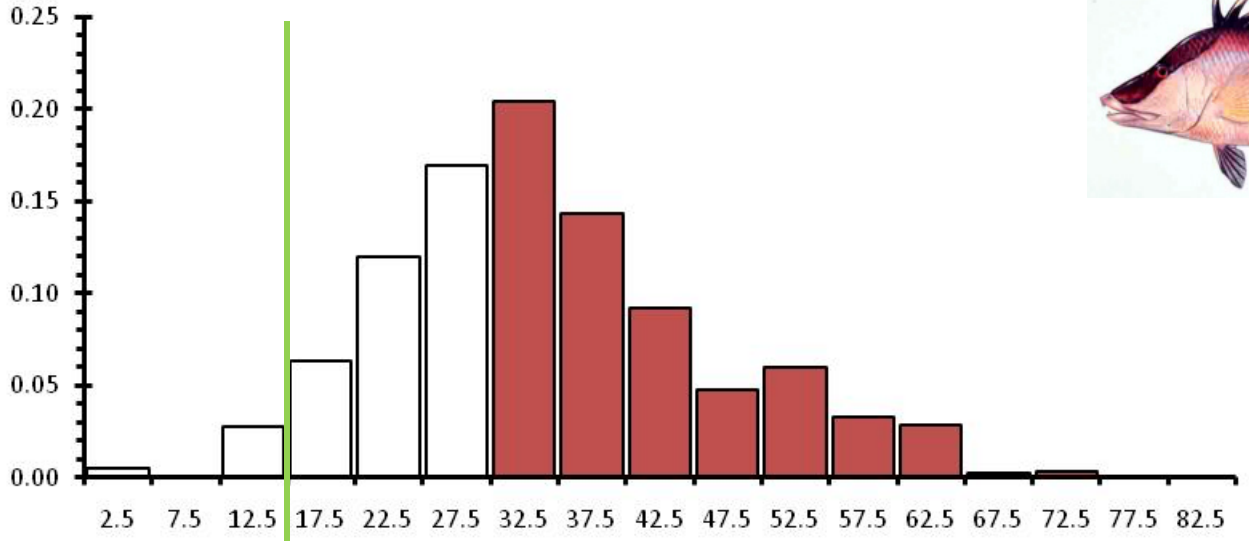
Black Grouper, Exploited and Protected
1997-2007



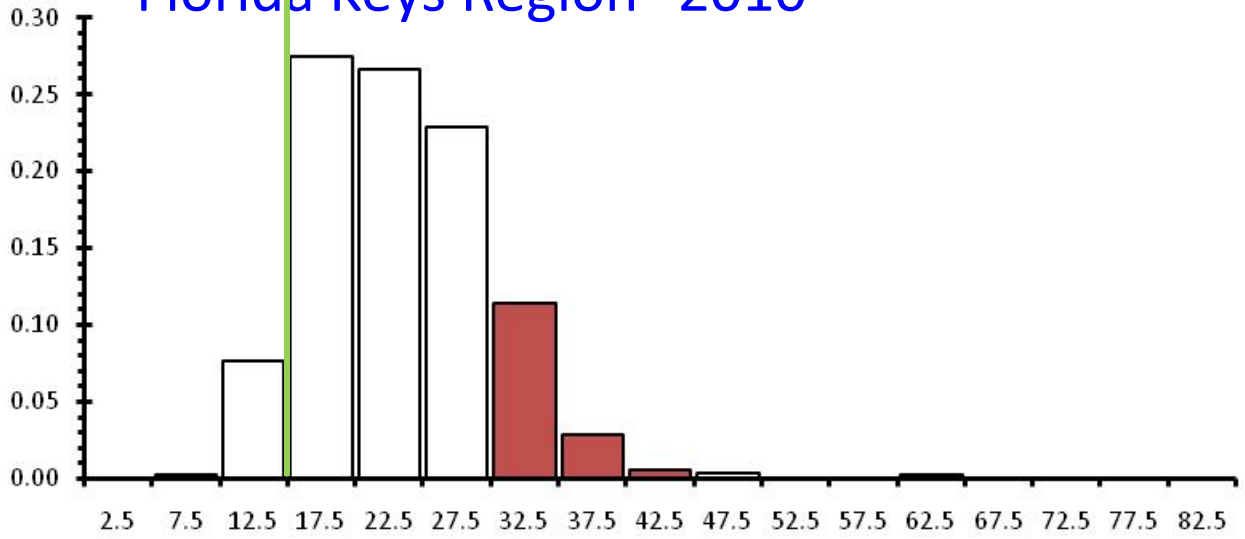


Fishery Regulations minimum length: 1985 - 18”, Feb 1990 - 20”,Dec 1998- 24”, Jan 1 2001 – 22”; 1986 - 5/fisher/day

Dry Tortugas Region--2010



Florida Keys Region--2010



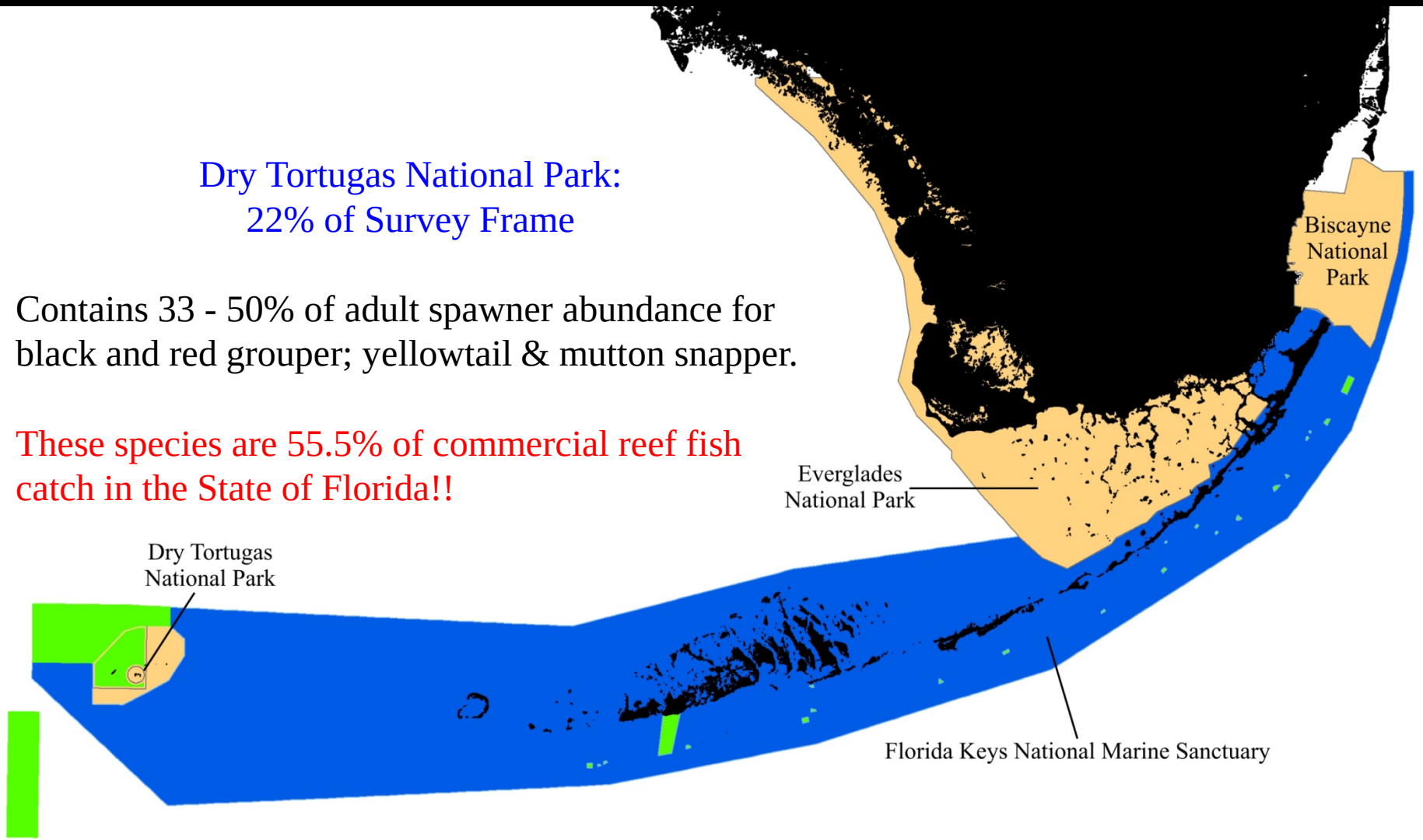
Spatial Distribution of the Spawning Stock for Several Exploited Reef Fishery Resources

Species	Time Period	Spawner Abundance (1000s)	Percentage of Adults: Bank Open (A=6.2%)	Bank ER (8.9%)	Park (22.4%)	Keys Open (58.9%)	Keys NTMR (3.6%)
Red Grouper	1999-2000	522.8	18.3	25.4	45.7	9.9	0.6
	2008-2010	540.1	5.1	24.7	48.6	19.9	1.6
Black Grouper	1999-2000	68.5	6.1	14.2	50.6	16.0	13.2
	2008-2010	130.5	0.5	7.7	52.3	34.9	4.6
Mutton Snapper	1999-2000	409.7	11.6	5.4	26.3	53.1	3.6
	2008-2010	1,078.4	12.3	13.0	32.0	39.5	3.3
Yellowtail Snapper	1999-2000	7,707.5	7.6	14.7	21.6	38.9	17.3
	2008-2010	14,982.7	3.2	17.3	46.3	28.5	4.6
Hogfish	1999-2000	2,758.3	8.5	8.3	21.9	59.0	2.3
	2008-2010	4,314.1	3.0	4.3	14.4	74.8	3.4

Dry Tortugas National Park:
22% of Survey Frame

Contains 33 - 50% of adult spawner abundance for black and red grouper; yellowtail & mutton snapper.

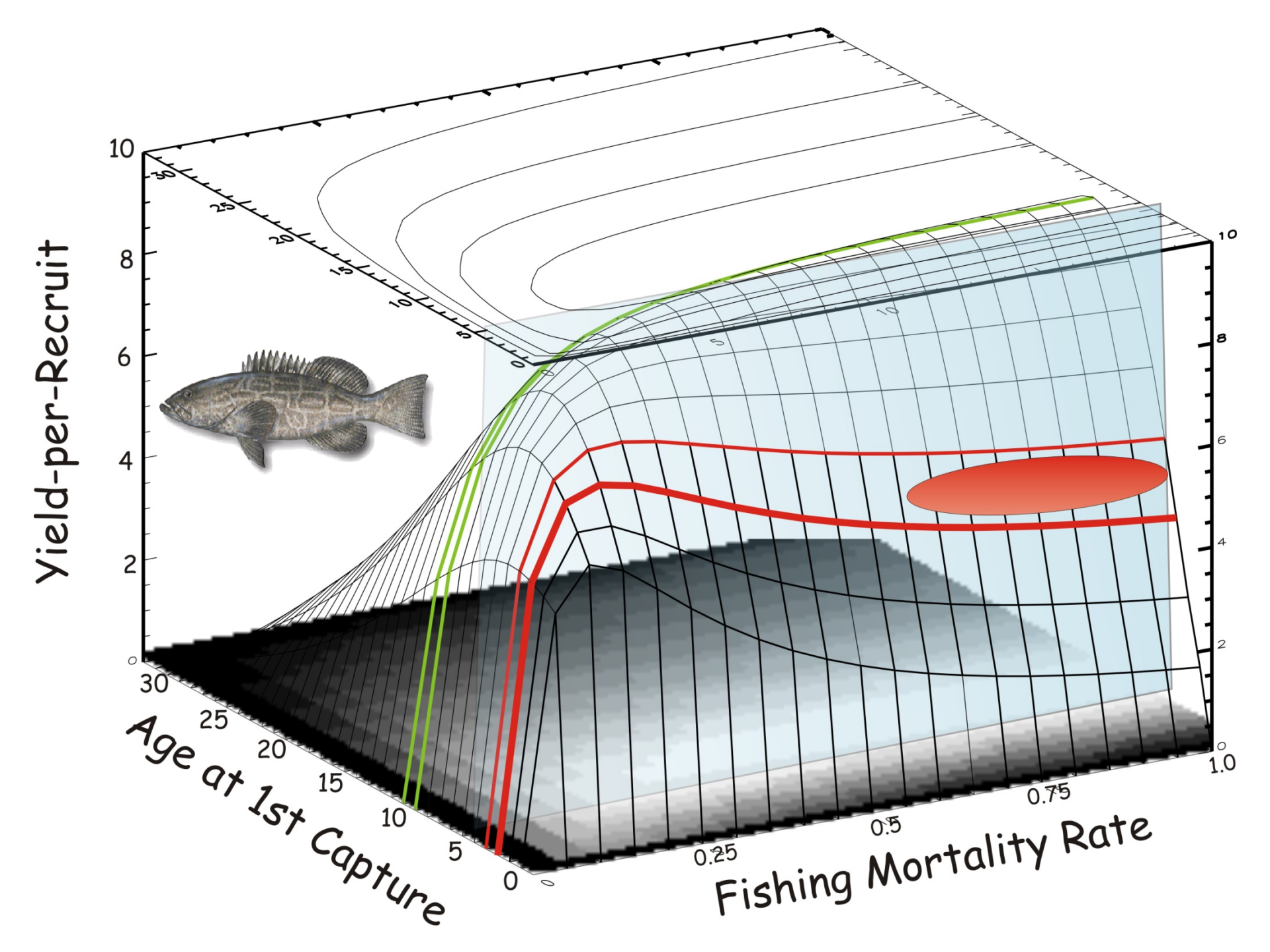
These species are 55.5% of commercial reef fish catch in the State of Florida!!



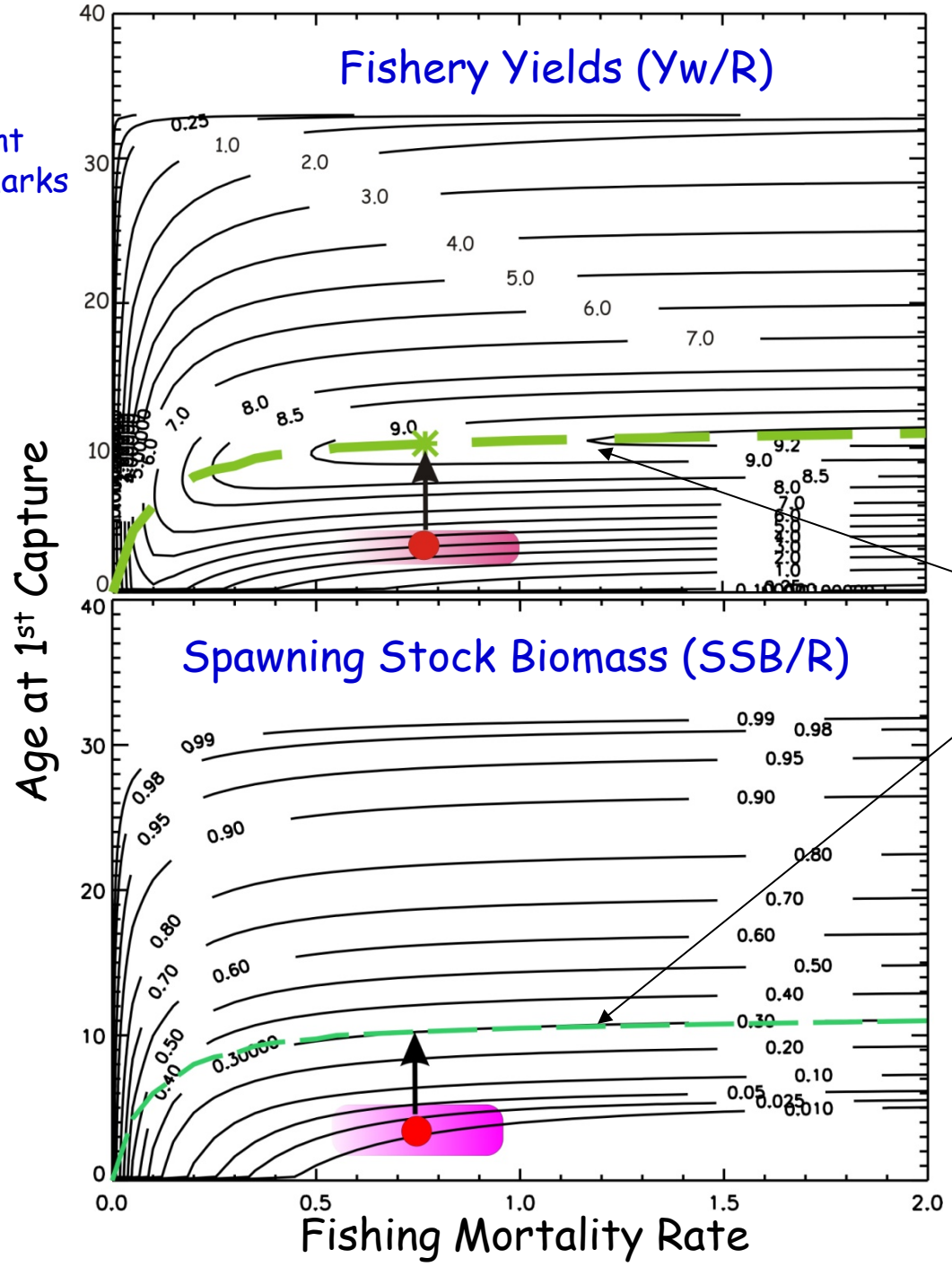
BULLETIN OF MARINE SCIENCE, 76(2): 595–622, 2005

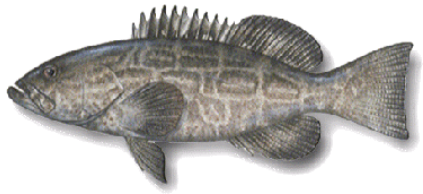
TOWARDS SUSTAINABLE MULTISPECIES FISHERIES IN THE FLORIDA, USA, CORAL REEF ECOSYSTEM

Jerald S. Ault, James A. Bohnsack, Steven G. Smith, and Jiangang Luo


Yield-per-Recruit
10
8
6
4
2
0
30
25
20
15
10
5
0
Age at 1st Capture
0
0.25
0.5
0.75
1.0
Fishing Mortality Rate

Traditional
Fishery Management
Sustainability Benchmarks
& Controls





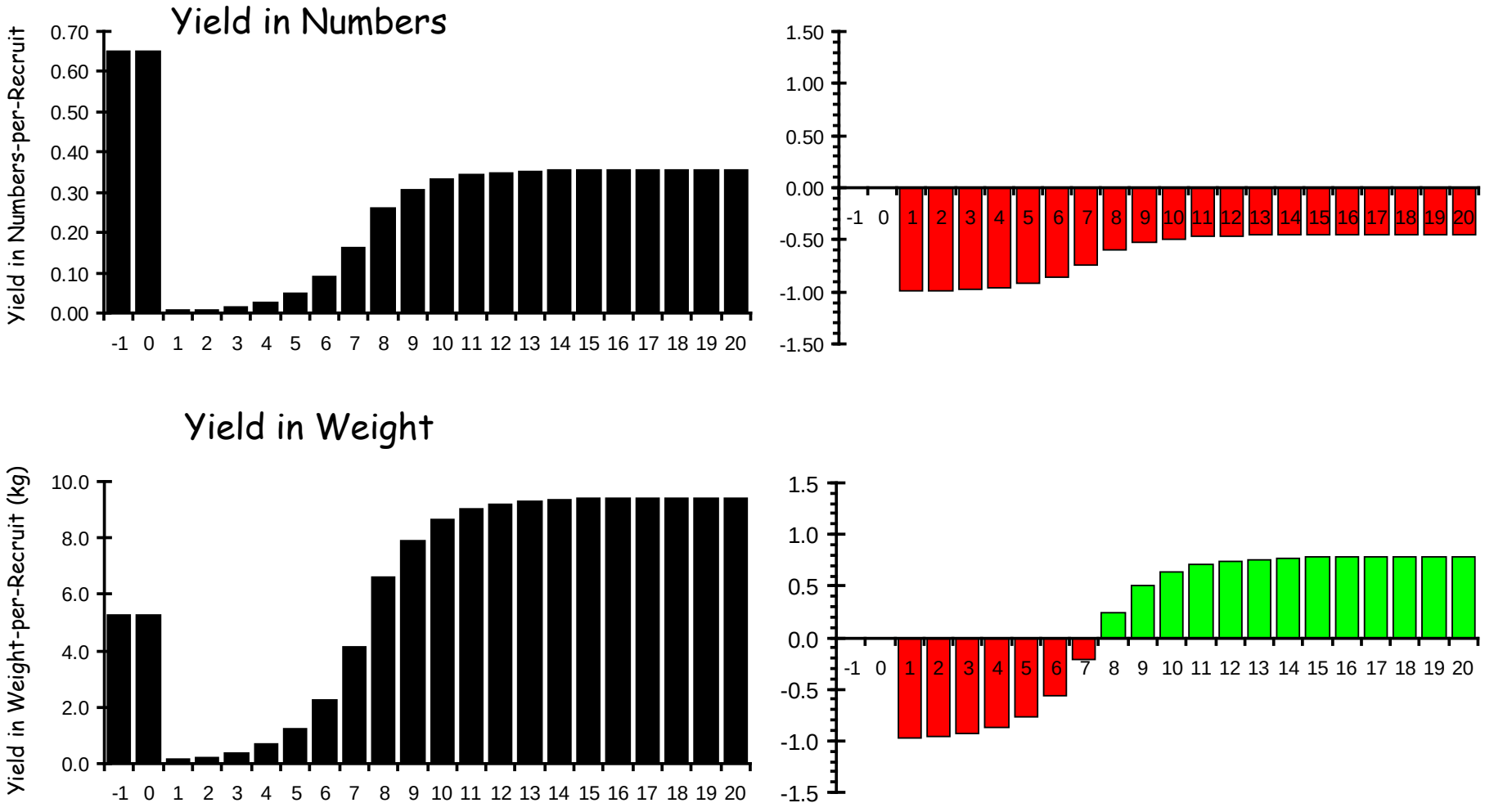
Yw/R
4.77 -> 9.14 kg
+ 92% increase

SSB/R
0.022 -> 0.305
+ 1286% increase

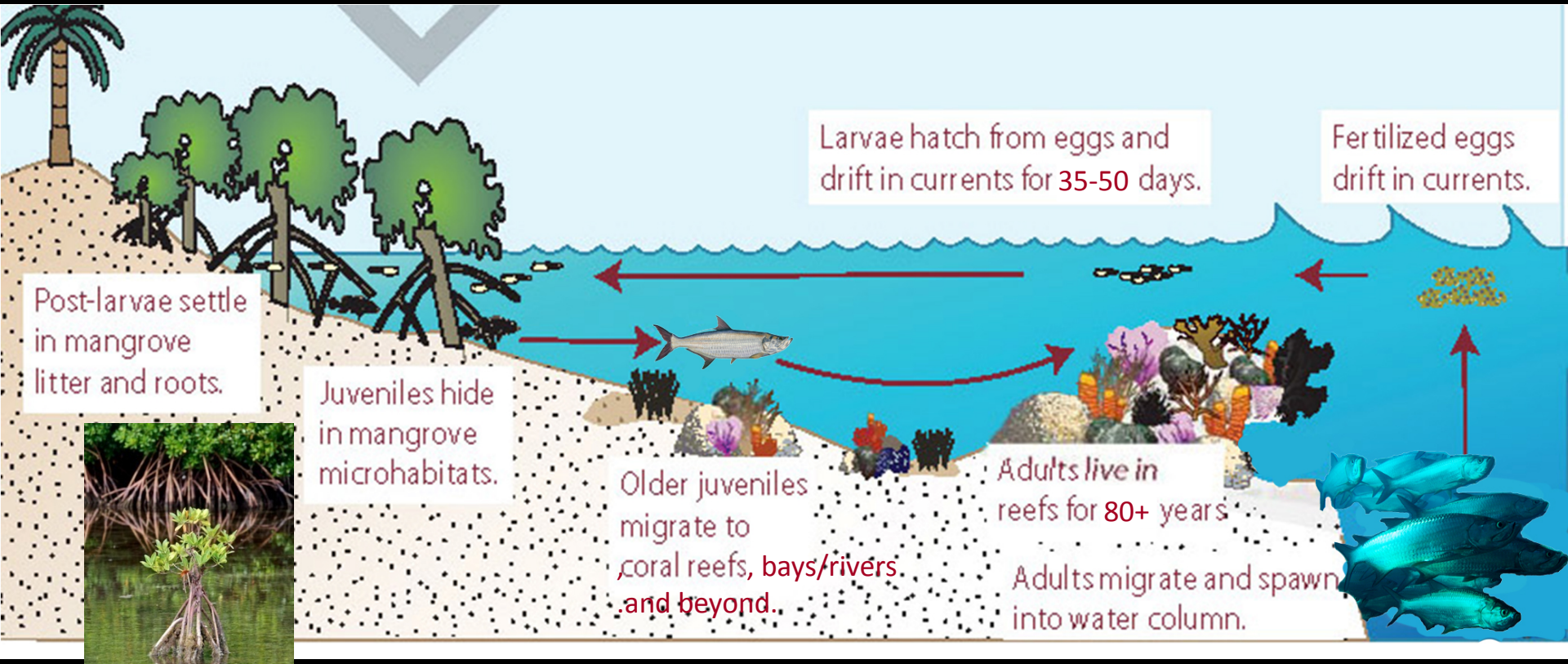
Alternative Management Actions: Size Limits

Species	Current					Optimal		
	F/Fmsy	Lc mm	tc years	tm years	SPR %	Lc mm	tc years	SPR %
Black grouper	9.2	610	3.4	5.2	0.8%	1078	10.0	31.2%
Hogfish	7.8	300	3.3	0.8	6.7%	569	10.5	44.2%
Red grouper	3.4	500	5.4	4.3	17.7%	648	8.8	35.7%
Mutton snapper	5.0	400	3.7	2.0	8.4%	703	10.0	38.0%
Gray snapper	7.9	250	2.3	2.0	3.1%	545	9.5	35.4%
Yellowtail snapper	2.1	250	2.4	1.3	14.1%	292	4.3	46.5%
White Grunt	4.6	170	1.5	1.6	4.9%	378	6.5	39.4%

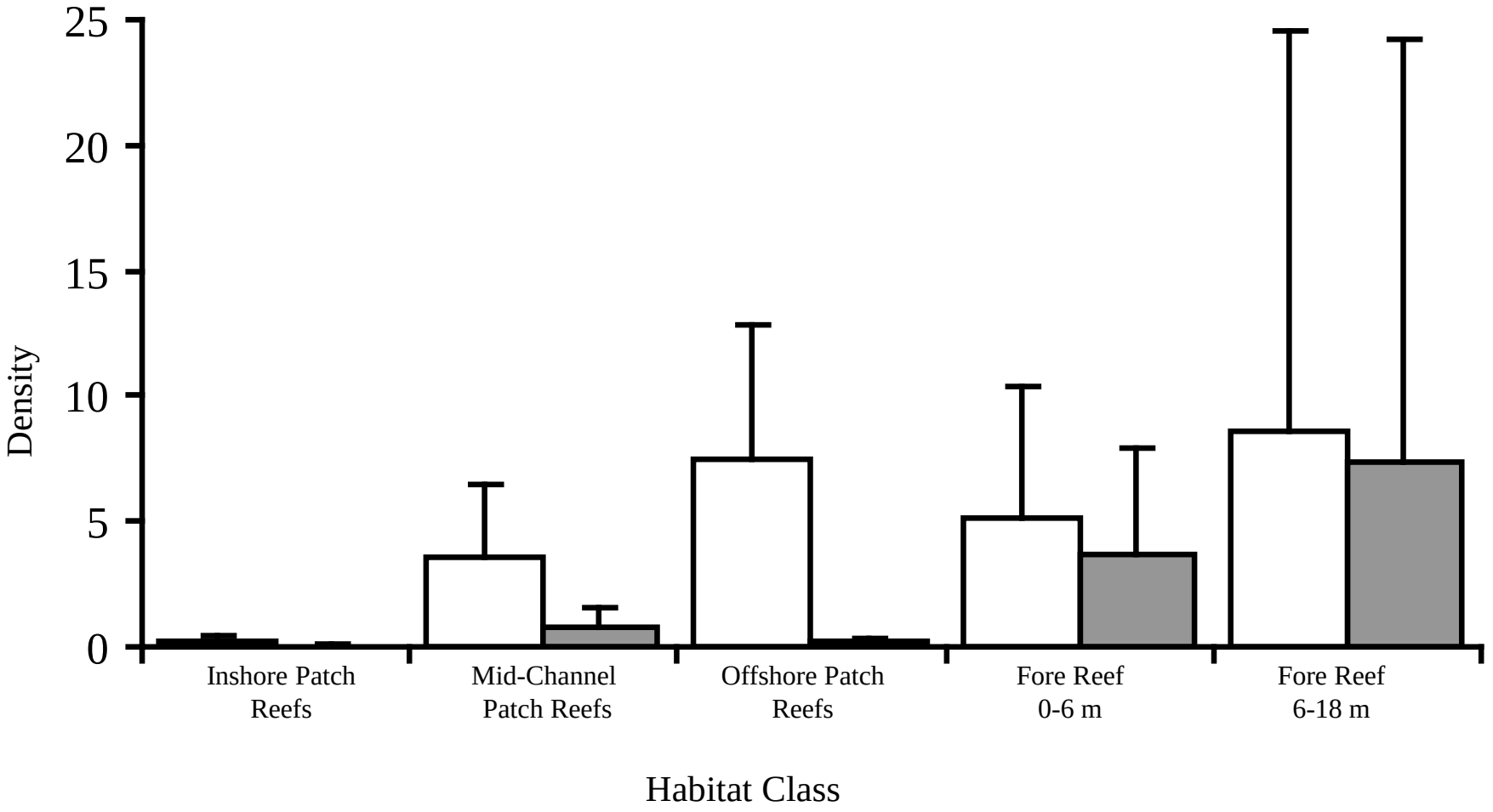
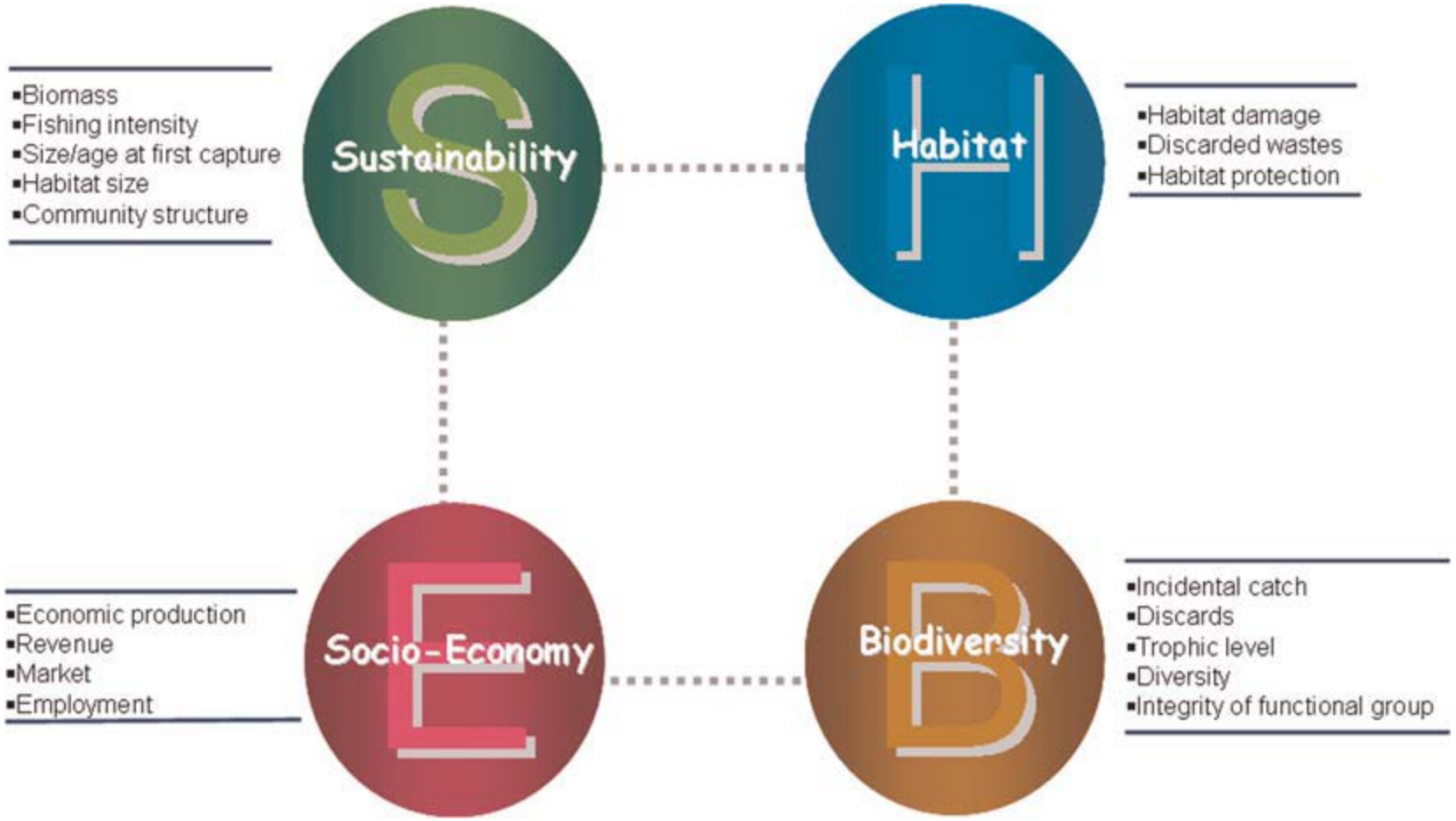
Transitional Dynamics for Florida Keys Black Grouper



Life-history Ontogenic Uses of "Habitat"



Yellowtail Snapper:
Juveniles (open) and Adults (dark)



Balancing Multiple Objectives