Sex-change in Stock Assessments

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Institute of Marine & Coastal Sciences,
Rutgers University

Protogynous Hermaphrodite Meeting
August 29-30, 2012

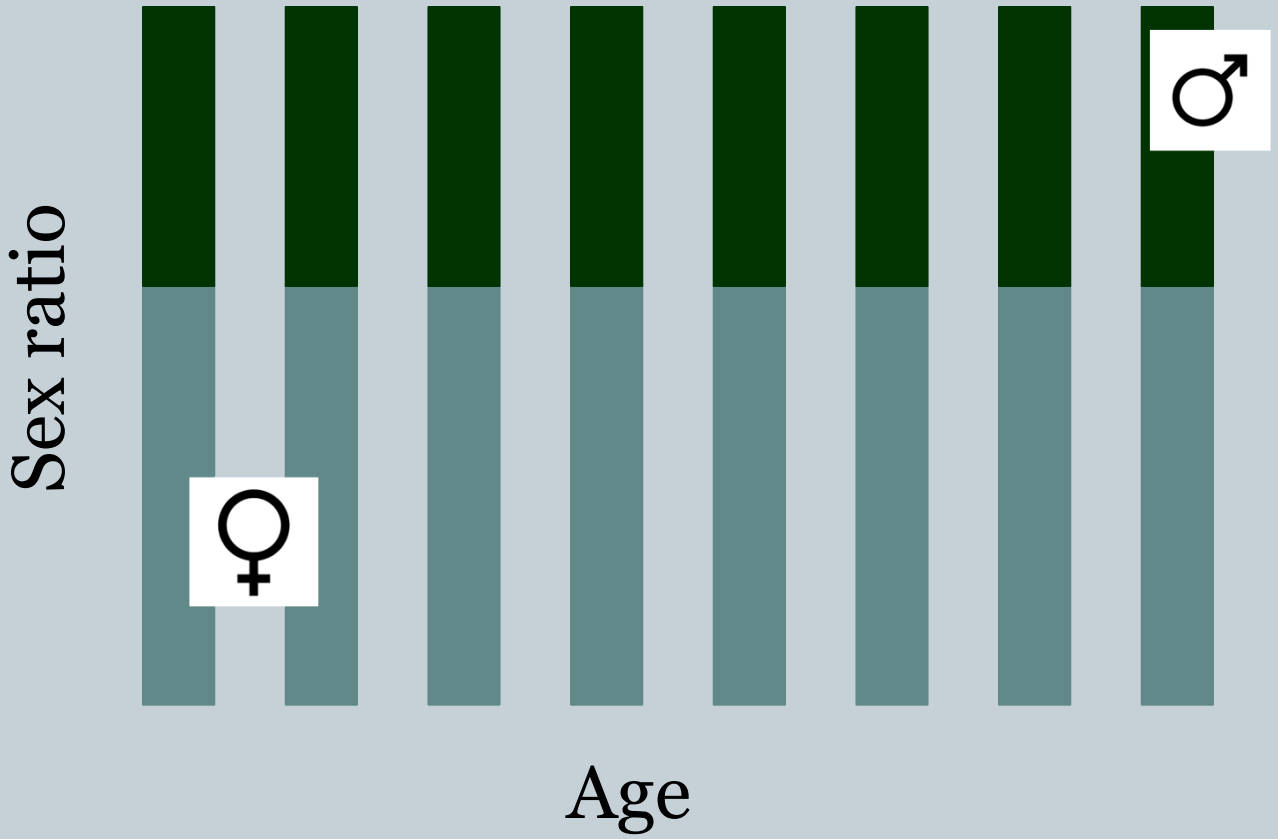
Introduction

- Aim: review how hermaphroditic species are treated in stock assessments

Outline

- Part 1 – What are the effects of fishing a hermaphroditic species? Evidence?
- Part 2 – What are the species of interest?
- Part 3 – How are these species treated in stock assessments?

Part 1: what are the effects of fishing?



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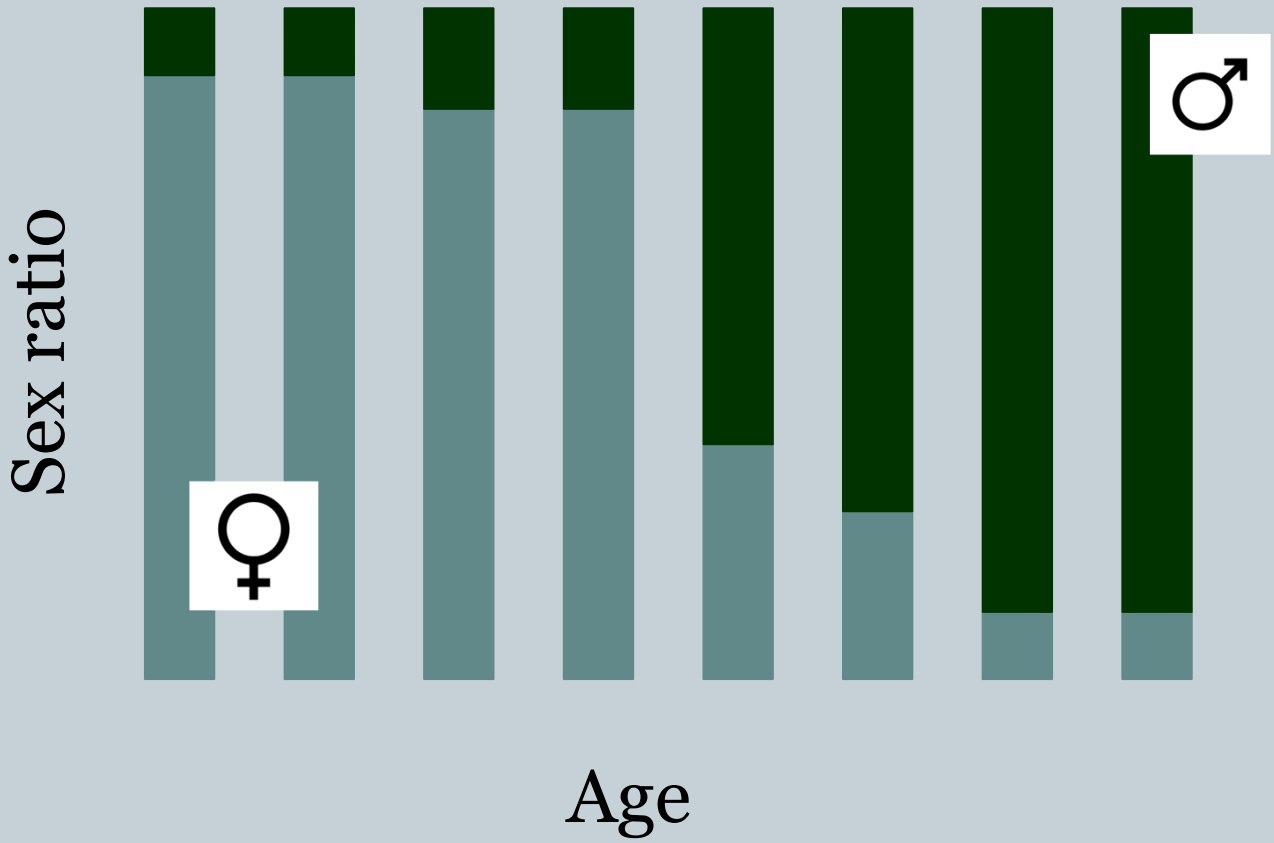

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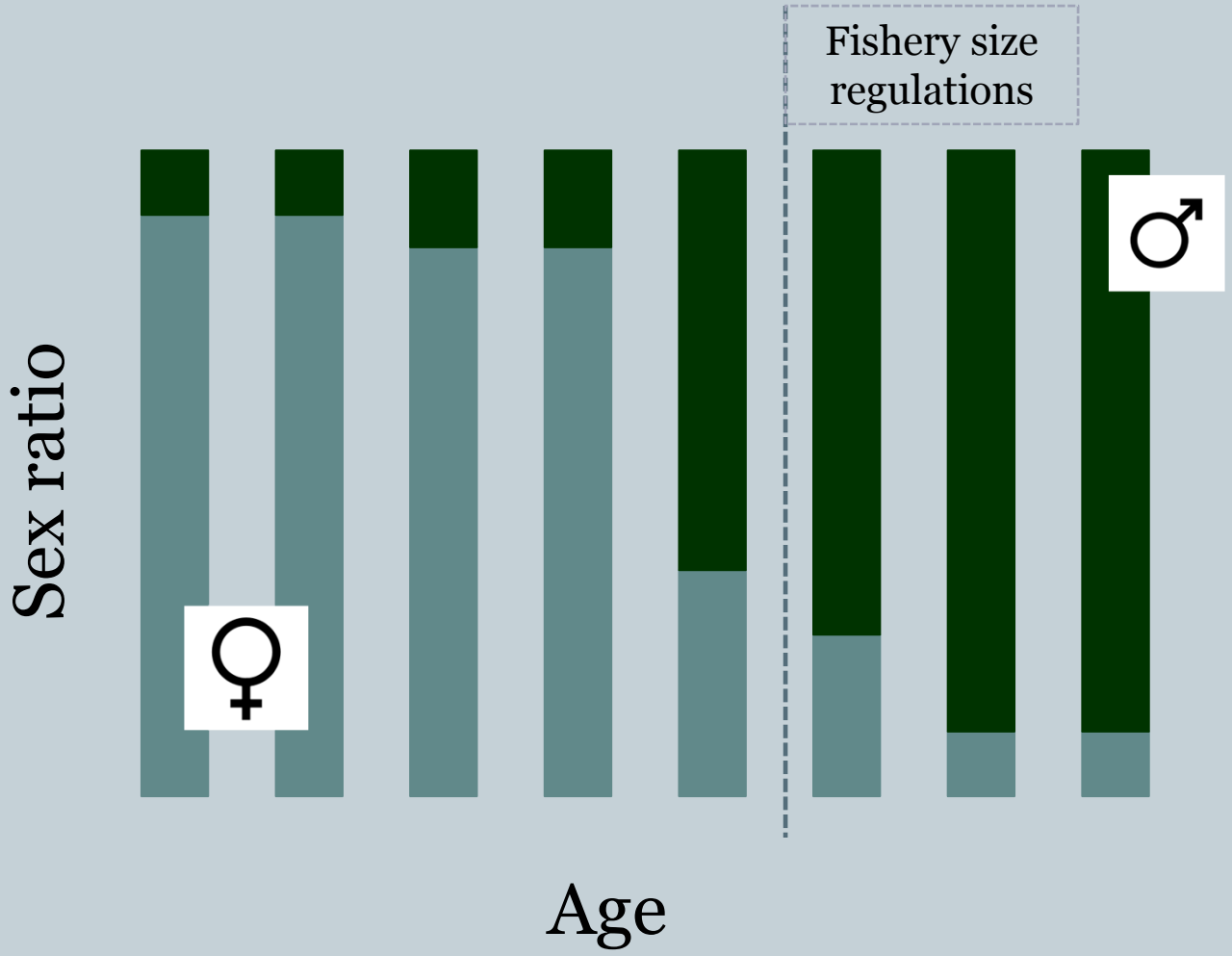

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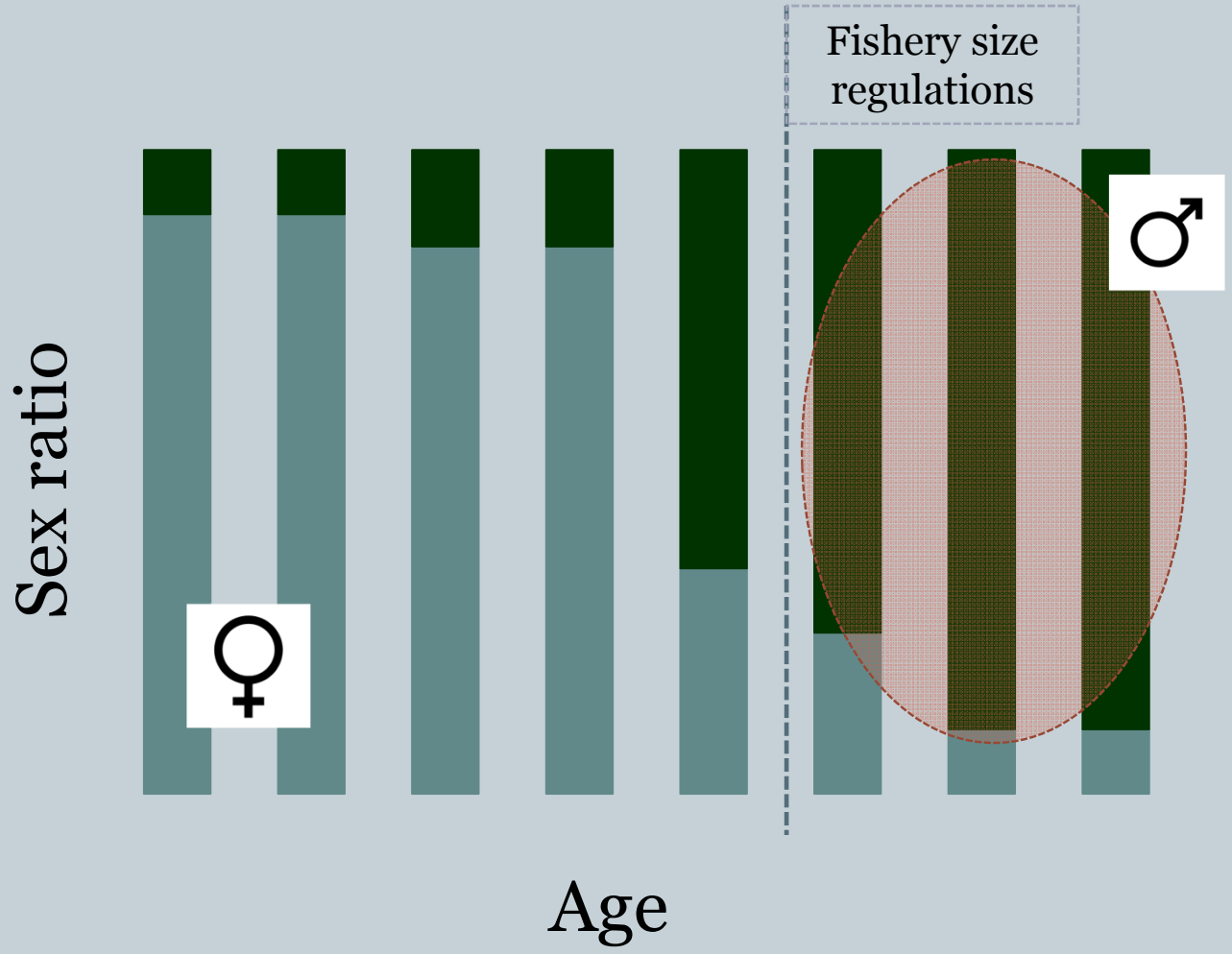


Part 1: what are the effects of fishing?

- Fishing has 2 effects:

    1) Increasingly skewed sex ratios
    2) Downward shift in the age at transition

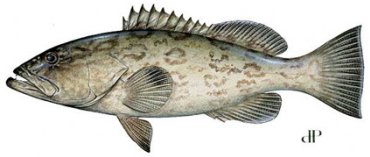
Sex Ratio

- Case study #1 - Coleman et al. 1996

Reproductive styles of shallow-water groupers (Pisces: Serranidae) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregations

Felicia C. Coleman[1], Christopher C. Koenig[1,2] & L. Alan Collins[2]
[1] *FSU/NMFS Institute for Fishery Resource Ecology, Department of Biological Science, Florida State University, Tallahassee, FL 32306-2043, U.S.A.*
[2] *National Marine Fisheries Service, 3500 Delwood Beach Road, Panama City, FL 32408-7499, U.S.A.*

Red Grouper



Gag grouper

Scamp grouper

- Red grouper (1960 – 1992)
- Gag grouper (1977 – 1993)
- Scamp grouper (1970 – 1992)

Sex Ratio

Species	Collection area	Collection dates	Sex ratio male:female
gag	N.E. Gulf of Mexico	1977–1980	1:4.9
	N.E. Gulf of Mexico	1991	1:35.6
	N.E. Gulf of Mexico	1992	1:38.6
	N.E. Gulf of Mexico	1993	1:76.6
	N.E. Gulf of Mexico	1992	1:50.8
	off South Carolina	1977–1982	1:5.0
	U.S. South Atlantic	1994	1:28.0
scamp	N.E. Gulf of Mexico	1970's	1:1.6
	N.E. Gulf of Mexico	1991	1:3.2
	N.E. Gulf of Mexico	1992	1:4.5
red grouper	N.E. Gulf of Mexico	1960's	1:5.9
	N.E. Gulf of Mexico	1991	1:2.2
	N.E. Gulf of Mexico	1991	1:3.6
	N.E. Gulf of Mexico	1992	1:3.5

Coleman et al. 1996

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Coleman et al. 1996

Sex Ratio

- Case study #2 - Beets & Friedlander 1998

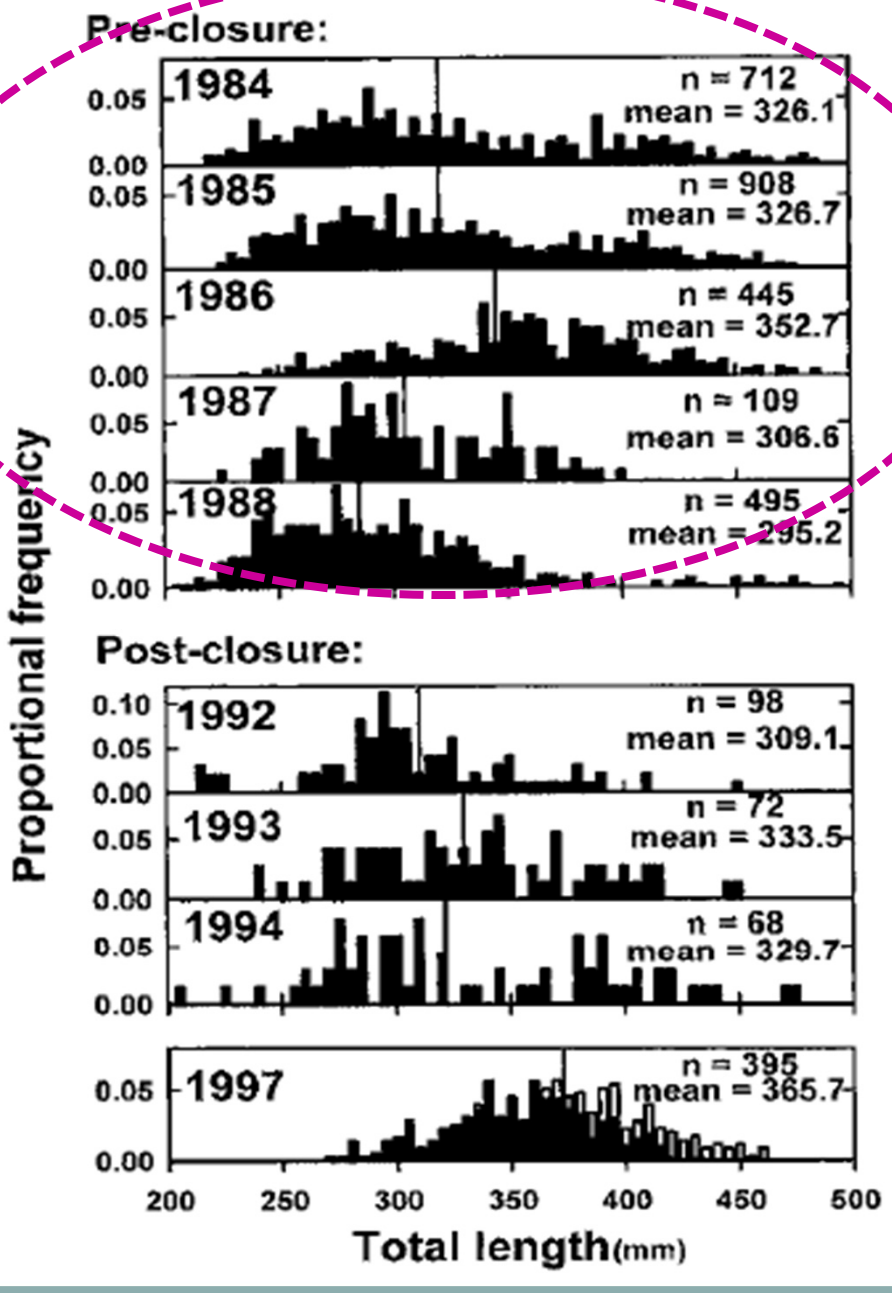
Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands

Jim Beets[a] & Alan Friedlander[b]
[a] *Jacksonville University, Department of Biology and Marine Science, 2800 University Blvd. N, Jacksonville, FL 32211, U.S.A. (e-mail: jbeets@ju.edu);*
[b] *The Oceanic Institute, 41-202 Kalanianaole Highway, Waimanalo, HI 96795, U.S.A.*

- Red hind (E. *guttatus*)
- St. Thomas, Virgin Islands
- (1984 – 1988) and (1992 – 1994)

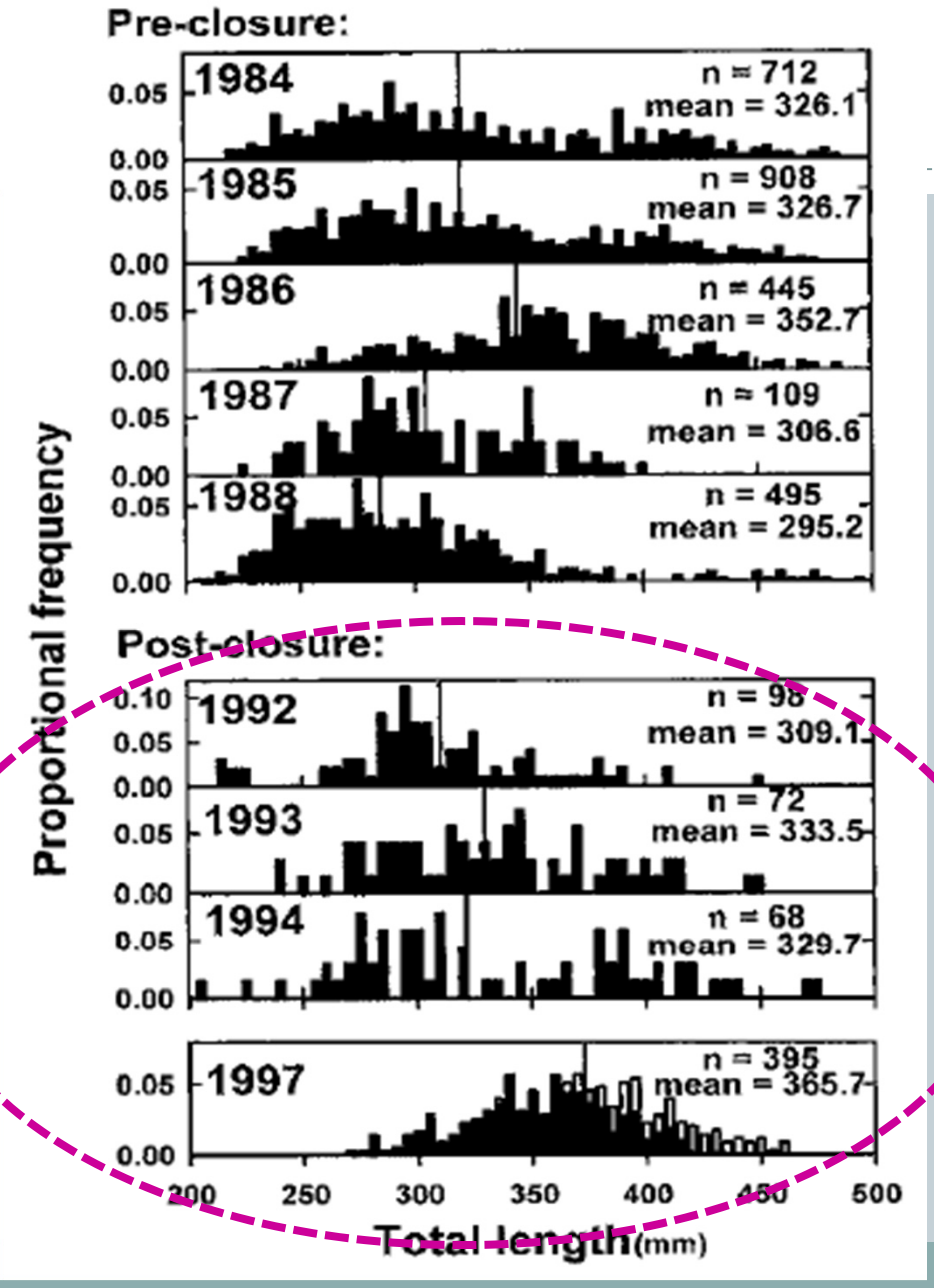
  6.7% male ⟶ 25% male

Pre-closure



Beets & Friedlander 1998

Post-closure



Beets & Friedlander 1998

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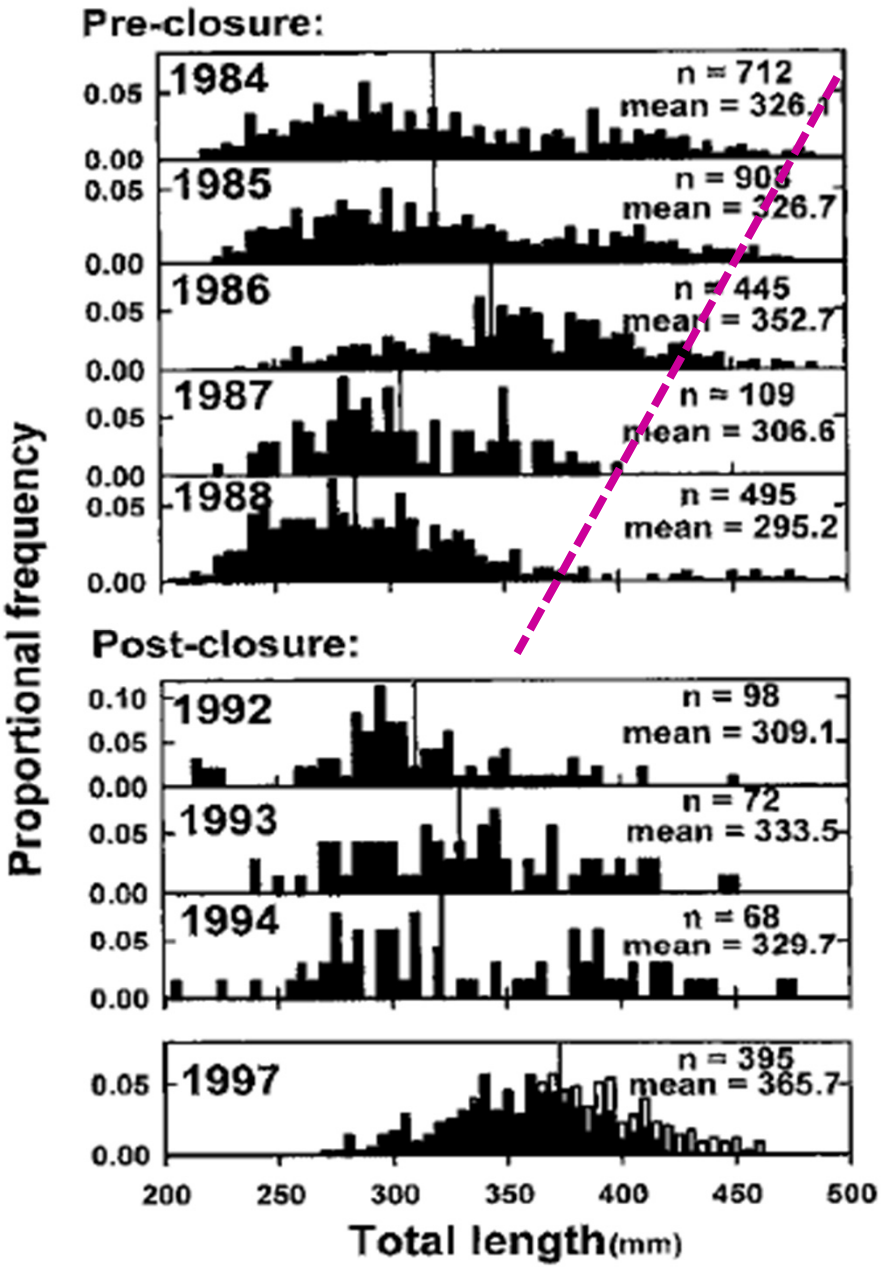

Beets & Friedlander 1998

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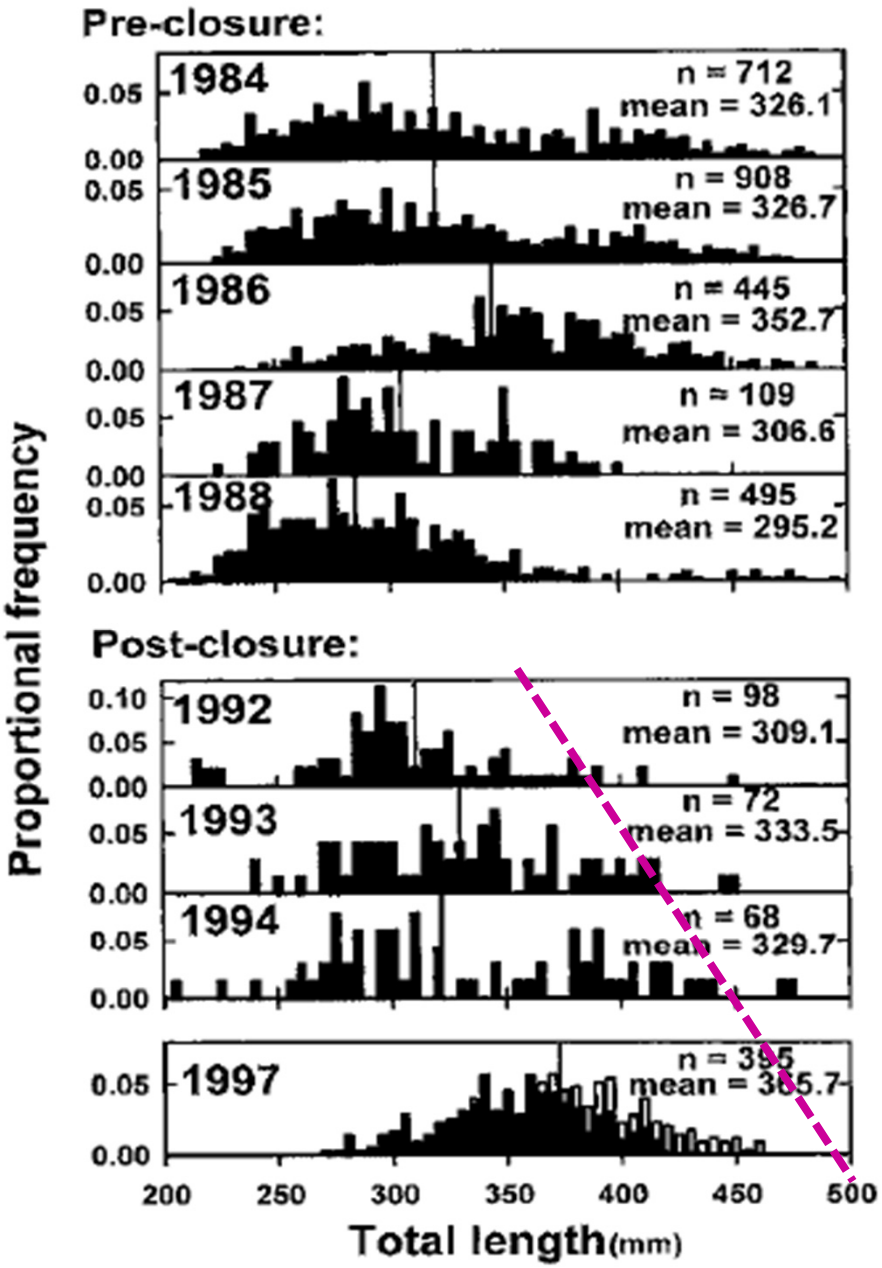
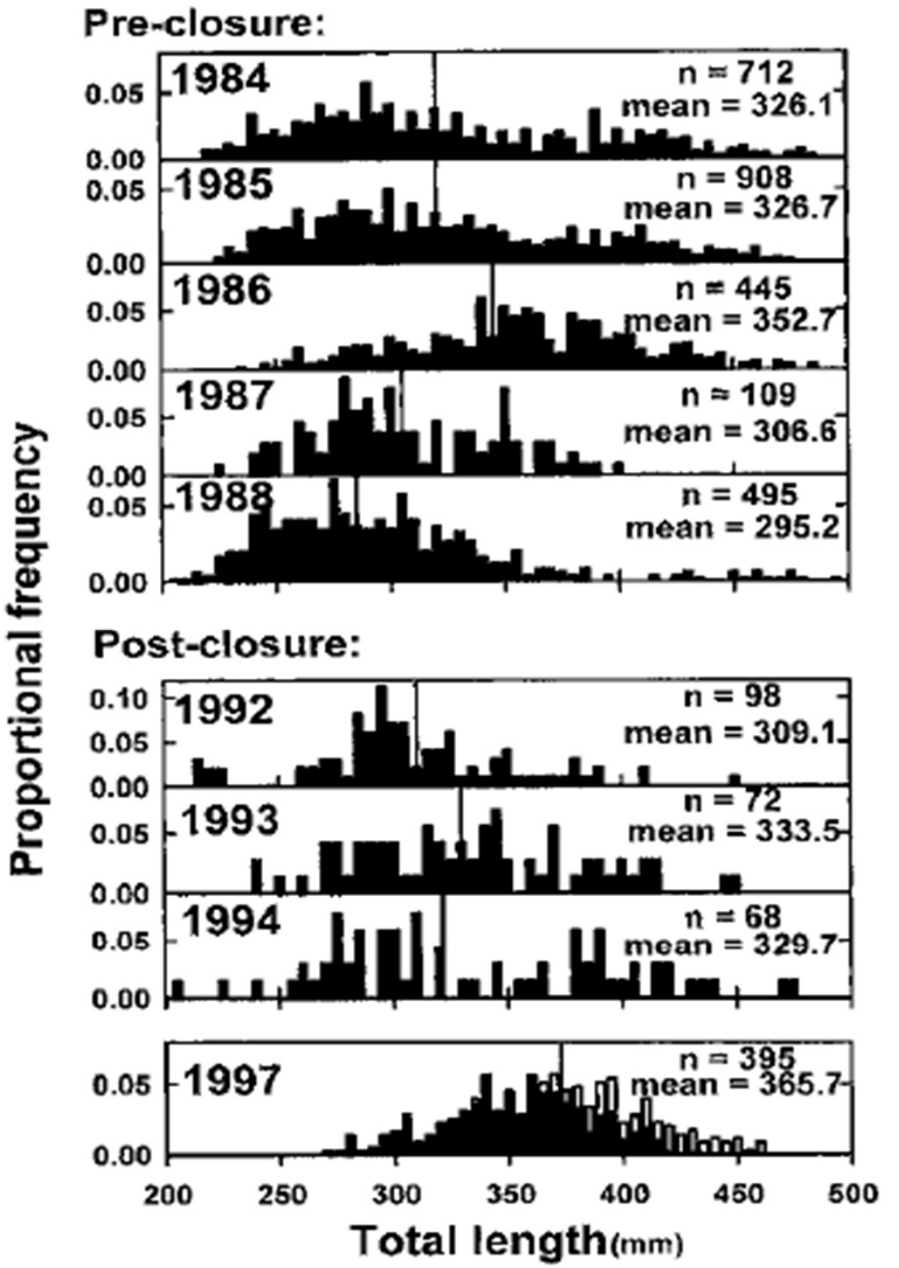


Beets & Friedlander 1998

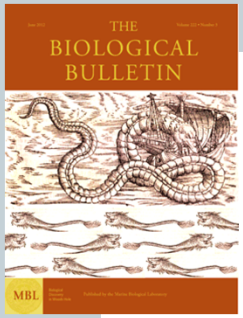
- Skewed sex ratio
- No change in transition



Beets & Friedlander 1998

Size at sex change

- Assumes sex change is, at least in part, triggered by social structure or sex-ratios.



Social Control of Sex Change in the Bluehead Wrasse, *Thalassoma bifasciatum* (Pisces: Labridae)

ROBERT R. WARNER* AND STEPHEN E. SWEARER†

**Department of Biological Sciences and Marine Science Institute, University of California, Santa Barbara, California 93106, and †Division of Biology and Medicine, Box G, Brown University, Providence, Rhode Island 02912*

Induced sex change in black sea bass

C. B. BENTON AND D. L. BERLINSKY*

Department of Zoology, University of New Hampshire, Durham, NH 03824, U.S.A.

Size at sex change

- Case study #1 – Hamilton et al. 2007

SIZE-SELECTIVE HARVESTING ALTERS LIFE HISTORIES OF A TEMPERATE SEX-CHANGING FISH

Scott L. Hamilton,[1,6] Jennifer E. Caselle,[2] Julie D. Standish,[1] Donna M. Schroeder,[3] Milton S. Love,[2] Jorge A. Rosales-Casian,[4] and Oscar Sosa-Nishizaki[5]

- California sheephead (*S. pulcher*)
- (1969–1982) and (1998)
- Size decreased from 327 → 255 (22% drop)
- Size decreased from 479 → 311 (35% drop)
- Size decreased from 258 → 254 (<1% drop)

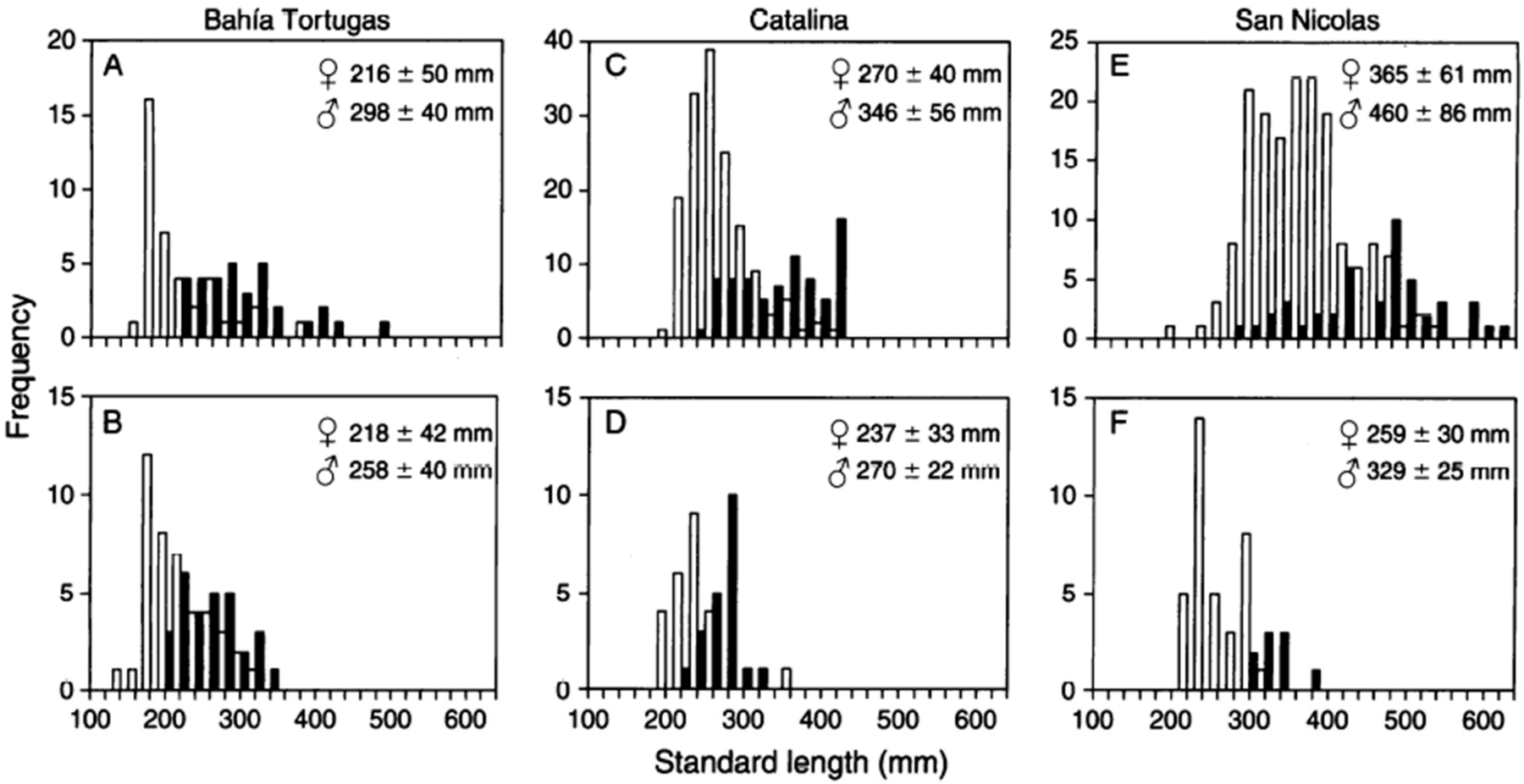


FIG. 3. Size-frequency distributions of mature female (open bars) and mature male (solid bars) *Semicossyphus pulcher* at the three study locations in successive 20-mm size bins. Mean sizes of each sex ± SD are shown in the upper right of each panel. Shown are (A, C, E) historic vs. (B, D, F) recent size frequencies: (A) Bahía Tortugas, 1981–1982, data from Cowen (1990); (B) Bahía Tortugas, 1998; (C) Catalina, 1969–1971, data from Warner (1975*b*); (D) Catalina, 1998; (E) San Nicolas, 1980–1982, data from Cowen (1990); (F) San Nicolas, 1998.

Hamilton et al. 2007

Size at sex change

TABLE 3. Size at maturation ($L_{50\,♀}$) and size at sex change ($L_{50\,♂}$) for historical and recent populations of *Semicossyphus pulcher*. Values are means with 95% CI in parentheses.

Trait and time period	Bahía Tortugas	Catalina	San Nicolas
Size at maturity (mm)			
Historic (1969–1982)	190†	221 (216–227)	291†
Recent (1998)	160 (138–171)	202 (195–212)	202 (NA)‡
Size at sex change (mm)			
Historic (1969–1982)	258 (235–288)	327 (314–343)	479 (456–515)
Recent (1998)	254 (230–294)	255 (236–278)	311 (299–347)

Notes: Sizes were determined by logistic regression. The 95% CI is the confidence interval around the predicted size at maturity and size at sex change based on the logistic regression model.

Hamilton et al. 2007

Size at sex change

- Case study #2 – Gotz et al. 2008

Effects of fishing on population structure and life history of roman *Chrysoblephus laticeps* (Sparidae)

Albrecht Götz[1,2,*], Sven E. Kerwath[1], Colin G. Attwood[3], Warwick H. H. Sauer[1]

- Roman (*C. laticeps*)
- (2000 – 2004)
- Size decreased from 330.3 → 289.91 (12% drop)
- Age decreased from 10.25 → 7.99 (22% drop)

Size at sex change

Table 6. *Chrysoblephus laticeps*. A comparison of parameter estimates for age (yr) and length (mm FL) at 50% maturity and sex-change between the inside and outside areas. The p-values derived from likelihood ratio tests for differences between areas are shown. *p < 0.05; **p < 0.01; FL: forklength

Parameter	Sample area		p
	Inside	Outside	
Age-at-50% maturity (t_{M50})	4.27	2.97	0.026*
Logistic delta (‰$_{tM50}$)	1.22	1.13	0.353
Length-at-50% maturity (L_{M50})	202.83	167.43	0.002**
Logistic delta (‰$_{LM50}$)	27.50	33.61	0.636
Age-at-50% sex-change (t_{SC50})	10.25	7.99	<0.001**
Logistic delta (‰$_{tSC50}$)	0.93	0.89	0.853
Length-at-50% sex-change (L_{SC50})	330.20	289.91	<0.001**
Logistic delta (‰$_{LSC50}$)	10.78	7.68	0.310

Size at sex change

Table 7. *Chrysoblephus laticeps*. Comparison of sex ratios (expressed as female:male ratio) between inside and outside areas in the fishing and UVC data sets. Expected sex ratios for the outside area using the sex-at-length keys for the inside area are shown to demonstrate the compensating effect of changes in age-at-maturity and age-at sex-change. The results of chi-squared tests on the differences between areas are listed as p-values

	Observed sex ratio			Sex ratio using inside sex-at-length key		
	Female	Intersex	Male	Female	Intersex	Male
Controlled fishing						
Inside	1.5	0.4	1.0	1.5	0.4	1.0
Outside	1.0	0.2	1.0	4.0	1.0	1.0
Overall	1.4	0.3	1.0			
p	<0.01**	<0.01**				
UVC						
Inside	4.9	0.5	1.0	4.9	0.5	1.0
Outside	4.1	0.3	1.0	11.3	0.8	1.0
Overall	5.2	0.4	1.0			
p	>0.1	<0.05*				

Side Effects…

- Side effects of increasingly skewed sex ratios….

  1. sperm limitation

  2. reduced genetic diversity

Side Effects…

- Side effects of increasingly skewed sex ratios….

1. sperm limitation
   - Lessios (1988)
   - Hines et al. (2003)
   - Brook et al. (2008)

2. reduced genetic diversity
   - Allee (1931)
   - Chapman et al. (1999)

Side Effects…

- Side effects of transitioning at smaller sizes….

- reduction in egg production?

- biological constraints?

- negative consequences of smaller males on average?

Part 2: what species are sex-changing on the east coast?

- Black sea bass (2 stocks)
- Gag grouper (2 stocks)
- Red grouper (2 stocks)
- Black grouper
- Goliath grouper (questionable)
- Scamp
- Snowy grouper
- Red porgy
- Hogfish
- Gulf yellowedge
- Nassau grouper ?
- Red hind

Table 1. Stock status

	Year	SSB combined?	F/Fmsy	B/Bmsy
BSB (Mid-Atlantic)	2012	Combined	0.48	0.97
BSB (S. Atlantic)	2011	Combined	1.07	0.70
Gulf yellowedge	2011	Combined	0.94	1.12
Gag grouper (S. Atlantic)	2006	Combined	1.36	0.12
Gag grouper (Gulf of Mexico)	2006	Combined	1.29	0.79
Black grouper	2010	Combined	0.44	1.4
Scamp grouper	2005	Female only(?)	<1.0	0.35
Red grouper (S. Atlantic)	2010	Female only	1.34	0.79
Snowy grouper	2004	Combined	0.24	2
Red hind	2004	Not reported	Not reported	Not reported

Table 1. cont'd

	Year	SSB combined?	F/Fmsy	B/Bmsy
Red porgy	2002	Combined	0.47	0.43
Hogfish	2004	Combined	4.35	0.34
Goliath grouper	2011	Not reported	N/A	N/A
Nassau grouper	2005	Not reported	N/A	N/A

Table 2. Sex change in assessments

	Tracks the sex ratio through time?	Δ in proportion male	Downward shift in size at transition?	Measures sex selectivity?
BSB (Mid-Atlantic)	No	Not reported	Not reported	No
BSB (S. Atlantic)	No	Not reported	Not reported	No
Gulf yellowedge	Yes	Not reported	Not reported	No
Gag grouper (S. Atlantic)	No	21.1 to 8.2% (1976-2004)	Yes	No
Gag grouper (Gulf of Mexico)	Yes	17% - 1% (1970-1992)	No decrease in size	No
Black grouper	No	Not reported	Not reported	No
Scamp grouper	No	36% - 18% (1970 – 1992)	Not reported	No
Red grouper (S. Atlantic, Gulf of Meixco)	No	Not reported	No decrease in size	No
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Table 2. cont'd

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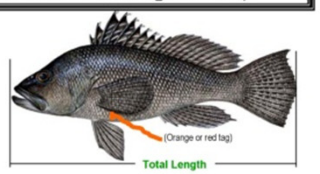
Red porgy	No	Not reported	Not reported	Reports proportion male at age for different gears
Hogfish	No	Not reported	Not reported	No
Goliath grouper	No	Not reported	Not reported	N/A
Northern shrimp	No	Not reported*	Not reported	No

REWARD

Reward offered for the return of **tagged black sea bass**
(whole fish or filleted carcass with guts intact)

Fisheries scientists from Rutgers University are working in cooperation with commercial and recreational fishermen to study sex change and reproductive biology of black sea bass. From May through August, 2011 the project will be releasing more than 1,500 tagged fish off the coast of New Jersey.



The tags are a 3 ½ " section of orange or red plastic tubing, inserted into the left side of the fish. Each tag contains a unique number which is necessary to claim a reward. Fishermen are asked to follow instructions below to claim a reward.

What to do if you catch a (legal size) tagged fish:

- Put whole fish or filleted carcass (with guts intact) with tag in freezer
- Call toll free: 1-888-776-6537 **OR** Email: blackseabassproject@gmail.com
- Call toll free # (or email) and provide the following information:
  - Name, address, phone #, and best location to pick up the fish
  - Date of recapture
  - Location of recapture (latitude/longitude preferred)

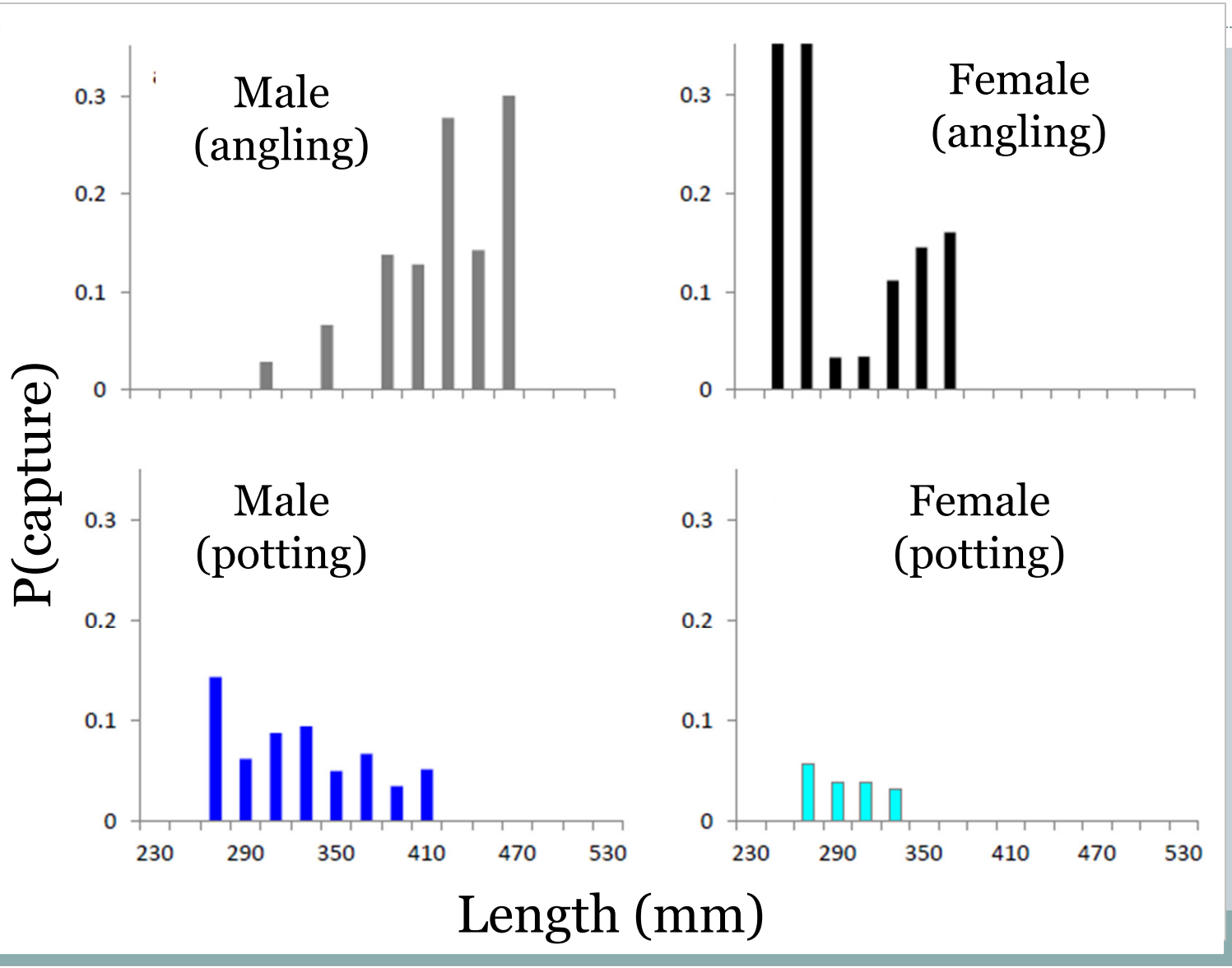
Don't have the fish? You can still help! In addition to the above information:

- Please tell us total length of fish (tip of head to end of tail, excluding the filament)
- tag number
- Disposition and fate (whether the fish was kept or released)

Orange Tag Reward	Red Tag Reward	Orange or Red Tag +fish
Baseball cap with logo	$100 (must return tag)	(Cap or $100 reward) PLUS entry into annual lottery for $1,000

For more information: http://marine.rutgers.edu/~ojensen/RBSB.html
Questions? Email: blackseabassproject@gmail.com

Importance of selectivity…



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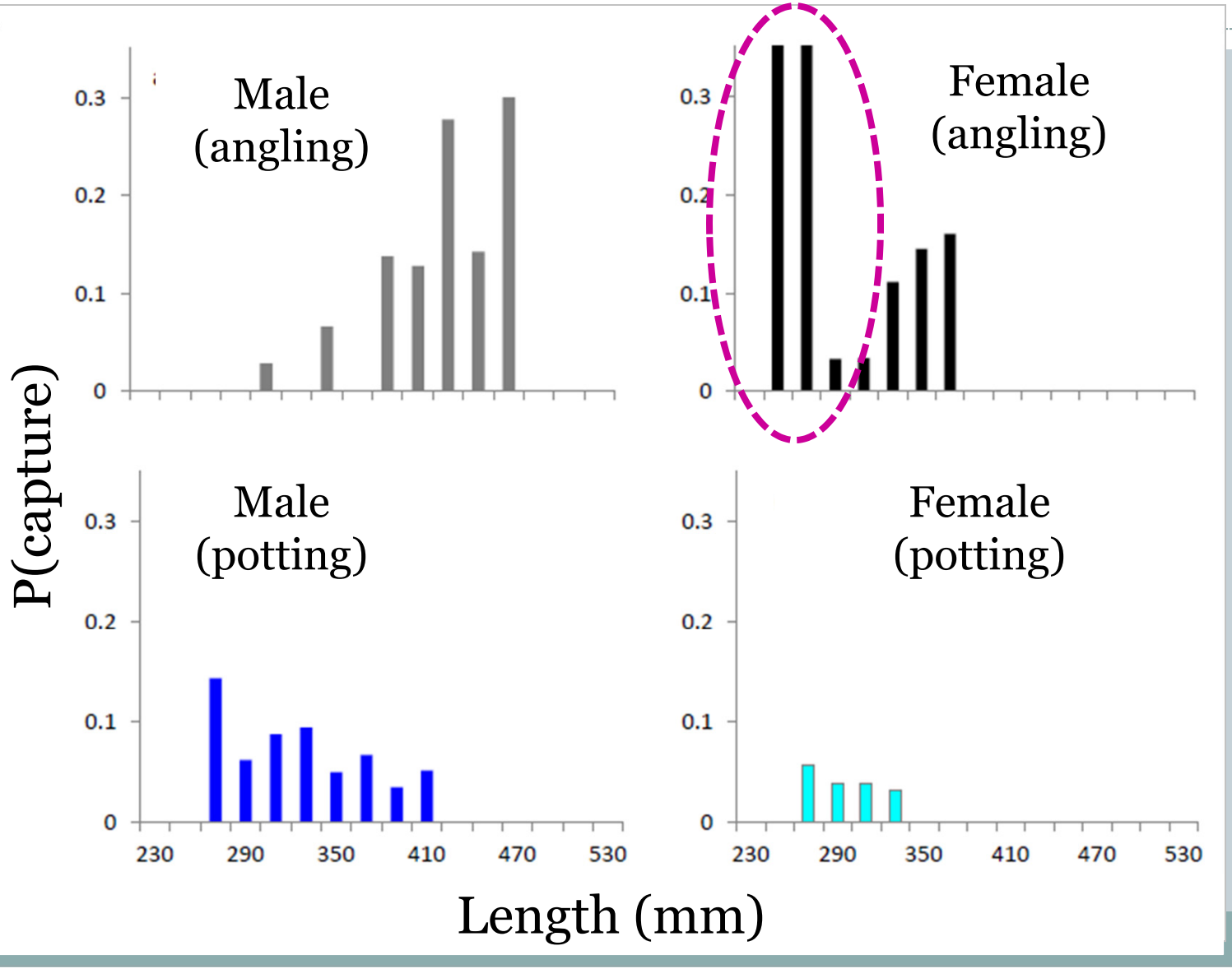

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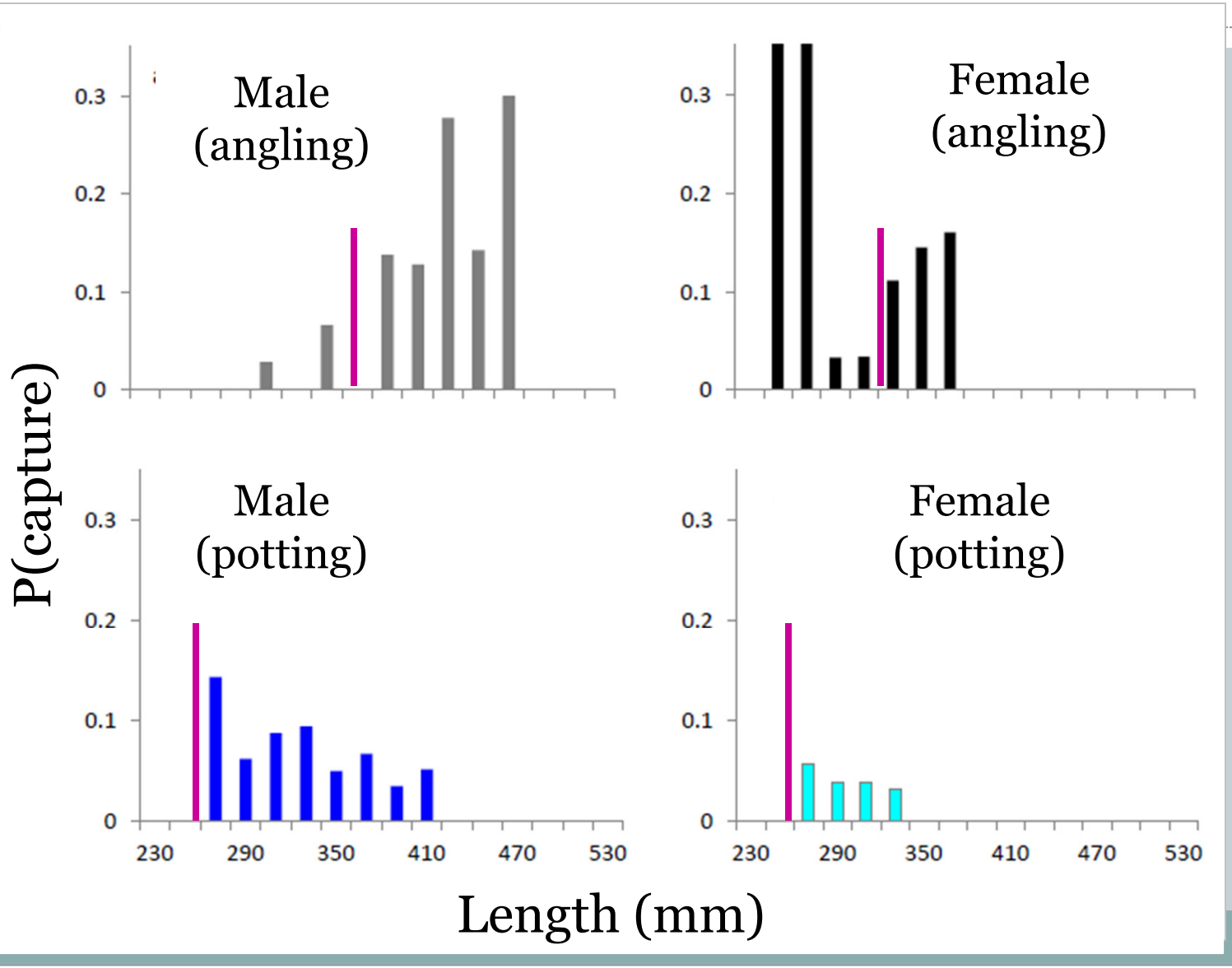

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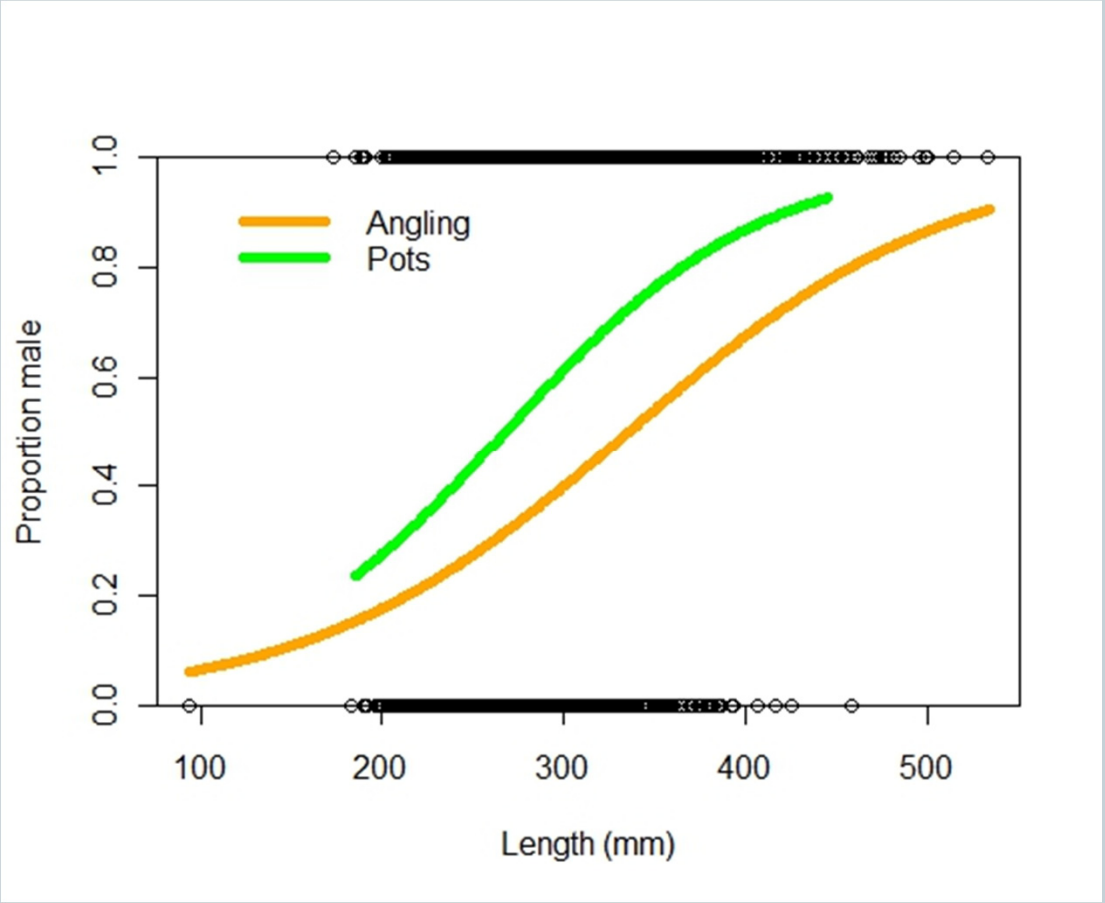

Table 4. Summary

How many stocks currently experience overfishing?	5 of 15
How many are overfished?	3 of 15
How often does SSB include male biomass?	8 of 15
How many stocks track the sex ratio?	2 of 15
Documented change in proportion male?	2 of 15
Decrease in size at transition?	1 of 15

Thank you!

Data from 1992, sex ratio here 15:1

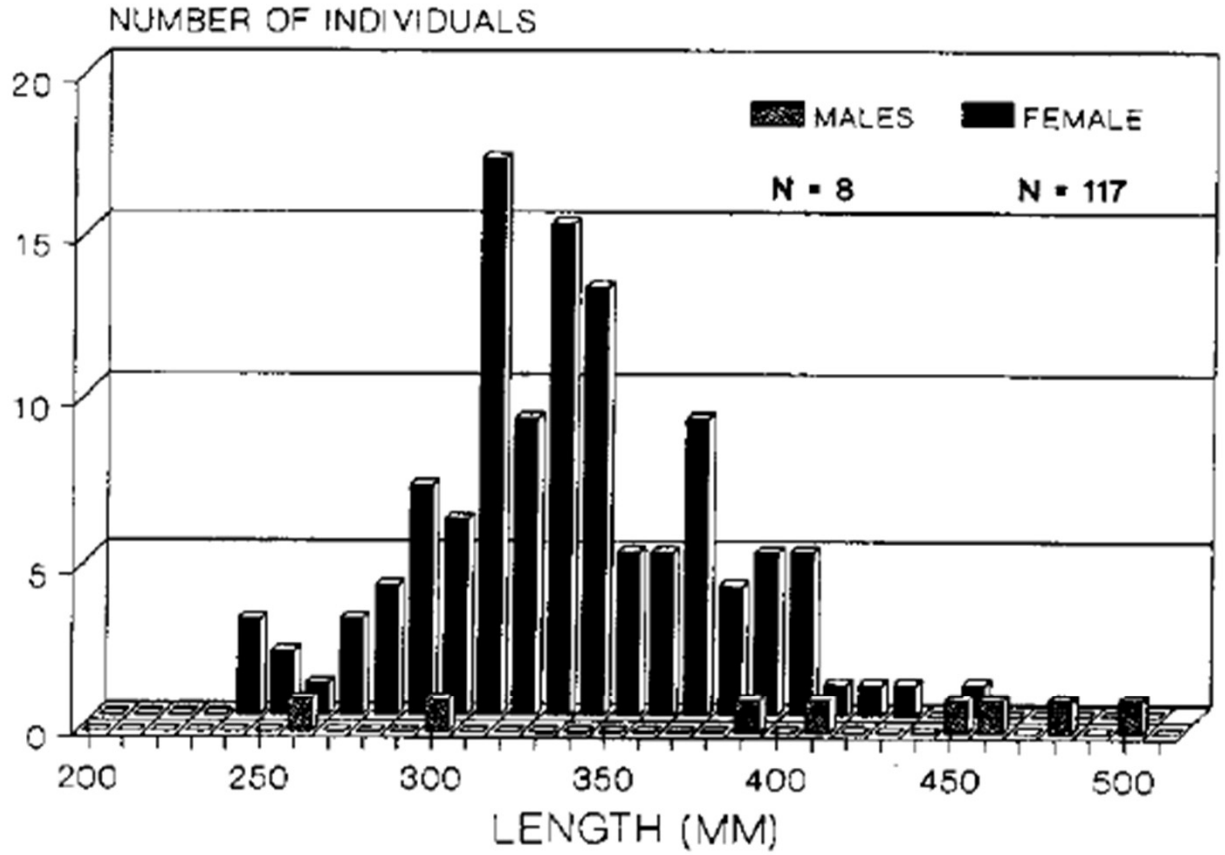

Figure 5. Length frequency distribution of red hind, *Epinephelus guttatus*, by sex for St. Thomas.

Beets & Friedlander 1992

Species	Collection area	Study	Collection dates	Males		Transitionals		Females		Sex ratio male:female
				N	%	N	%	N	%	
gag	N.E. Gulf of Mexico	Hood & Schlieder 1992	1977–1980	134	17	6	0.8	659	82	1:4.9
	N.E. Gulf of Mexico	NMFS	1991	12	2.7	1	0.2	427	97	1:35.6
	N.E. Gulf of Mexico	NMFS	1992	8	2.5	2	0.6	309	97	1:38.6
	N.E. Gulf of Mexico	NMFS	1993	8	1.3	2	0.3	613	98	1:76.6
	N.E. Gulf of Mexico	FSU	1992	9	1.9	3	0.6	457	97	1:50.8
	off South Carolina	Collins et al. 1987	1977–1982	51	17	4	1.3	253	82	1:5.0
	U.S. South Atlantic	NMFS Beaufort Lab	1994	44	3.4	6	0.5	1233	96	1:28.0
scamp	N.E. Gulf of Mexico	Hood, unpublished data	1970's	291	37.9	0	–	477	62	1:1.6
	N.E. Gulf of Mexico	NMFS	1991	33	24.1	0	–	104	76	1:3.2
	N.E. Gulf of Mexico	FSU	1992	26	18.3	0	–	116	81.6	1:4.5
red grouper	N.E. Gulf of Mexico	Moe 1969	1960's	109	14.4	11	1.5	638	84.2	1:5.9
	N.E. Gulf of Mexico	NMFS	1991	34	30.9	0	–	76	69.1	1:2.2
	N.E. Gulf of Mexico	FSU	1991	56	21.7	1	0.4	201	77.9	1:3.6
	N.E. Gulf of Mexico	FSU	1992	51	22.4	0	–	177	77.6	1:3.5

Coleman et al. 1996