Collaborative fisheries research on *Panulirus interruptus* at the Santa Barbara Channel Islands

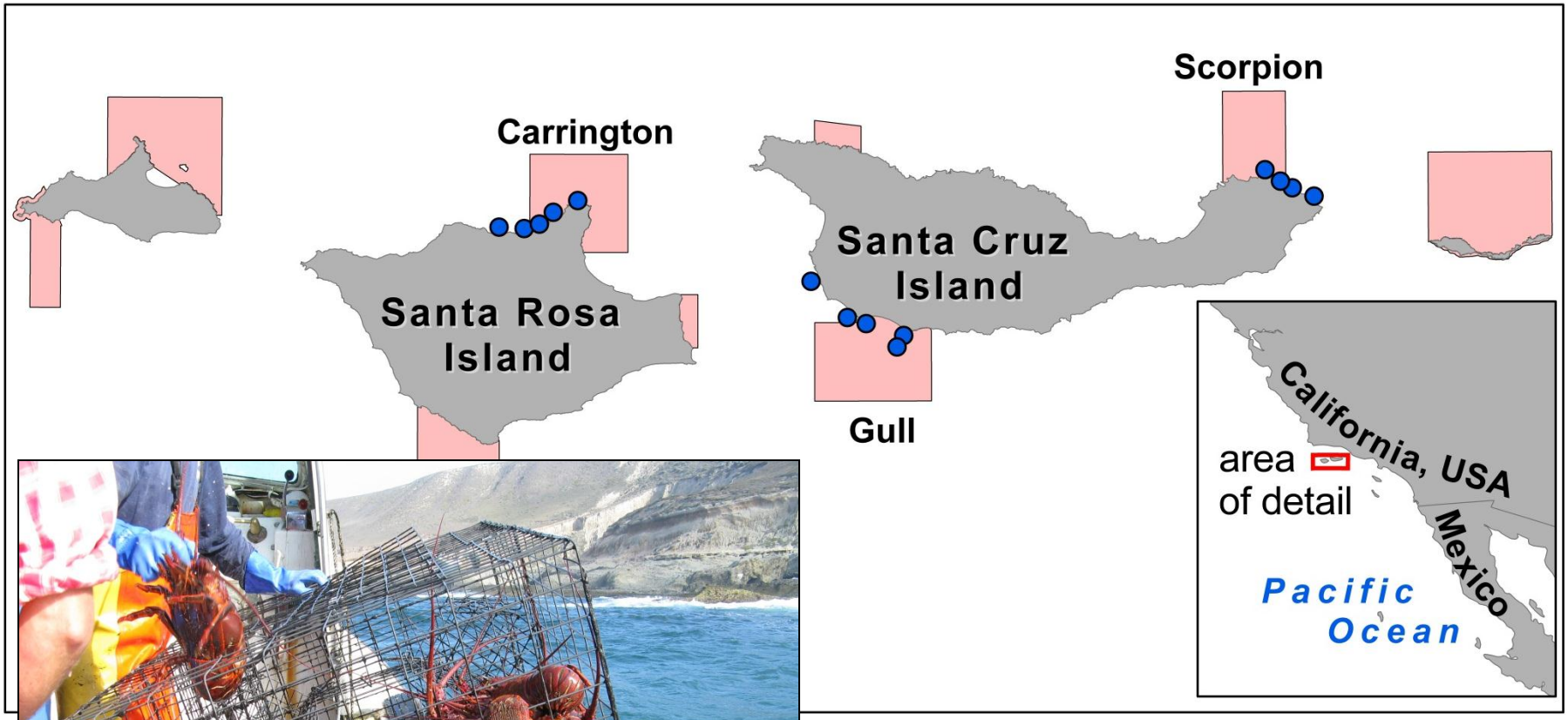
Matt Kay
Shoreline Resource Consultants
California spiny lobster FMP
LAC Meeting- 5 Sept 2012

Collaborative research objectives at SBCI

1) Assess changes to lobster populations inside reserves

2) Develop harvest rate assessment
(interpret in context of SPR/YPR for CA spiny lobster)

1) Changes inside reserves



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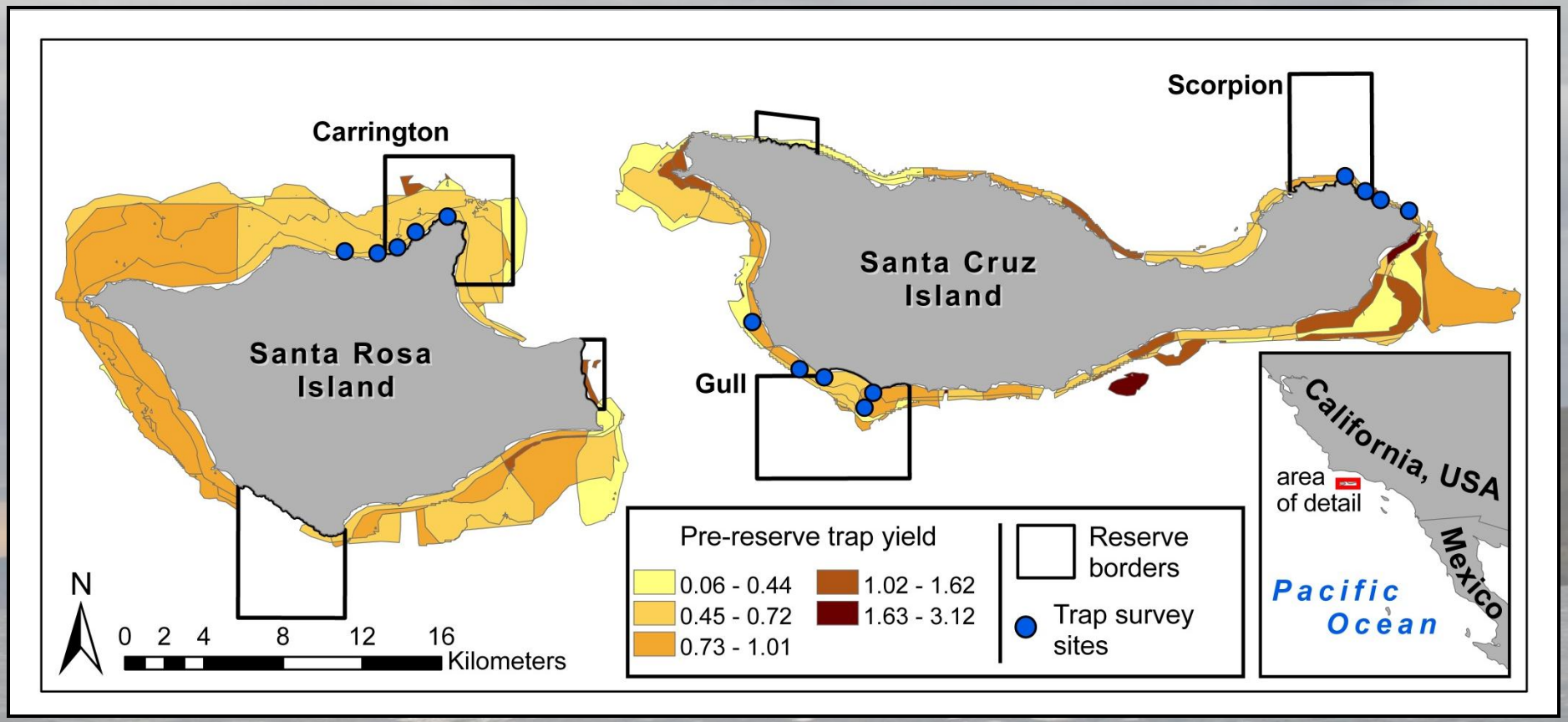

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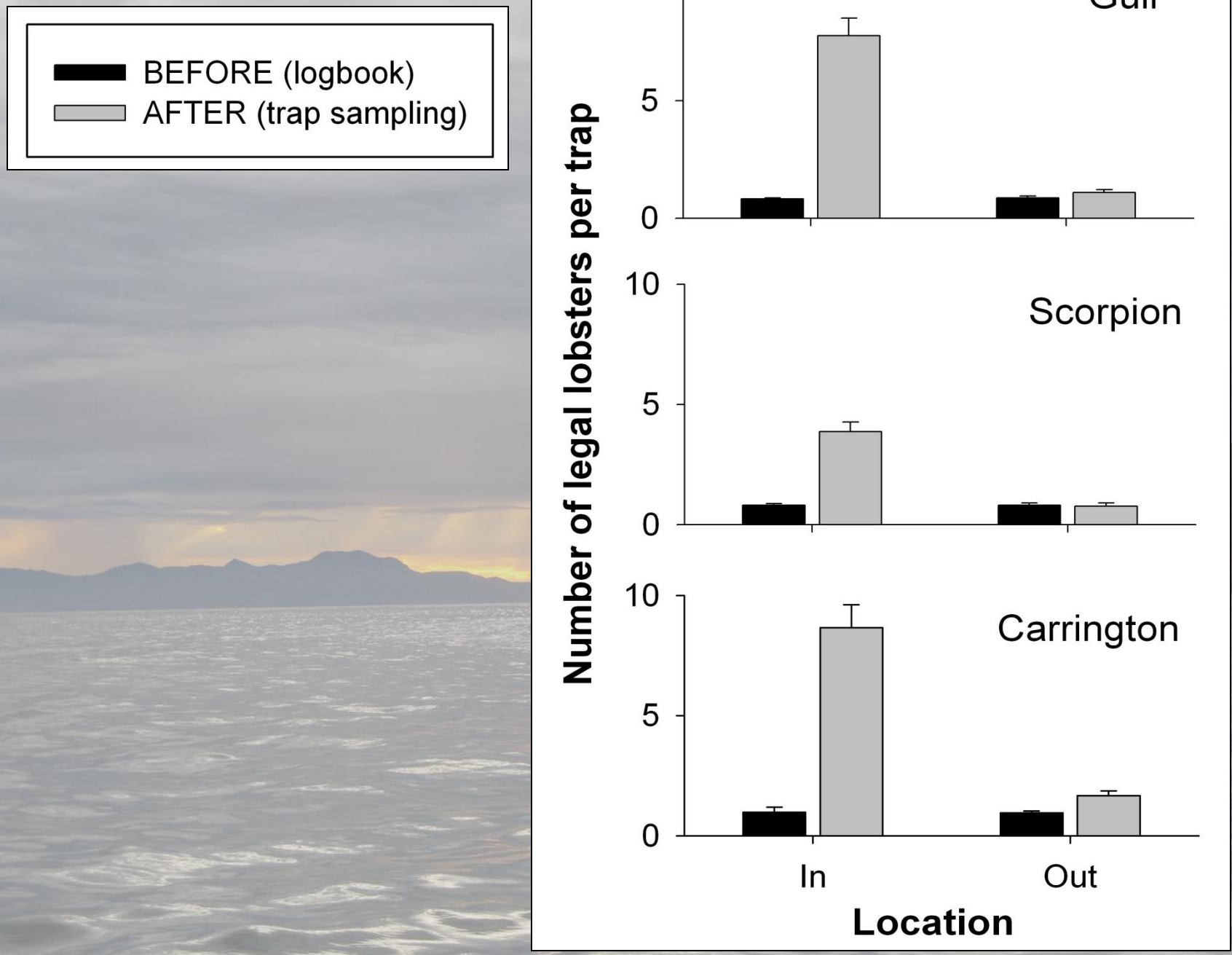

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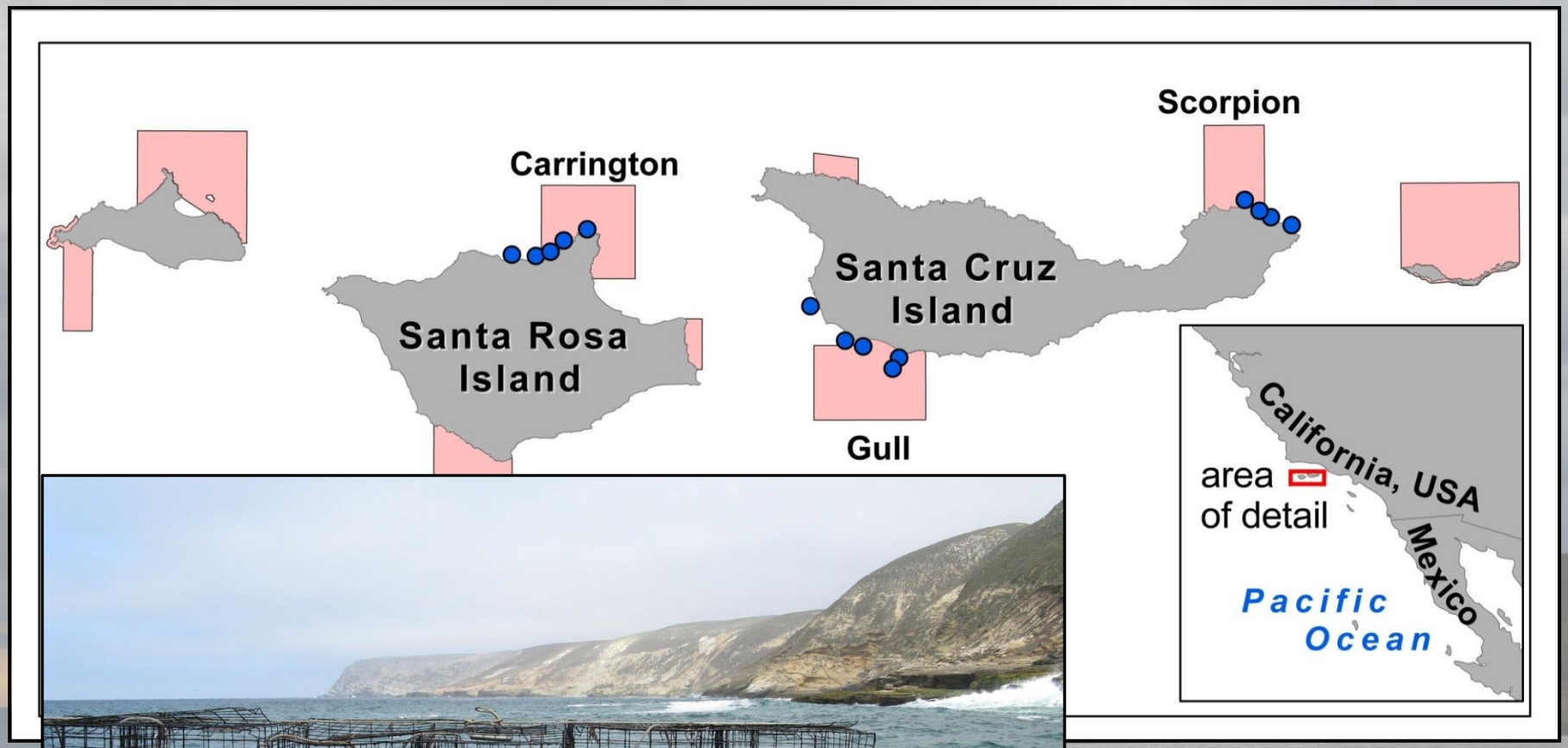
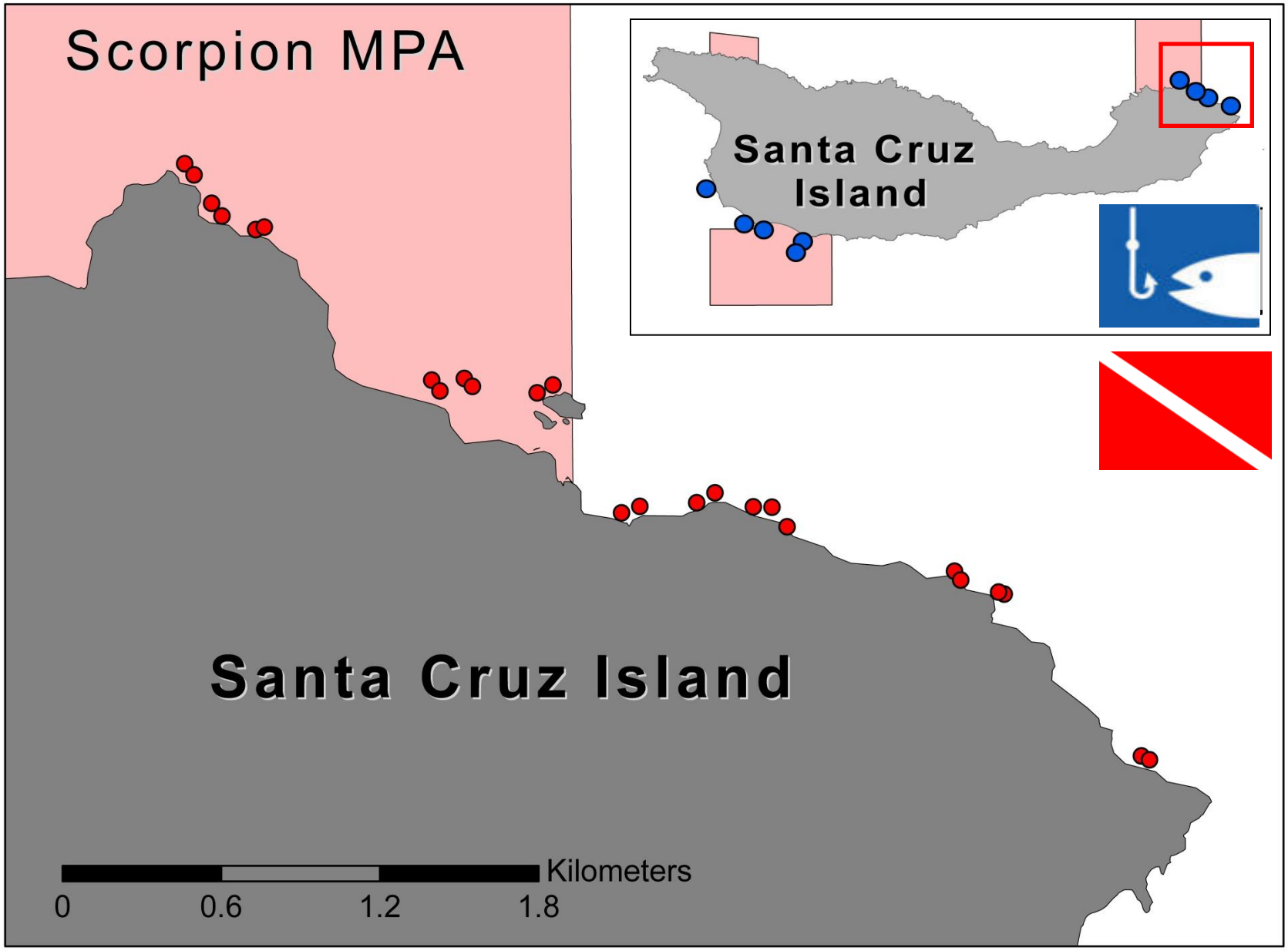


Controlling for Habitat



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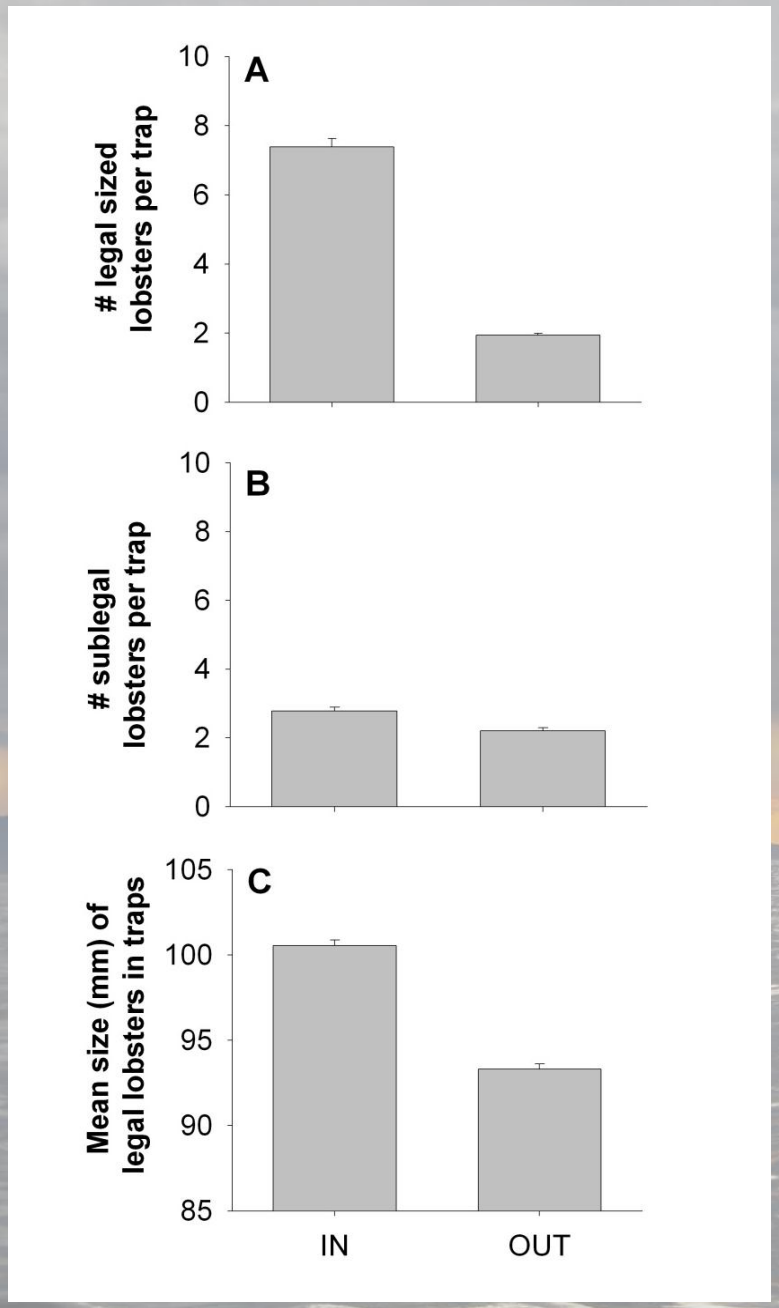
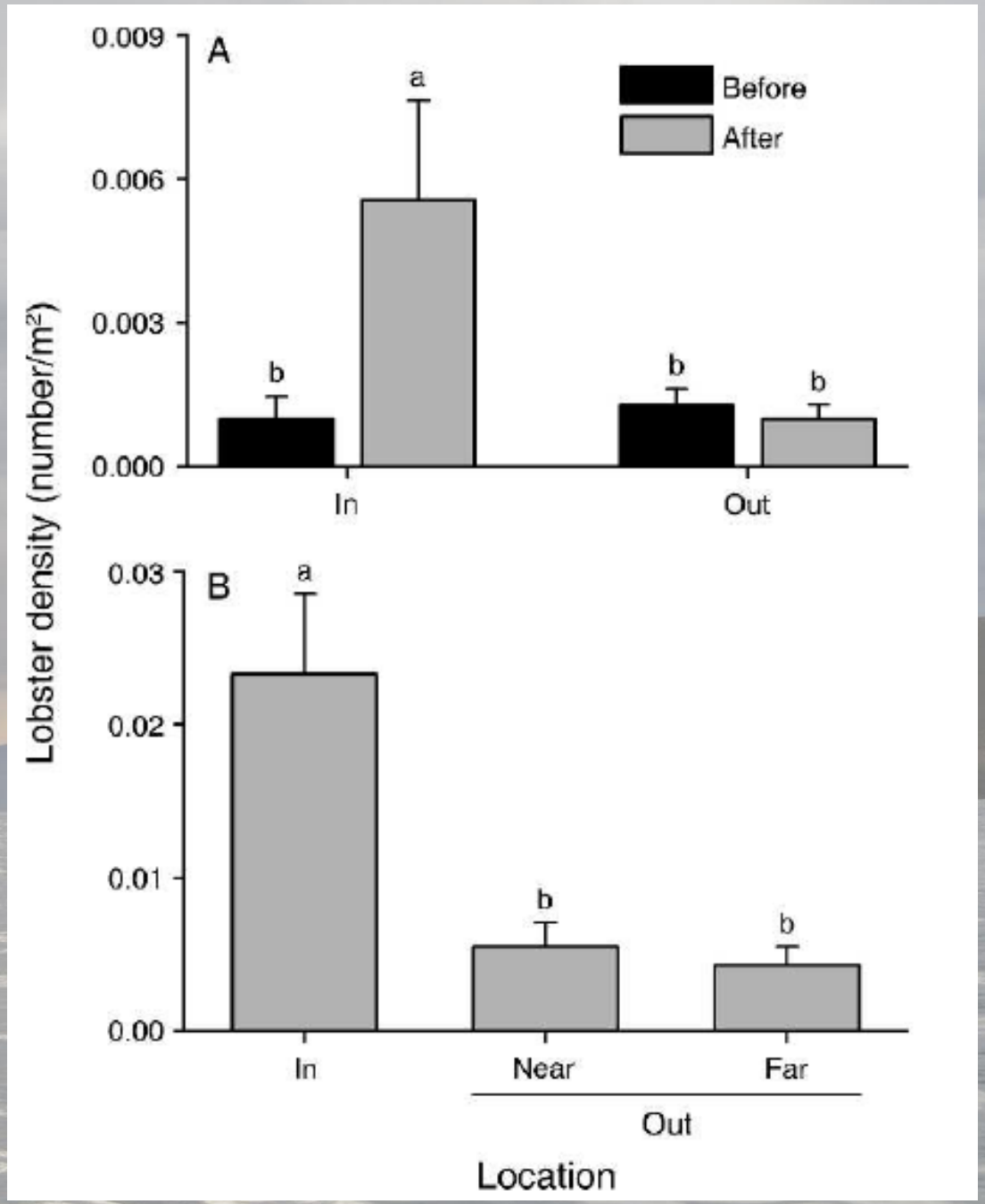


	Model 1	
	# legals	*mean size legals*
Reserve	**4.81(9.30)*** **	**7.03(7.23)*** **
# sublegals	**0.74(3.62)** **	**-0.37(-3.67)** **
Depth	0.003 (0.62)	0.03(1.51)
Nights	0.03(0.56)	-0.01(-0.15)
Dens	**0.20(4.56)*** **	**0.21(2.78)***
Caves	**0.63(2.33)***	-0.97(-1.80)
Cracks	-0.01(-0.15)	**0.07(2.68)***
Scorpion	**-7.09(-6.57)*** **	0.78(0.75)
Carrington	-0.20(-0.18)	**2.01(2.54)***
Gull	---	---
2006	-1.49(-1.24)	1.68(1.52)
2007	0.58 (1.19)	-0.30(-0.53)
2008	---	---
Constant	-1.82(-1.66)	**90.09(73.19)*** **
Observations	1955	1442
Adjusted R^2	0.51	0.22
AIC	11186.57	10231.11

1) Changes inside reserves



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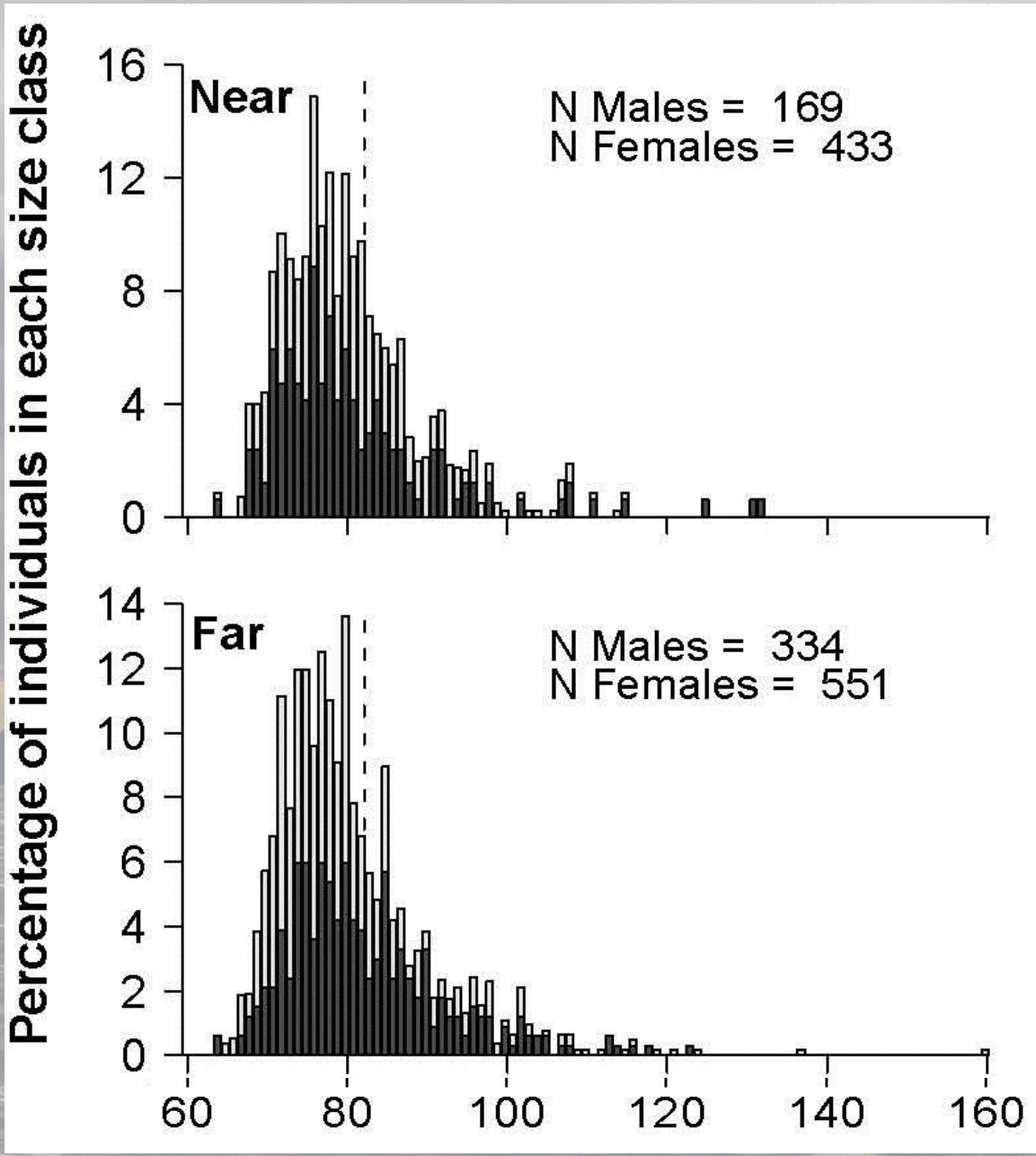

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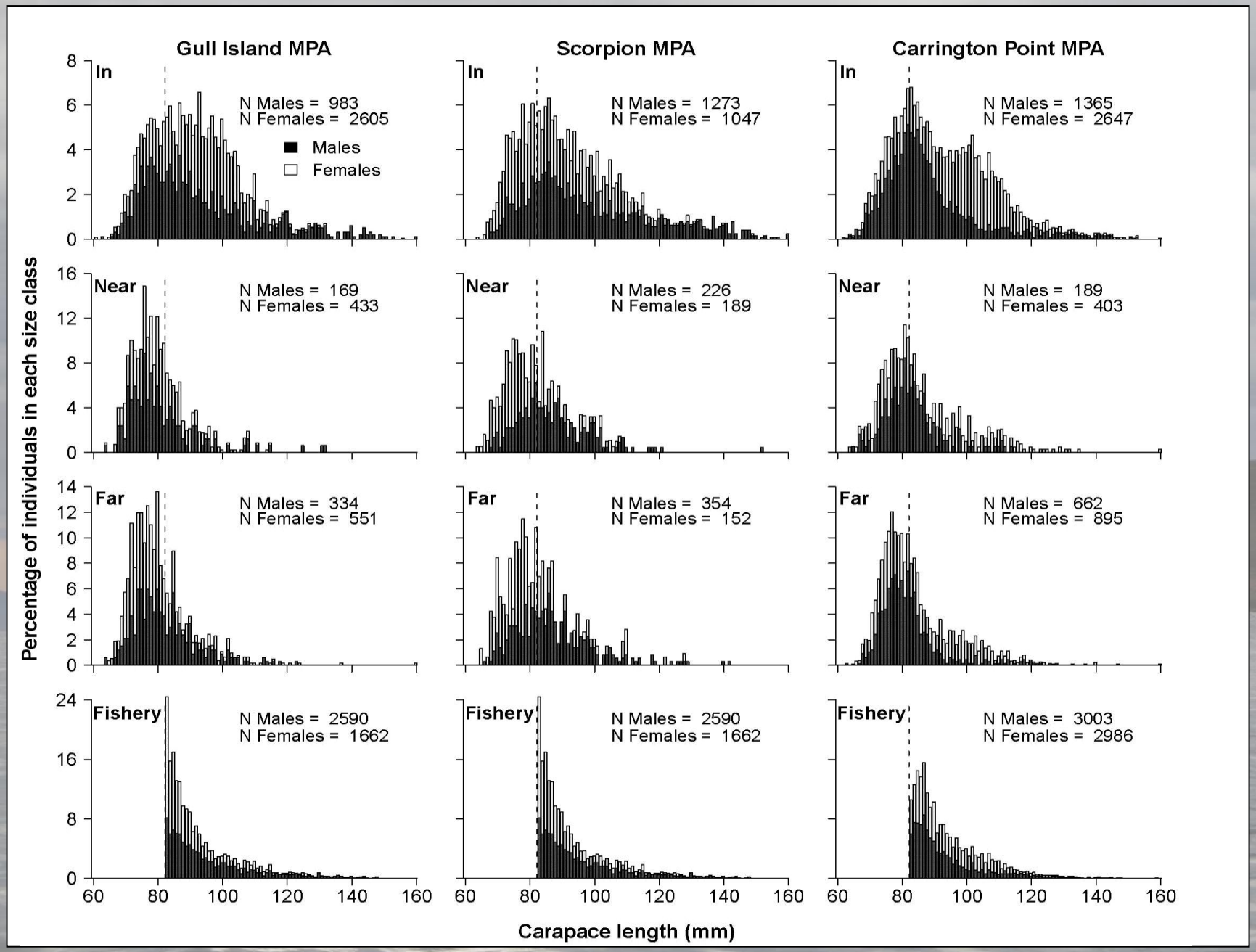

General conclusions

1) Assess changes to lobster populations inside reserves

a) Legal lobster density and trap yield ≈ 4-5x higher in reserves

b) Populations in reserves have higher proportion of individuals in large size classes

2) Develop harvest rate assessment (interpret in context of SPR/YPR for CA spiny lobster)

General conclusions

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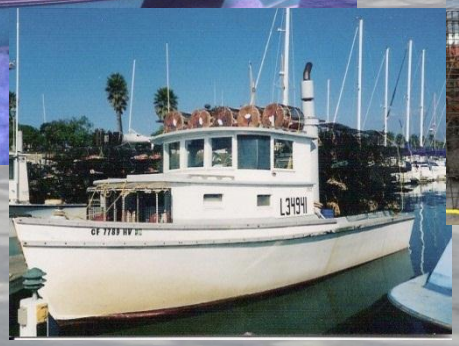
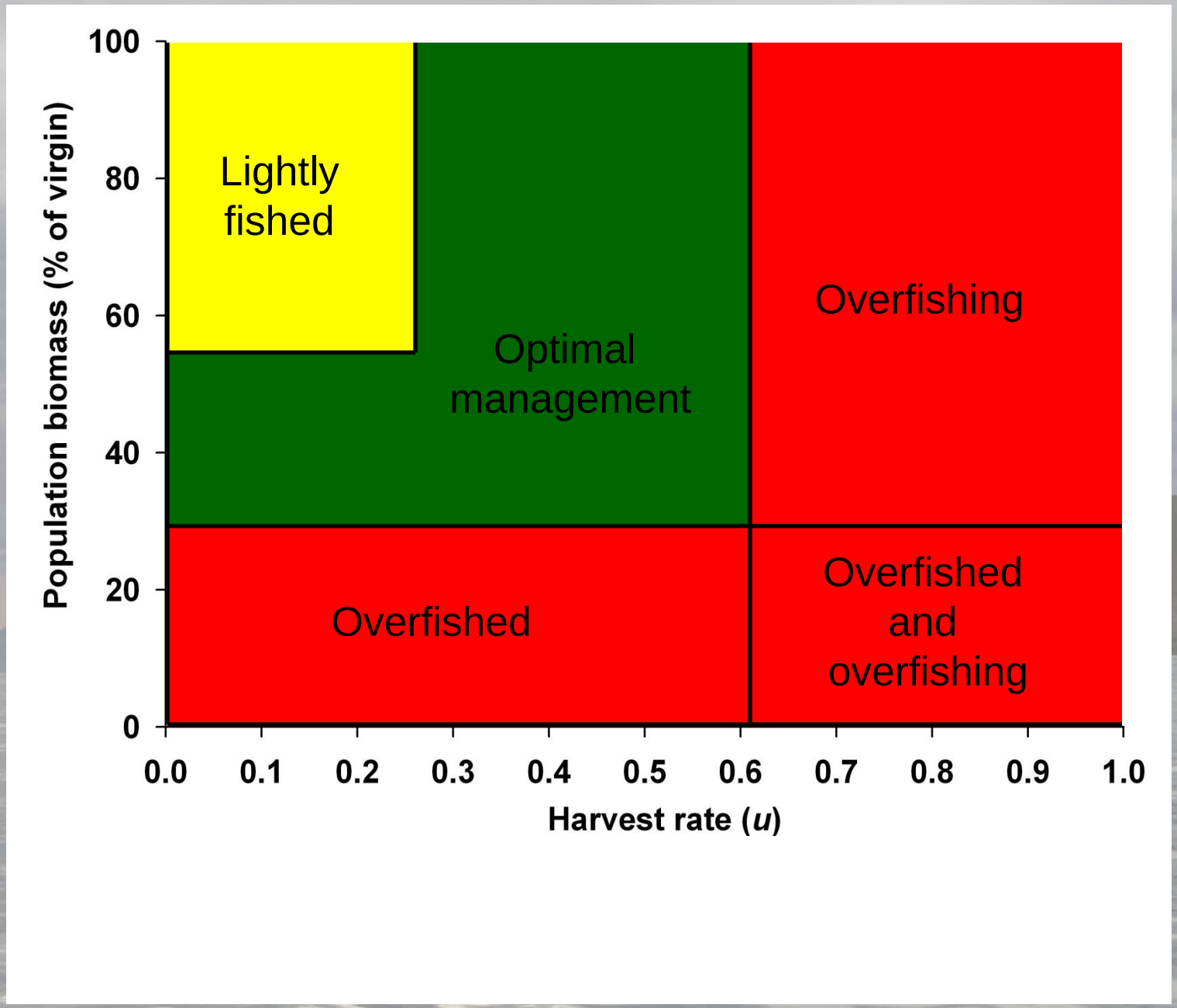
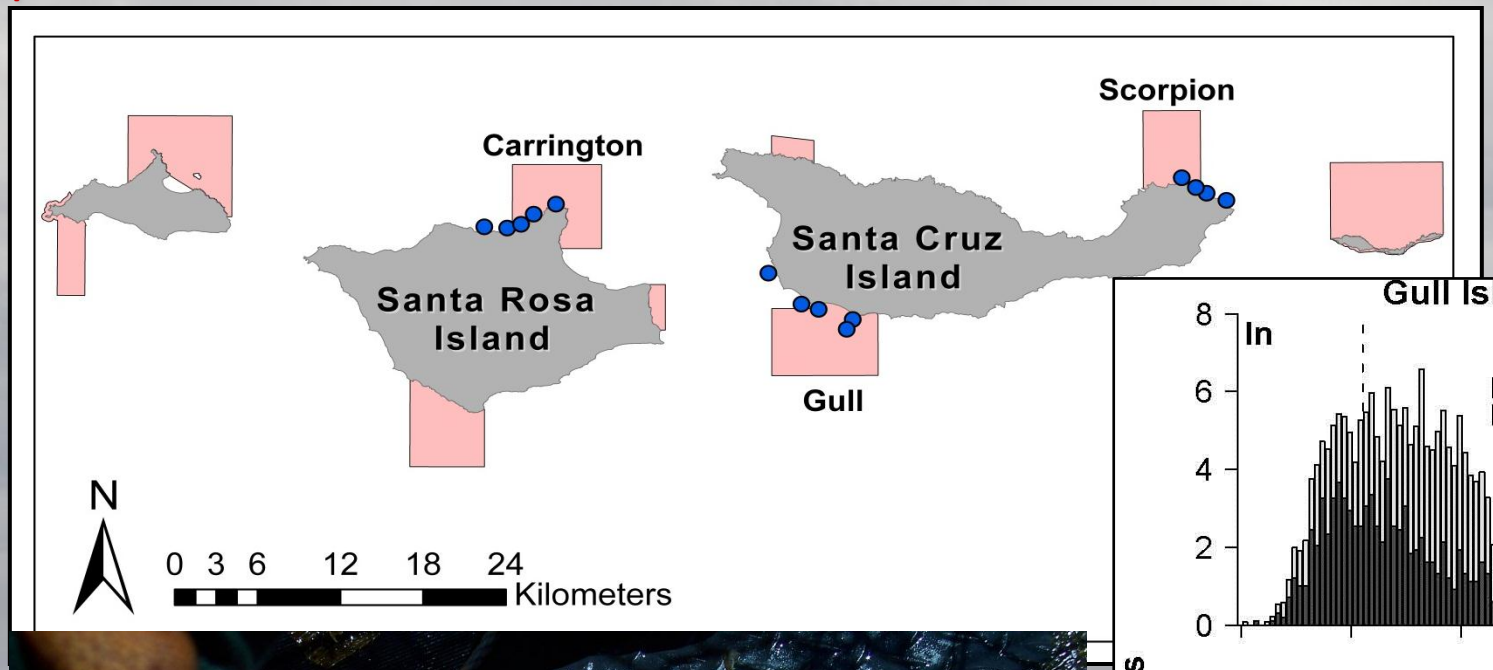


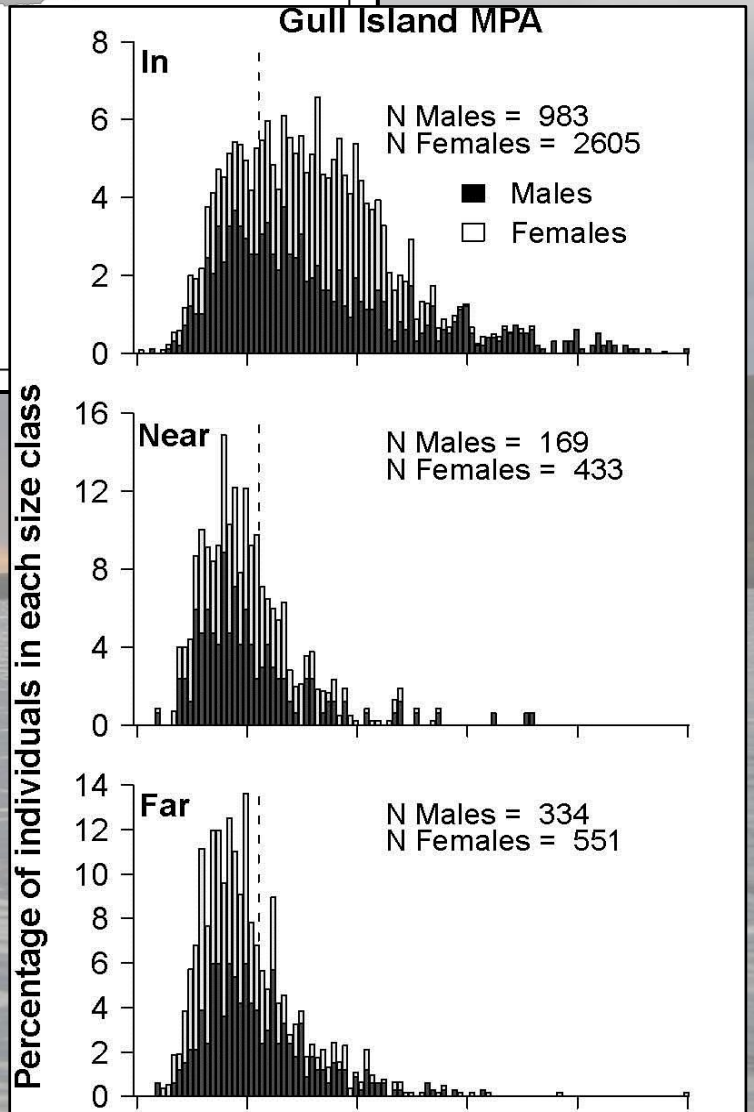
2) Harvest rate assessment



For general demonstration purposes only – exact values NOT applicable to P. interruptus

2) Harvest assessment





General conclusions

1) Assess changes to lobster populations inside reserves

a) lobster density and trap yield ≈ 4-5x higher in reserves

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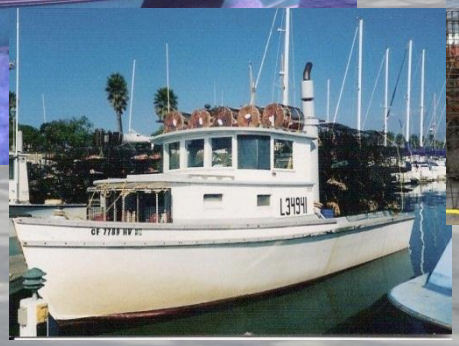
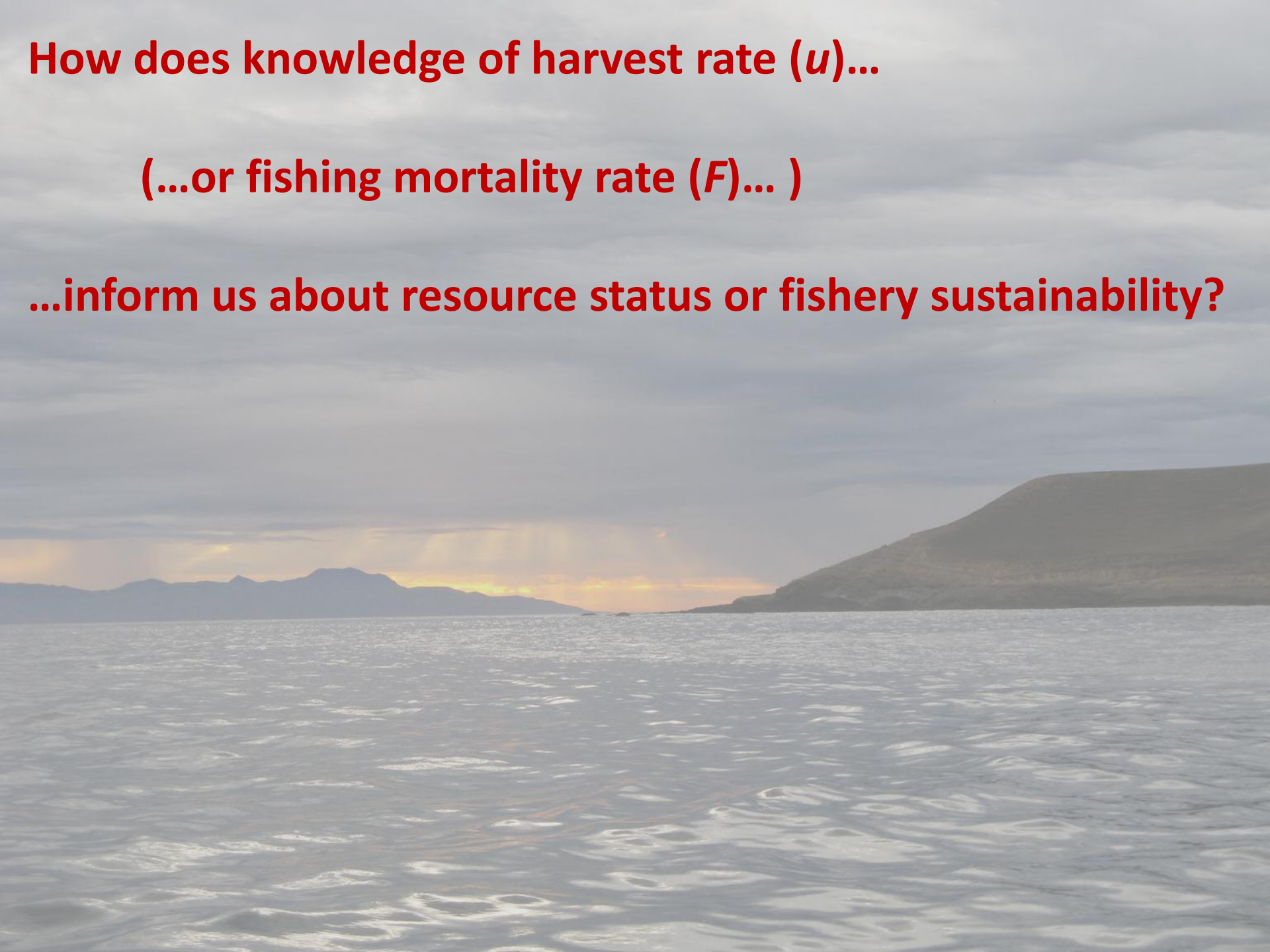
a) harvest rate ≈ 0.33 at SBCI

(interpret in context of SPR/YPR for CA spiny lobster)





How does knowledge of harvest rate (*u*)…

(…or fishing mortality rate (*F*)…)

…inform us about resource status or fishery sustainability?

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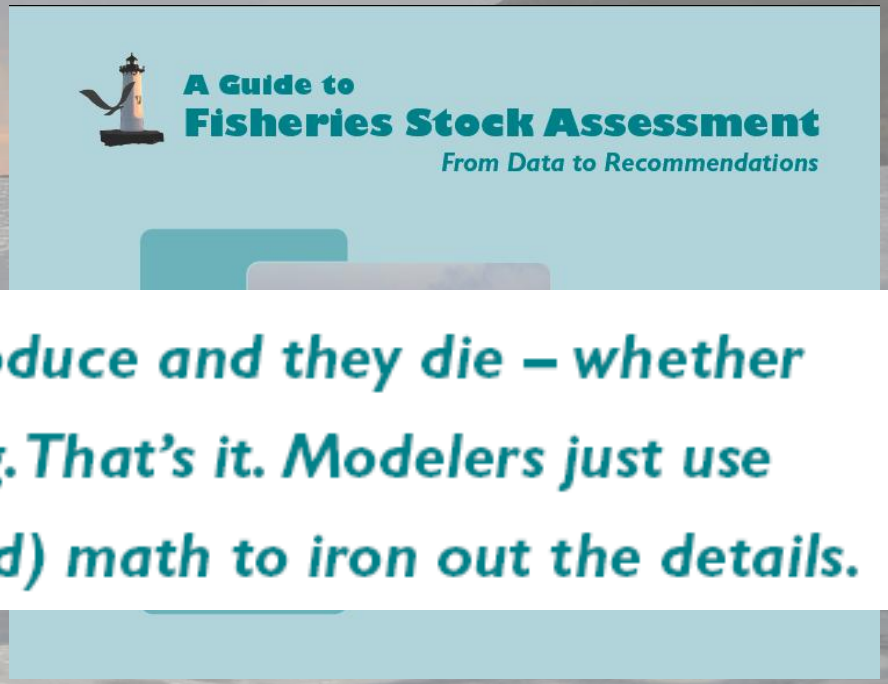
(…or fishing mortality rate (*F*)…)

…inform us about resource status or fishery sustainability?

Use models to explore how different harvest levels impact:

1) Reproduction of the population (SPR)

2) Yield to the fishery (YPR)



Fish are born, they grow, they reproduce and they die – whether from natural causes or from fishing. That's it. Modelers just use complicated (or not so complicated) math to iron out the details.

Understanding SPR and YPR models…

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size
1	
2	
.	
.	
5	
6	
7	
8	
9	
10	
.	
.	
oldest (25)	

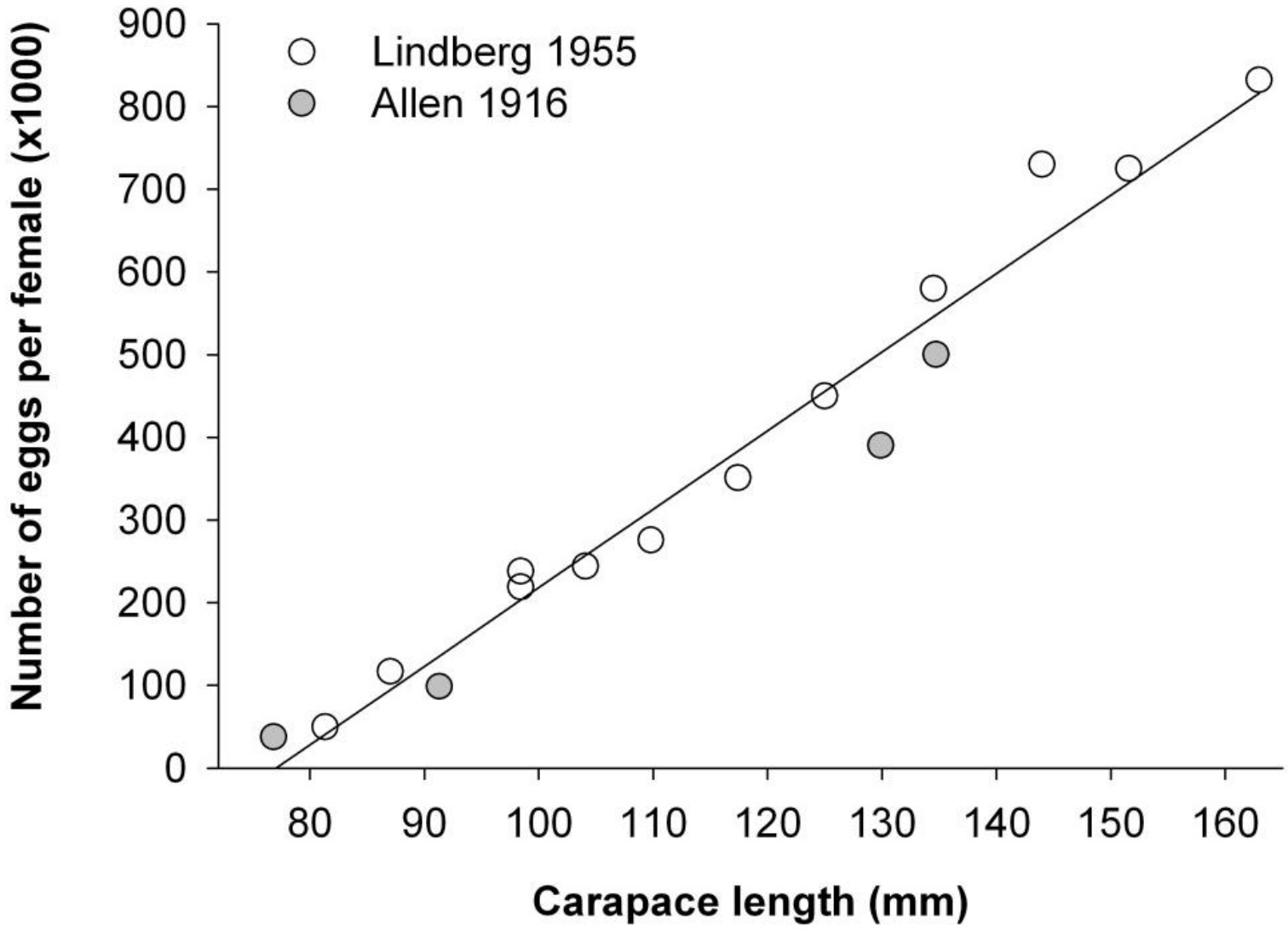
For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature
1		0
2		0
.	.	.
.	.	.
5		0
6		30%
7		80%
8		90%
9		100%
10		100%
.	.	.
.	.	.
oldest (25)		100%

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature	fecundity
1		0	0
2		0	0
.	.	.	.
.	.	.	.
5		0	0
6		30%	100,000
7		80%	200,000
8		90%	300,000
9		100%	400,000
10		100%	500,000
.		.	.
.		.	.
oldest (25)		100%	1,000,000

For general demonstration purposes only – exact values NOT applicable to P. interruptus


Lindberg 1955
Allen 1916
Number of eggs per female (x1000)
900
800
700
600
500
400
300
200
100
0
80
90
100
110
120
130
140
150
160
Carapace length (mm)

Age (yrs)	Size	% mature	fecundity
1		0	0
2		0	0
.	.	.	.
.	.	.	.
5		0	0
			

Fish are born, they grow, they reproduce and they die – whether from natural causes or from fishing. That's it. Modelers just use complicated (or not so complicated) math to iron out the details.

9		100%	400,000
10		100%	500,000
.		.	.
.		.	.
oldest (25)		100%	1,000,000

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature	fecundity	# lobsters
1		0	0	100
2		0	0	
.	.	.	.	.
.	.	.	.	.
5		0	0	
6		30%	100,000	
7		80%	200,000	
8		90%	300,000	
9		100%	400,000	
10		100%	500,000	
.		.	.	
.		.	.	
oldest (25)		100%	1,000,000	

*FOR DEMONSTRATION PURPOSES: EXACT VALUES HERE ARE NOT BIOLOGICALLY ACCURATE FOR CA SPINY LOBSTER – ACTUAL SPR ESTIMATES APPEAR IN FOLLOWING SLIDES!!

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature	fecundity	# lobsters	Total eggs
1		0	0	100	
2		0	0	83	
.	.	.	.	.	.
.	.	.	.	.	.
5		0	0	47	
6		30%	100,000	39	
7		80%	200,000	33	
8		90%	300,000	27	
9		100%	400,000	23	
10		100%	500,000	19	
.		.	.	.	
.		.	.	.	
oldest (25)		100%	1,000,000	1	

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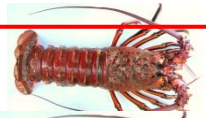
Harvest rate = 0 (no harvest)

GRAND TOTAL # EGGS = 33,440,000

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature	fecundity	# lobsters	Total eggs
1		0	0	100	0
2		0	0	83	0
.	.	.	.		.
.	.	.	.	.	.
5		0	0	47	0
6		30%	100,000	39	1,170,000
7		80%	200,000	33	5.280.000
8		90%	300,000	27	7,290,000
9		100%	400,000	23	9,200,000
10		100%	500,000	19	9,500,000
.	.	.	.		
.	.	.	.	.	.
oldest (25)		100%	1,000,000	1	1,000,000

 # eggs$_{fished}$= 17,810,100

 # eggs$_{unfished}$= 33,440,000

= SPR*

Harvest rate = 0 (no harvest)

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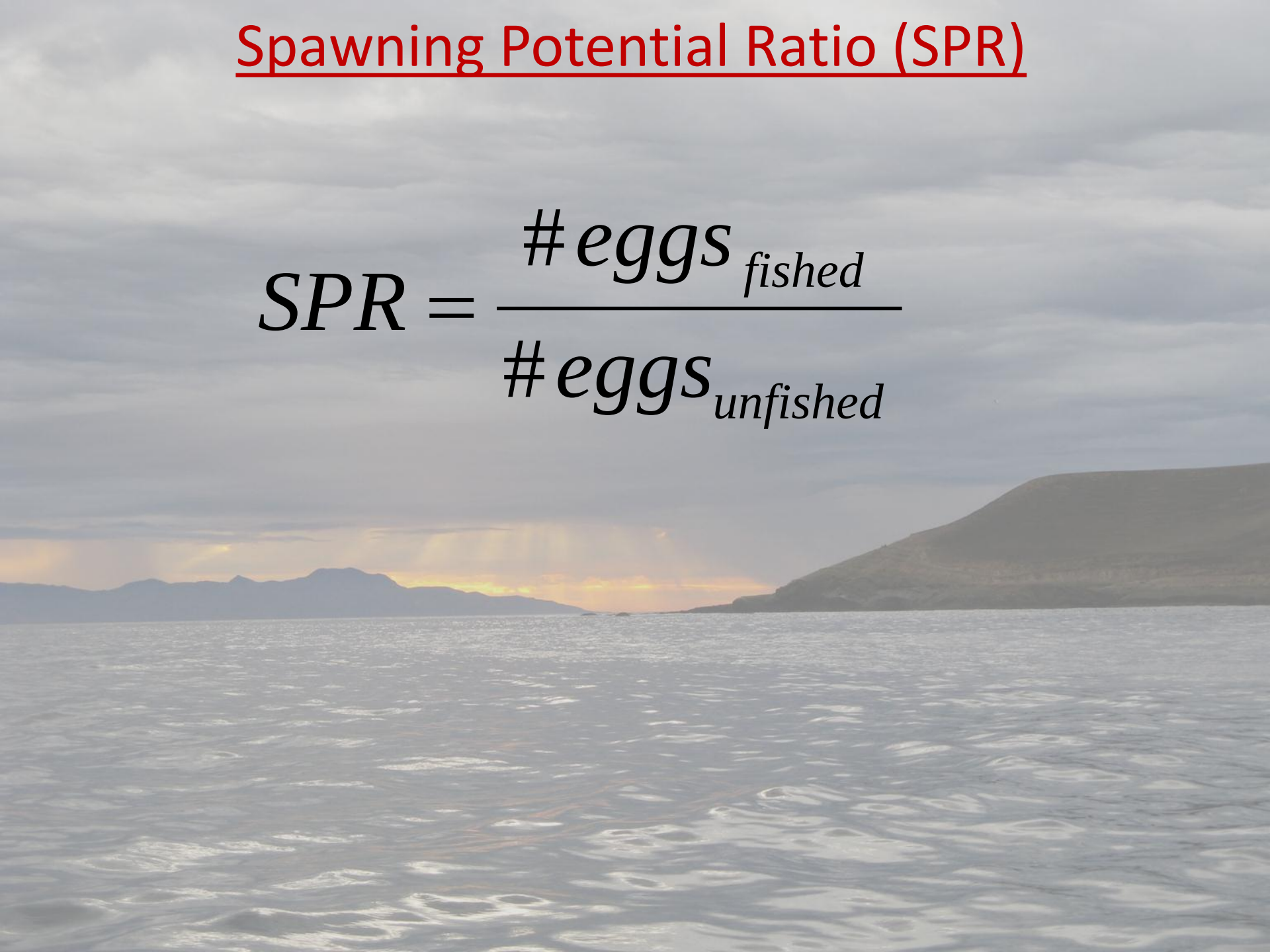
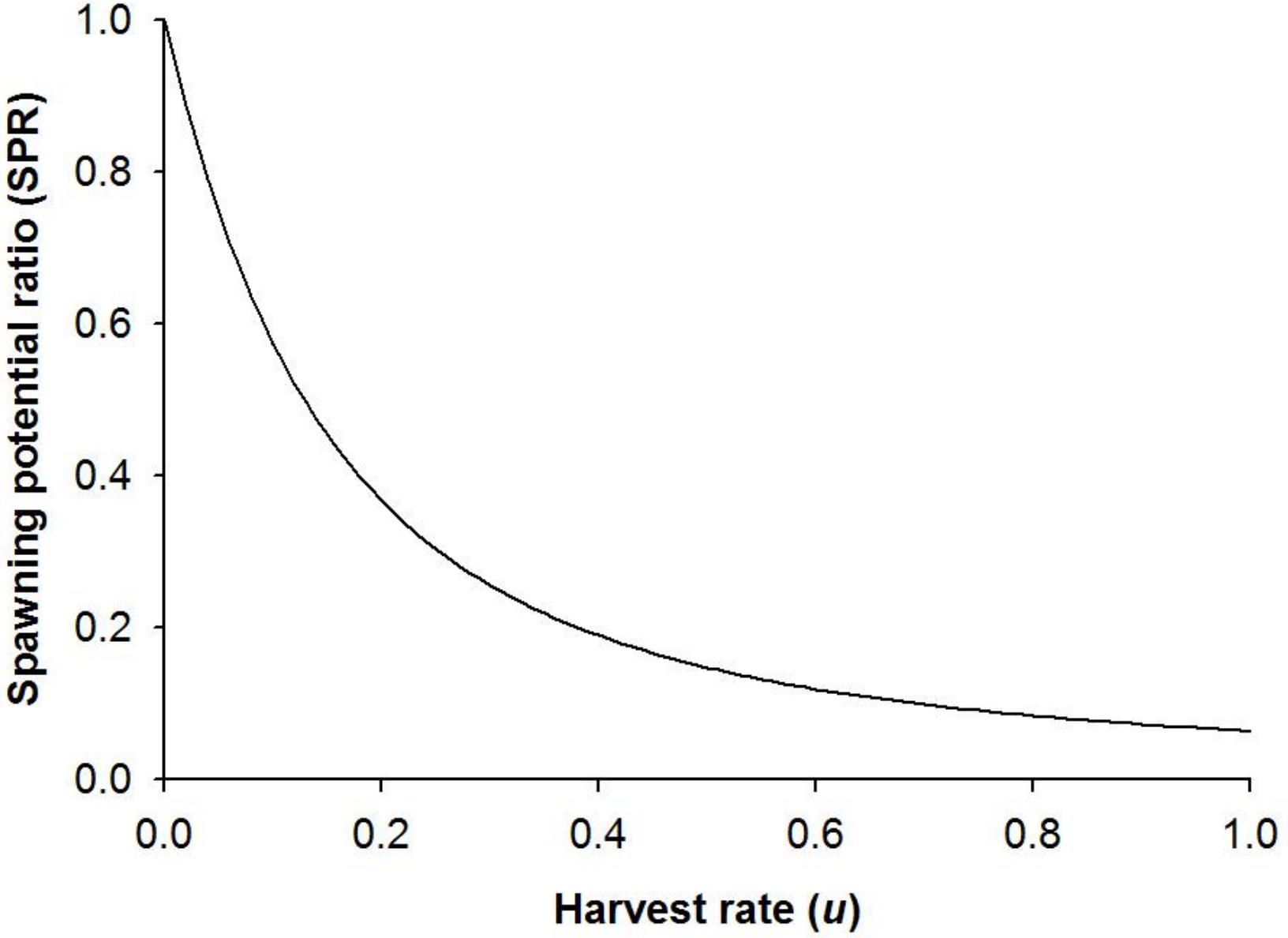
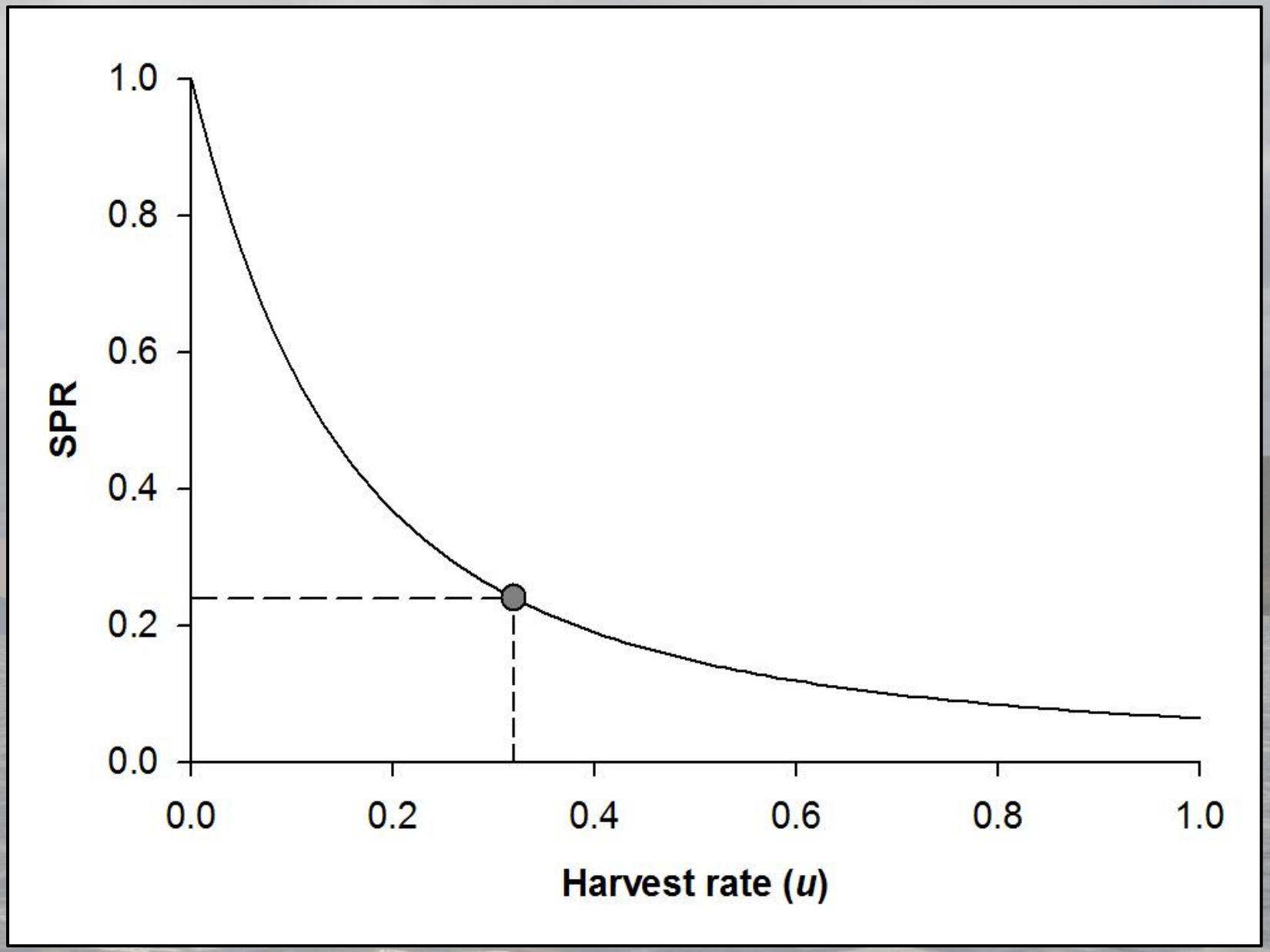
Spawning Potential Ratio (SPR)

$$SPR = \frac{\#eggs_{fished}}{\#eggs_{unfished}}$$




Spawning potential ratio (SPR)
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Harvest rate (u)

2) Harvest assessment



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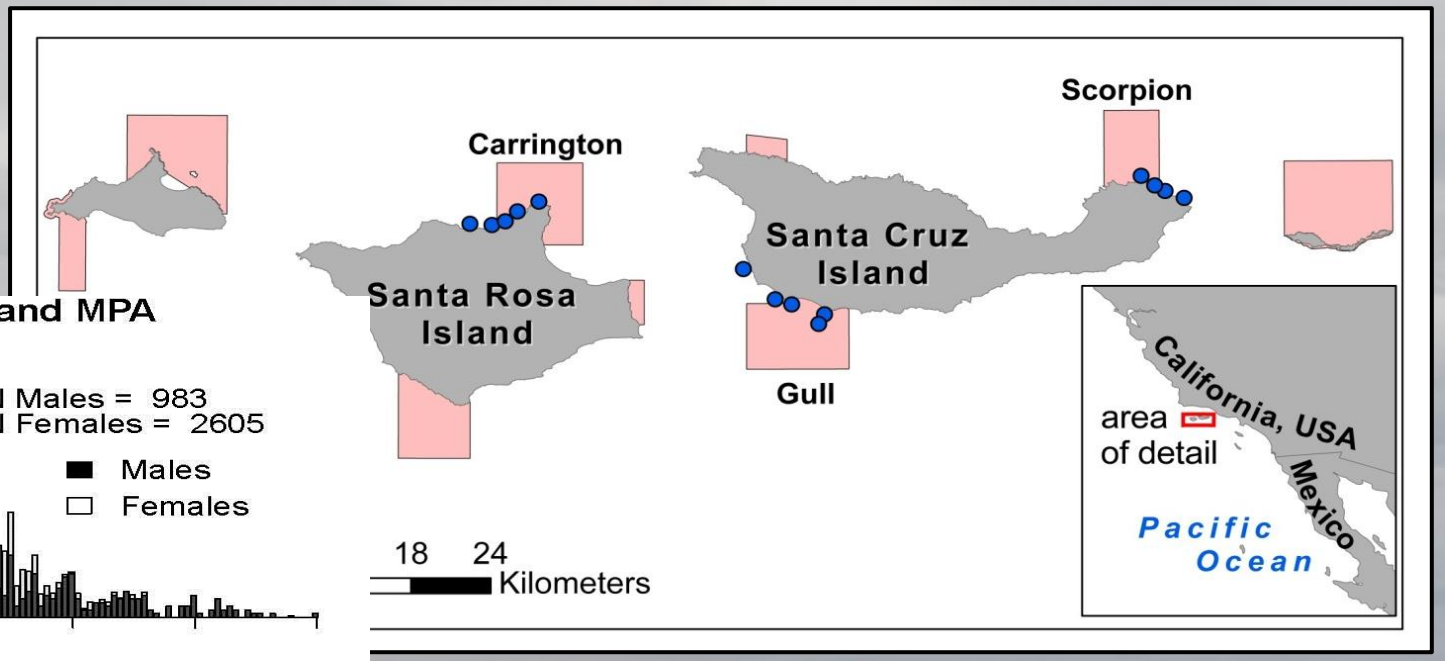
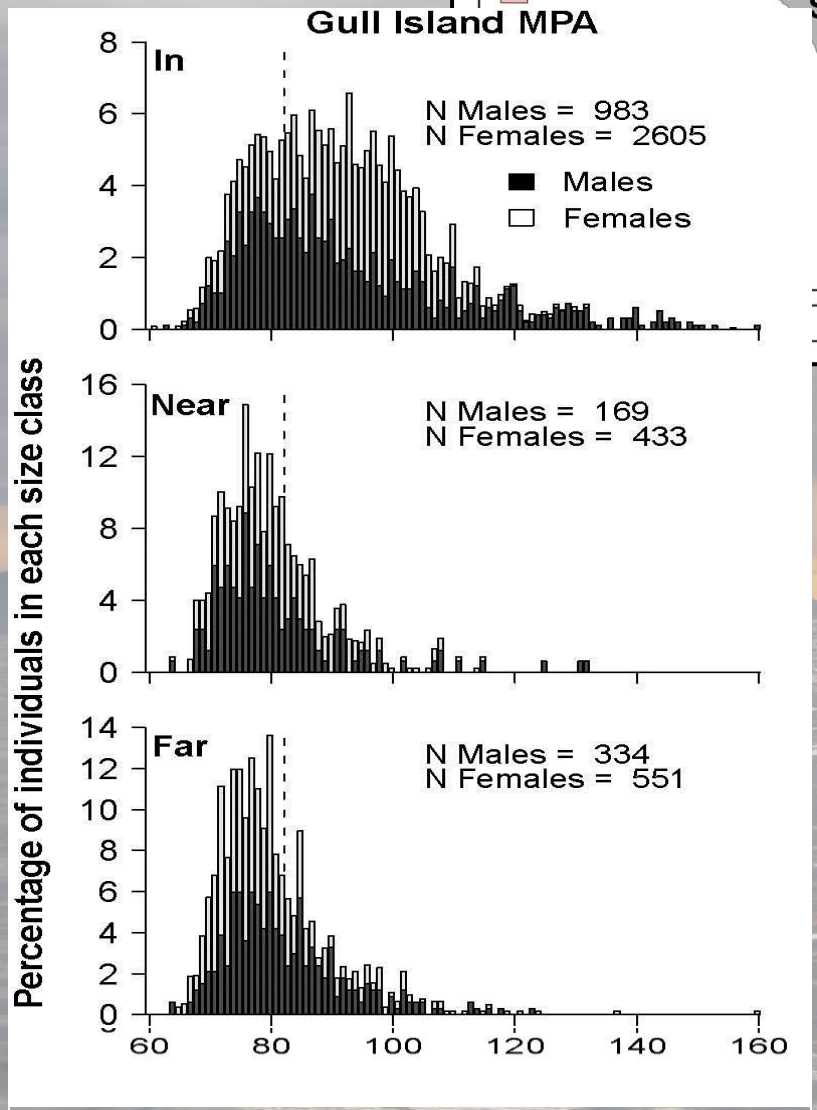
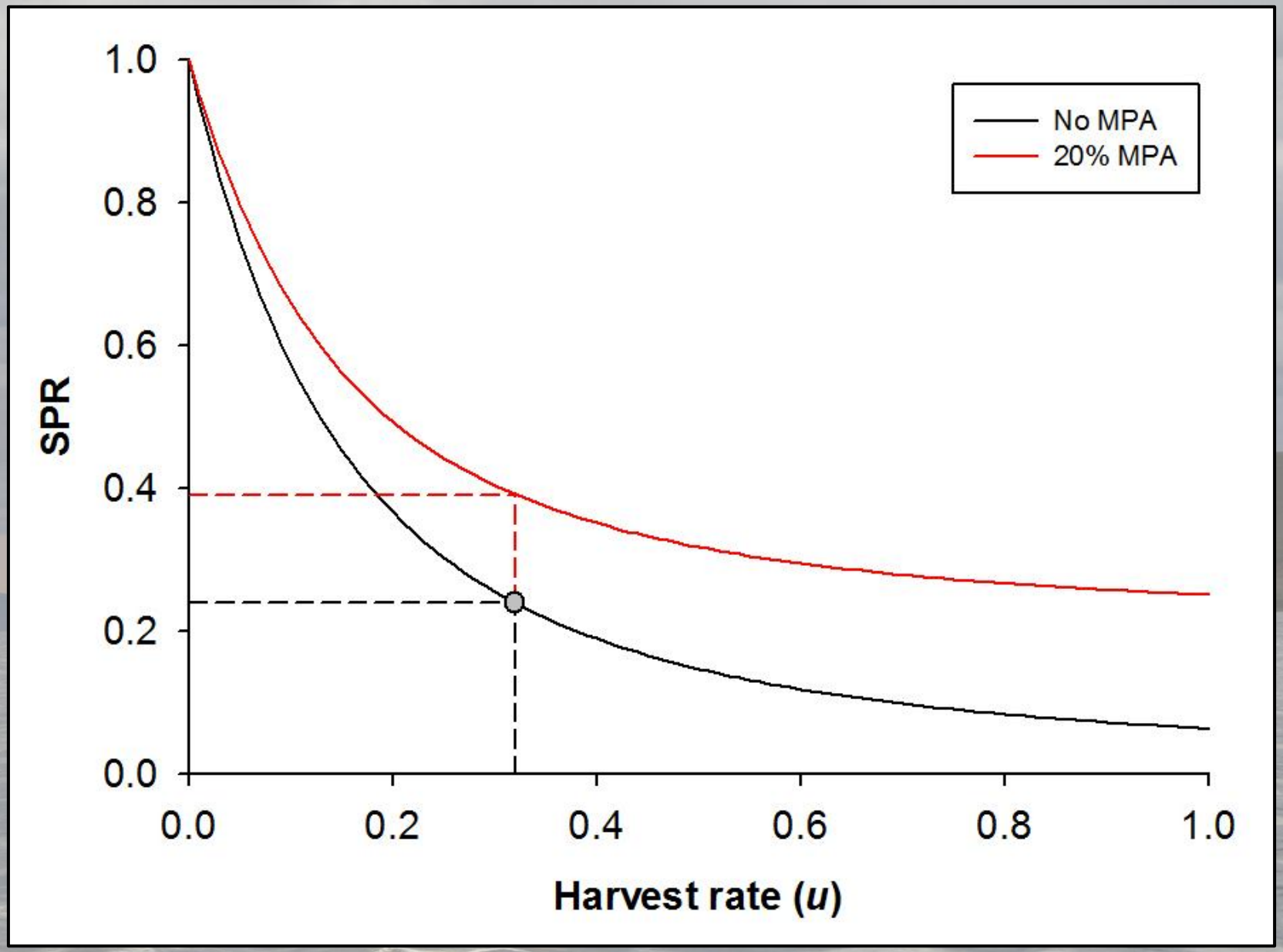




Northern SBCI:

≈ 20% MPA

2) Harvest assessment



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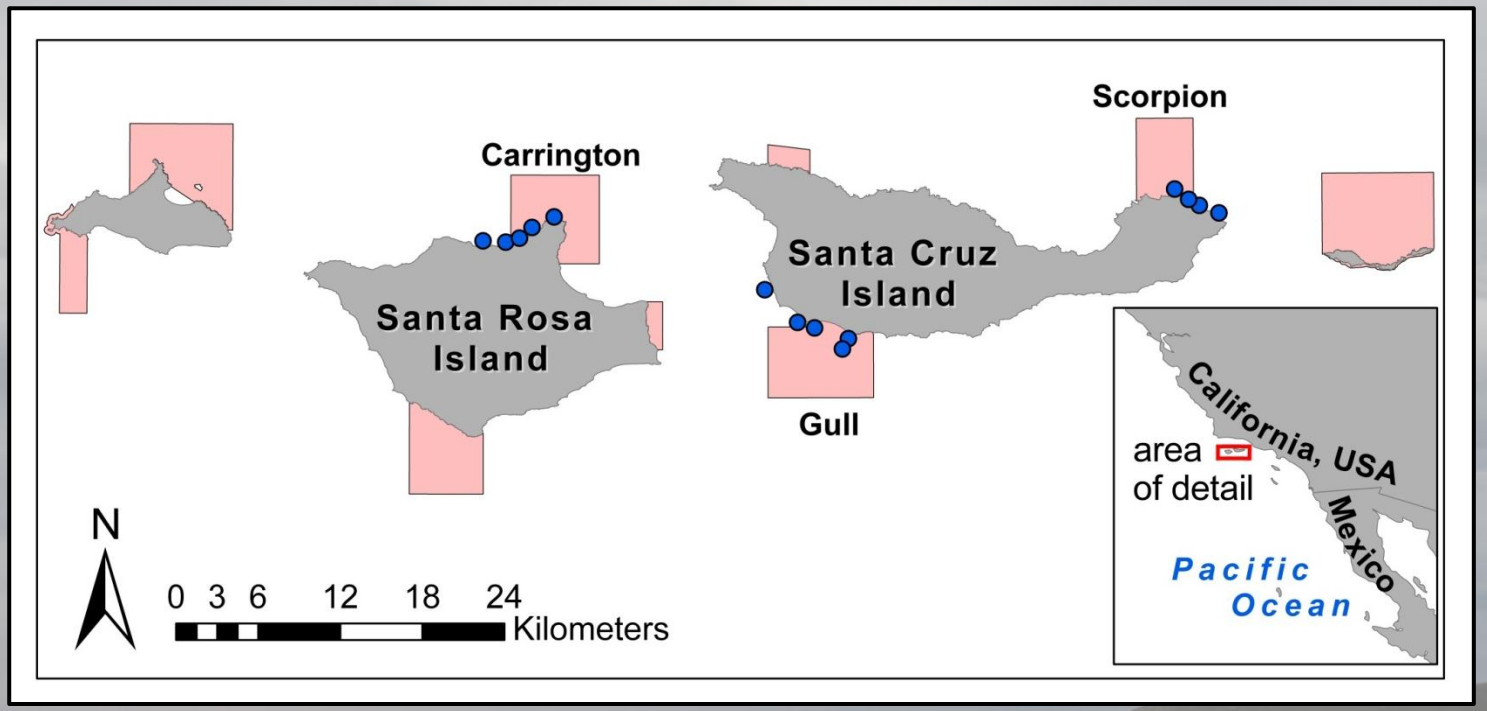
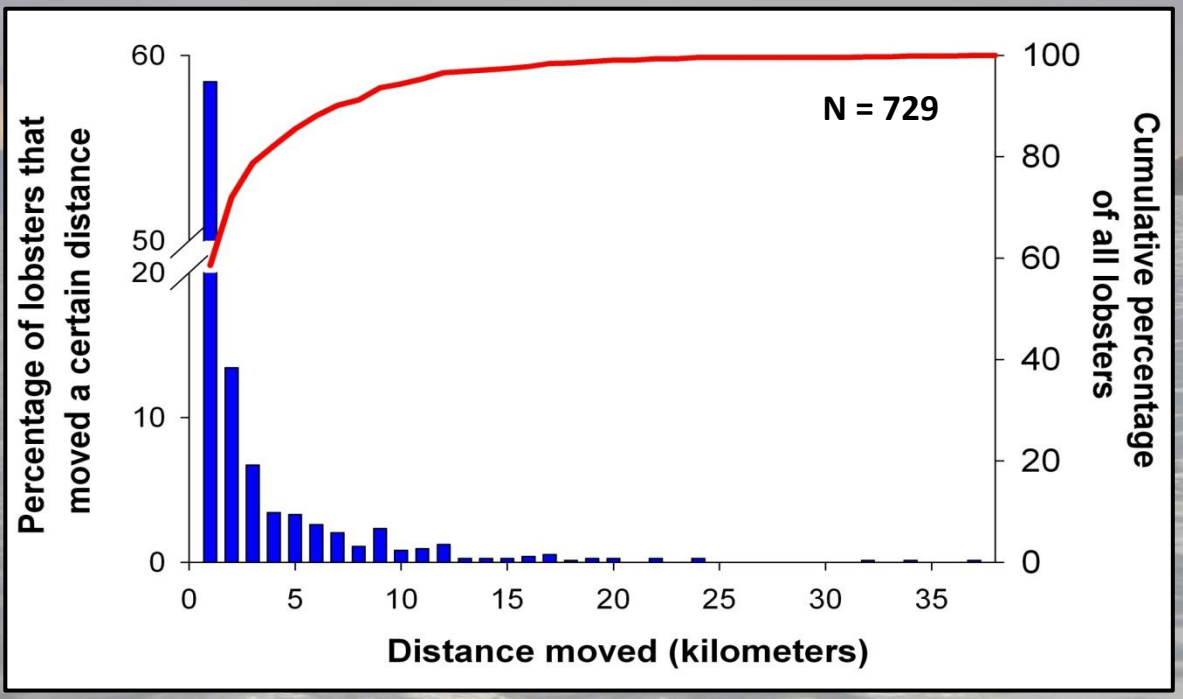
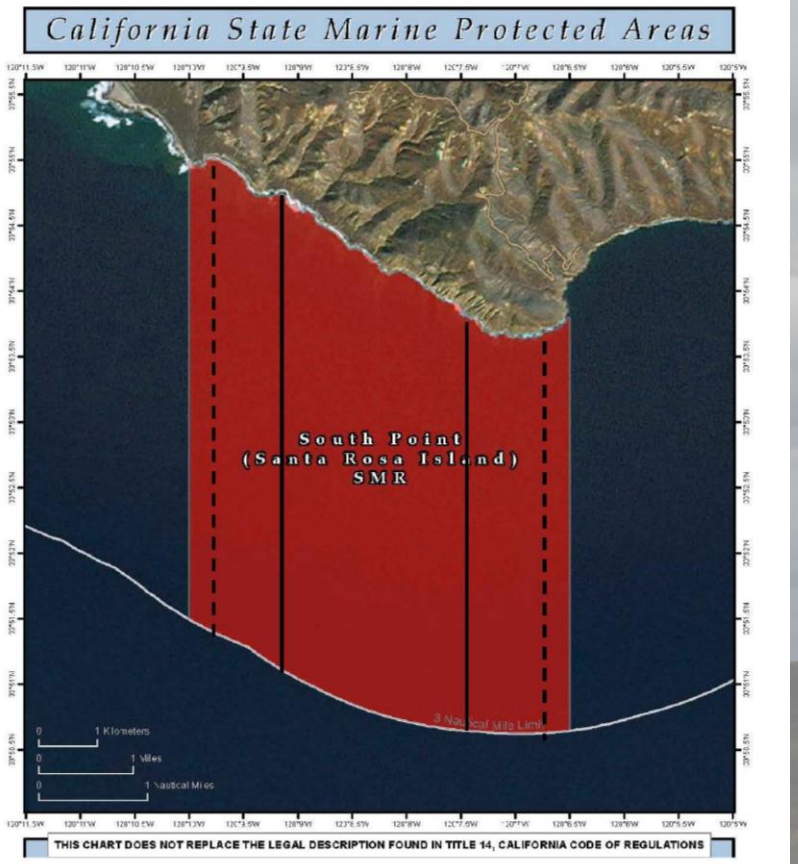




F inside 20% of F in Open Area



MPAs Movement and Foraging Distance

Lindberg (1955) Tagging data Table 5 Page 167

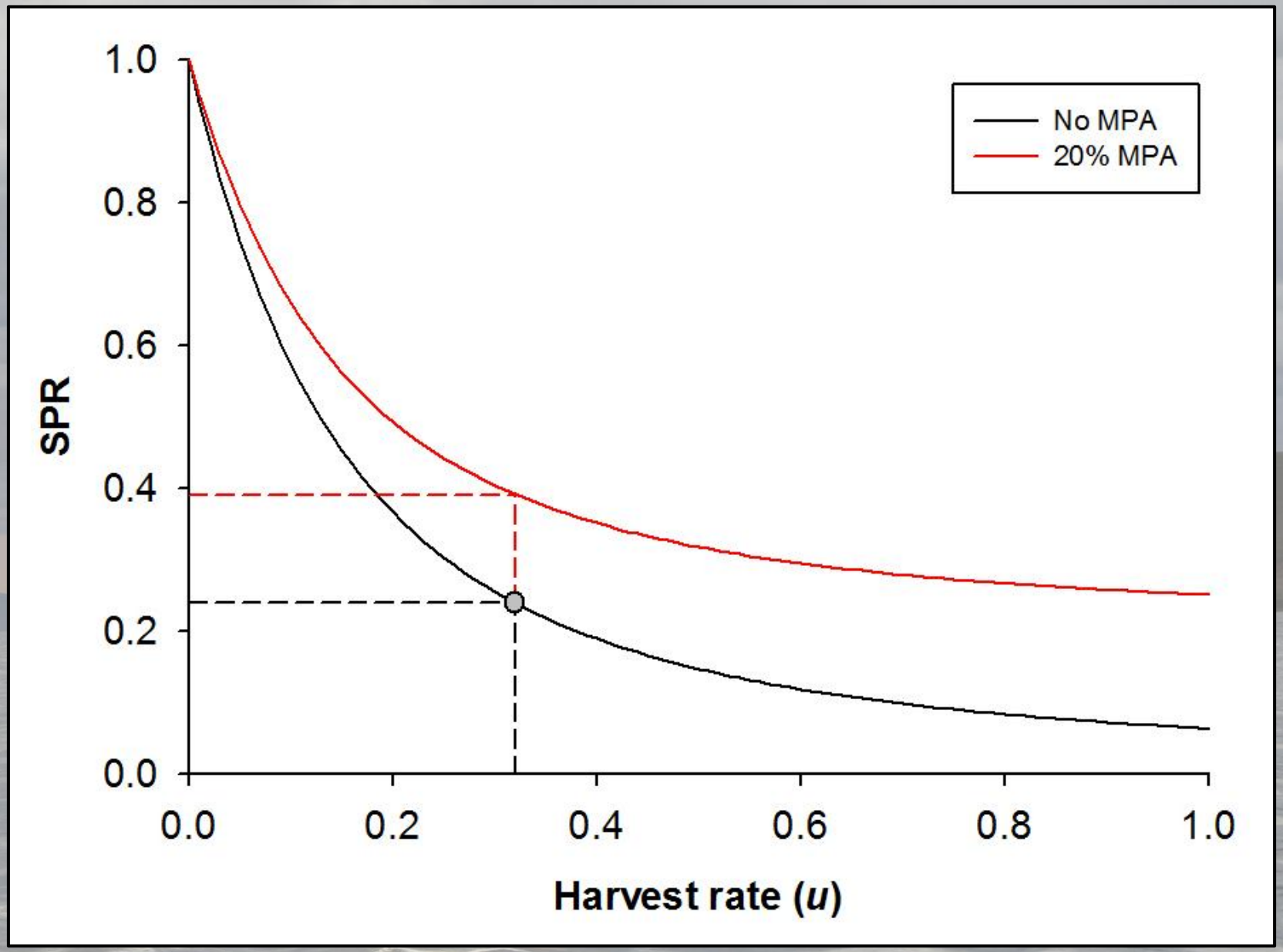
	1949-50	1950-51	1951-52	Total	Revise
N Tagged	803	598	347	1748	1748
N Recovered	35	29	12	76	76
% Recovered	4.48	4.85	3.45	4.4	4.35%
Ave Time (mo)	3.9	2.4	1.5	2.6	2.9
Ave Distance mi	0.7	0.7	0.4	0.6	0.65

California MPAs - 3 mile square box

5% of Lobster within 0.75 mile of alongshore boundary will move in or out of a MPA or in or out of the 1.5 mile center of MPA.

Lindberg also suggested that the nightly foraging distance was not greater than 0.25 mile.

2) Harvest assessment



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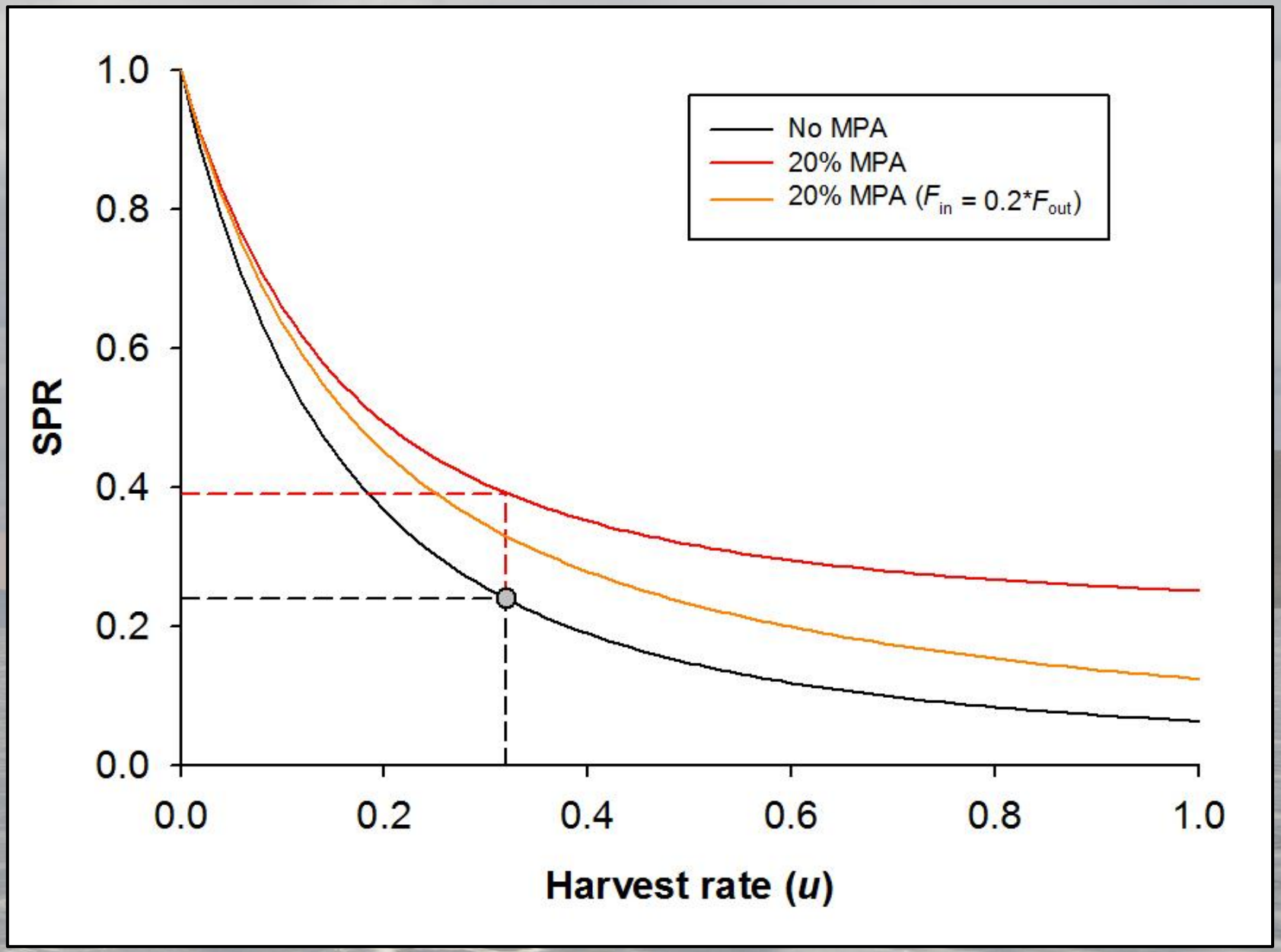


General conclusions

1) Assess changes to lobster populations inside reserves

   a) lobster density and trap yield ≈ 4-5x higher in reserves

   b) Populations in reserves have higher proportion of individuals in large size classes

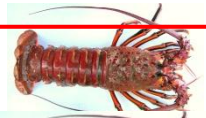
2) Develop harvest rate assessment

   a) harvest rate ≈ 0.33 at SBCI

3) interpret in context of SPR/YPR for CA spiny lobster

   a) SPR provides biological reference point (directly related to reproductive status of stock)

   b) SPR provides basis for including MPAs in assessment

Age (yrs)	Size (weight)	% mature	fecundity	# lobsters	Total eggs
1		0	0	100	0
2		0	0	83	0
				(83)	
.	.	.	.	.	.
.	.	.	.	.	.
5		0	0	47	0
				(47)	
6		30%	100,000	39	1,170,000
				(39)	(1,170,000)
7		80%	200,000	33	5,280,000
				(33)	(5,280,000)
8		90%	300,000	27	7,290,000
				(18)	(4,860,000)
9		100%	400,000	23	9,200,000
				(10)	(4,000,000)
10		100%	500,000	19	9,500,000
				(5)	(2,500,000)
.	.	.	.	.	.
.	.	.	.	.	.
oldest (25)		100%	1,000,000	1	1,000,000
				(.0001)	(100)

Catch (weight)

*FOR DEMONSTRATION PURPOSES: EXACT VALUES HERE ARE NOT BIOLOGICALLY ACCURATE FOR CA SPINY LOBSTER – ACTUAL SPR ESTIMATES APPEAR IN FOLLOWING SLIDES!!

Harvest rate = 0 (no harvest)

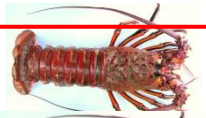
Harvest rate = .33 (33% annual)

$eggs_{fished}$= 17,810,100

$eggs_{unfished}$= 33,440,000

YPR = Total weight of catch (per recruit)

For general demonstration purposes only – exact values NOT applicable to P. interruptus

Age (yrs)	Size	% mature	fecundity	# lobsters	Total eggs	Catch
1		0	0	100	0	0
						(0)
2		0	0	83	0	0
.	.	.	.	(83)	.	.
.	.	.	.	.	.	.
5		0	0	47	0	0
				(47)		(0)
6		30%	100,000	39	1,170,000	0
				(39)	(1,170,000)	(0)
7		80%	200,000	33	5,280,000	0
				(33)	(5,280,000)	(0)
8		90%	300,000	27	7,290,000	0
				(18)	(4,860,000)	(#caught x weight)
9		100%	400,000	23	9,200,000	0
				(10)	(4,000,000)	(#caught x weight)
10		100%	500,000	19	9,500,000	0
.		.	.	(5)	(2,500,000)	(#caught x weight)
.		.	.	.	.	.
oldest (25)		100%	1,000,000	1	1,000,000	0
				(.0001)	(100)	(#caught x weight)

Harvest rate = 0 (no harvest)

Harvest rate = .33 (33% annual)

YPR = Total weight of catch (per recruit)

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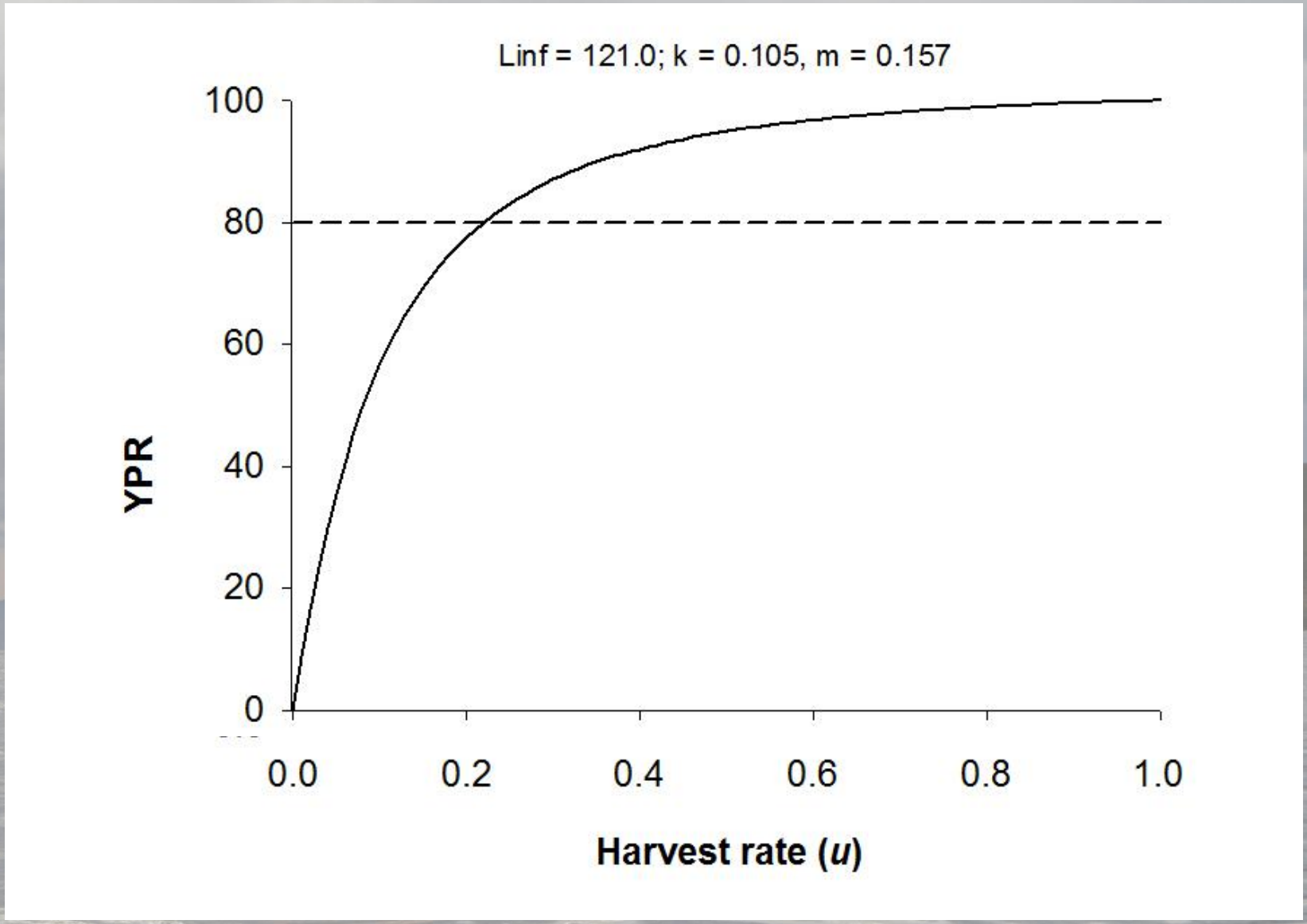
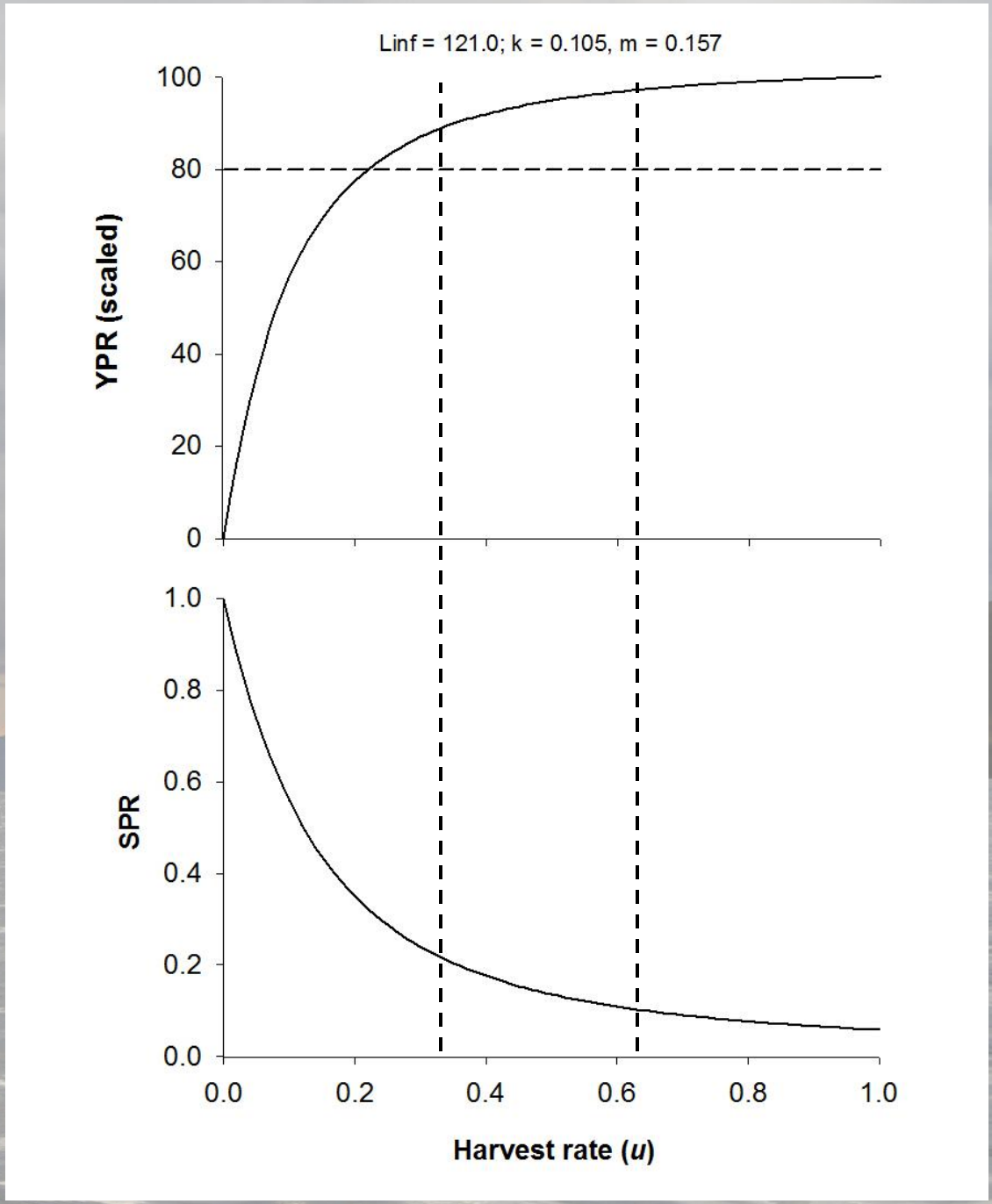
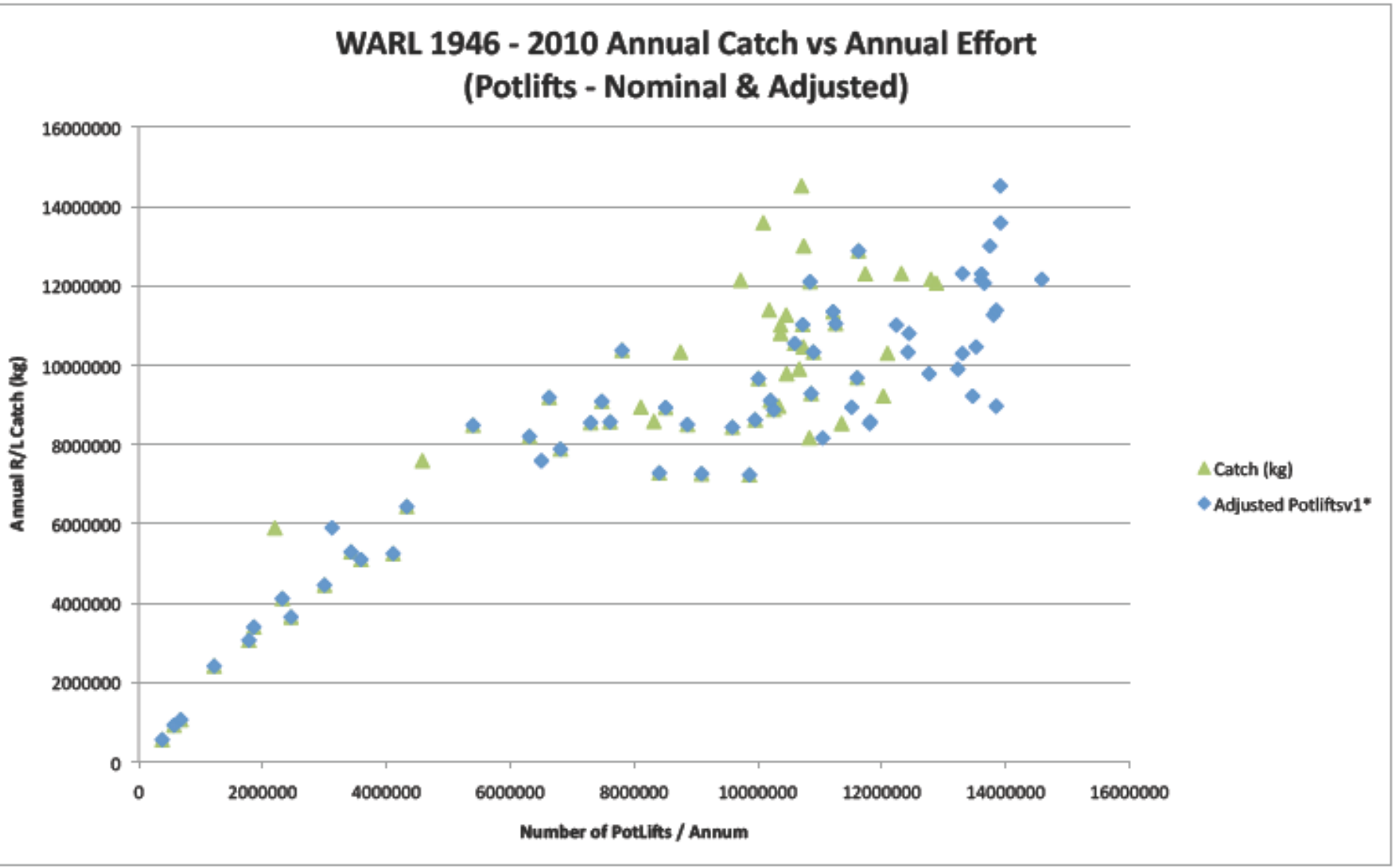
2) Harvest assessment



2) Harvest assessment



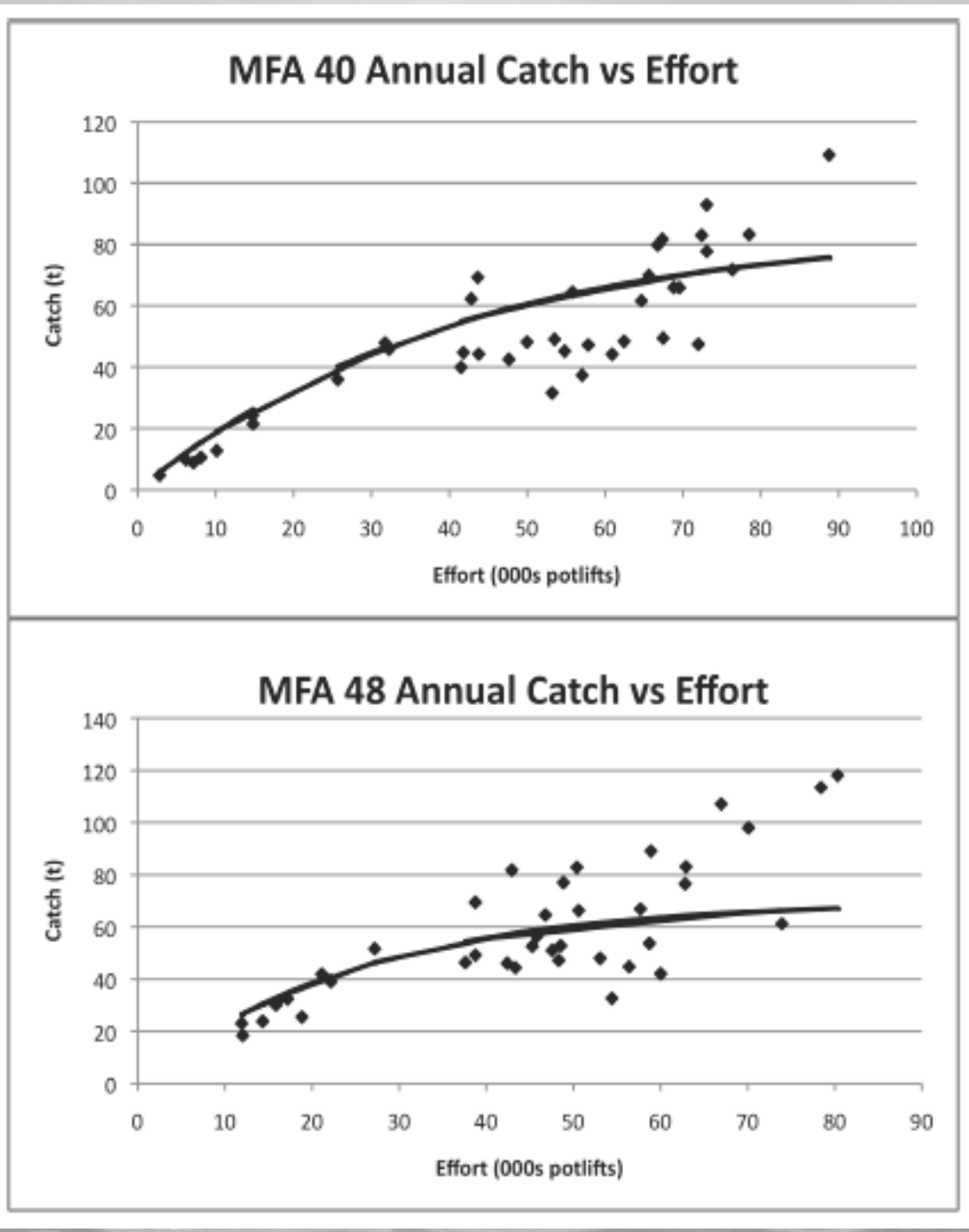

WARL 1946 - 2010 Annual Catch vs Annual Effort
(Potlifts - Nominal & Adjusted)
Annual R/L Catch (kg)
16000000
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
0
2000000
4000000
6000000
8000000
10000000
12000000
14000000
16000000
Number of PotLifts / Annum
Catch (kg)
Adjusted Potliftsv1*

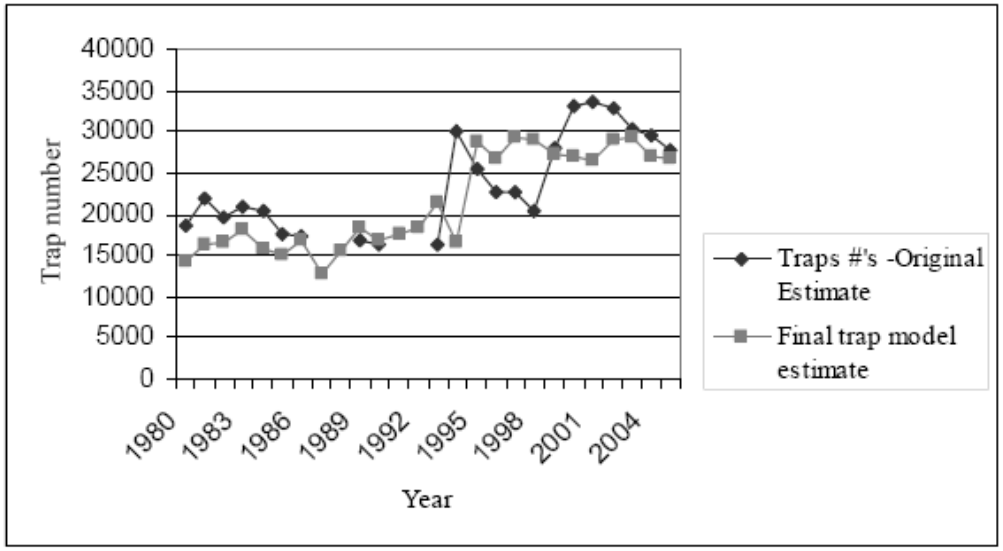
South
Australian Rock
Lobster
(1970-2008)

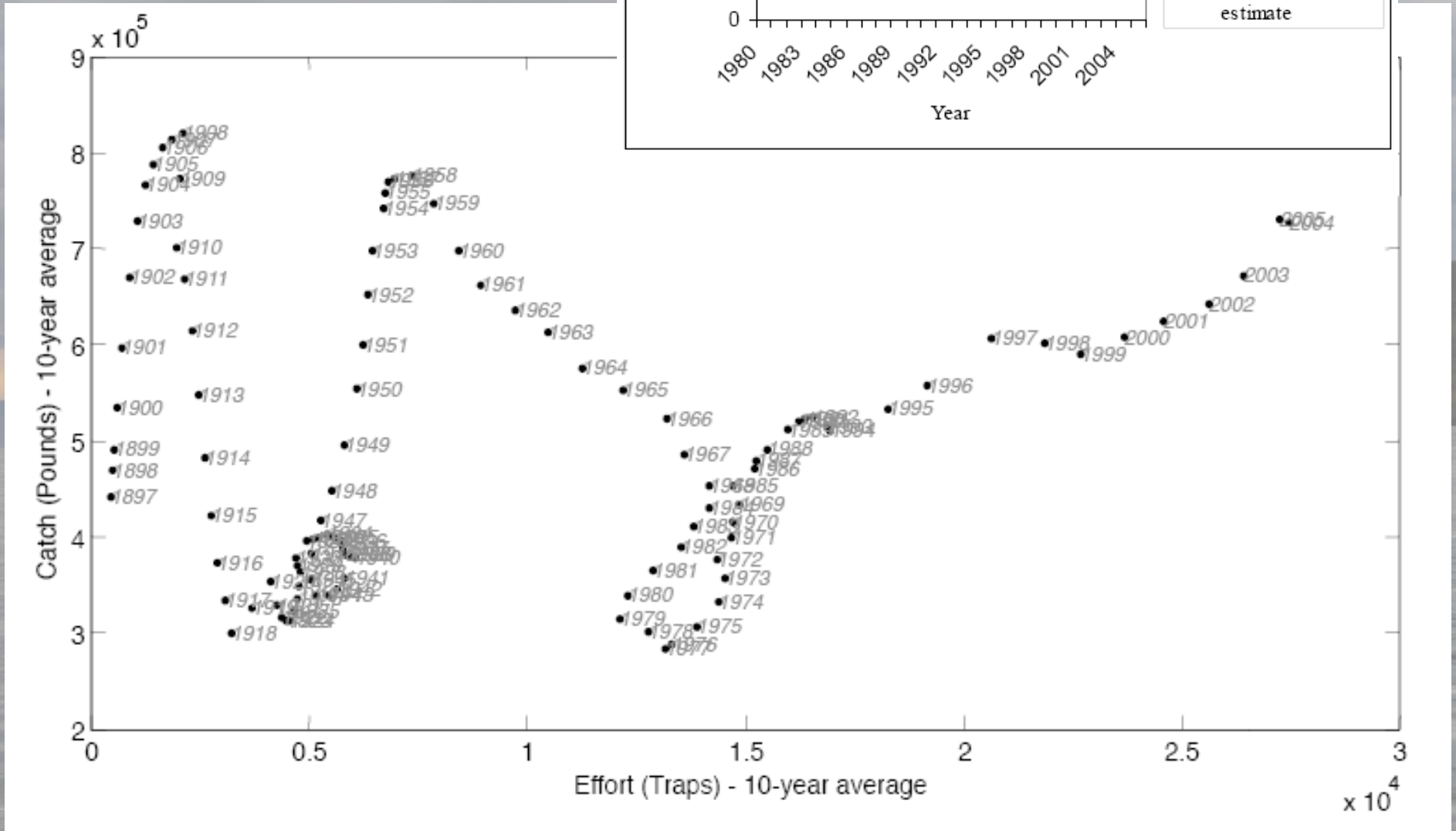
Beverton and Holt (1957)

Constant Recruitment Fishery:

Catch = Av. Biomass x $(1-e^{\wedge(-A \times effort)})$




40000
35000
30000
25000
20000
15000
10000
5000
0
Trap number
1980
1983
1986
1989
1992
1995
1998
2001
2004
Year
Traps #'s -Original Estimate
Final trap model estimate


x 10^5
9
8
7
6
5
4
3
2
Catch (Pounds) - 10-year average
0
0.5
1
1.5
2
2.5
3
Effort (Traps) - 10-year average
x 10^4
1898
1905
1904
1909
1903
1910
1902
1911
1912
1901
1913
1900
1899
1914
1898
1897
1948
1915
1947
1916
1918
1958
1955
1954
1959
1953
1960
1961
1952
1962
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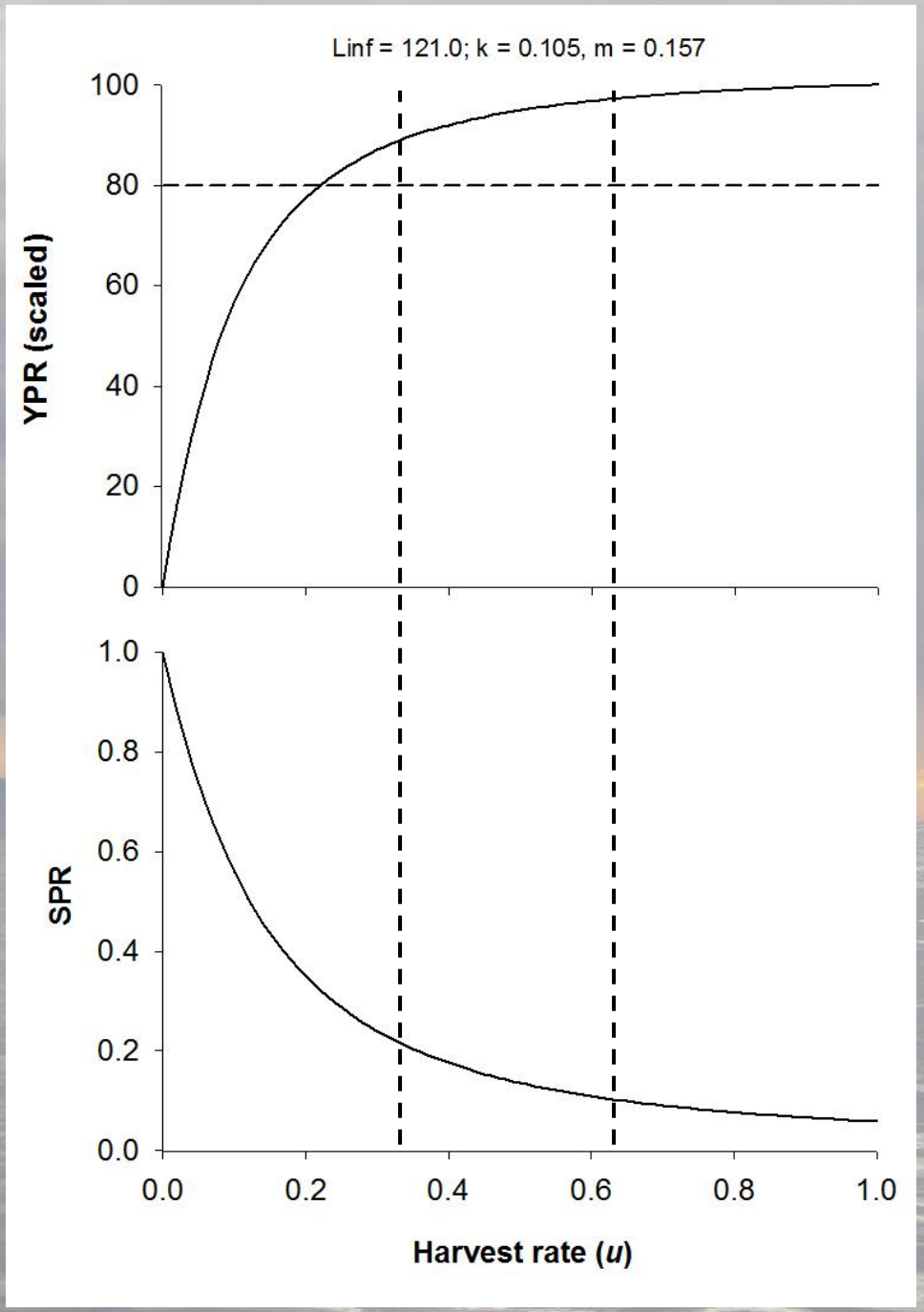
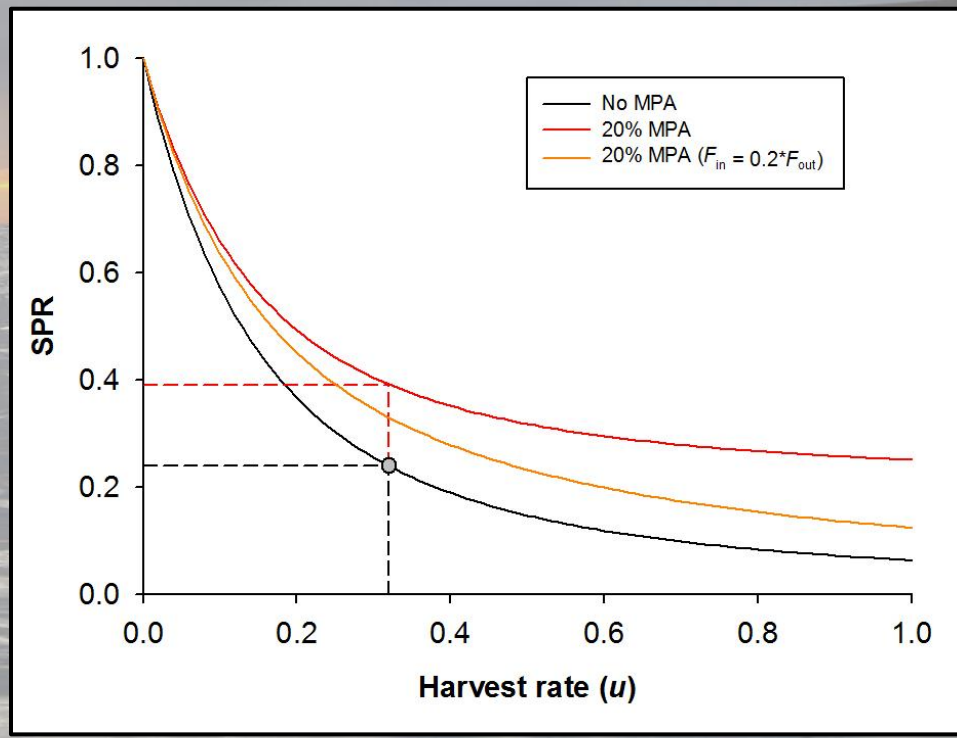
2001
2002
2003
2004

2) Harvest assessment



Don't forget about the economics…



General conclusions

1) Assess changes to lobster populations inside reserves

   a) lobster density and trap yield ≈ 4-5x higher in reserves

   b) Populations in reserves have higher proportion of individuals in large size classes

2) Develop harvest rate assessment

   a) harvest rate ≈ 0.33 at SBCI; >0.6 on SB mainland

3) interpret in context of SPR/YPR for CA spiny lobster

   a) SPR provides biological reference point (directly related to reproductive status of stock)

   b) SPR provides basis for including MPAs in assessment

   c) Apparent YPR/SPR "sweet spot" at u ≈ 0.33-0.50

What about…?

a) Minimum size limit

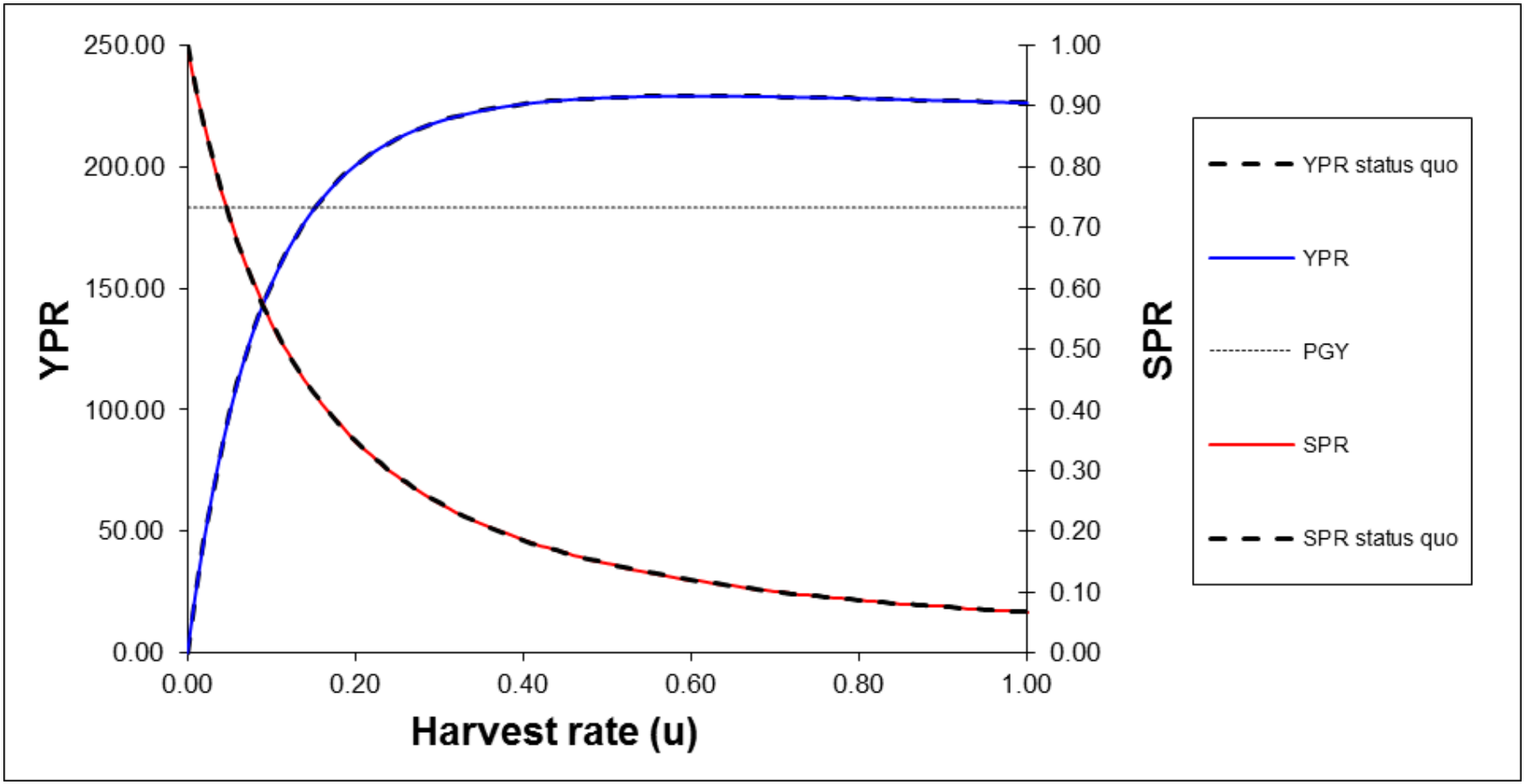
- Growth overfishing
- Recruitment overfishing

b) Upper size limit (‘slot limit’)

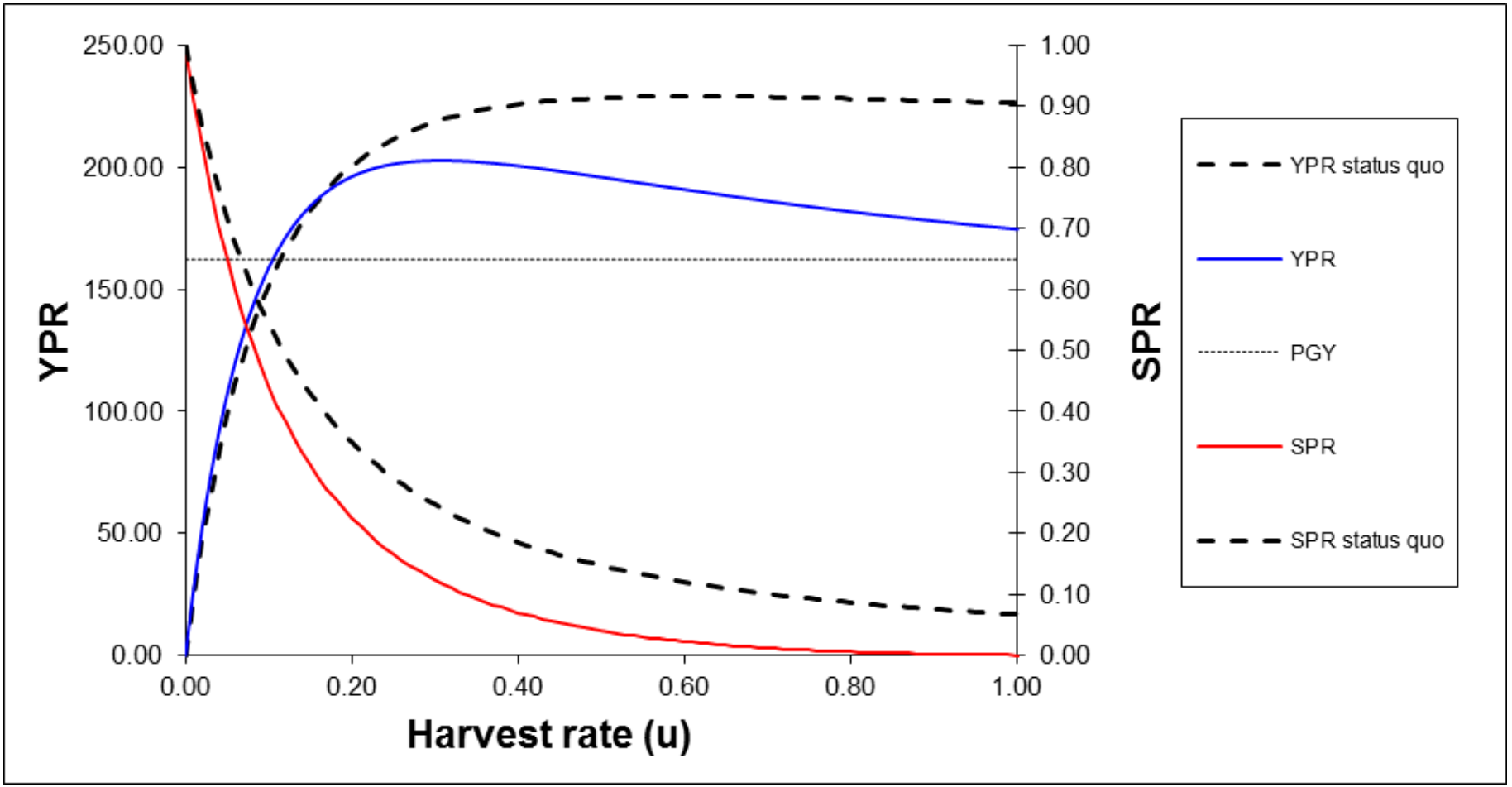
- Recruitment overfishing

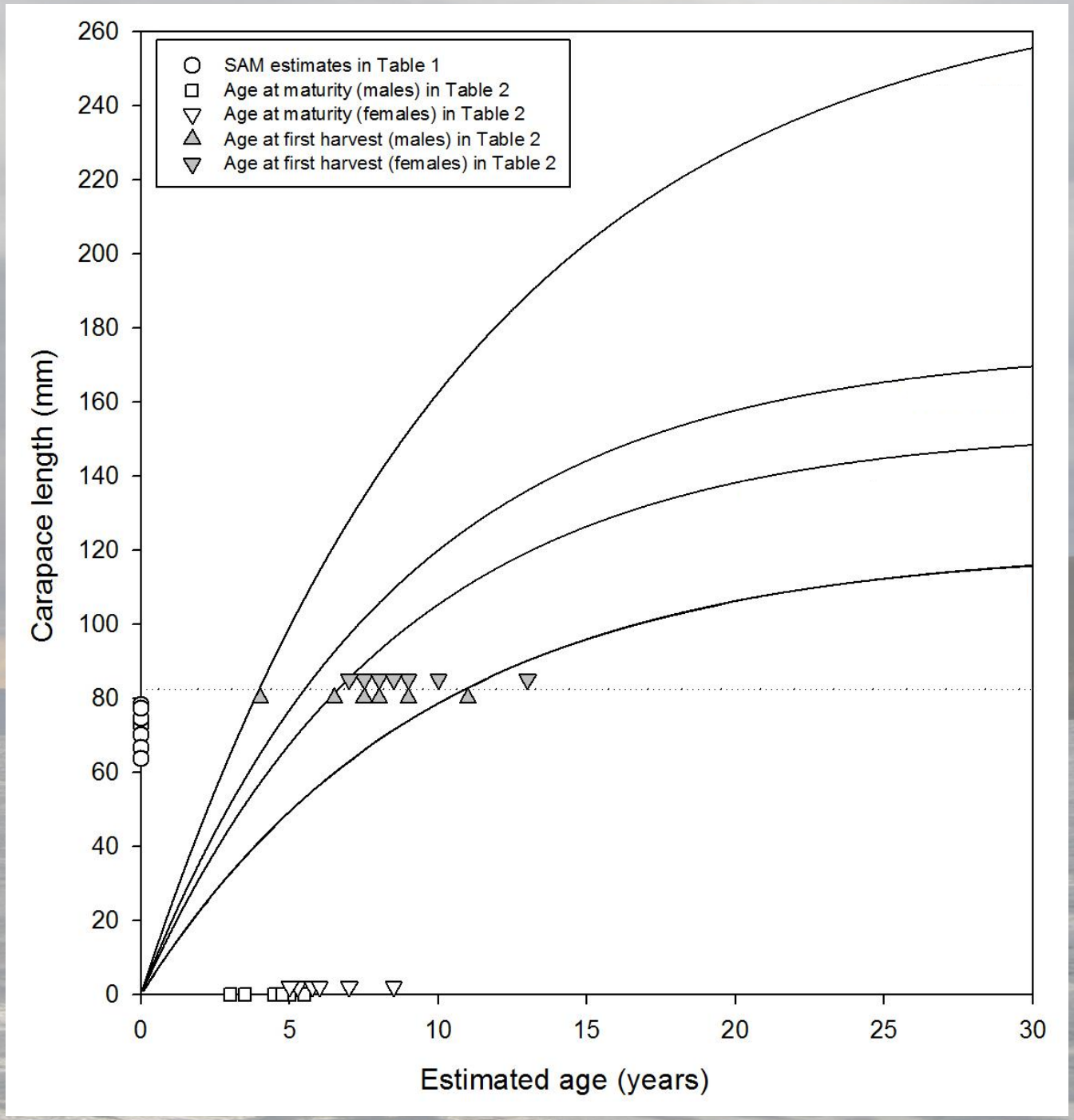
…we can use SPR / YPR to evaluate…

L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = NONE

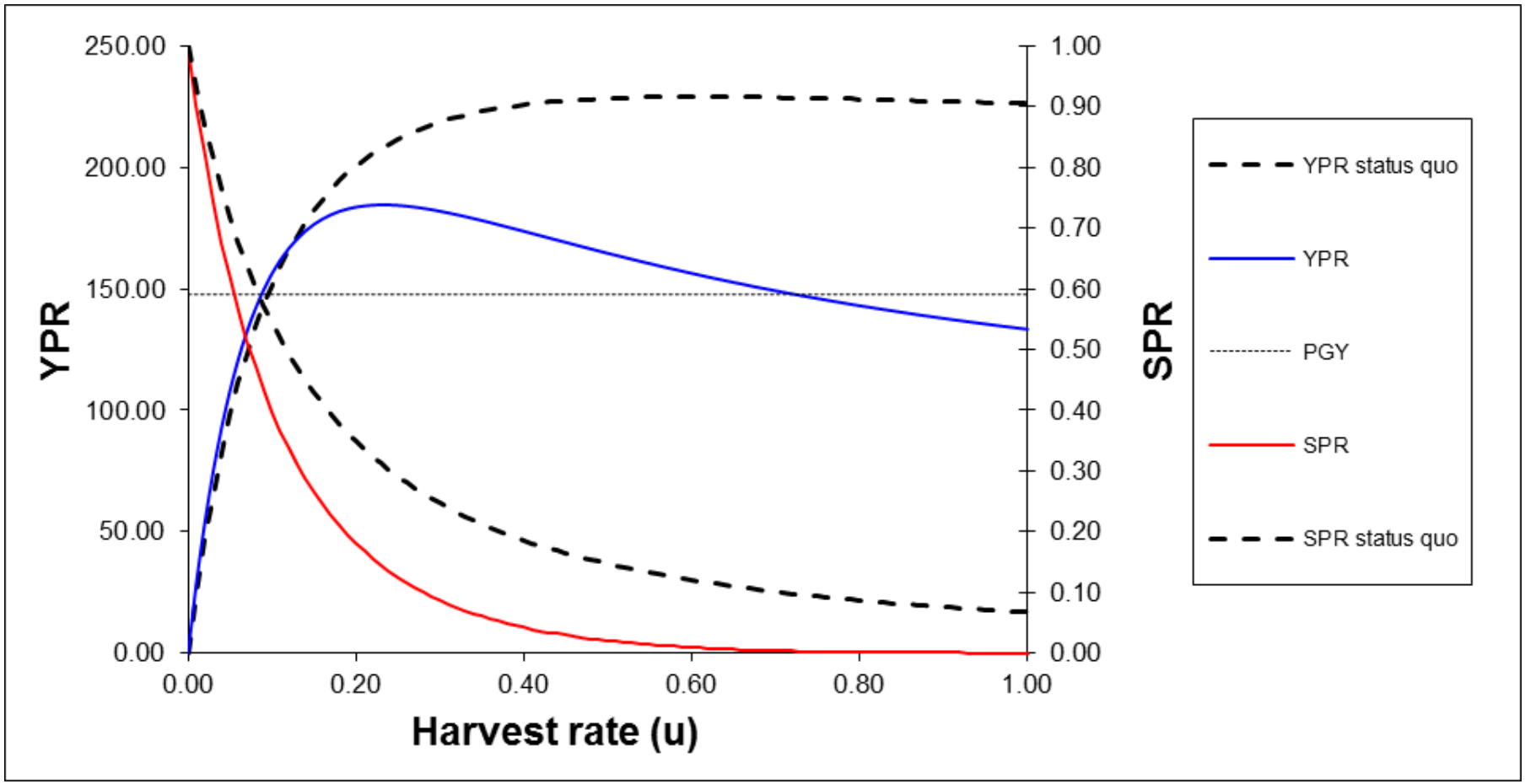


L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 70mm, Upper Size Limit = NONE;

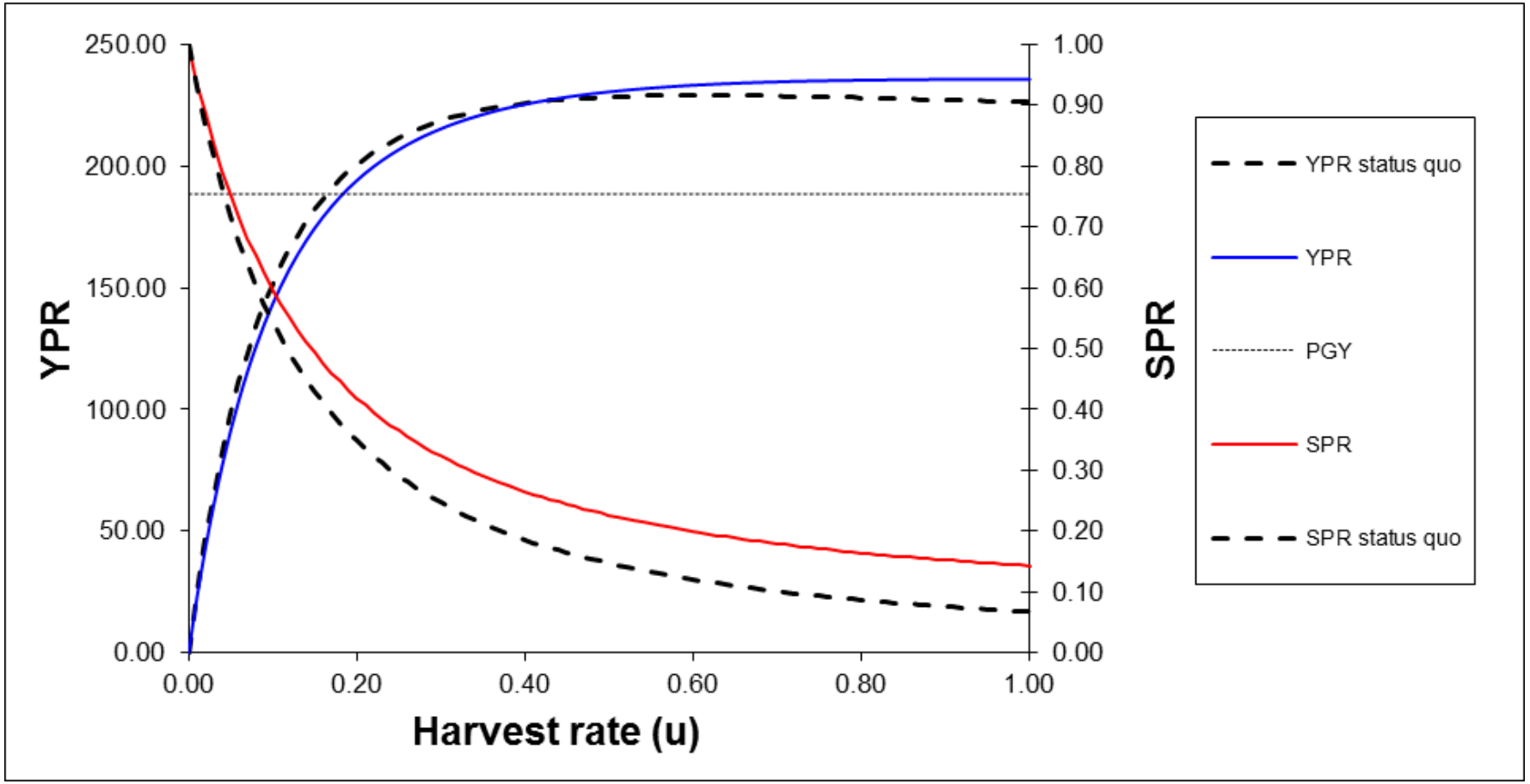



SAM estimates in Table 1
Age at maturity (males) in Table 2
Age at maturity (females) in Table 2
Age at first harvest (males) in Table 2
Age at first harvest (females) in Table 2
Carapace length (mm)
Estimated age (years)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0
5
10
15
20
25
30

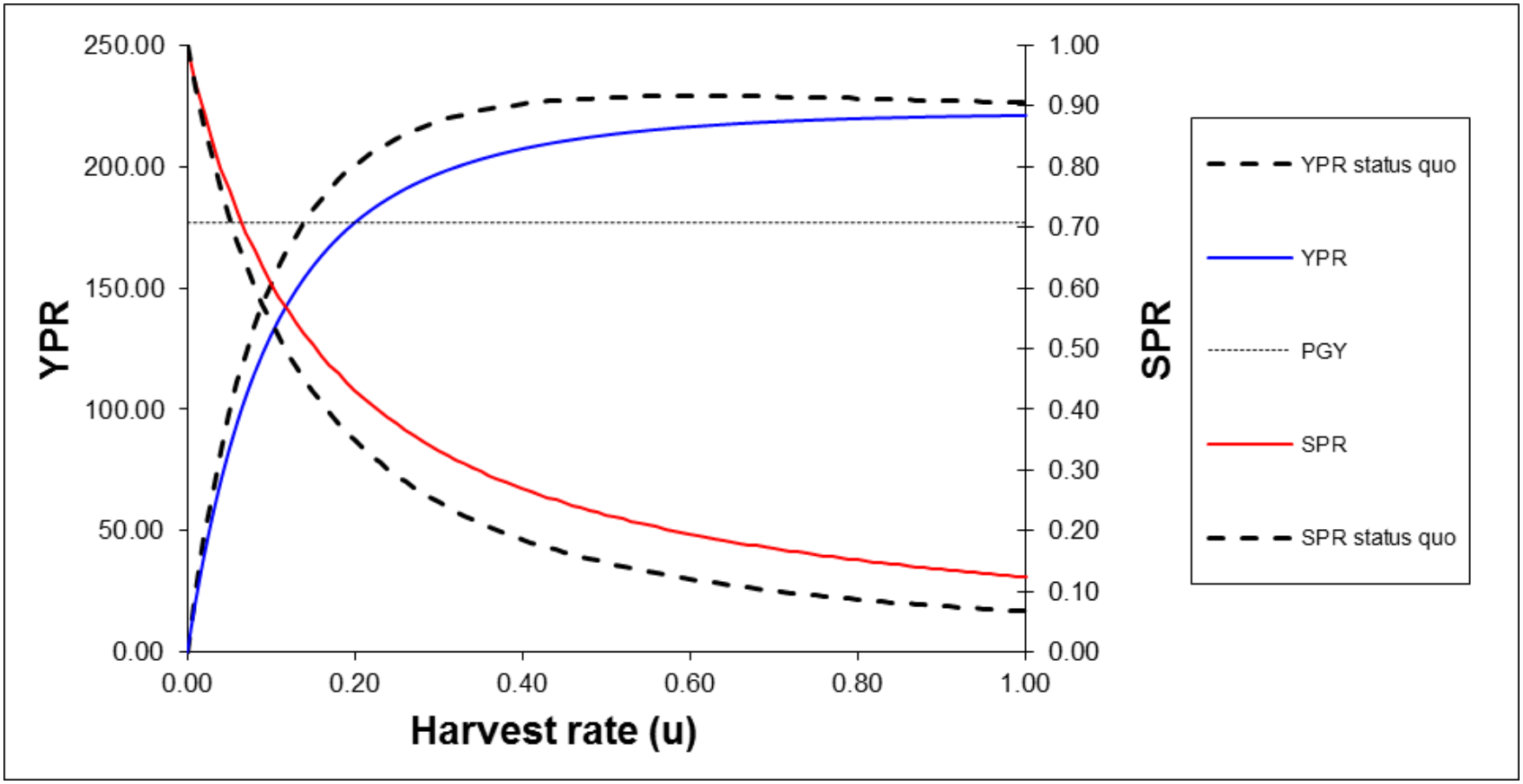
L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 60mm, Upper Size Limit = NONE;



L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 90mm, Upper Size Limit = NONE;

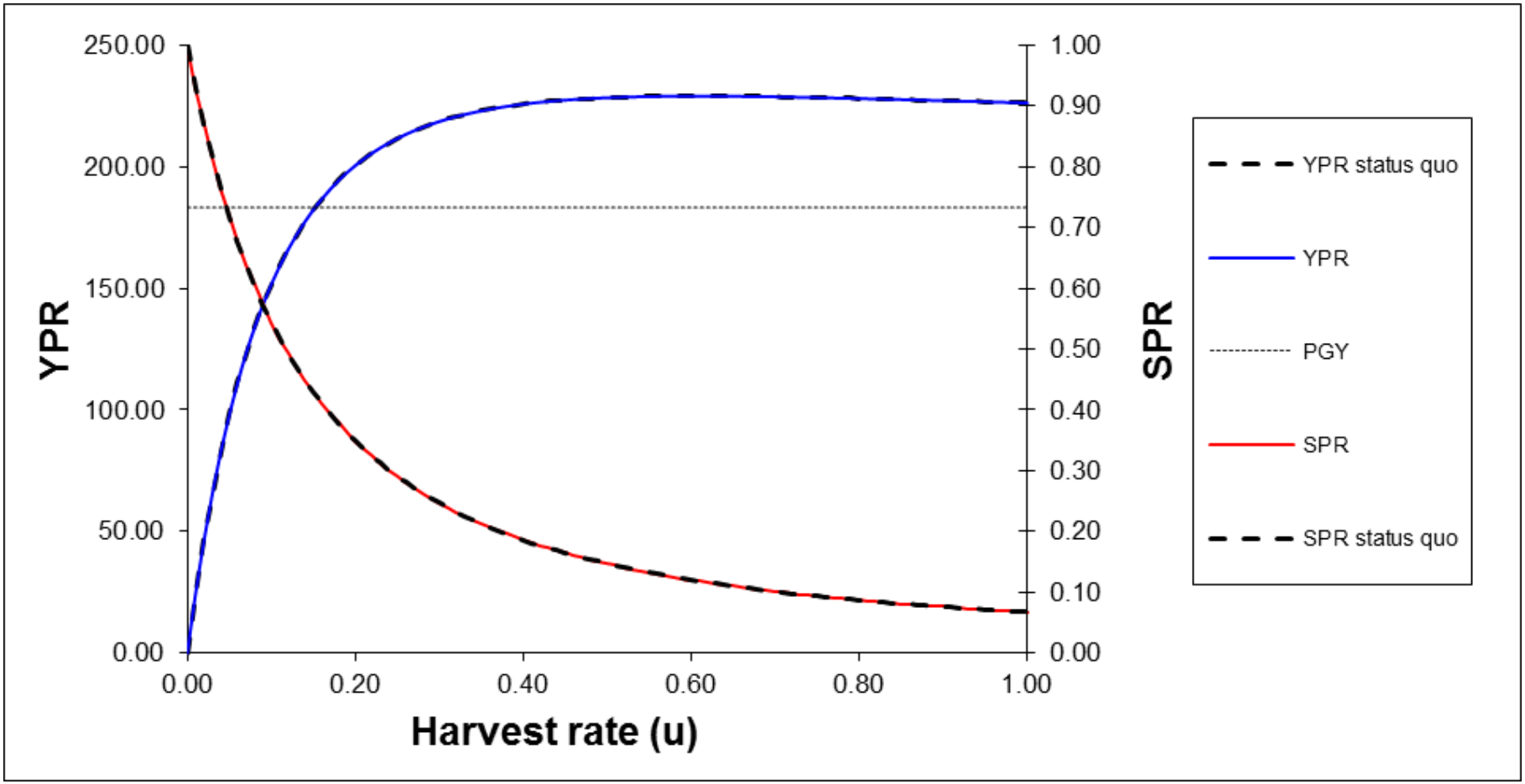


L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = NONE;
MPA = 20% (*with F inside = 20% of F outside: i.e., spillover*)

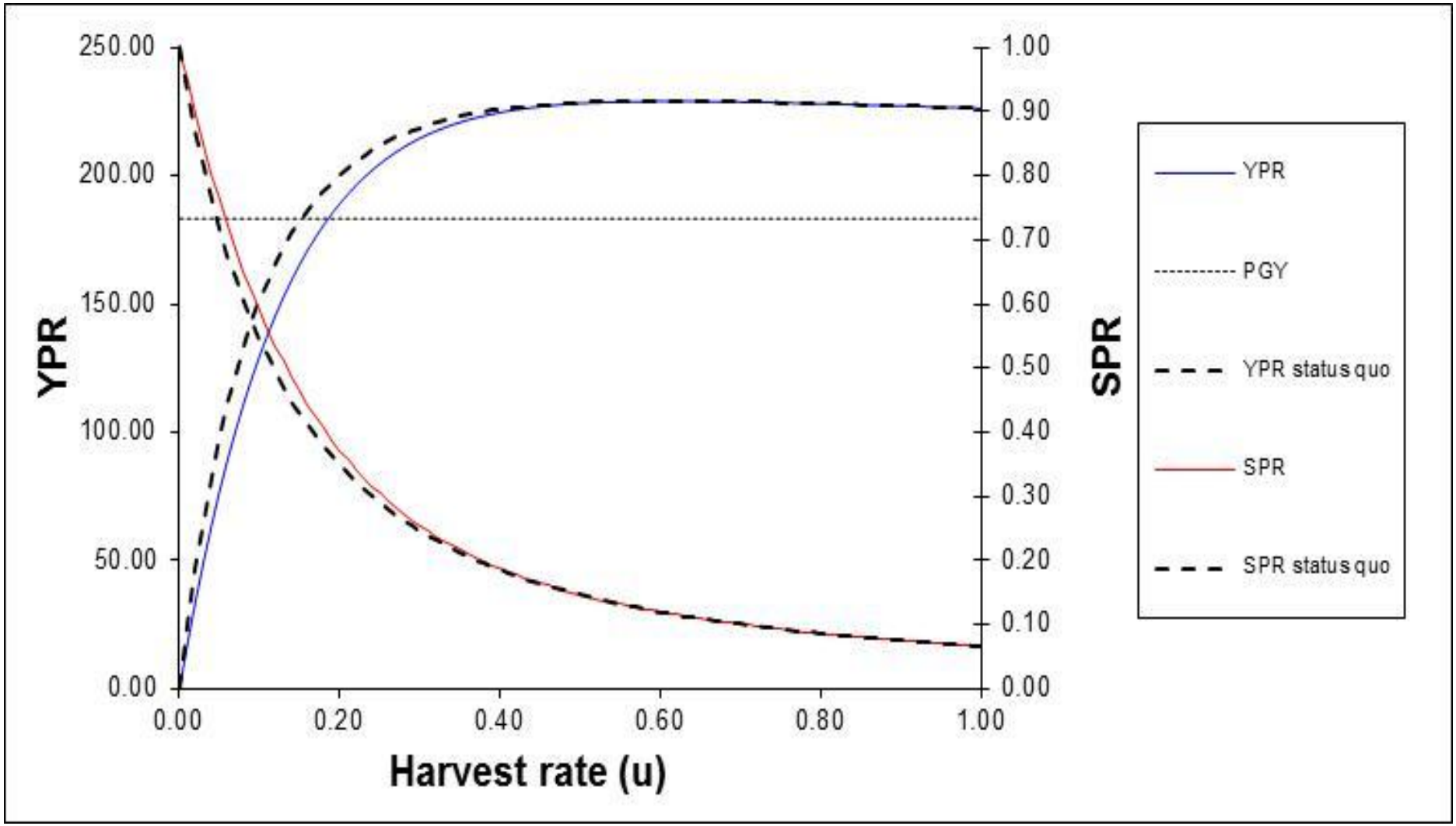


Let's explore an upper limit…

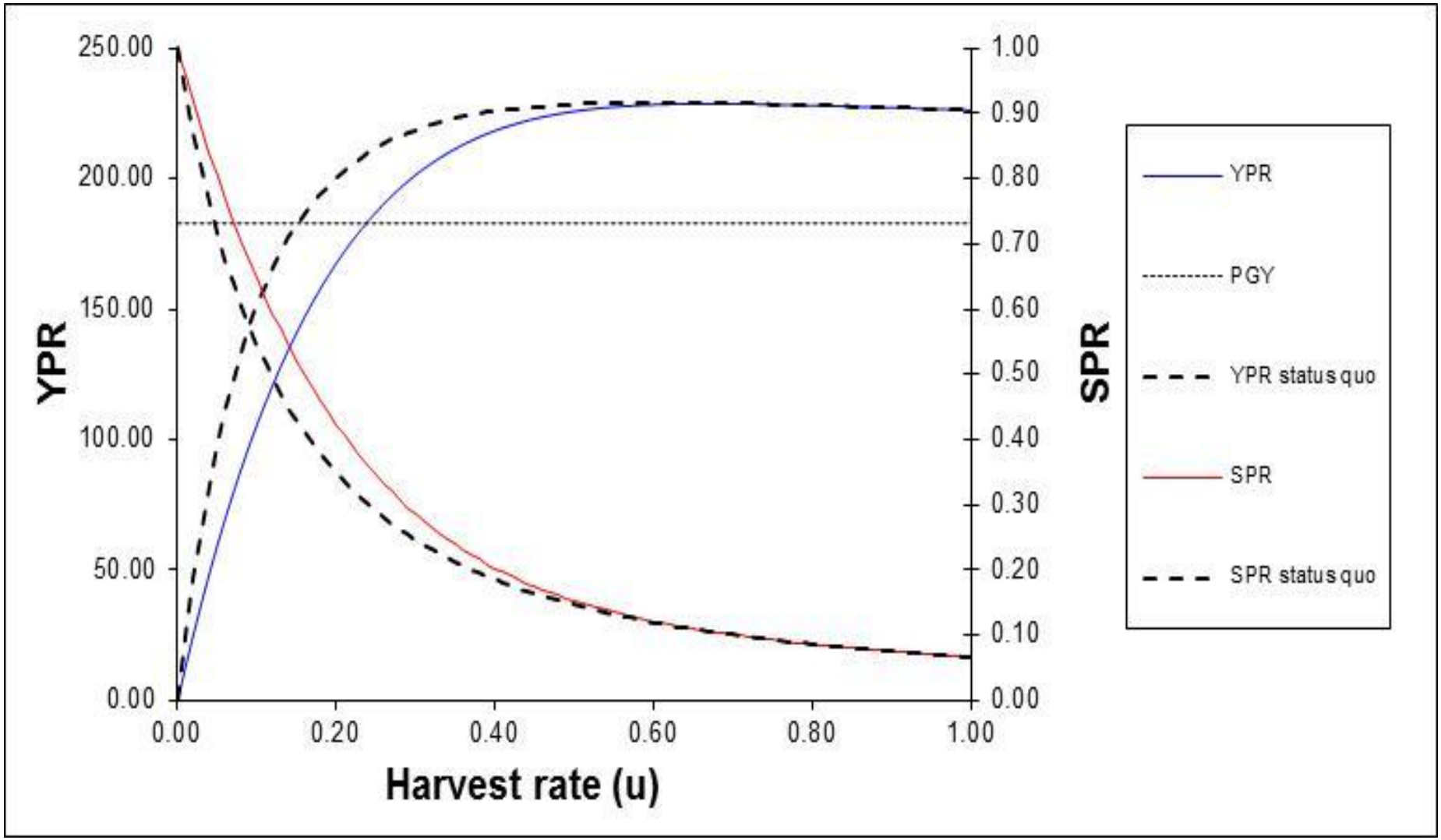
L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = NONE;



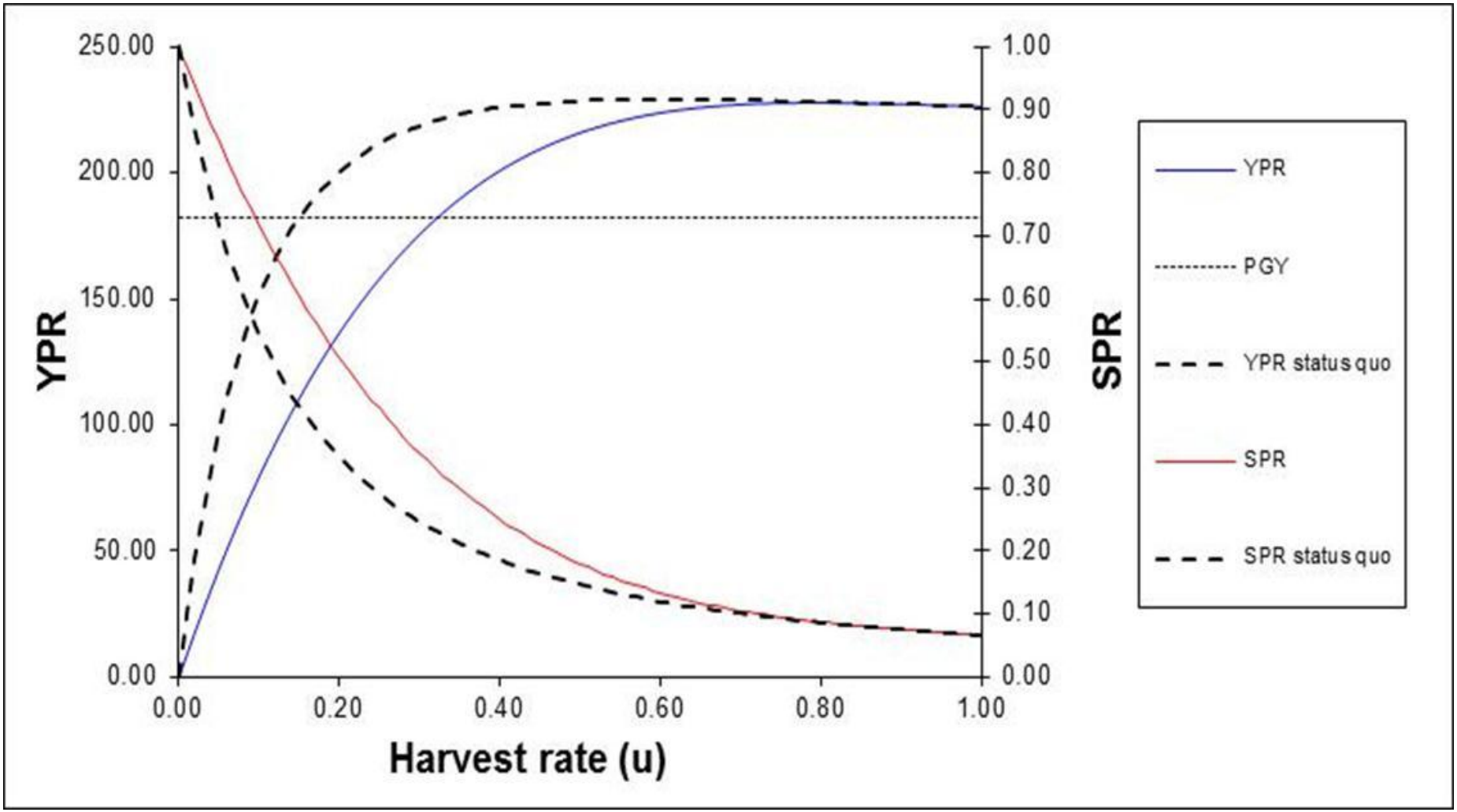
L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5, Upper Size Limit = 130mm
%MPA = 0



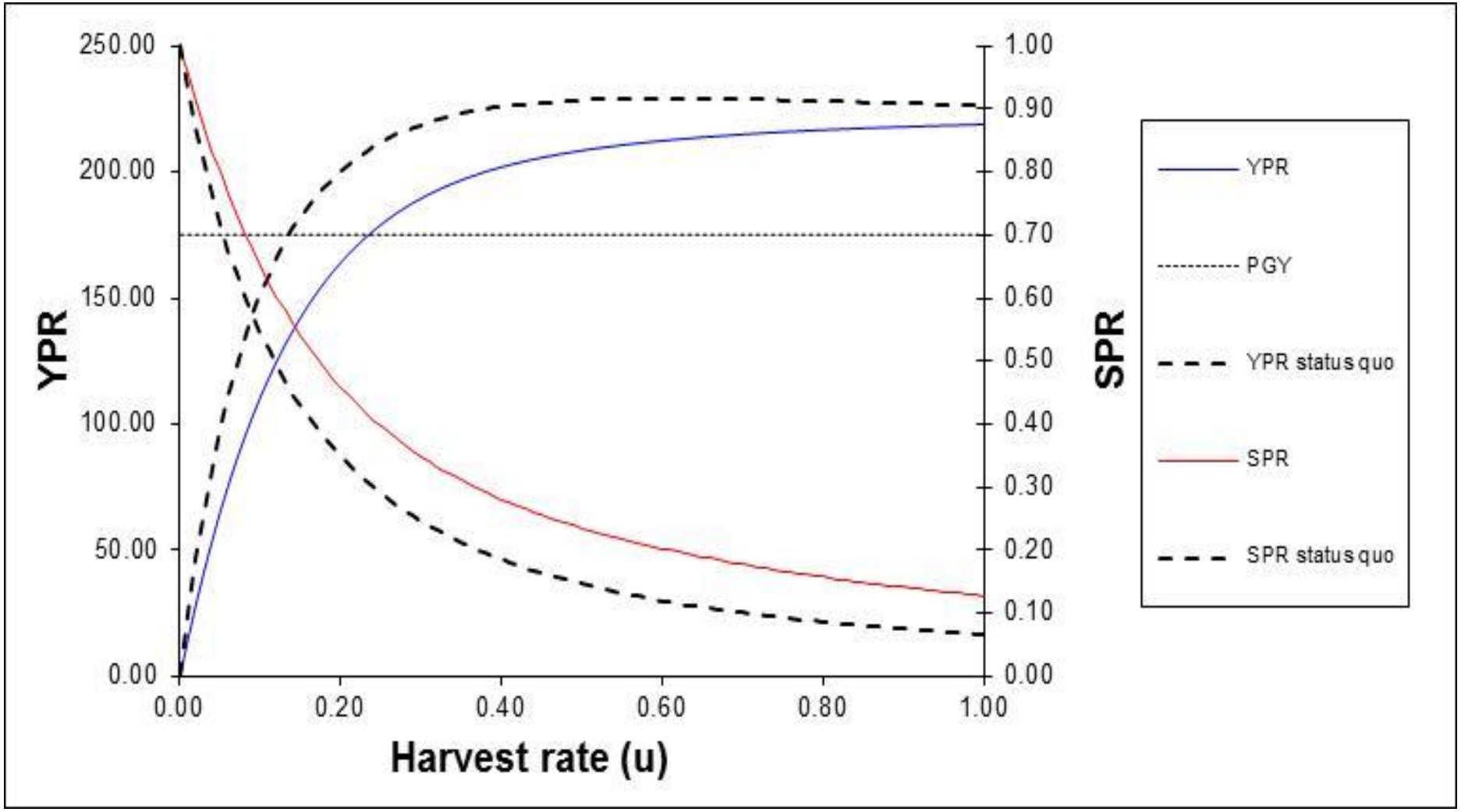
L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = 120mm;
%MPA = 0



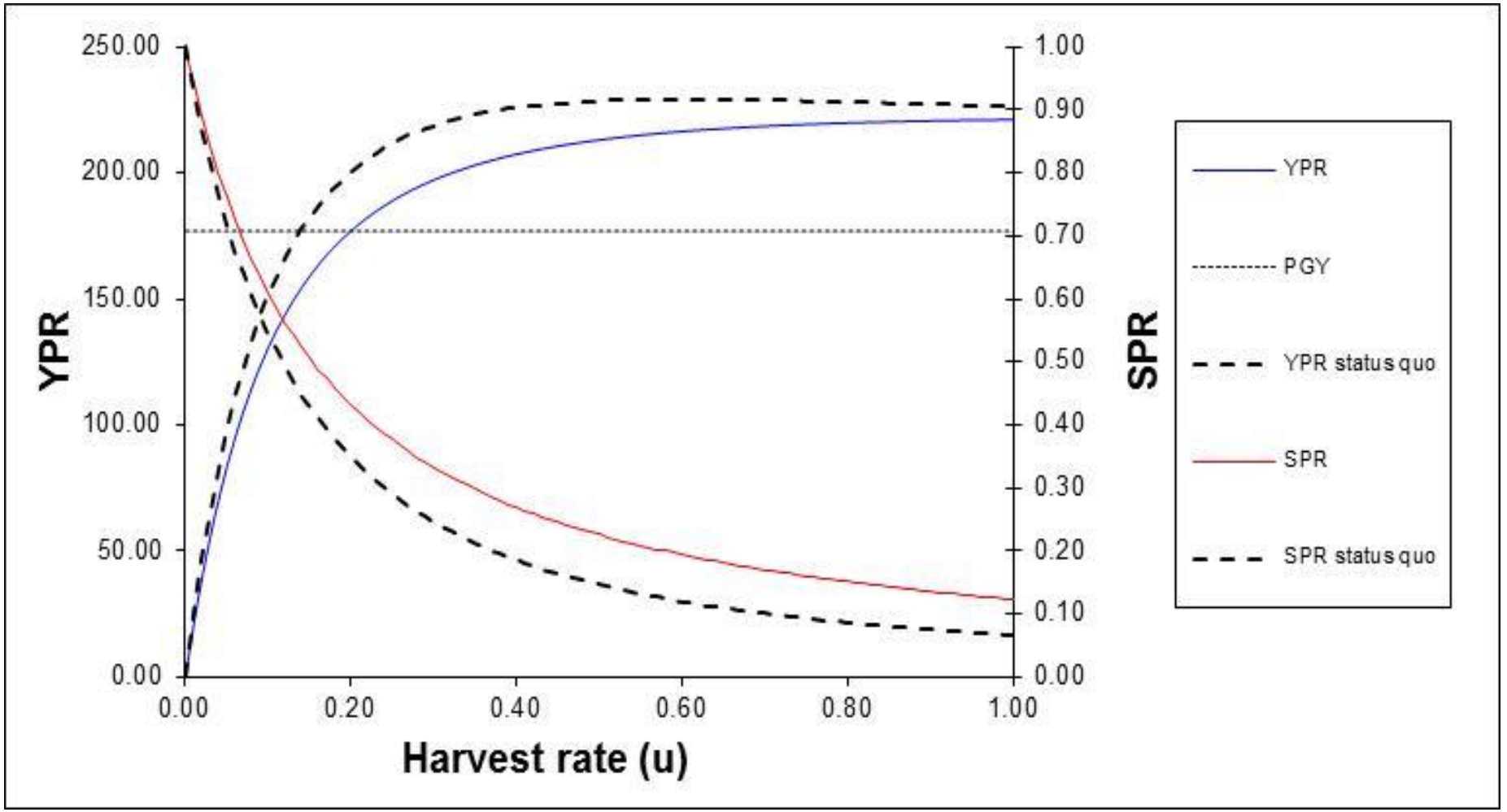
L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = 110mm;
%MPA = 0



L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = 130mm;
%MPA = 20%, (*F* in MPA = .2 of F outside: this is effect of 'spillover')



L_∞ = 153, K = 0.1195, t_0 = -0.21, Longevity = 50 yrs;
MLS = 82.5mm, Upper Size Limit = NONE;
%MPA = 20%, (*F* in MPA = .2 of F outside: this is effect of 'spillover')



Conclusions

The perspectives of *Shoreline Resource Consultants*, based upon:

- **SPR/YPR analyses with…**
- **best available data as of September 2012.**

(This should be repeated by the MSE team (and others!!) using updated data from CFR in San Diego and beyond…)

a) Minimum size limit

- Adequate ('big enough') to avoid growth overfishing

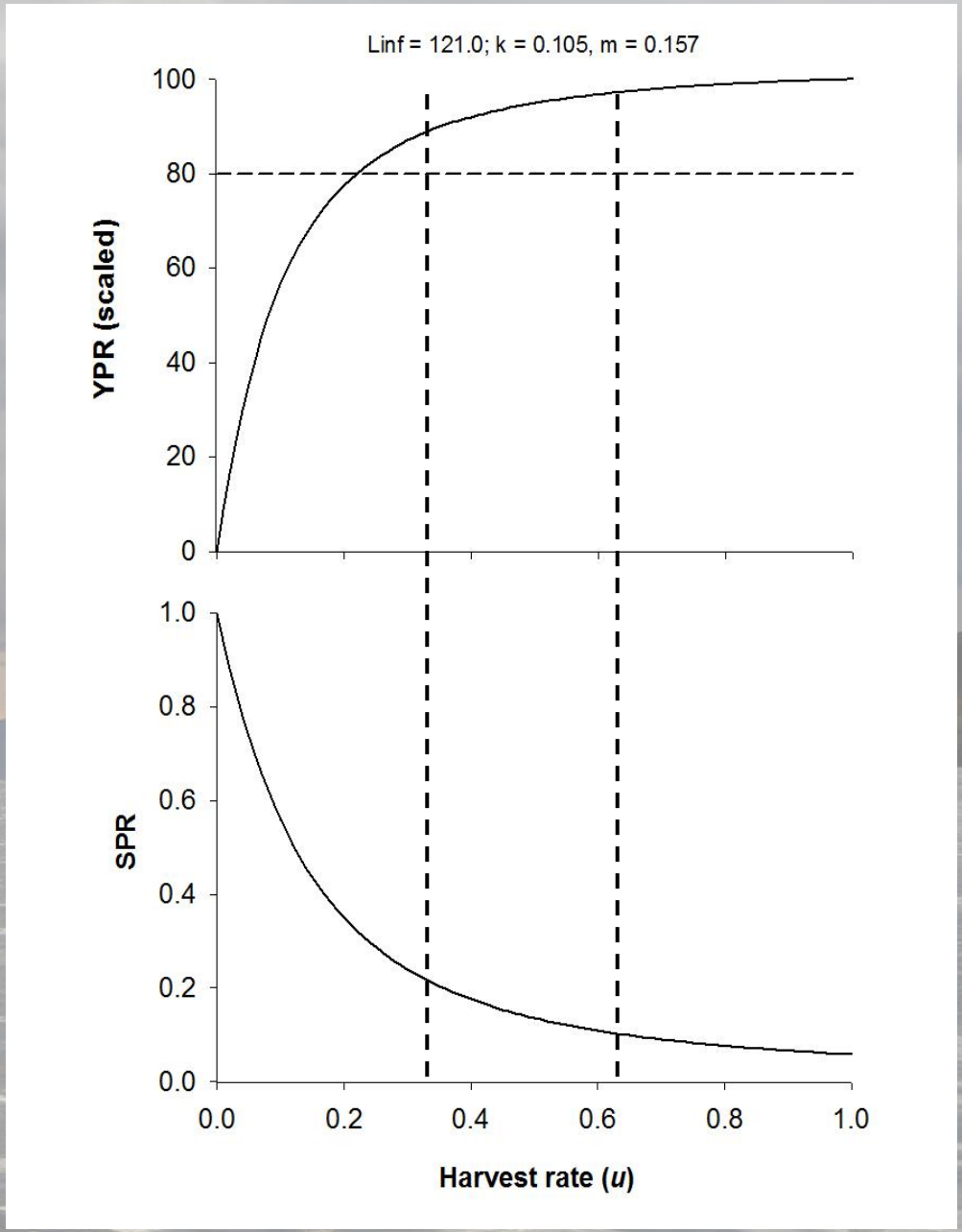
- Adequate ('big enough') to maintain SPR near limits used in other spiny lobster fisheries (≈10-20), except at high harvest rates where YPR is asymptotic (can't increase with more effort or *F*). (MPAs and new size at maturity data may increase confidence in SPR?)

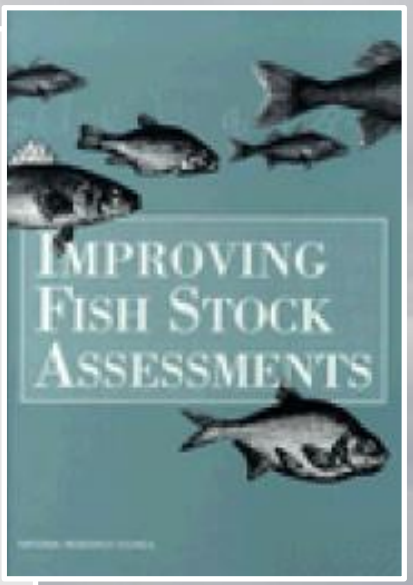
b) Upper size limit ('slot limit')

- Increases SPR only at low-to-moderate harvest rates (where SPR buffering is likely unnecessary)

- SPR not only reason consider slot limit

Moving forward…





Sustainability

Manage Escapement

(primarily salmon)

- Area-time closures
- Effort control (gear and number of participants
- Fishery closure if desired escapement level not met

Manage *F*

Manage with Complex Time Policy

- Stock recovery timetable
- Actions depending on occurrence of given events (e.g., population thresholds or specific regulations)
- Catches dependent on bycatch of other species

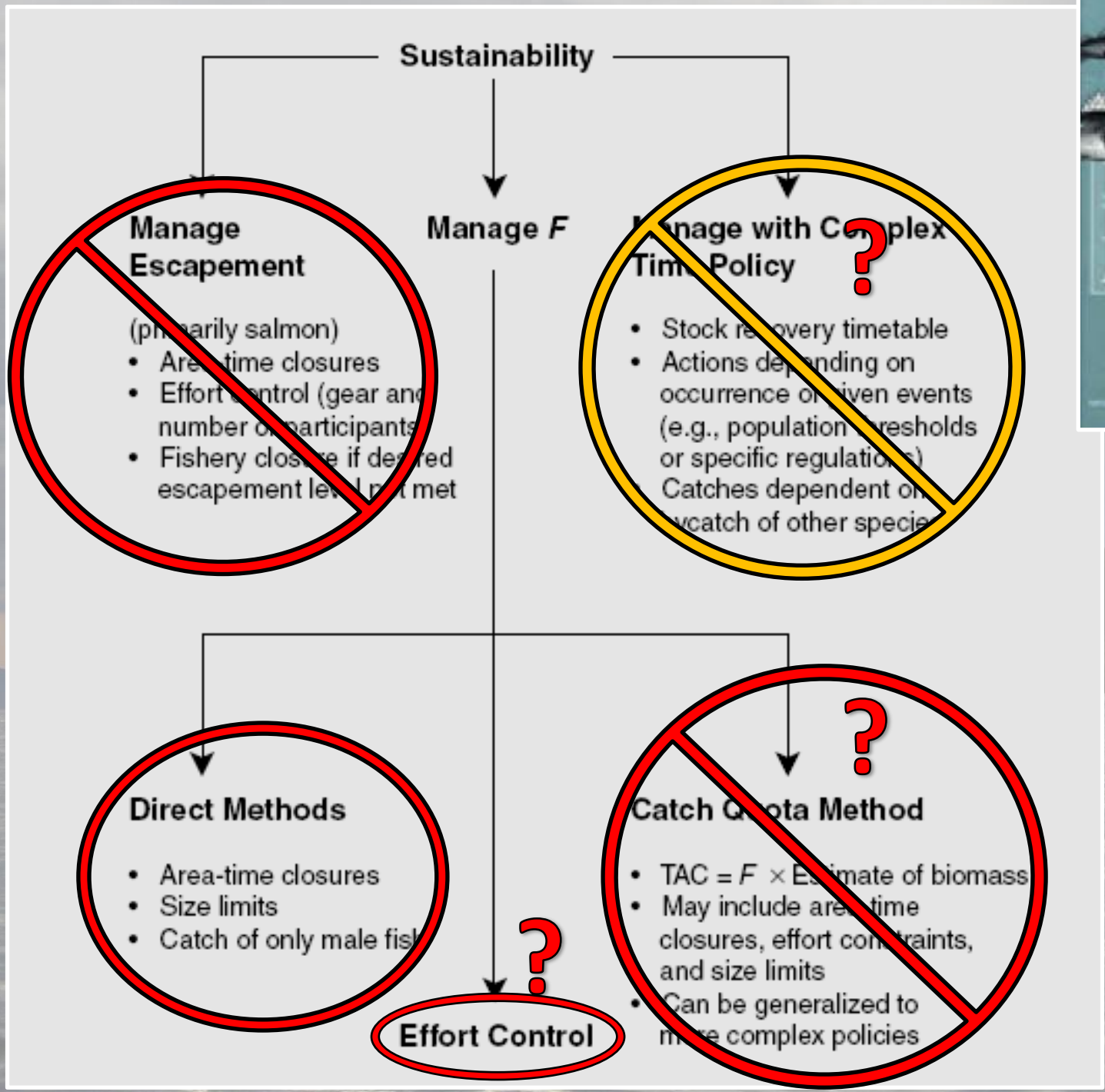
Direct Methods

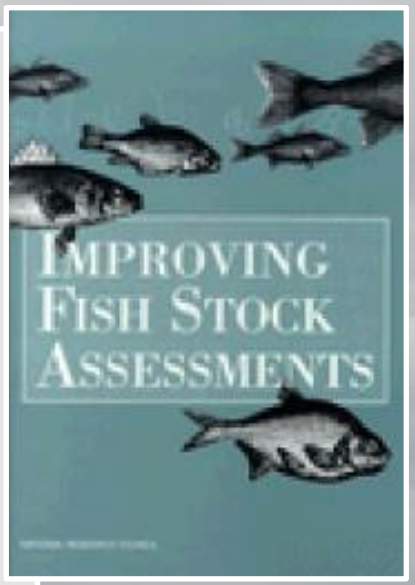
- Area-time closures
- Size limits
- Catch of only male fish

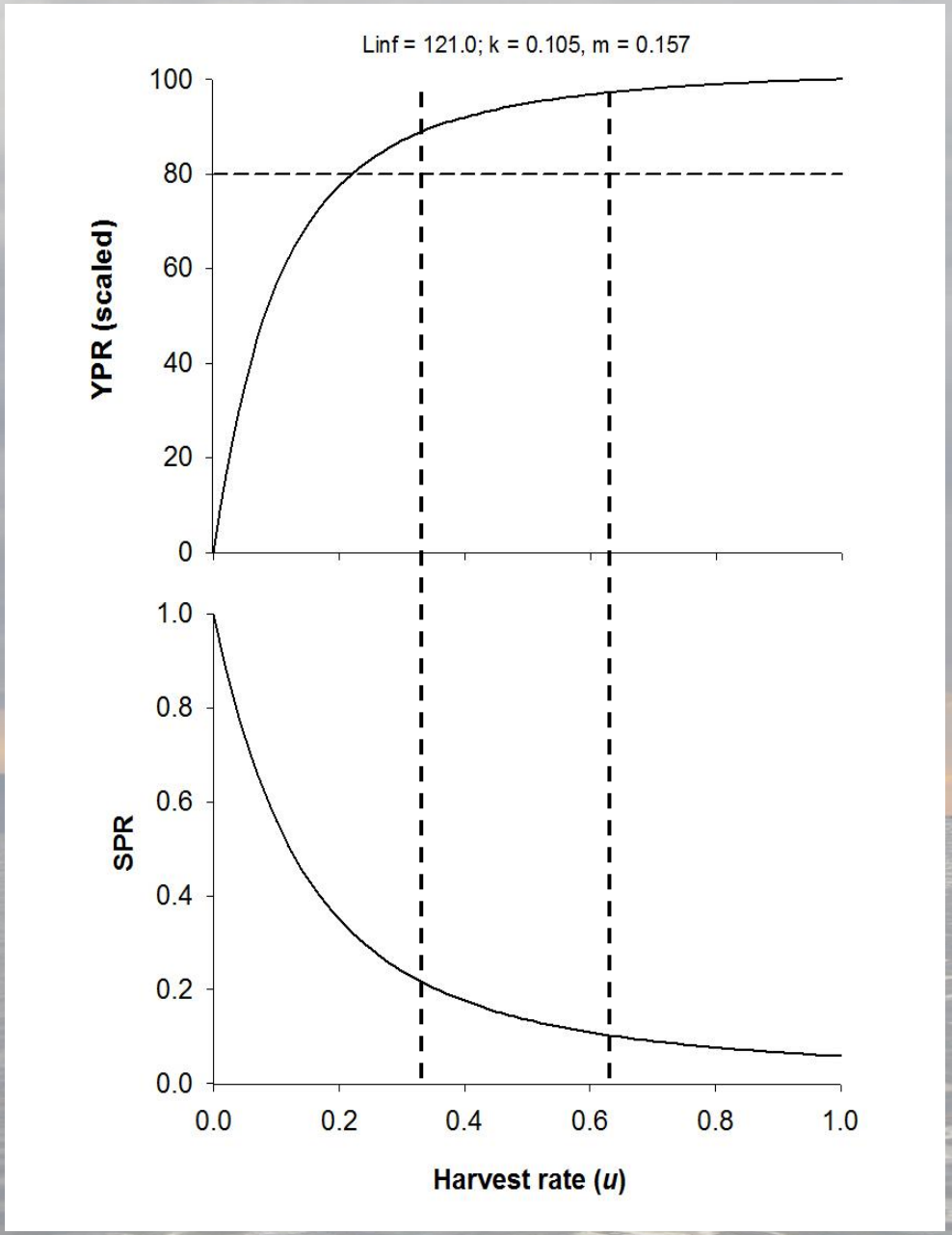
Effort Control

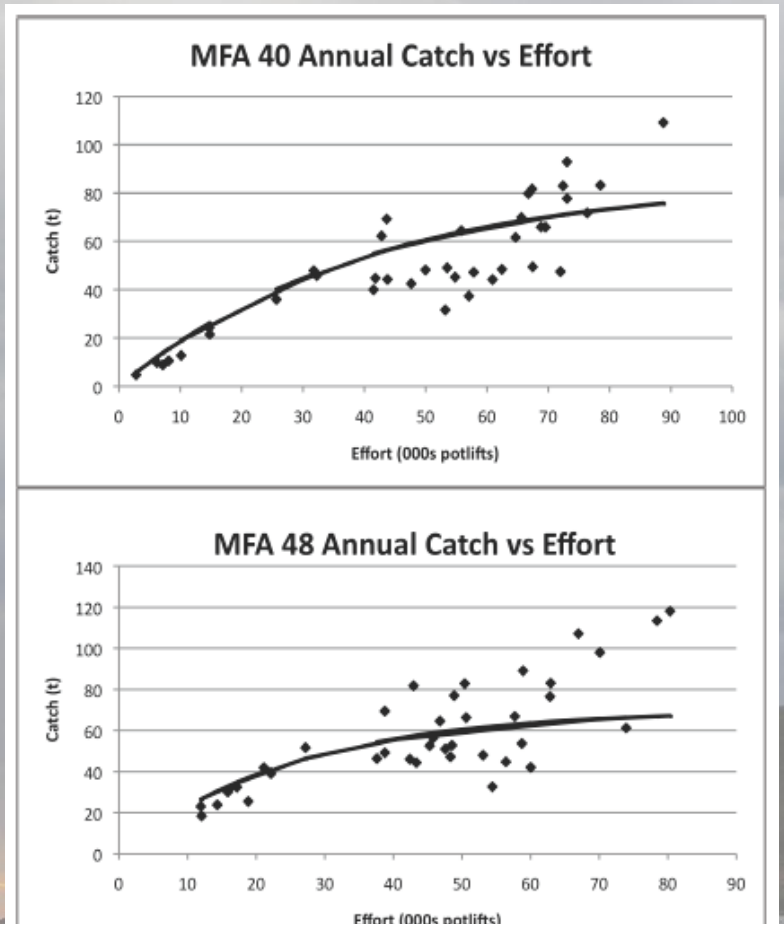
Catch Quota Method

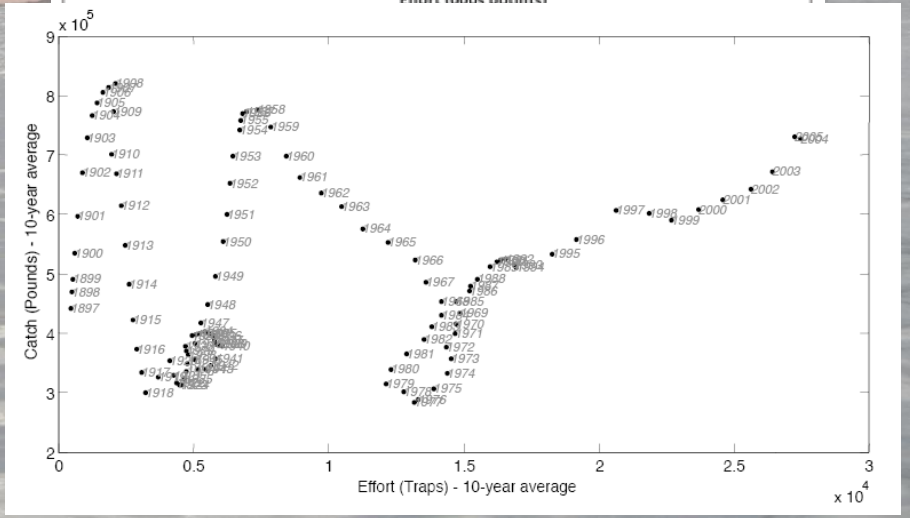
- TAC = F × Estimate of biomass
- May include area-time closures, effort constraints, and size limits
- Can be generalized to more complex policies


Sustainability
Manage Escapement
(primarily salmon)
• Area-time closures
• Effort control (gear and number of participants)
• Fishery closure if desired escapement level not met
Manage F
Manage with Complex Time Policy
?
• Stock recovery timetable
• Actions depending on occurrence of given events (e.g., population thresholds or specific regulations)
• Catches dependent on bycatch of other species
Direct Methods
• Area-time closures
• Size limits
• Catch of only male fish
?
Effort Control
?
Catch Quota Method
• TAC = F × Estimate of biomass
• May include area-time closures, effort constraints, and size limits
• Can be generalized to more complex policies


IMPROVING
FISH STOCK
ASSESSMENTS


Linf = 121.0; k = 0.105, m = 0.157
YPR (scaled)
SPR
Harvest rate (u)


MFA 40 Annual Catch vs Effort
Catch (t)
Effort (000s potlifts)
MFA 48 Annual Catch vs Effort
Catch (t)
Effort (000s potlifts)


Catch (Pounds) - 10-year average
Effort (Traps) - 10-year average