Lobster FMP Science and Technical Presentation: Cable Model for Calculation of a SPR biological reference point

Peer Review Webinar – Continued

March 18, 2015

Presented by: Tom Mason, Julia Coates, Carlos Mireles and Tony Shiao

CA Department of Fish and Wildlife

Marine Region

Outline

- Background
  - Reference point review
  - Origin of Cable model
- Model structure and use
- CDFW growth analyses
- Results
- Cable to Cable-CDFW changes
- Sensitivity analyses, limitations, future work
- Management implications

Catch reference point

Identifies possible change in stock stability, particularly growth overfishing

$$\frac{average\ catch\ for\ 3\ most\ recent\ seasons}{average\ catch\ for\ 10\ most\ recent\ seasons} \leq 0.8$$

Data Source

Annual commercial landings recorded on CDFW landing receipts

CPUE reference point

Identifies potential adverse changes in the fishery, mainly economic overfishing

$$\frac{CPUE\ for\ 3\ most\ recent\ seasons}{CPUE\ for\ 10\ most\ recent\ seasons} \leq\ 0.8$$

Data Source

Total number of legal lobster caught per total trap pulls recorded on CDFW commercial fishing logs

SPR reference point

Spawning Potential Ratio detects biological sustainability, particularly recruitment overfishing

$$SPR_{Current} \leq SPR_{Threshold\,(avg\ wt\text{-}2000/01\text{-}2009/10\ seasons)}$$

<u>Data Source</u>

Mean weight of lobsters landed based on total # of individuals retained on CDFW commercial fishing logs and total commercial landings (lbs) from receipts

*Only data from landing receipts that can be matched to a specific fishing log are included

Cable Model

- FMP process sought a model to calculate a biological reference point and incorporate Marine Protected Areas (MPAs)
- Developed by Dr. Richard Parrish through contract with the South Bay Cable Liaison Committee (provides estimate of SPR)
- Dr. Parrish aided CDFW with refinements to model and proposed new growth models
- CDFW has updated the model:
    1) Addition of new growth model
    2) Changes to initial time step (i.e. size, age, season)
    3) Streamlining of model

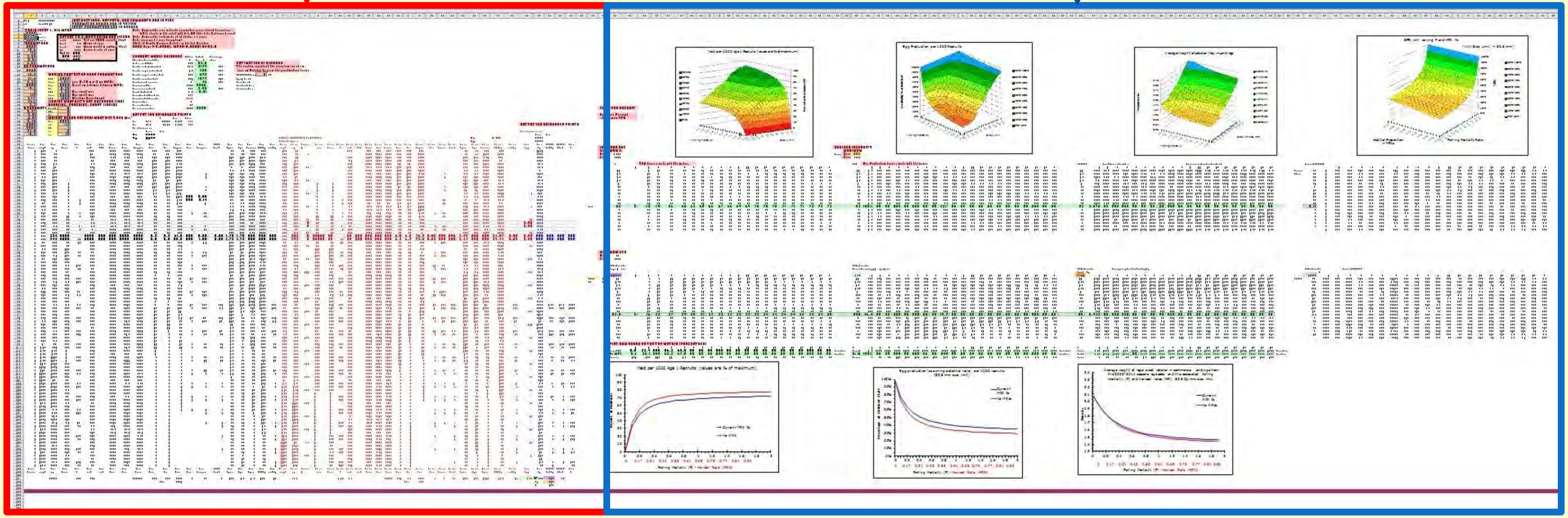
Model features

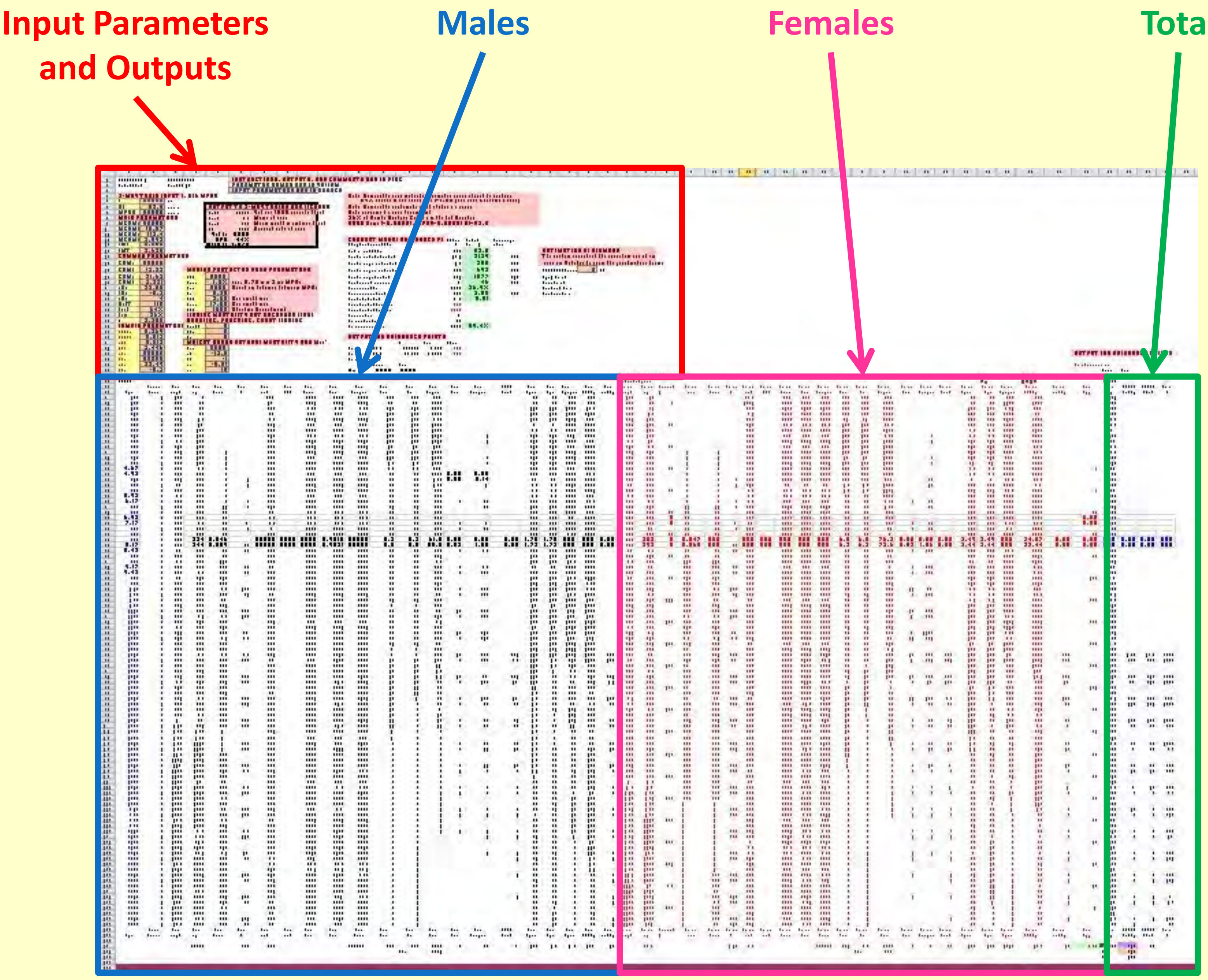
- Cohort analysis
- Equilibrium
- No stock-recruitment
- No set spatial scale
- No recreational component

Overview

The Population Model

Graphical Output





Model structure & use

Female Growth, Fecundity & Maturity

Natural Mortality

Output

Management Regime

MPAs

Common Growth, Vulnerability & Fishing Effort

Unrecorded Fishing Mortality

Male Growth

CABLE-CDFW 0.1	CDFW REVISION		INSTRUCTIONS, OUTPUTS, AND COMMENTS ARE IN PINK
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			INPUT PARAMETERS ARE IN ORANGE

2-WAY TABLE INPUT F, SL& MPAS		
F	0.70000	row
SL	82.5	column
MPAS	14.600%	column

OUTPUT TO 2-WAY TABLES AND FIGURES		
YieldT	31.758	Yield per 1000 recruits (kgs)
FecT	20.3	Millions of eggs
AveWt	0.712	Mean weight in landings (kgs)
HR	12.7%	Harvest rate of legals
Yield lbs	70.014	
SPR	44%	
Mean lbs	1.570	

Note Vulnerability uses maturity parameter values altered to produce
69% shorts in the catch with F=1.08 (the total California F value)
Note Vulnerability relationship of old lobster is a guess
Note seasonal F is area dependent
36% of Santa Barbara Catch is in the 1st Quarter
BASE Run: F=0.00001, MPAS=0.00001 SL=82.5

MALE PARAMETERS	
MGRWa	4.7791
MGRWb	18.5716
MGRWc	112.366
MGRWd	2.5927
aWT	0.0053
bWT	2.6247

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GRWc	21.6275
GRWd	3.2212
aVul	23.50
bVul	-0.304
cVul	4
VulLT	110
Foct	64%
Fjan	36%
lbs	2.2046

MARINE PROTECTED AREA PARAMETERS		
MPA	14.600%	
Migout	1.0%	ave. 0.75 mi in 3 mile MPAs
Migin	0.09%	Based on distance between MPAs
Fin	0.20	
MPAmi	3.00	Ave length miles
Open	17.55	Ave length miles
REC	1000	Starting Recruitment

FISHING MORTALITY NOT RECORDED (FNR) HANDLING, POACHING, GHOST FISHING	
HandM	0
Ghost	0
Tloss	0

FEMALE PARAMETERS	
FGRWa	8.3691
FGRWb	0.0121
aWTf	0.0129
bWTf	2.4455
aFe	0.9197
bFe	2.7000
aSam	23.489
bSam	-0.30417

WEIGHT BASED NATURAL MORTALITY SEE Male*	
base	-0.160
aM	-12.5
bM	-1
aa	-0.008
ag	18

CURRENT MODEL REFERENCE POINTS		This Rui	Unfished	Percentage
Fishing Mortality Rate (cell B3)	F=	0.7000	F=0.00001	of Bun
Size Limit in mm (cell B4)	CL=	82.5	82.5	
Total Biomass of Cohort (October lbs)		1601	2139	75%
Total Biomass legal males (October lbs)		105	385	27%
Total Biomass legal females (October lbs		447	693	64%
Total Biomass legals (October lbs)		551	1077	51%
Total Fecundity (millions of eggs)		20	46	44%
Percentage Shorts		69.8%	36.9%	
Average size in landings lbs		1.57	2.08	76%
Total Yield of Cohort lbs		70.01	0.01	
Harvest Rate Yield/Age 1+ Biom		4.4%		
Harvest Rate Yield/Legals Biom		12.7%		
Males in landings		20		
Females in Landings		25		
Female sex ratio in landings		55.8%	59.4%	

ESTIMATION OF BIOMASS
This section calculatest the population size of an area on October 1: given the paratmeters below:

REAL CATCH fo	0	MT
Age 1+ biomass	0	0
Legal Biomass (	0	0
Virgin Age 1+ B	0	0
Virgin Legal Bio	0	0

OUTPUT FOR REFERENCE POINTS				
		lbs	Bun	%Bun
Oct	lbs M+F	551.265	1077.4	51%
Apr	lbs M+F	480.364	1033.38	46%

Biomass (kg) of legal males

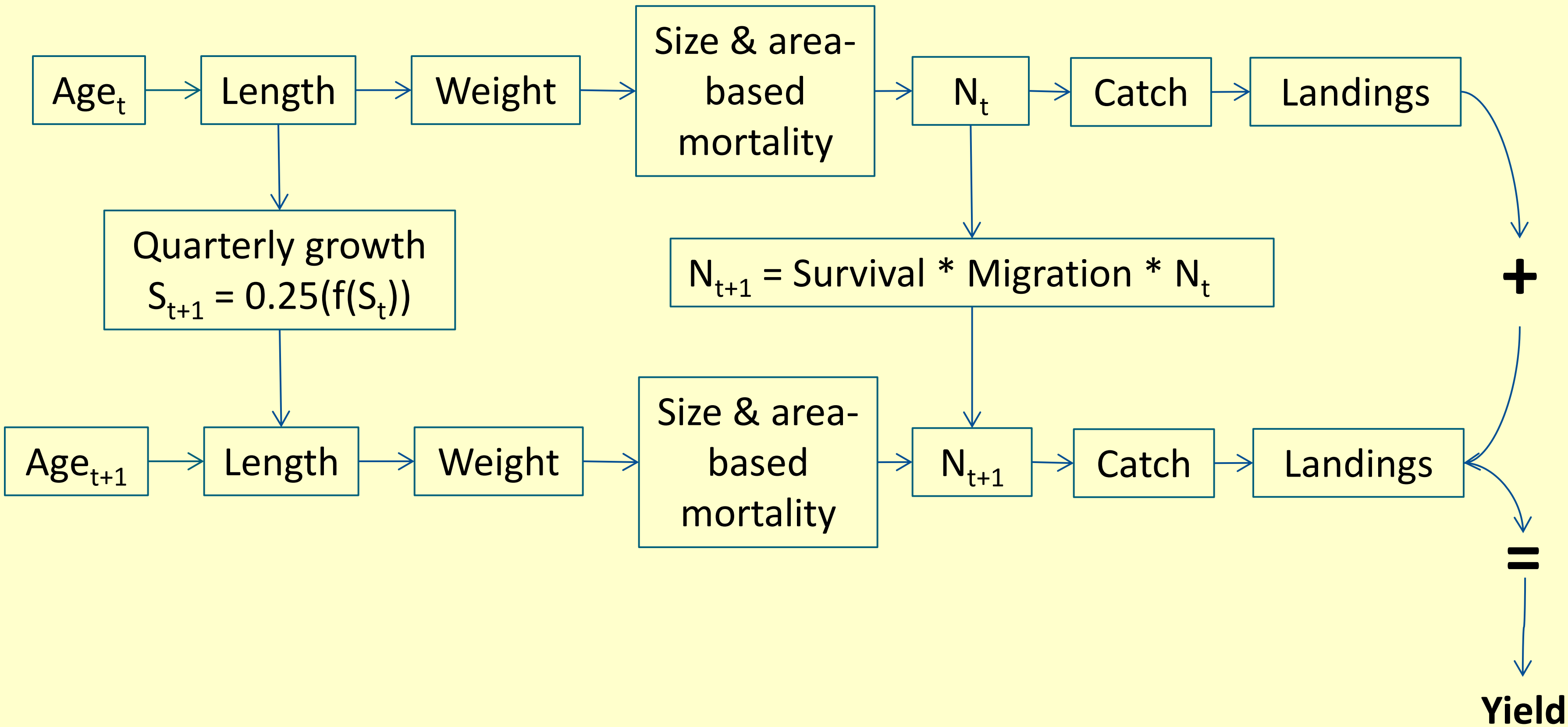
	Recruits	Total
Oct	**16.52**	**47.45**
April	**11.42**	**36.39**

IF(C25<FemCL,

Model structure & use

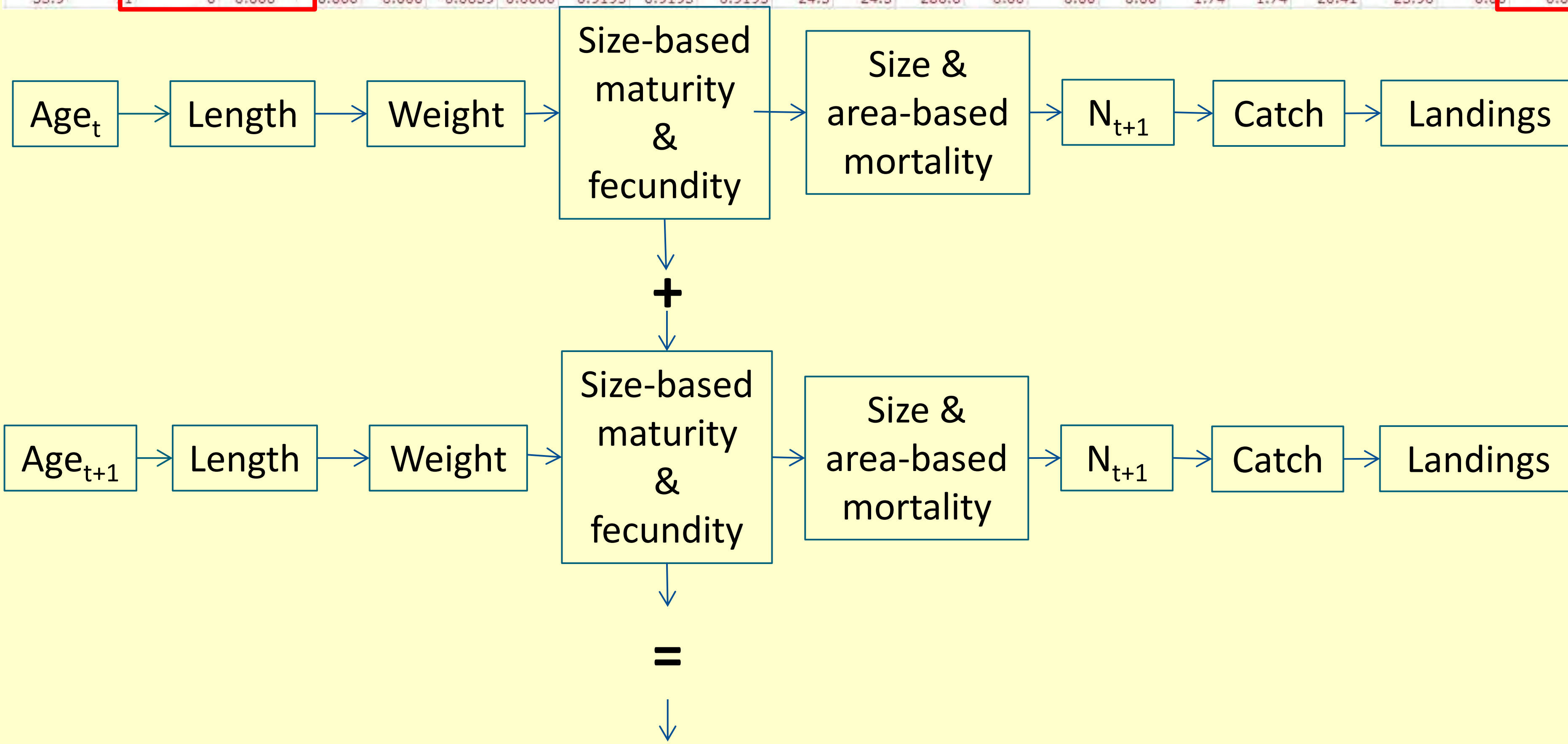
Model flow

MODEL																						
Age	Season Quarter	Male length	Male wt gms	Male Vulner	Male F	Male* var M	Male FNR	Male Sur in-in	Male Sur in	Male Sur open	Male N in-in	Male N in	Male Nopen	Male Cat in	Male Catopen	MALE Nland	Male kgin-in	Male kg in	Male kg open	Male TOT kg	Male land kg
1.42	1	17.2	9	0.000	0.000	-0.3770	0.0000	0.6859	0.6859	0.6859	36.5	36.5	427.0	0.00	0.00	0.00	0.34	0.34	3.96	4.64	0.00
1.67	2	25.5	26	0.000	0.000	-0.1600	0.0000	0.8521	0.8521	0.8521	25.0	25.0	292.9	0.00	0.00	0.00	0.65	0.65	7.62	8.93	0.00
1.92	3	33.9	55	0.000	0.000	-0.0968	0.0000	0.9077	0.9077	0.9077	21.3	21.3	249.6	0.00	0.00	0.00	1.17	1.17	13.73	16.08	0.00



Females

Female length	Female wt gms	Fecundity 1000s	Female mature	Female Vulner	Female F	Female* var M	Female FNR	Female Sur in-in	Female Sur in	Female Sur open	Female N in-in	Female N in	Female N open	Female Cat in	Female Catopen	Female Nland	Female kginin	Female kg in	Female kg open	Female TOT kg	Female land kg	Millions Eggs
17.2	14	0	0.000	0.000	0.000	-0.2706	0.0000	0.7630	0.7630	0.7630	36.5	36.5	427.0	0.00	0.00	0.00	0.49	0.49	5.79	6.78	0.00	0.00
25.5	35	6	0.000	0.000	0.000	-0.1281	0.0000	0.8798	0.8798	0.8798	27.8	27.8	325.8	0.00	0.00	0.00	0.99	0.99	11.55	13.53	0.00	0.00
33.9	71	0	0.000	0.000	0.000	-0.0839	0.0000	0.9195	0.9195	0.9195	24.5	24.5	286.6	0.00	0.00	0.00	1.74	1.74	20.41	23.90	0.00	0.00



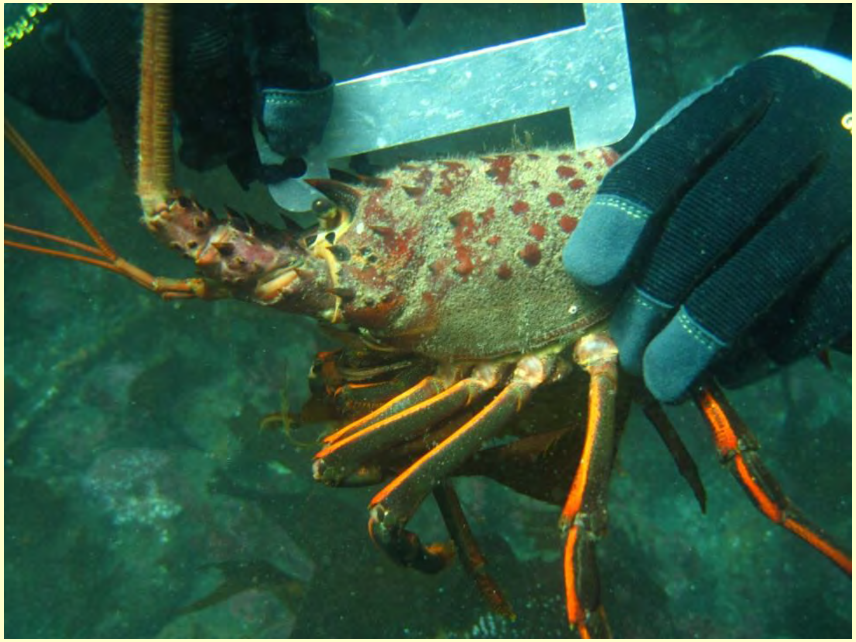
Egg Production

Growth

Age → Length → Weight

Length → Quarterly growth $S_{t+1} = 0.25(f(S_t))$

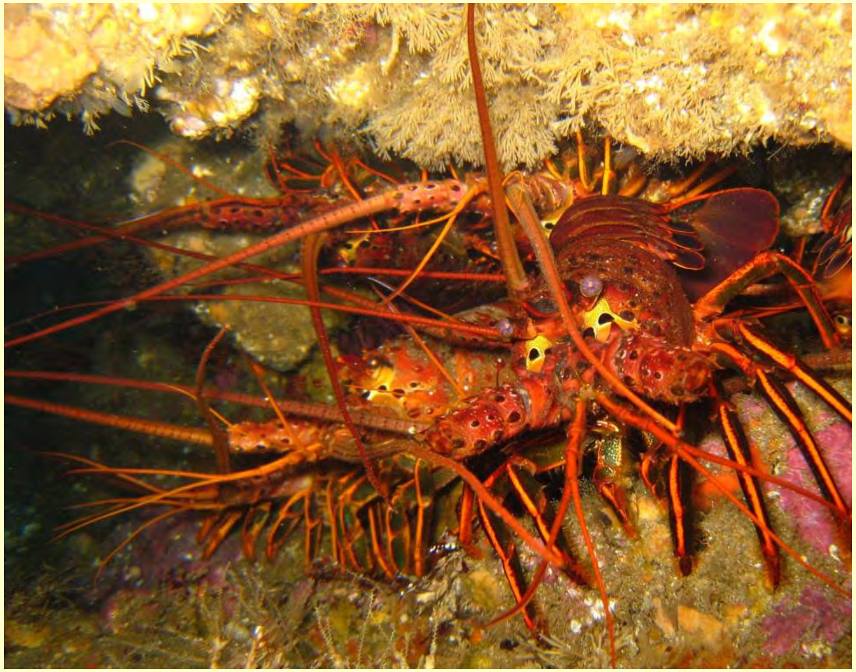
- Dr. Parrish identified von Bertalanffy model a poor fit
- CDFW developed growth models using raw tag-recapture data (Engle, Hovel, Kay)



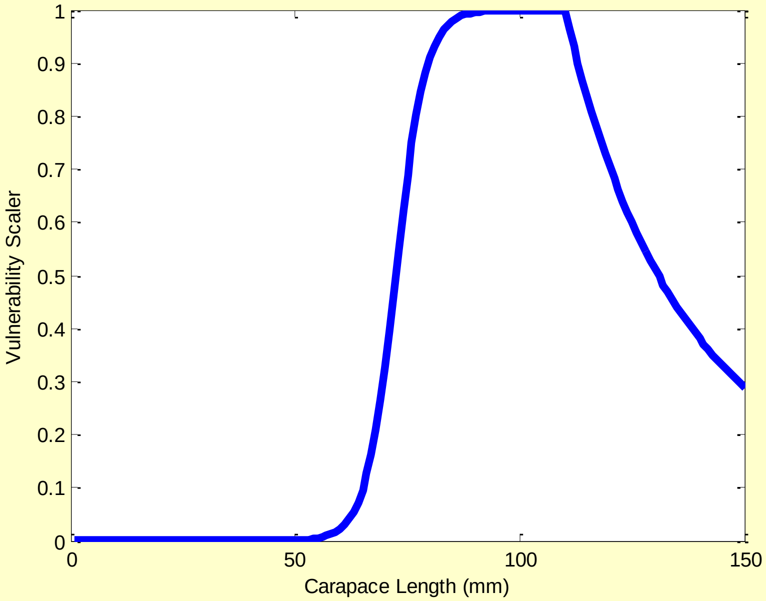
Size & area-based mortality

Age → Length → Weight → Size & area-based mortality

- Vulnerability – gear selectivity
- Instantaneous fishing mortality (F)
- Natural mortality
- Unrecorded fishing mortality
- Survival



Vulnerability



- Legal lobsters 84% vulnerable
- After CL reaches VulLT, vulnerability is dampened by a subtracting factor
- Vulnerability parameters adjusted to produce % shorts in the catch from logs

Instantaneous fishing mortality

- Iteratively found by adjusting until Mean lbs is equal to log and landing receipt data
- Multiplied by
    - Vulnerability
    - Foct if in quarter 4
    - Fjan if quarter 1
- If quarter = 2 or 3, F = 0

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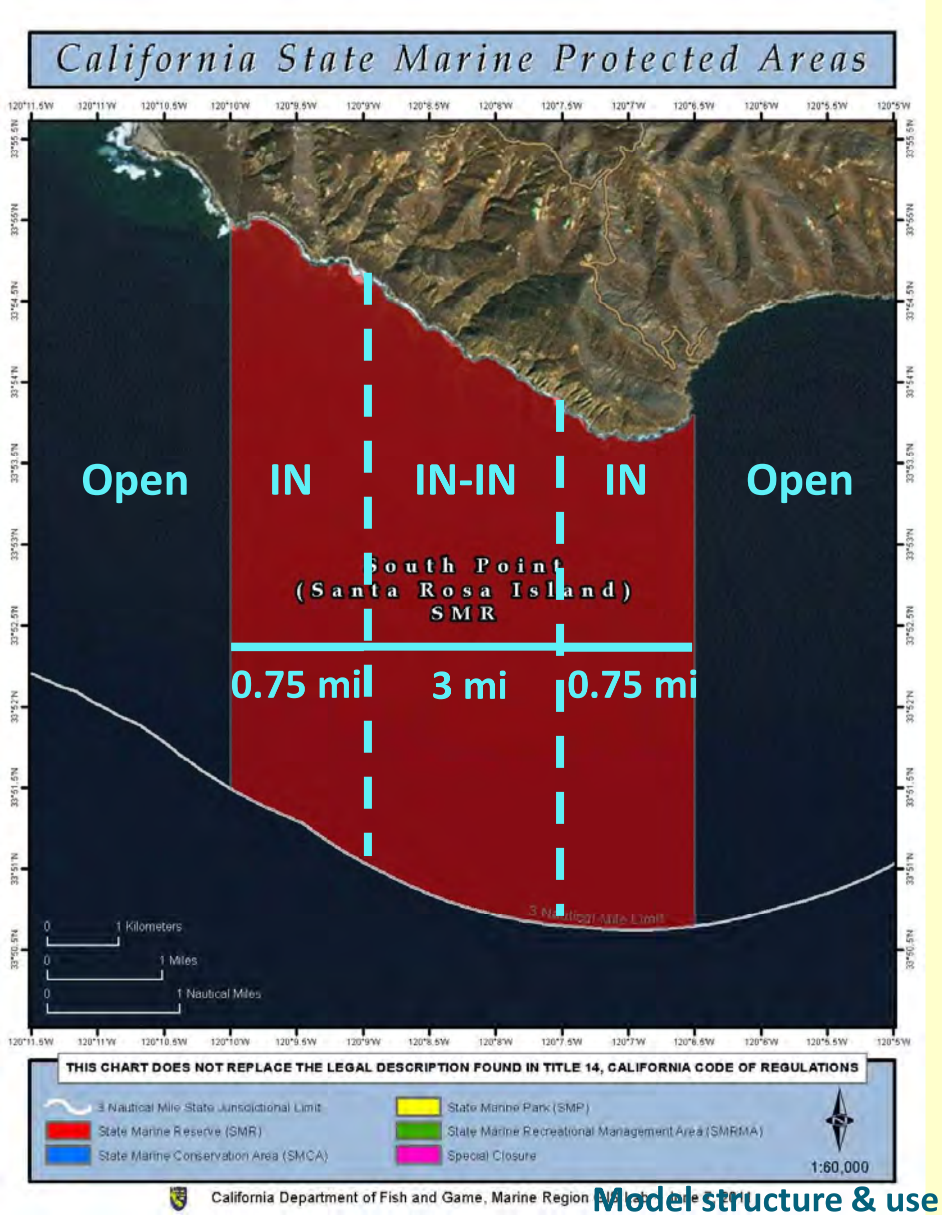
1.92	3	33.9	55	0.000	0.000	-0.0968	0.0000	0.9077	0.9077	0.9077	21.3	21.3	249.6	0.00	0.00	0.00	1.17	1.17	13.73	16.08	0.00

Survival (Incorporating MPAs)

- Allows F to be applied differently relative to MPAs
- IN-IN: no F
- IN: 20% F
- Open: full F



Model structure & use

Number of lobsters

Age → Length → Weight → Size & area-based mortality → N_t

- Initial state assumes even lobster density along the coastline
- Incorporates survival and movement rates in N_{t+1}
- 2% of lobster move 0.75 miles or more in 3 months (Lindberg 1955)

MODEL

Age	Season Quarter	Male length	Male wt gms	Male Vulner	Male F	Male* var M	Male FNR	Male Sur in-in	Male Sur in	Male Sur open	Male N in-in	Male N in	Male Nopen	Male Cat in	Male Catopen	MALE Nland	Male kgin-in	Male kg in	Male kg open	Male TOT kg	Male land kg
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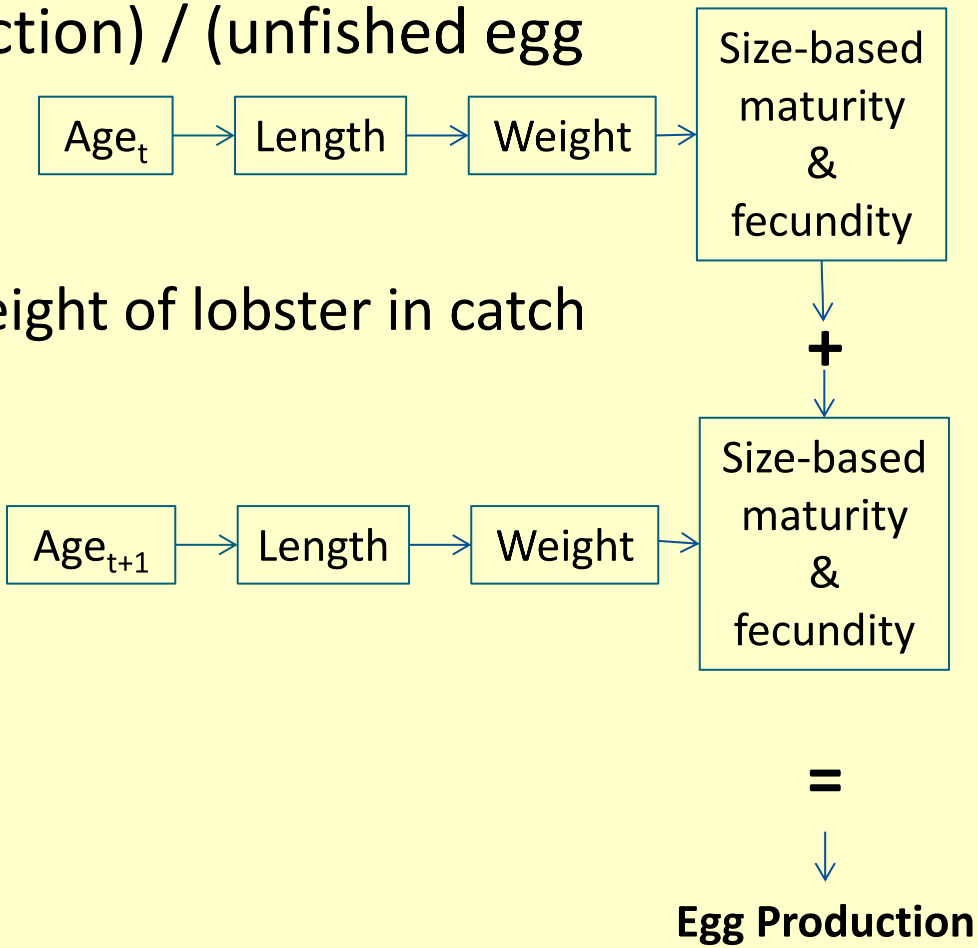
Spawning potential ratio

- SPR = (current egg production) / (unfished egg production)
- Current
  - F matched to average weight of lobster in catch
  - 14.6% habitat in MPAs
- Unfished
  - F = 0.0001
  - MPA coverage = 0.0001



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	Recruits	Total		
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ESTIMATION OF BIOMASS
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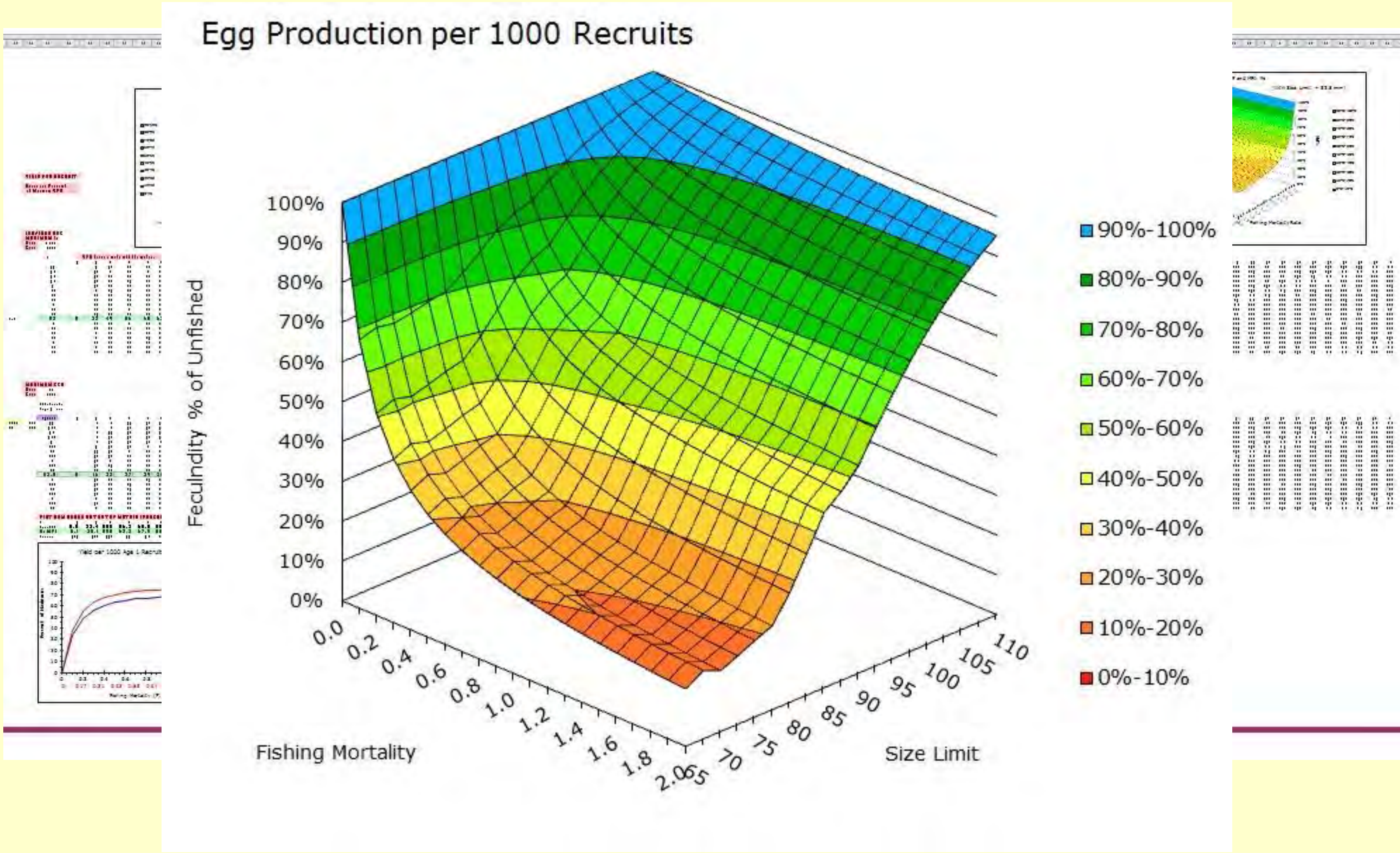
REAL CATCH fo	0	MT
Age 1+ biomass	0	0
Legal Biomass (	0	0
Virgin Age 1+ B	0	0
Virgin Legal Bio	0	0

IF(C25<FemCL,C

Graphical output – 3d plots



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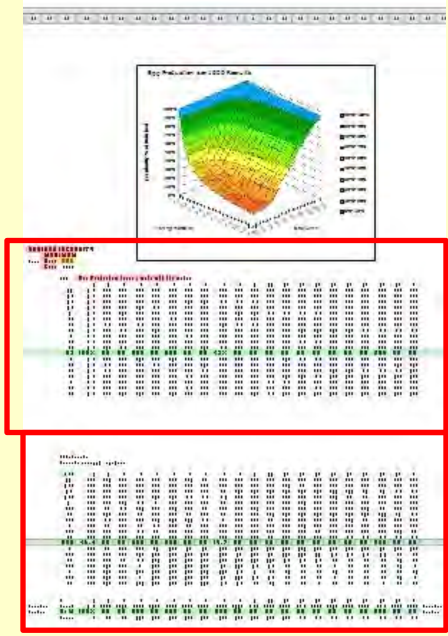


REVISED FECUNDITY
MAXIMUM

Tapla	Base	46.43
	Curren	46.43

FPR Egg Produciton Figure is made with this matrix

	0.0001	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
110	100%	99%	99%	98%	98%	97%	97%	97%	97%	96%	96%	96%	96%	96%	96%	96%	95%	95%	95%	95%	95%
108	100%	99%	97%	97%	96%	95%	95%	94%	94%	93%	93%	93%	93%	93%	92%	92%	92%	92%	92%	92%	92%
105	100%	98%	96%	94%	93%	92%	91%	91%	90%	90%	90%	89%	89%	89%	89%	89%	88%	88%	88%	88%	88%
103	100%	96%	93%	91%	90%	89%	88%	87%	86%	86%	86%	85%	85%	85%	84%	84%	84%	84%	84%	84%	84%
100	100%	95%	91%	88%	86%	85%	84%	83%	82%	81%	81%	80%	80%	80%	80%	79%	79%	79%	79%	79%	79%
98	100%	93%	88%	84%	82%	80%	79%	78%	77%	76%	76%	75%	75%	74%	74%	74%	74%	73%	73%	73%	73%
95	100%	90%	84%	80%	77%	75%	73%	72%	71%	70%	70%	69%	69%	68%	68%	68%	67%	67%	67%	67%	67%
93	100%	87%	80%	75%	71%	69%	67%	66%	65%	64%	63%	62%	62%	61%	61%	61%	61%	60%	60%	60%	60%
90	100%	84%	75%	69%	65%	62%	60%	59%	58%	57%	56%	55%	55%	54%	54%	53%	53%	53%	53%	52%	52%
88	100%	83%	73%	67%	62%	59%	57%	56%	54%	53%	52%	51%	51%	50%	50%	49%	49%	48%	48%	48%	47%
85	100%	81%	70%	63%	58%	55%	53%	51%	50%	49%	48%	47%	47%	46%	46%	45%	45%	45%	44%	44%	44%
83	100%	77%	64%	57%	52%	48%	46%	44%	42%	41%	40%	39%	39%	38%	38%	37%	37%	36%	36%	36%	35%
80	100%	73%	59%	51%	45%	41%	39%	37%	35%	34%	33%	32%	31%	30%	30%	29%	29%	28%	28%	28%	27%
78	100%	70%	55%	46%	40%	36%	33%	31%	29%	28%	27%	26%	25%	24%	24%	23%	23%	22%	22%	21%	21%
75	100%	70%	54%	45%	39%	35%	32%	30%	28%	26%	25%	24%	23%	23%	22%	21%	21%	20%	20%	20%	19%
73	100%	69%	52%	43%	37%	33%	30%	28%	26%	24%	23%	22%	21%	21%	20%	19%	19%	18%	18%	17%	17%
70	100%	68%	51%	42%	36%	31%	28%	26%	24%	23%	21%	20%	20%	19%	18%	17%	17%	16%	16%	16%	15%
73	100%	69%	52%	43%	37%	33%	30%	28%	26%	24%	23%	22%	21%	21%	20%	19%	19%	18%	18%	17%	17%
65	100%	67%	51%	41%	35%	31%	28%	25%	23%	22%	21%	20%	19%	18%	17%	17%	16%	16%	15%	15%	14%

F

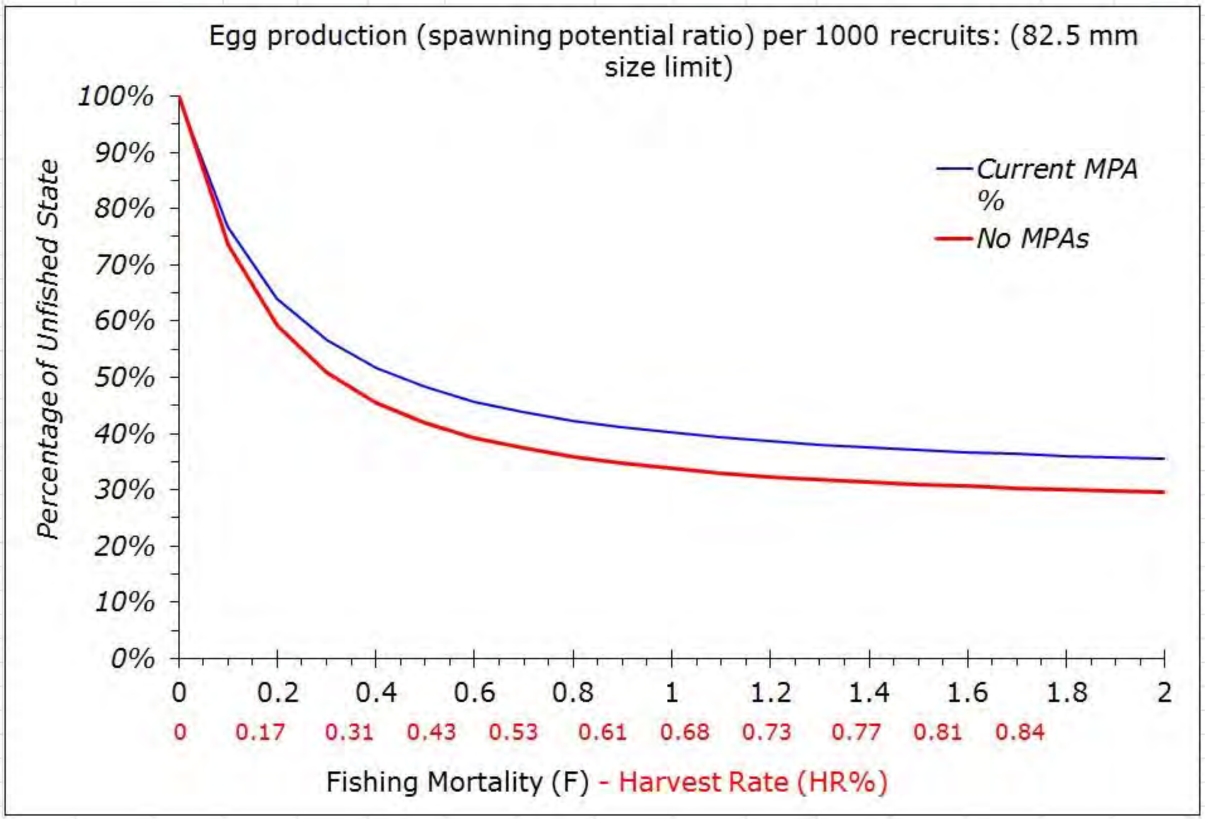
Legal Size

This is the 2-way table
Fecundity in millions of eggs/ 1000 age 1 recruits

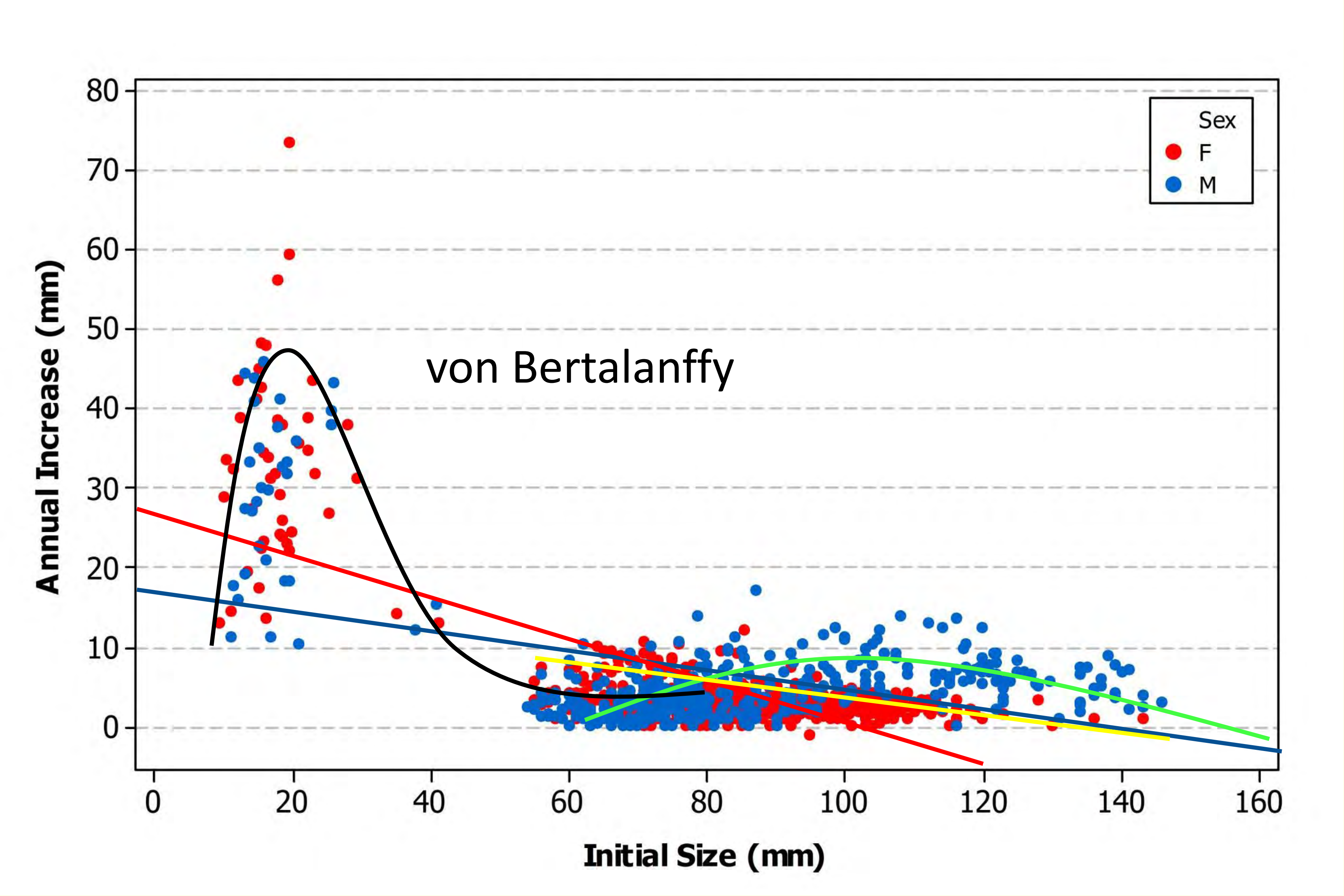
20.34	0.0001	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
110.0	46.4	46.1	45.8	45.6	45.4	45.2	45.1	45.0	44.9	44.8	44.7	44.6	44.5	44.5	44.4	44.4	44.3	44.3	44.3	44.2	44.2
107.5	46.4	45.8	45.2	44.8	44.5	44.2	43.9	43.7	43.5	43.4	43.3	43.2	43.1	43.0	42.9	42.9	42.8	42.8	42.7	42.7	42.7
105.0	46.4	45.3	44.4	43.8	43.2	42.8	42.5	42.2	42.0	41.8	41.6	41.5	41.4	41.3	41.2	41.1	41.1	41.0	41.0	40.9	40.9
102.5	46.4	44.7	43.4	42.5	41.7	41.2	40.8	40.4	40.1	39.9	39.7	39.6	39.4	39.3	39.2	39.1	39.0	39.0	38.9	38.9	38.8
100.0	46.4	43.9	42.1	40.9	40.0	39.3	38.8	38.4	38.0	37.8	37.5	37.3	37.2	37.1	36.9	36.8	36.7	36.7	36.6	36.5	36.5
97.5	46.4	43.0	40.7	39.1	37.9	37.1	36.5	36.0	35.6	35.3	35.1	34.8	34.7	34.5	34.4	34.3	34.2	34.1	34.0	33.9	33.9
95.0	46.4	41.8	38.9	37.0	35.6	34.7	34.0	33.4	33.0	32.6	32.3	32.1	31.9	31.7	31.5	31.4	31.3	31.2	31.1	31.0	30.9
92.5	46.4	40.5	36.9	34.6	33.1	31.9	31.1	30.5	30.0	29.6	29.3	29.0	28.7	28.5	28.4	28.2	28.1	28.0	27.9	27.8	27.7
90.0	46.4	39.0	34.7	32.0	30.2	28.9	28.0	27.3	26.7	26.3	25.9	25.6	25.3	25.1	24.9	24.8	24.6	24.5	24.4	24.3	24.2
87.5	46.4	38.4	33.8	30.9	29.0	27.6	26.6	25.8	25.2	24.7	24.2	23.9	23.6	23.3	23.0	22.8	22.6	22.5	22.3	22.1	22.0
85.0	46.4	37.4	32.3	29.2	27.1	25.7	24.7	23.9	23.3	22.8	22.3	22.0	21.7	21.5	21.2	21.1	20.9	20.7	20.6	20.5	20.4
82.5	46.4	35.6	29.8	26.2	24.0	22.4	21.2	20.3	19.7	19.1	18.6	18.3	17.9	17.7	17.4	17.2	17.0	16.9	16.7	16.6	16.5
80.0	46.4	34.0	27.4	23.5	21.0	19.2	18.0	17.0	16.3	15.7	15.2	14.7	14.4	14.1	13.8	13.6	13.4	13.2	13.0	12.9	12.7
77.5	46.4	32.7	25.5	21.3	18.6	16.8	15.5	14.4	13.6	13.0	12.4	12.0	11.6	11.3	11.0	10.7	10.5	10.3	10.1	9.9	9.8
75.0	46.4	32.3	25.0	20.8	18.1	16.2	14.8	13.8	12.9	12.3	11.7	11.2	10.8	10.5	10.2	9.9	9.7	9.4	9.3	9.1	8.9
72.5	46.4	31.9	24.4	20.0	17.2	15.3	13.9	12.9	12.0	11.3	10.8	10.3	9.9	9.5	9.2	9.0	8.7	8.5	8.3	8.1	8.0
70.0	46.4	31.5	23.8	19.4	16.6	14.6	13.2	12.1	11.3	10.6	10.0	9.5	9.1	8.7	8.4	8.1	7.9	7.6	7.4	7.3	7.1
72.5	46.4	31.9	24.4	20.0	17.2	15.3	13.9	12.9	12.0	11.3	10.8	10.3	9.9	9.5	9.2	9.0	8.7	8.5	8.3	8.1	8.0
65.0	46.4	31.3	23.5	19.1	16.2	14.3	12.8	11.7	10.9	10.2	9.6	9.1	8.7	8.3	8.0	7.7	7.5	7.2	7.0	6.8	6.7

Graphical output – 2d (MPA)plots

	F	0.0001	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	
Current Run	Current	100%	76.8%	64.1%	####	51.6%	####	45.7%	43.8%	42.3%	41.1%	40.2%	####	38.6%	38.0%	37.5%	37.1%	36.7%	###	####	35.7%	####	C
Base Run	No MPA	100%	73.4%	59.2%	50.8%	45.5%	41.9%	39.3%	37.4%	35.9%	34.7%	33.8%	33.0%	32.4%	31.8%	31.4%	31.0%	30.6%	30.3%	30.1%	29.8%	29.6%	E
	Differen	0%	5%	8%	11%	13%	15%	16%	17%	18%	18%	19%	19%	19%	20%	20%	20%	20%	20%	20%	20%	20%	

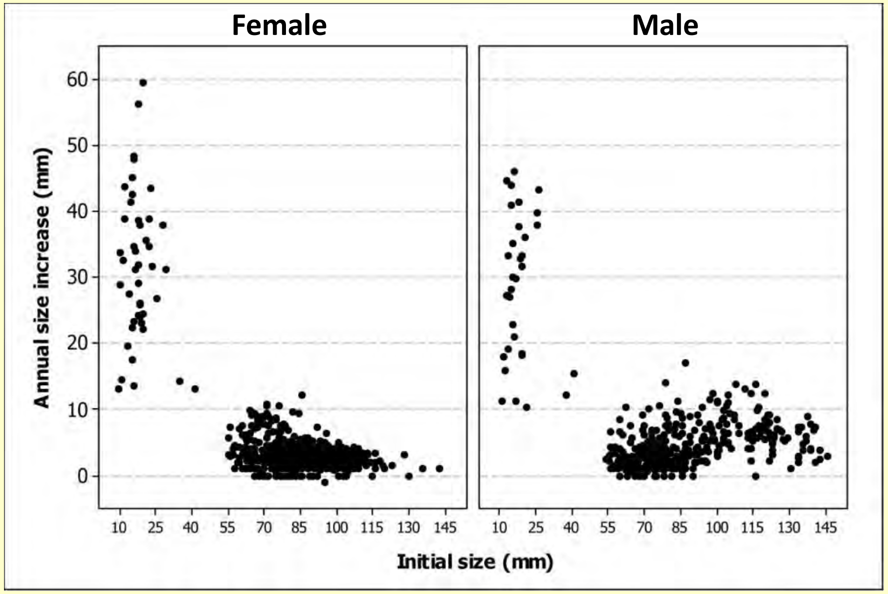


Challenges With Lobster Growth



Growth

- Collected all available mark and recapture raw data (Engle, Hovel, Kay)
- Data treatment
    - Only initial and most recent capture used
    - Days at liberty > 150 days for individuals < 50 mm CL
    - Days at liberty > 200 for individuals >50 mm CL and span molting season
    - Removed negative growth
    - Removed extreme outliers
    - Kept zero growth



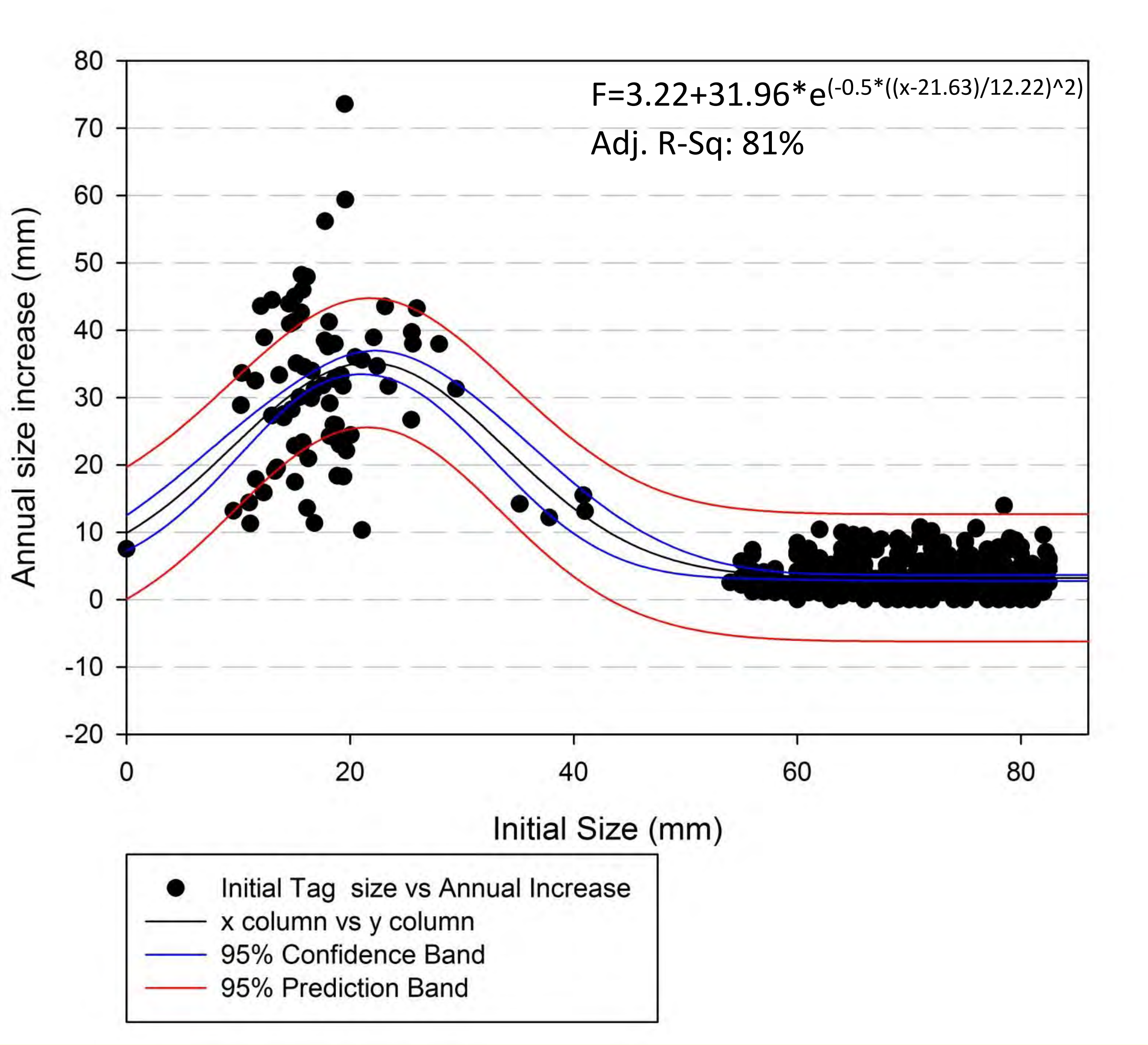
Growth model fitting

- Raw data (Engle, Hovel, Kay):
  - Sub-legal males and females **combined** (0-82.5 mm)
  - Legal males and females **separate** (>55 mm)
- Growth models presented in Rogers-Bennet et al., 2003 used as a template for invertebrates
- Models tested include: von Bertalanffy, Ricker, Logistic, Weibull, and Gaussian
- Fits tested

Model fitting comparisons (sub-legals)

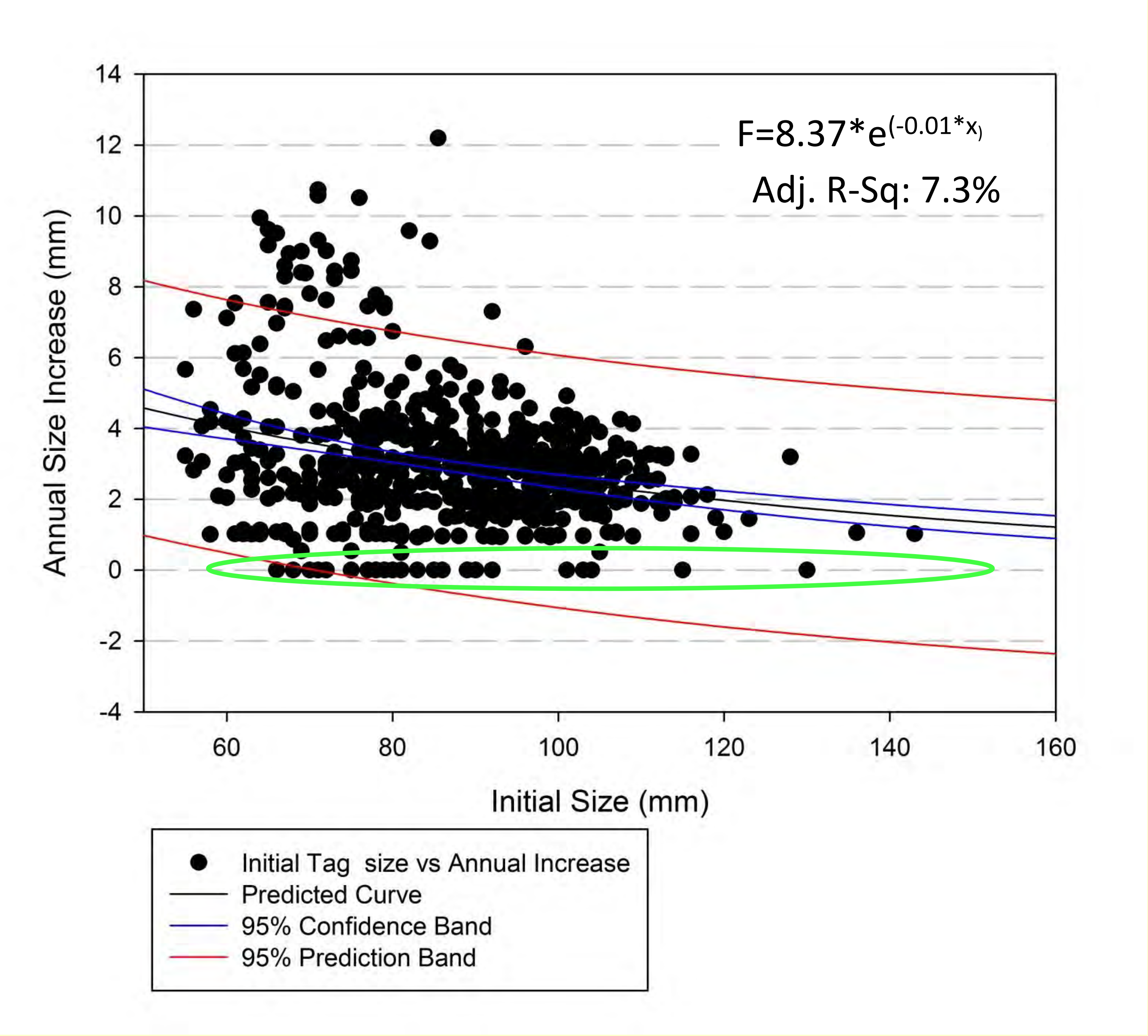
Model	# of parameters	R-sq	Adj R-sq	SE	RSS	AIC
Gaussian	4	90%	81%	4.8	12284	**1690**
Logistic	4	79%	79%	5.0	13472	**1741**
Weibull	4	89%	79%	5.0	13565	**1744**
Ricker	2	88%	78%	5.2	14281	**1767**
Logistic	3	88%	77%	5.2	14700	**1785**
von Bertalanffy	2	83%	69%	6.1	20073	**1950**

Male & Female Gaussian 4-parameter

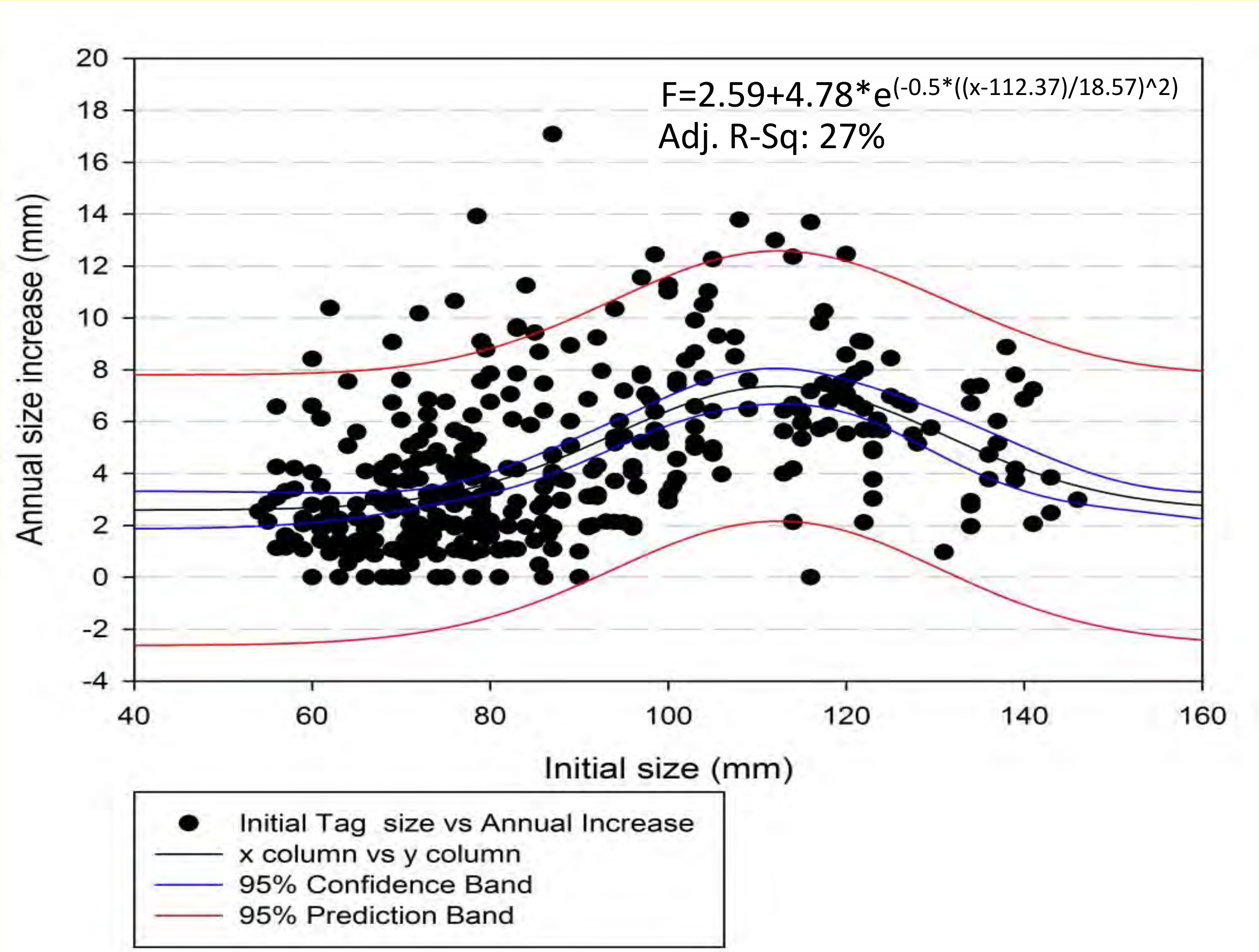


Growth

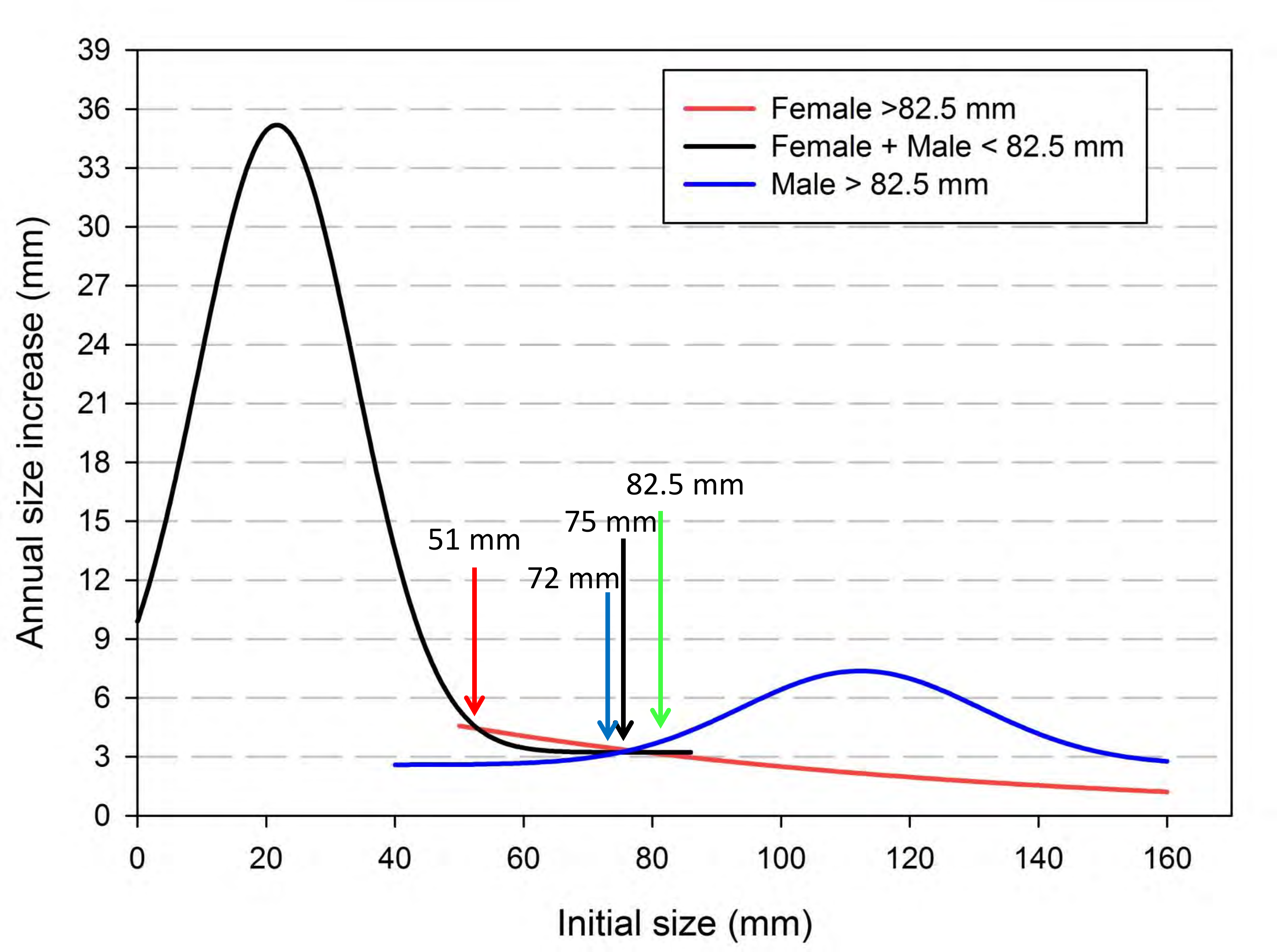
Female Exponential Decay 2 parameter



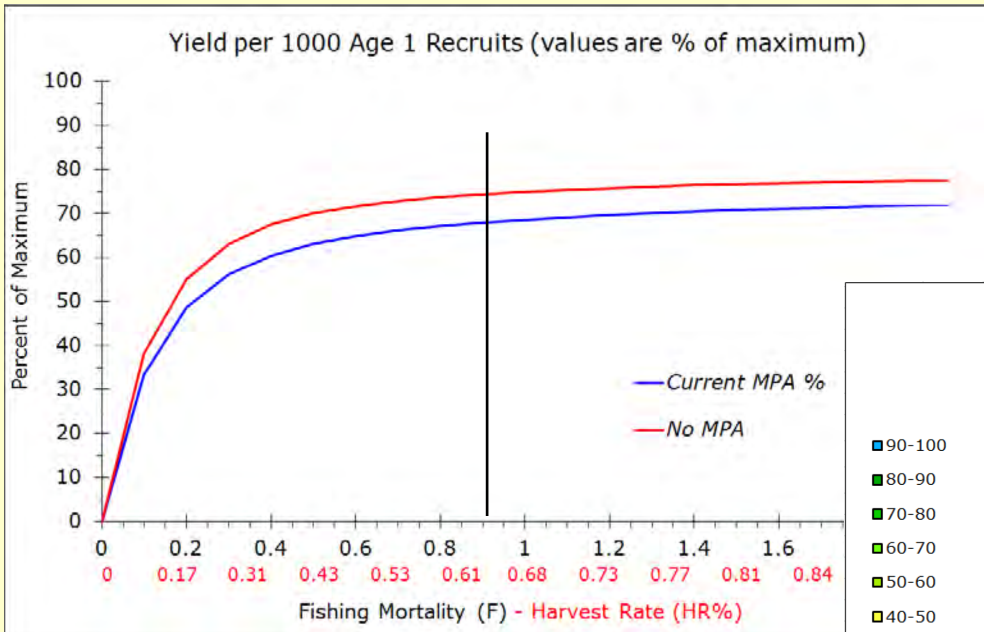
Male Gaussian 4-parameter



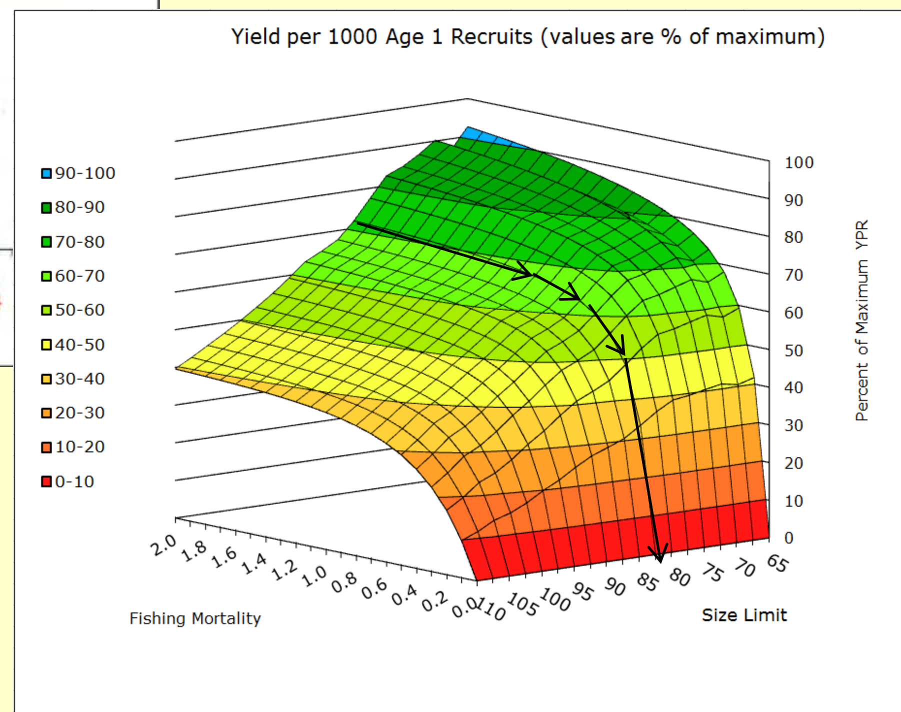
All Growth Models



Yield

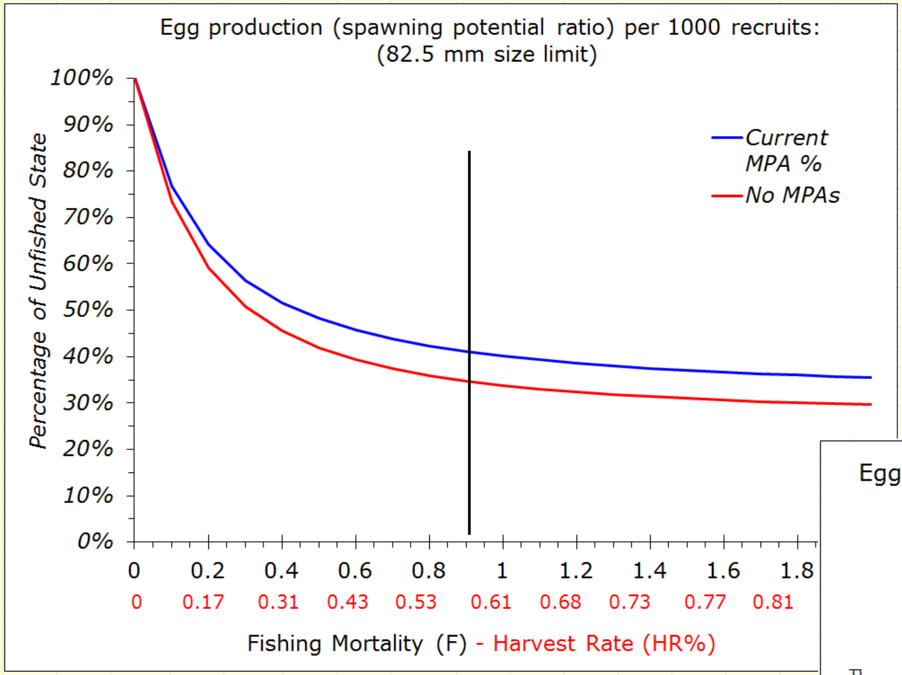


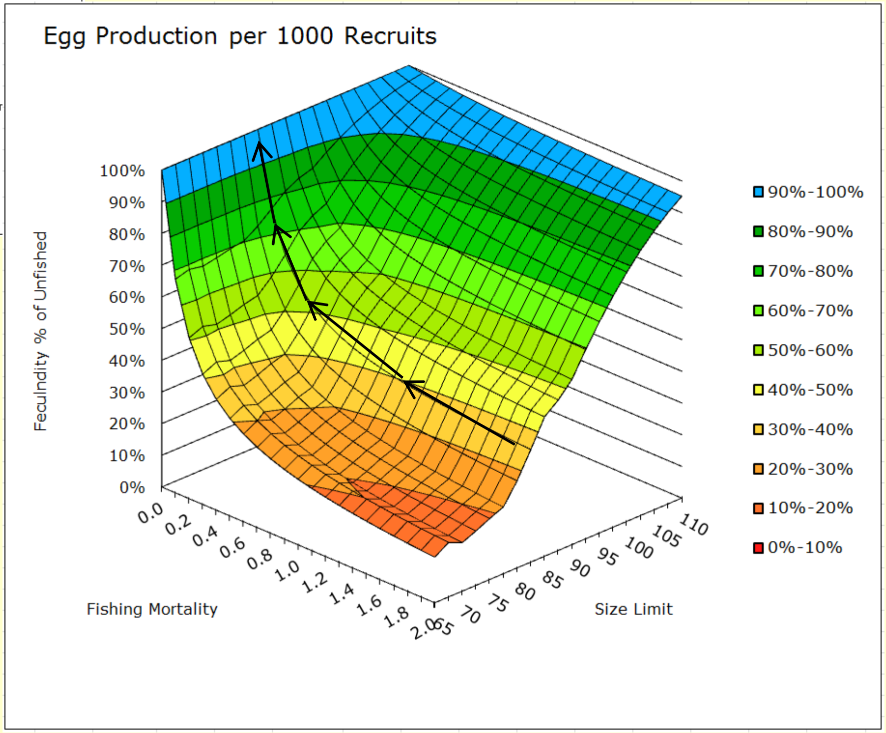
Yield per 1000 Age 1 Recruits (values are % of maximum)
Percent of Maximum
100
90
80
70
60
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
0
0.17
0.31
0.43
0.53
0.61
0.68
0.73
0.77
0.81
0.84
Fishing Mortality (F) - Harvest Rate (HR%)
Current MPA %
No MPA



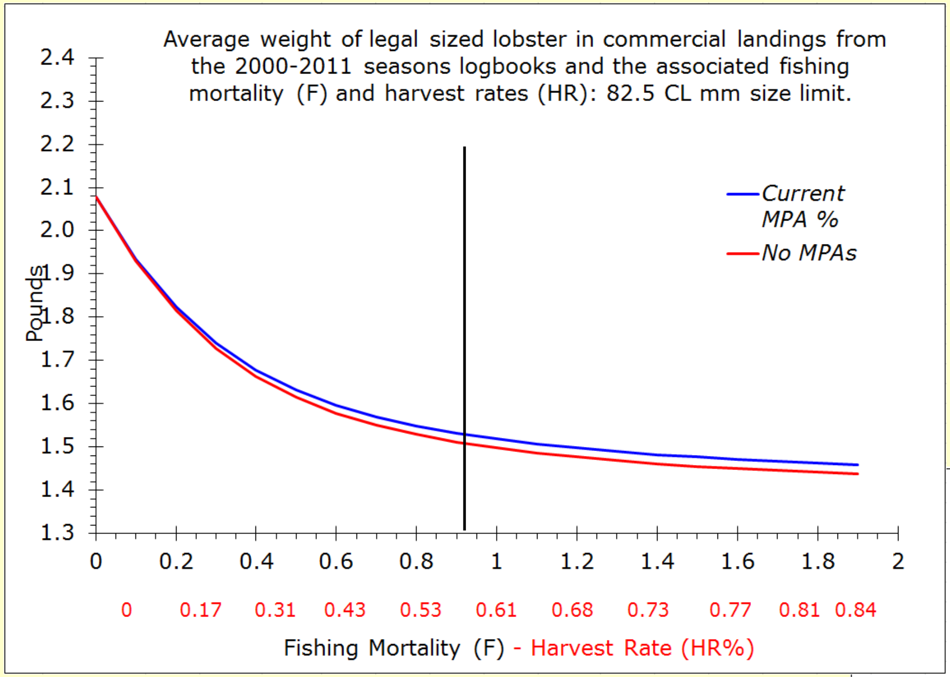
Yield per 1000 Age 1 Recruits (values are % of maximum)
90-100
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
100
90
80
70
60
50
40
30
20
10
0
Percent of Maximum YPR
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Fishing Mortality
110
105
100
95
90
85
80
75
70
65
Size Limit

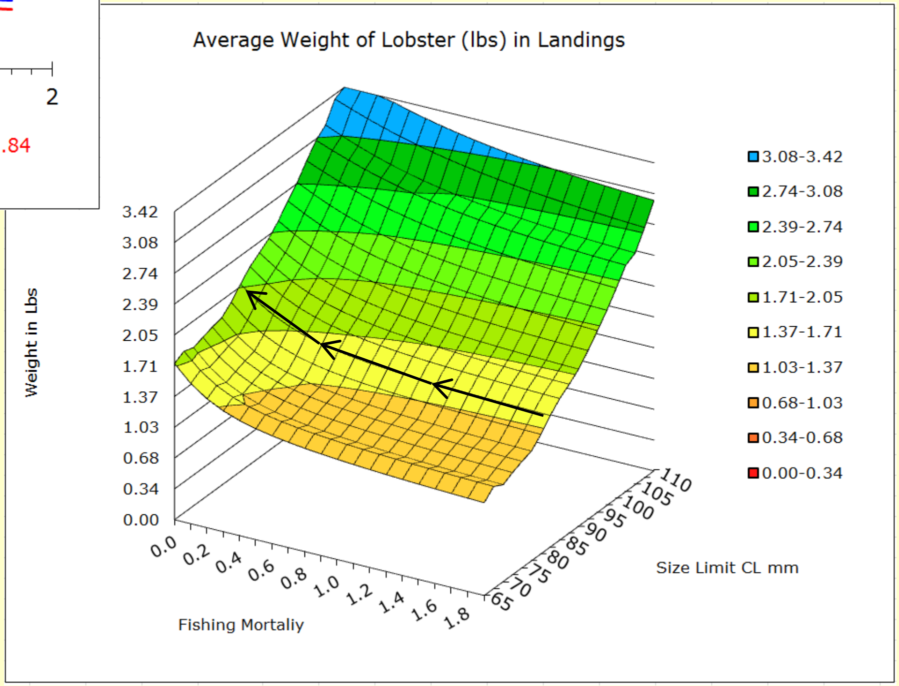
SPR


Egg production (spawning potential ratio) per 1000 recruits:
(82.5 mm size limit)
Percentage of Unfished State
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
0.17
0.31
0.43
0.53
0.61
0.68
0.73
0.77
0.81
Fishing Mortality (F) - Harvest Rate (HR%)
Current MPA %
No MPAs


Egg Production per 1000 Recruits
Feculndity % of Unfished
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fishing Mortality
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Size Limit
65
70
75
80
85
90
95
100
105
110
90%-100%
80%-90%
70%-80%
60%-70%
50%-60%
40%-50%
30%-40%
20%-30%
10%-20%
0%-10%

Average weight





2-way table outputs

OUTPUT TO 2-WAY TABLES AND FIGURES		
YieldT	32.657	Yield per 1000 recruits (kgs)
FecT	19.1	Millions of eggs
AveWt	0.694	Mean weight in landings (kgs)
HR	13.7%	Harvest rate of legals
Yield lbs	71.995	
SPR	41%	
Mean lbs	1.530	

Fecundity: Total fecundity of the cohort over its lifetime in terms of millions of eggs and ratio over an unfished population

Average Weight: Average weight of a landed lobster in lbs and kgs

Harvest rate: Harvest rate of the legal-size individuals over a cohort's lifetime

Yield: Lifetime yield of a cohort in lbs and kgs

Reference points

CURRENT MODEL REFERENCE POINTS	This Rur	Unfished	Percentage
Fishing Mortality Rate (cell B5) F=	0.9100	F=0.00001	of Bun
Size Limit in mm (cell B6) CL=	82.5	82.5	
Total Biomass of Cohort (October lbs)	1613	2152	75%
Total Biomass legal males (October lbs)	92	379	24%
Total Biomass legal females (October lbs)	108	359	30%
Total Biomass legals (October lbs)	200	739	27%
Total Fecundity (millions of eggs)	19	46	41%
Percentage Shorts	74.1%	36.9%	
Average size in landings lbs	1.53	2.08	74%
Total Yield of Cohort lbs	71.99	0.01	
Harvest Rate Yield/Age 1+ Biom	4.5%		
Harvest Rate Yield/Legals Biom	36.0%		
Males in landings	21		
Females in Landings	26		
Female sex ratio in landings	55.8%	59.4%	

Total Biomass of Cohort: Total cumulative biomass at the start of each fishing season (Season 4)

Total Biomass legal males: Cumulative biomass of male lobsters at the start of each season (Season 4) over the lifespan of the cohort (starting at row 87)

Total Biomass legal females: Cumulative biomass of female lobsters at the start of each season (Season 4) over the lifespan of the cohort (starting at row 87 as well)

Total Biomass legals: males + females

CDFW growth models produce slower juvenile growth, resulting in lower number of lobsters ultimately recruited into the fishery from each cohort

Males initially suffer higher natural mortality

Modifications from Cable 6.0 to Cable-CDFW 1.0
Substantive Changes

1. New growth model
2. Iterative adjustment of aVul
3. Set handling and ghost fishing parameters to 0
4. Change the age at first time step from 1 to 1.42
5. Initial size at first time step changed to 17.2 mm

Modifications from Cable 6.0 to Cable-CDFW 1.0
Removed Components

1. All notes and inputs associated with the Bertalanffy equations
2. Graphs, tables, and features that contain redundant or outdated information
3. All components related to the value-per-recruit outputs

Sensitivity analyses

- Growth model
- Growth schedule

Model limitation – discrete growth

- Annual growth – annual molt
- Quarterly growth – more continuous
- Discrete growth causes “knife edge” selection problem

First fishing season at legal size (CL > 82.5mm)

First fishing season after reaching legal size

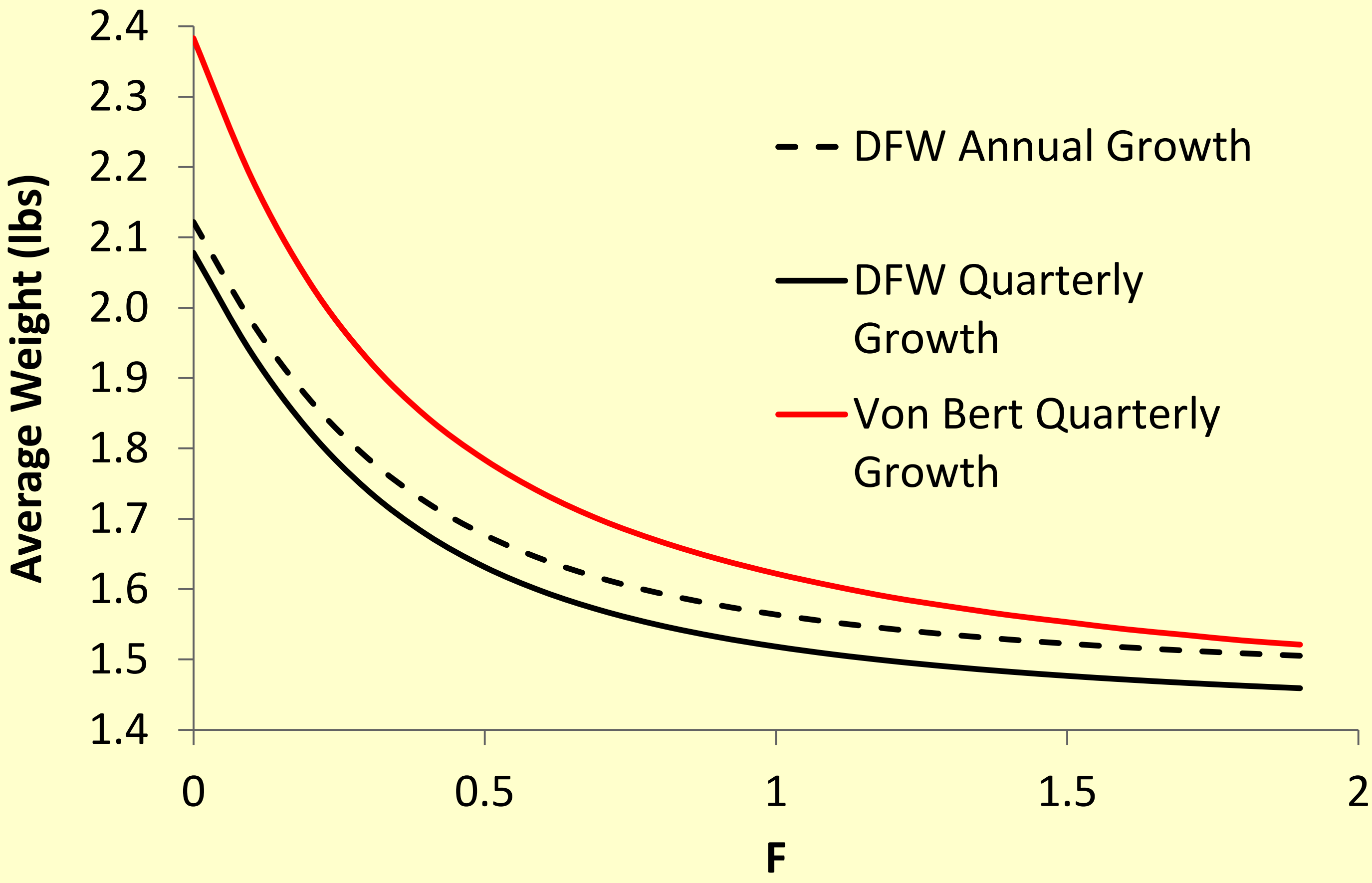
	Season	Male	Male	Female	Female
Age	**Quarter**	**length**	**wt lbs**	**length**	**wt lbs**
11.92	3	80.3	1.17	80.3	1.29
12.17	4	81.1	1.20	81.1	1.32
12.42	1	81.9	1.23	81.9	1.36
12.67	2	82.7	1.26	82.7	1.39
12.92	3	83.7	1.30	83.5	1.42
13.17	4	84.7	1.34	84.2	1.45

Sensitivity analyses

Growth Model	CDFW		von Bertalanffy
Growth Schedule	Quarterly	Annual	Quarterly
SPR Threshold	40%	44%	18%
SPR Current	41%	44%	20%
Age to legal male	12.7	12.7	6.4
Age to legal female	12.7	12.7	6.9
% survival to legal	6.6%	6.7%	27.9%

*CDFW currently employs quarterly growth model

Model limitation – minimum weight

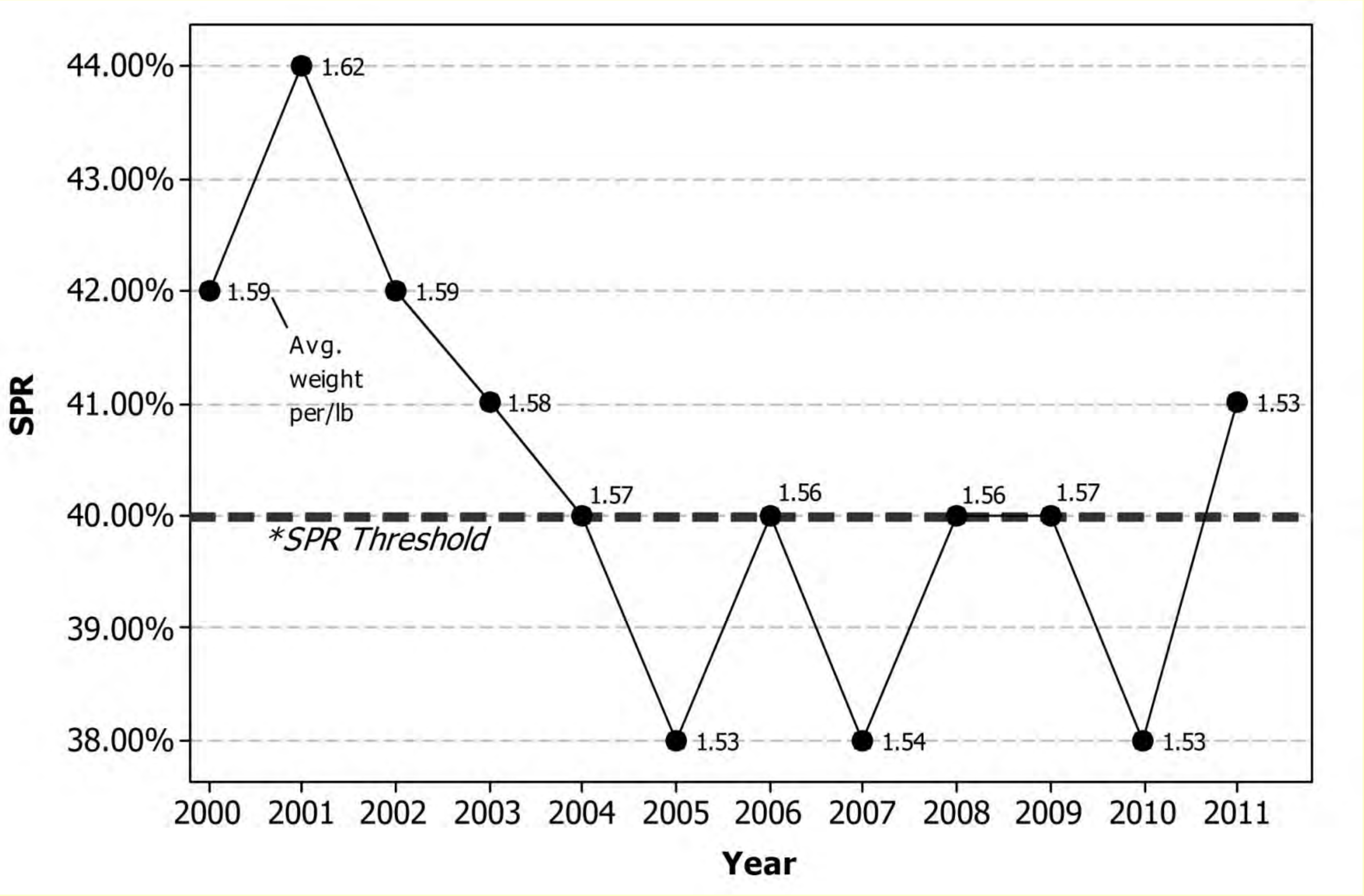


Future work

- Data collection and/or parameterization
  - Vulnerability
  - Fecundity & size at maturity
  - Natural mortality
  - Movement
  - Average weight
- Sensitivity analyses
- Recreational

Management implications

- Current SPR calculation of 41% shows that we are close to the SPR threshold of 40%



Cable Model & Future Management

- SPR provides a metric to measure the status of the stock in ways that catch and CPUE cannot
- Function of Cable Model provides ability to incorporate the effects of MPAs into SPR calculation
- Proposed regulation changes (e.g. trap limit) and maturing MPAs may effect all three FMP thresholds