Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien
iotc ctoi

Skipjack Tuna Stock Assessment (Stock Synthesis)

IOTC-2012-WPTT-14-29

R. Sharma, M. Herrera, J. Million

Sp. Acknowledgements: I. Taylor (NOAA), A. Langley (IOTC consultant) & D. Kolody (SPC)

Outline of the presentation

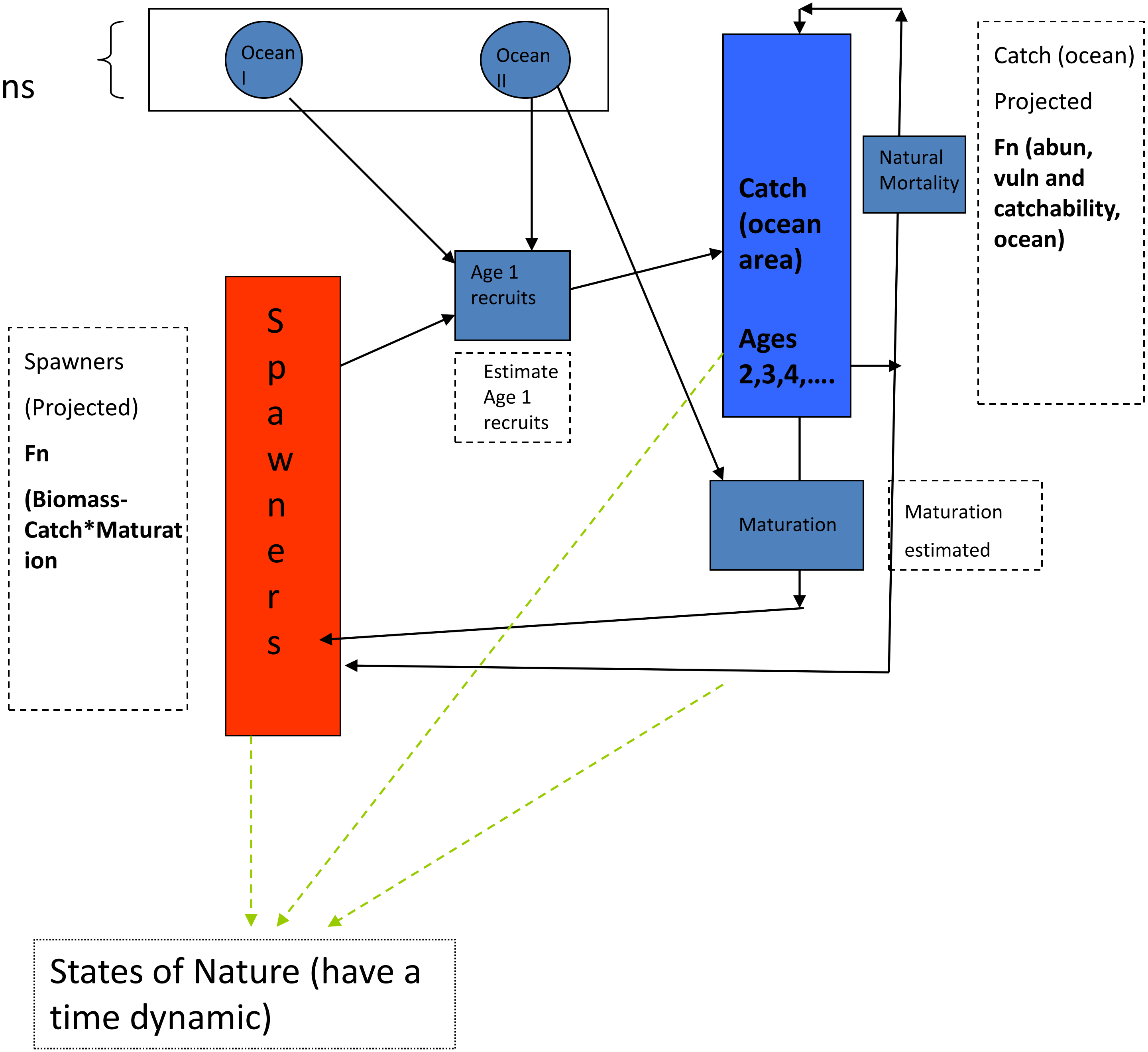
- The model specifics
- Parameterization and assumptions.
- Results
- Comparisons with a Mark-Recapture estimate.
- Stock Status Summary.
- New Information Sensitivity.

Approach

- Builds on work of Kolody et. al. 2011.
- Focuses on key areas, namely areas, natural mortality, steepness and selectivity.
- Runs assessed on these key options and on weights to the Likelihood (i.e. CPUE vs length composition).
- Ground truths results with the tag data using simple MR methods.
- Examines the effect of the over-dispersion parameter on assessments.

Environmental
Forcing functions

MODEL
MECHANISM



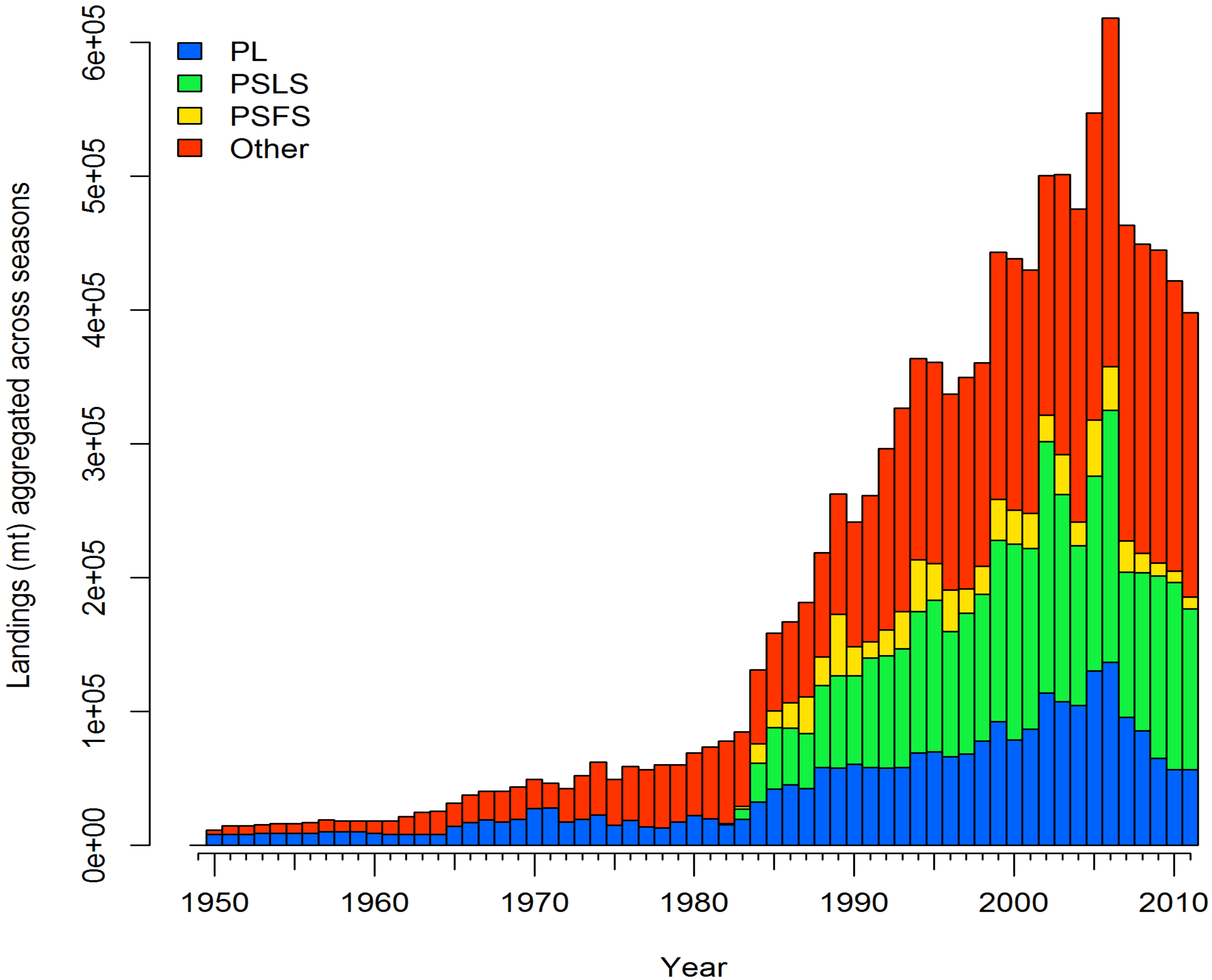
Assessment Model

- Stock Synthesis Software
- Integrates:
  - Total Catch
  - CPUE
  - Catch-at-Length
  - Tag Releases and Recoveries
  - Biological research
- Quarterly time-step (1950-2011)
  - Annual/4 season configuration

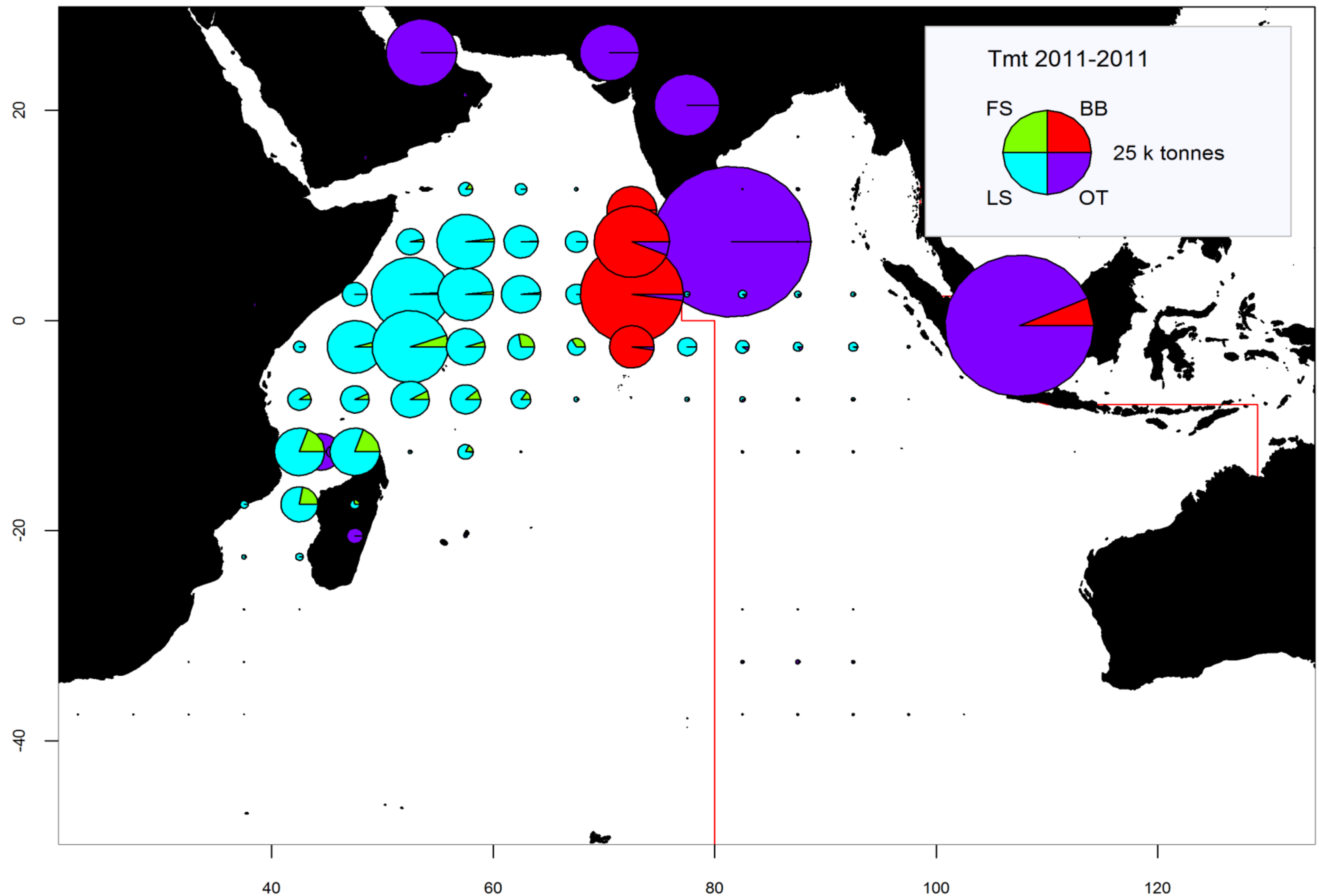
Main Assumptions:

- 4 Fishing Fleets
  - PL = Maldives Pole and Line
    - CPUE, tag recoveries
  - PSLS = EU/SEZ Purse Seine Log Sets
    - tag recoveries
  - PSFS = EU/SEZ Purse Seine Free School Sets
    - tag recoveries (French nominal CPUE examined)
  - Other = Gillnets, non-EU/SEZ PS, LL, other

Catch

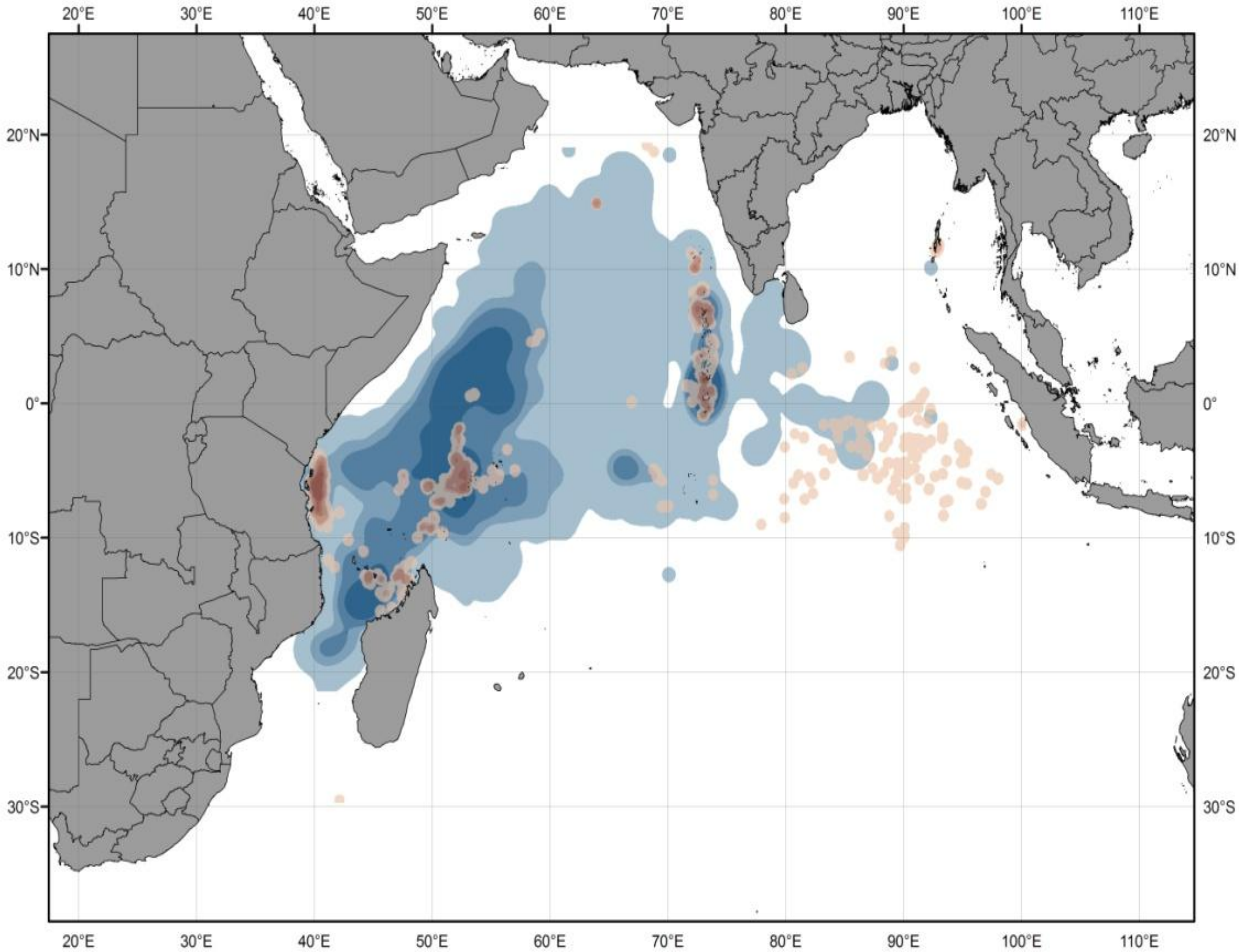


PL
PSLS
PSFS
Other
Landings (mt) aggregated across seasons
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
1950
1960
1970
1980
1990
2000
2010
Year

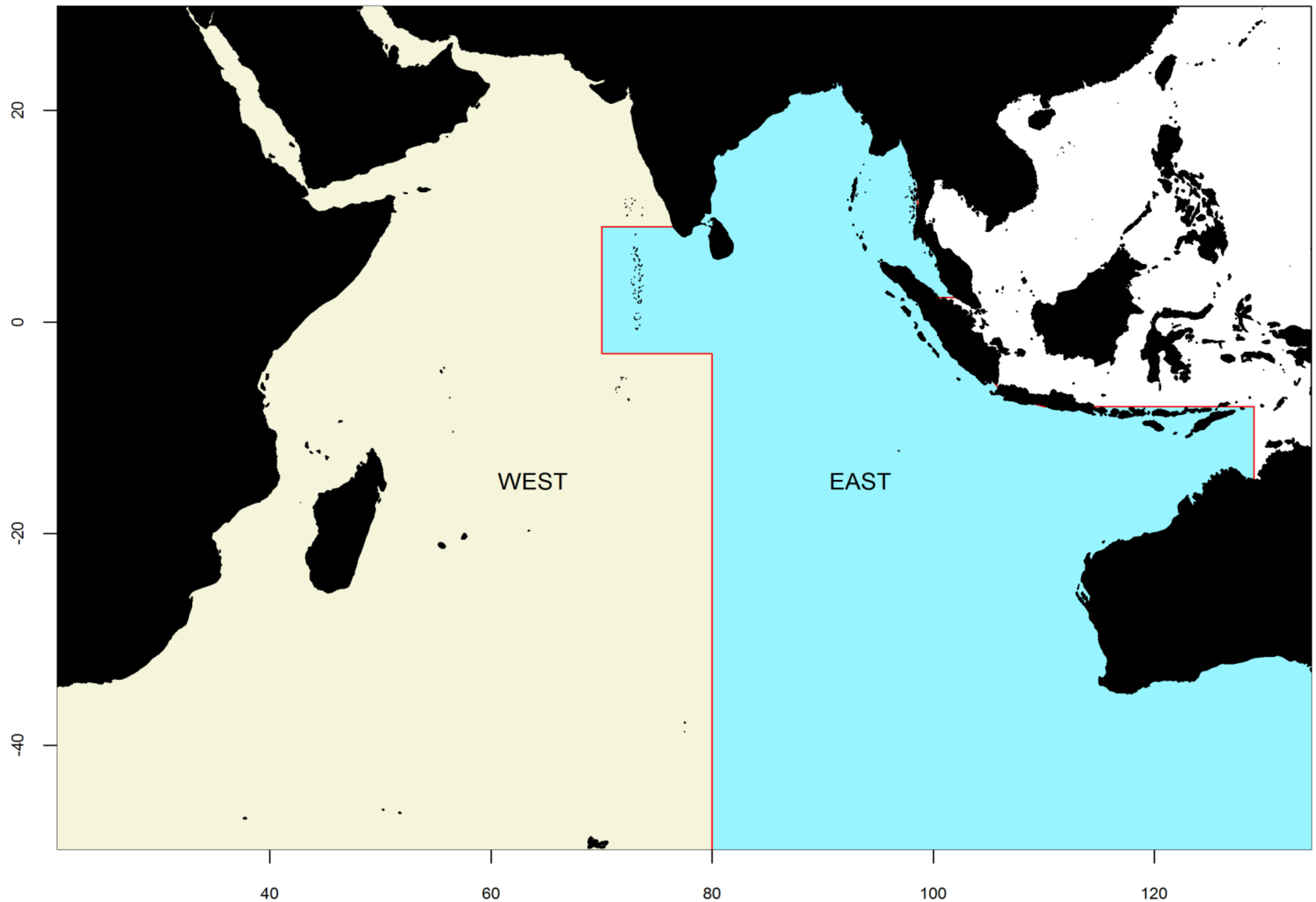


Tmt 2011-2011
FS
BB
25 k tonnes
LS
OT
20
0
-20
-40
40
60
80
100
120

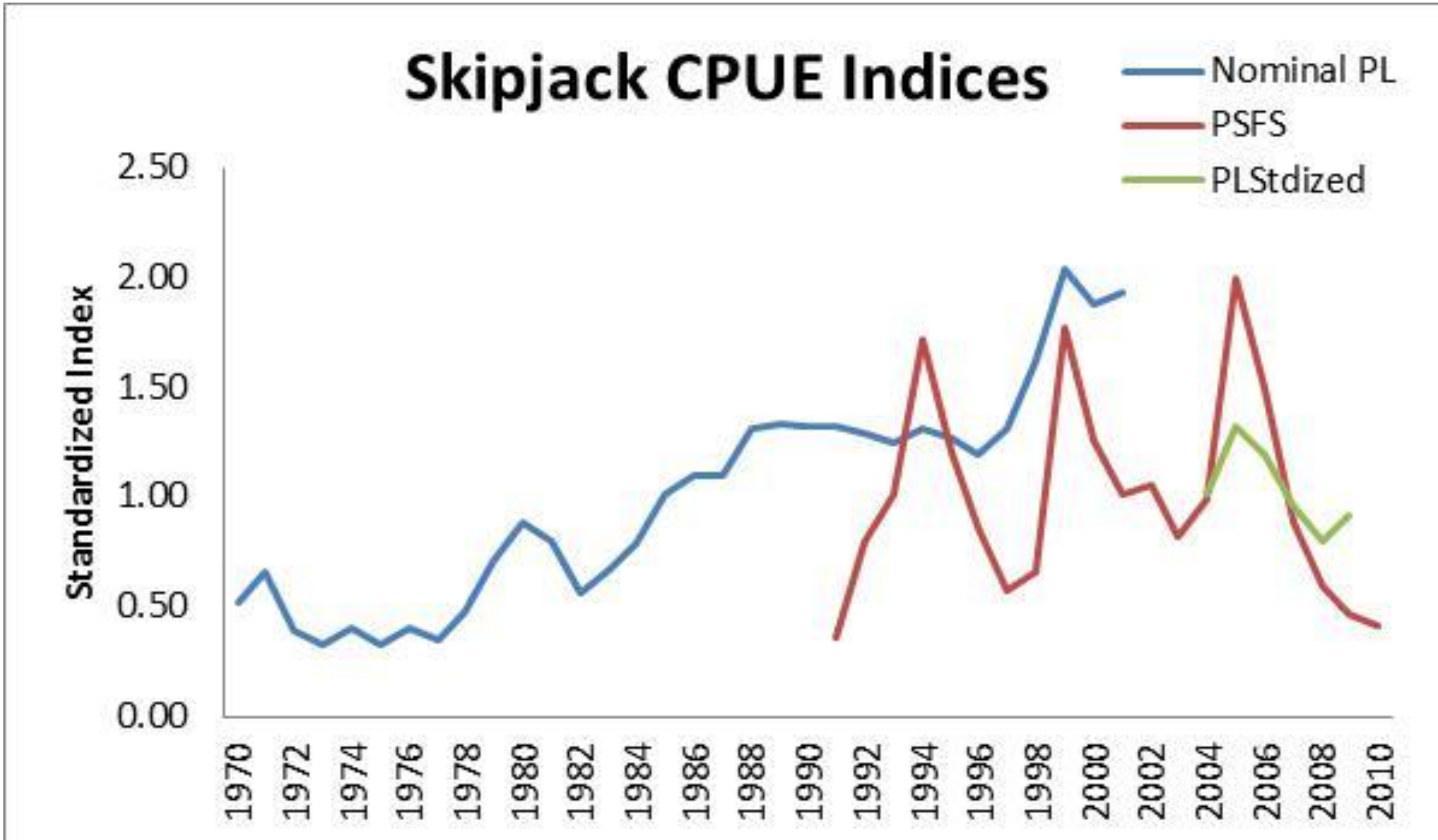
Single Spatial Area?



Alternate Hypothesis

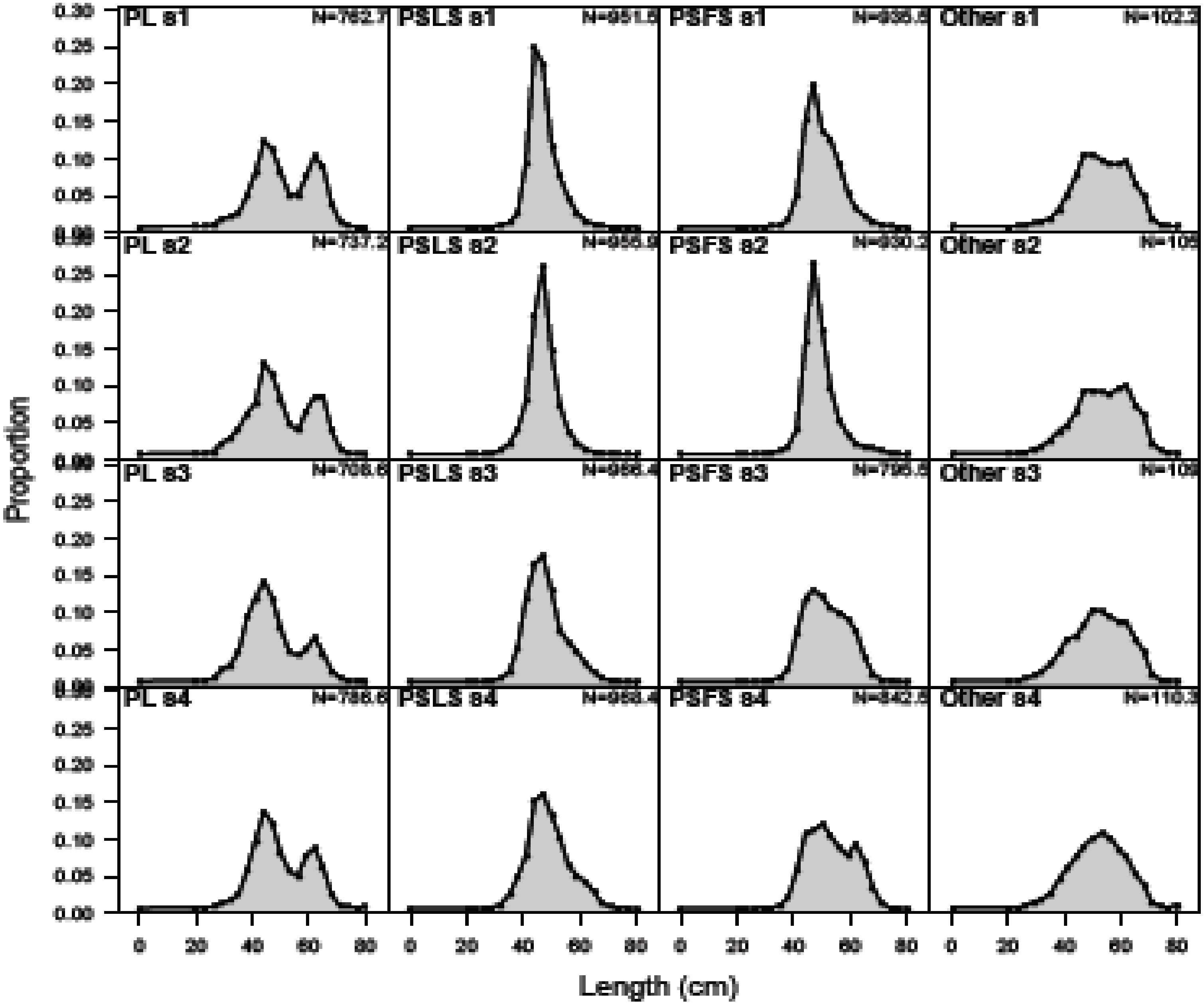


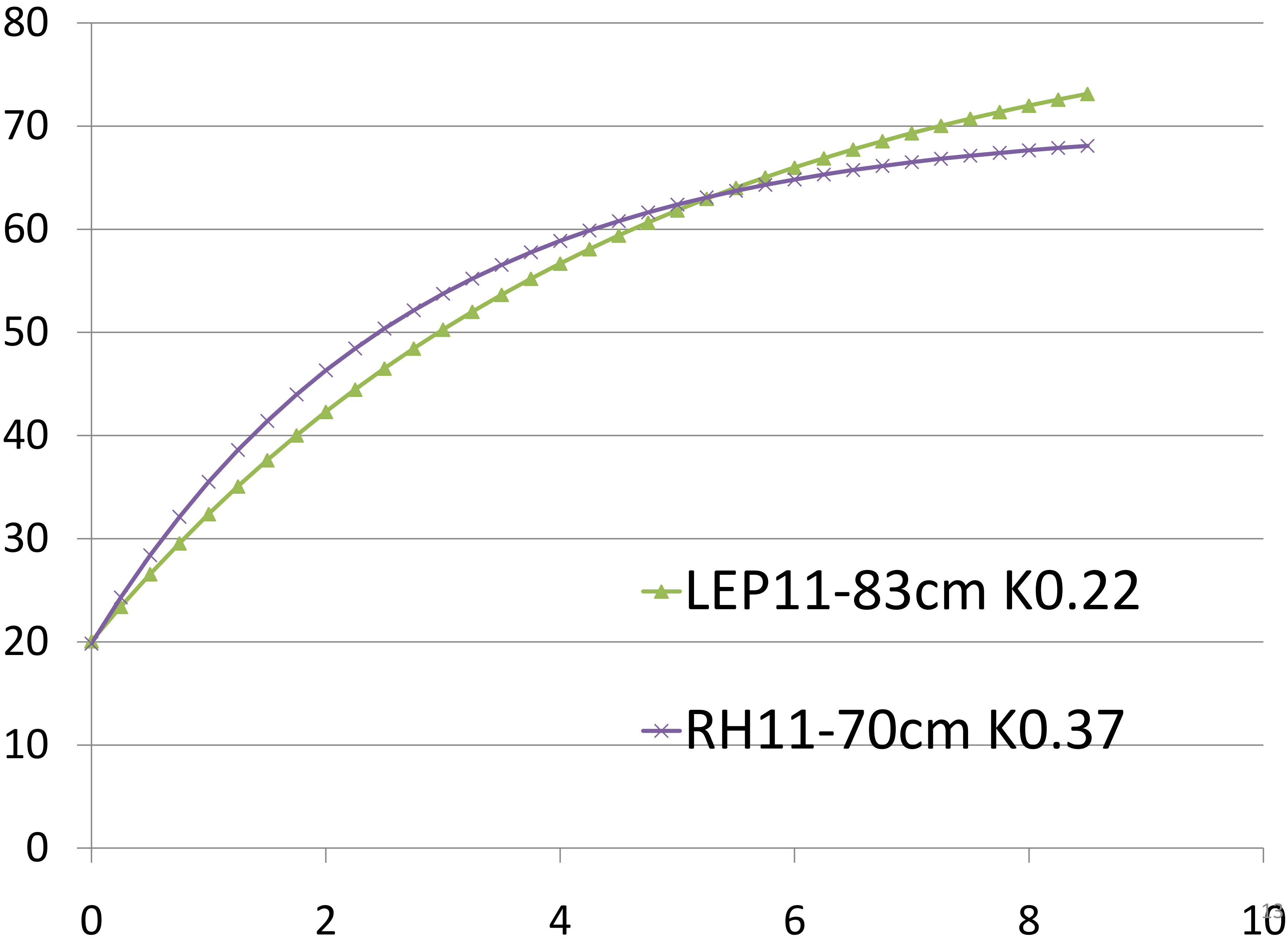
CPUE:
Standardized Maldives PL/Nominal Maldives PL
(Nominal French PSFS, Chassot et al 2011)



Note 2005-6 CPUE peak in Japanese research cruises in Eastern IO

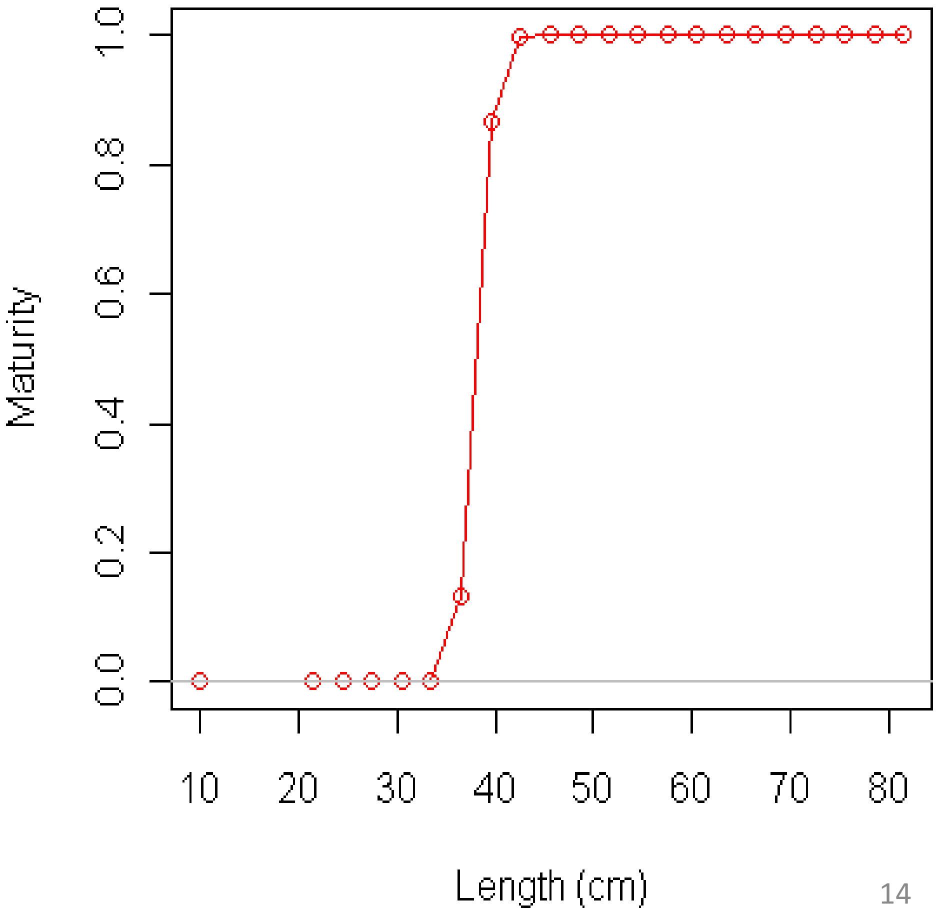
length comp data, sexes combined, whole catch,
aggregated within season by fleet




80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
LEP11-83cm K0.22
RH11-70cm K0.37

Main Assumptions:

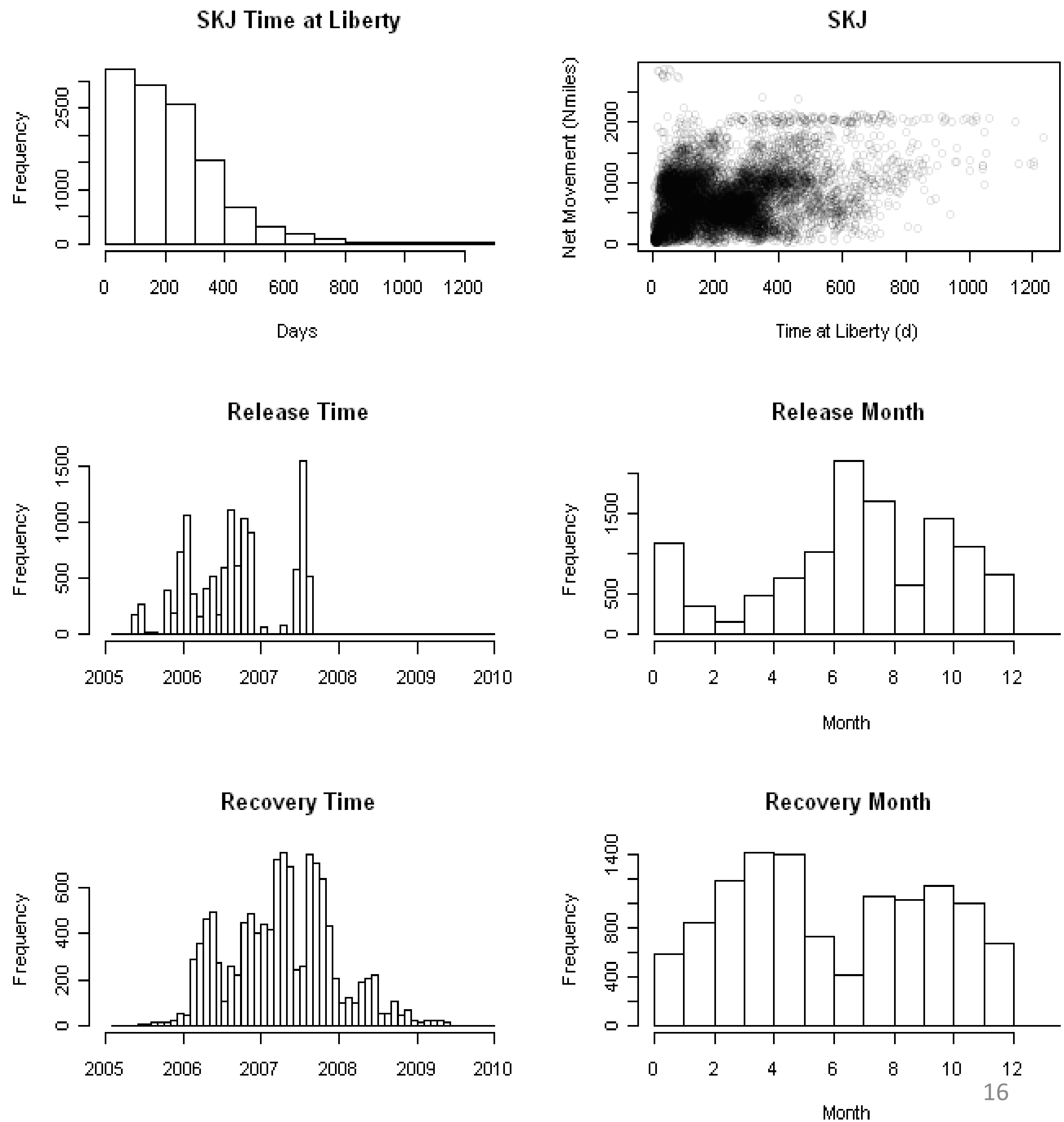
- 50% Maturity 38cm



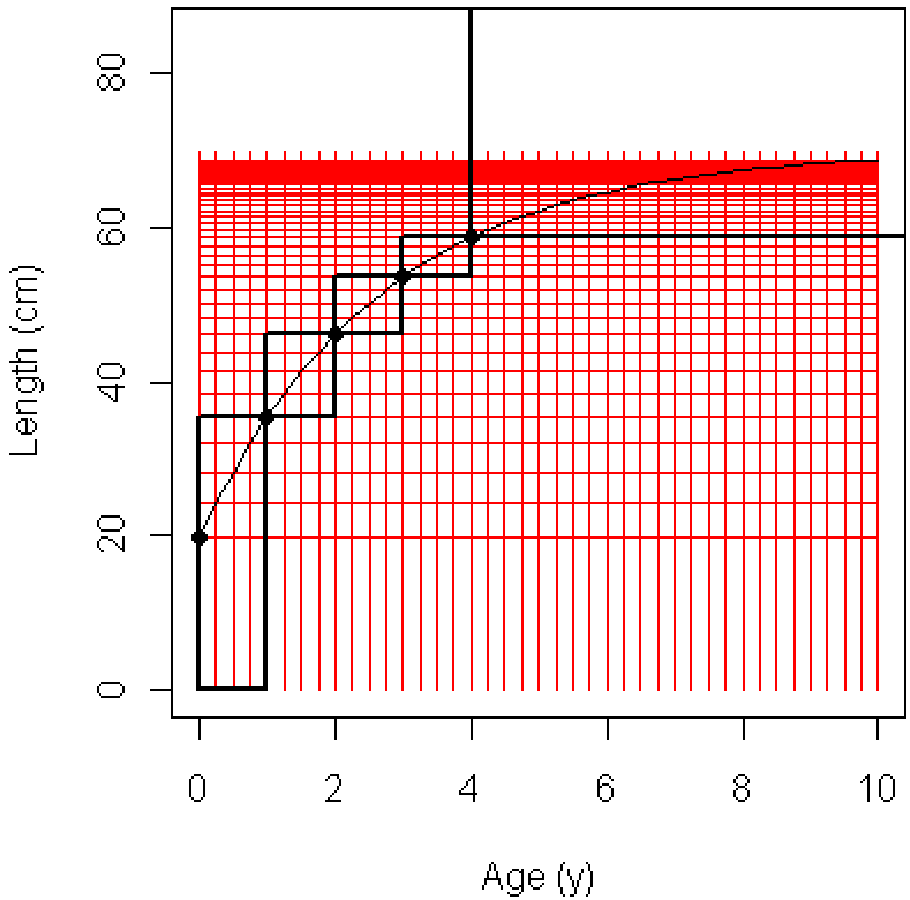
Main Assumptions: tagging program

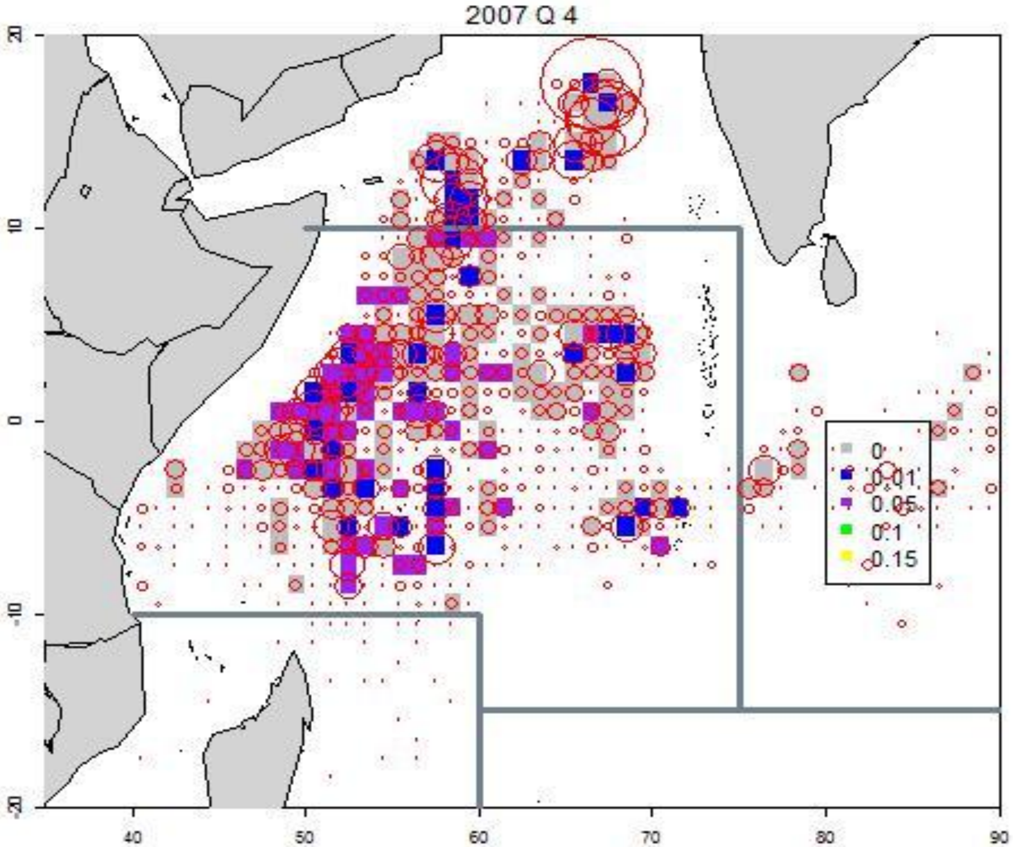
- option :
  - RTTP + small-scale (>100000 releases)
  - includes smaller fish and extends time range
  - PSFS and PSLS tag recoveries (tag seeding rep rate)
  - PL tag recoveries (estimated reporting rate)

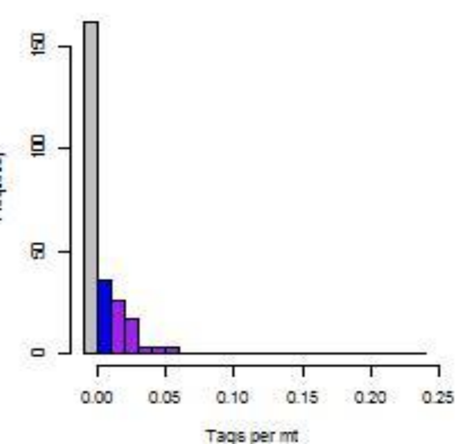
RTTP Tagging Data

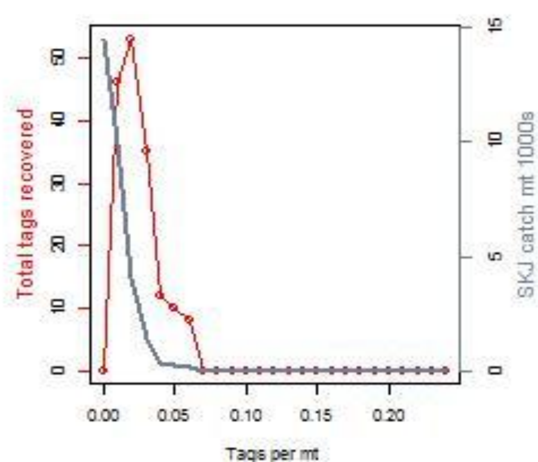


Main Assumptions: tag age estimation 'cohort-slicing' ages 0 – 4+



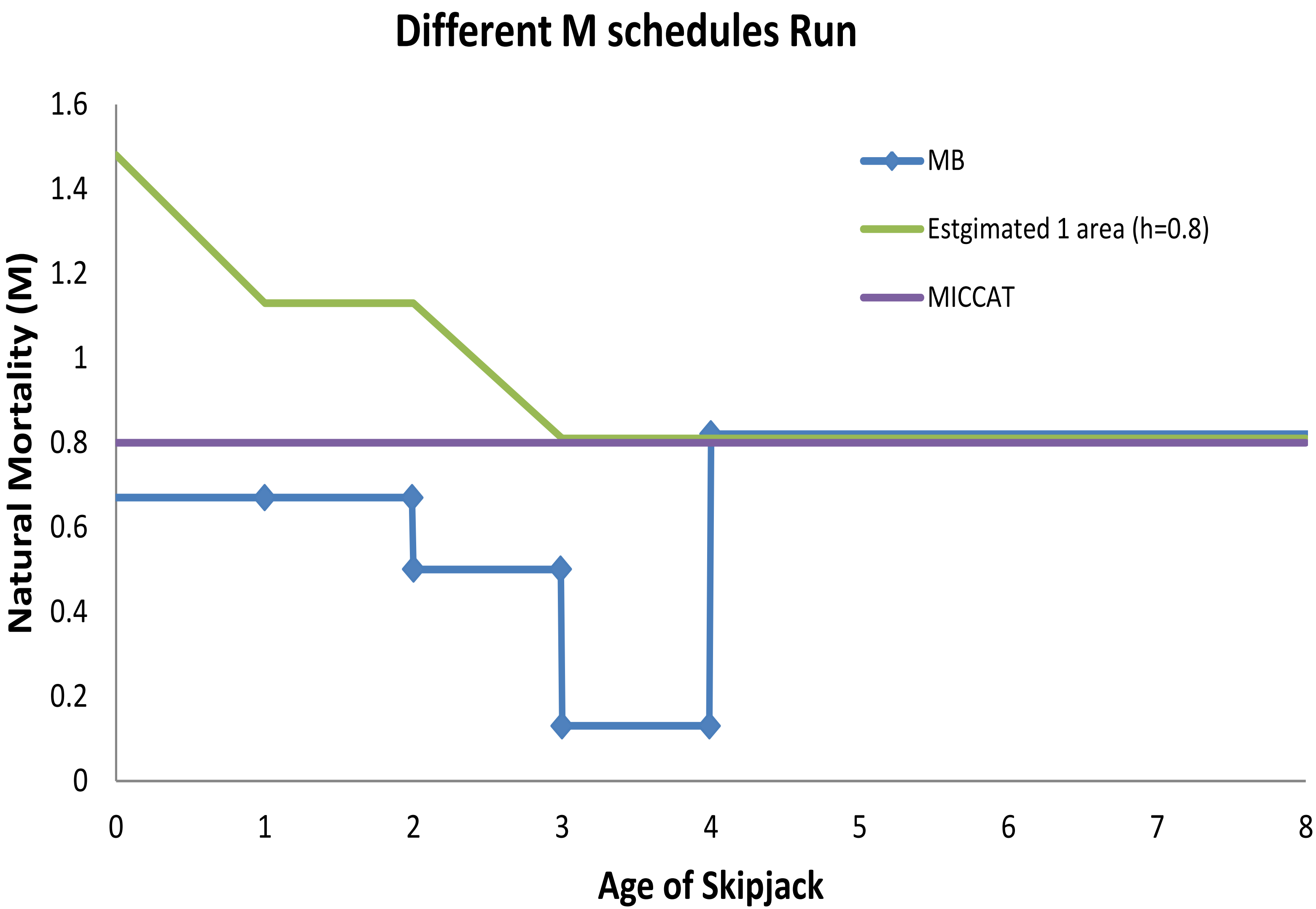






Courtesy Adam Langley

Main Assumptions: M



Main Assumptions: Selectivity

- (pseudo-) length based cubic spline
- independent for each fleet
- Options examined:
  - Stationary
  - Time variant by blocks
  - Time variant by year recent years (estimation problems)

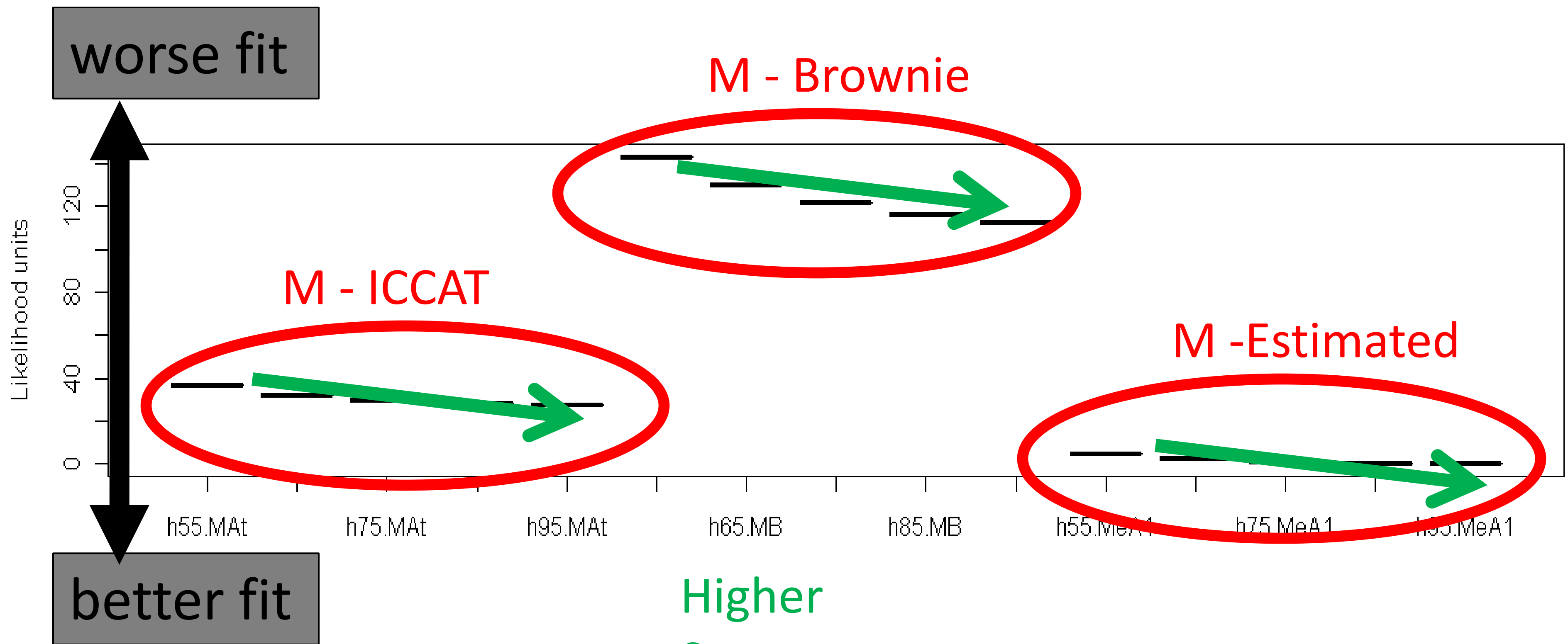
Estimated Parameters (N)

- All models:
  - Virgin recruitment (1) & SigmaR (1)
  - Selectivities (22)
  - Catchability (1-2)
- Most models
  - Seasonal recruitment distribution off annual (3).
  - Recruitment deviations (26 annual + 78 seasonal)
- Some models
  - M (3-5)
  - Tag Reporting Rate PL (1)
- 2 Area Models
  - Movement rates by season and age (32).

Results

- Kolody results (2011).
- Case (estimated M one area, M2)
- Case (estimated M 2 area, M9)
- Comparisons with Tag Data
- Case (M12 one area weighted to CPUE).
- Final recommendations.

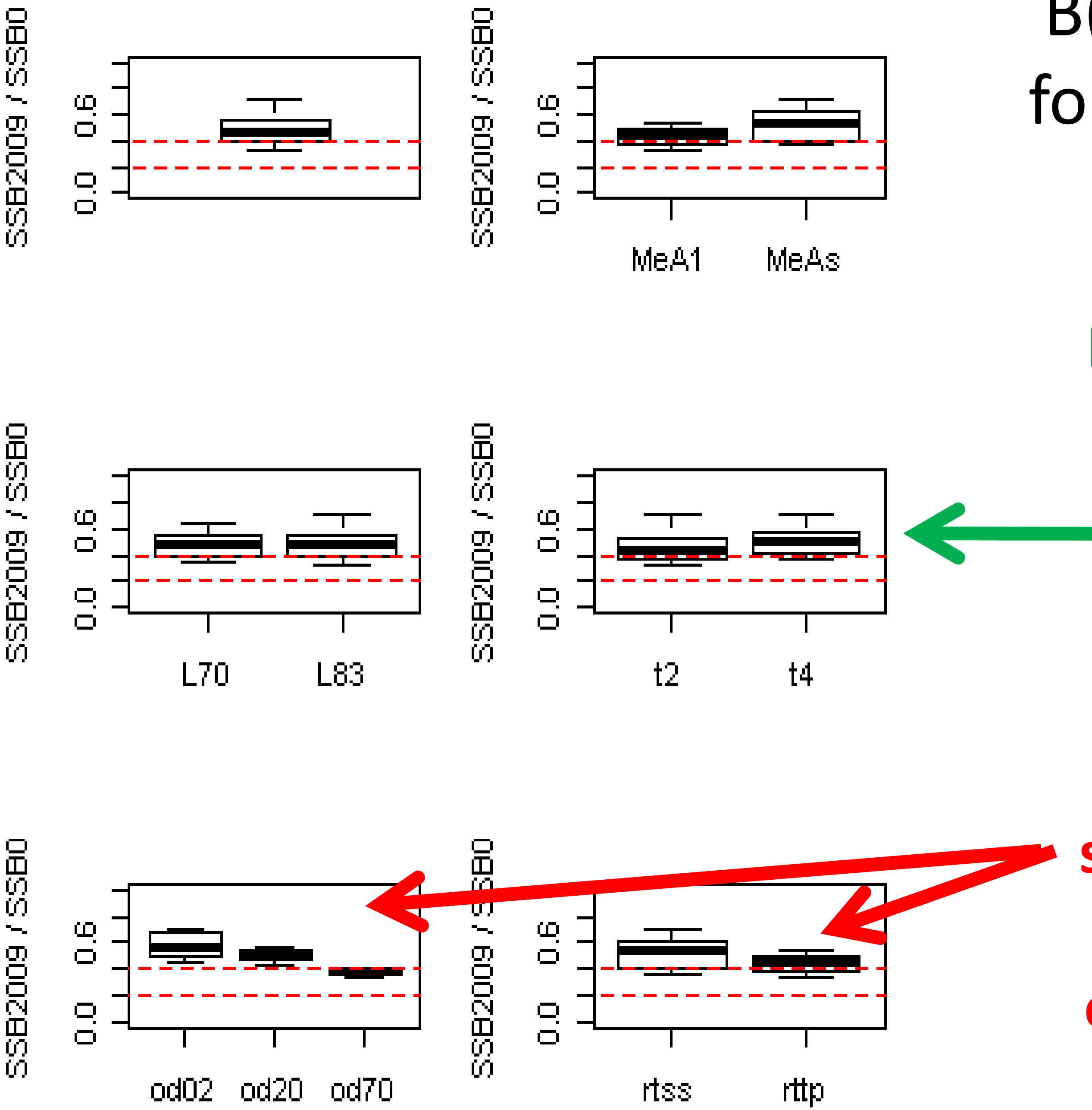
What does likelihood say about M and Steepness



Higher
Steepness
Preferred

FROM Kolody (2011)

B(2009)/B0 for grid of 24 models



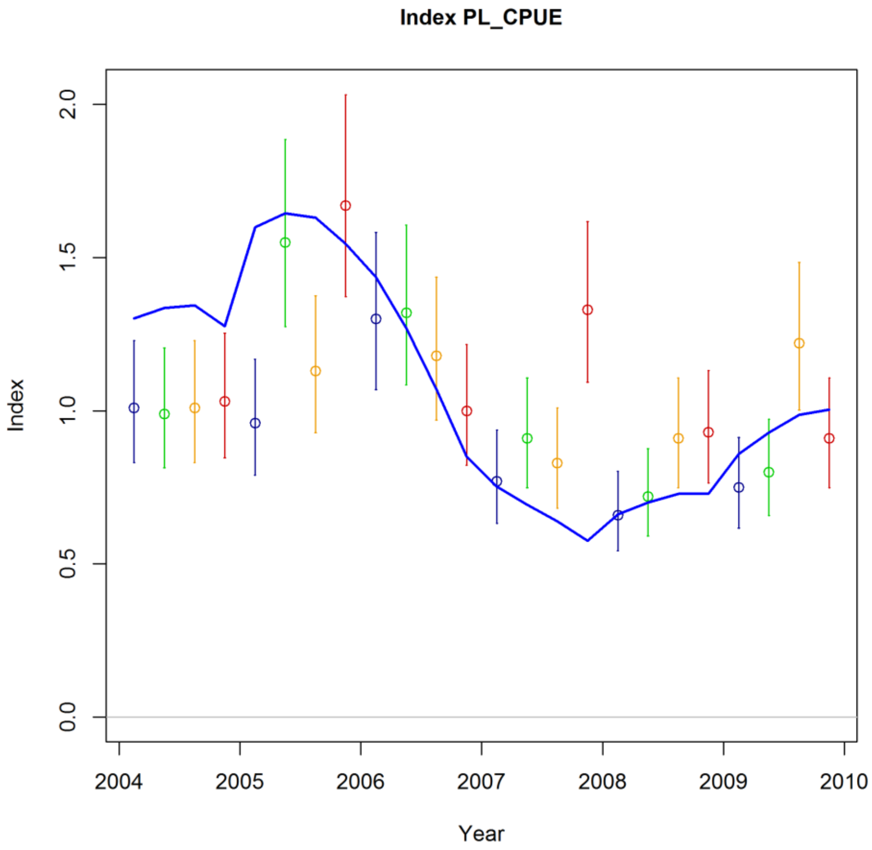
Depletion not sensitive to growth or mixing rate assumptions

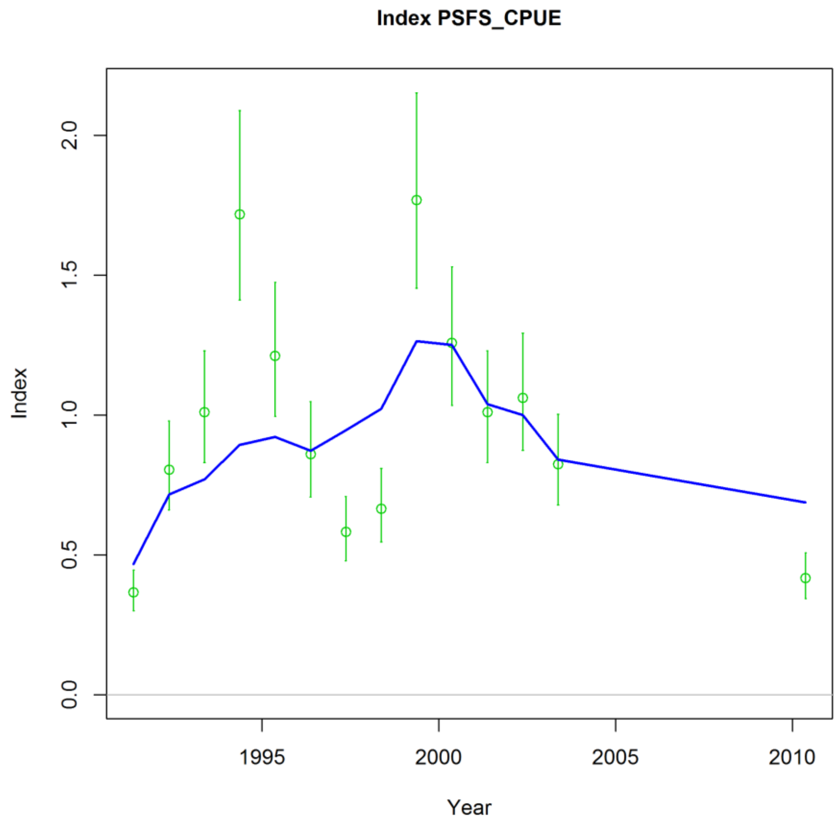
Depletion sensitive to tag program and overdispersion parameter

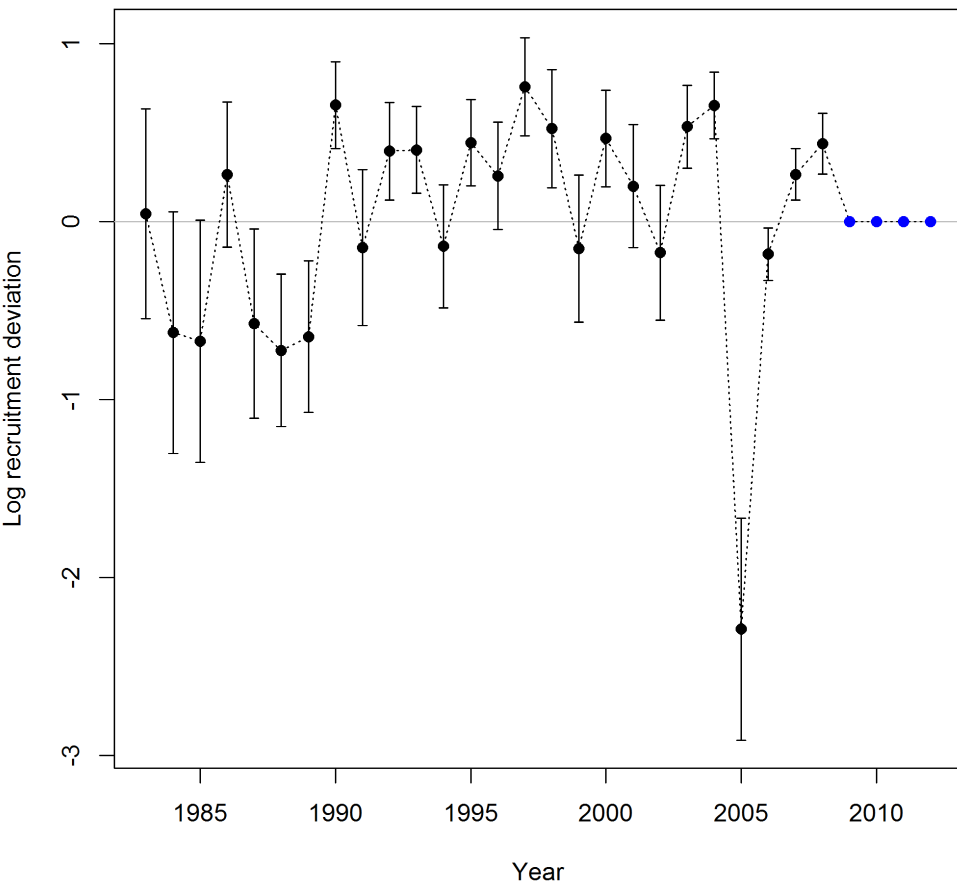
FROM Kolody (2011)

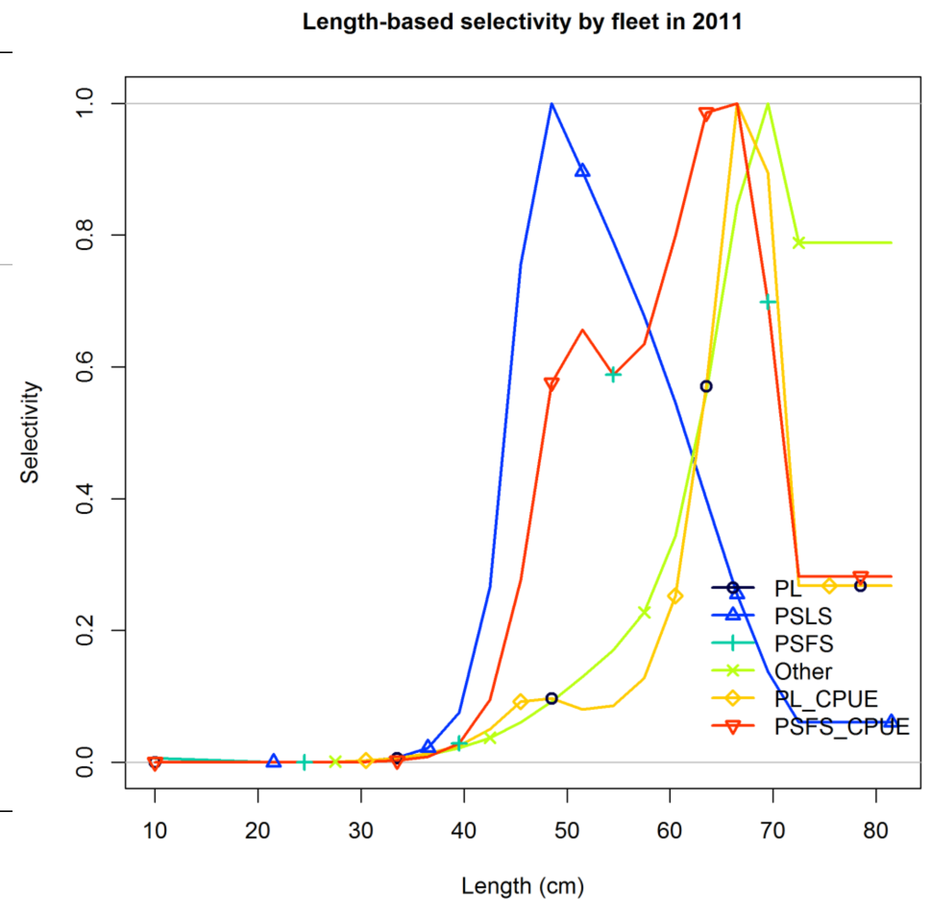
One area								
SR No.	Model Runs	B_0	B_{MSY}	C_{MSY}	B_{2011}/B_{MSY} **	F_{2011}/F_{MSY}**	C_{2011}/C_{MSY} **	Negative (Log(Likelihood)
M1	Constant M (h= 0.8)	4189250 (359665)	1487700 (142052)	1039160 (92711)	1.89 (0.12)	0.23 (0.02)	0.39 (0.03)	8087
M2	Estimated M (h= 0.8)	2069460 (95337)	868006 (51395)	416844 (28213)	1.47 (0.11)	0.73 (0.04)	0.96 (0.06)	8041
M3	Brownie M (h= 0.8)	8331810 (583049)	1939060 (137275)	1497250 (104574)	4.31 (0.25)	0.08 (0.01)	0.26 (0.02)	8380
M4	Effect of Prior on Recruitment at B(0) & Recruitment deviates (Est M) (h= 0.8)	7649530 (1617090)	3115760 (671602)	1622620 (372867)	0.73 (0.1)	0.31 (0.05)	0.25 (0.05)	7957
M5	Effect of Time Varying Selectivity:PL, Est M (h= 0.8)	2093400 (109412)	871395 (58049)	415915 (31414)	1.27 (0.1)	0.9 (0.07)	0.96 (0.06)	7939
M6	Steepness (h0.55): Constant M	3679180 (367021)	1016610 (116494)	711451 (70800)	2.73 (0.19)	0.24 (0.02)	0.56 (0.06)	8097
M7	Steepness (h0.55) & Est M	2404980 (109301)	886605 (58390)	436316 (28040)	1.22 (0.09)	0.79 (0.05)	0.91 (0.06)	8056
Two area								
M8	Two area Assessment (Constant M, h=0.8)	4343640 (301887)	2363380 (178038)	718911 (50016)	0.84 (0.05)	0.64 (0.04)	0.55 (0.04)	7505
M9	Two area Assessment (M same as one area estimated, h=0.8)*	2076340 (419624)	1088440 (30596)	316834 (13432)	1.11 (0.06)	1.16 (0.05)	1.25 (0.05)	7494
M10	Two area Assessment 5 Point Cubic Spline PL Selectivity	4394800 (293292)	2394380 (173459)	713860 (48521)	0.84 (0.06)	0.65 (0.04)	0.56 (0.04)	7592

One Area Key results-M2

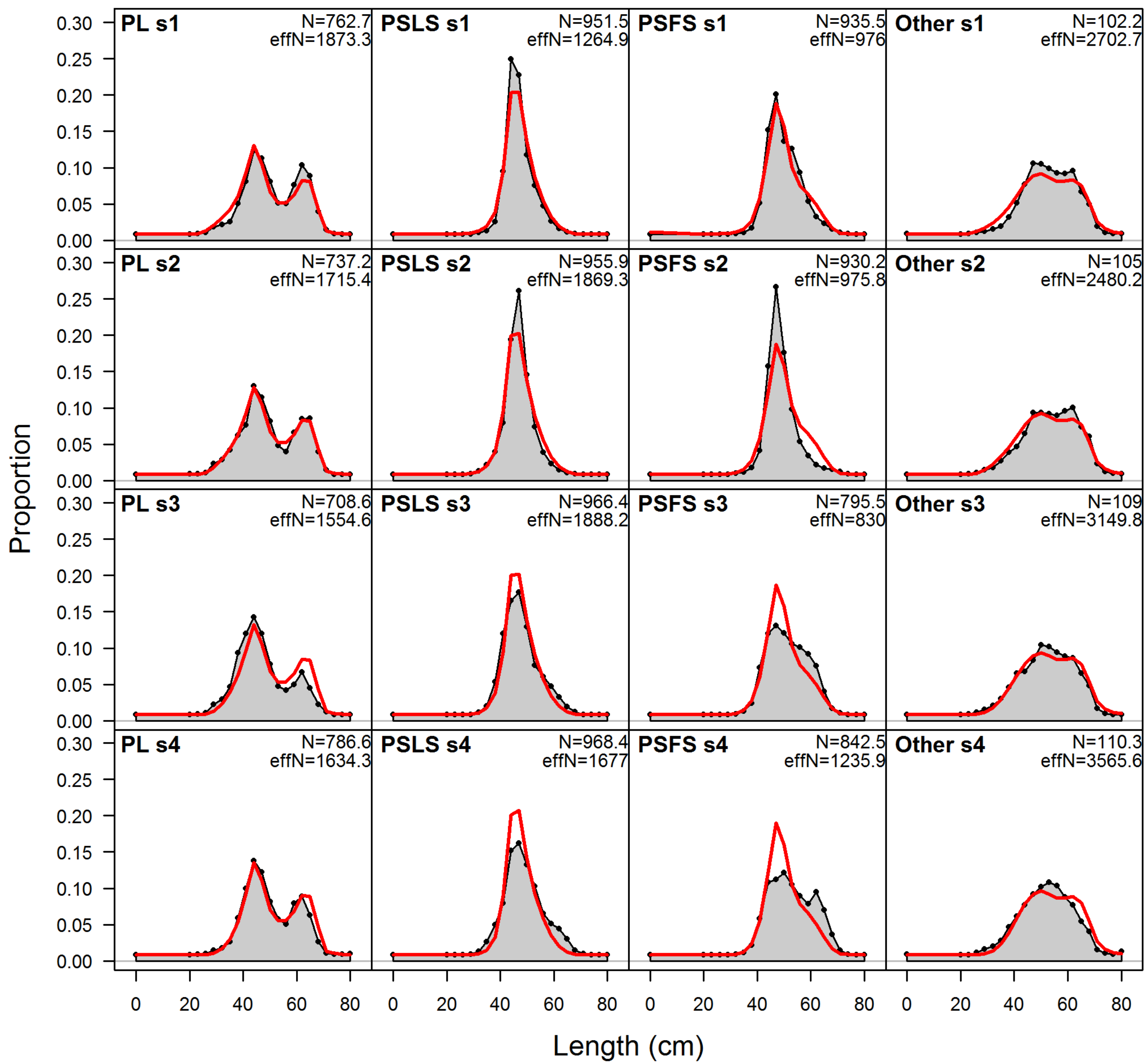


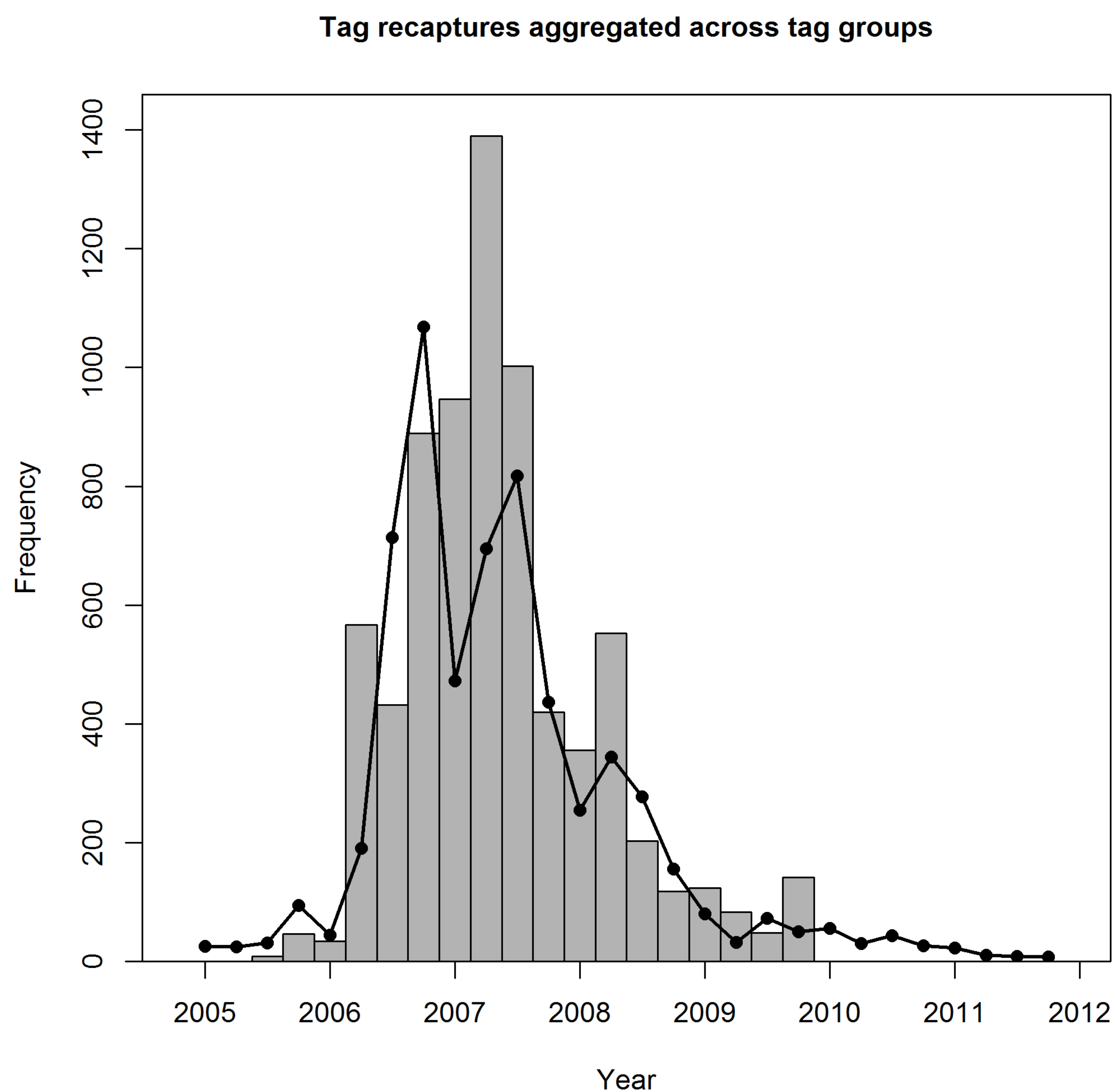


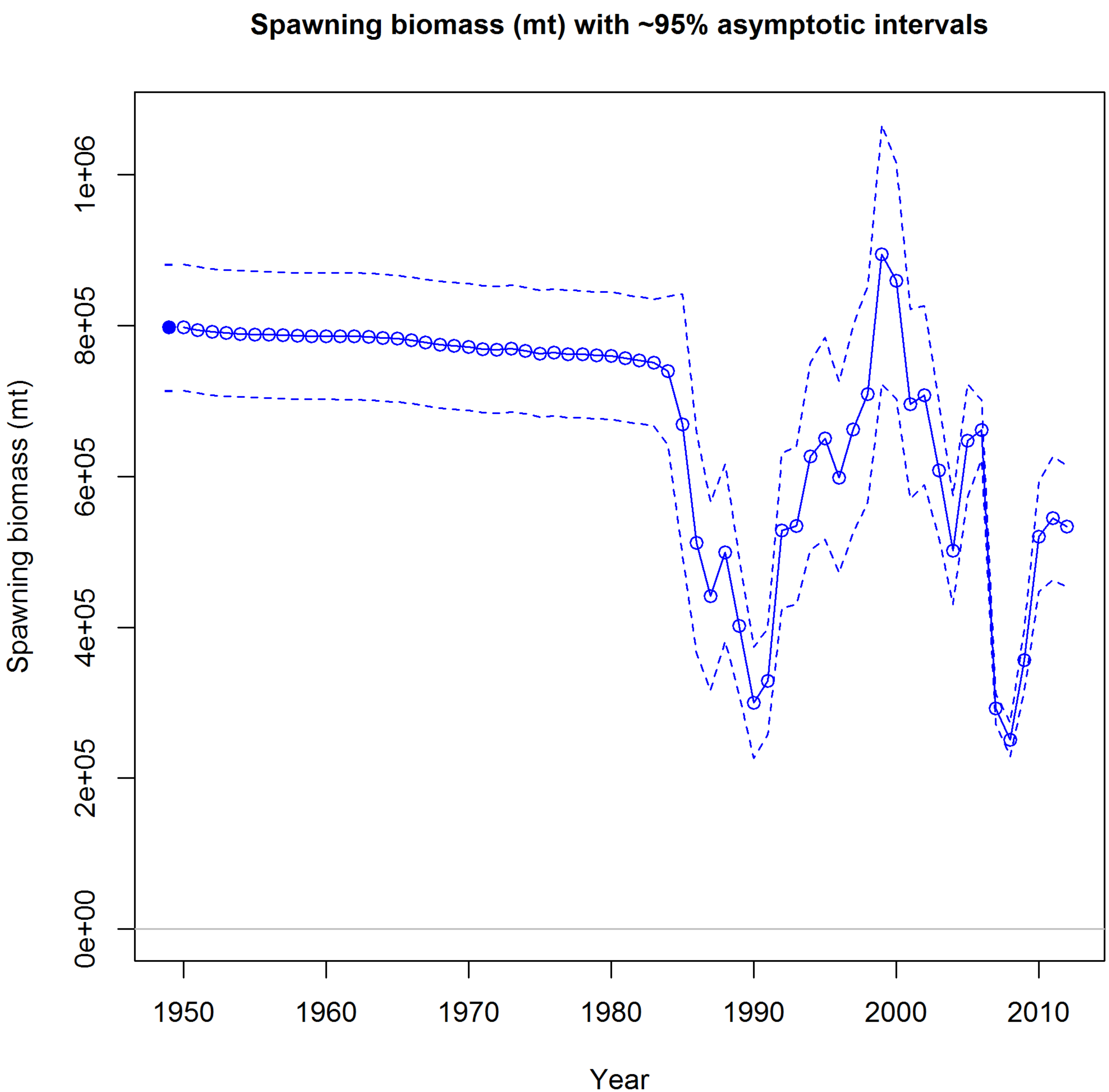

Log recruitment deviation
Year
1985
1990
1995
2000
2005
2010
1
0
-1
-2
-3


Length-based selectivity by fleet in 2011
Selectivity
Length (cm)
PL
PSLS
PSFS
Other
PL_CPUE
PSFS_CPUE

length comps, sexes combined, whole catch,
aggregated within season by fleet

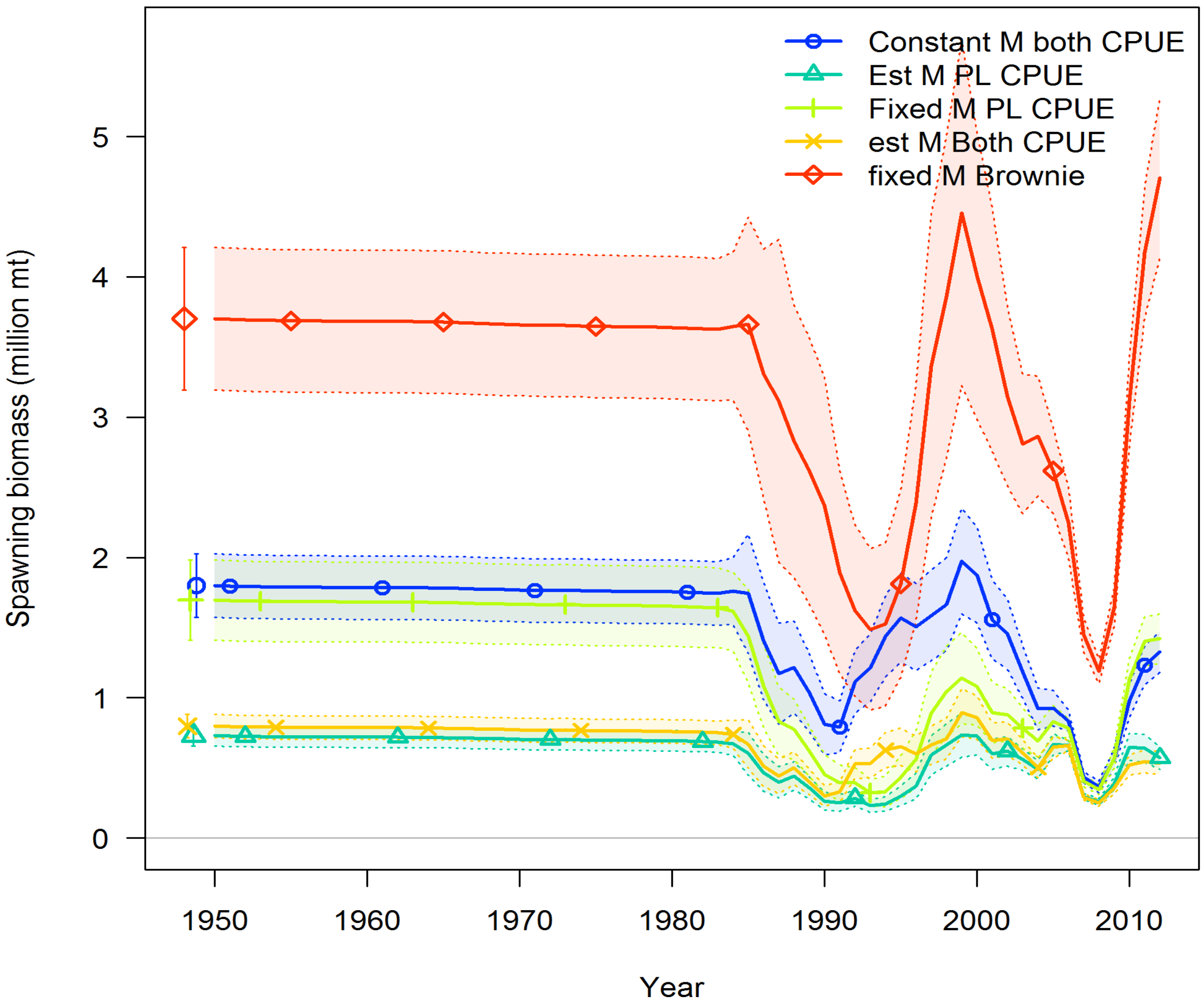



Tag recaptures aggregated across tag groups
Frequency
Year
0
200
400
600
800
1000
1200
1400
2005
2006
2007
2008
2009
2010
2011
2012

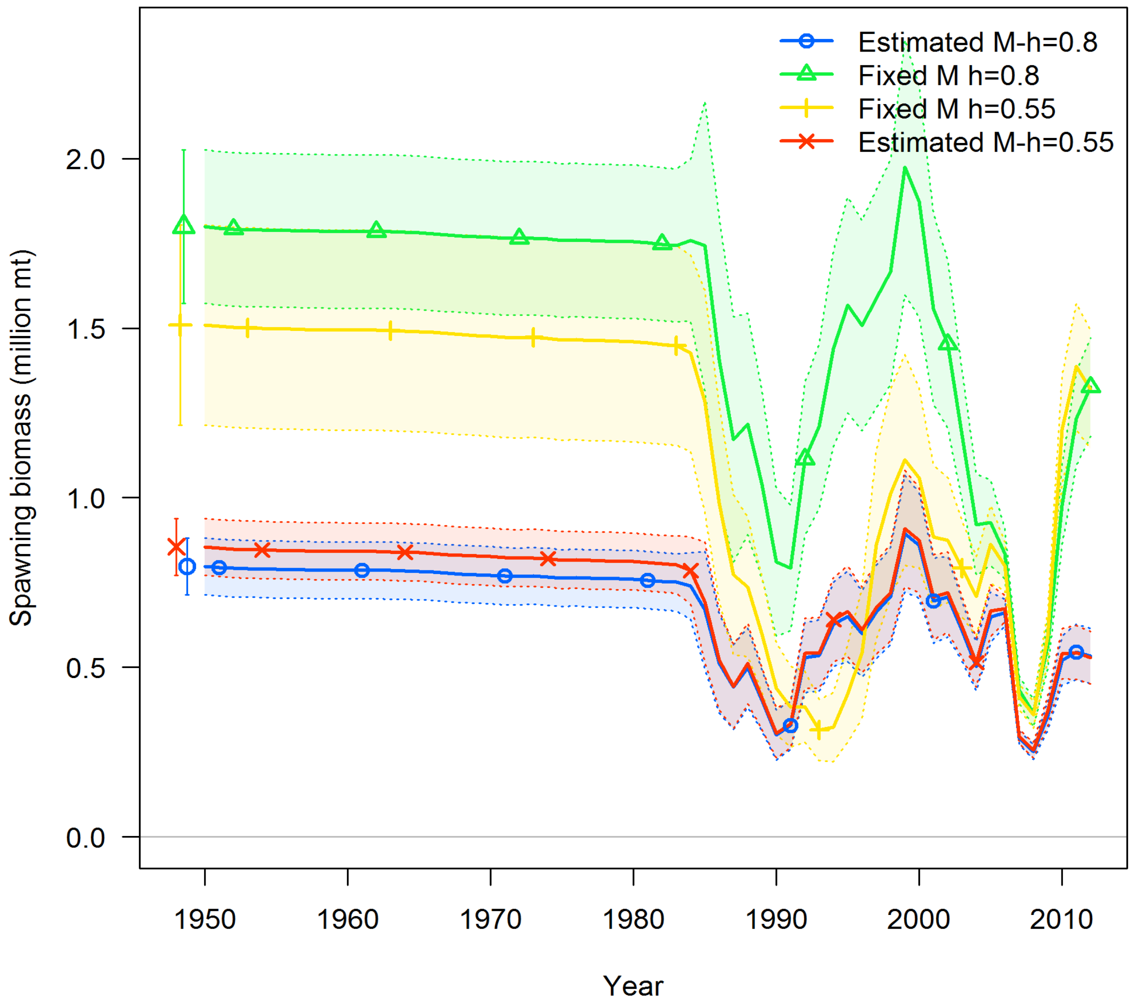


Spawning biomass (mt) with ~95% asymptotic intervals
Spawning biomass (mt)
0e+00
2e+05
4e+05
6e+05
8e+05
1e+06
1950
1960
1970
1980
1990
2000
2010
Year

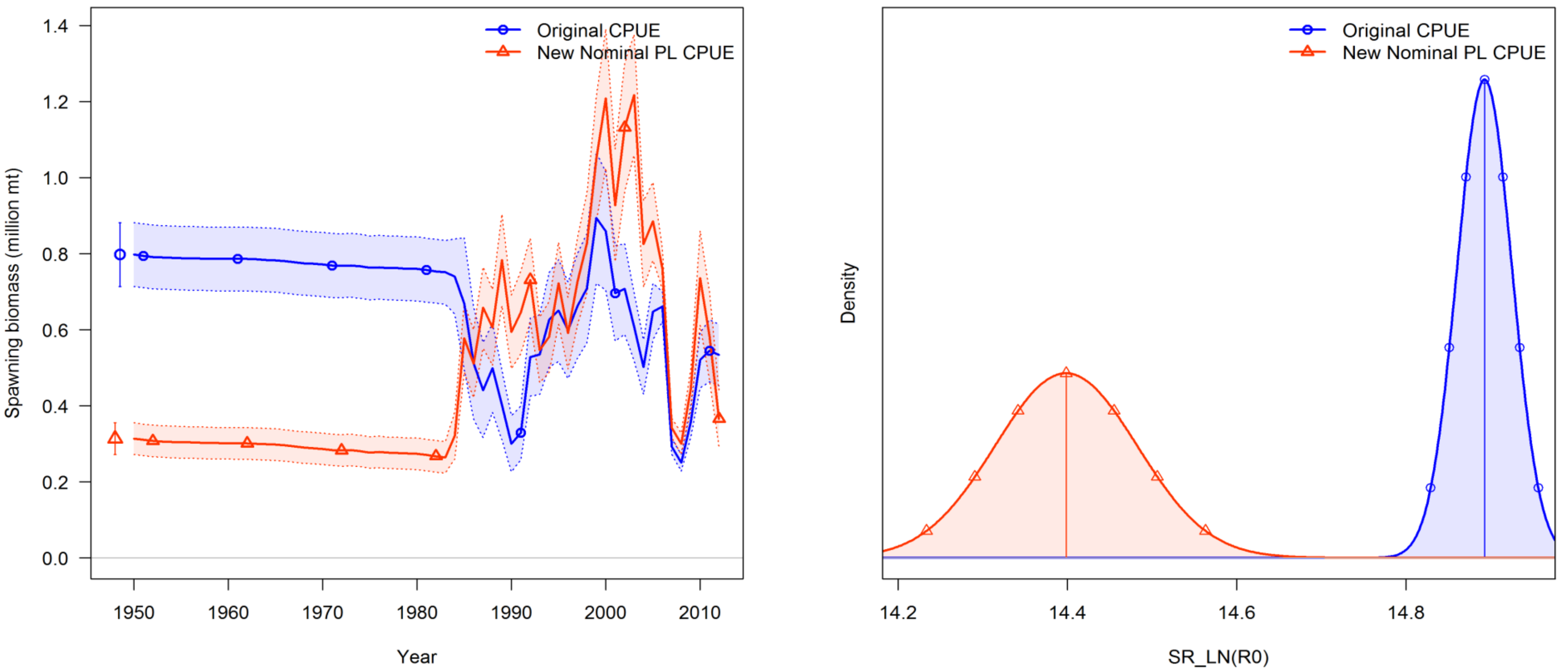
One area sensitivities-M



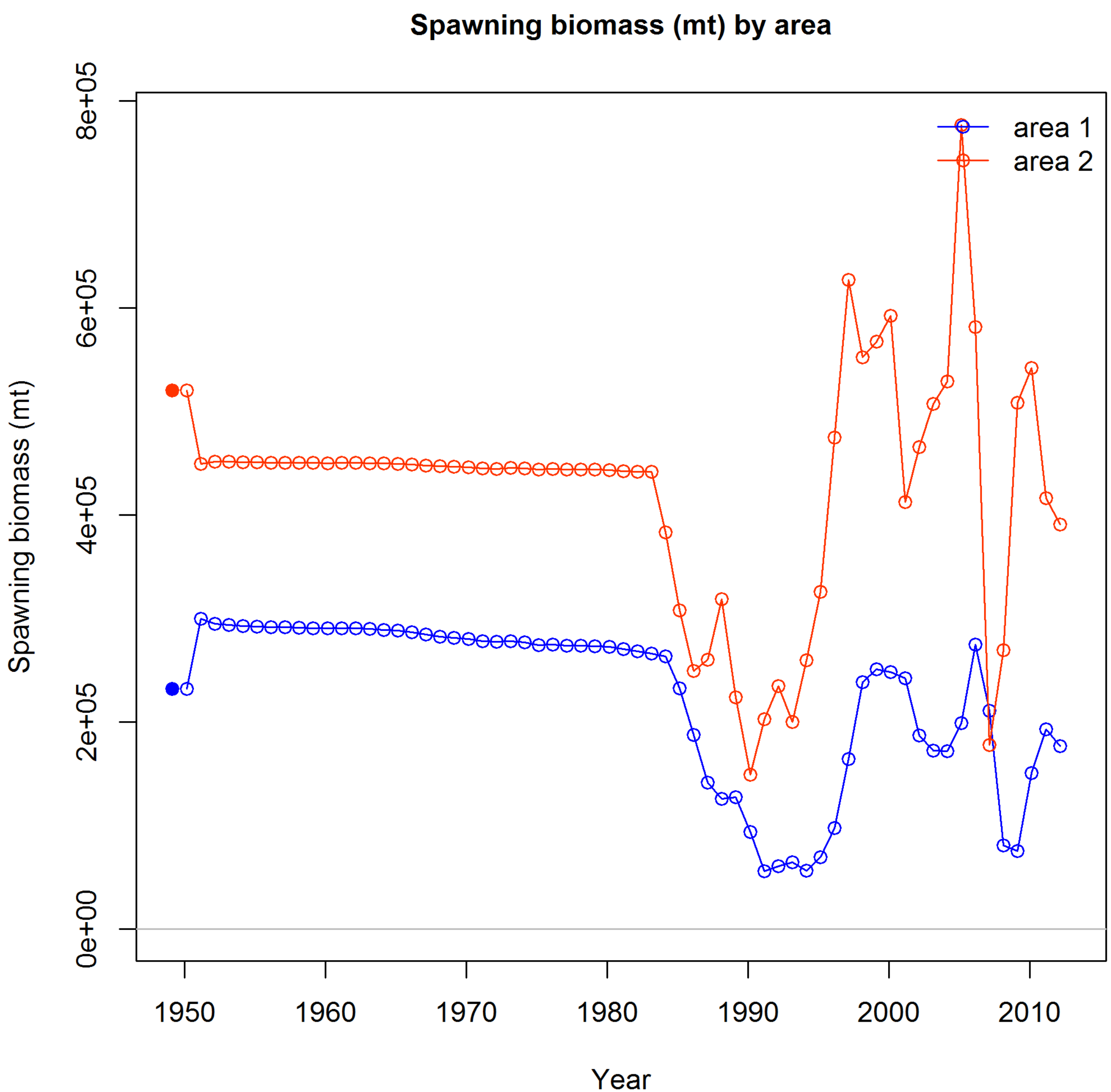
One Area Sensitivity-Interaction with steepness and M

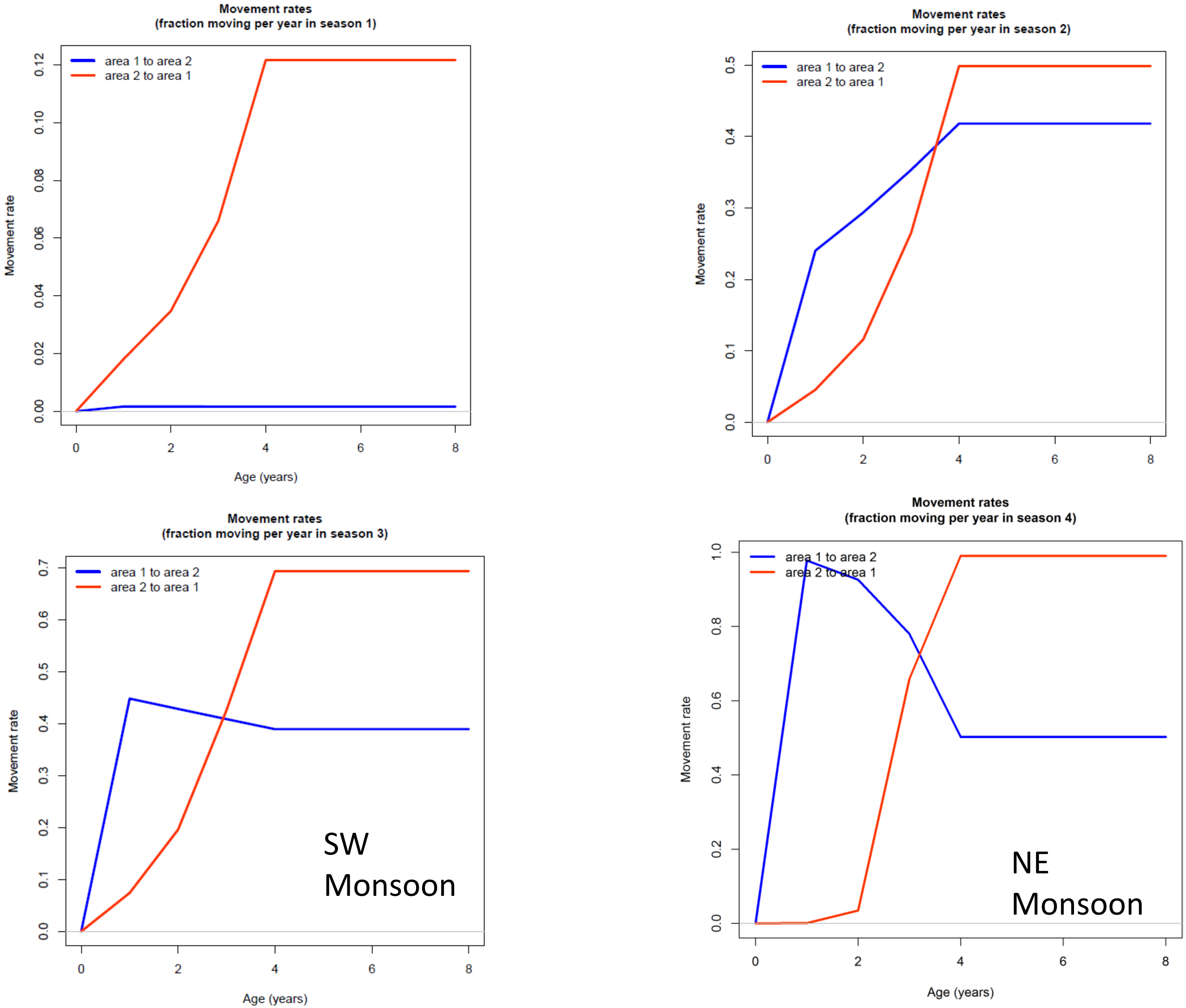


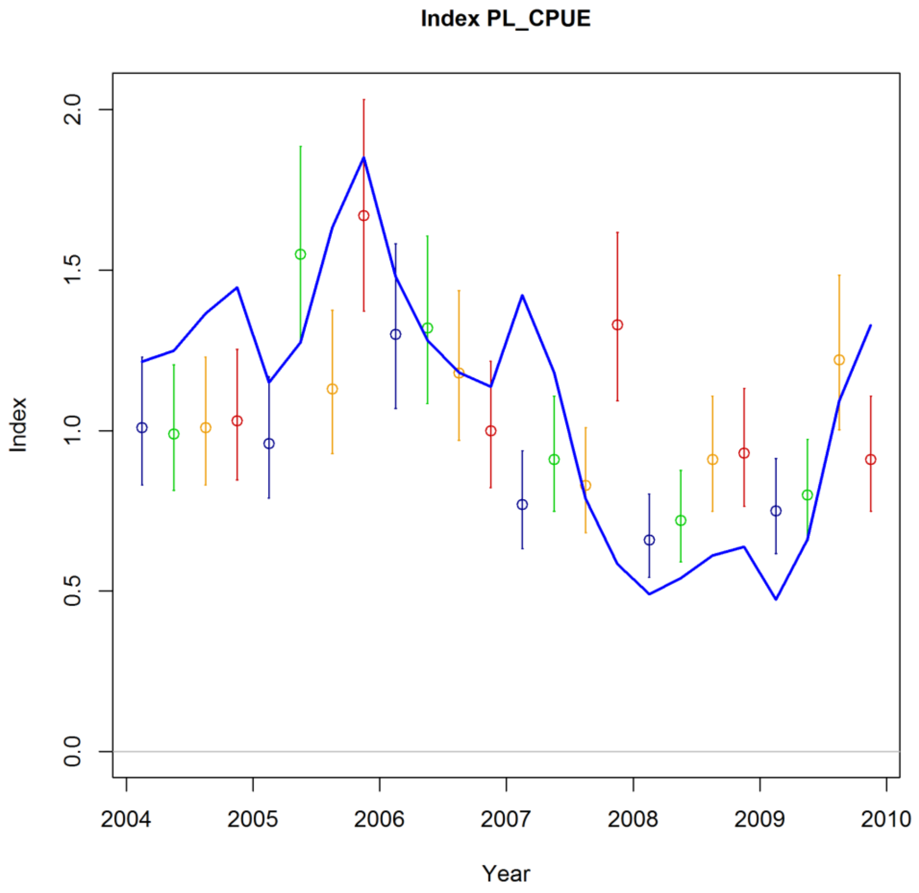
Maldives PL Nominal Index

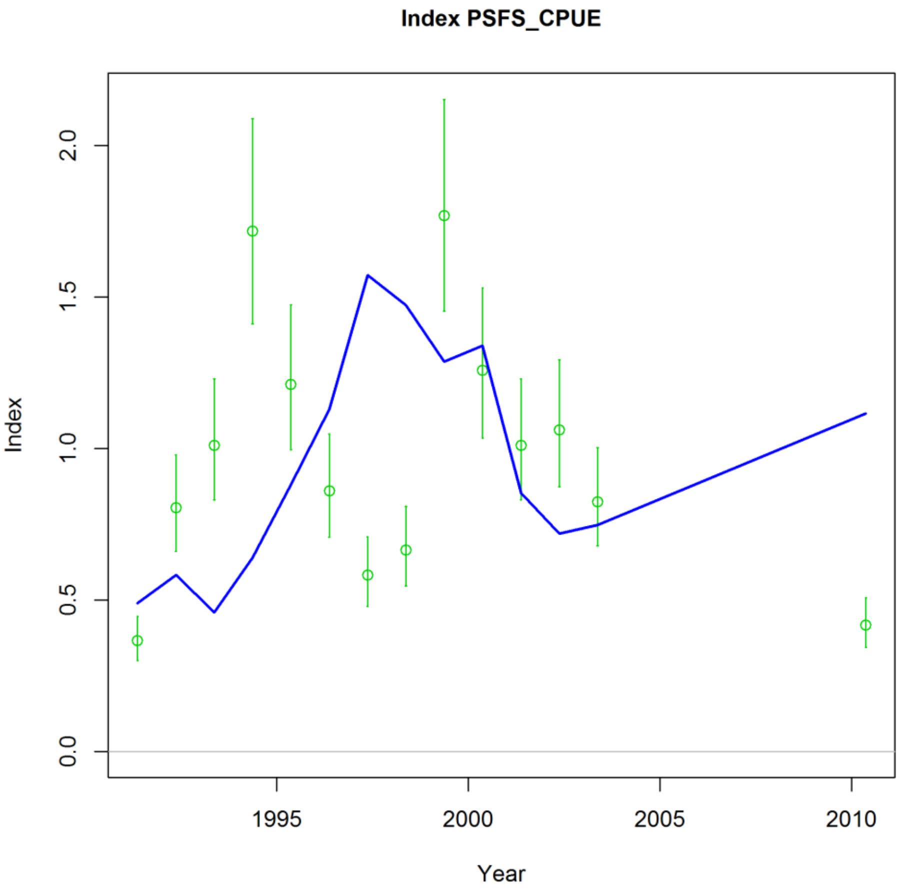


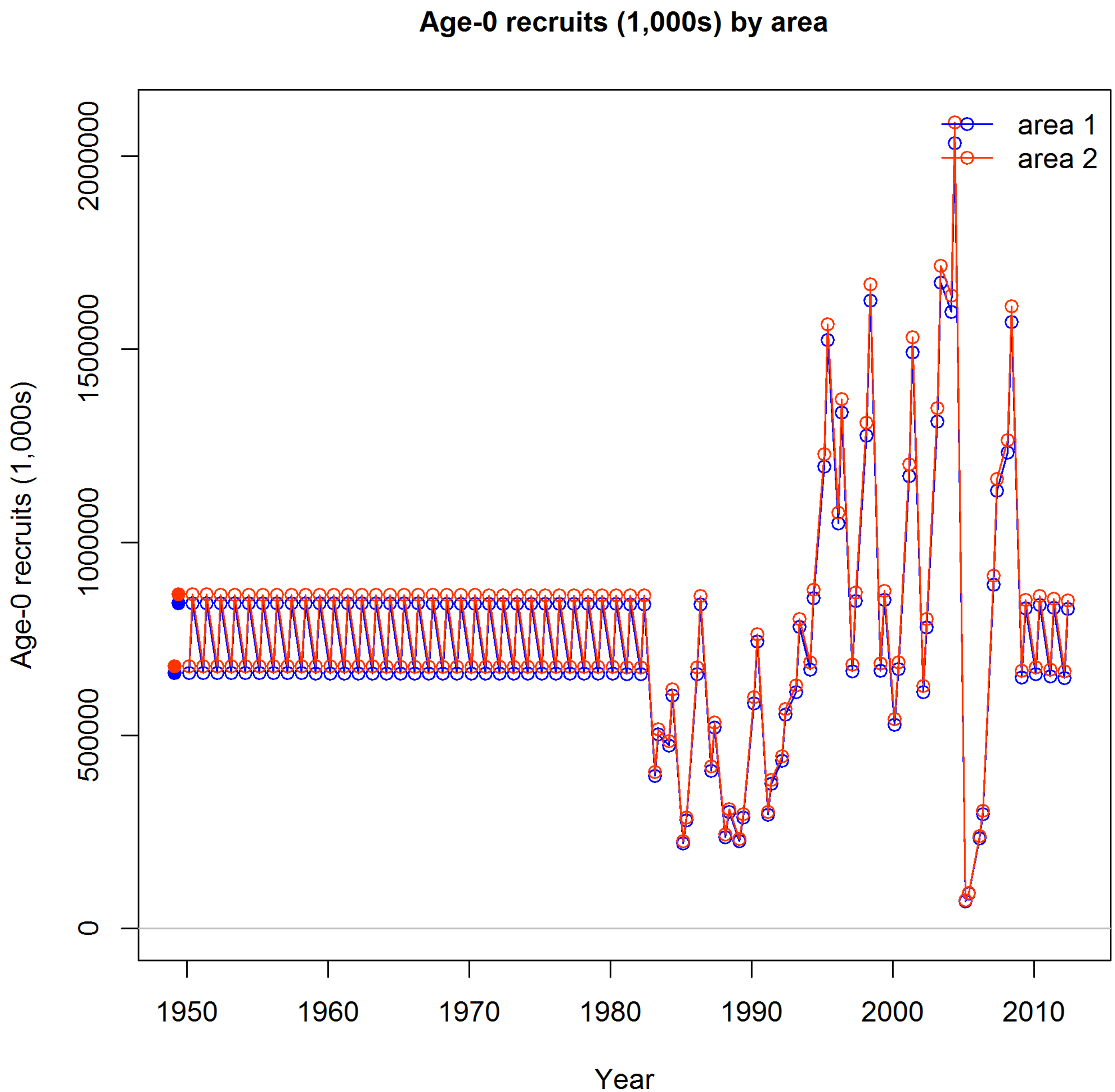
Two Area Key Results




Movement rates
(fraction moving per year in season 1)
area 1 to area 2
area 2 to area 1
Movement rate
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0
2
4
6
8
Age (years)
Movement rates
(fraction moving per year in season 2)
area 1 to area 2
area 2 to area 1
Movement rate
0.0
0.1
0.2
0.3
0.4
0.5
0
2
4
6
8
Movement rates
(fraction moving per year in season 3)
area 1 to area 2
area 2 to area 1
Movement rate
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
SW
Monsoon
0
2
4
6
8
Age (years)
Movement rates
(fraction moving per year in season 4)
area 1 to area 2
area 2 to area 1
Movement rate
0.0
0.2
0.4
0.6
0.8
1.0
NE
Monsoon
0
2
4
6
8
Age (years)

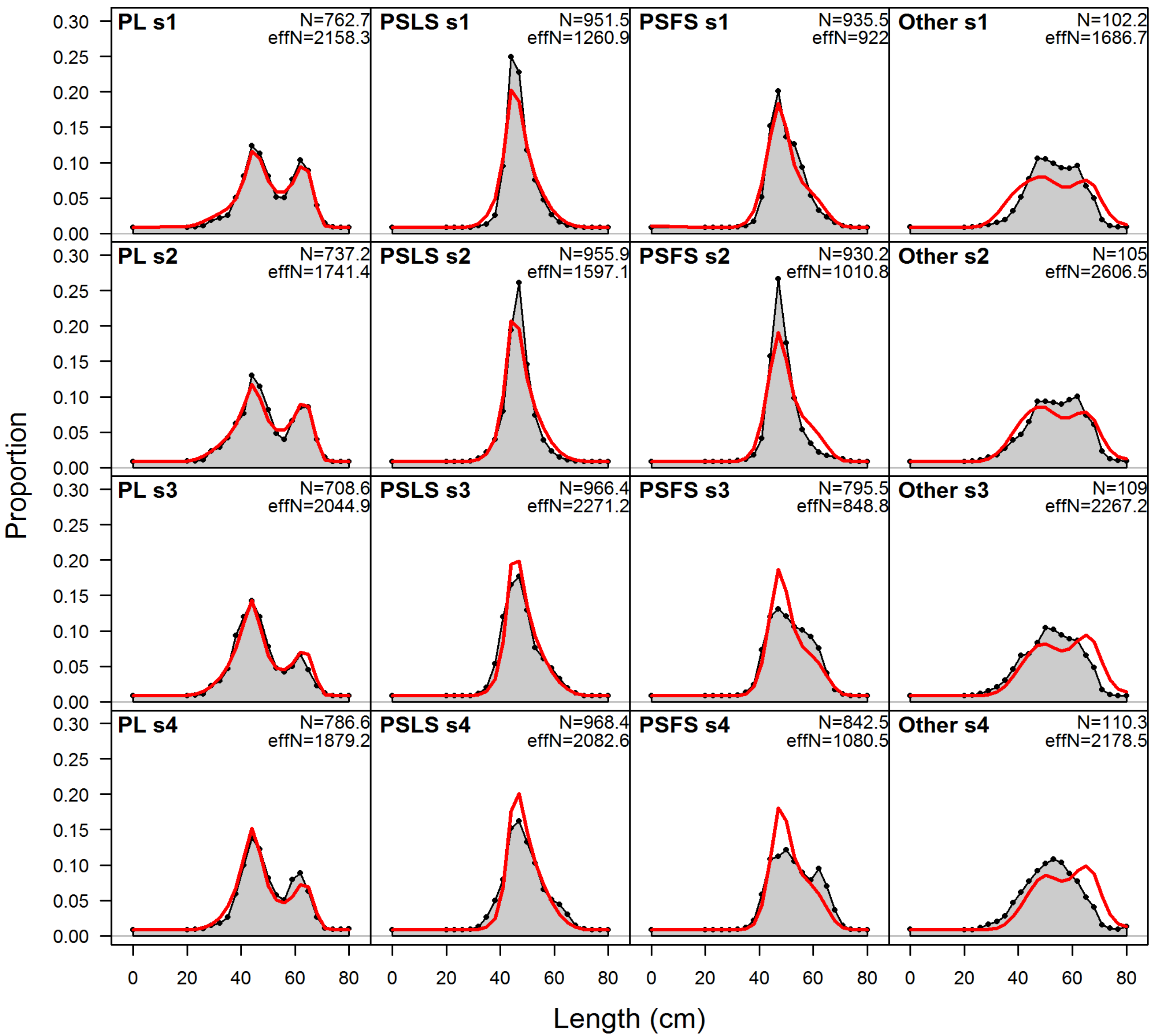

Index PL_CPUE
Index
Year
0.0
0.5
1.0
1.5
2.0
2004
2005
2006
2007
2008
2009
2010

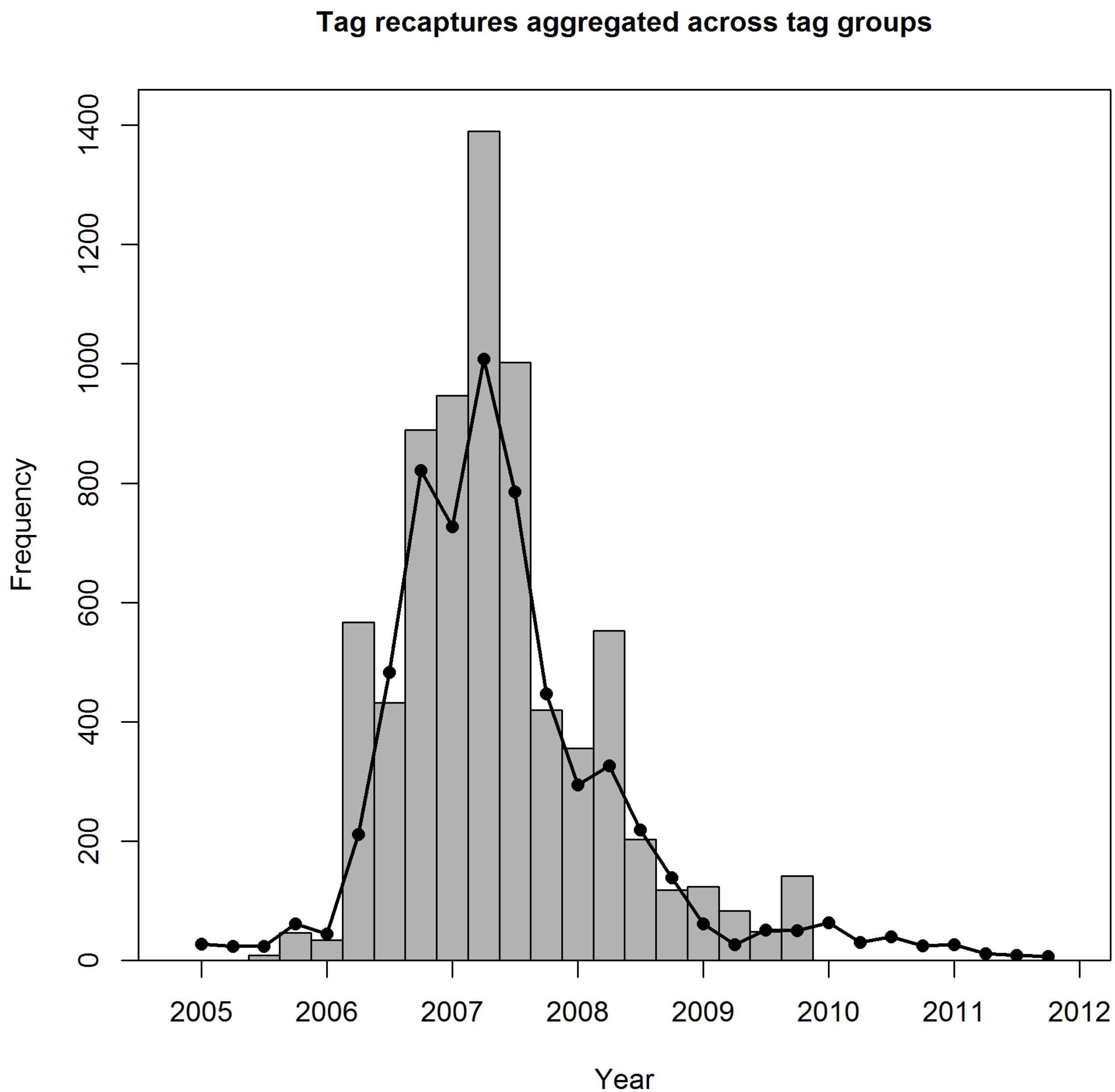

Index PSFS_CPUE
Index
Year
0.0
0.5
1.0
1.5
2.0
1995
2000
2005
2010



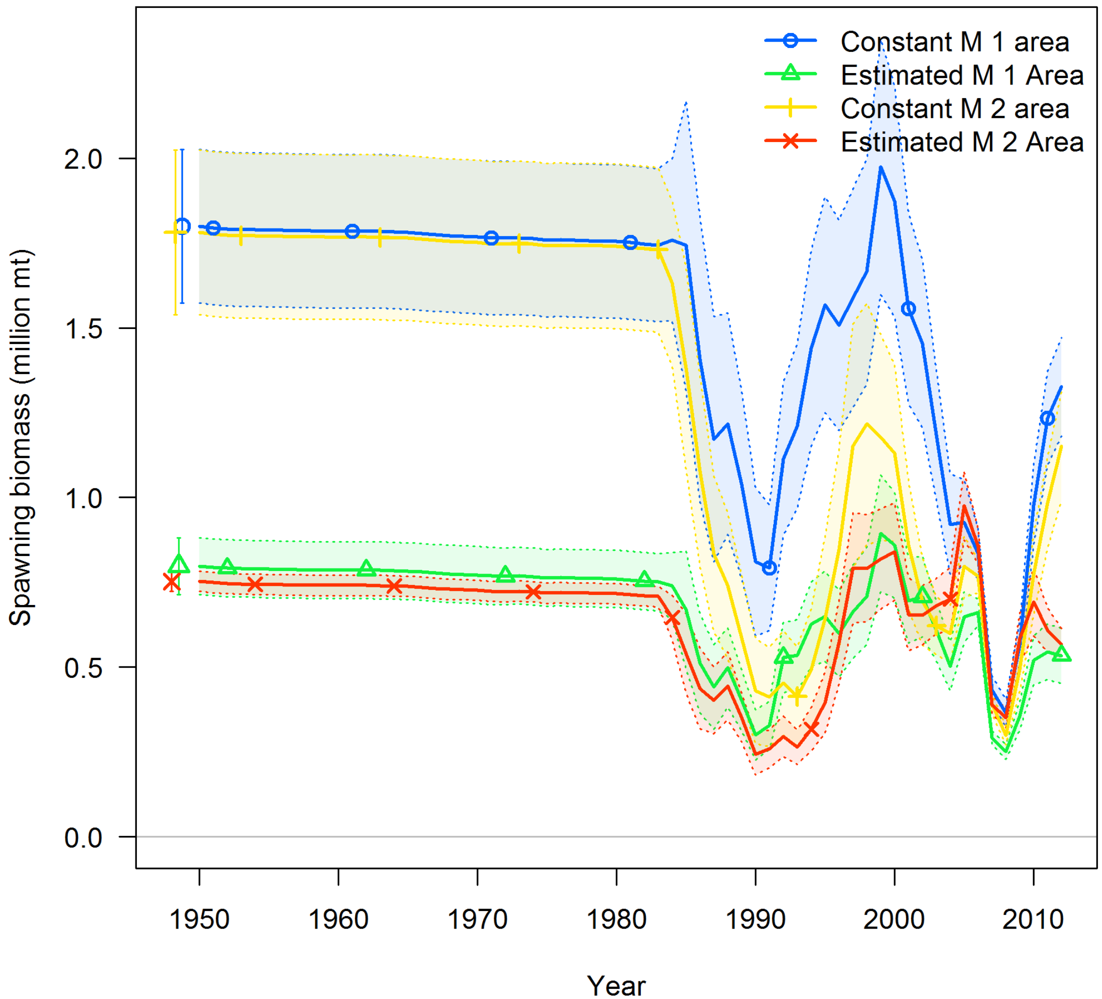
Age-0 recruits (1,000s) by area
area 1
area 2
Age-0 recruits (1,000s)
0
500000
1000000
1500000
2000000
1950
1960
1970
1980
1990
2000
2010
Year

length comps, sexes combined, whole catch, aggregated within season by fleet



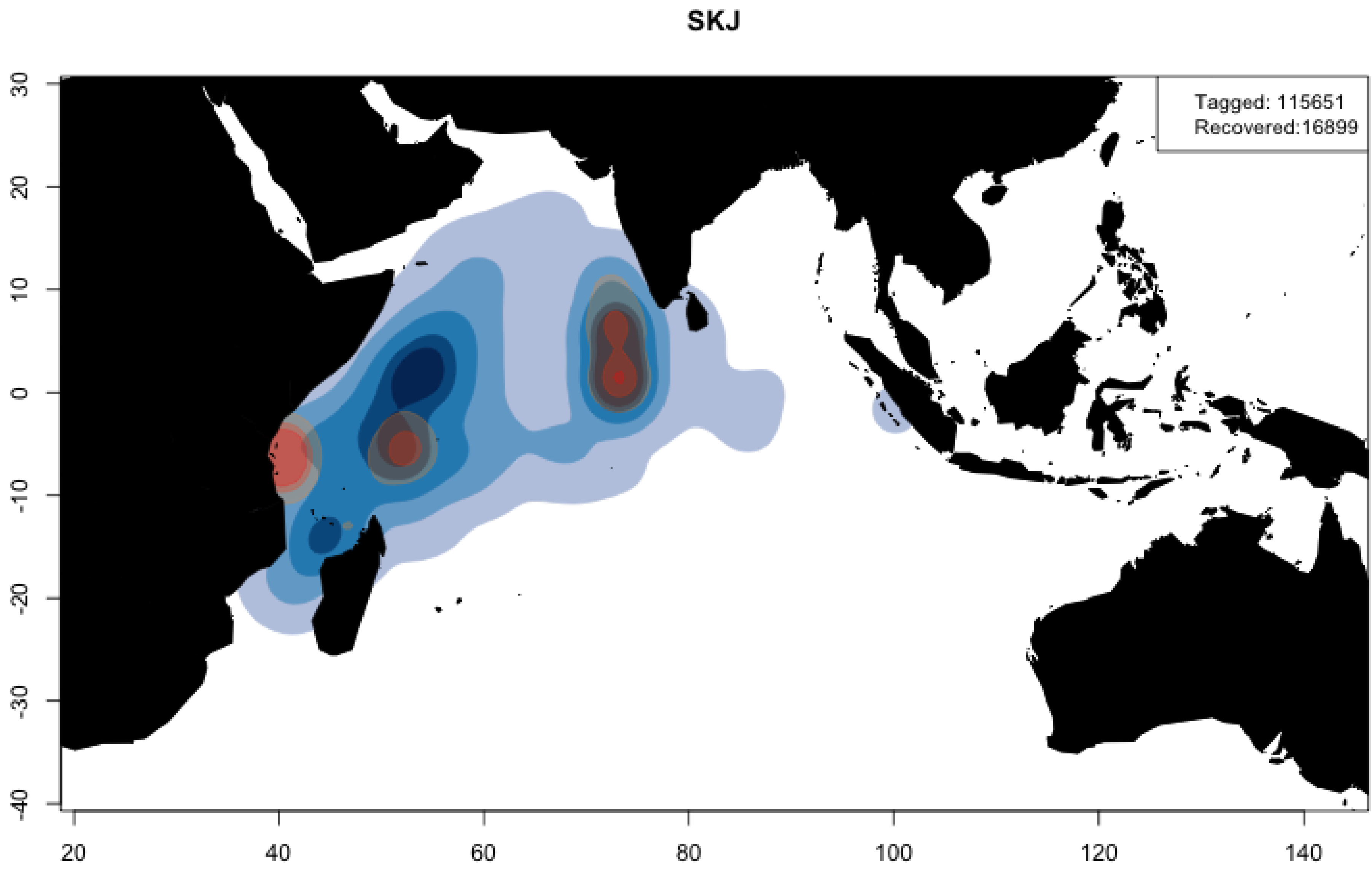

Tag recaptures aggregated across tag groups
Frequency
0
200
400
600
800
1000
1200
1400
2005
2006
2007
2008
2009
2010
2011
2012
Year

One and 2 area sensitivity



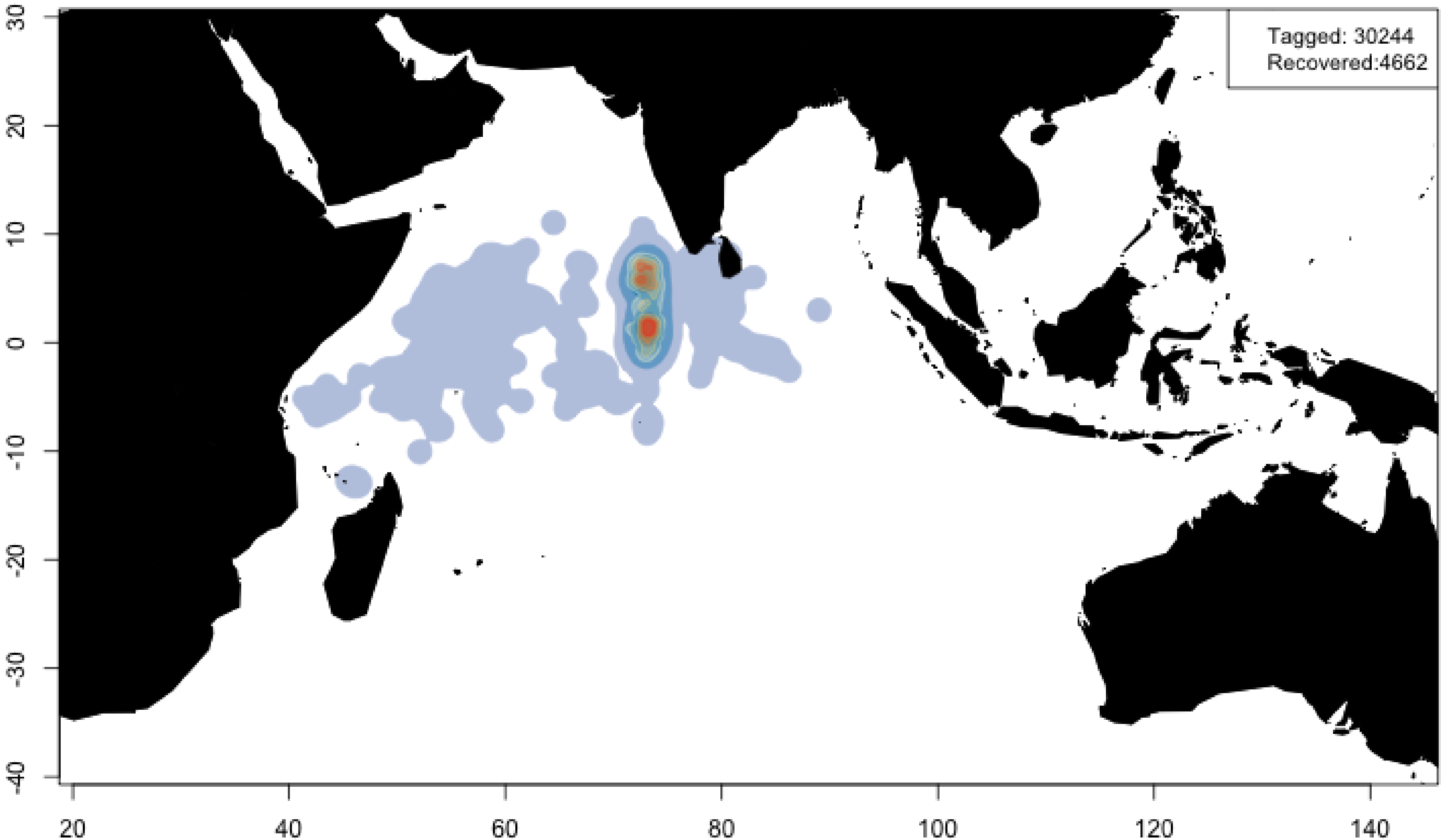
Caveats

- 1st attempt to do this simultaneously.
- The F MSY are complicated to calculate as we have different available Biomass in each area and different fisheries operating (assume last period selectivity and based on available Biomass).
- Splitting inevitably provides higher reference points for management (should be interpreted with caution).
- Movement across regions are sensitive to tags recovered and the reporting rates (which are few tags across regions).

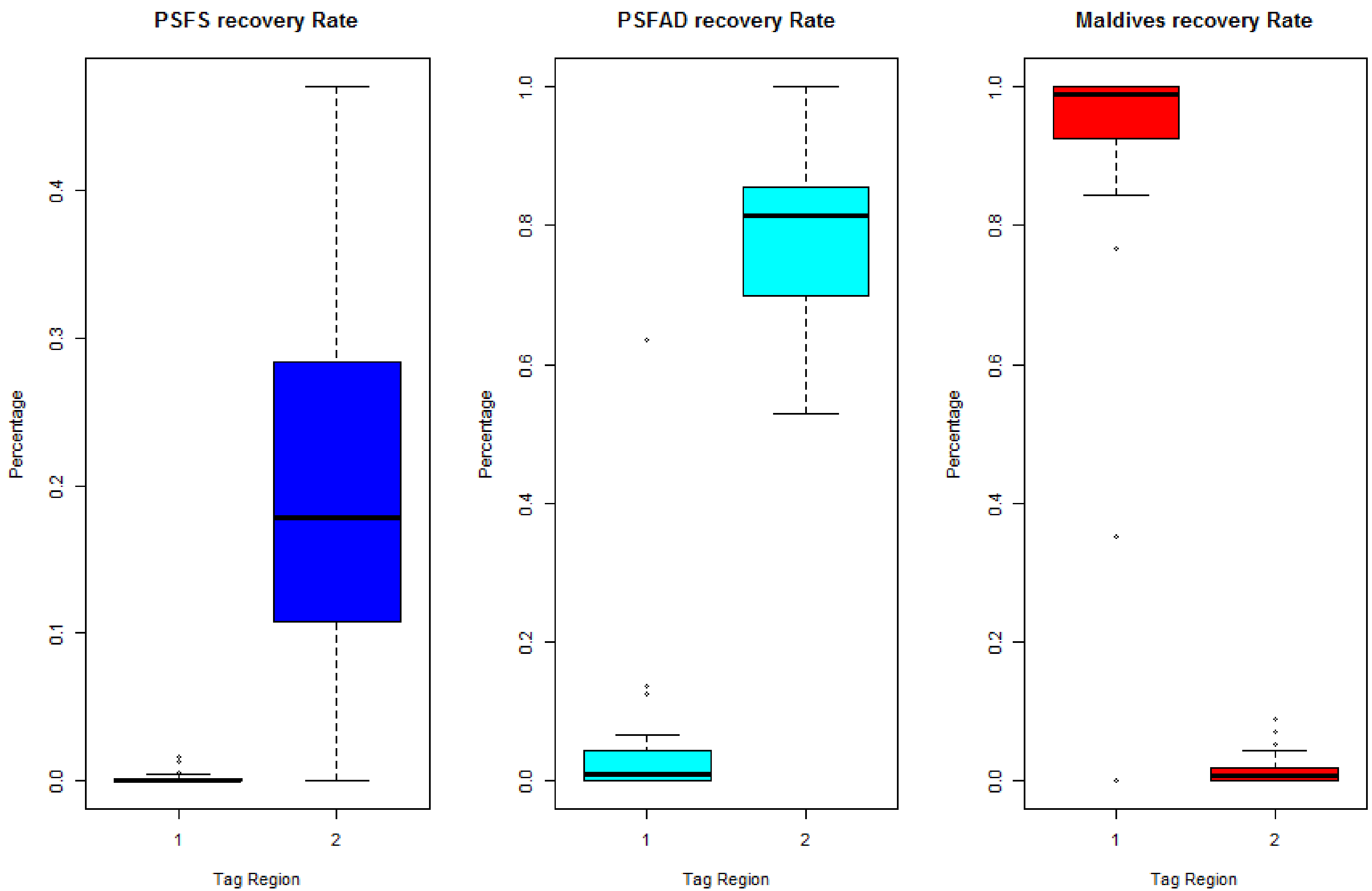


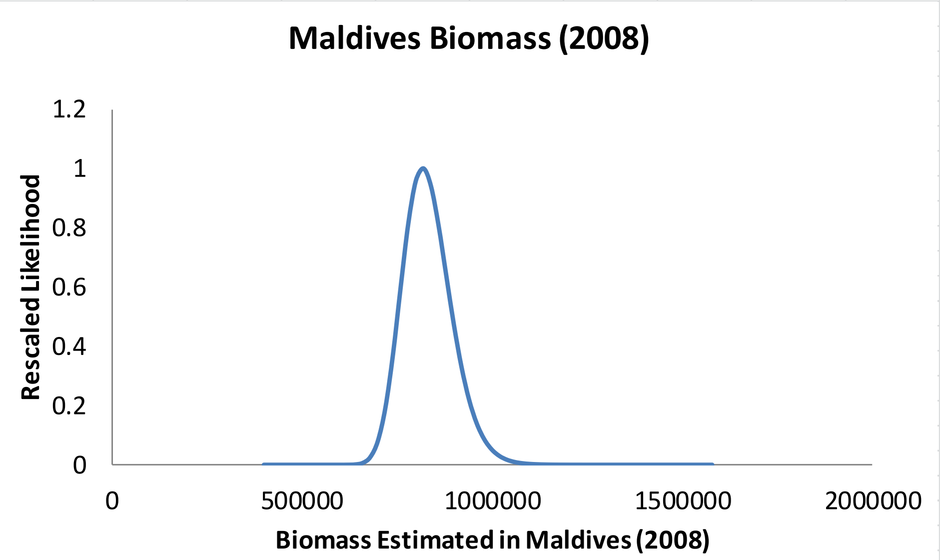
SKJ
Tagged: 115651
Recovered:16899
30
20
10
0
-10
-20
-30
-40
20
40
60
80
100
120
140

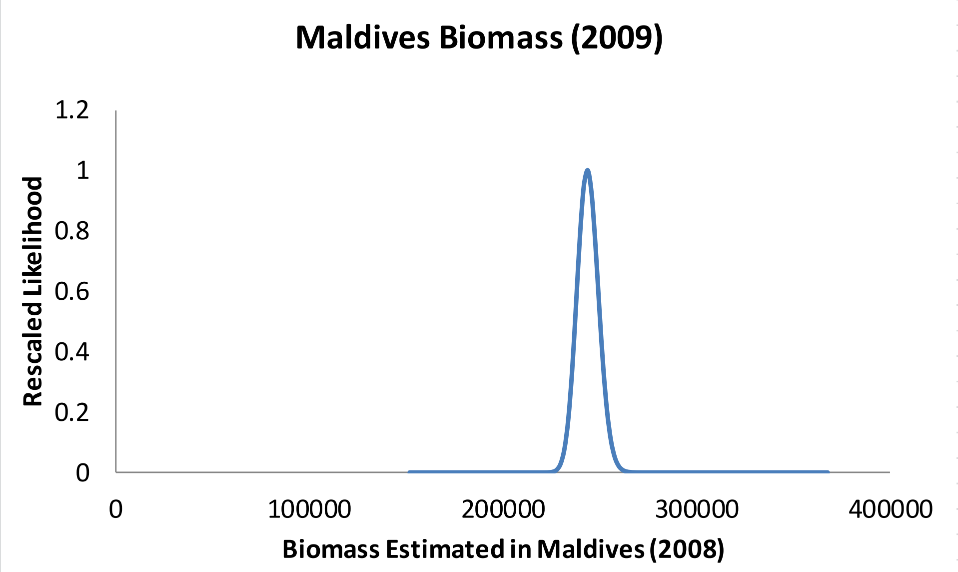
SKJ_mdv

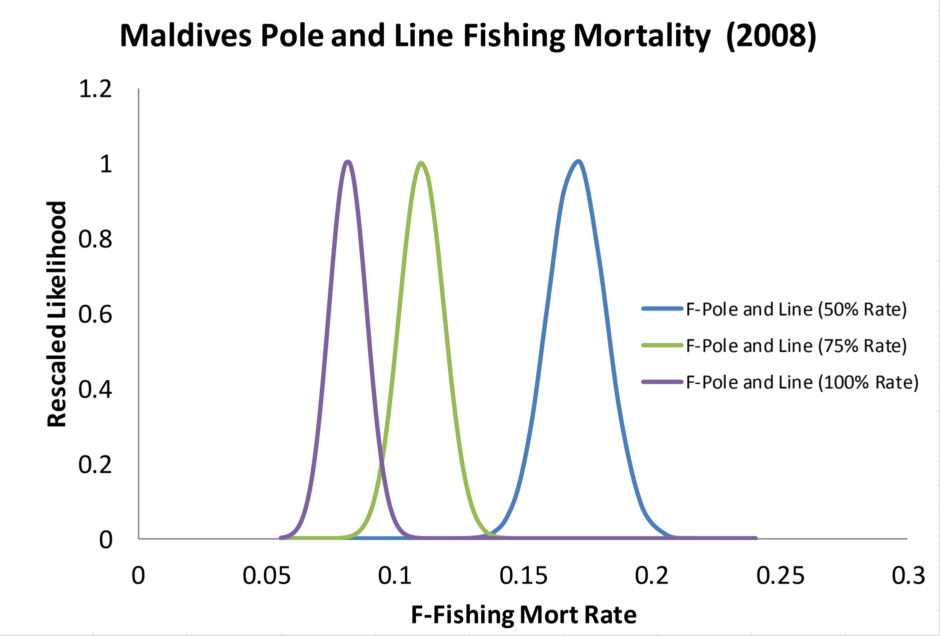

Tagged: 30244
Recovered:4662
30
20
10
0
-10
-20
-30
-40
20
40
60
80
100
120
140

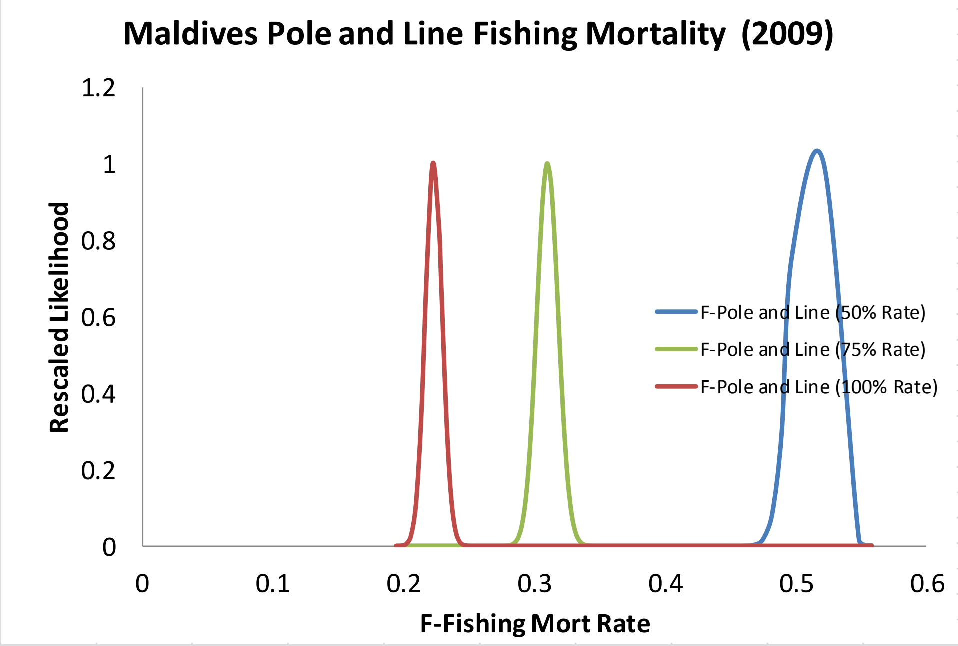
Comparisons with MR Results

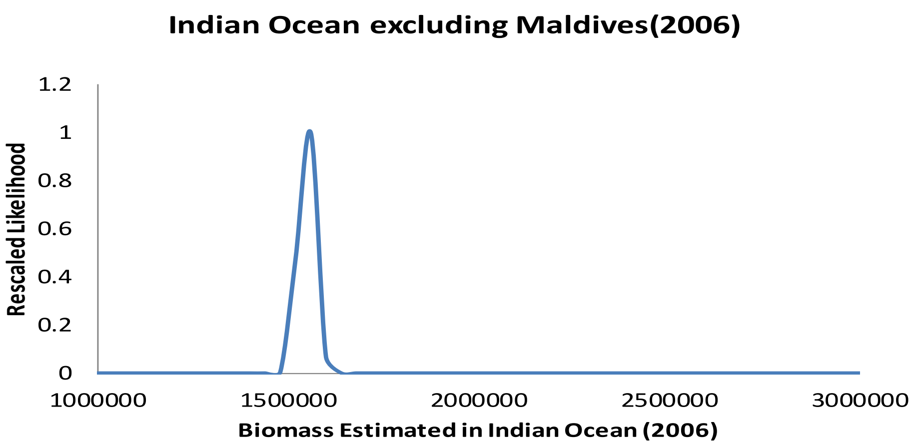


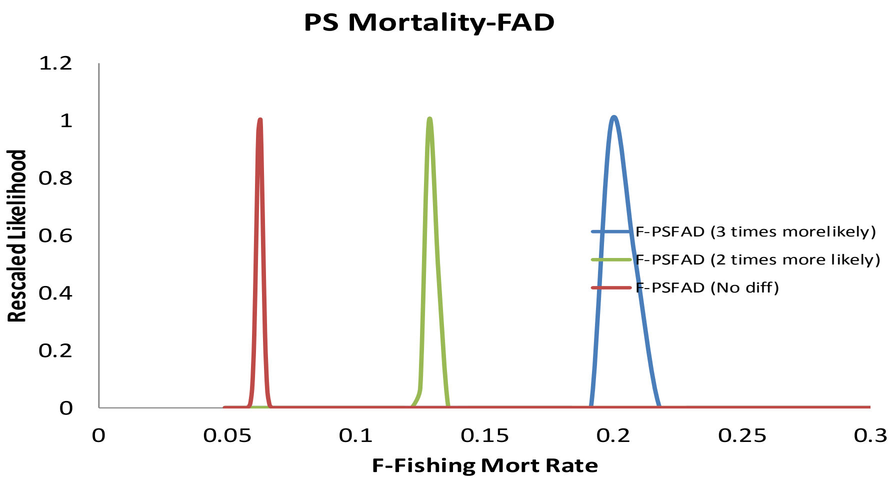

Maldives Biomass (2008)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
500000
1000000
1500000
2000000
Biomass Estimated in Maldives (2008)

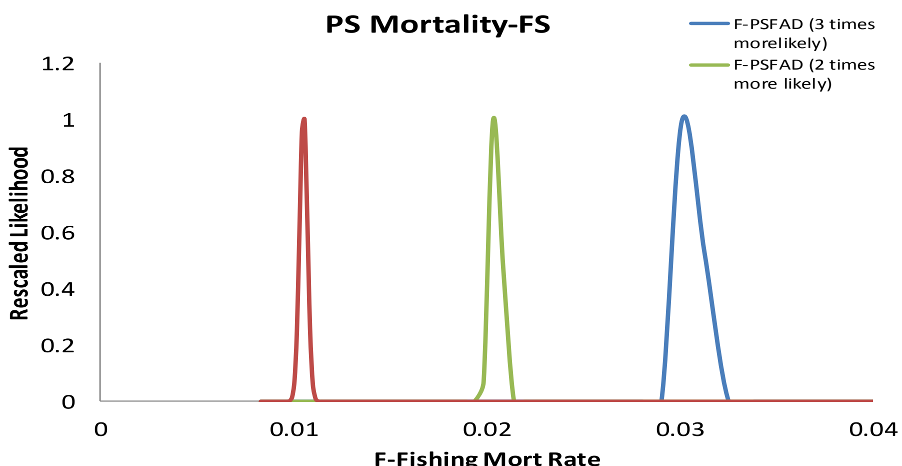

Maldives Biomass (2009)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
100000
200000
300000
400000
Biomass Estimated in Maldives (2008)

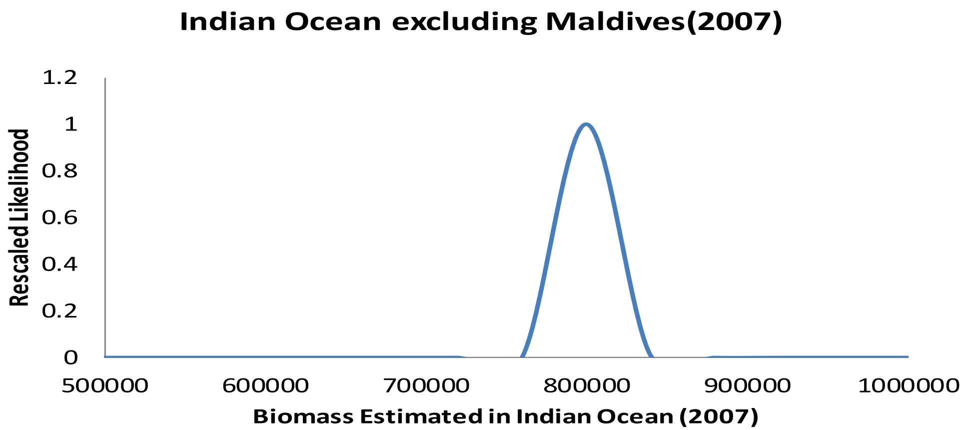

Maldives Pole and Line Fishing Mortality (2008)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.05
0.1
0.15
0.2
0.25
0.3
F-Fishing Mort Rate
F-Pole and Line (50% Rate)
F-Pole and Line (75% Rate)
F-Pole and Line (100% Rate)

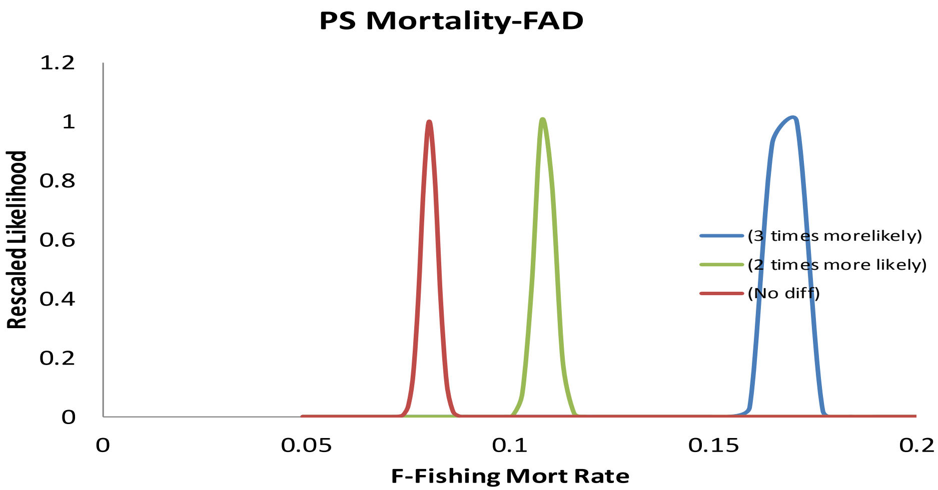

Maldives Pole and Line Fishing Mortality (2009)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
F-Fishing Mort Rate
F-Pole and Line (50% Rate)
F-Pole and Line (75% Rate)
F-Pole and Line (100% Rate)

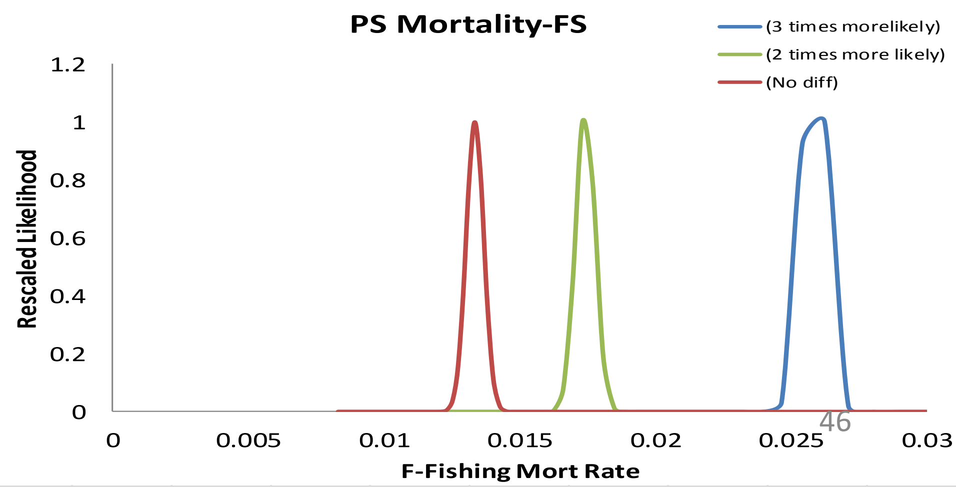

Indian Ocean excluding Maldives(2006)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
1000000
1500000
2000000
2500000
3000000
Biomass Estimated in Indian Ocean (2006)


PS Mortality-FAD
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.05
0.1
0.15
0.2
0.25
0.3
F-Fishing Mort Rate
F-PSFAD (3 times morelikely)
F-PSFAD (2 times more likely)
F-PSFAD (No diff)


PS Mortality-FS
F-PSFAD (3 times morelikely)
F-PSFAD (2 times more likely)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.01
0.02
0.03
0.04
F-Fishing Mort Rate


Indian Ocean excluding Maldives(2007)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
500000
600000
700000
800000
900000
1000000
Biomass Estimated in Indian Ocean (2007)


PS Mortality-FAD
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.05
0.1
0.15
0.2
F-Fishing Mort Rate
(3 times morelikely)
(2 times more likely)
(No diff)


PS Mortality-FS
(3 times morelikely)
(2 times more likely)
(No diff)
Rescaled Likelihood
1.2
1
0.8
0.6
0.4
0.2
0
0
0.005
0.01
0.015
0.02
0.025
0.03
F-Fishing Mort Rate

Fishing Mortality comparisons between Peterson estimate and SS-III

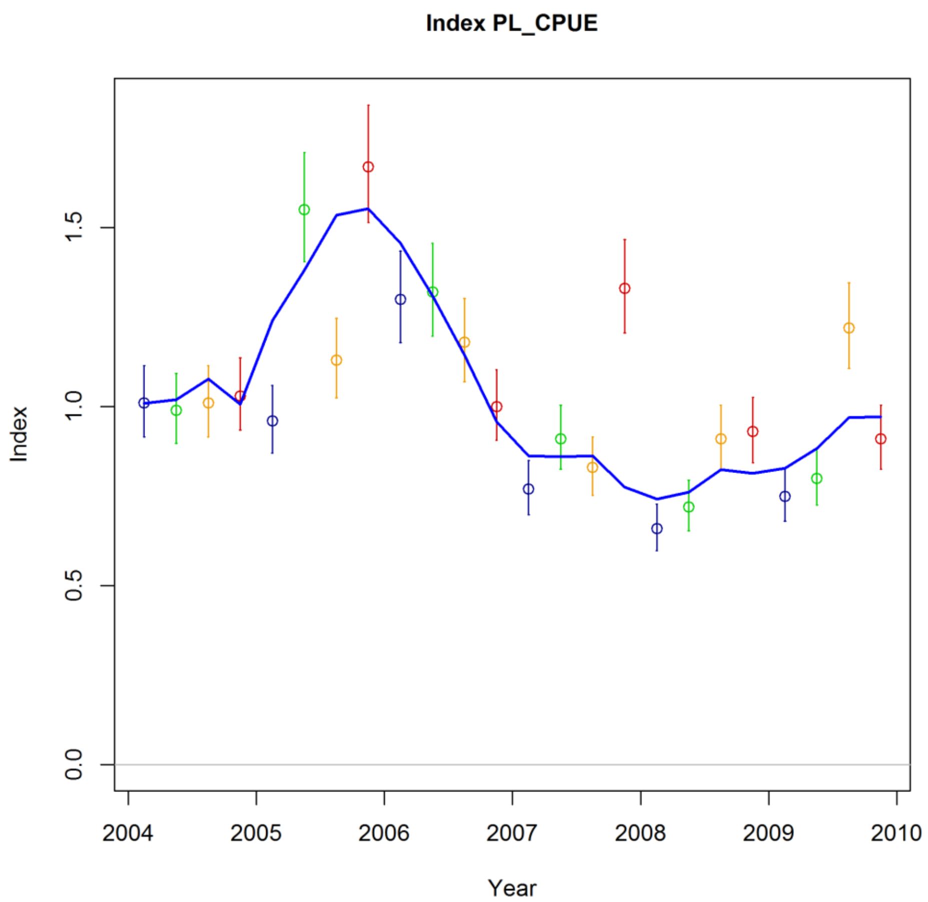
Fishing Mortality		2006	2007	2008	2009
Area					
Indian Ocean PS F	Estimate	0.14	0.16		
	SE	0.02	0.03		
Maldives PL F	Estimate			0.11	0.31
	SE			0.04	0.07
Integrated Assessments					
SS--III (one area)		**0.06**	**0.141**	**0.43**	**0.25**
SS-III (2 area)		**0.06**	**0.23**	**0.57**	**0.49**

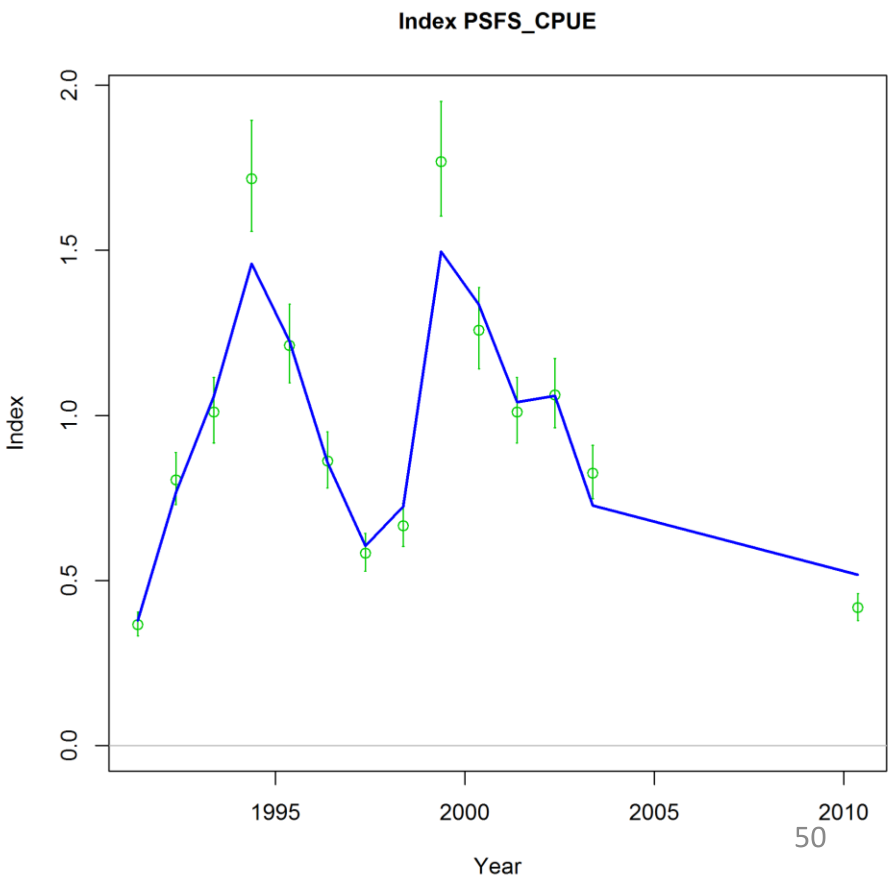
Caveats

- Closed population assumption is not correct.
- F’s a function of RR in Maldives and ascension (attraction rate in PS fisheries).
- Discrepancies in 2005 and 2008 could be primarily due to different ascension rates and RR.
- In 2006 if no difference between FADs and other gear attracting Skipjack is assumed then F’s are similar.
- If RR ~20% in Maldives PL in 2008, then F’s are again similar.
- Could use a stratified Peterson by size and compare it to the pooled results.

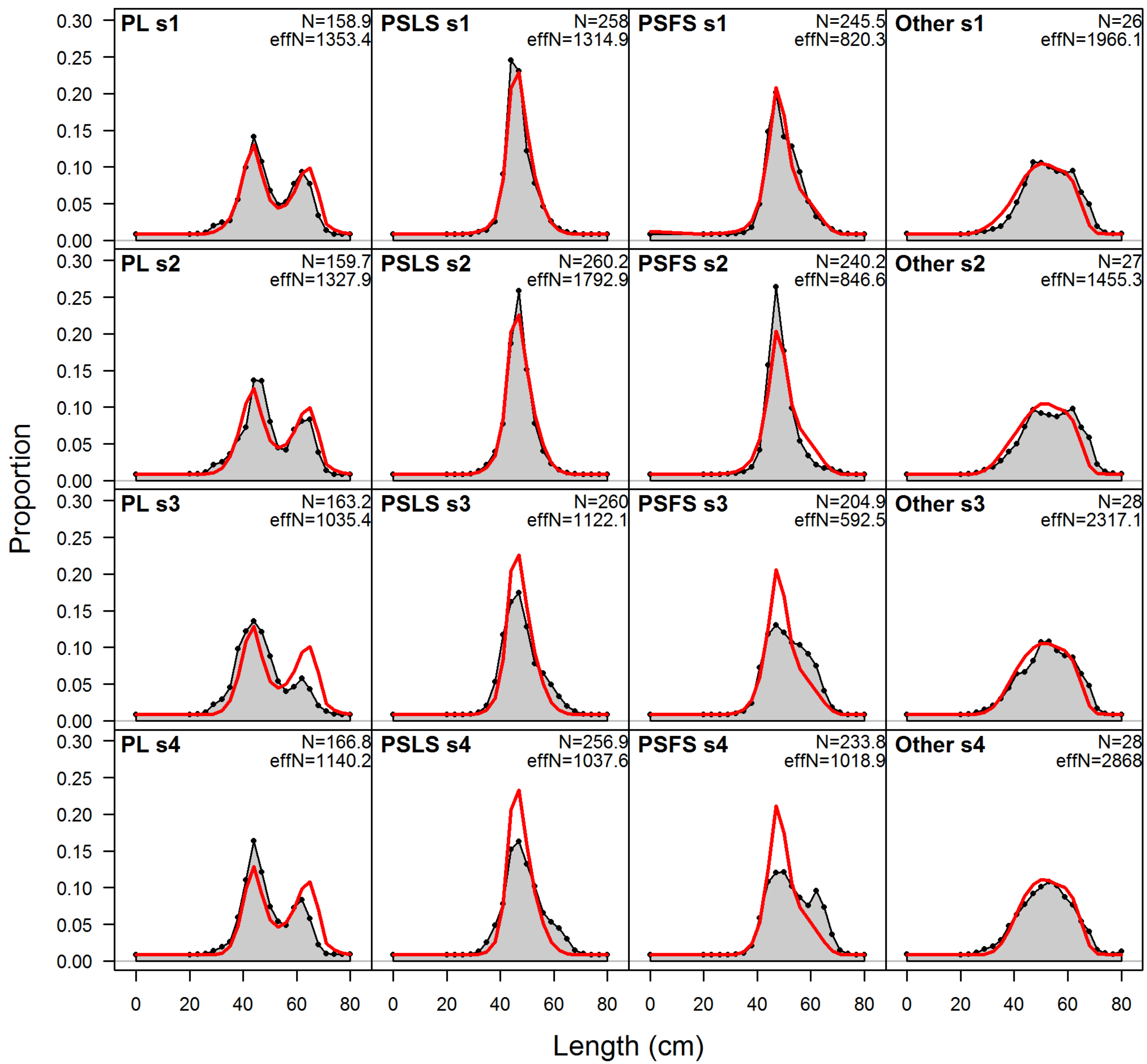
One Area weighted Likelihoods

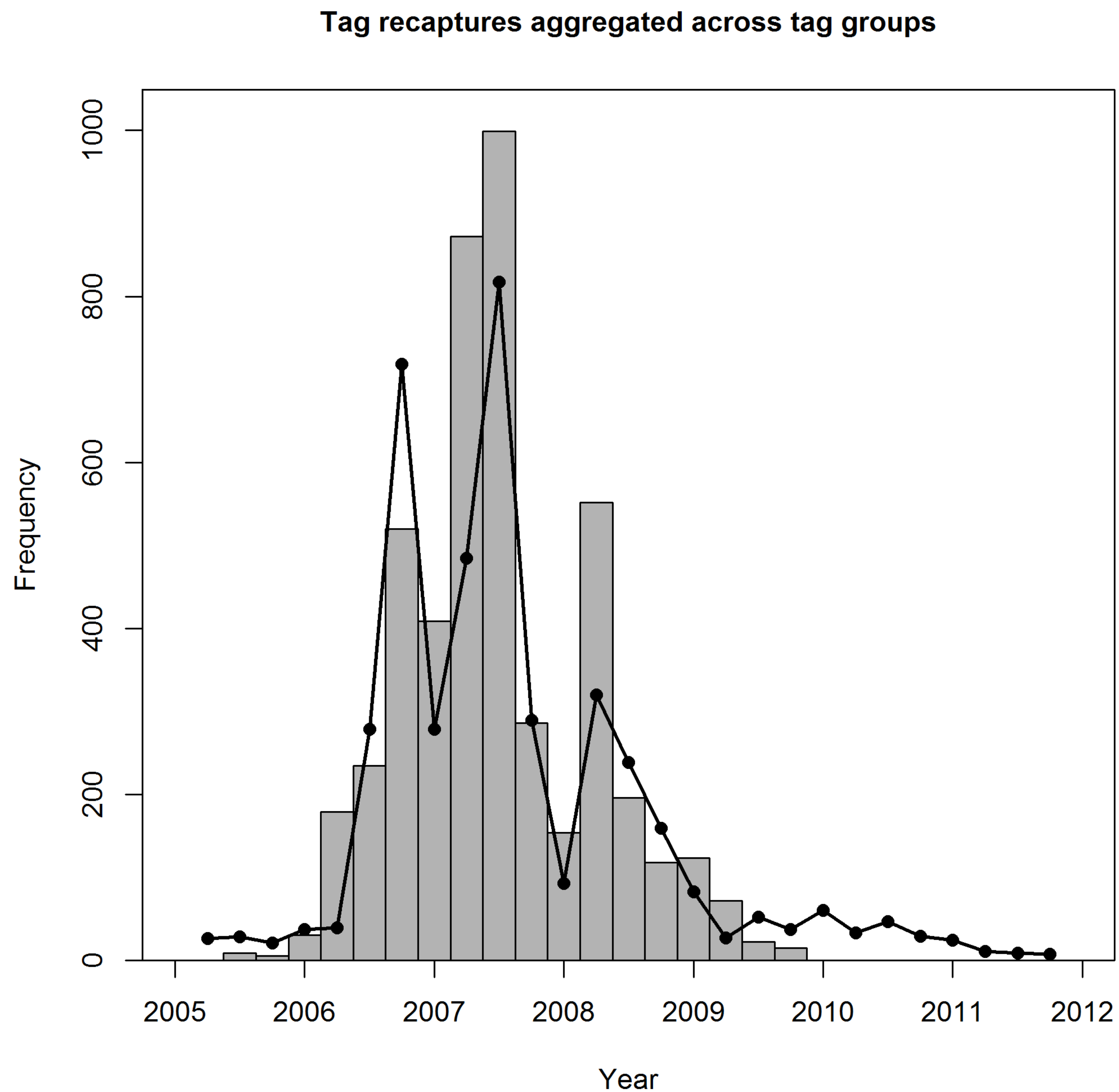
- Francis paper (2011).
- How do we weight the different components of our likelihood.
- CPUE (cv=0.05)
- Length based data
    - PL:min (N/10, 150)
    - PSLS, PSFS: min (N/10, 250)
    - Other: min (N/10, 10)

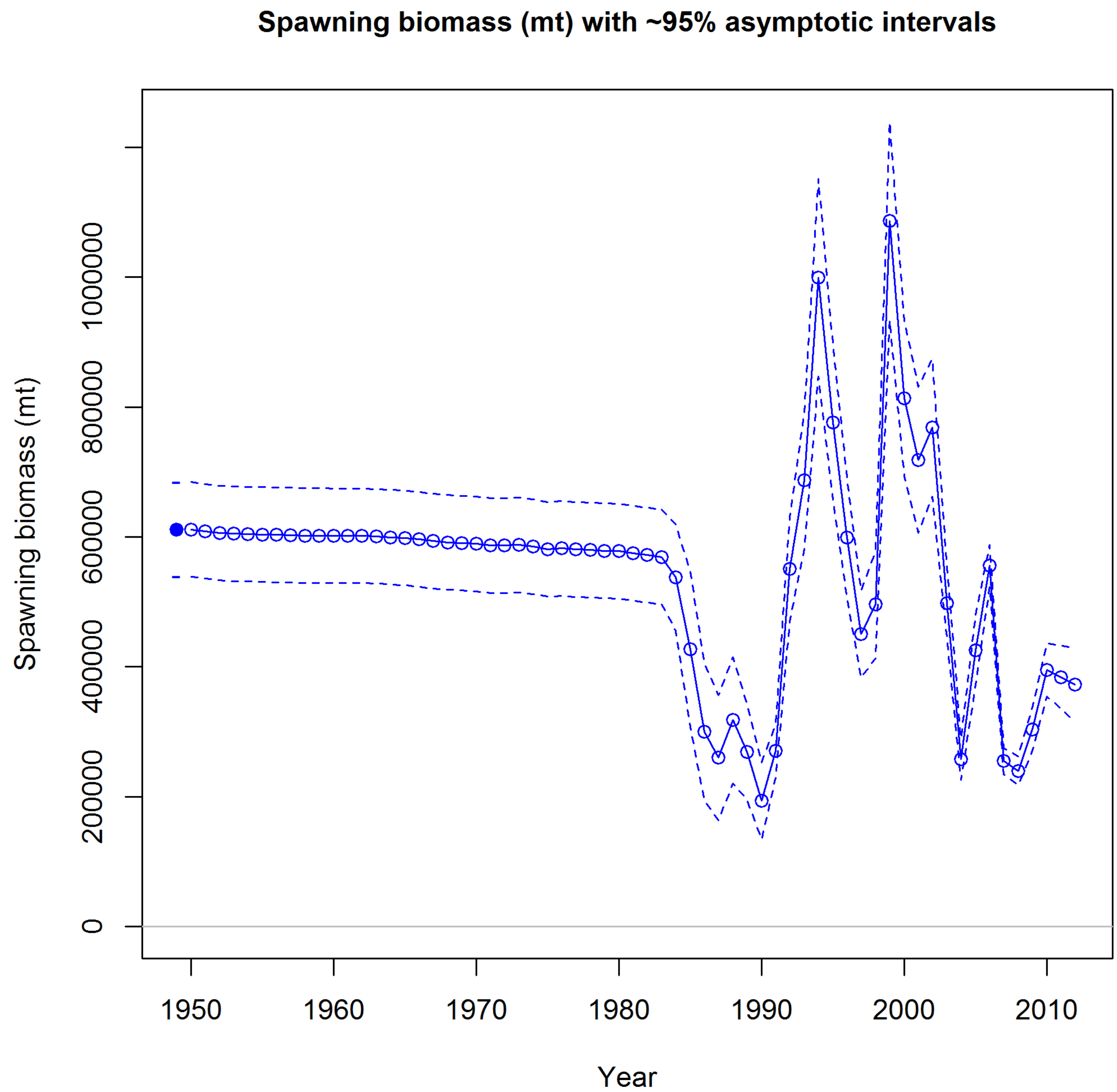

Index PL_CPUE
Index
Year
0.0
0.5
1.0
1.5
2004
2005
2006
2007
2008
2009
2010


Index PSFS_CPUE
Index
Year
0.0
0.5
1.0
1.5
2.0
1995
2000
2005
2010

length comps, sexes combined, whole catch, aggregated within season by fleet




Tag recaptures aggregated across tag groups
Frequency
0
200
400
600
800
1000
2005
2006
2007
2008
2009
2010
2011
2012
Year

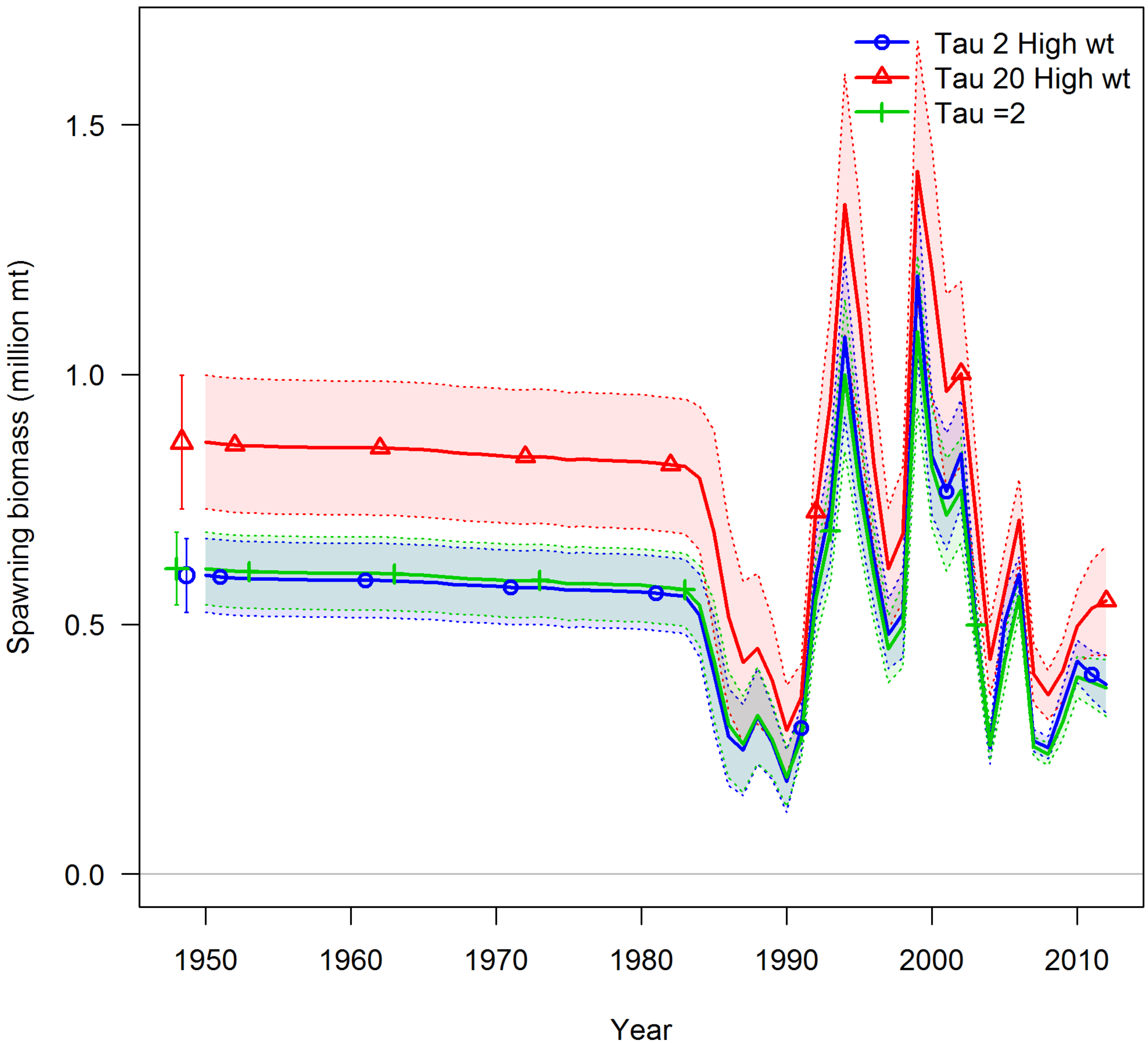

Spawning biomass (mt) with ~95% asymptotic intervals
Spawning biomass (mt)
0
200000
400000
600000
800000
1000000
1950
1960
1970
1980
1990
2000
2010
Year

Tag Overdispersion and Weights

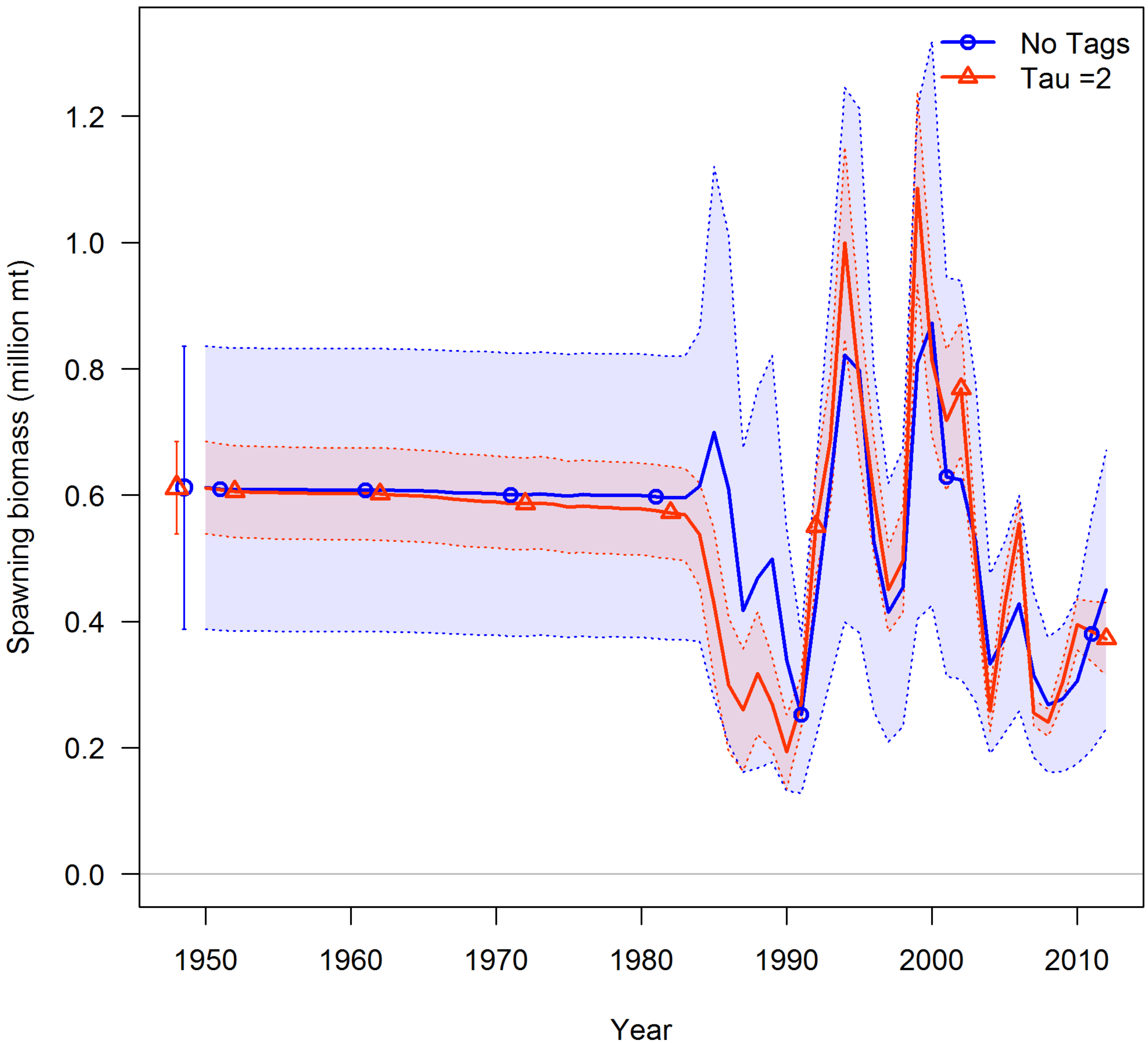
- Hypothesis 1: Poisson Distribution like, and weight higher than CPUE or Effective S.
- Hypothesis 2: Over-dispersion high. Weights high.

$$\mathcal{L}_g^{\mathrm{tags1}} = -\sum_y R_{yg} \sum_{a=1}^{N_a} p_{yga} \log\left(\hat{p}_{yga}/p_{yga}\right)$$

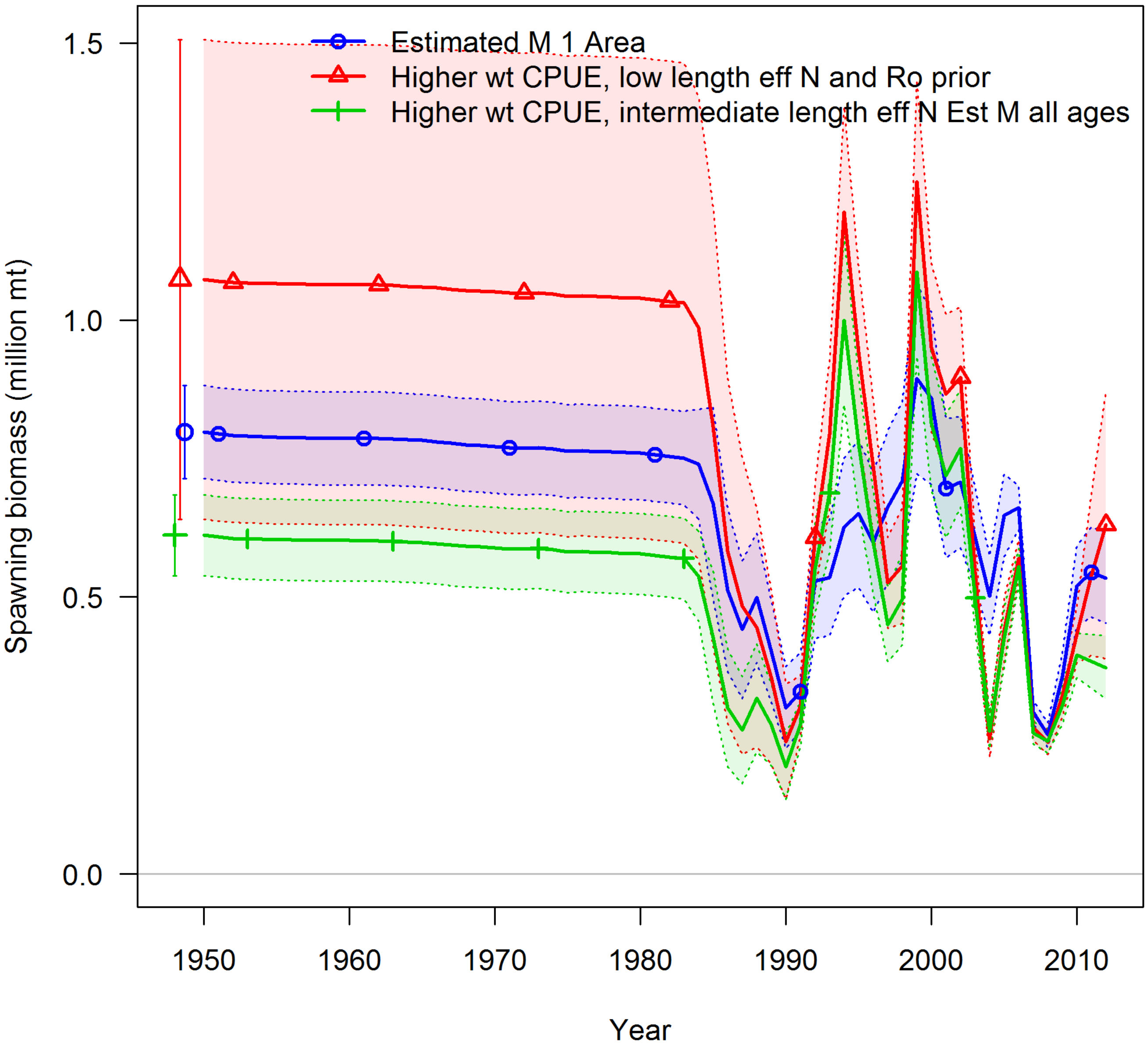
$$\begin{aligned}\mathcal{L}_g^{\mathrm{tags2}} \;=\; & \sum_y \left\{ \log\left(\Gamma\left(R_{yg} + \frac{\hat{R}_{yg}}{(\tau-1)}\right)\right) - \log\left(\Gamma\left(R_{yg}+1\right)\right) \right. \\ & \left. - \log\left(\Gamma\left(\frac{\hat{R}_{yg}}{(\tau-1)}\right)\right) - \frac{\tau R_{yg}}{(\tau-1)} \log(\tau) + R_{yg}\log(\tau-1) \right\}\end{aligned}$$



Tau 2 High wt
Tau 20 High wt
Tau =2
Spawning biomass (million mt)
0.0
0.5
1.0
1.5
1950
1960
1970
1980
1990
2000
2010
Year



No Tags
Tau =2
Spawning biomass (million mt)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1950
1960
1970
1980
1990
2000
2010
Year



Stock Status-I

Stock Status-II

- Regardless of parameterization, the stock appears to be bouncing around optimal spawning stock size levels.
- Estimate of F-optimal currently difficult to estimate accurately from SS.
- Proxy F (C/CMSY) and F-standardized also indicate stock is near or optimal F or slightly higher than optimal rates (in some cases).

Stock Status-III

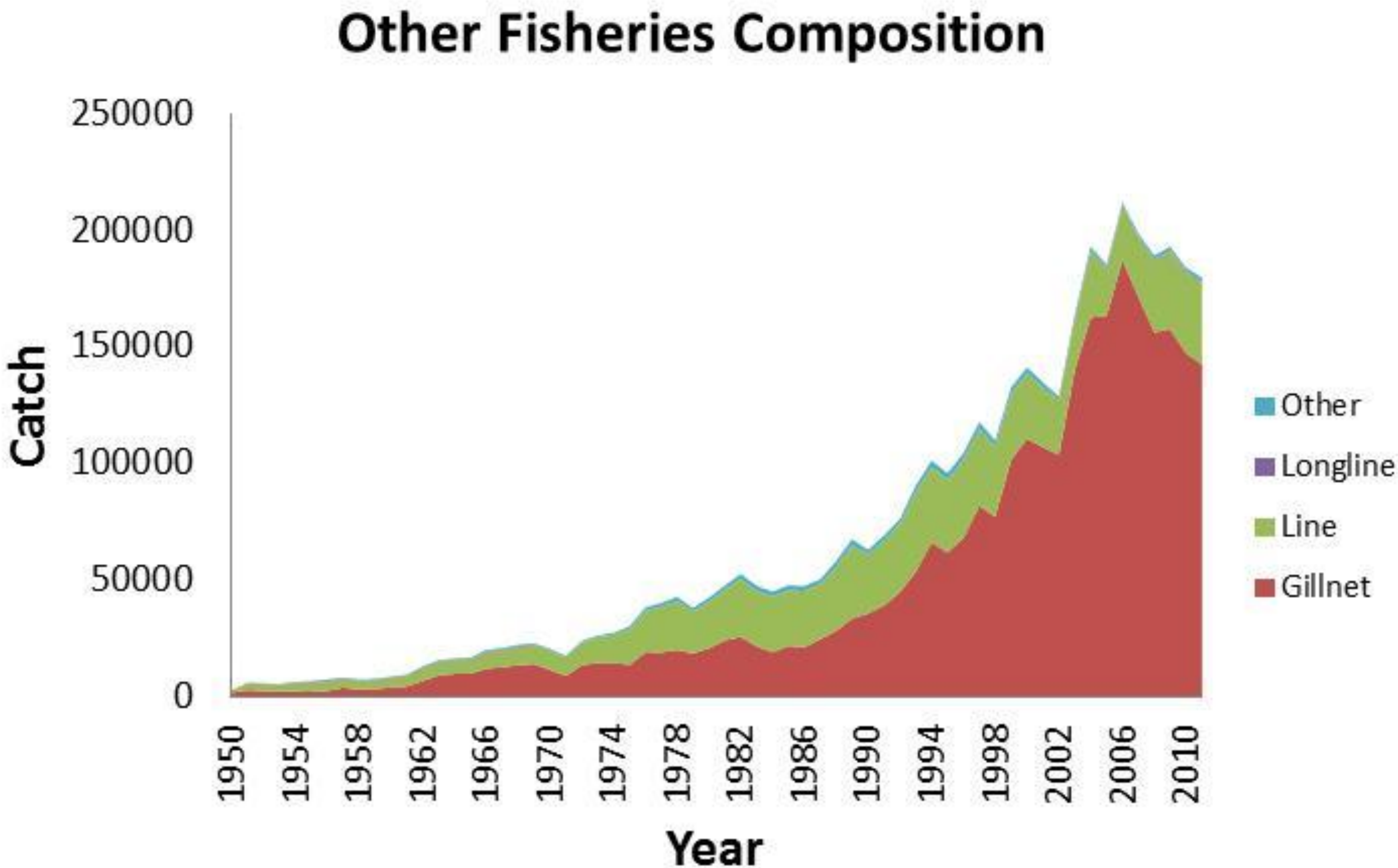
- Optimal Yield is between 325K-625K Tons based on choice of models presented.
- Optimal Spawning Stock Size (0.8M-2M Tons)
- B0 levels (1.5 M-9M Tons).
- Current levels recommended:
  - B_{2011}/B_{MSY} = 1.47 (1.25 – 1.69) -(Model M2)-1 Area
  - B_{2011}/B_{MSY} = 1.11 (0.99 – 1.23) –(Model M9)-2 Area
  - B_{2011}/B_{MSY} = 1.15 (1.01 – 1.29) –(Model M12)-1 Area

General Conclusions:

- Assessment still highly uncertain, but generally optimistic (as in Kolody et. al. 2011)
- Relative abundance indices questionable, though given weight as that is only source of information available on available Biomass.
- Life history seems favourable with substantial young, weakly selected spawners
- Recruitment variability seems to drive large fluctuations in abundance including 2005-6 peak and consequential decline in abundance.

Priorities for further investigation:

- Population structure needs to be further developed.
- Abundance indices: pre-2004?
  - PSFS standardization? Still not available
  - PL atoll records-Relationship between standardized and nominal and extrapolated to entire TS based on the standardized ratio. This will still cause problems though as CPUE increases with catch.
  - Alternative only PL (BB from NM or sails) CPUE should be used for entire TS using nominal catch.
- Tagging data:
  - Add small scale tagging in the 1990’s.
  - Analysis of mixing rates.
- Growth curve:
  - rapid early growth + large LL fish (effect marginal)
- Potential for maturity bias?


Other Fisheries Composition
Catch
250000
200000
150000
100000
50000
0
1950
1954
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002
2006
2010
Year
Other
Longline
Line
Gillnet

Growth bias

- Difficult to model the growth fn in SS-III.
- However, rapid growth will bias current estimate to be low and optimal yield targets and reference F’s would likely increase with the new curve.
- In addition, sensitivity to different growth curves (Kolody et. al. 2011) indicates that the bias is minimal (probably as the bias cancels out by the length composition data from the fisheries, selectivity and maturation schedules).

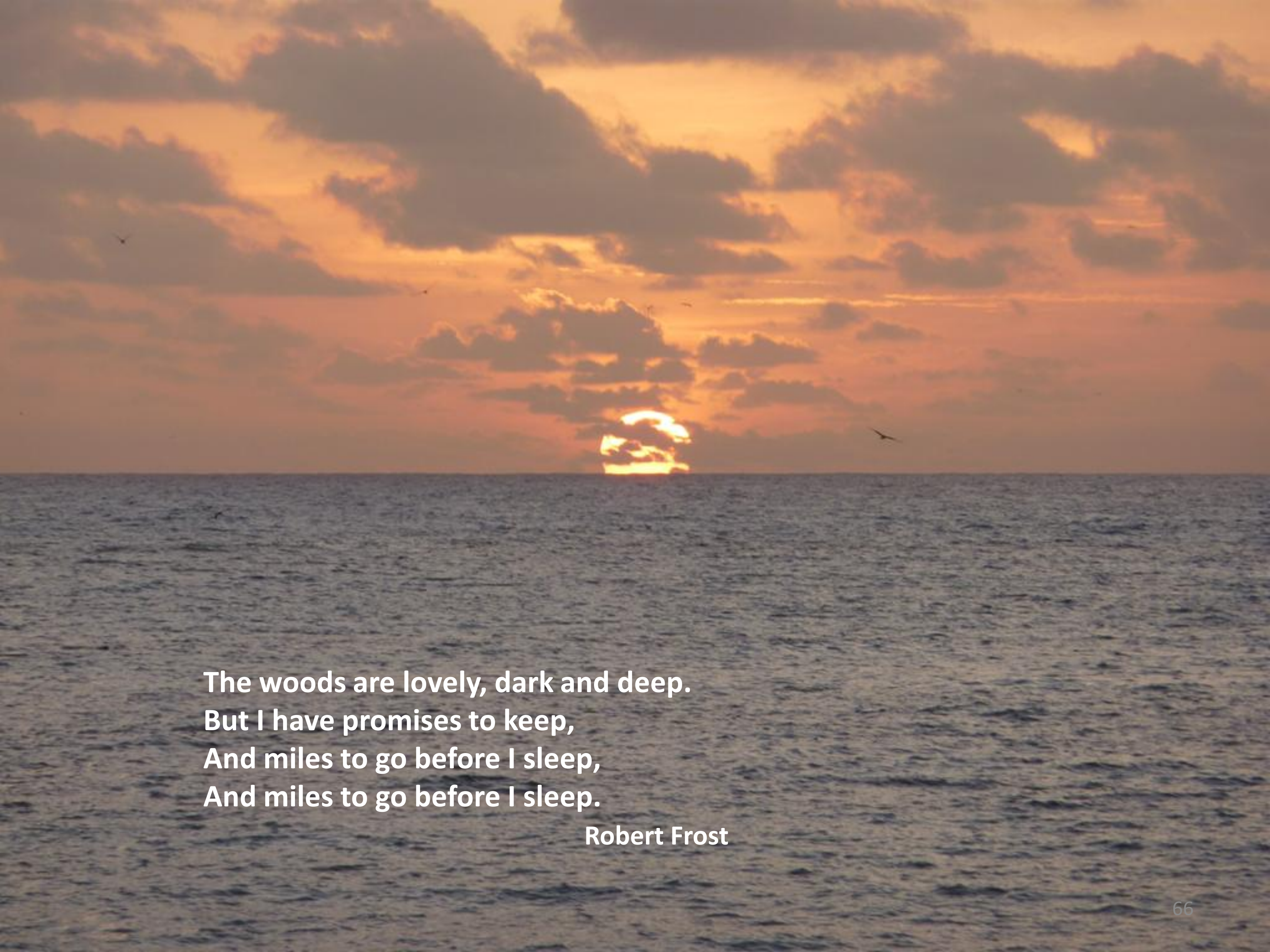
However as far as Exploited Fish Population dynamics

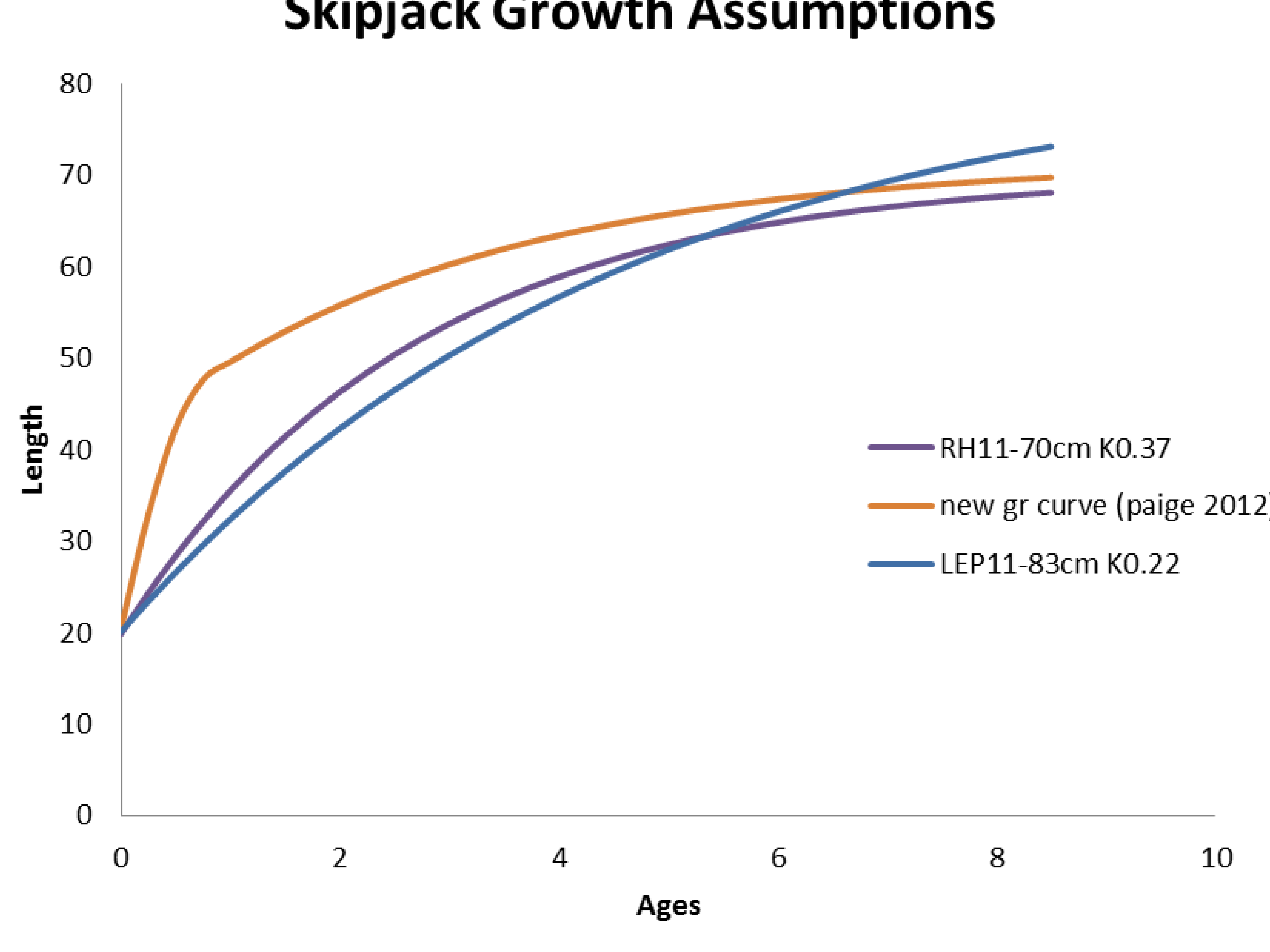
The resilience of a fish population to fishing is very much dependent on its biological features relating to growth, maturity, fecundity, natural mortality, life span etc.

	Yellowfin	**Bigeye**
Reproductive mode	Serial spawning	Multiple spawners
Fercundity	2 million+	2 million+
Growth rate	45-50cm (1yr)	40cm (1yr), 80cm (2yr)
Age to maturity	2-3yr (100-110cm)	3yr+ (100-130cm)
Life span	7-8yr	12+
Recruitment to fishery	0.5-1yr(PS), ~2+yr(LL)	0.5-1yr(PS), 2+yr(LL)
	Albacore	**Skipjack**
Reproductive mode	?	Serial spawners
Fercundity	0.8-2.6 million	2 million+
Growth rate	40cm (1yr)	44-48cm (1yr), 61-68 (2yr)
Age to maturity	4-5yrs (80cm)	<1yr (44cm)
Life span	18+yr	~4yr
Recruitment to fishery	~2yr(troll), 5+(LL)	0.5-1yr(PS)

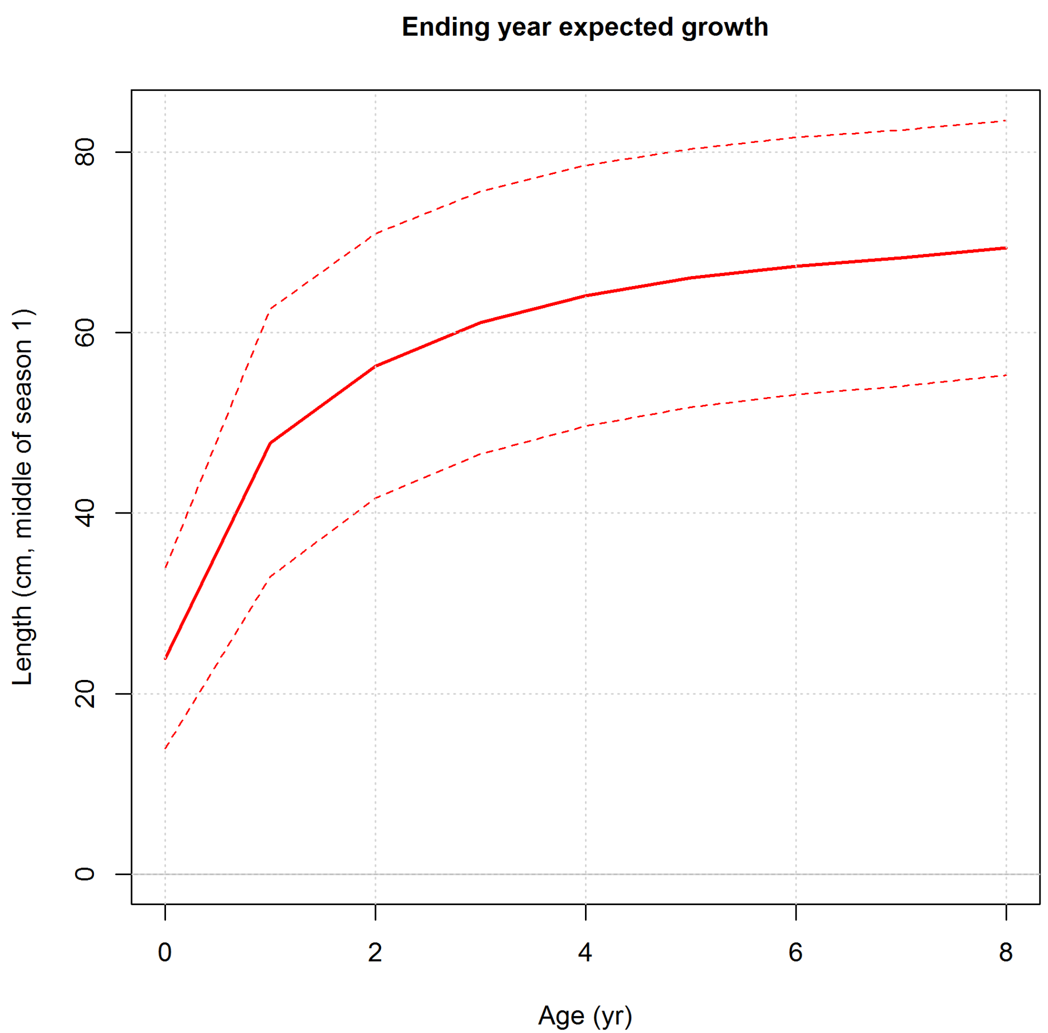
Acknowledgements

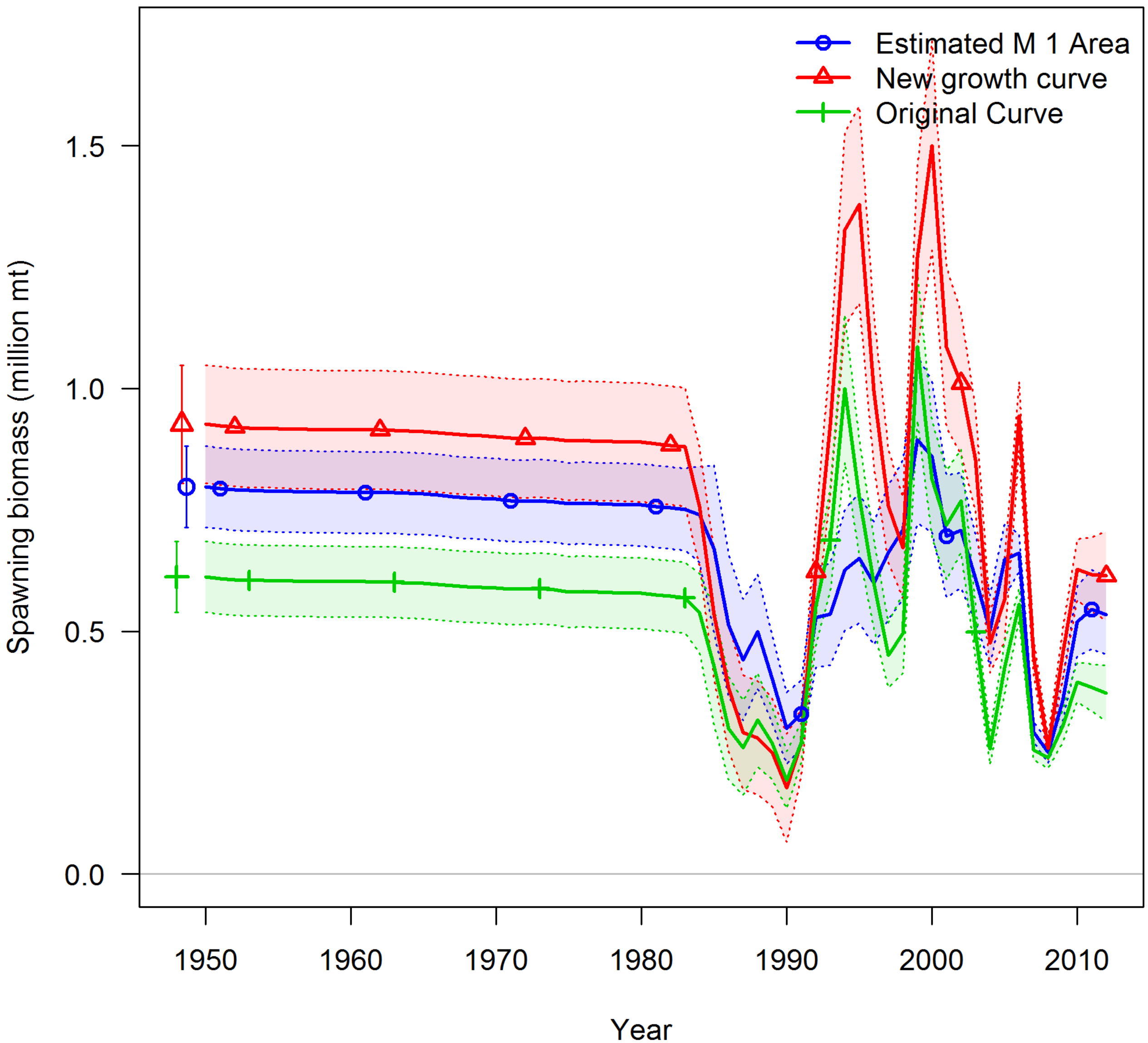
- Ian Taylor, Adam Langley & Dale Kolody for help in SS, for review and ideas to improve the analysis.
- Alain Fontaineau for his helpful insights.
- Alejandro Anganuzzi for support and ideas on improvements.
- Shiham Adam for the PL series from the Maldives.
- Tom Nishida/Japan for Kobe plot software.


The woods are lovely, dark and deep.
But I have promises to keep,
And miles to go before I sleep,
And miles to go before I sleep.
Robert Frost

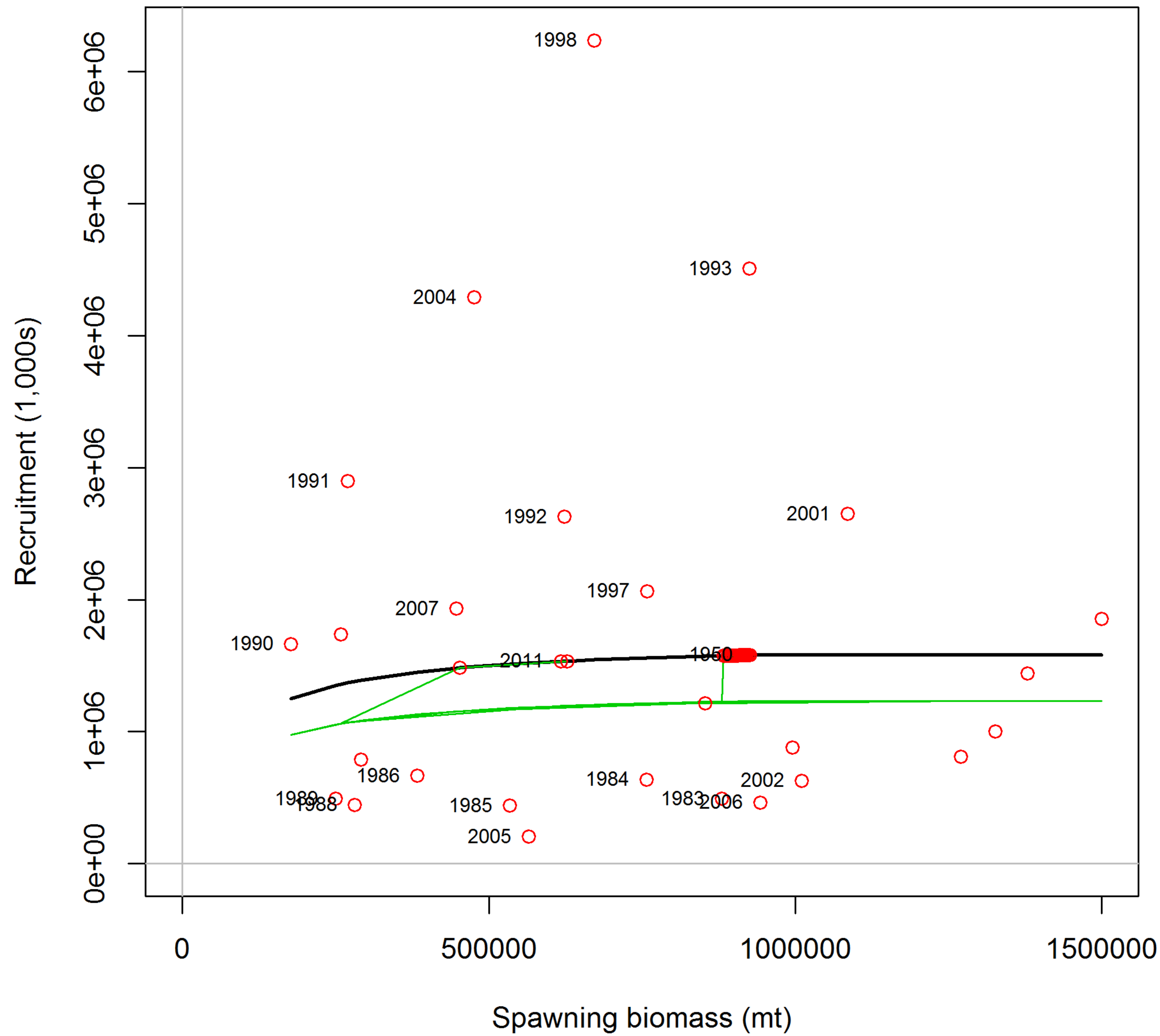

Skipjack Growth Assumptions
80
70
60
50
40
30
20
10
0
Length
0
2
4
6
8
10
Ages
RH11-70cm K0.37
new gr curve (paige 2012)
LEP11-83cm K0.22

Use Richards growth curve that approximates Eveson (2012)





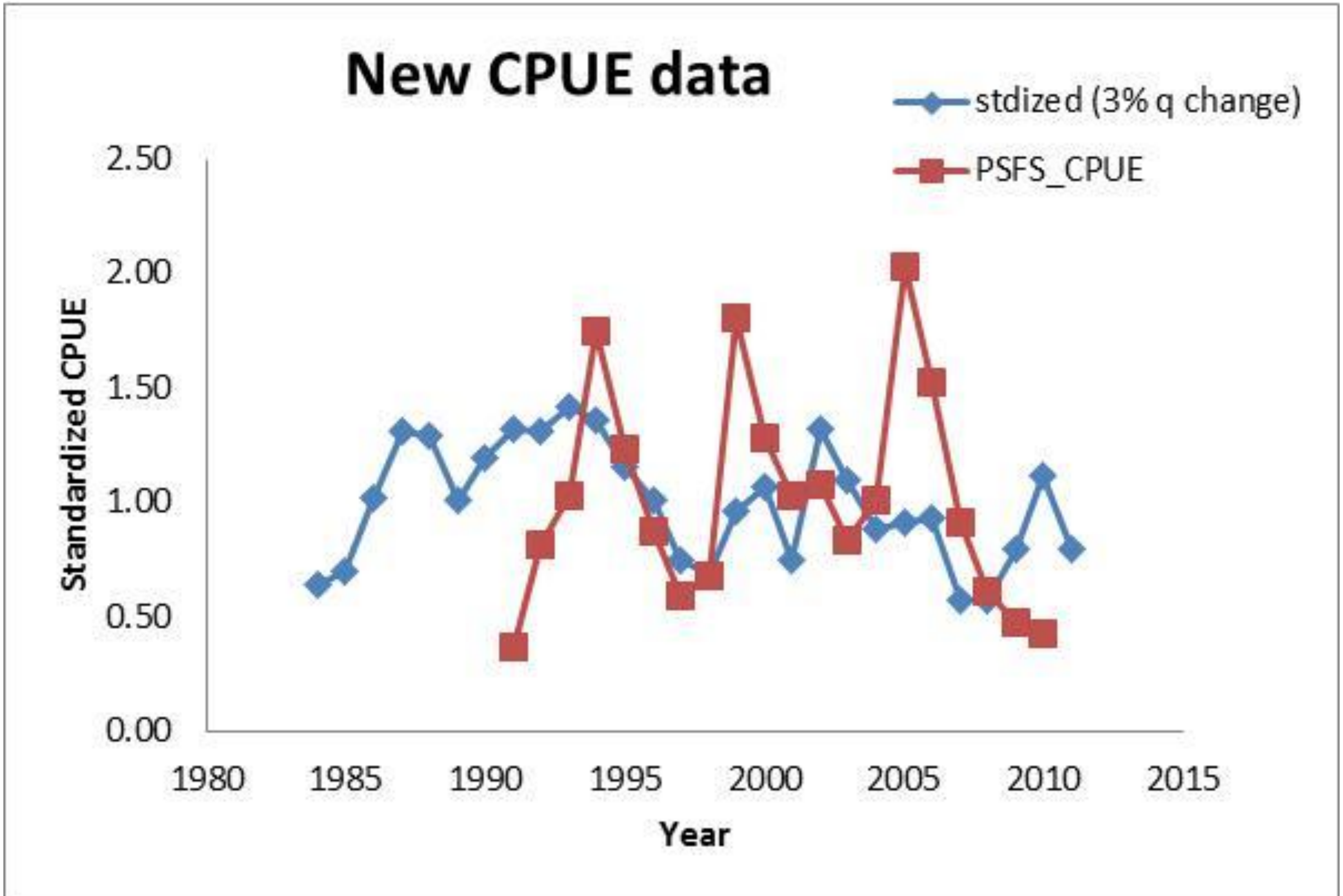
Estimated M 1 Area
New growth curve
Original Curve
Spawning biomass (million mt)
0.0
0.5
1.0
1.5
1950
1960
1970
1980
1990
2000
2010
Year


Recruitment (1,000s)
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
6e+06
0
500000
1000000
1500000
Spawning biomass (mt)
1998
1993
2004
1991
1992
2001
1997
2007
1990
2011
1950
1986
1989
1988
1985
2005
1984
1983
2006
2002

Faster growth implies

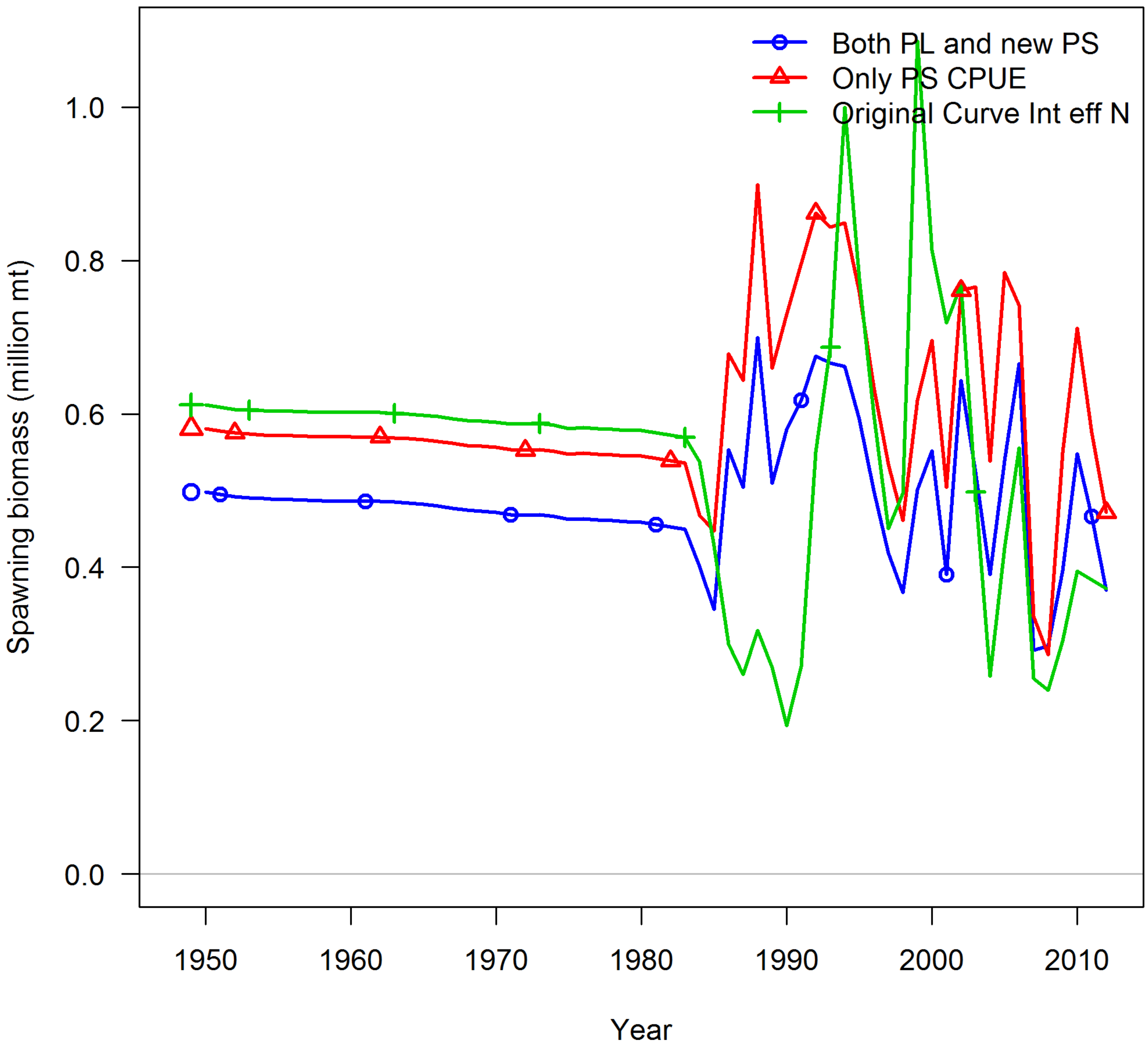
- Higher Yield
- Higher F-rates.
- Lower chance of exceeding target reference points.

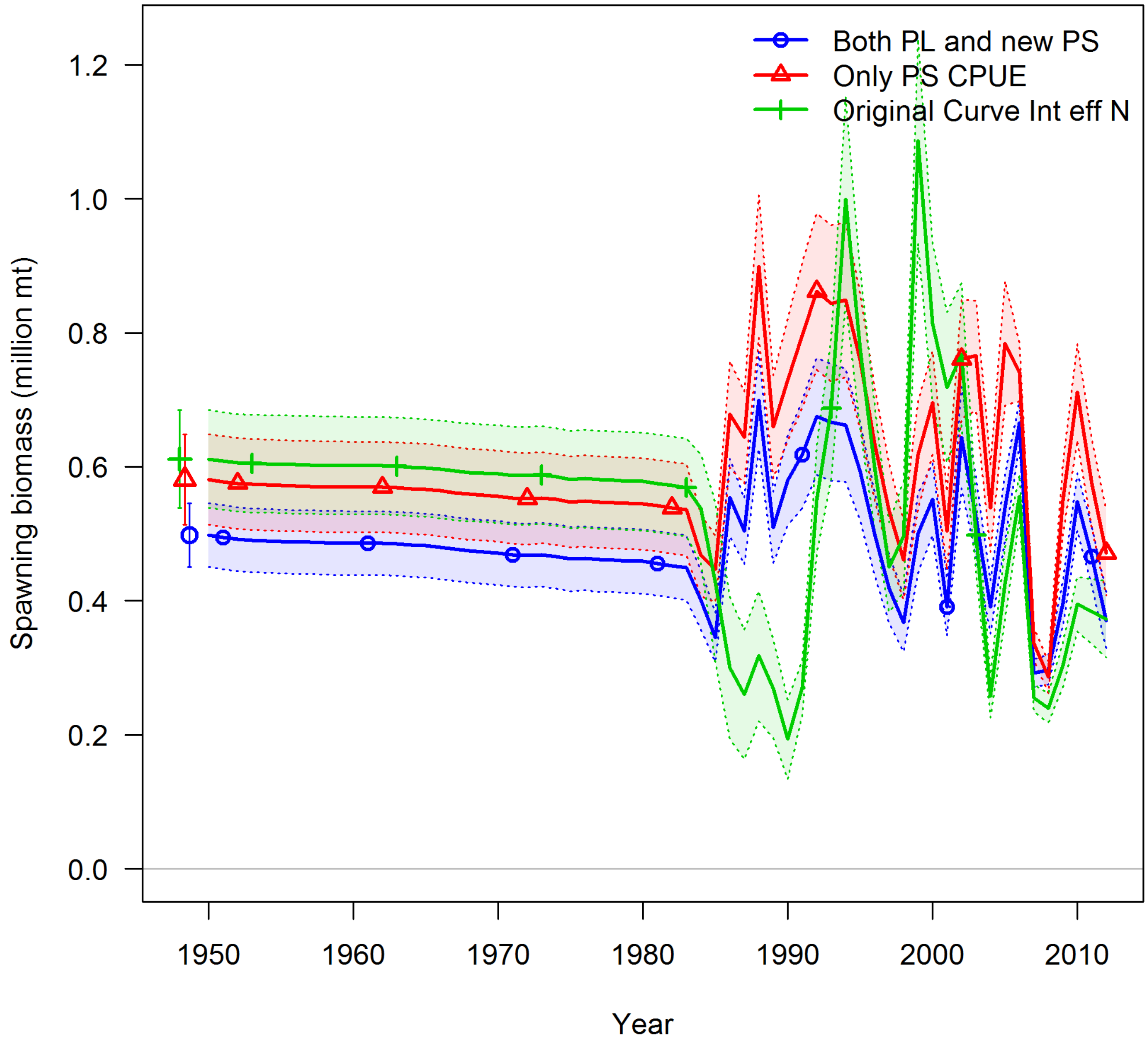
Additional Runs for new CPUE



2 Runs Examined

- The first fit to both the Maldives and new PS CPUE
- The second discounting Maldives CPUE, and fitting to PS CPUE.


Both PL and new PS
Only PS CPUE
Original Curve Int eff N
Spawning biomass (million mt)
1.0
0.8
0.6
0.4
0.2
0.0
1950
1960
1970
1980
1990
2000
2010
Year



Both PL and new PS
Only PS CPUE
Original Curve Int eff N
Spawning biomass (million mt)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1950
1960
1970
1980
1990
2000
2010
Year