Dynamic Reference Points in Context of Climate change

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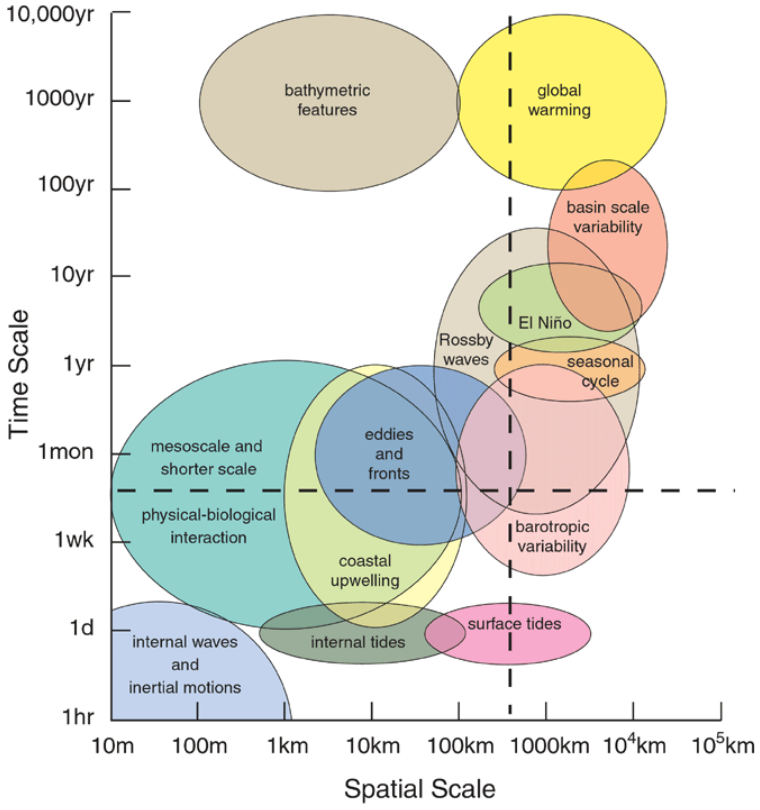


Climate Impacts on Marine Fishes

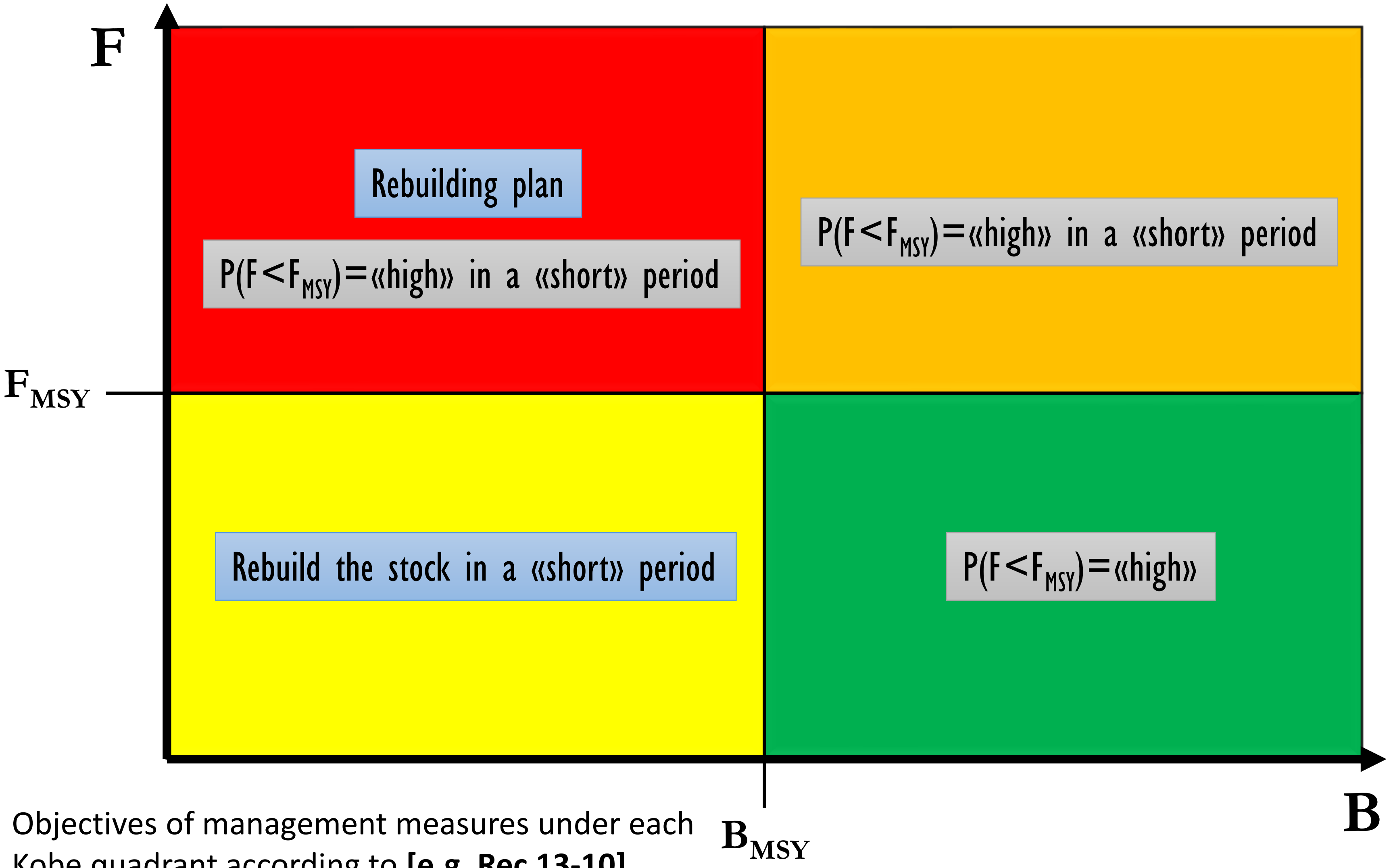
- Typically two issues:
  - Changes in species abundance / community composition
    - Food Availability
    - Larval Transport (advection)
    - Temperature
    - Predators
  - Changes in spatial distribution

But how does this effect management, and how we do business?

Outline

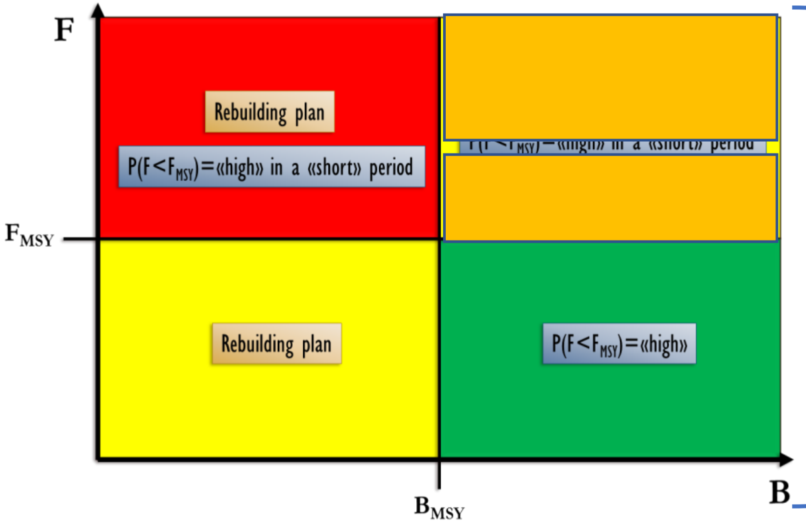
- Overview of objectives / And Eg. resolutions in tRFMO's.
- Reference Points and current management approach
- Alternatively rethinking what we are managing for.
- Quantifying risks based on current understanding of the dynamics.
- Presenting a MSE framework and case studies to address this.

Harvest Control Rules (HCR) -Objectives



Objectives of management measures under each Kobe quadrant according to **[e.g. Rec 13-10]**

Harvest Control Rules (HCR)

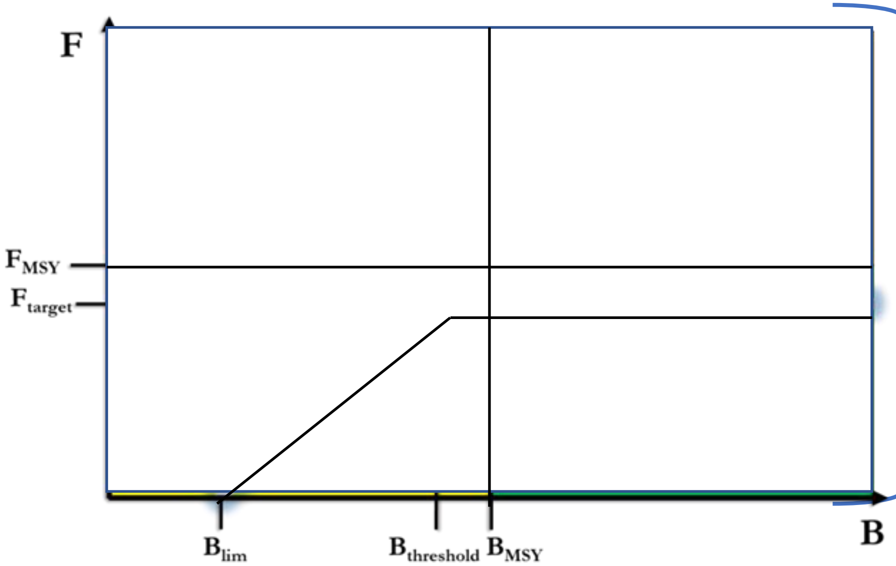


HIGH probability

IPCC: 80%
Canada: 75%
MSC: 70%-80%

SHORT period

USA: 10 years or 1.5 generations
Australia: 10 years + 1 generation
MSC: 2 generations



F target

[0.7, 0.75, 0.8, 0.85, 0.9 and 1] x F_{MSY}

B threshold

[0.6, 0.8 and 1] x B_{MSY}

B lim

$0.4B_{MSY}$

Limits and Targets

- Based on MSY Targets
- Implicit assumptions on h and σ_r
- But how does this change with climate?

The Dilemma of Low Spawning Biomass

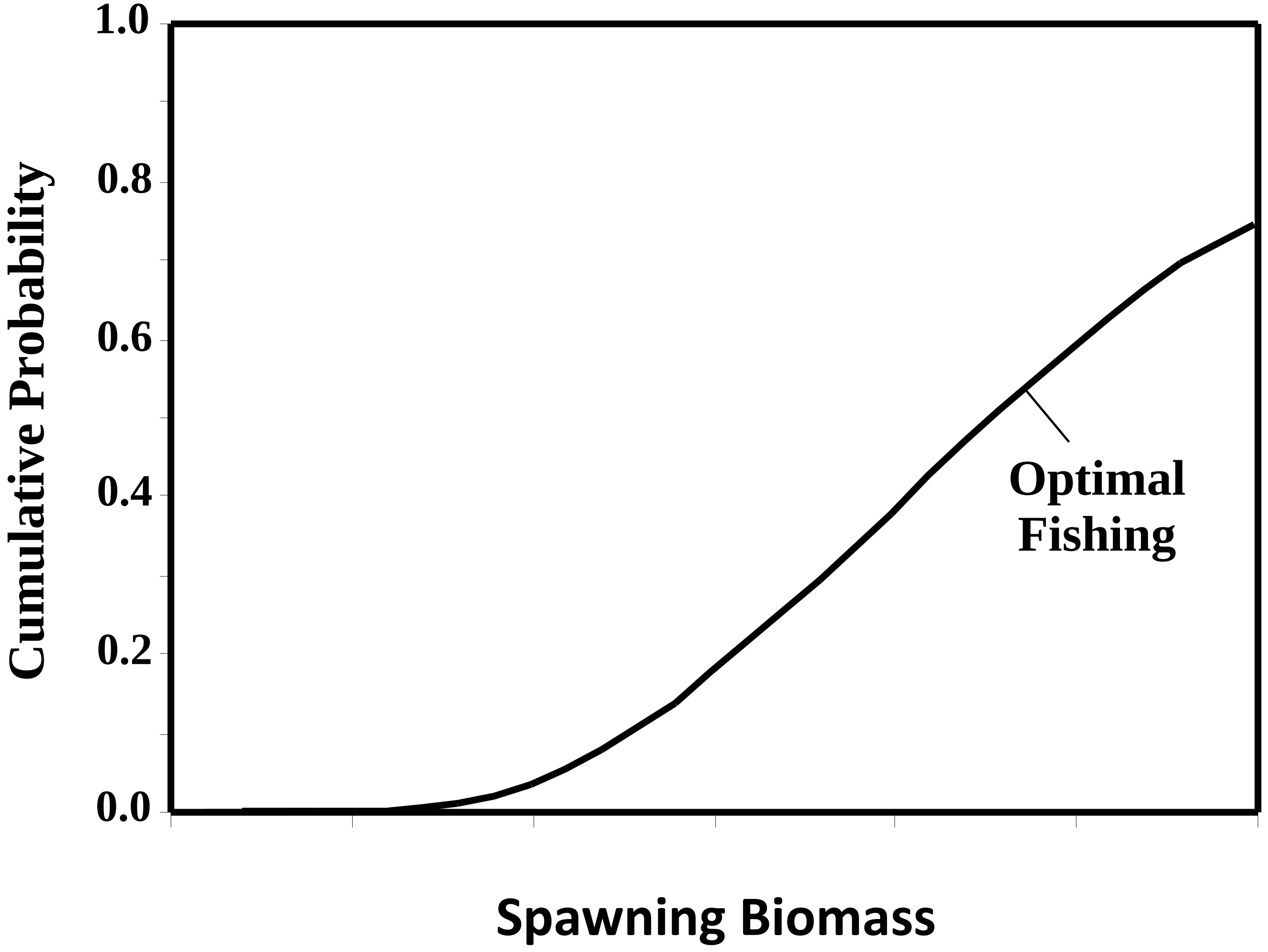
Spawning Biomass have been low for few years:

Are these low Sp Biomass due to a passing weakness in year class strengths, and no additional action should be taken?

Or

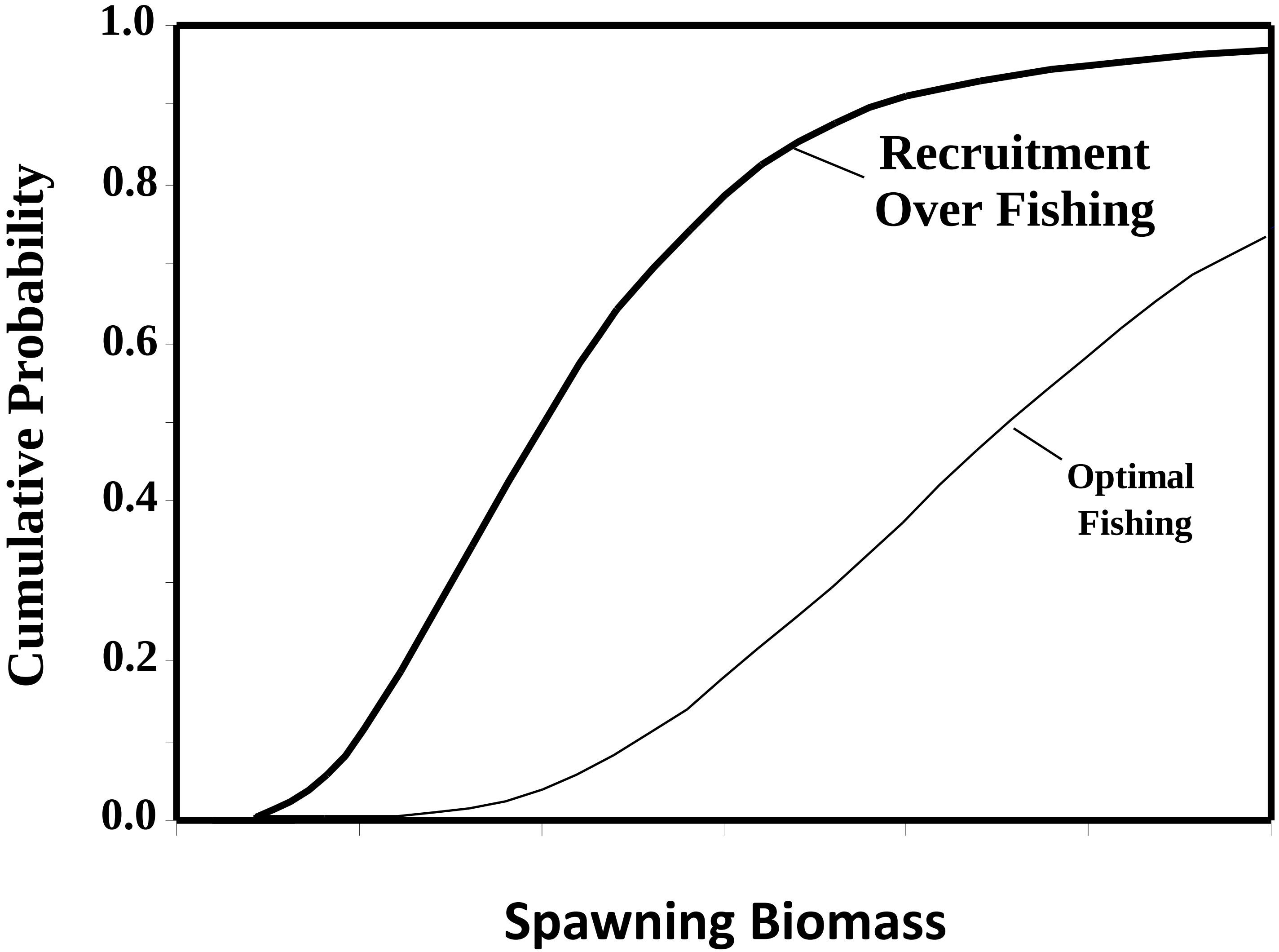
Is this the start of overfishing, and additional action is warranted?

Management Action is NOT Needed



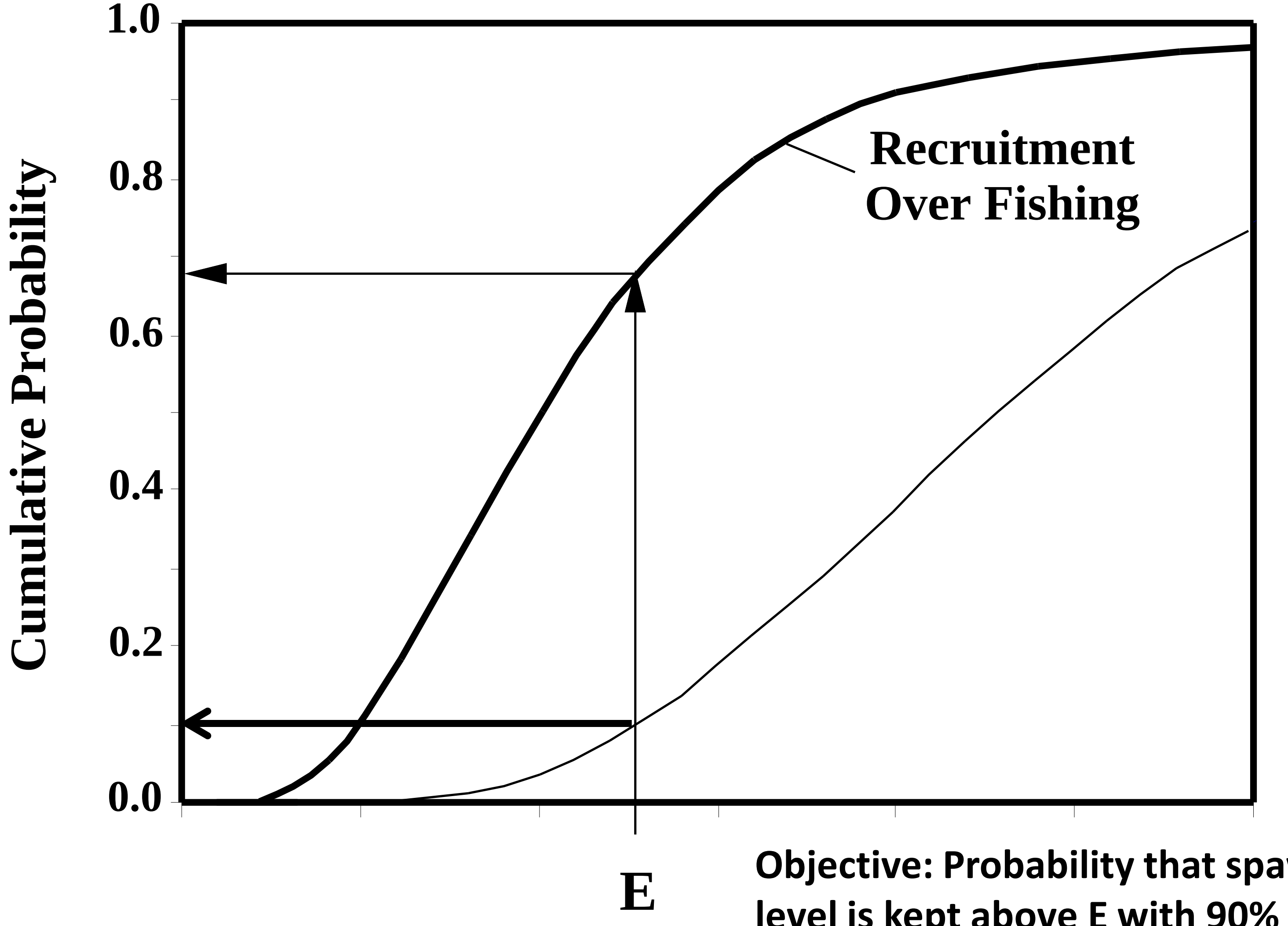
Management Action IS Needed

Consequence of climate change



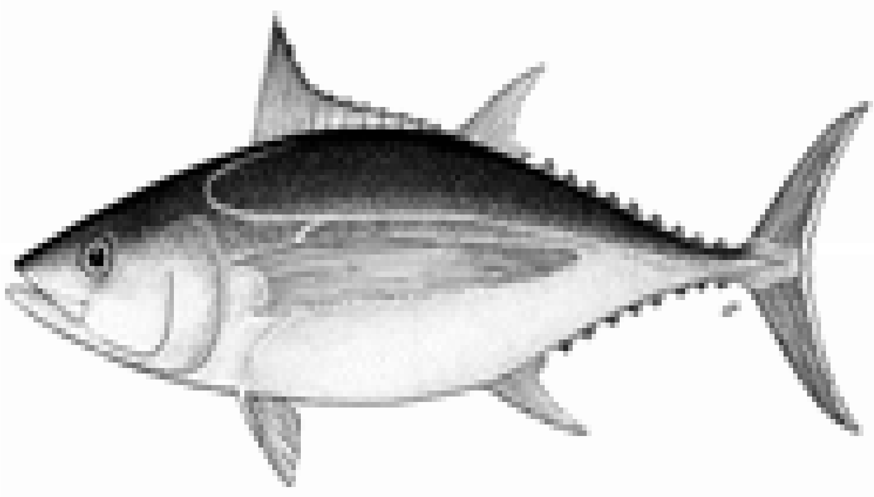
Management Action IS Needed

Even with recruitment overfishing stock is above threshold/limit 32% of the time

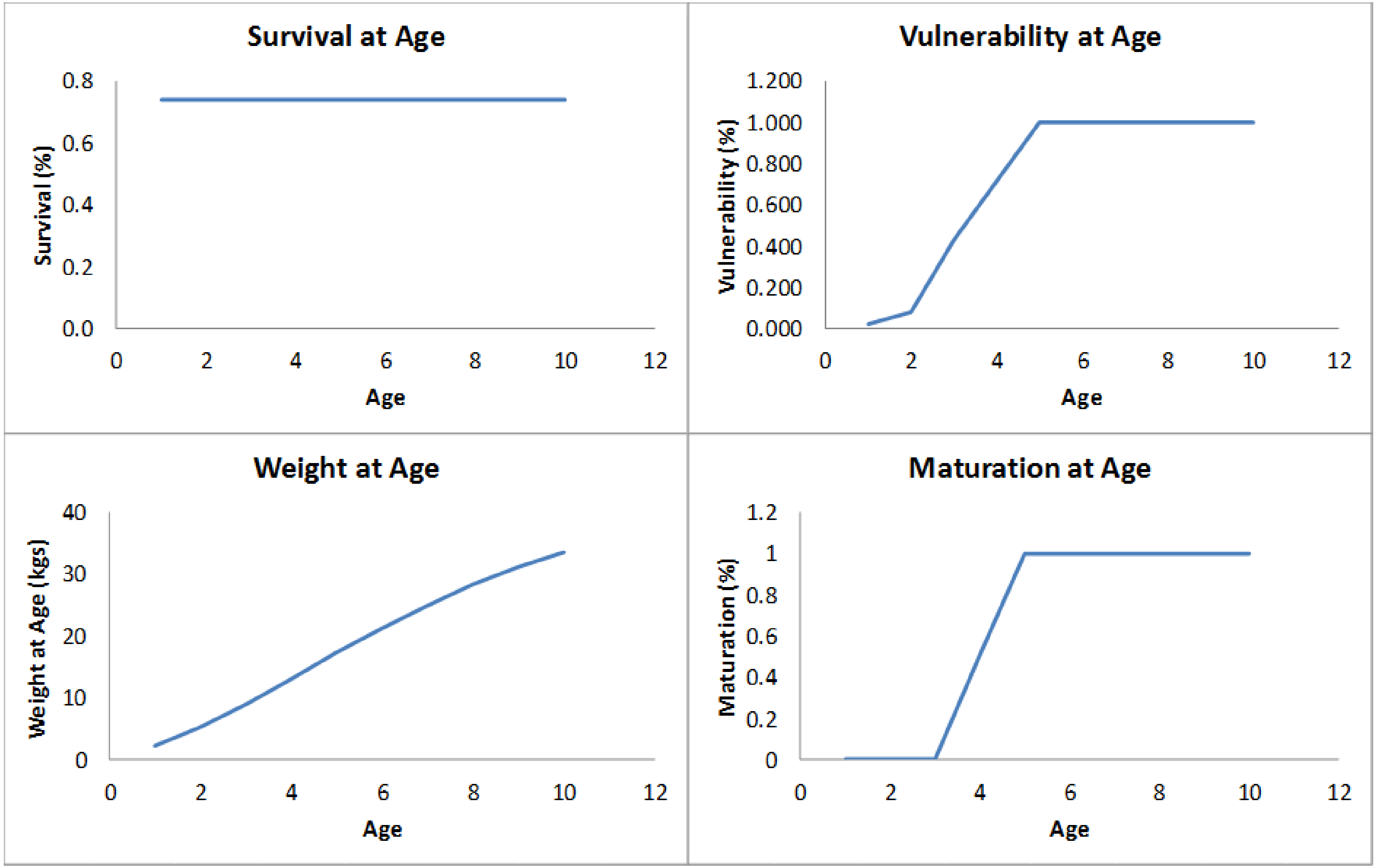


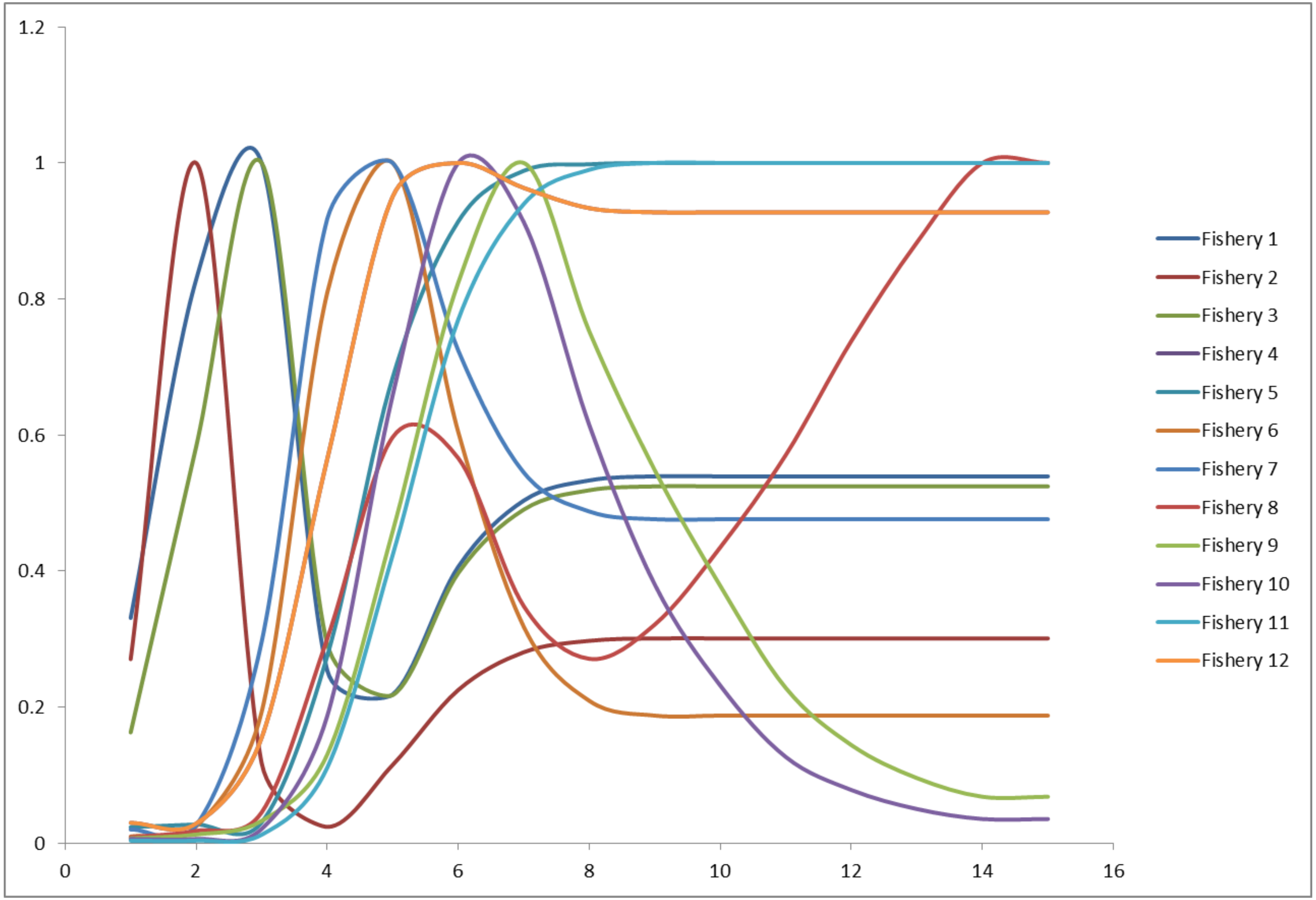
Objective: Probability that spawning biomass level is kept above E with 90% probability

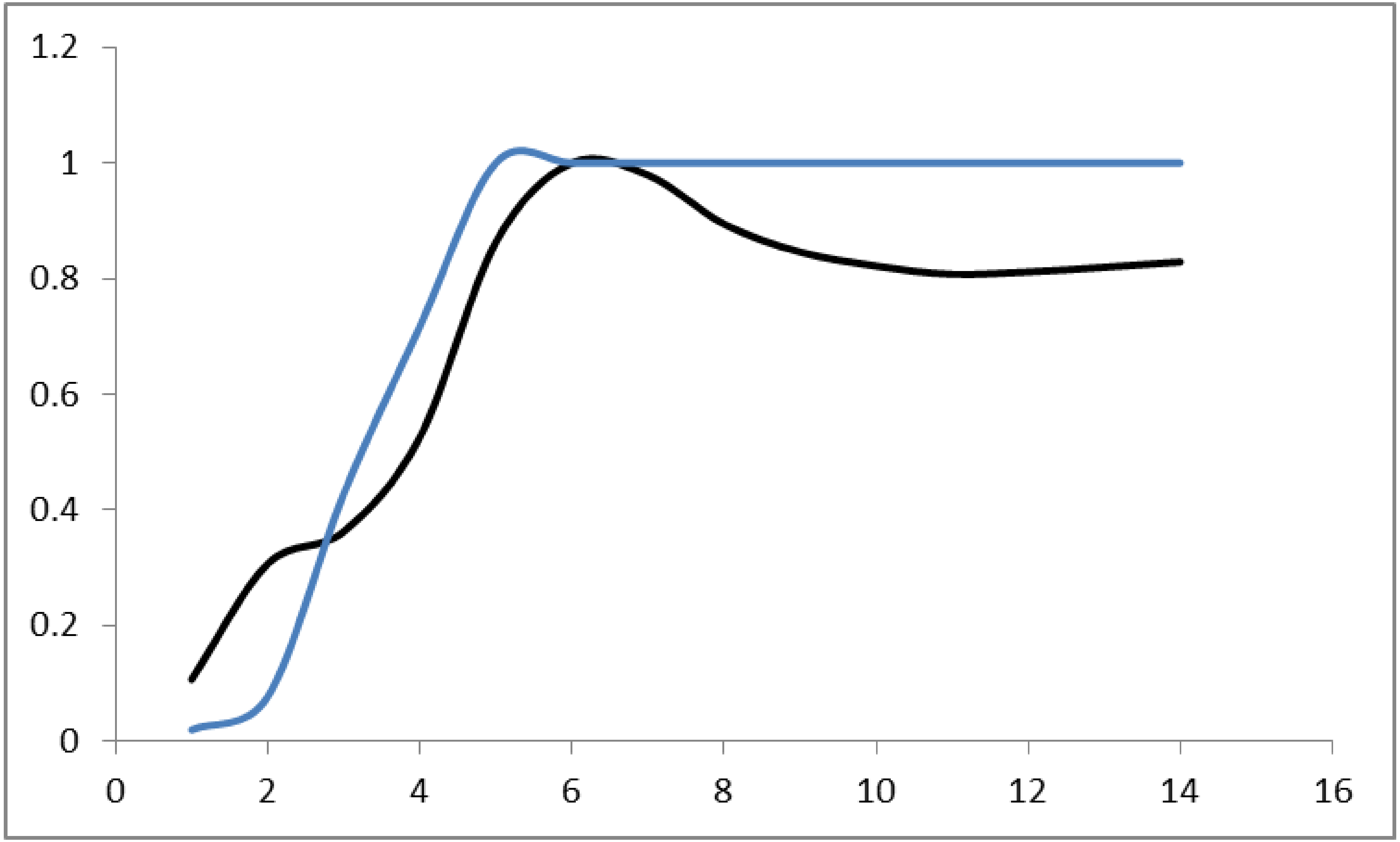
Evaluation Albacore Like Stock NAO



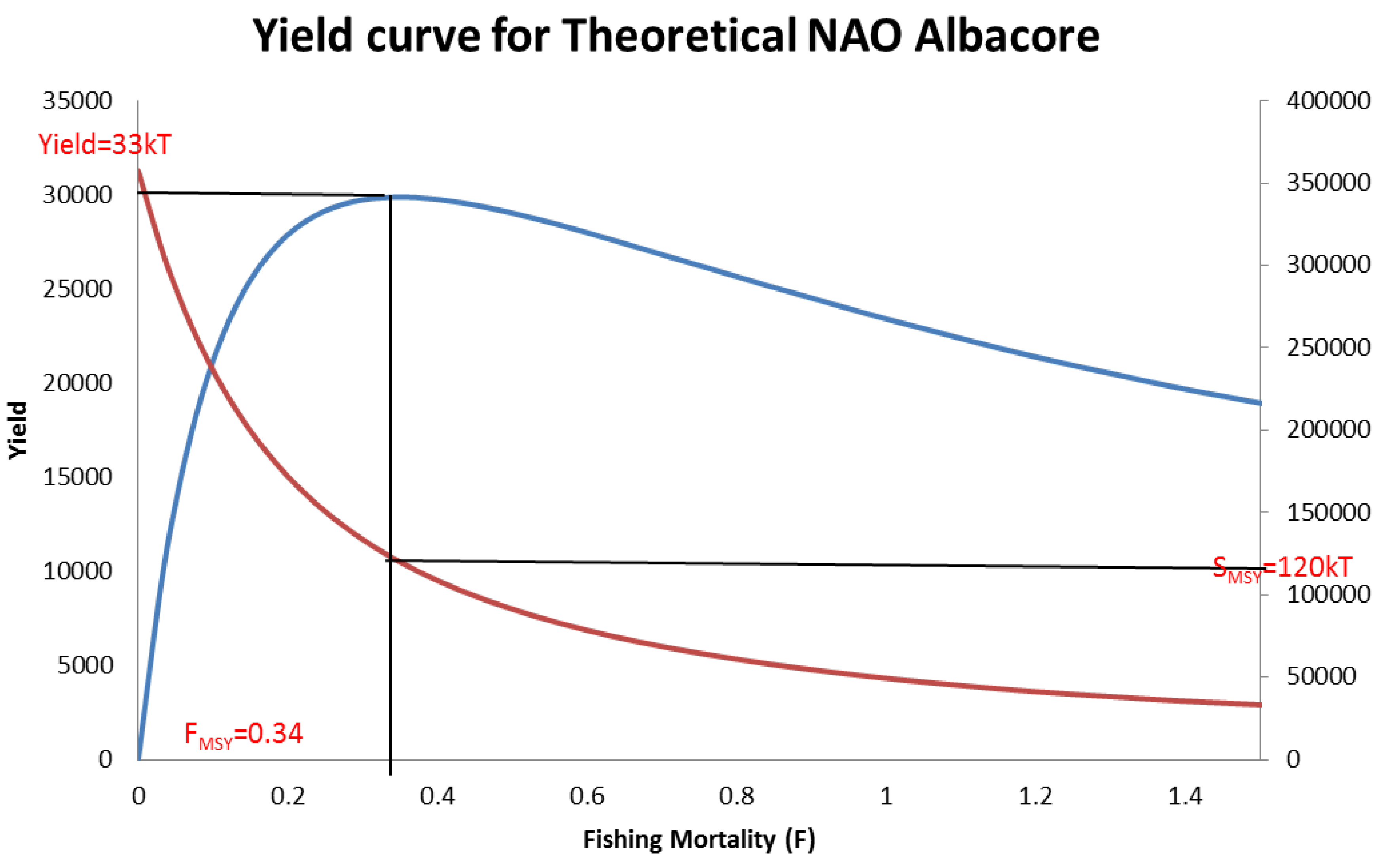
Albacore Life History



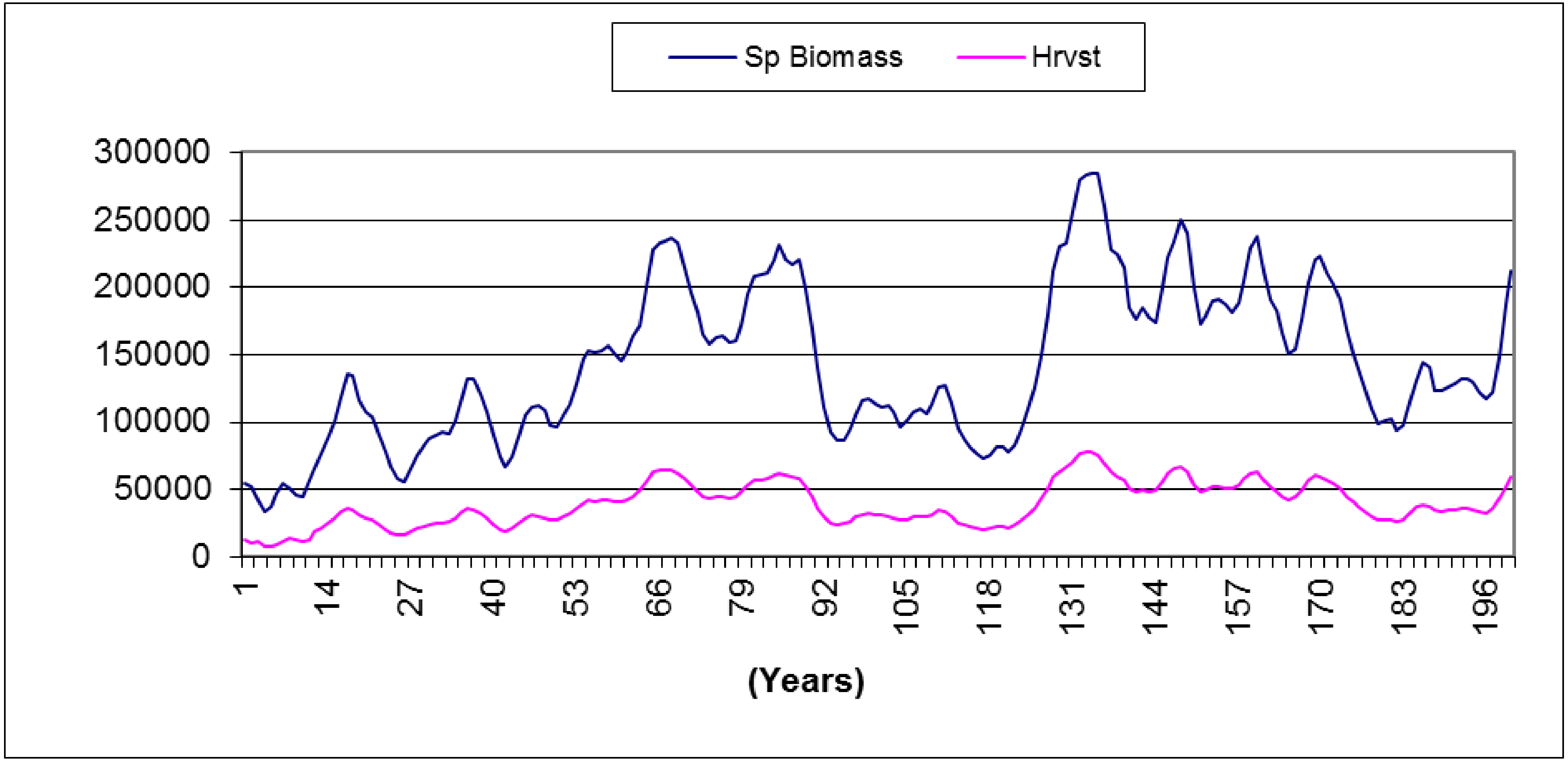

1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14
16
Fishery 1
Fishery 2
Fishery 3
Fishery 4
Fishery 5
Fishery 6
Fishery 7
Fishery 8
Fishery 9
Fishery 10
Fishery 11
Fishery 12



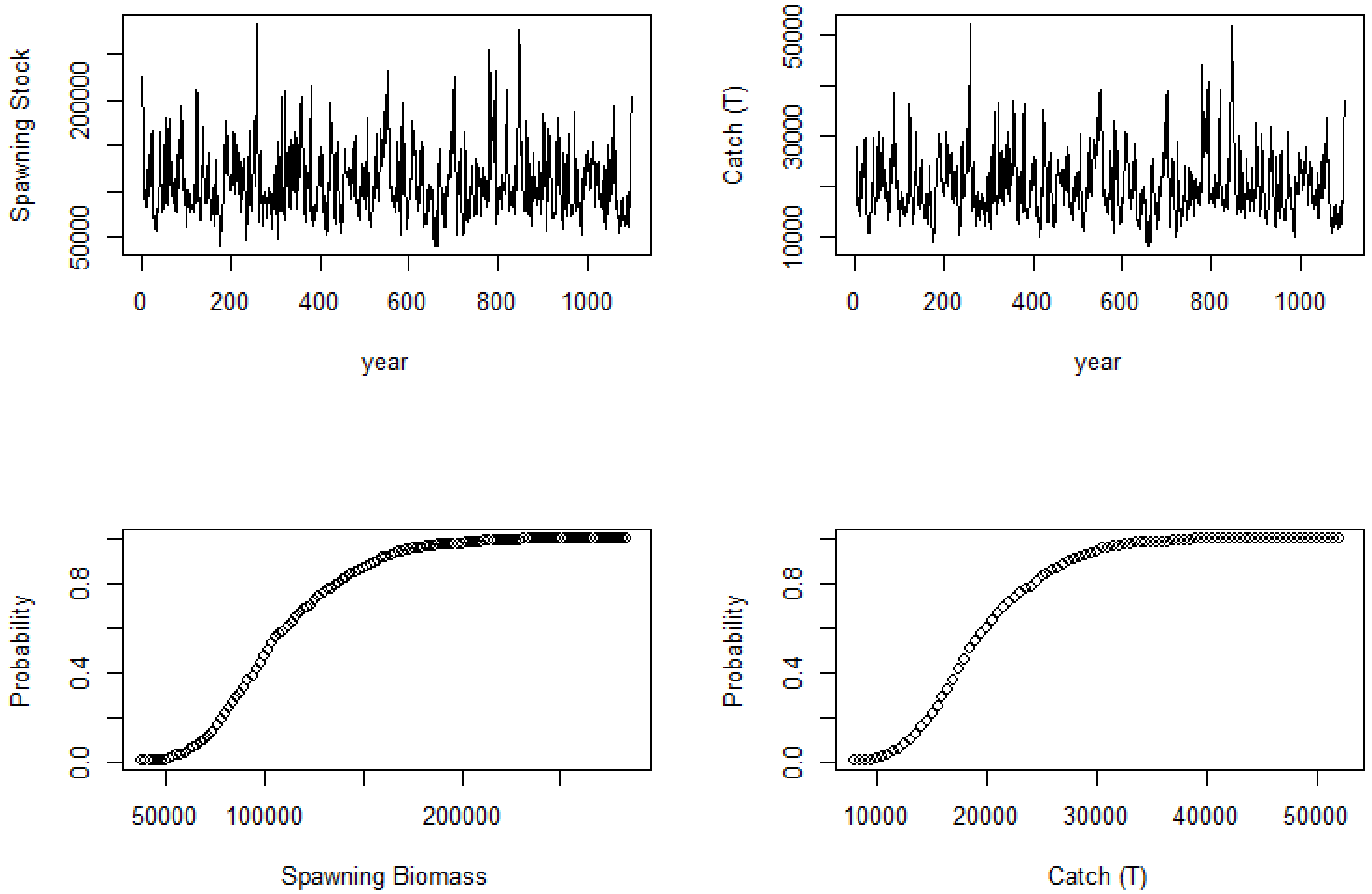
Composite sel from MFAN (black) and used selectivity (blue)



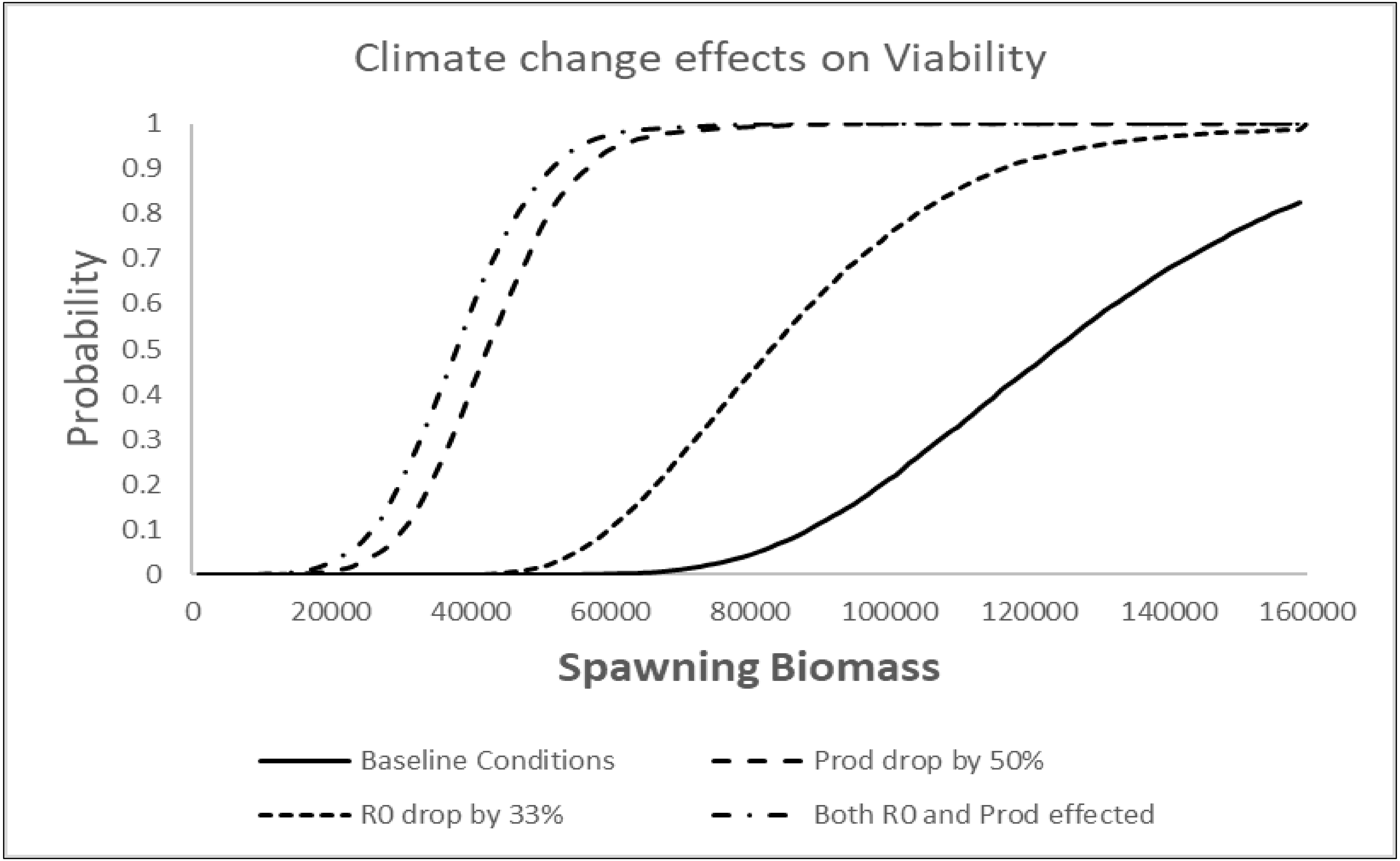
Depends on ϕ, h and selectivity

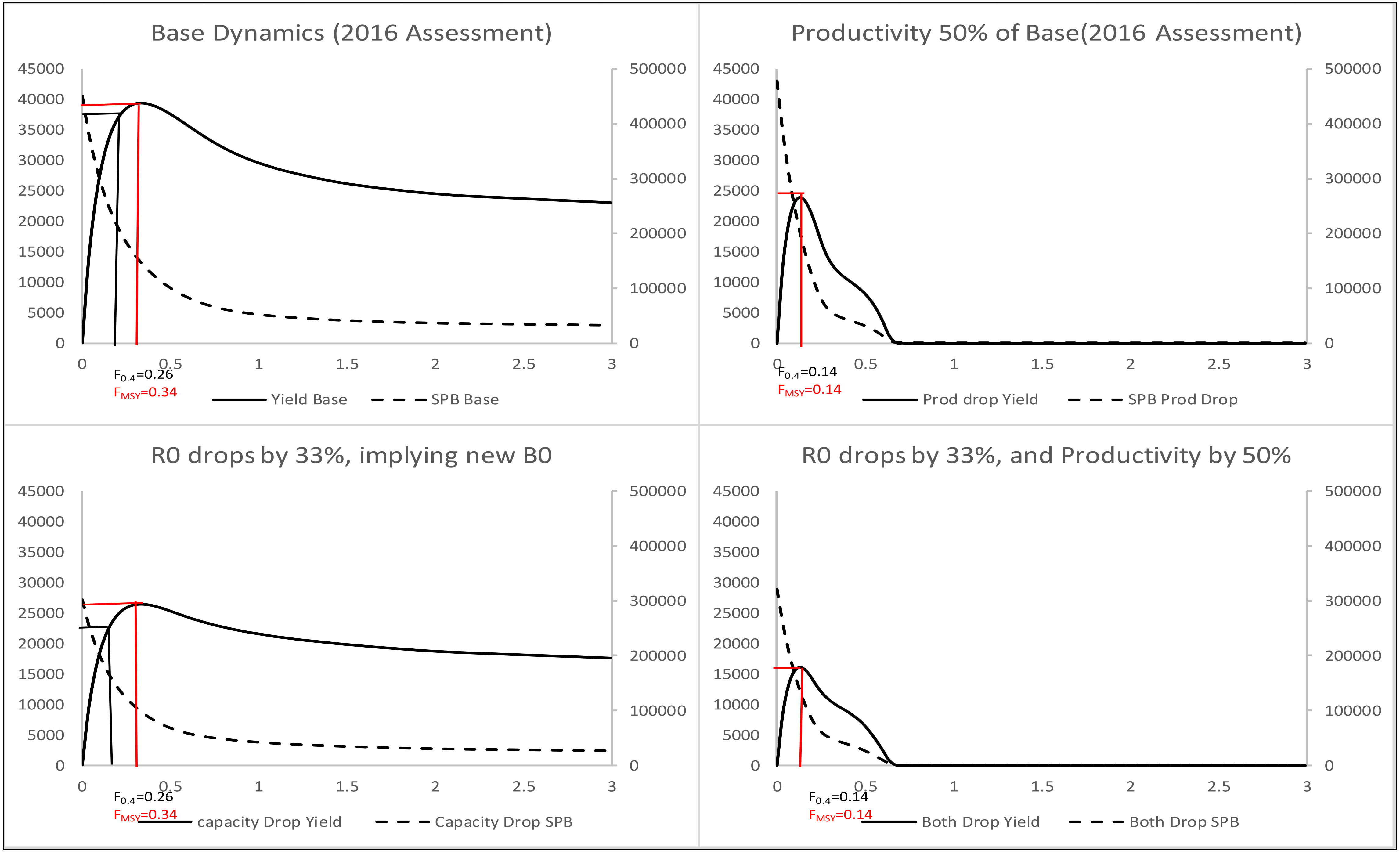


Sp Biomass
Hrvst
300000
250000
200000
150000
100000
50000
0
1
14
27
40
53
66
79
92
105
118
131
144
157
170
183
196
(Years)

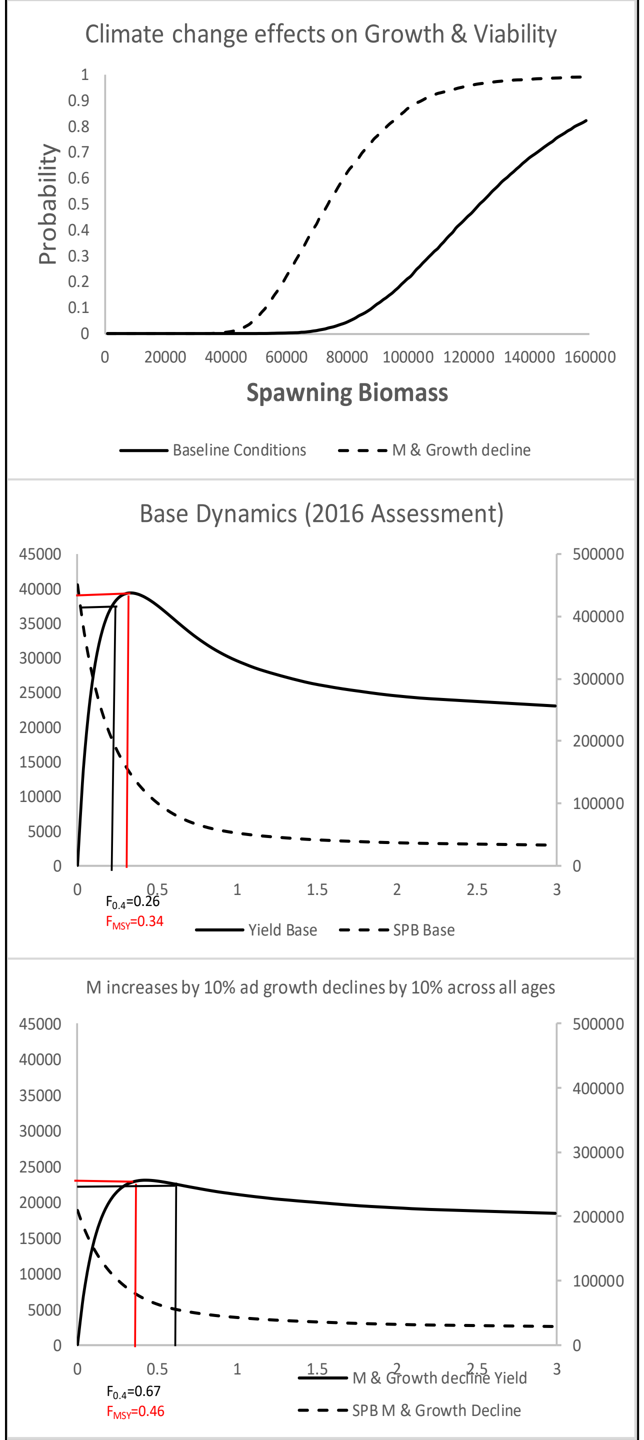


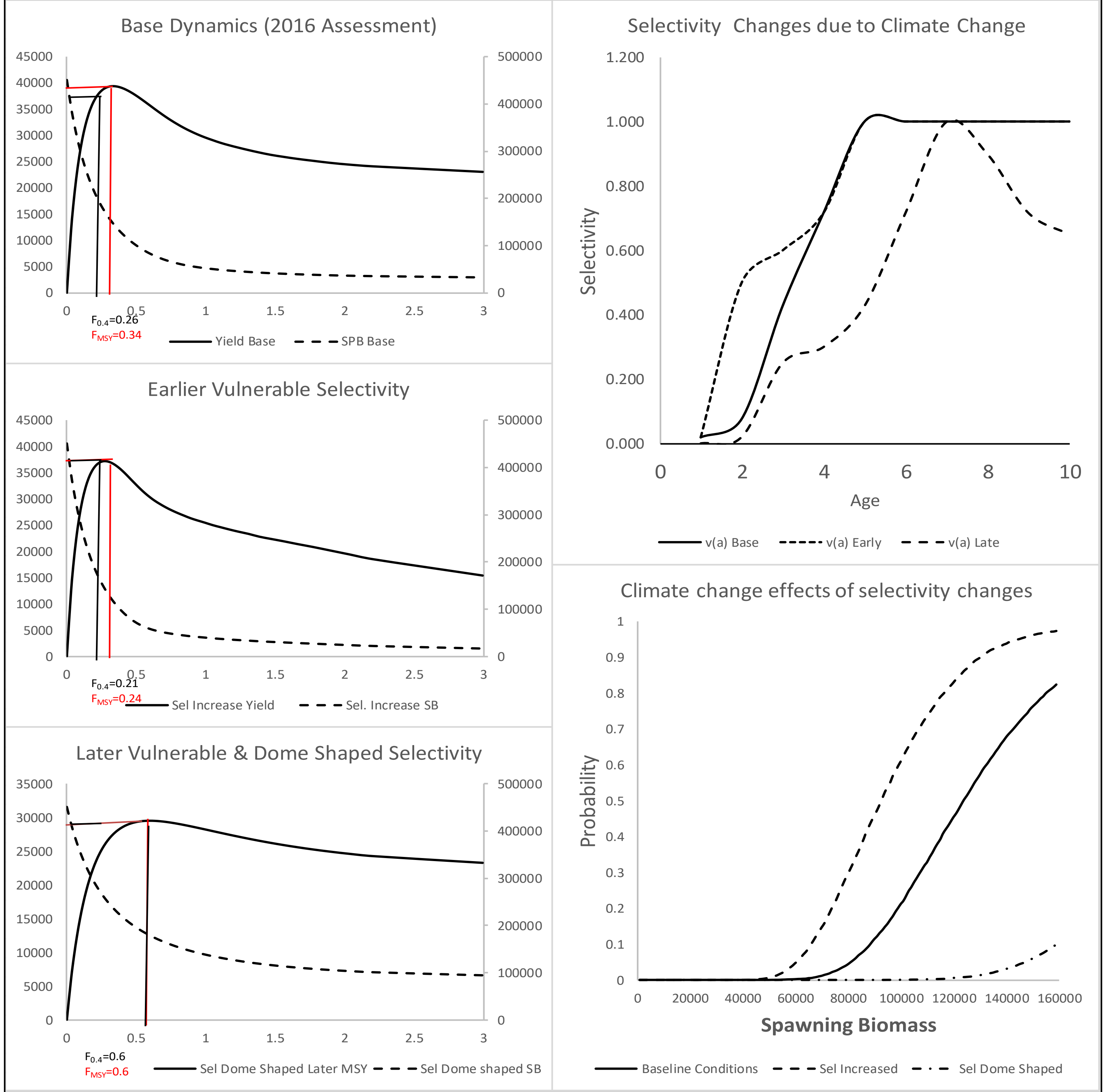
Spawning Stock
50000
200000
0
200
400
600
800
1000
year
Catch (T)
10000
30000
50000
0
200
400
600
800
1000
year
Probability
0.0
0.4
0.8
50000
100000
200000
Spawning Biomass
Probability
0.0
0.4
0.8
10000
20000
30000
40000
50000
Catch (T)

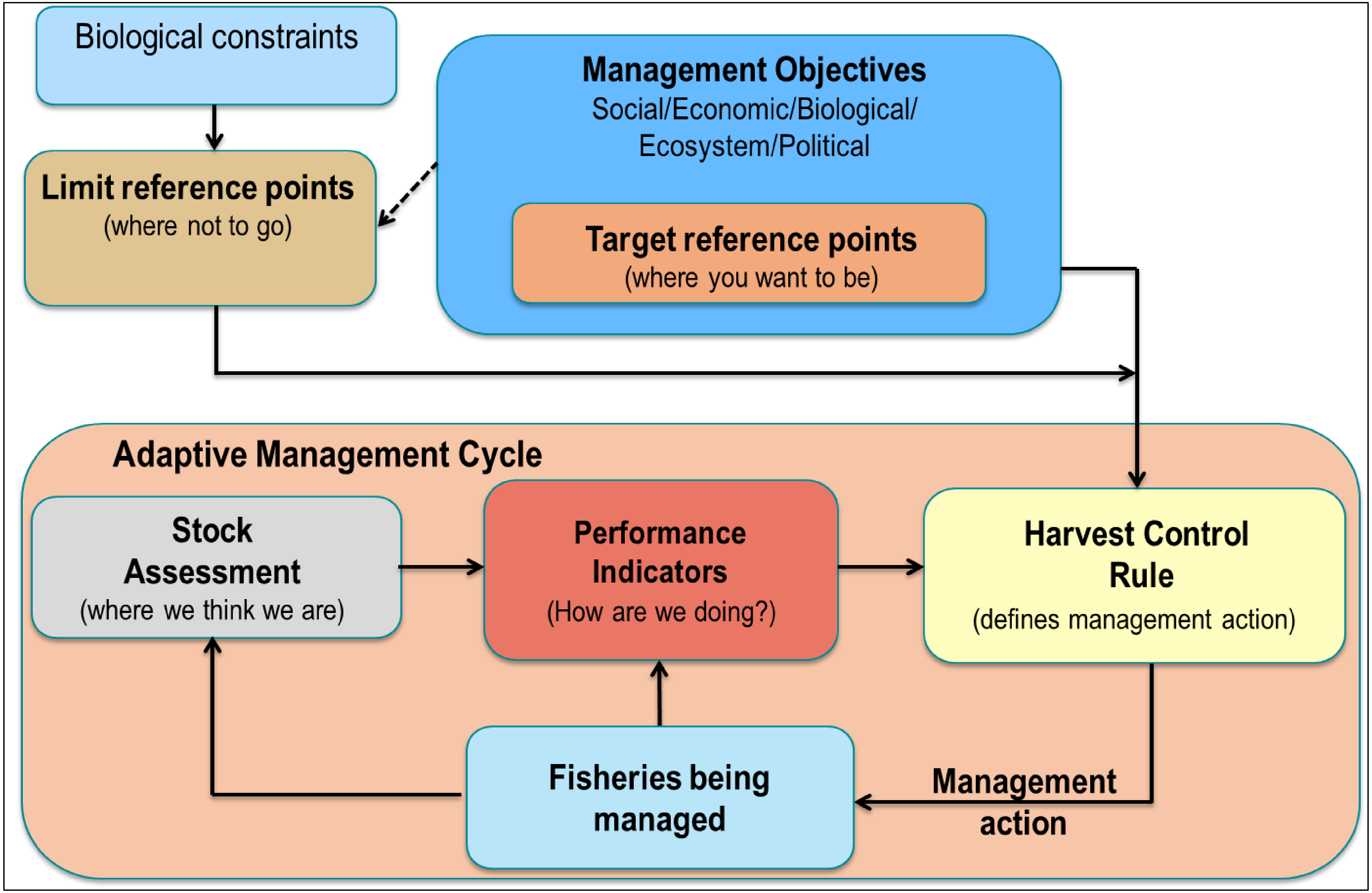

Climate change effects on Viability
Probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20000
40000
60000
80000
100000
120000
140000
160000
Spawning Biomass
Baseline Conditions
Prod drop by 50%
R0 drop by 33%
Both R0 and Prod effected



Base Dynamics (2016 Assessment)
$F_{0.4}$=0.26
F_{MSY}=0.34
Yield Base
SPB Base
Productivity 50% of Base(2016 Assessment)
$F_{0.4}$=0.14
F_{MSY}=0.14
Prod drop Yield
SPB Prod Drop
R0 drops by 33%, implying new B0
$F_{0.4}$=0.26
F_{MSY}=0.34
capacity Drop Yield
Capacity Drop SPB
R0 drops by 33%, and Productivity by 50%
$F_{0.4}$=0.14
F_{MSY}=0.14
Both Drop Yield
Both Drop SPB


Climate change effects on Growth & Viability
Probability
Spawning Biomass
0 20000 40000 60000 80000 100000 120000 140000 160000
Baseline Conditions
M & Growth decline
Base Dynamics (2016 Assessment)
$F_{0.4}$=0.26
F_{MSY}=0.34
Yield Base
SPB Base
M increases by 10% ad growth declines by 10% across all ages
$F_{0.4}$=0.67
F_{MSY}=0.46
M & Growth decline Yield
SPB M & Growth Decline

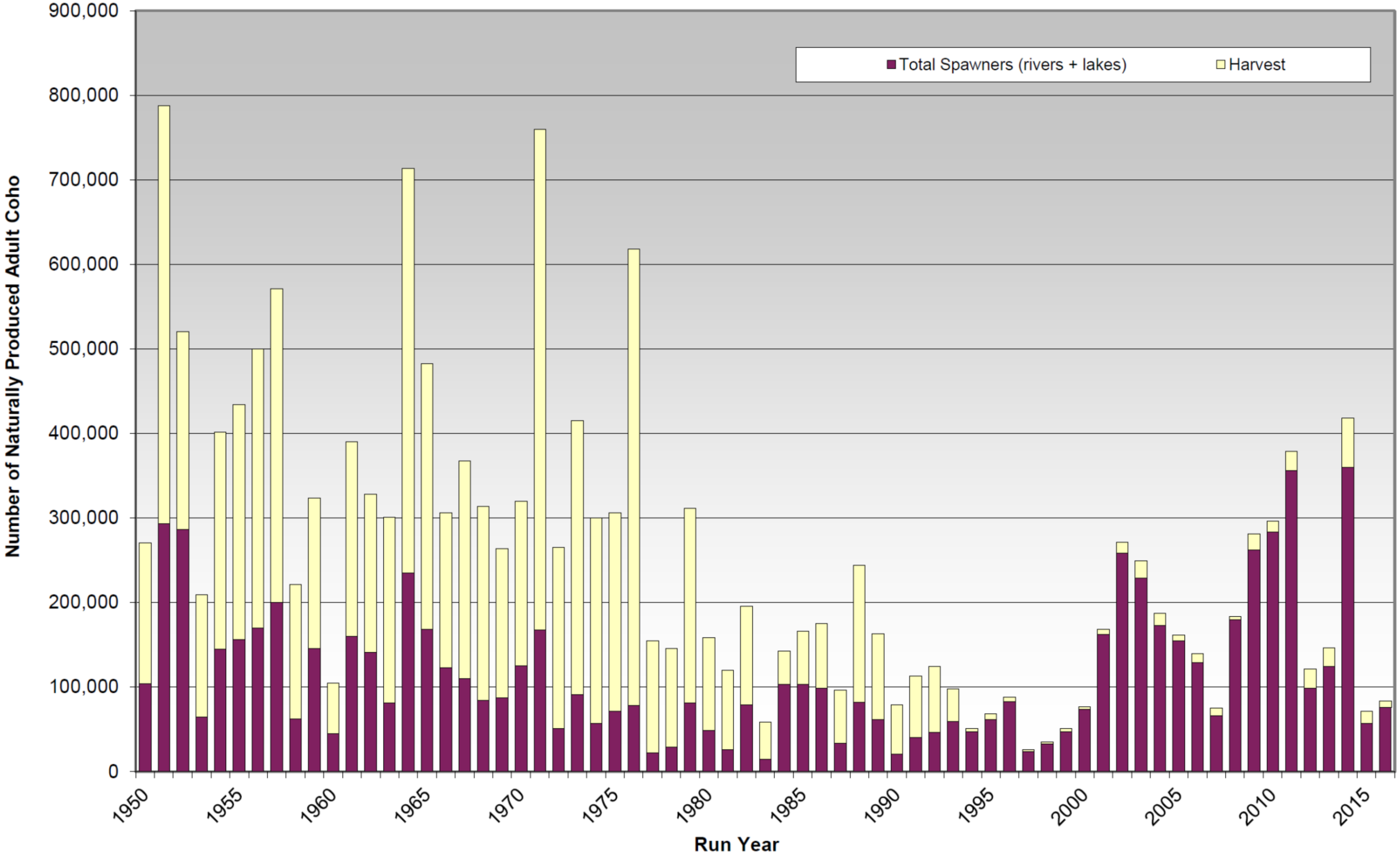

Base Dynamics (2016 Assessment)
$F_{0.4}$=0.26
F_{MSY}=0.34
Yield Base
SPB Base
Earlier Vulnerable Selectivity
$F_{0.4}$=0.21
F_{MSY}=0.24
Sel Increase Yield
Sel. Increase SB
Later Vulnerable & Dome Shaped Selectivity
$F_{0.4}$=0.6
F_{MSY}=0.6
Sel Dome Shaped Later MSY
Sel Dome shaped SB
Selectivity Changes due to Climate Change
Selectivity
Age
v(a) Base
v(a) Early
v(a) Late
Climate change effects of selectivity changes
Probability
Spawning Biomass
0 20000 40000 60000 80000 100000 120000 140000 160000
Baseline Conditions
Sel Increased
Sel Dome Shaped

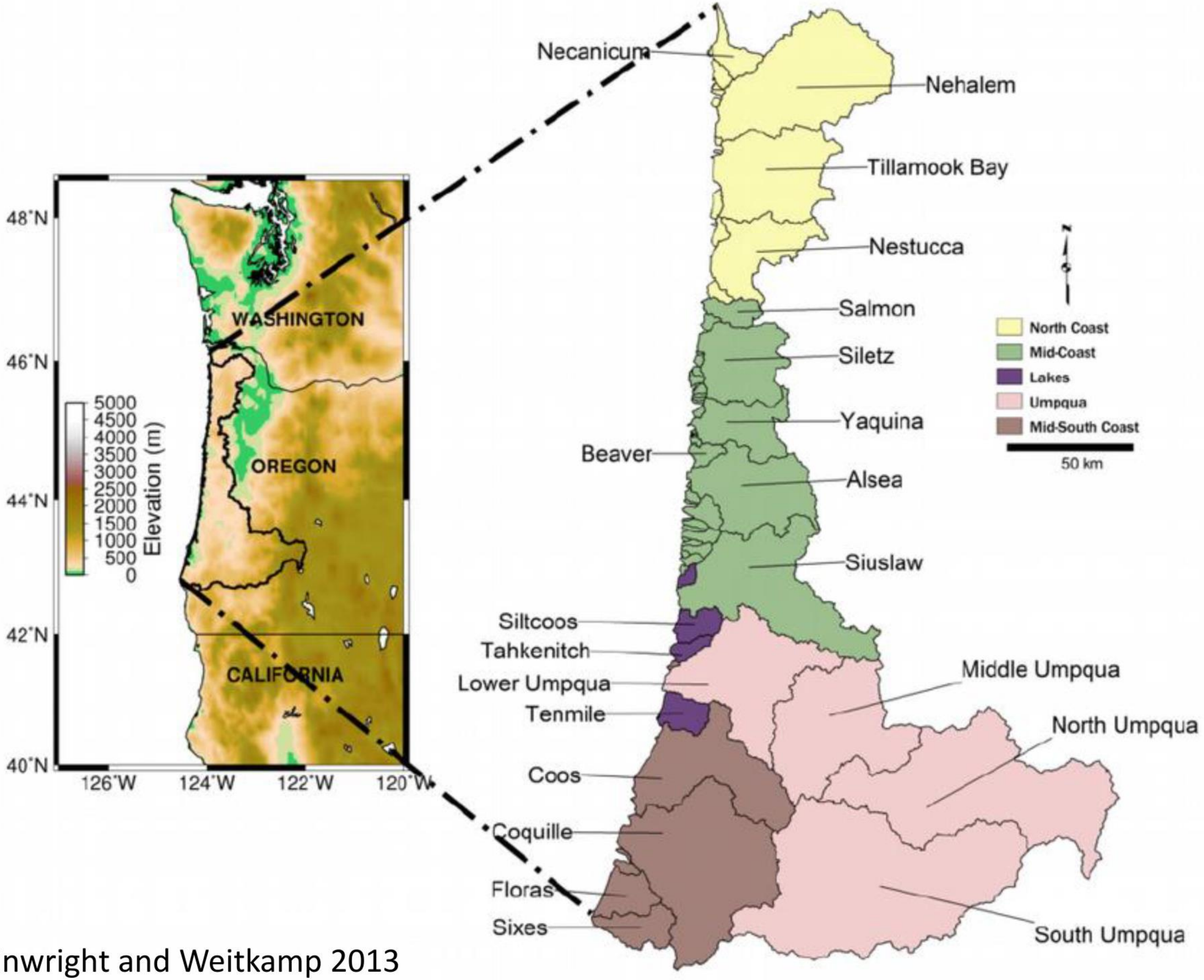


Biological constraints
Management Objectives
Social/Economic/Biological/
Ecosystem/Political
Limit reference points
(where not to go)
Target reference points
(where you want to be)
Adaptive Management Cycle
Stock
Assessment
(where we think we are)
Performance
Indicators
(How are we doing?)
Harvest Control
Rule
(defines management action)
Fisheries being
managed
Management
action

Oregon Coast Coho

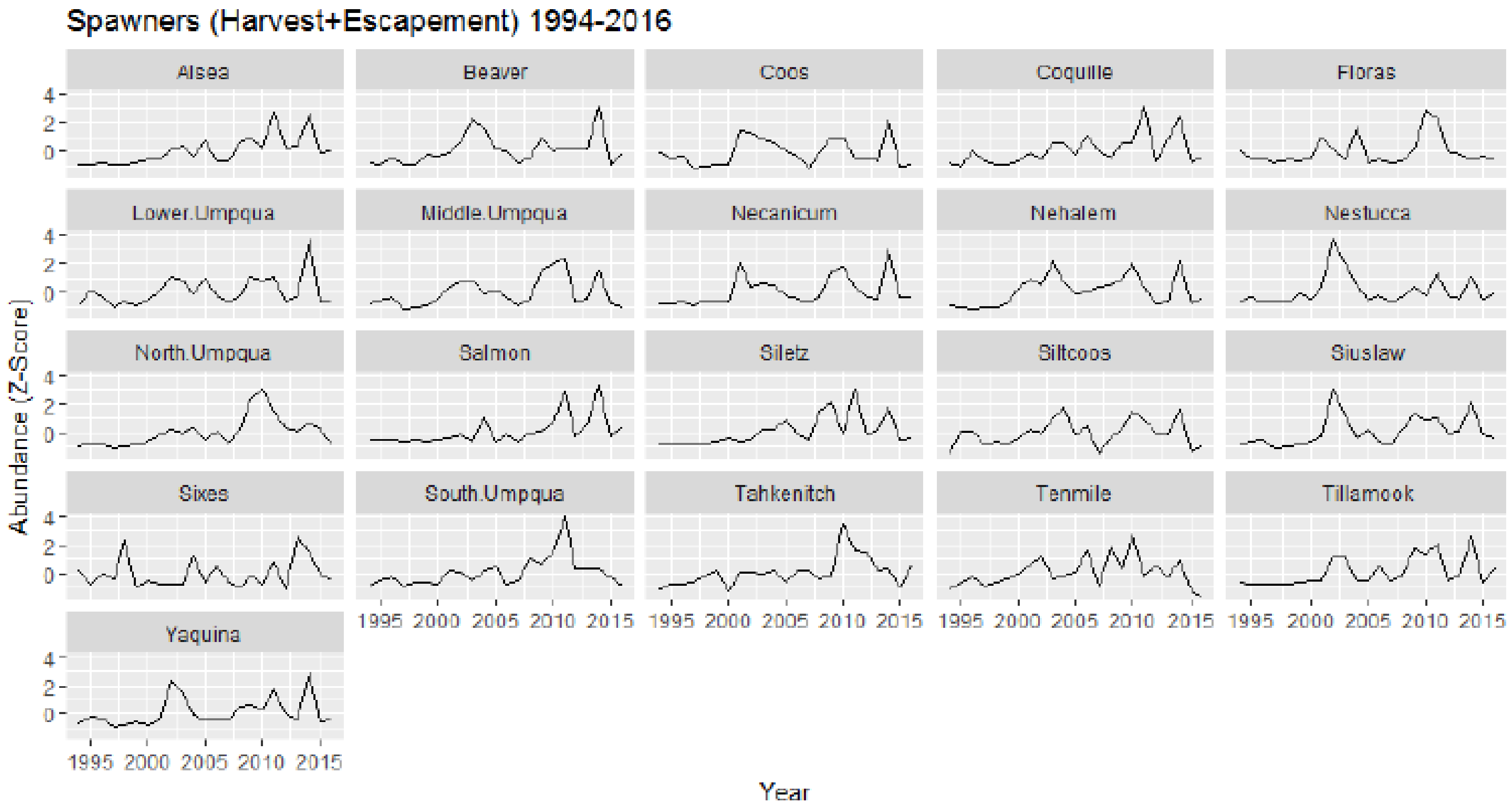
OC Coho Story





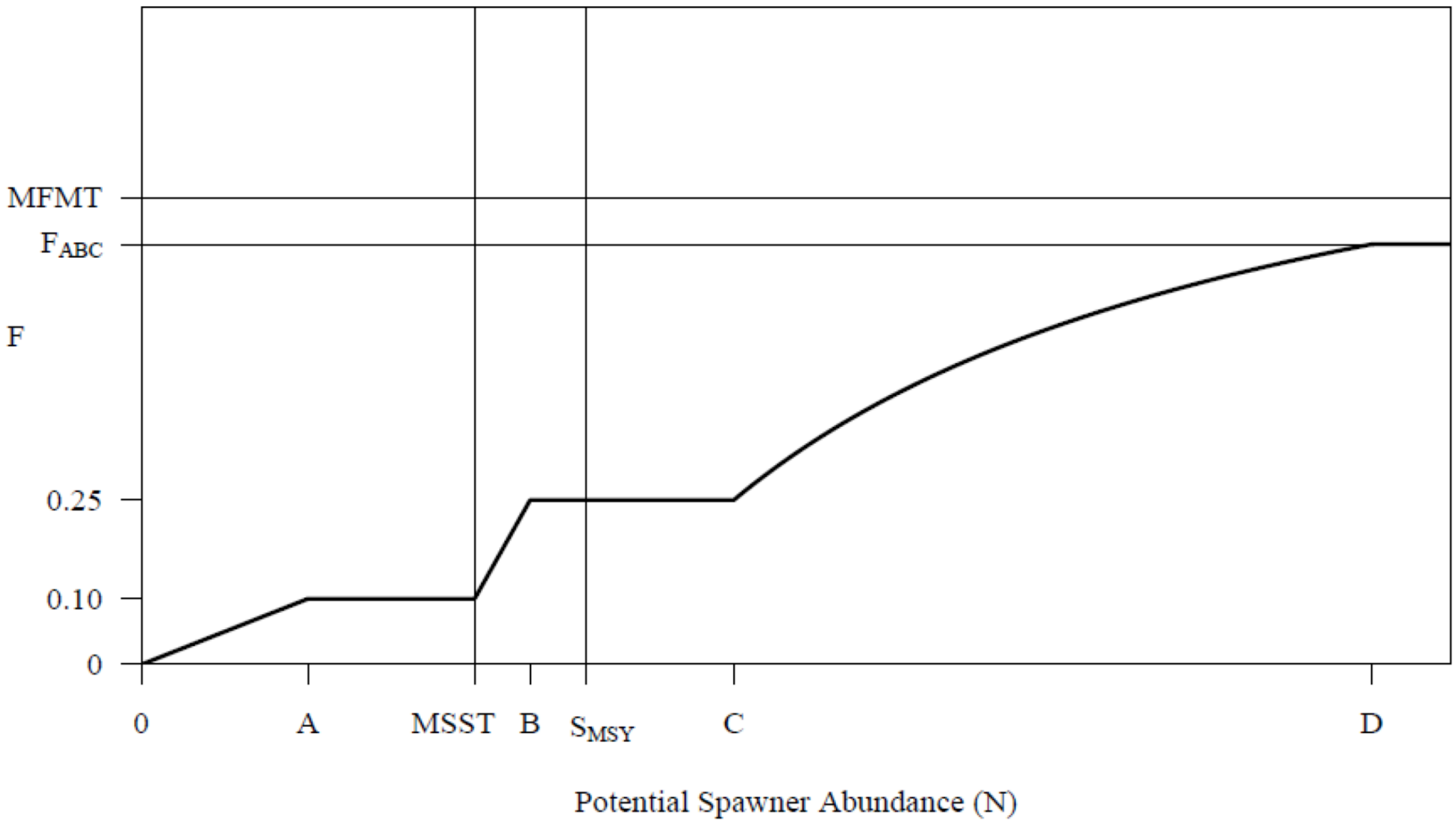
Wainwright and Weitkamp 2013

Assembling the OC coho portfolio



Adult coho abundance: 1994-2016

Control rules in salmon management



FMP Guidelines developed

OCN managed under ESA consultation standards. Amendment 13 (PFMC 1999) established a recovery and rebuilding plan for OCN coho which:

(1) defines individual management criteria for four separate stock components,

(2) sets overall harvest exploitation rate targets for OCN coho that significantly limit the impact of fisheries on the recovery of depressed stock components,

(3) promotes stock rebuilding while allowing limited harvest of other abundant salmon stocks during critical rebuilding periods,

(4) is consistent with the Oregon State recovery plan, and

(5) has been adopted by NMFS as a consultation standard for OCN coho.

So what is the rule exactly?

Max ER range

from <10% - 35%

PARENT SPAWNER STATUS		MARINE SURVIVAL INDEX (based on return of jacks per hatchery smolt) Low (<0.0009)	Medium (0.0009 to 0.0034)	High (>0.0034)
		Allowable Total Fishery Impact Rate		
High:	Parent spawners achieved Level #2 rebuilding criteria; grandparent spawners achieved Level #1	≤15%	≤30%[a/]	≤35%[a/]
Medium:	Parent spawners achieved Level #1 or greater rebuilding criteria	≤15%	≤20%[a/]	≤25%[a/]
Low:	Parent spawners less than Level #1 rebuilding criteria	≤15% ≤10-13%[b/]	≤15%	≤15%

Rebuilding Criteria	OCN Coho Spawners by Stock Component: Northern	North-Central	South-Central	Southern	Total
Full Seeding at Low Marine Survival:	21,700	55,000	50,000	5,400	132,100
Level #2 (75% of full seeding):	16,400	41,300	37,500	4,100	99,300
Level #1 (50% of full seeding):	10,900	27,500	25,000	2,700	66,100
38% of Level #1 (19% of full seeding):	4,100	10,500	9,500	1,000	25,100

Stock Component (Boundaries)	Full Seeding of Major Basins at Low Marine Survival (Number of Adult Spawners)				
Northern: (Necanicum River to Neskowin Creek)	Nehalem: 17,500	Tillamook: 2,000	Nestucca: 1,800	Ocean Tribs.: 400	
North-Central: (Salmon River to Siuslaw River)	Siletz: 4,300	Yaquina: 7,100	Alsea: 15,100	Siuslaw: 22,800	Ocean Tribs.: 5,700
South-Central: (Siltcoos River to Sixes River)	Umpqua: 29,400	Coos: 7,200	Coquille: 5,400	Coastal Lakes: 8,000	
Southern: (Elk River to Winchuck River)	Rogue: 5,400				

a/ When a stock component achieves a medium or high parent spawner status under a medium or high marine survival index, but a major basin within the stock component is less than 10% of full seeding: (1) the parent spawner status will be downgraded one level to establish the allowable fishery impact rate for that component and (2) no coho-directed harvest impacts will be allowed within that particular basin.

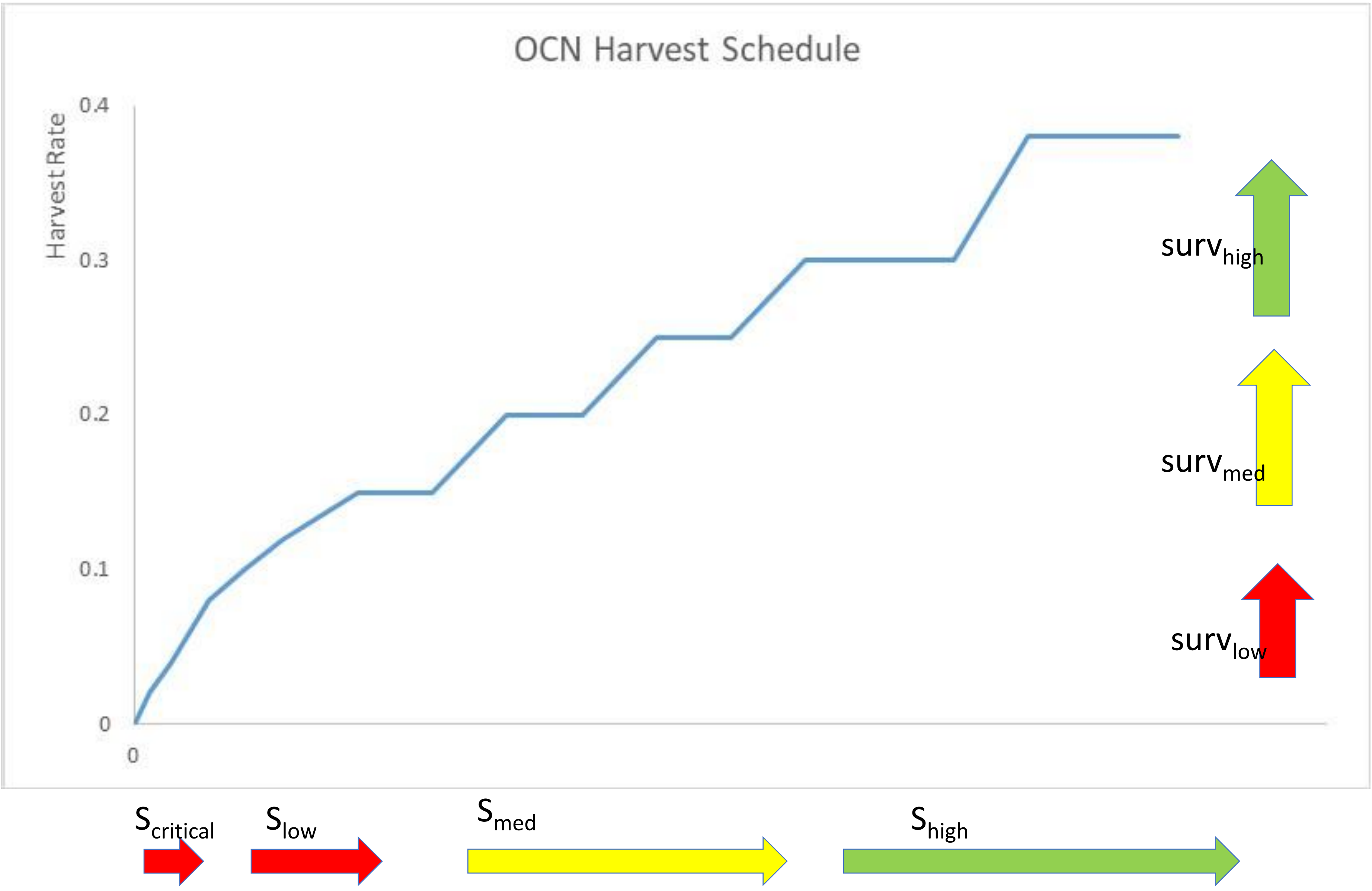
Modified in 2012-13

TABLE A-4. Fishery impact rate criteria for OCN coho stock components based on the harvest matrix resulting from the OCN work group 2000 review of Amendment 13 including modifications to the marine survival index adopted during the 2012 and 2013 methodology reviews.

Parent Spawner Status[a/]	Marine Survival Index (Wild adult coho salmon survival as predicted by the two-variable GAM ensemble forecast)			
	Extremely Low <2%	**Low** 2%-4.5%	**Medium** >4.5%-8%	**High** >8%
High Parent Spawners > 75% of full seeding	E ≤ 8%	J ≤ 15%	O ≤ 30%	T ≤ 45%
Medium Parent Spawners > 50% & ≤ 75% of full seeding	D ≤ 8%	I ≤ 15%	N ≤ 20%	S ≤ 38%
Low Parent Spawners > 19% & ≤ 50% of full seeding	C ≤ 8%	H ≤ 15%	M ≤ 15%	R ≤ 25%
Very Low Parent Spawners > 4 fish per mile & ≤ 19% of full seeding	B ≤ 8%	G ≤ 11%	L ≤ 11%	Q ≤ 11%
Critical Parent Spawners ≤4 fish per mile	A 0 – 8%	F 0 – 8%	K 0 – 8%	P 0 – 8%

Sub-aggregate and Basin Specific Spawner Criteria Data

Sub-aggregate	Miles of Available Spawning Habitat	100% of Full Seeding	"Critical"		Very Low, Low, Medium & High		
			4 Fish per Mile	12% of Full Seeding	19% of Full Seeding	50% of Full Seeding	75% of Full Seeding
Northern	899	21,700	3,596	NA	4,123	10,850	16,275
North-Central	1,163	55,000	4,652	NA	10,450	27,500	41,250
South-Central	1,685	50,000	6,740	NA	9,500	25,000	37,500
Southern *(Removed per adoption of Amendment 16)*							
Coastwide Total	*3,747*	*126,700*	*14,988*		*24,073*	*63,350*	*95,025*


OCN Harvest Schedule
Harvest Rate
0.4
0.3
0.2
0.1
0
0
$surv_{high}$
$surv_{med}$
$surv_{low}$
$S_{critical}$
S_{low}
S_{med}
S_{high}

Use of environmental indices to predict the recruitment of Pacific sardine

Juan P. Zwolinski[1,2], David A. Demer[2]

[1]Institute of Marine Sciences, University of California Santa Cruz, affiliated to the Fisheries Resources Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration

[2]Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 8901 La Jolla Shores Drive, La Jolla, CA, USA, 92037

Is there a S-R relationship for Pacific sardine?

2010: Yes.

2011: Probably.

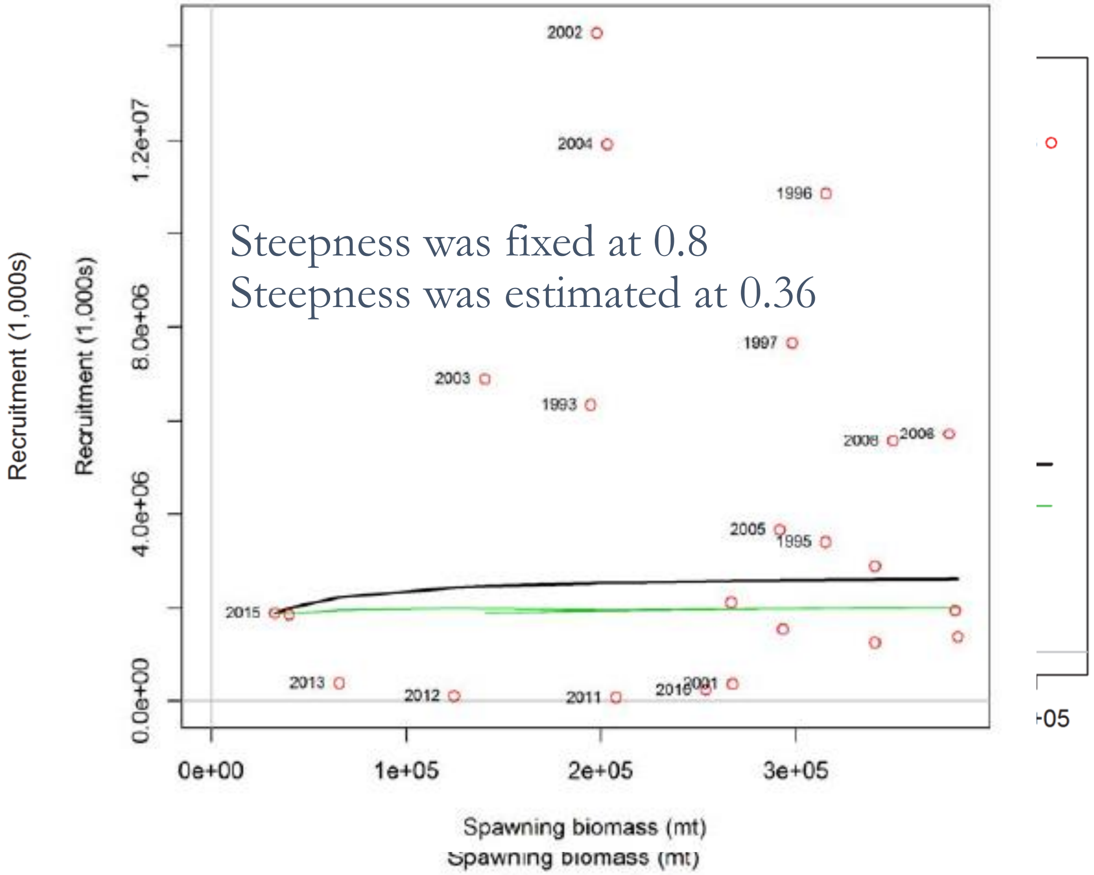
2016: Definitely not!

2017: I guess so…

It's schizophrenic

Invariably, post-hoc analyses found a solid S-R model when environment was taken into consideration

The confidence on these models was such that the environment became part of the harvest control rule.

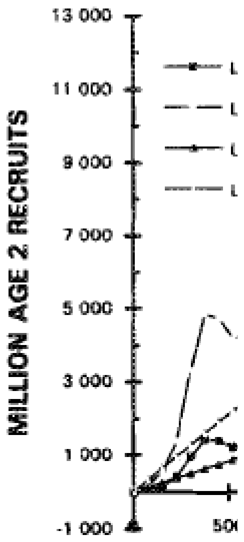


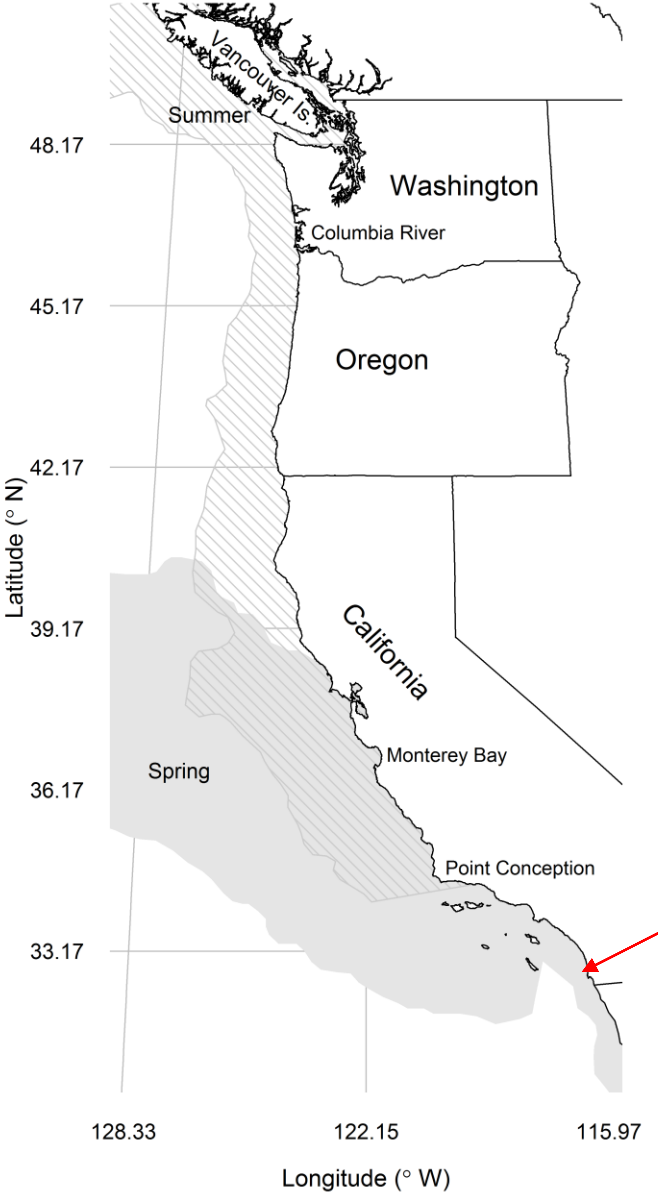
Environmental dependence of Pacific sardine

Sardine recruitment is primarily driven by biomass, and it's further modulated by temperature (Jacobson and MacCall, 1995)

Sardine surplus production increases with increasing temperature

Exploitation rate of the stock could be based on temperature measured at the Scripps pier in La Jolla





SST

Stock-recruitment feeds here

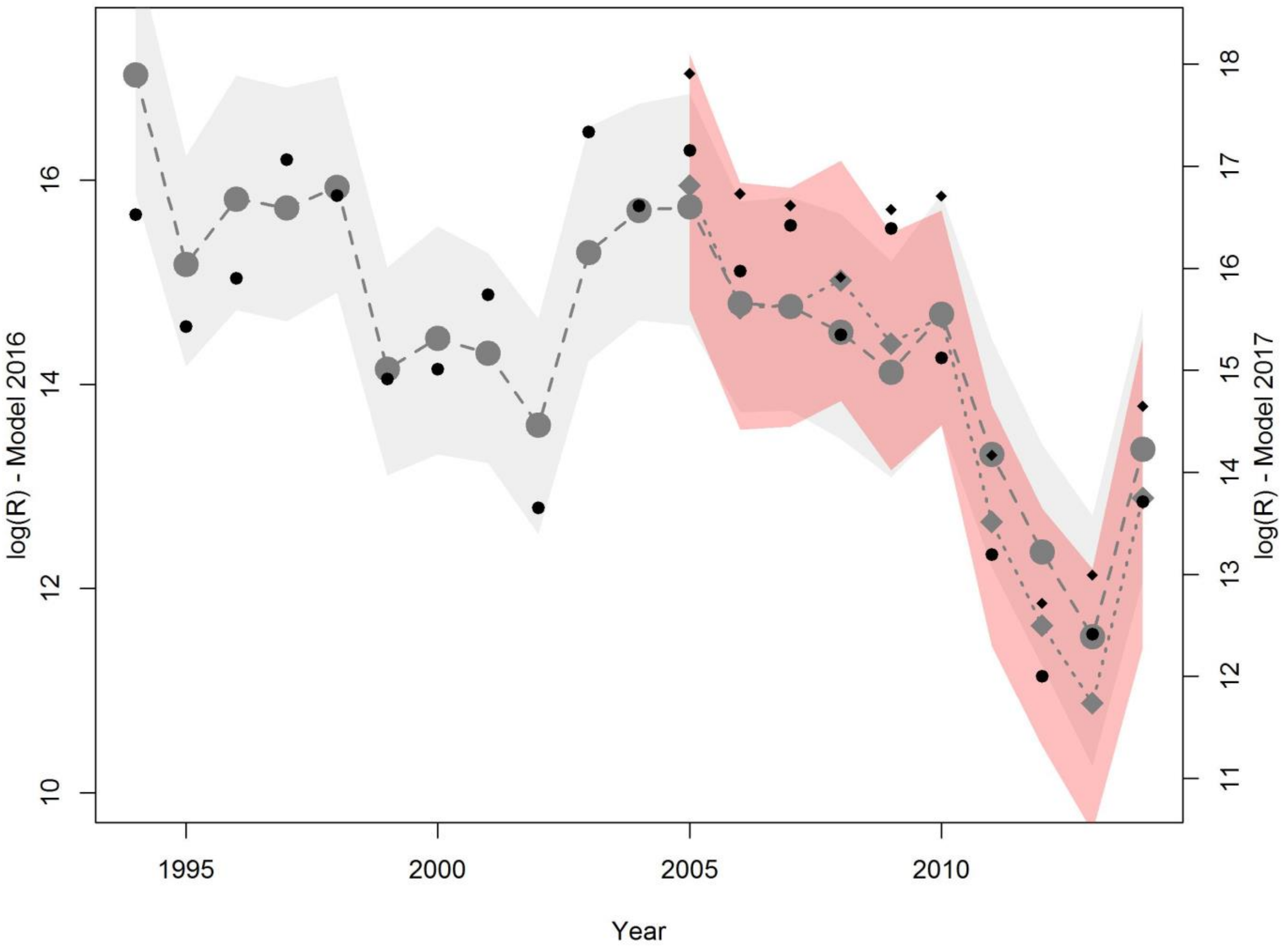
$$HG = (Biomass - Cutoff)*Fraction*Distribution$$

and

$$Fraction = 0.248649805*SST^2+-8.19004957*SST+ 67.4558326$$

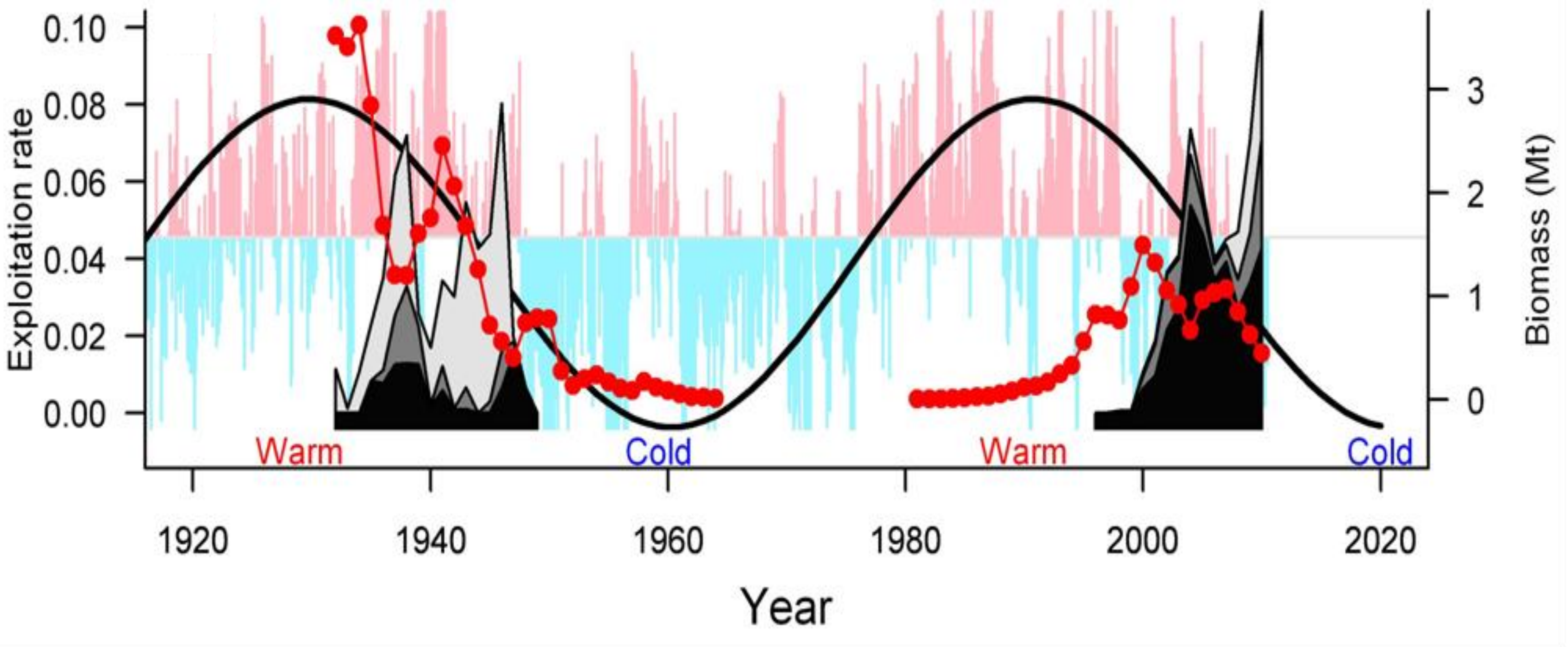
(bounded between 5% and 15%)

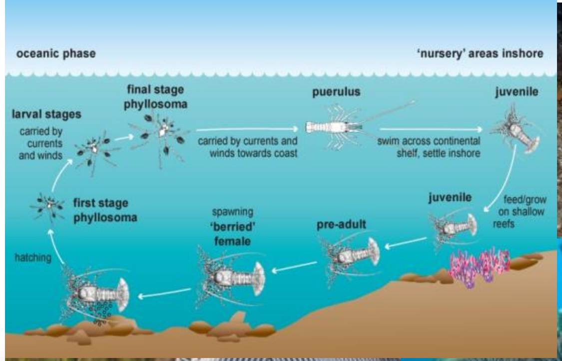
Testing environmental dependence for the northern subpopulation – Results 3



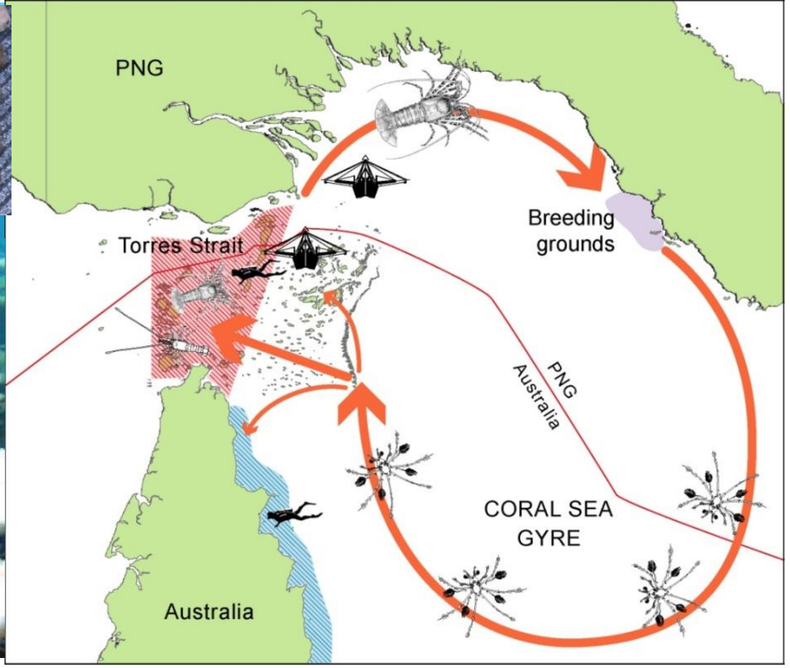
Conclusions

- There seems to be a stock-recruitment relationship that is modulated by the environment
- CalCOFI SST does not inform sardine recruitment
  - Contamination from the southern stock to the northern stock assessment might have been stronger in higher temperatures, providing the illusion of local recruitment
- PDOcombined continues to inform recruitment (although with lower r^2 than before)
  - It explains year to year variability of sardine
  - It explains decadal variability







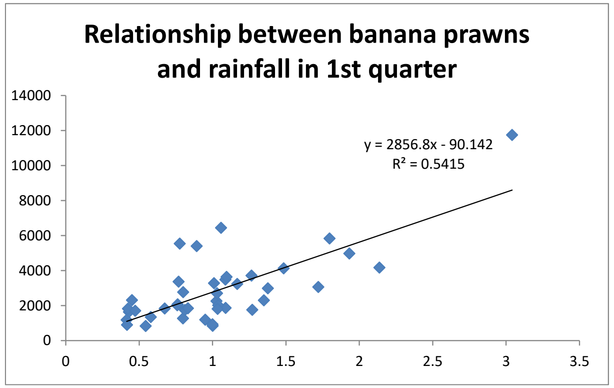



Management implications of modelling recruitment : Eva Plaganyi et. al. (in progress)

Recruitment: theory, estimation and application in fishery stock assessment models
CAPAM, 30 Oct – 3 Nov 2017, Miami

Common banana prawns – rainfall as a driver

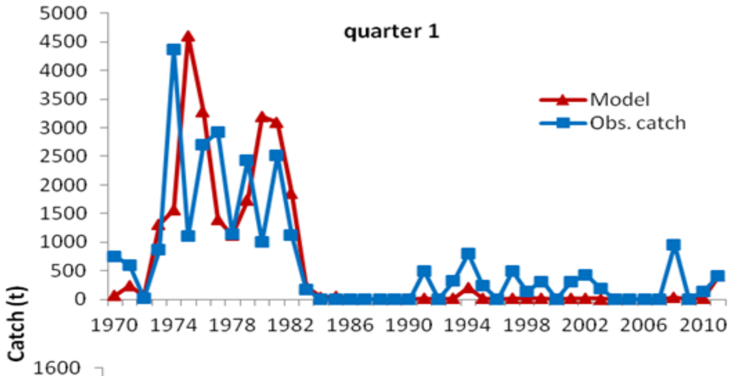
Northern Prawn Fishery (NPF) fishery



Incorporating environmental driver:

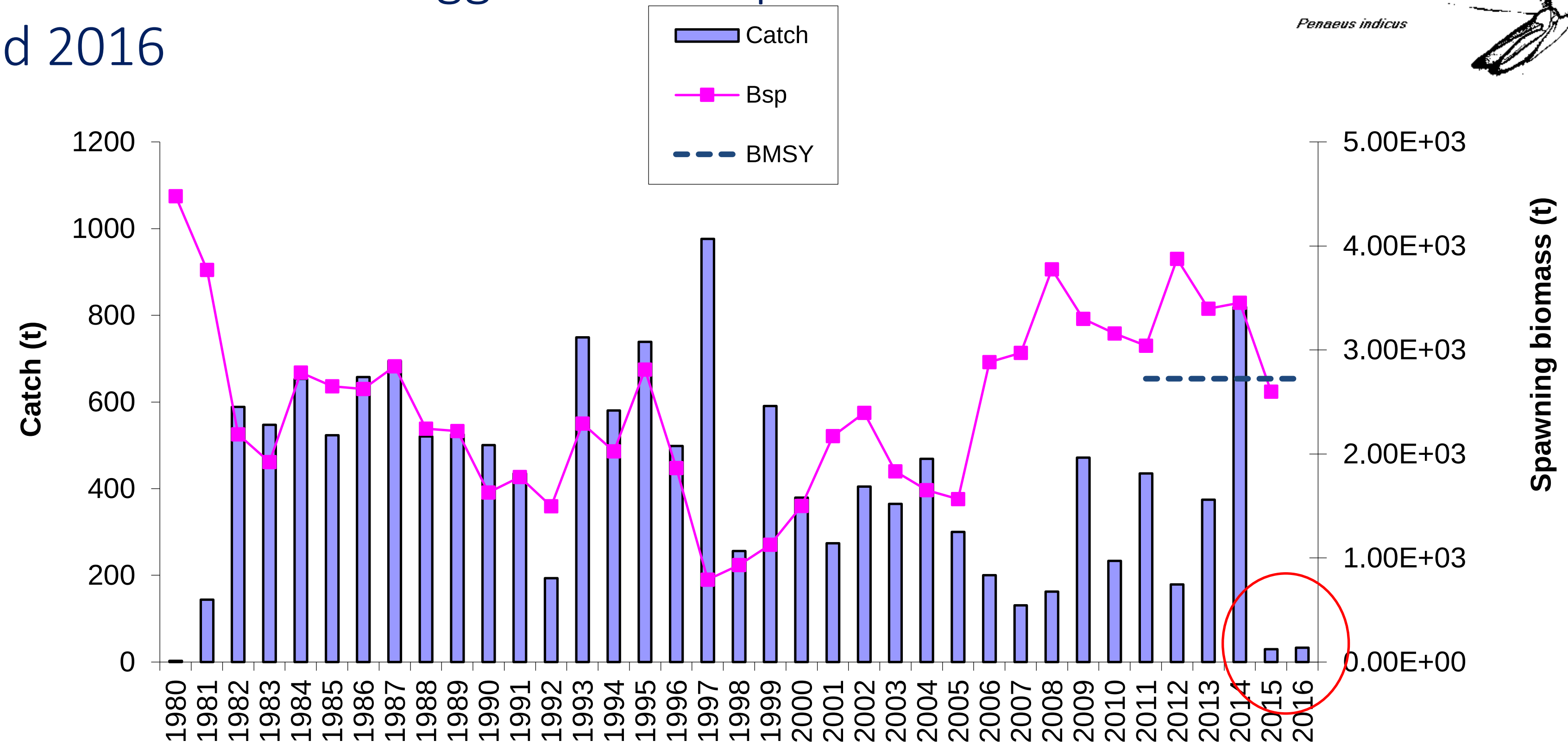
Banana prawns:

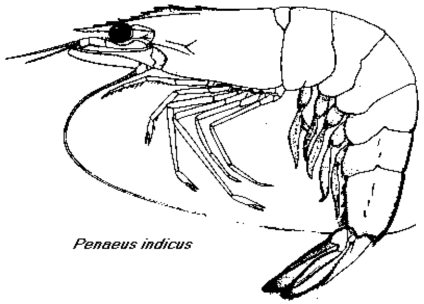
$$R_{p,y,s+1} = \frac{\alpha_p B^{sp}_{p,y,s-1}}{\beta_p + \left(B^{sp}_{p,y,s-1}\right)} e^{(\tau_y - (\sigma_R)^2/2)}$$



Residuals a function of quarter one rainfall deviations

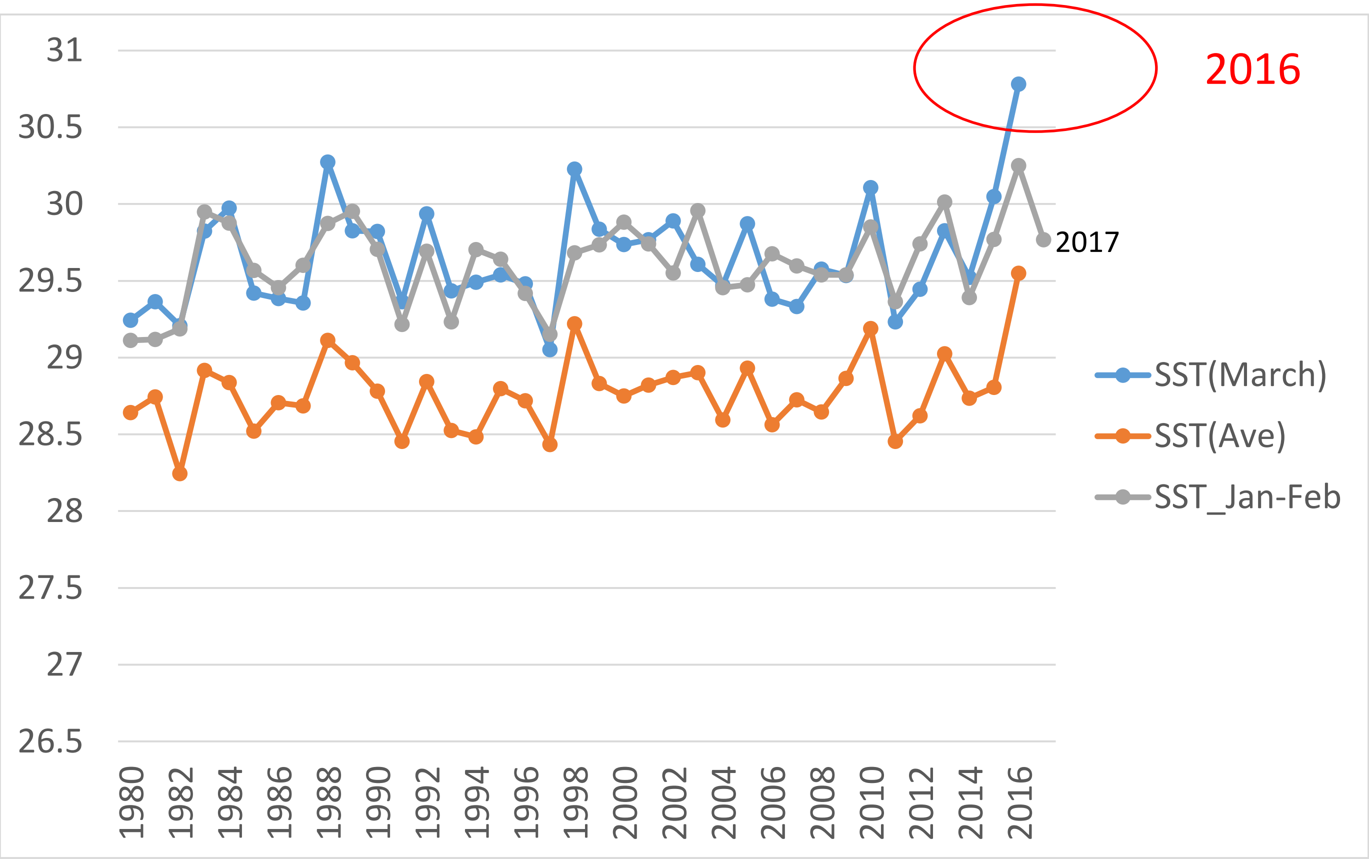
Joseph Bonaparte Gulf (JBG), reported anomalously low catches of red-legged banana prawns in 2015 and 2016





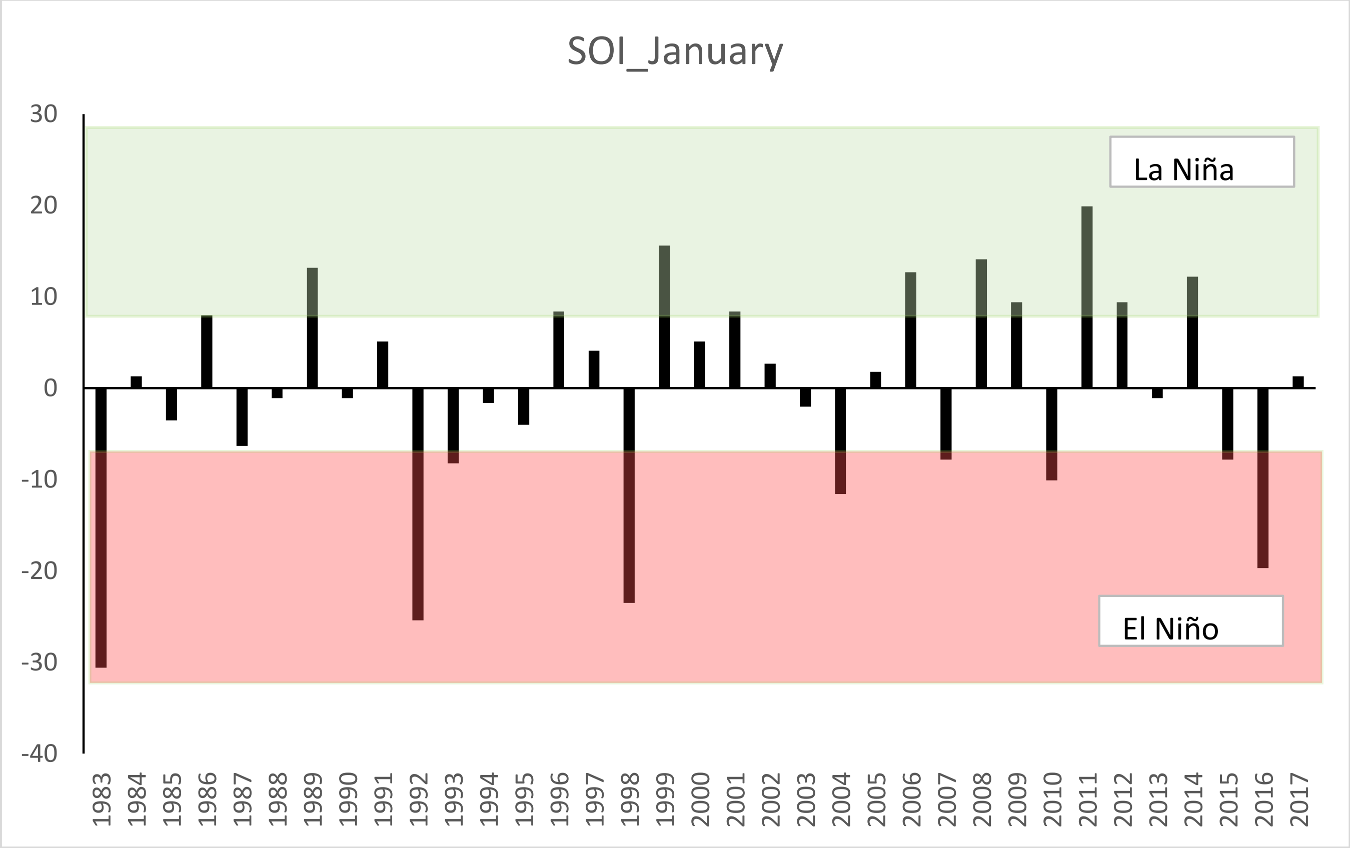
Too few data to reliably update stock assessment model and obtain forecast TAE

Sea Surface Temperature

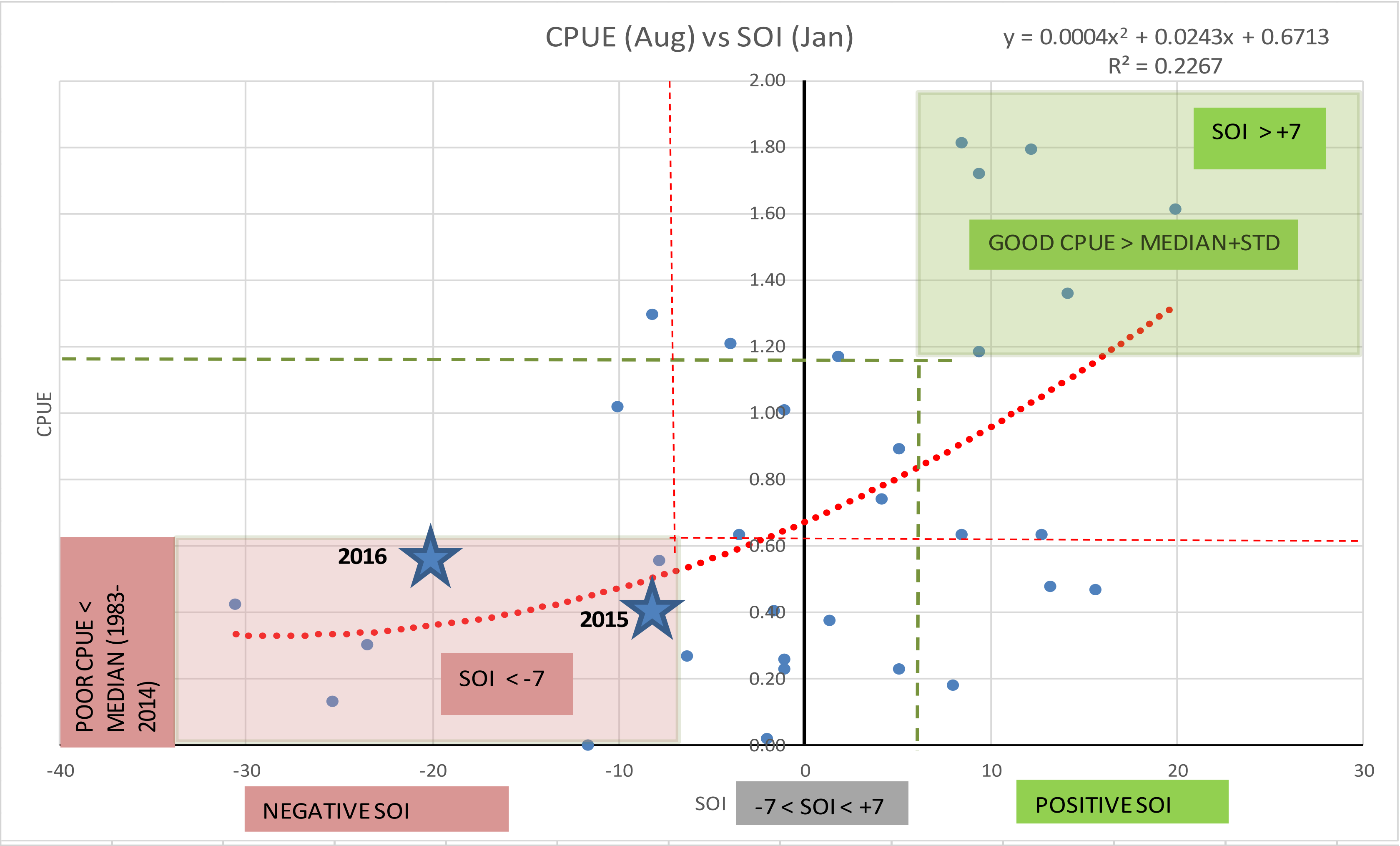


Source: http://www.metoffice.gov.uk/hadobs/hadisst/data/download.html

Southern Oscillation Index (SOI) in January



Sustained positive values of the SOI above +7 typically indicate La Niña while sustained negative values below −7 typically indicate El Niño. Values between about +7 and −7 generally indicate neutral conditions


CPUE (Aug) vs SOI (Jan)
y = 0.0004x² + 0.0243x + 0.6713
R² = 0.2267
CPUE
SOI
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-40
-30
-20
-10
0
10
20
30
SOI > +7
GOOD CPUE > MEDIAN+STD
2016
2015
POOR CPUE < MEDIAN (1983-2014)
SOI < -7
NEGATIVE SOI
-7 < SOI < +7
POSITIVE SOI

	NEGATIVE SOI	NEUTRAL	POSITIVE SOI
HIGH RAINFALL HIGH CPUE	SOI (Jan) < -7 Rain (Jan+Feb) > median AVERAGE-HIGH CPUE		SOI (Jan) > +7 Rain (Jan+Feb) > median HIGH CPUE
AVERAGE CPUE		-7 ≤ SOI≤ 7	
LOW RAINFALL LOW CPUE	SOI (Jan) < -7 Rain (Jan+Feb) < median LOW CPUE		SOI (Jan) > +7 Rain (Jan+Feb) < median LOW-AVERAGE CPUE

Understanding and predicting inter-annual variability in recruitment and catches

- Useful to have a heads up if predicting very bad year
- But we know that red-legged fishing effort in this multispecies fishery also depends on performance relative to fishing the other species and economic considerations
- Hence need to understand other drivers of low vs high Effort in the JBG to correctly attribute reasons for poor or good catches - compare the revenue per unit effort in different regions
- Revising harvest strategy to include rules based on environmental and economic conditions

In prep with Pascoe, Hutton, Lawrence, Deng, Punt, Moeseneder, Miller, Upston

Some conclusions

- MSE and climate scenarios. Use of dynamic vs static reference points
- M&E to assess changes through routine examination
- Use the Precautionary Principle and don’t pretend its business as usual. Act/err on the side of caution.
- Finally, its not all bad- as there are some winners that do better with these changes.

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Issue paper

Impacts of climate change on fisheries and aquaculture. Synthesis of current knowledge, adaptation and mitigation options. FAO Fisheries and Aquaculture Technical Paper 627

An overview of the current scientific knowledge available on climate change implications for fisheries and aquaculture is provided through three technical papers that were presented and discussed during the Expert Workshop on Climate Change Implications for Fisheries and Aquaculture (Rome, 7�9 April 2008). A summary of the workshop outcomes as well as key messages on impacts of climate change on aquatic ecosystems and on fisheries- and aquaculture-based livelihoods are provided in the introduction of this Technical Paper.

The first paper reviews the physical and ecological impacts of climate change relevant to marine and inland capture fisheries and aquaculture. The paper begins with a review of the physical impacts of climate change on marine and freshwater systems and then connects these changes with observed effects on fish production processes. It also outlines a series of scenarios of climate change impacts on fish production and ecosystems through case studies in different regions and ecosystems.

The second paper tackles the consequences of climate change impacts on fisheries and their dependent communities. It analyses the exposure, sensitivity and vulnerability of fisheries to climate change and presents examples of adaptive mechanisms currently used in the sector. The contribution of fisheries to greenhouse gas emissions is addressed and examples of mitigation strategies are given. The role of public policy and institutions in promoting climate change adaptation and mitigation is also explored.

Finally, the third paper addresses the impacts of climate change on aquaculture. It provides an overview of the current food fish and aquaculture production and a synthesis of existing studies on climate change effects on aquaculture and fisheries. The paper focuses on the direct and indirect impacts of climate change on aquaculture, in terms of biodiversity, fish disease and fishmeal. Contribution of aquaculture to climate change is addressed (carbon emission and carbon sequestration), as well as possible adaptation and mitigation measures that could be implemented.

URL

http://www.fao.org/3/i9705en/I9705EN.pdf

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Adaptive management of fisheries in response to climate change

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Author

This report aims to accelerate climate change adaptation implementation in fisheries management throughout the world. It showcases how flexibility can be introduced in the fisheries management cycle in order to foster adaptation, strengthen the resilience of fisheries, reduce their vulnerability to climate change, and enable managers to respond in a timely manner to the projected changes in the dynamics of marine resources and ecosystems. The publication includes a set of good practices for climate-adaptive fisheries management that have proven their effectiveness and can be adapted to different contexts, providing a range of options for stakeholders including the fishing industry, fishery managers, policymakers and others involved in decision-making. These good practices were linked to one or more of the three common climate-related impacts on fisheries resources: distributional change; productivity change; and species composition change. Therefore, these three impacts can serve as practical entry points to guide decision-makers in identifying good practice adaptation measures suitable for their local contexts. These good practices are based upon transferable