Developing simple multi-species trophic interaction models* driven by climate for testing management systems

*(as mediated through complex models--i.e., FEAST)

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Andre Punt

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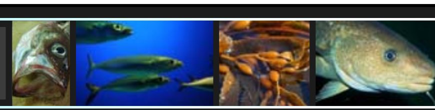
Council activities



Workshop held in early 2012

1. Update overview of FEAST model
2. Outline economic management models
3. Identify priority management strategies
   - Assessment approaches -> OFL-ABC-TAC
4. Review suite of climate scenarios to use
   - Operating model
5. Develop multi-species OFL and ABC control rule approaches

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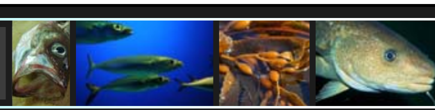
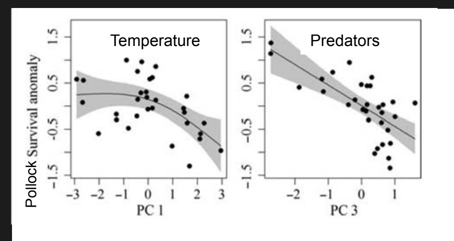
INTRODUCTION

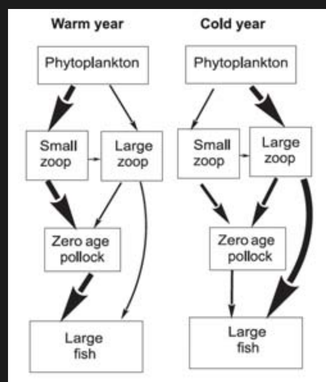


Recruitment & survival decline with increasing Temp (Mueter et al. 2011, Coyle et al. 2011)

Predation is stronger in warm years (Coyle et al. 2011)



Mueter et al. 2011



Coyle et al. 2011

SeaWiFS

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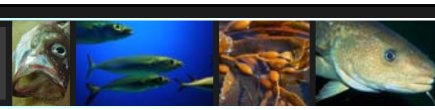
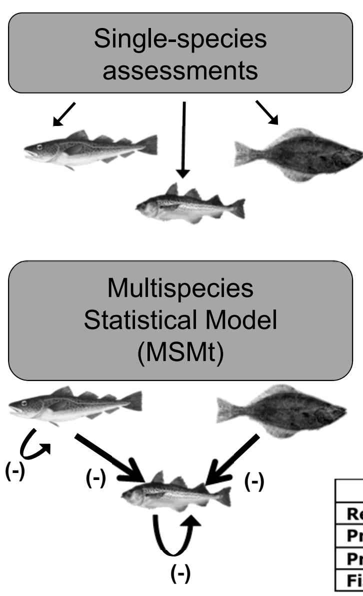
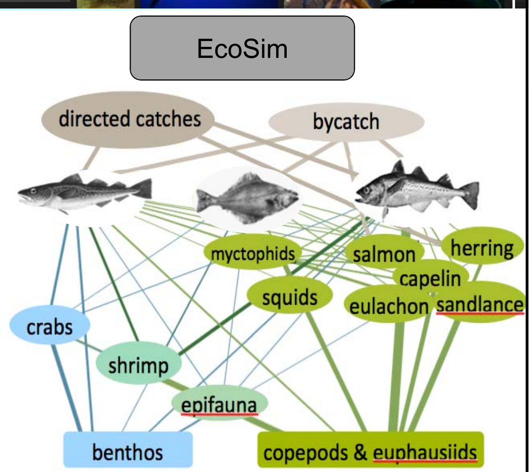
BSIERP MSE

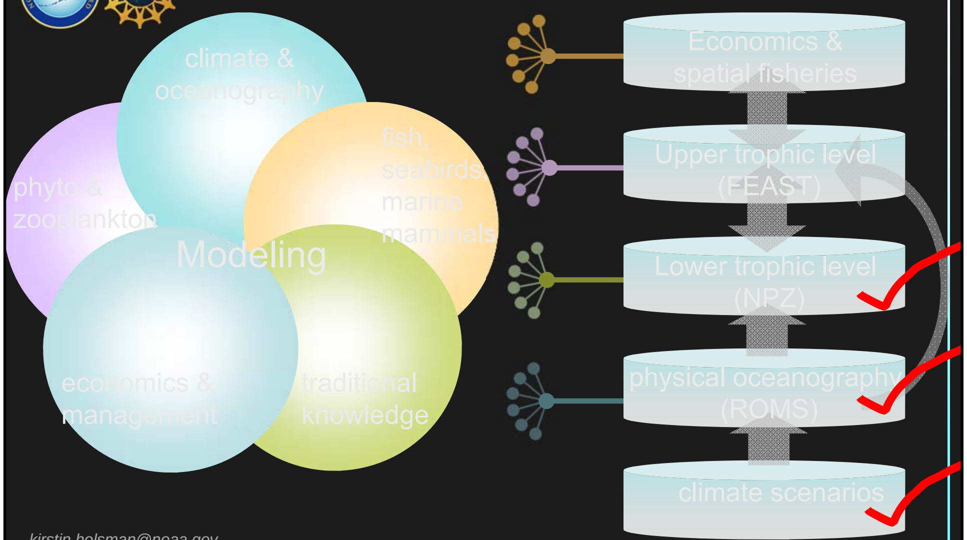






	SSA	MSM	Ecosim
Recruitment	S/R (fit)	mean	S/R (food based)
Predation mortality	fixed	top-down	top-down
Predation/growth	fixed	fixed	bottom-up
Fisheries selectivity	fit/varies	fit/varies	fixed

The Bering Sea Project
BEST/BSIERP Research Program



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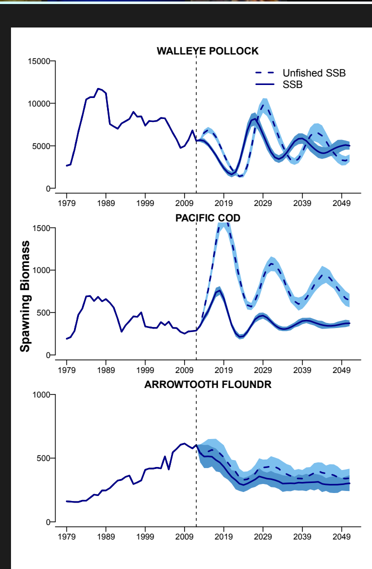
The revised OM

1. Fit to data from 1979-2012
2. GAMMs for W_{age}, R, foraging, etc.~f(zoop, tempC, cold pool)
3. Downscale IPCC
4. Run NPZ model
5. Project MSMo forward using ROMS/NPZ drivers



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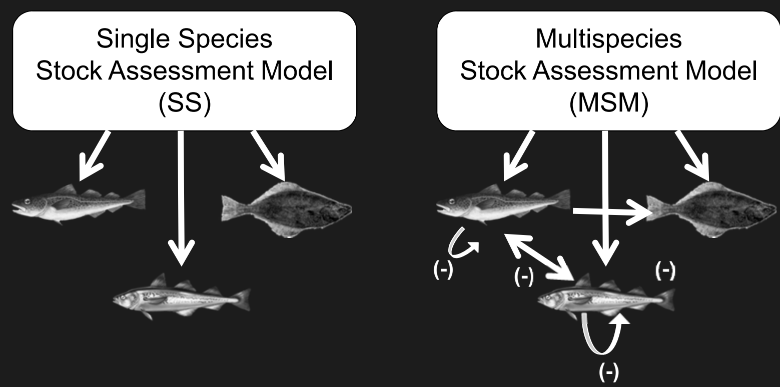
Alternatives



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Operating model

Description	Equations		
Recruitment	$N_{y,1} = R_t = R_0 e^{\tau_y}$		
Catch	$C_{y,a} = \frac{F_{y,a}}{Z_{y,a}} \left(1 - e^{-Z_{y,a}}\right) N_{y,a} w_{y,a}$	$1 \leq y \leq Y$	$1 \leq a \leq A$
Numbers at age	$N_{y+1,a+1} = N_{y,a} e^{-Z_{y,a}}$	$1 < y \leq Y$	$1 \leq a < A$
	$N_{y+1,A} = N_{y,A-1} e^{-Z_{y,A-1}} + N_{y,A} e^{-Z_{y,A}}$	$1 \leq y \leq Y$	$a \geq A$
Spawning biomass	$S_t = \sum_{a=1}^{A} w_{y,a} \phi_a N_{y,a}$	$1 \leq y \leq Y$	
Total catch (yeild)	$C_t = \sum_{a=1}^{A} w_{y,a} C_{y,a}$		
Fishery age selectivity	$s_{f,a} =$		
Fishing mortality	$F_{y,a} =$		
Natural mortality	$M_{y,a} = M1_a + M2_{y,a}$		
Total mortality	$Z_{y,a} = M_{y,a} + F_{y,a}$		

$$M_{y,a} = M1_a + M2_{y,a}$$

Residual Natural Mortality

Predation Natural Mortality

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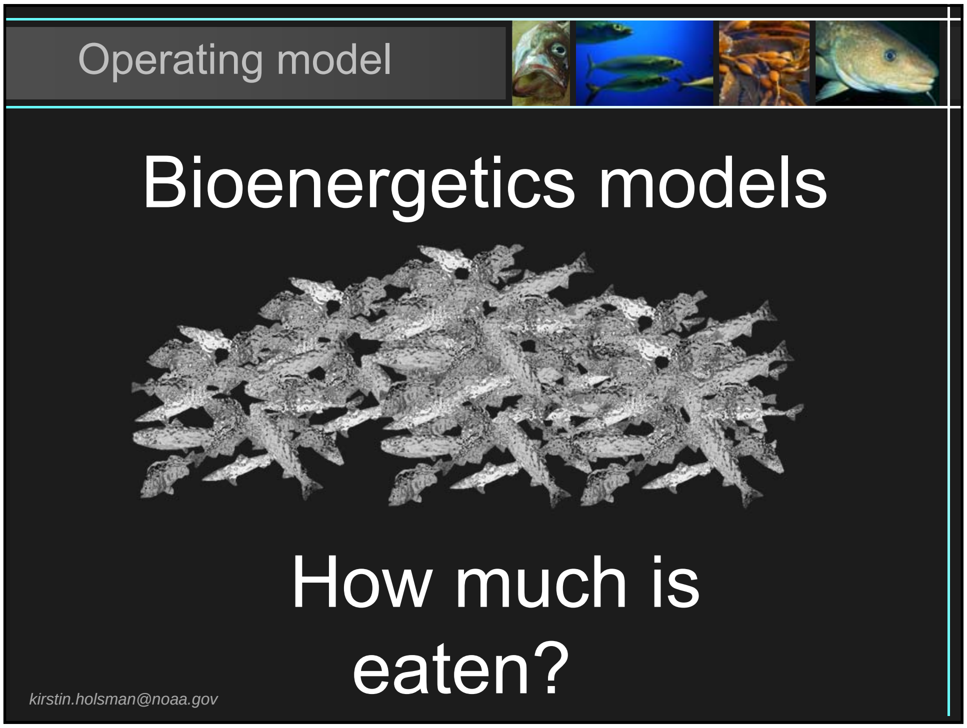
Operating model
Bioenergetics models
How much is eaten?
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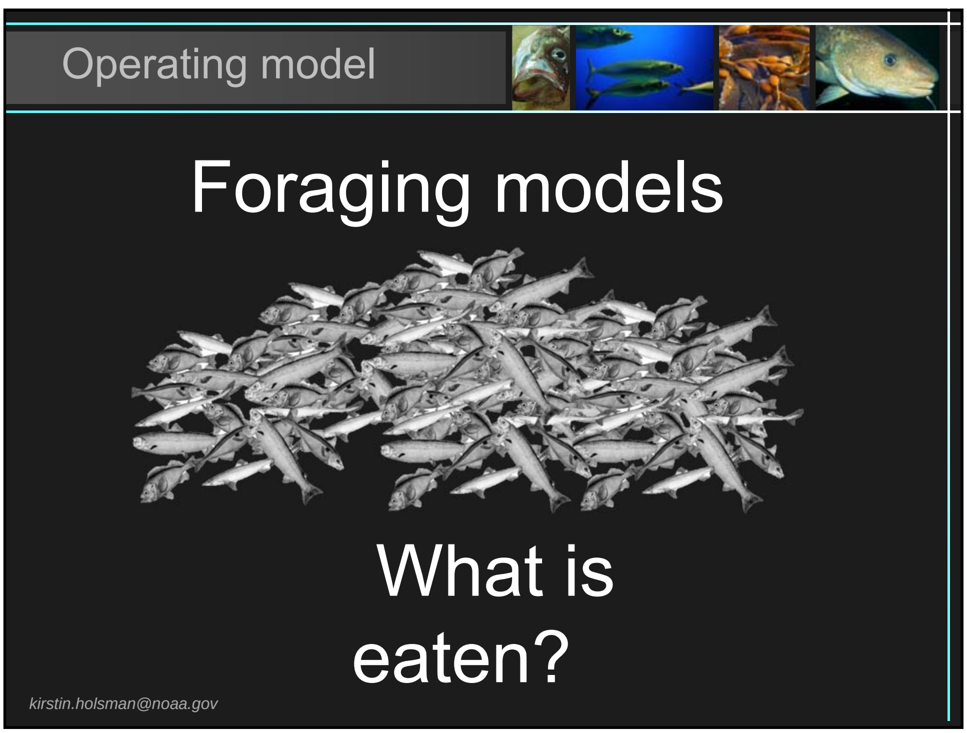
Operating model
Foraging models
What is eaten?
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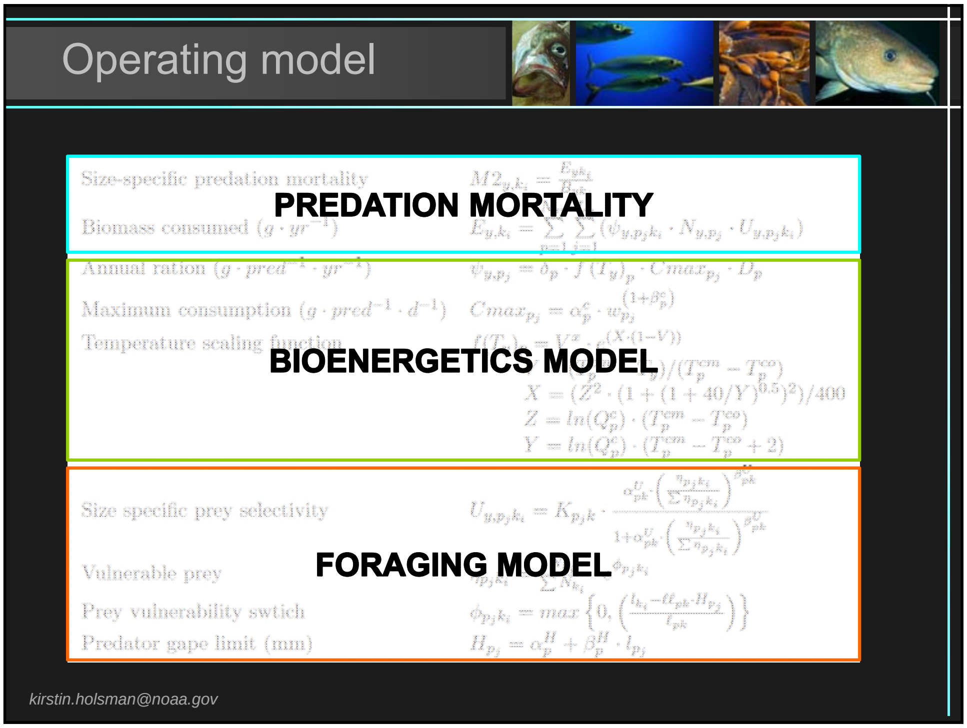
Operating model
Size-specific predation mortality
PREDATION MORTALITY
Biomass consumed $(g \cdot yr^{-1})$
Annual ration $(g \cdot pred^{-1} \cdot yr^{-1})$
Maximum consumption $(g \cdot pred^{-1} \cdot d^{-1})$
Temperature scaling function
BIOENERGETICS MODEL
Size specific prey selectivity
Vulnerable prey
FORAGING MODEL
Prey vulnerability swtich
Predator gape limit (mm)
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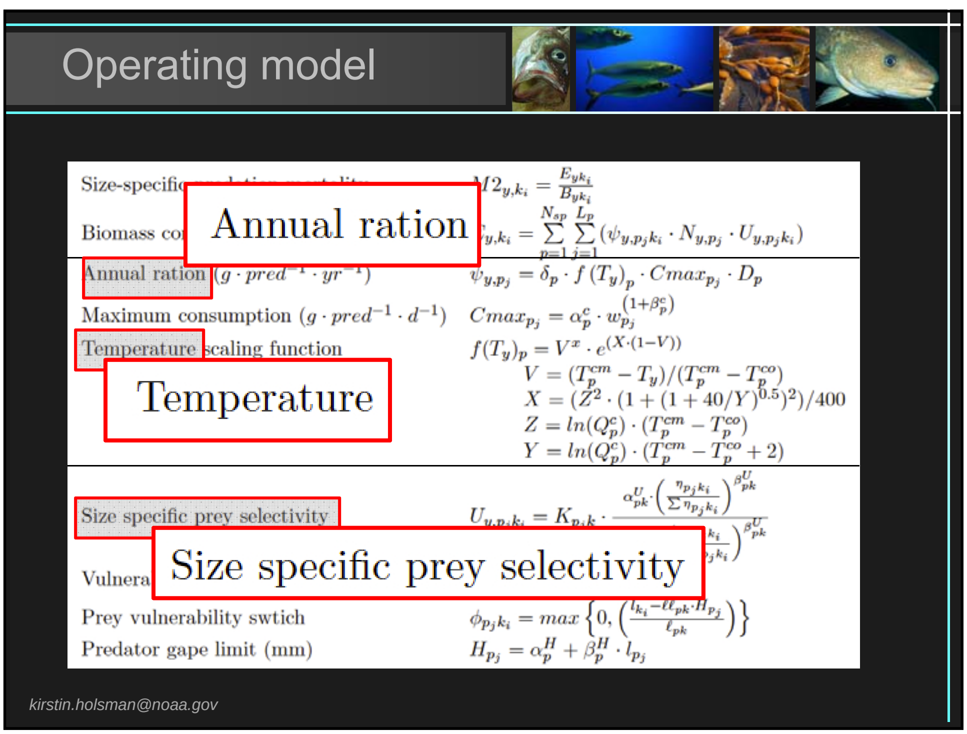
Operating model
Size-specific predation mortality
$M2_{y,k_i} = \frac{E_{yk_i}}{B_{yk_i}}$
Annual ration
Biomass consumed
$E_{y,k_i} = \sum_{p=1}^{N_{sp}} \sum_{j=1}^{L_p} (\psi_{y,p_jk_i} \cdot N_{y,p_j} \cdot U_{y,p_jk_i})$
Annual ration $(g \cdot pred^{-1} \cdot yr^{-1})$
$\psi_{y,p_j} = \delta_p \cdot f(T_y)_p \cdot Cmax_{p_j} \cdot D_p$
Maximum consumption $(g \cdot pred^{-1} \cdot d^{-1})$
$Cmax_{p_j} = \alpha_p^c \cdot w_{p_j}^{(1+\beta_p^c)}$
Temperature scaling function
$f(T_y)_p = V^x \cdot e^{(X \cdot (1-V))}$
Temperature
$V = (T_p^{cm} - T_y)/(T_p^{cm} - T_p^{co})$
$X = (Z^2 \cdot (1 + (1 + 40/Y)^{0.5})^2)/400$
$Z = ln(Q_p^c) \cdot (T_p^{cm} - T_p^{co})$
$Y = ln(Q_p^c) \cdot (T_p^{cm} - T_p^{co} + 2)$
Size specific prey selectivity
Size specific prey selectivity
Vulnerable prey
Prey vulnerability swtich
$\phi_{p_jk_i} = max \left\{0, \left(\frac{l_{k_i} - \ell_{pk} \cdot H_{p_j}}{\ell_{pk}}\right)\right\}$
Predator gape limit (mm)
$H_{p_j} = \alpha_p^H + \beta_p^H \cdot l_{p_j}$
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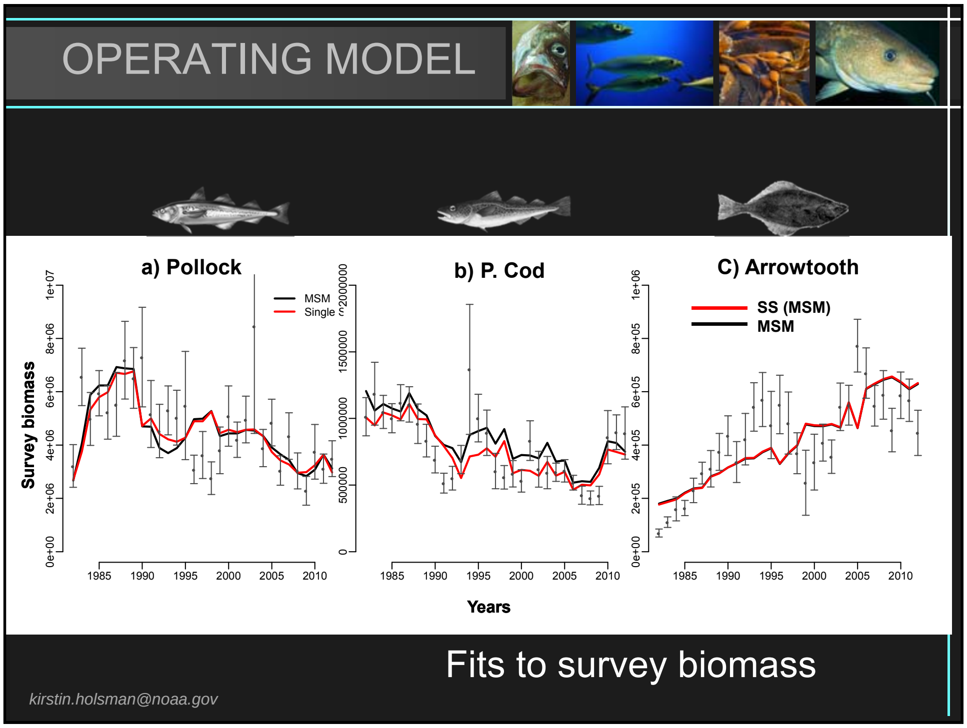
OPERATING MODEL
a) Pollock
b) P. Cod
C) Arrowtooth
MSM
Single
SS (MSM)
MSM
Survey biomass
Years
Fits to survey biomass
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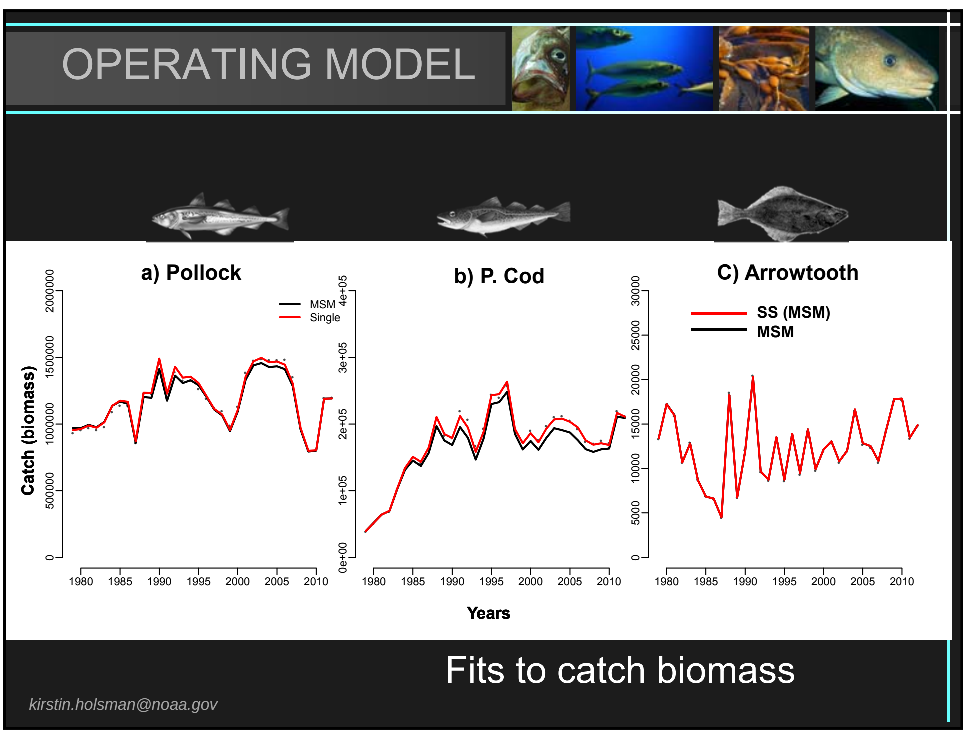
OPERATING MODEL
a) Pollock
b) P. Cod
C) Arrowtooth
MSM
Single
SS (MSM)
MSM
Catch (biomass)
Years
Fits to catch biomass
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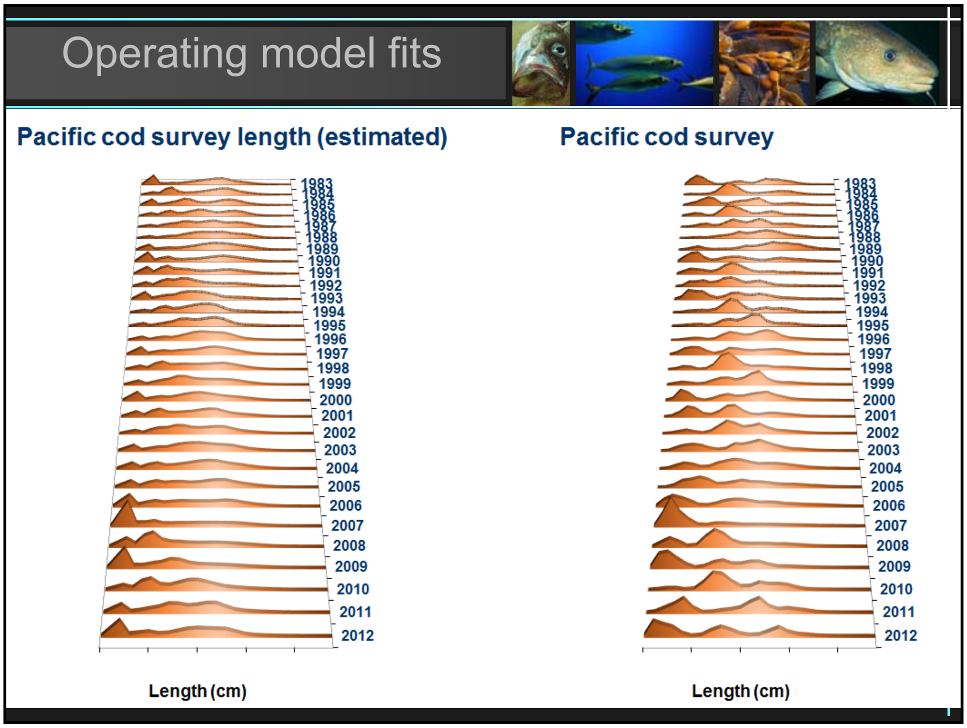
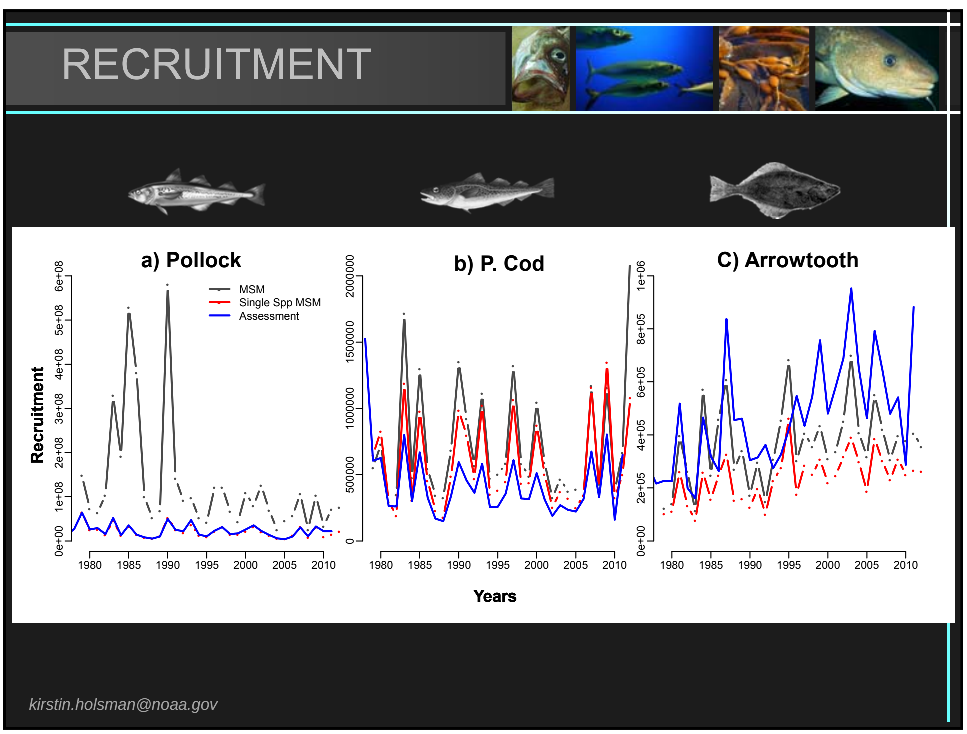

Operating model fits
Pacific cod survey length (estimated)
Pacific cod survey
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Length (cm)
Length (cm)


RECRUITMENT
a) Pollock
b) P. Cod
C) Arrowtooth
MSM
Single Spp MSM
Assessment
Recruitment
Years
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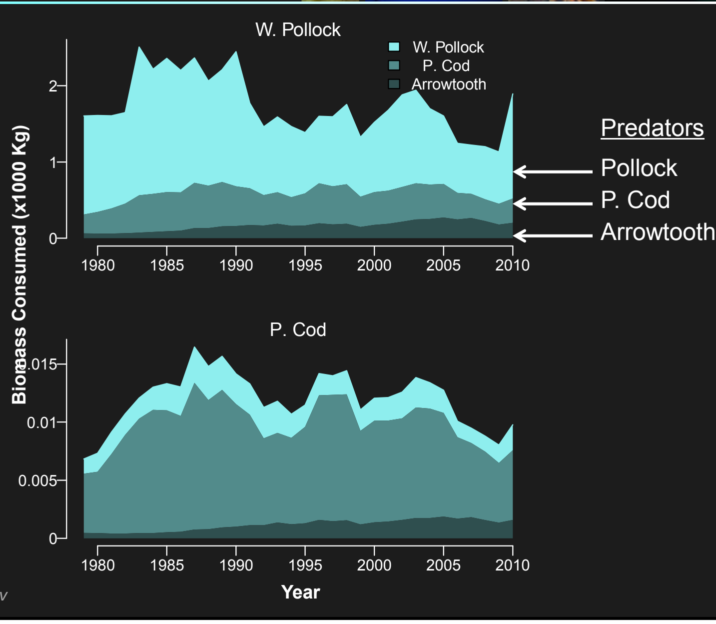
CANNIBALISM



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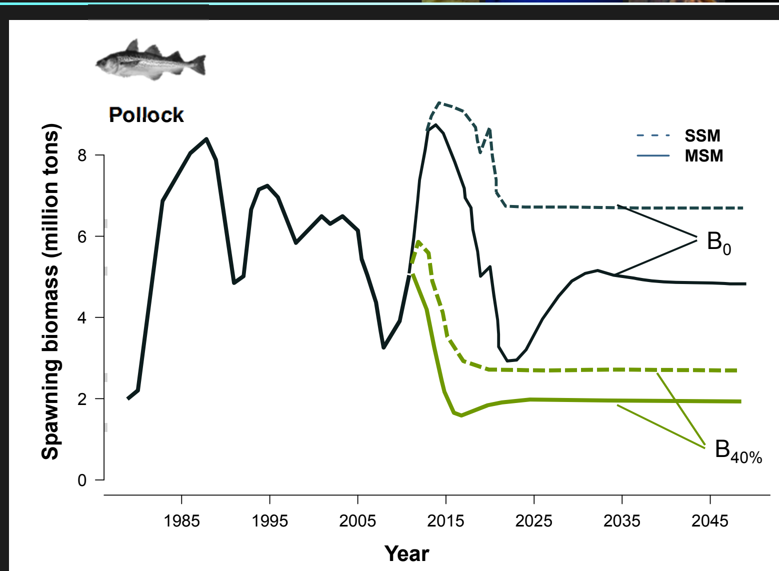
SPAWNING BIOMASS



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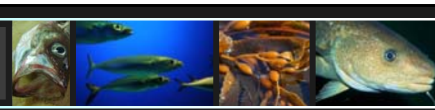
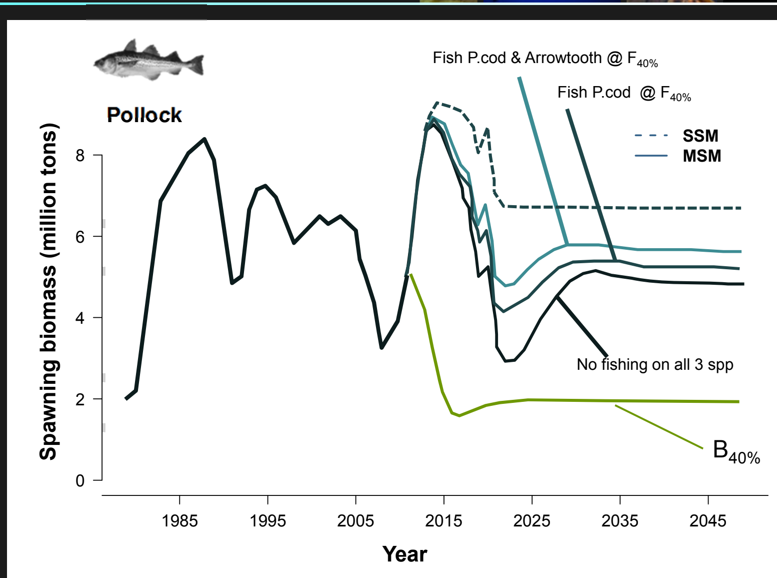
SPAWNING BIOMASS





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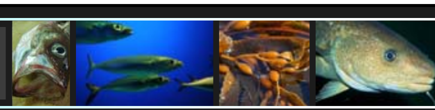
Projections



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Total catch (yeild)	$C_t = \sum_{a=1}^{A} w_{y,a} C_{y,a}$		
Fishery age selectivity	$s_{f,a} = e^{\eta_{f,a}}$	$\eta_{f,a} \sim N\left(0, \sigma^2_{f,a}\right)$	
Fishing mortality	$F_{y,a} = \mu_F e^{\varepsilon_{f,y}} S_{f,a}$	$\varepsilon_{f,y} \sim N\left(0, \sigma^2_F\right)$	
Natural mortality	$M_{y,a} = M1_a + M2_{y,a}$		
Total mortality	$Z_{y,a} = M_{y,a} + F_{y,a}$		

***f* (Climate)**

$$log\left(R^{fut}_{p,v}\right) = \log\left(\alpha_{R,p} \cdot SSB_{p,v-1}\right) - \beta_{R,p} \cdot SSB_{p,v-1} + \beta^{spr}_{Z,p} \cdot Z^{spr}_v - \beta^{fall}_{Z,p} \cdot \left(\delta^{fut}_{p1,v} / Z^{fall}_v\right)$$

Future recruitment

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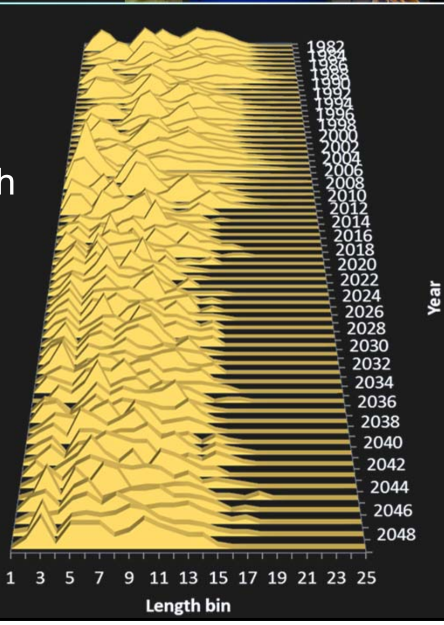
Projections

Example
Pacific cod
survey length
frequency



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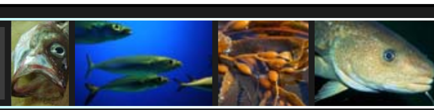
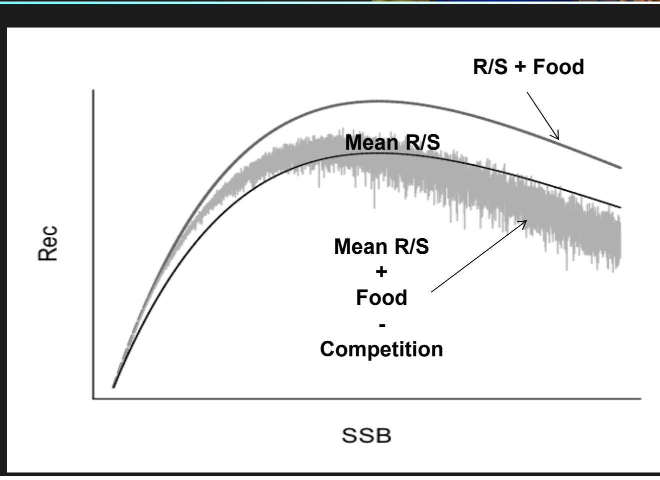
Projections





$$log(R^{fut}_{p,v}) = \log(\alpha_{R,p} \cdot SSB_{p,v-1}) - \beta_{R,p} \cdot SSB_{p,v-1} + \beta^{spr}_{Z,p} \cdot Z^{spr}_{v} - \beta^{fall}_{Z,p} \cdot \left(\delta^{fut}_{p1,v} / Z^{fall}_{v} \right)$$

Future recruitment

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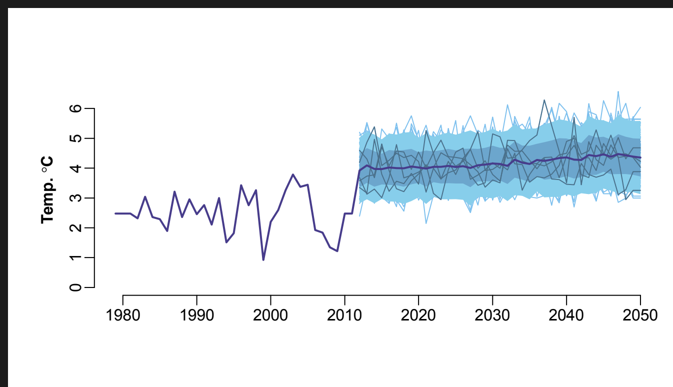
Projections



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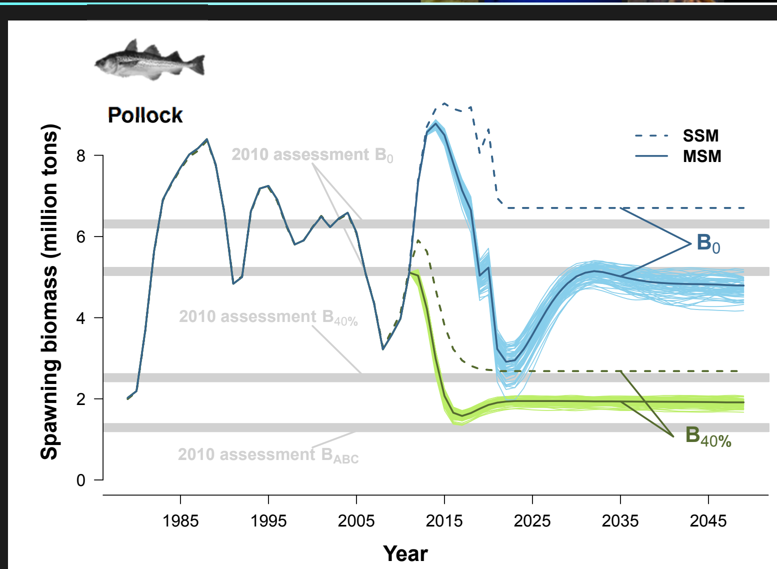
MSM RESULTS



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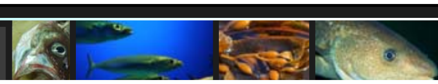
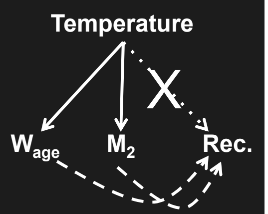
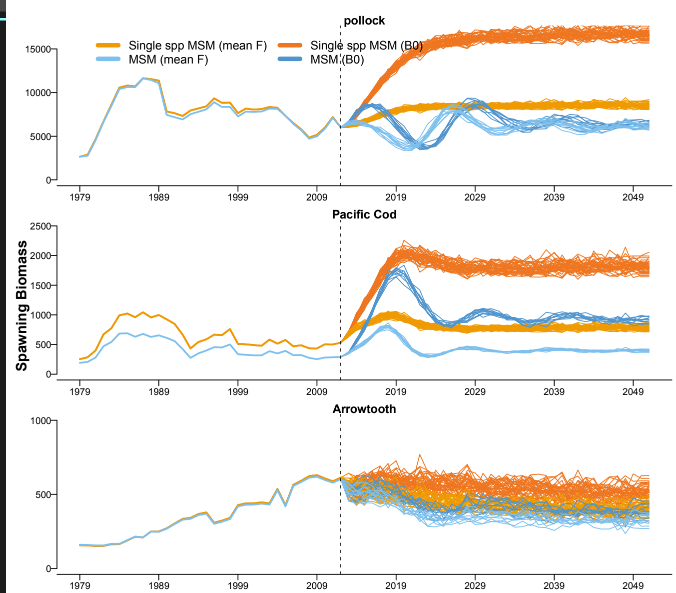
FORECAST (mn Rec)







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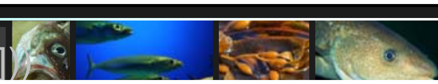
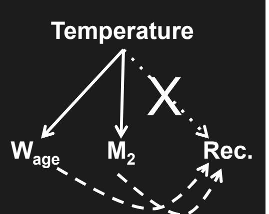
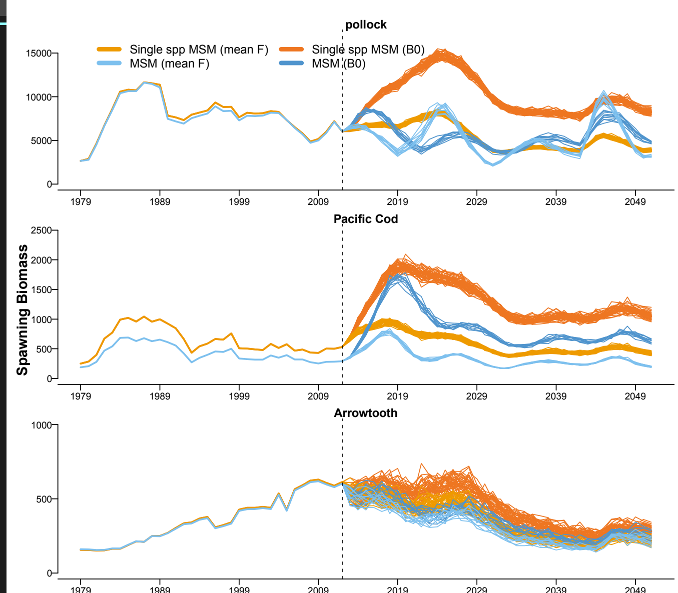
FORECAST (rand rec [1])







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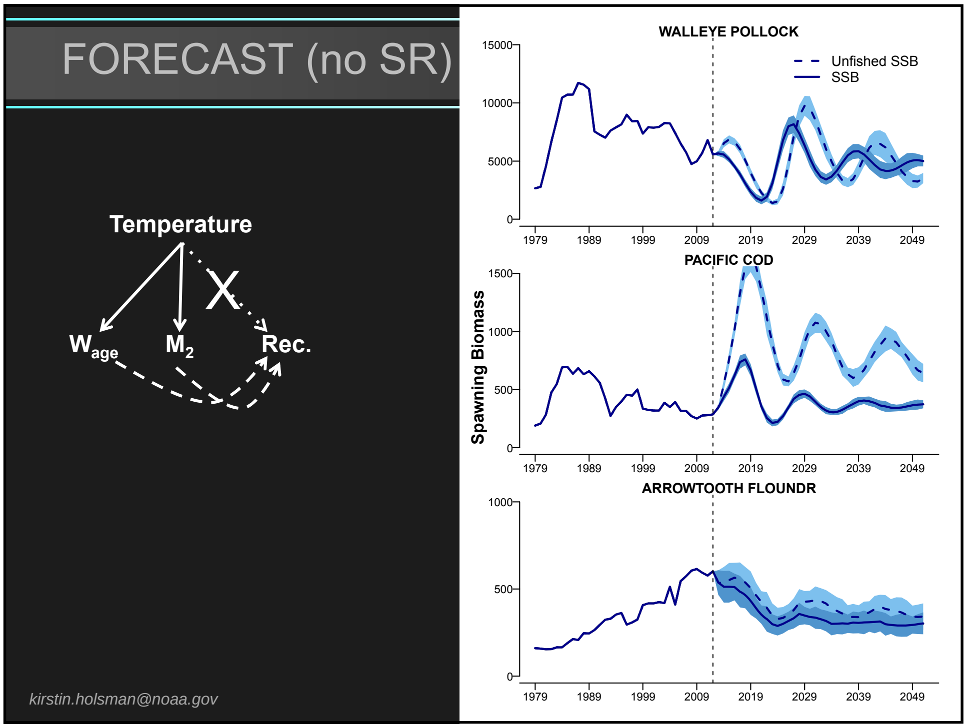
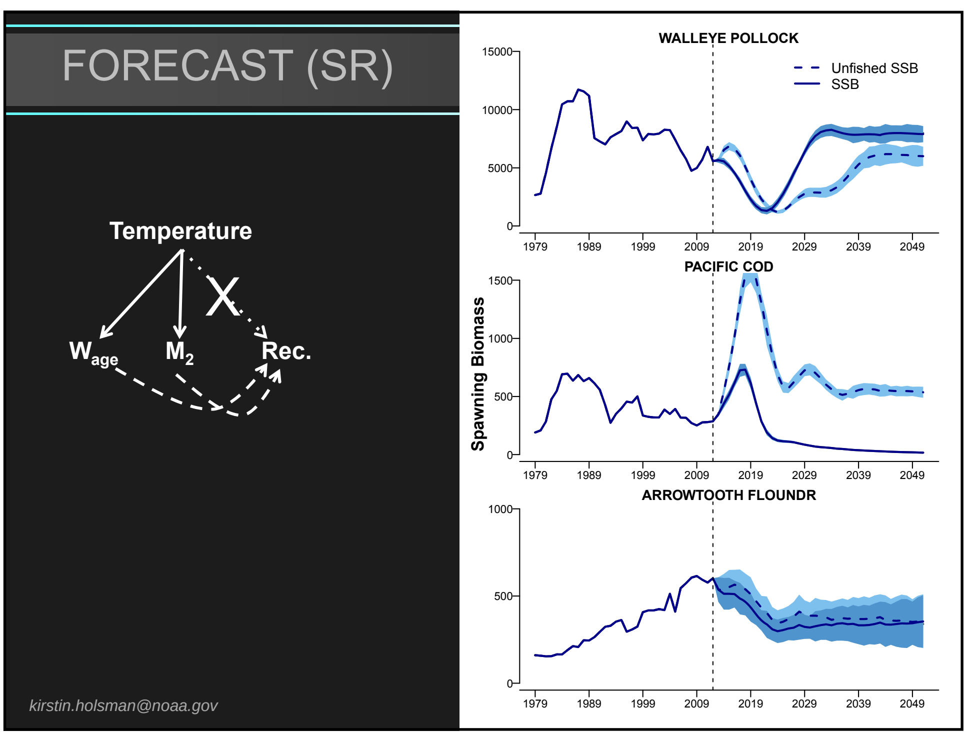

FORECAST (no SR)
Temperature
X
W age
M 2
Rec.
kirstin.holsman@noaa.gov
WALLEYE POLLOCK
Unfished SSB
SSB
PACIFIC COD
ARROWTOOTH FLOUNDR
Spawning Biomass
15000
10000
5000
1500
1000
500
0
1979
1989
1999
2009
2019
2029
2039
2049


FORECAST (SR)
Temperature
X
W age
M 2
Rec.
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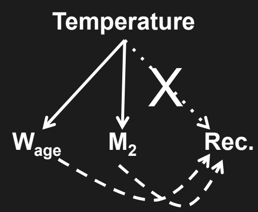
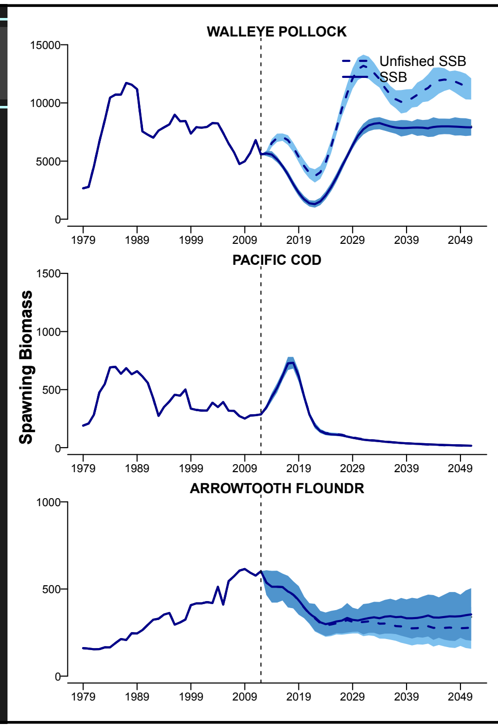
WALLEYE POLLOCK
Unfished SSB
SSB
PACIFIC COD
ARROWTOOTH FLOUNDR
Spawning Biomass
15000
10000
5000
1500
1000
500
0
1979
1989
1999
2009
2019
2029
2039
2049

FORECAST (SR)





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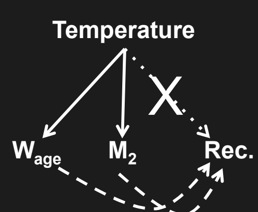
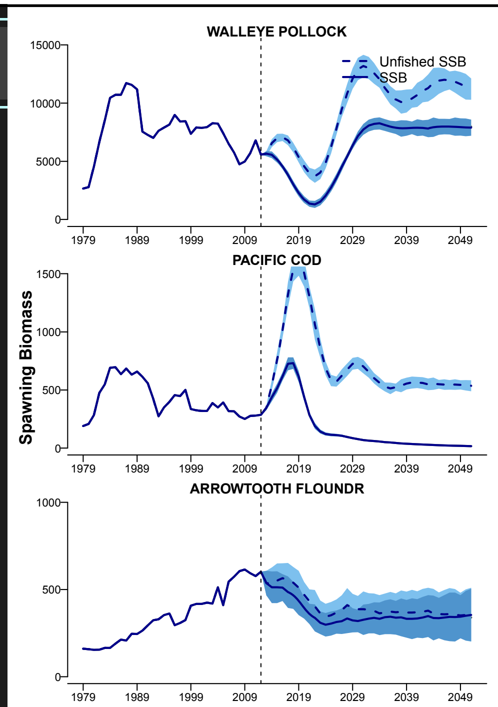
FORECAST (SR)





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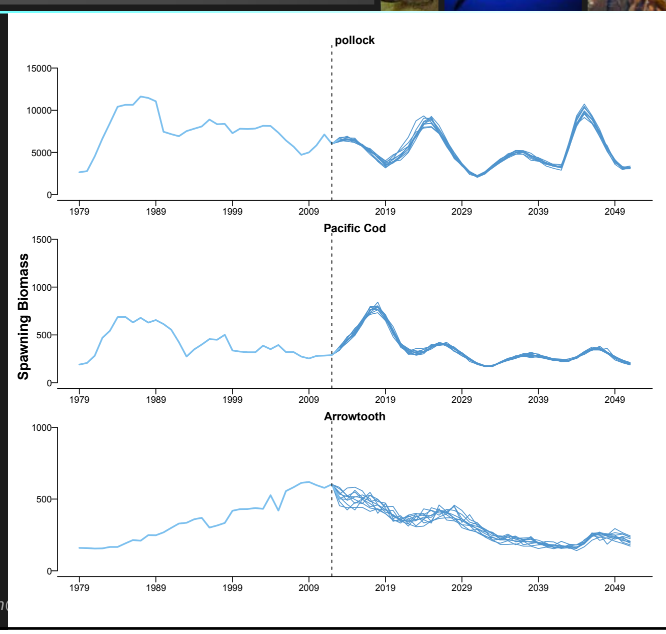
CONCLUSIONS

- MSM provides annual estimates of natural mortality
- Can project MSM models to derive multi-species BRPs
- BRPs are highly variable & depend on control rules
- Climatic variability introduces some differences but they are less than that introduced by control rules (4 pollock)
- For species with low predation – MSM ~ SS models

CLIMATE VAR.



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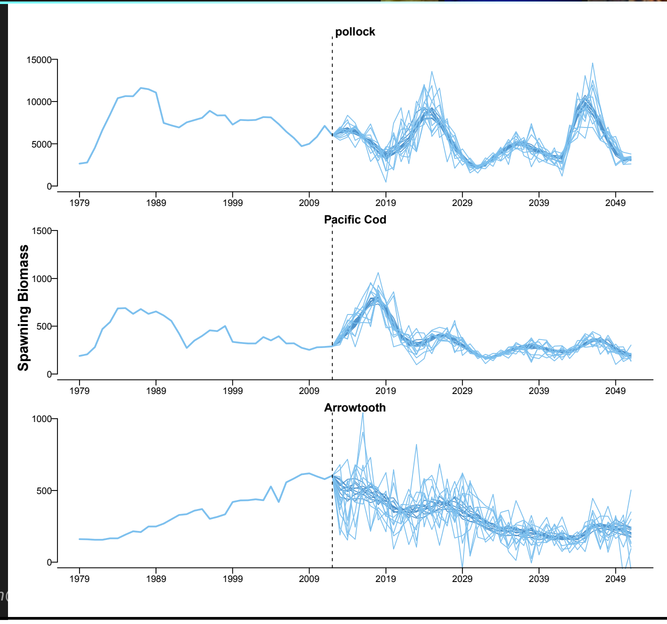
RANDOM+CLIMATE VAR



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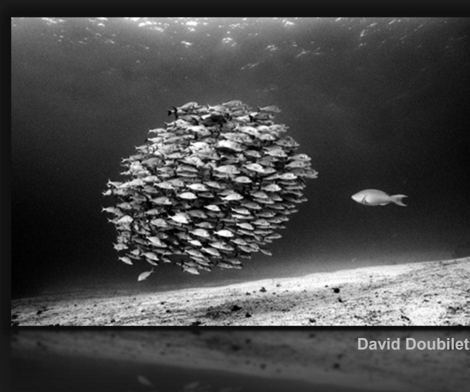
THANKS!

<u>Collaborators</u>

Kerim Aydin, Bruce Miller, Elizabeth Moffitt

<u>Colleagues</u>

Brain Knoth, Troy Buckley, Matt Baker, William Stockhausen, Sarah Gaichas, P.Sean McDonald, Ivonne Ortiz, Stephani Zador



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BEST-BSIERP Bering Sea Project

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