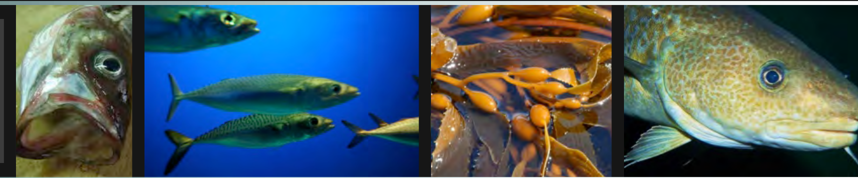
Using MSMt to evaluate climate and trophic impacts on recommended harvest rates of groundfish in the Bering Sea

Kirstin Holsman
kirstin.holsman@noaa.gov
UW JISAO / NOAA AFSC

Collaborators:

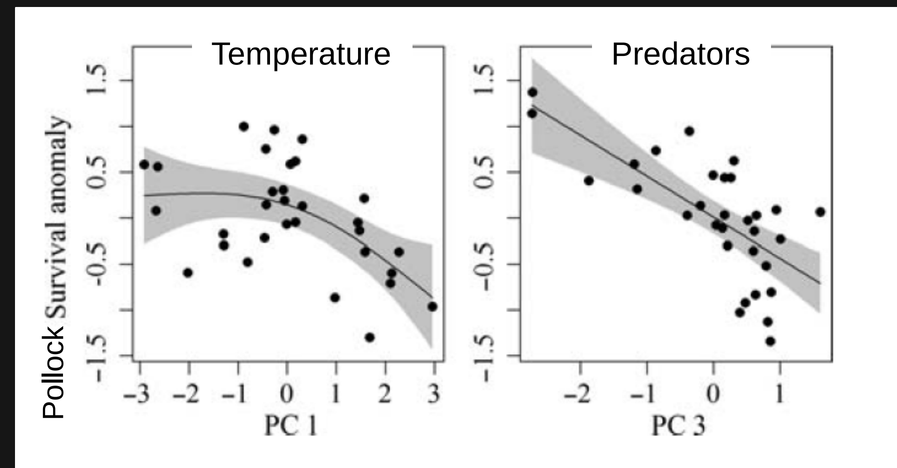
Anne Hollowed
Kerim Aydin
André Punt
Ingrid Spies
Al Hermann
Jim Ianelli
Ivonne Ortiz
Paul Spencer
Nick Bond
Georgina Gibbson

EBS & Climate

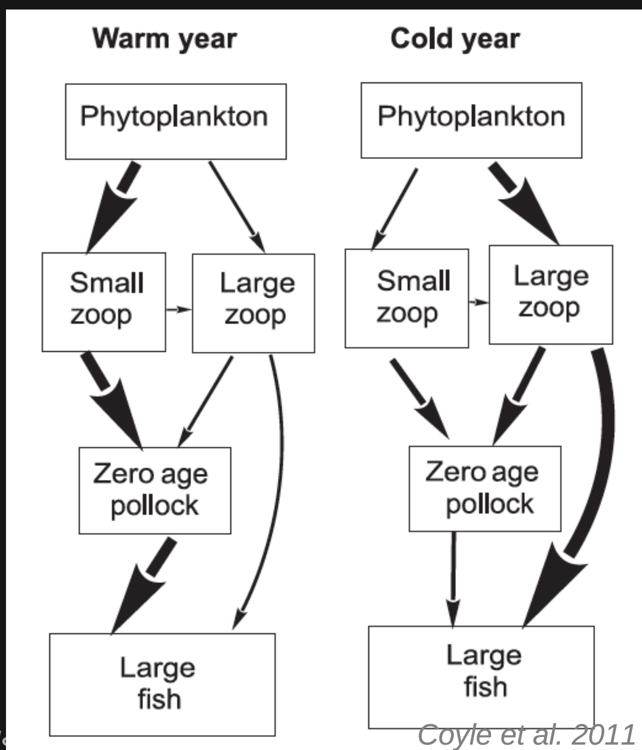


Recruitment & survival decline with increasing Temp *(Mueter et al. 2011, Coyle et al. 2011)*

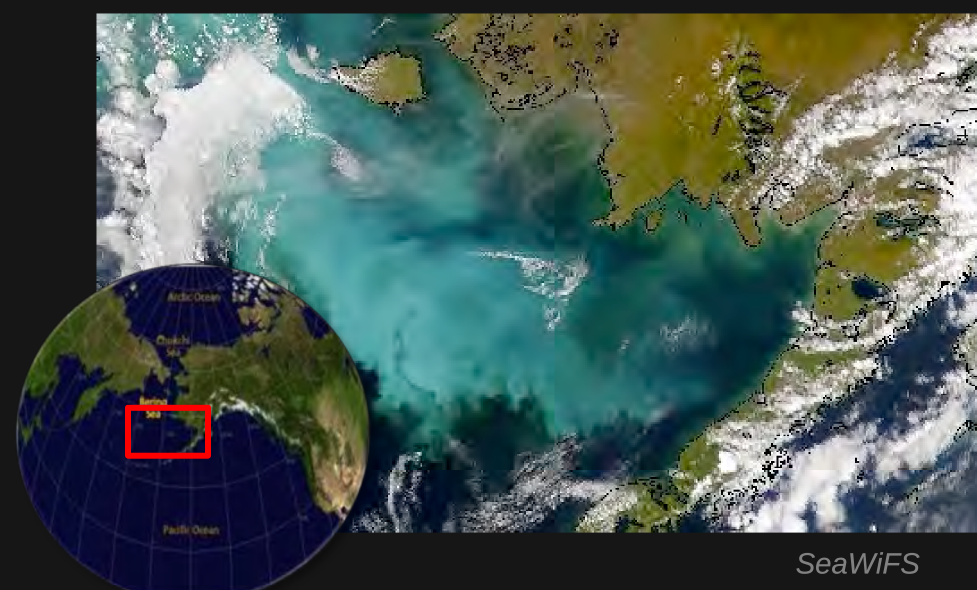
Predation is stronger in warm years *(Coyle et al. 2011)*



Mueter et al. 2011



Coyle et al. 2011



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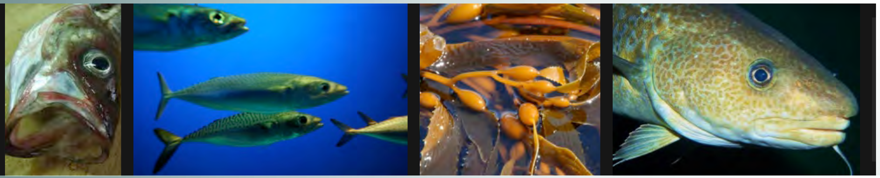

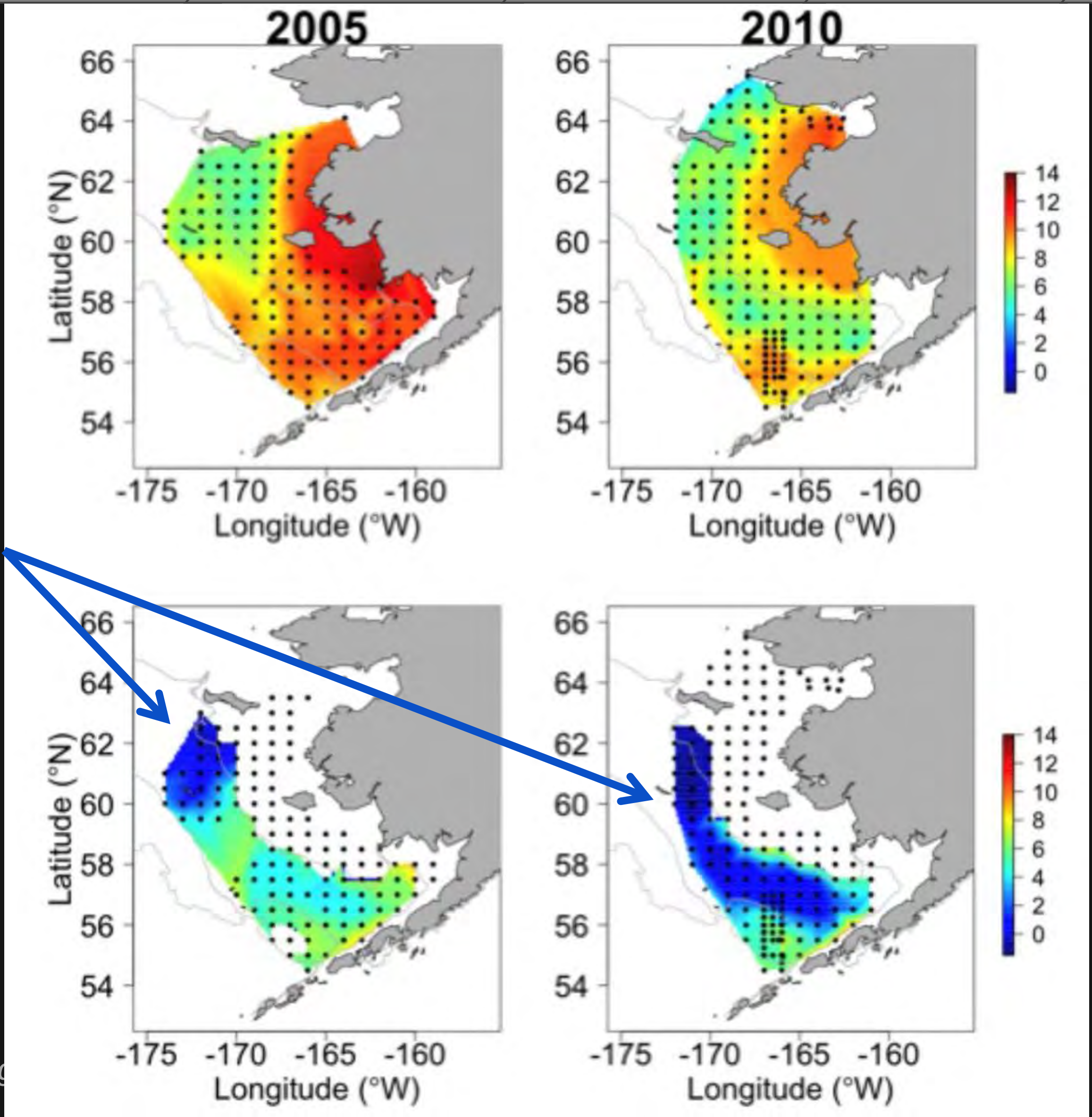

SST

"Cold Pool"

Bottom T

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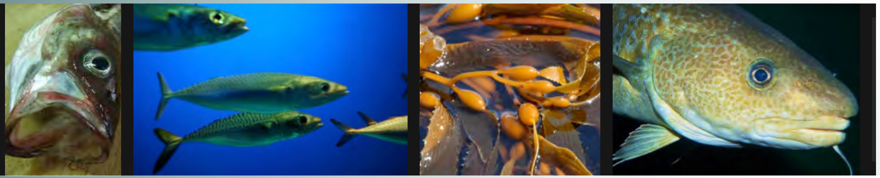
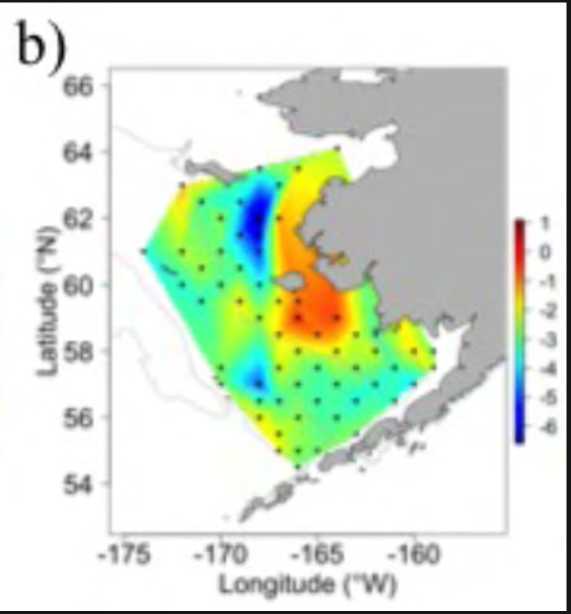
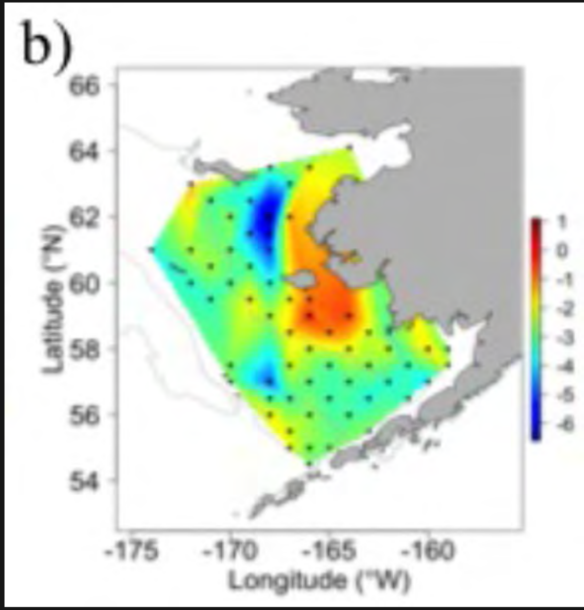


Log Zooplankton Biomass (g WW)

WARM (2005) | **COOL (2010)**





Siddon et al. (2013). *Spatial match-mismatch between juvenile fish and prey explains recruitment variability across contrasting climate conditions in the eastern Bering Sea. PLoS ONE.*

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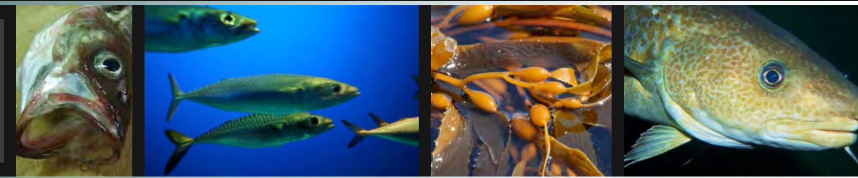

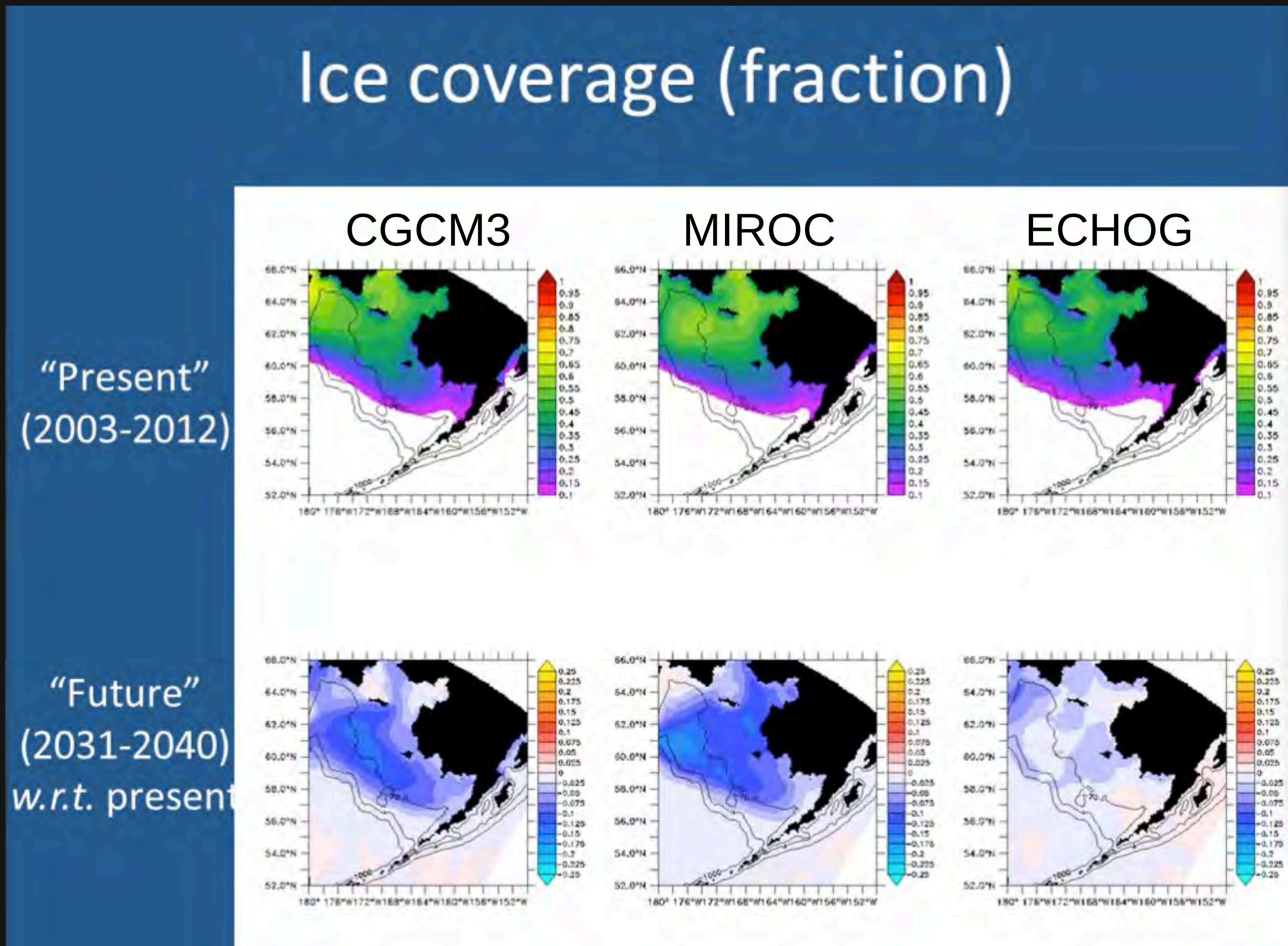

Slide Credit: Albert Hermann

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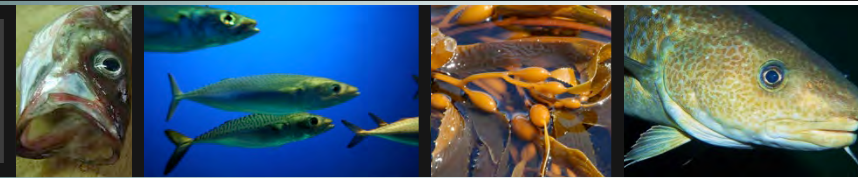

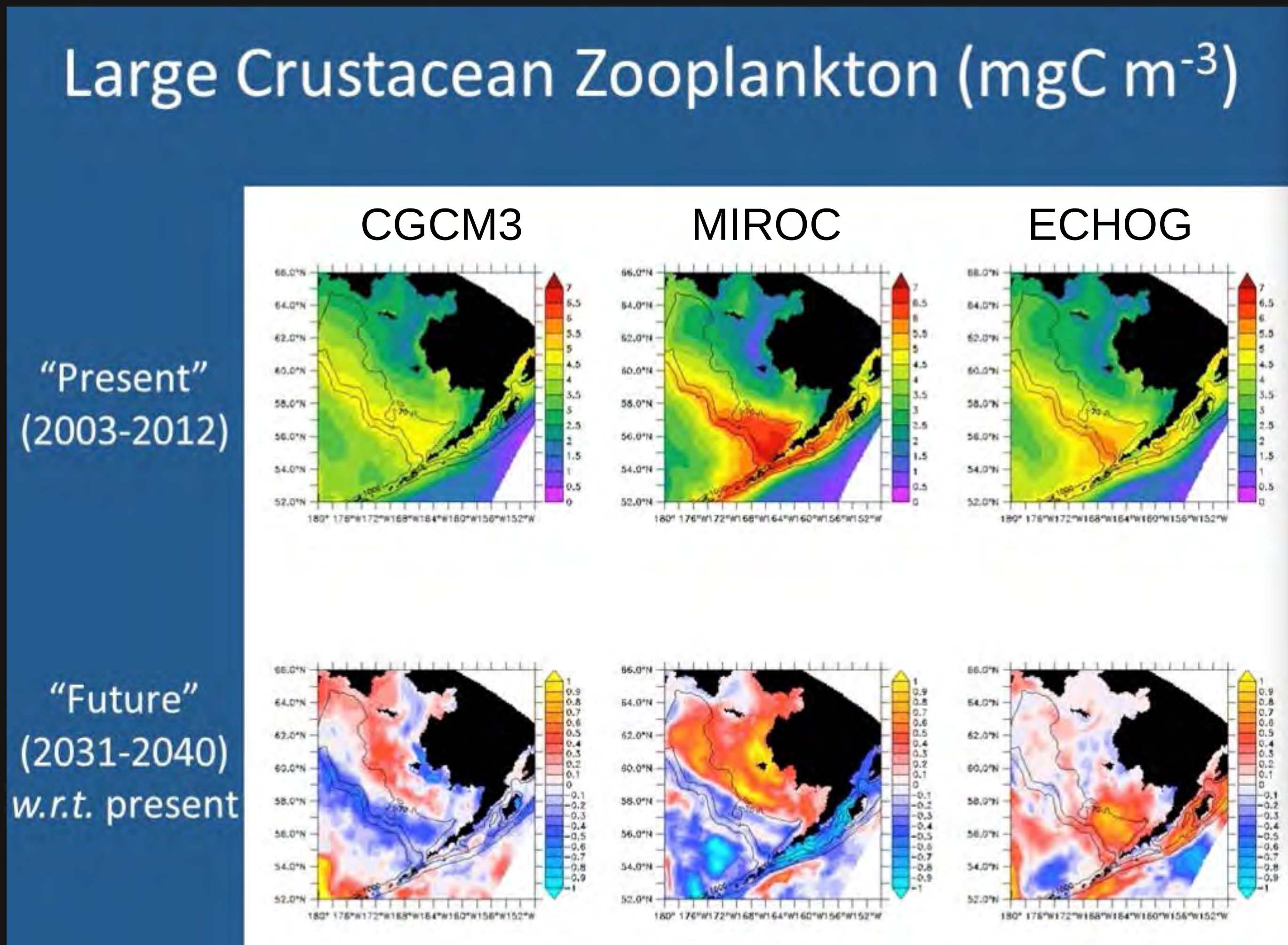

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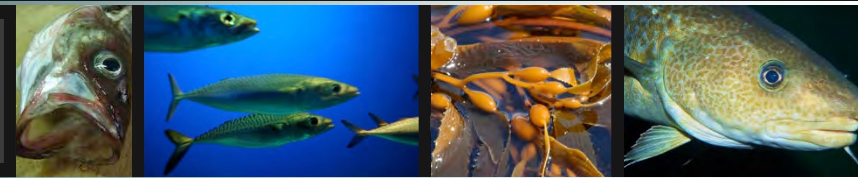
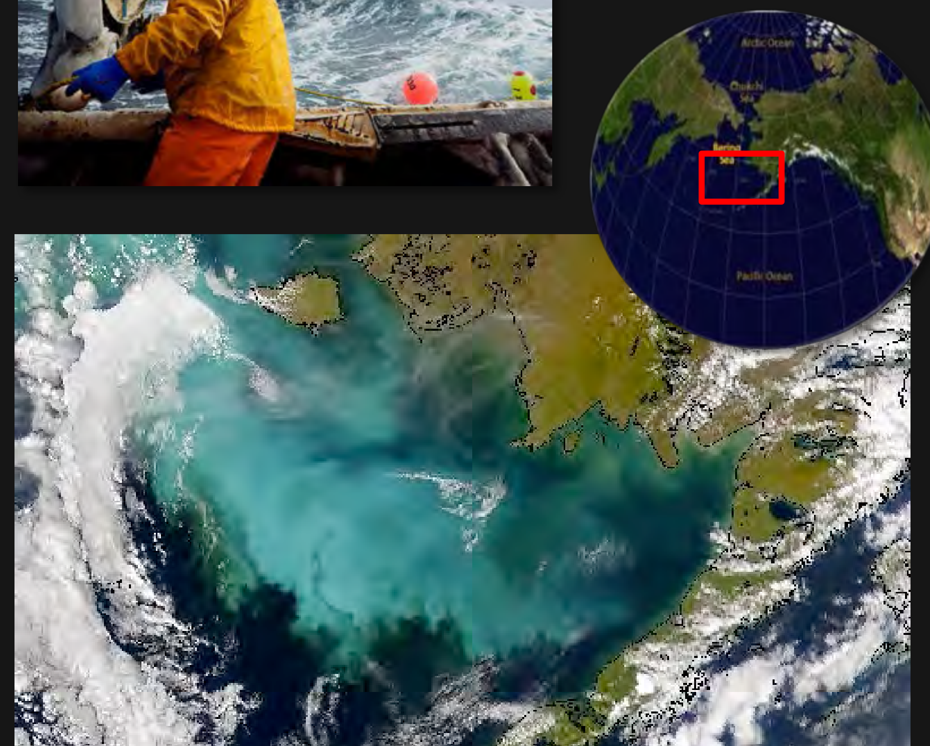
EBS & Climate Change



What is the range of effects of climate change on biomass, production, & recommended harvest rates?

Are current assessment models robust to climate driven changes? (if not, why not)?



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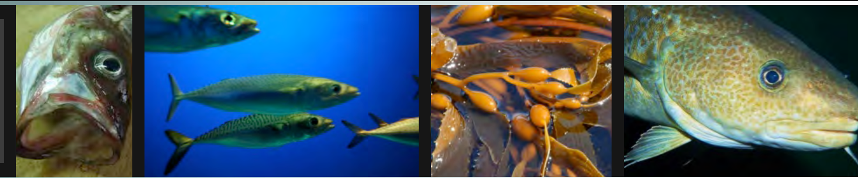
CC Analysis



Observed Conditions
X =[SST, wind, Predators]

R=f(X)
Assessment
single spp R

Forecast with
Avg. X+ error from
IPCC projections

ROMS/NPZ
High res 3D

R=f(X)
Assessment
Multi-spp R

Forecast with
X+ error from
IPCC→ROMS/NPZ

ROMS
High res 3D
oceanography

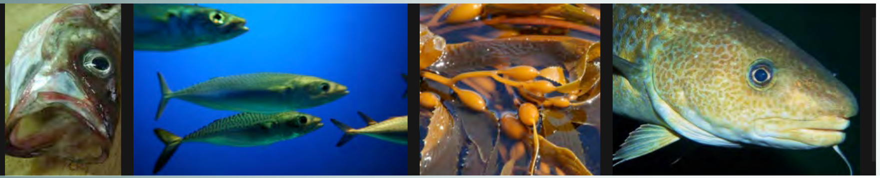
NPZ<->FEAST
mechanistic fish model
with feedback to
plankton

FEAST model driven
by IPCC climate
models

COMPLEXITY

kirstin.holsman@noaa.gov

CC Analysis



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→ Forecast with
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→ R=*f*(X)
Assessment
Multi-spp R

→ Forecast with
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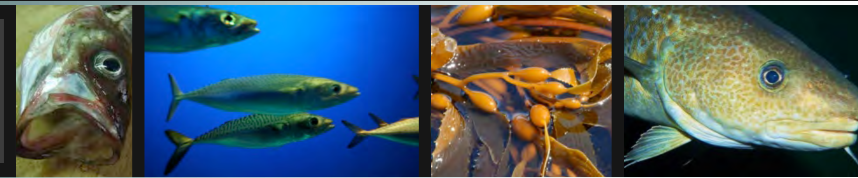

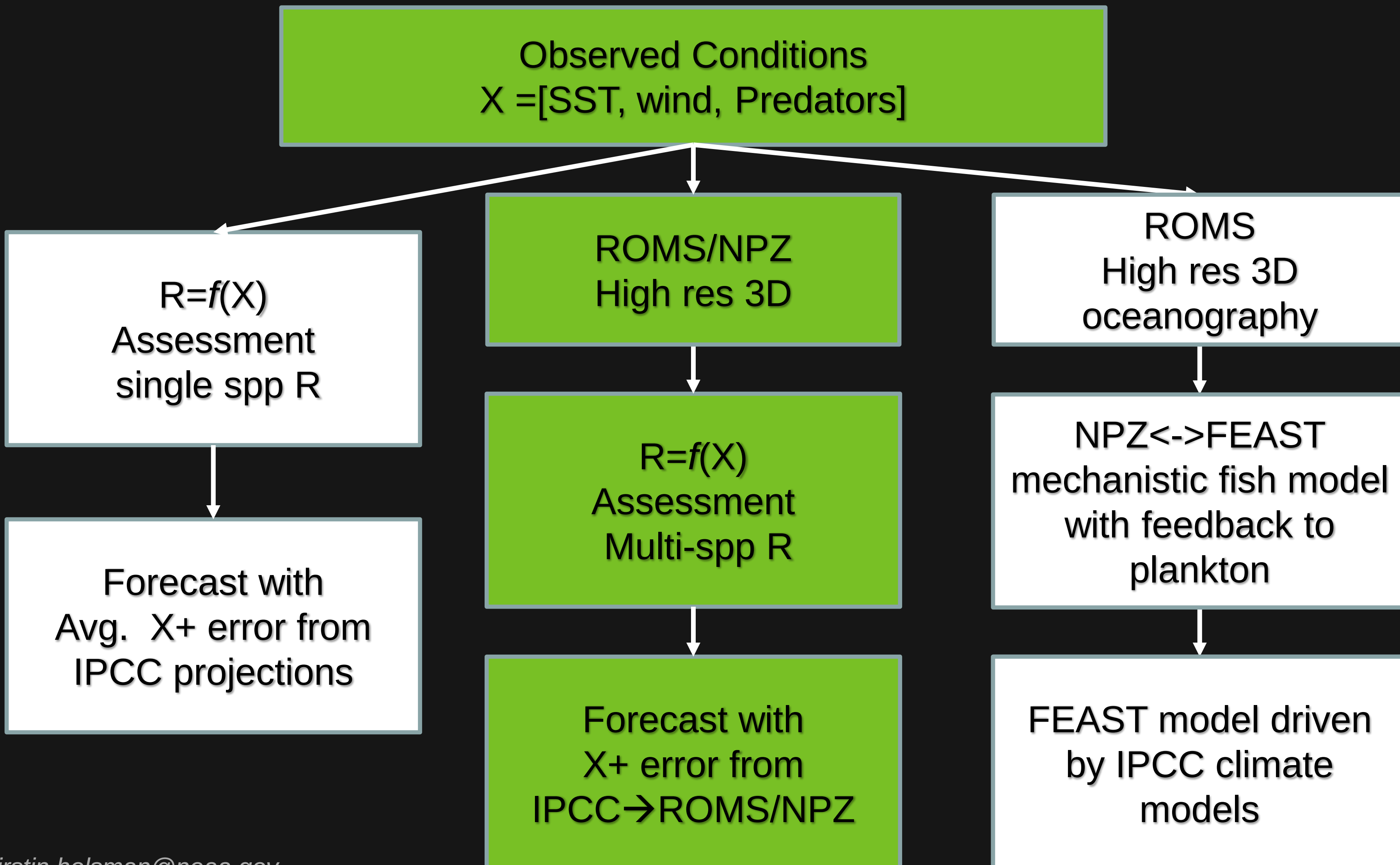

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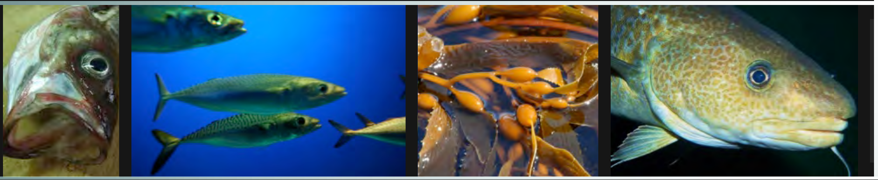
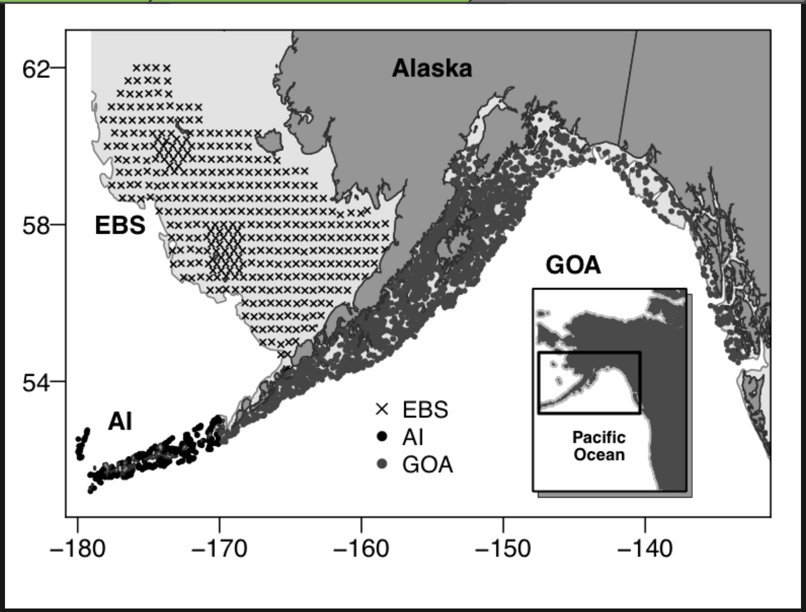
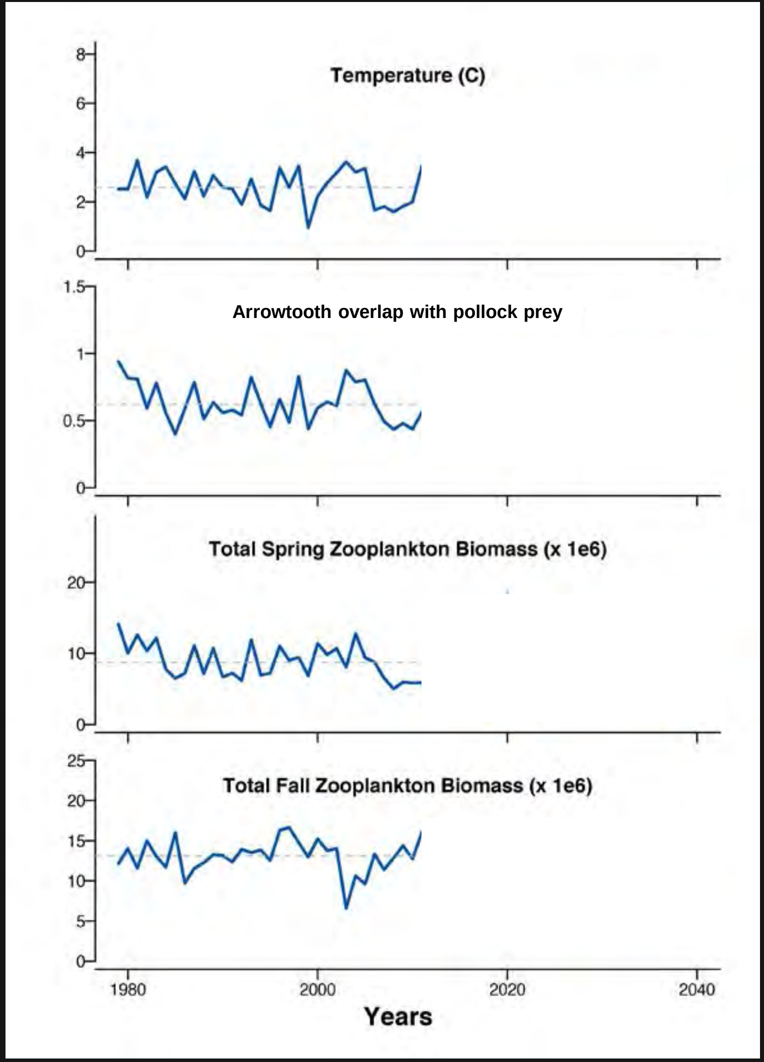


MSMt Approach





Pacific cod

Arrowtooth flounder

Walleye pollock

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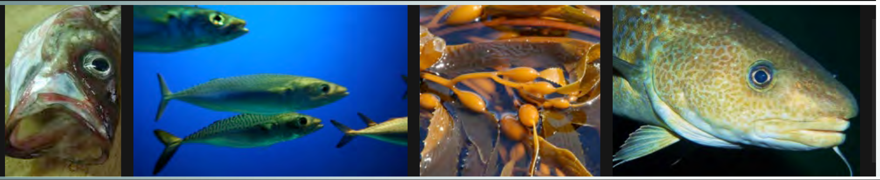
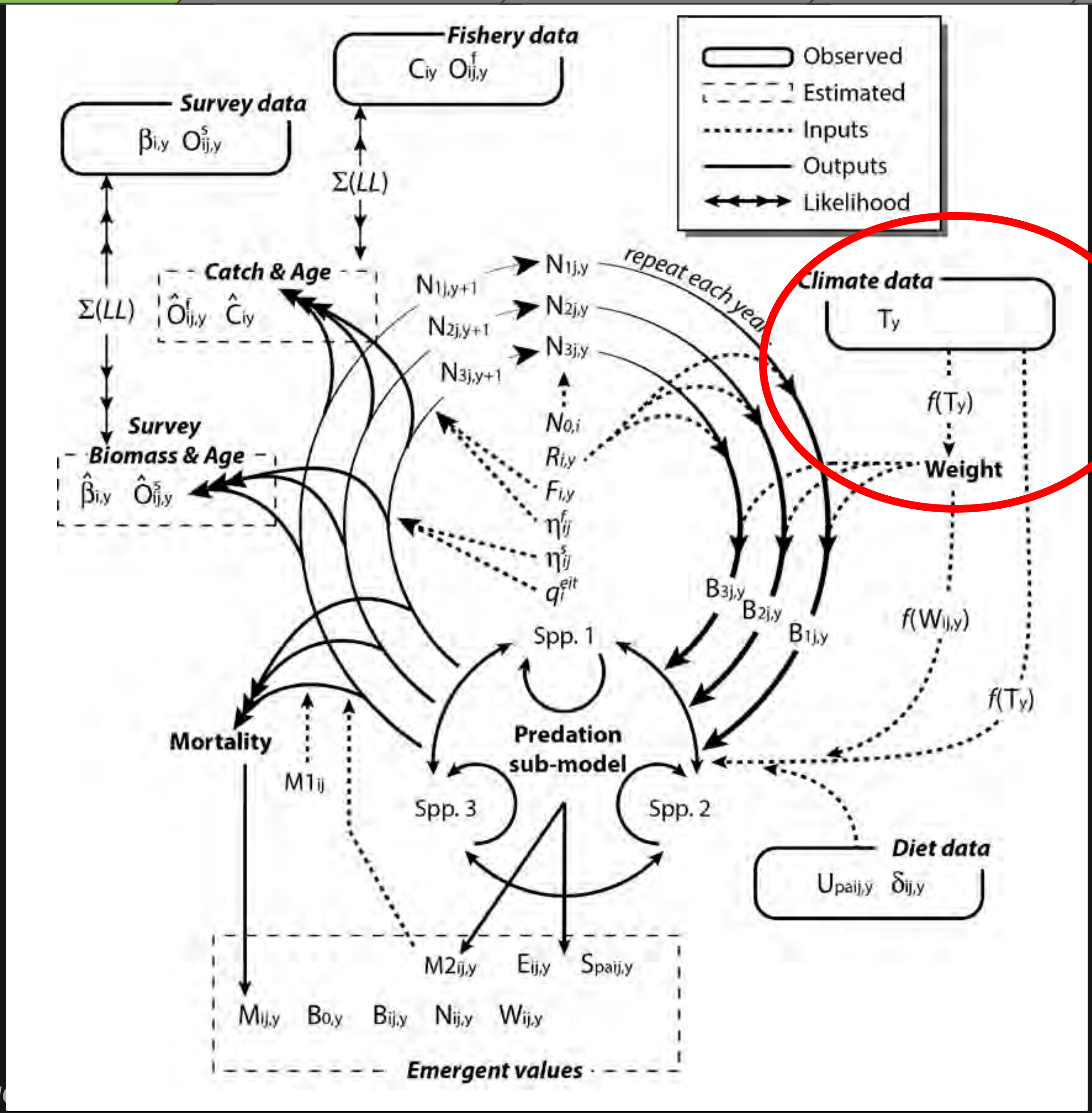
MSMt Weight at Age





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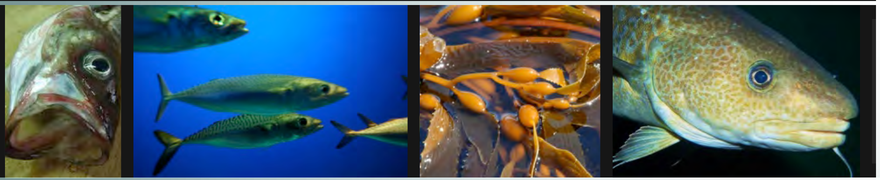
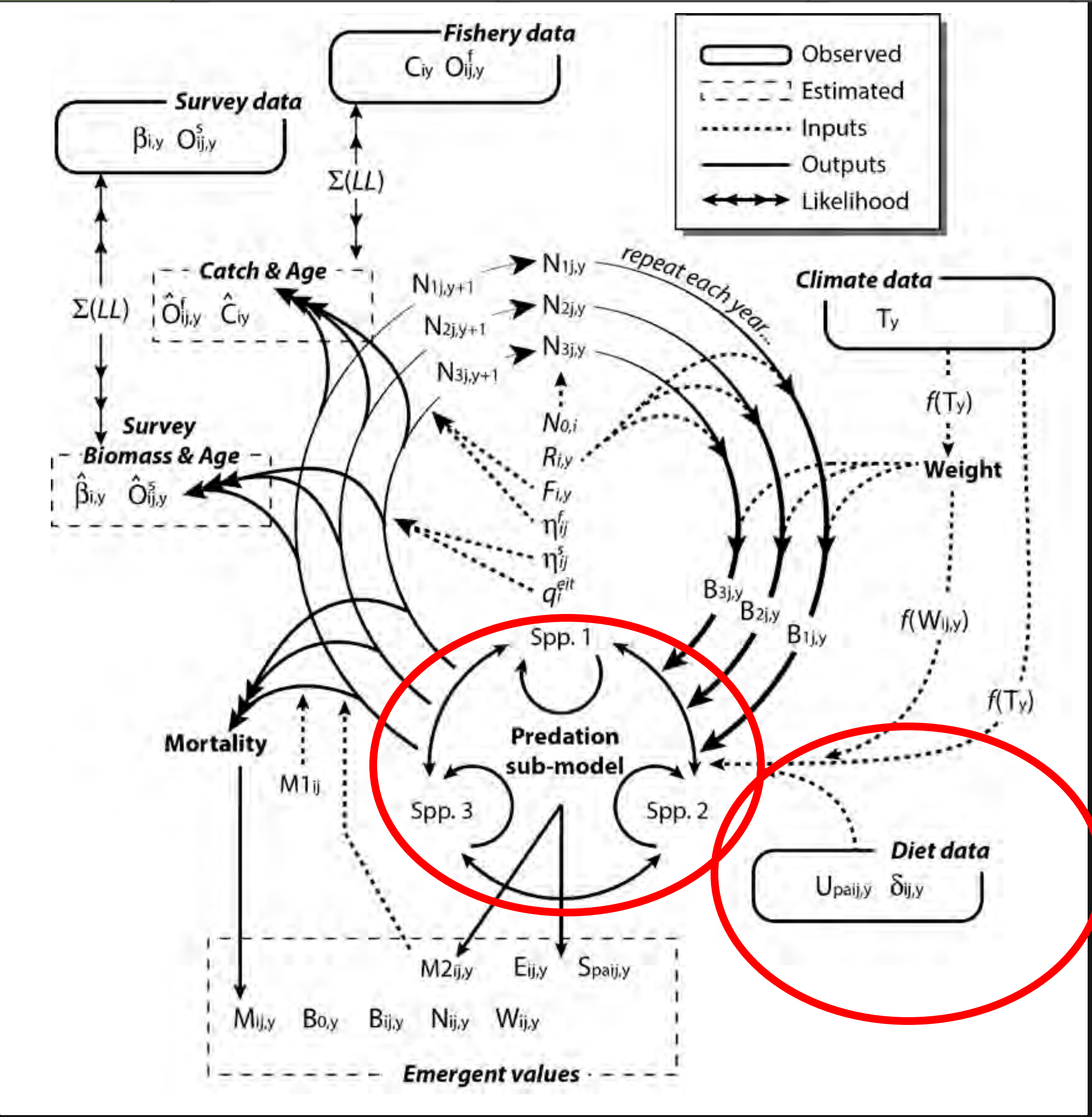
MSMt Pred. mort (M2)





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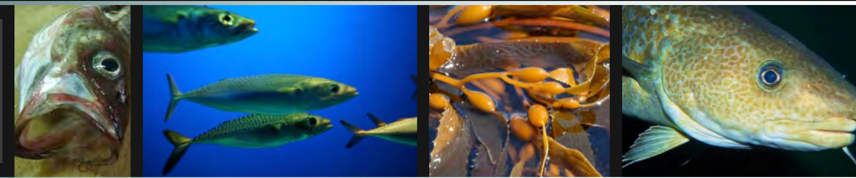


Recruitment	$N_{i1,y}=R_{i,y}=R_{0,i}e^{\tau_{i,y}}$	$\tau_{i,y}\sim \mathrm{N}(0,\sigma^2)$	T1.1
Initial abundance	$N_{ij,1}=\begin{cases} R_{0,i}e^{(-j\,M1_{ij})}N_{0,ij} \\ R_{0,i}e^{(-j\,M1_{i,A_i})}N_{0,i,A_i}/\left(1-e^{(-j\,M1_{i,A_i})}\right)\end{cases}$	$y=1 \quad 1<j\le A_i$ $y=1 \quad j>A_i$	T1.2
Numbers at age	$N_{i,j+1,y+1}=N_{ij,y}e^{-Z_{ij,y}}$ $N_{i,A_i,y+1}=N_{i,A_i-1,y}e^{-Z_{i,A_i-1,y}}+N_{i,A_i,y}e^{-Z_{i,A_i,y}}$	$1\le y\le n_y \quad 1\le j<A_i$ $1\le y\le n_y \quad j>A_i$	T1.3
Catch	$C_{ij,y}=\frac{F_{ij,y}}{Z_{ij,y}}(1-e^{-Z_{ij,y}})N_{ij,y}$		T1.4
Total yield (kg)	$Y_{i,y}=\sum_i^{A_i}\left(\frac{F_{ij,y}}{Z_{ij,y}}(1-e^{-Z_{ij,y}})N_{ij,y}W_{ij,y}\right)$		T1.5
Biomass at age (kg)	$B_{ij,y}=N_{ij,y}W_{ij,y}$		T.16
Spawning biomass at age (kg)	$SSB_{ij,y}=B_{ij,y}\rho_{ij}$		T1.7
Total mortality at age	$Z_{ij,y}=\mathrm{M1}_{ij}+\mathrm{M2}_{ij,y}+F_{ij,y}$		T1.8
Fishing mortality at age	$F_{ij,y}=F_{0,i}e^{\varepsilon_{i,y}}s^f_{ij}$	$\varepsilon_{i,y}\sim \mathrm{N}(0,\sigma^2_{F,i})$	T1.9
Weight at age	$W_{ij,y}=\log(W_{\infty,iy})+\left(1/(1-d_{i,y})\right)\log\left(1-e^{(-K_i(1-d_{i,y})(j-t_{0,i}))}\right)$		T1.10a
Fishery age composition	$O^f_{ij,y}=\frac{C_{ij,y}}{\sum_j C_{ij,y}}$		T1.13
BT survey age composition	$O^s_{ij,y}=\frac{N_{ij,y}e^{0.5(-Z_{ij,y})}s^s_{ij}q^s_{ij}}{\sum_j\left(N_{ij,y}e^{0.5(-Z_{ij,y})}s^s_{ij}q^s_{ij}\right)}$		T1.14
EIT survey age composition	$O^{eit}_{1j,y}=\frac{N_{1j,y}e^{0.5(-Z_{1j,y})}s^{eit}_{1j}q^{eit}_{1j}}{\sum_j\left(N_{1j,y}e^{0.5(-Z_{1j,y})}s^{eit}_{1j}q^{eit}_{1j}\right)}$		T1.15

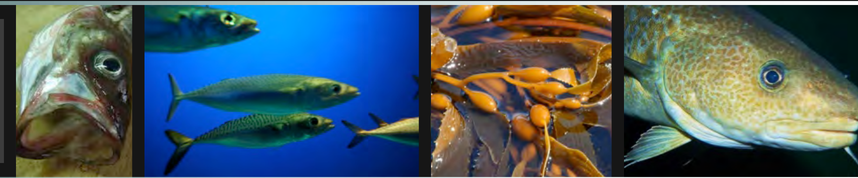
Residual Natural Mortality

Predation Natural Mortality

$$Z_{ij,y}=\mathrm{M1}_{ij}+\mathrm{M2}_{ij,y}+F_{ij,y}$$

kirstin.holsman@noaa.gov

MSMt Pred. mort (M2)



Definition	Equation	
Predation morality	$M2_{ij,y} = \sum_{pa} \left(\frac{N_{pa,y} \delta_{pa,y} \bar{S}_{paij}}{\sum_{ij}(\bar{S}_{paij} B_{ij,y}) + B_p^{other}\left(1 - \sum_{ij}(\bar{S}_{paij})\right)} \right)$	T2.1
Predator-prey suitabilit[y]	$\ldots_{paij} \ldots n_y \sum_y \left(\ldots \sum_{ij} \left(\frac{U_{paij}}{B_{ij,y}} \right) + \frac{1 + \sum_{ij} U_{paij}}{B_p^{other}} \right)$	T2.2
Mean gravimetric die[t] proportion		T2.3
Individual specific ration (kg kg^{-1} yr^{-1})	$\delta_{pa,y} = \hat{\varphi}_{p,y} \alpha_\delta W_{pa,y}{}^{(1+\beta_\delta)} f(T_y)_p$	T2.4
Temperature scaling algorithm	$f(T_y) = V^X e^{(X(1-V))}$	T2.5
		T2.5a
		T2.5b
	$Z = ln(Q_p^c)(T_p^{cm} - T_p^{co})$	T2.5c
	$Y = ln(Q_p^c)(T_p^{cm} - T_p^{co} + 2)$	T2.5d

Age-specific prey selectivity

Size-specific annual ration

Temperature specific

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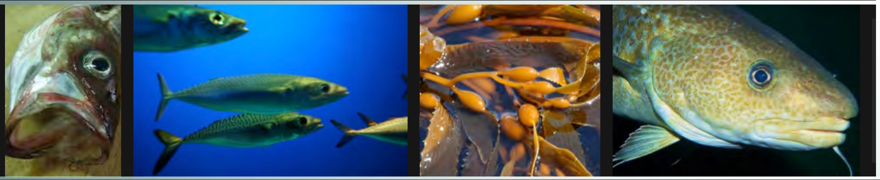
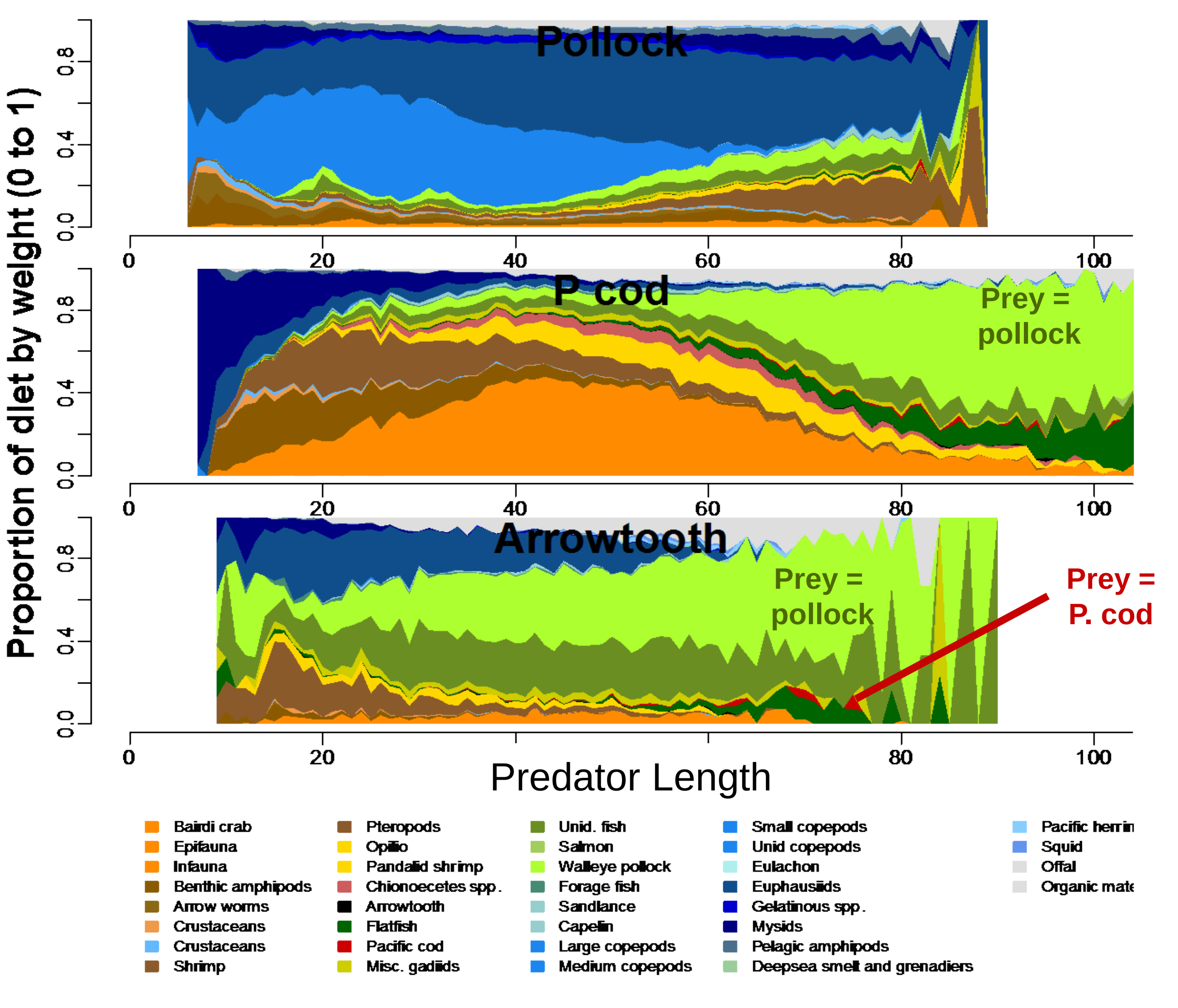
MSMt Pred. mort (M2)





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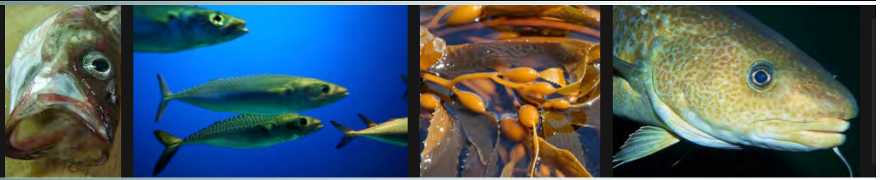
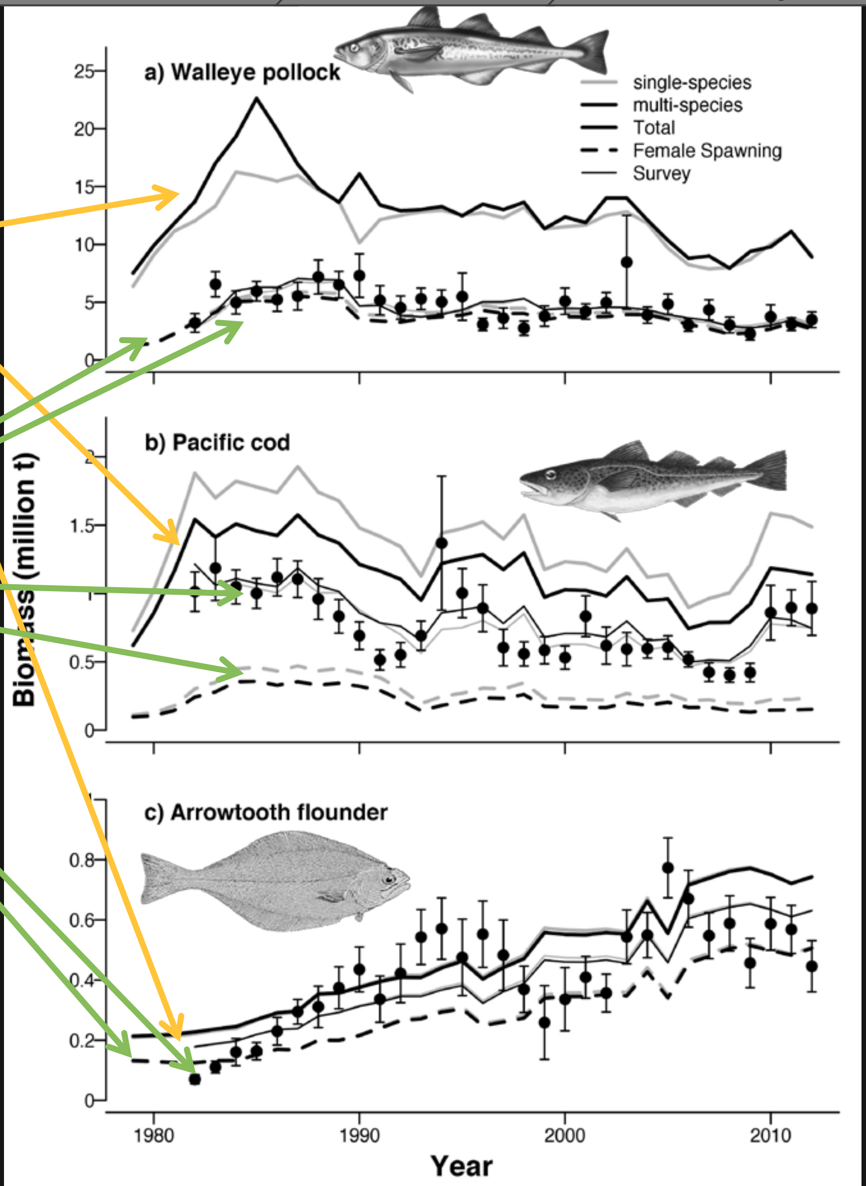
MSMt Estimation



Total biomass differed between models

Female spawning and survey biomass estimates were similar



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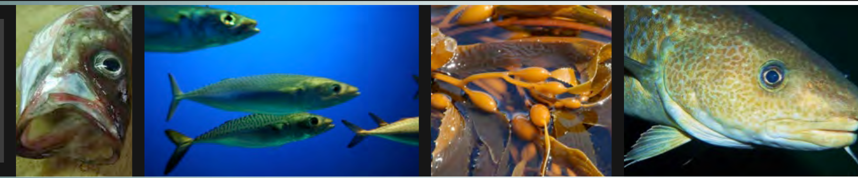

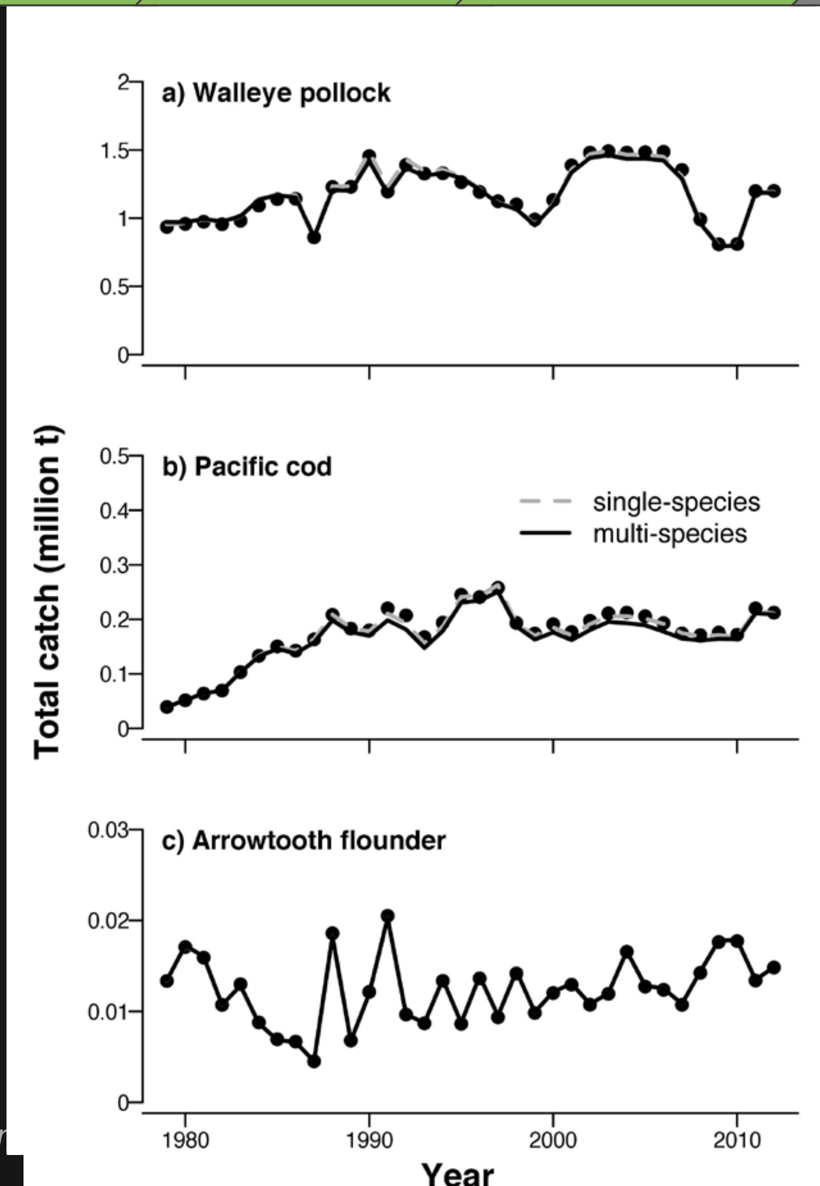

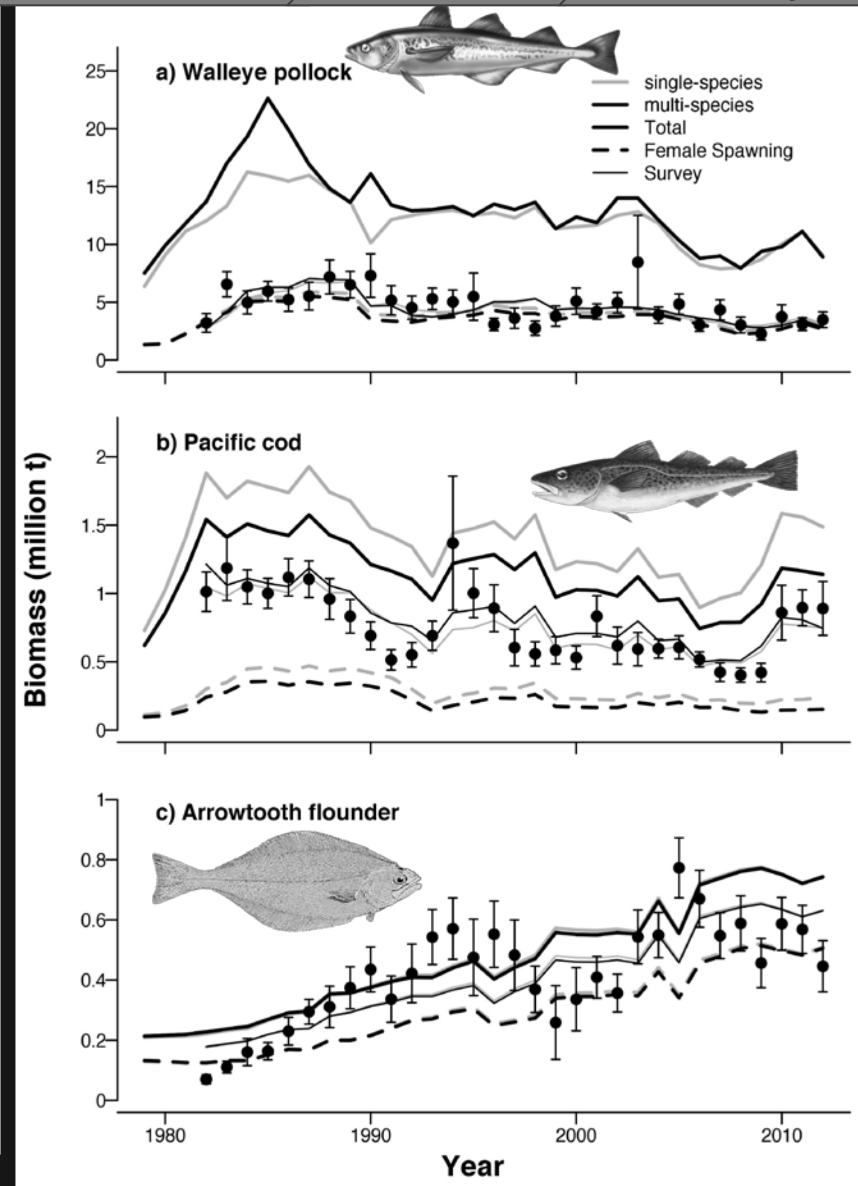

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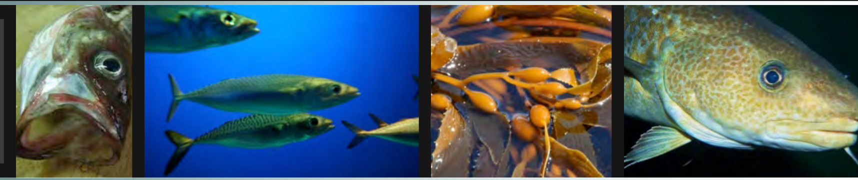

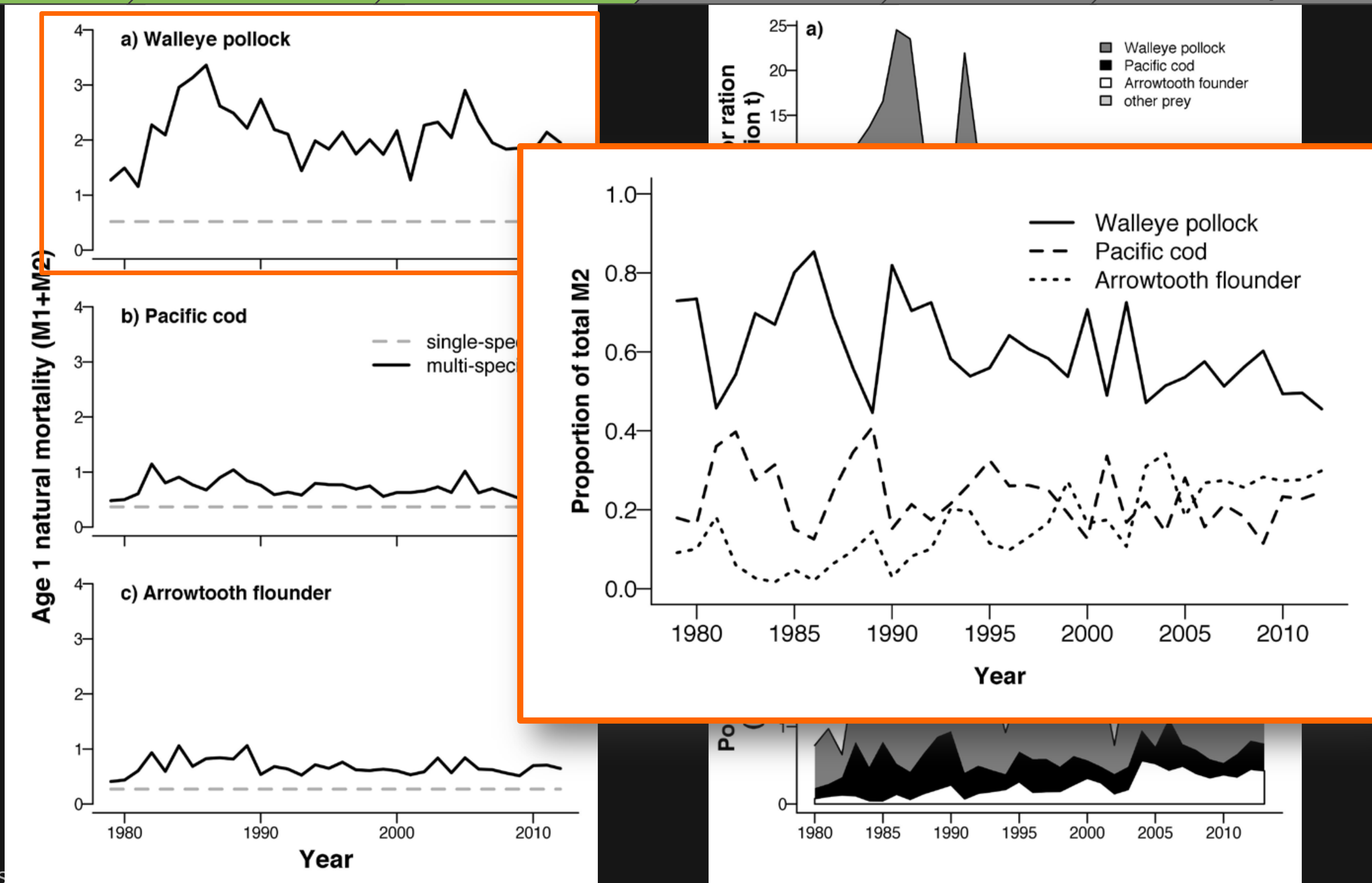

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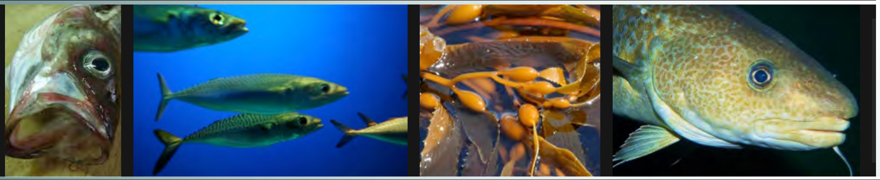
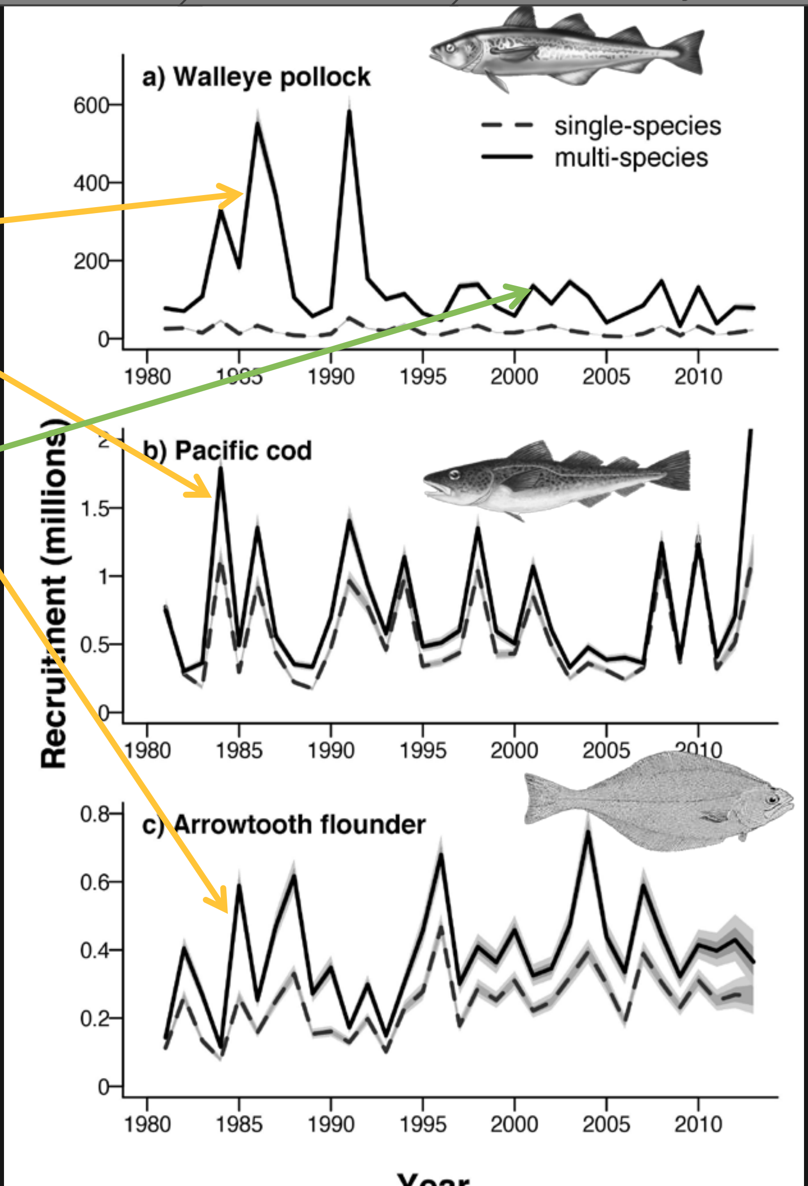


MSMt Recruitment (M2 effect) ⬆

Peaks in recruitment (Temp. effect)



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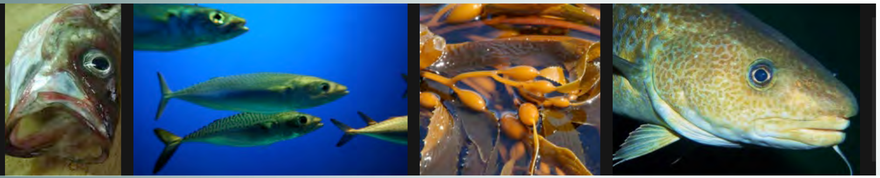
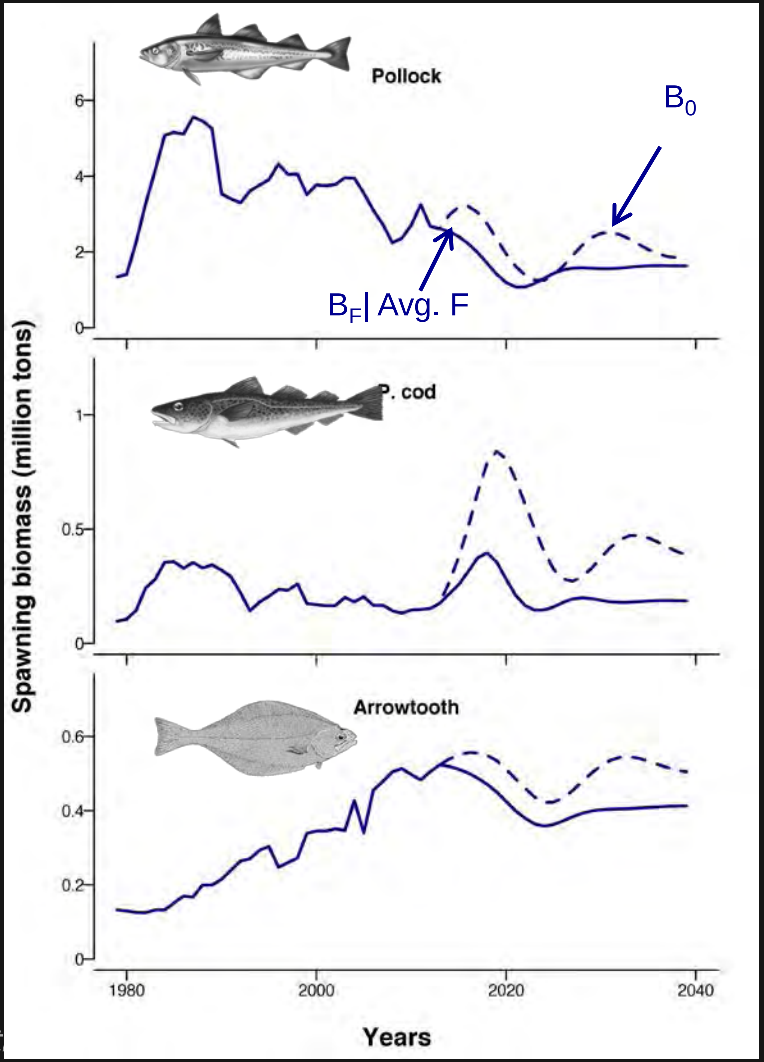
Biological Ref. Points



Multi-Species Model



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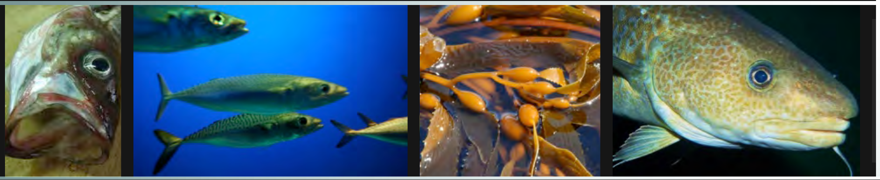

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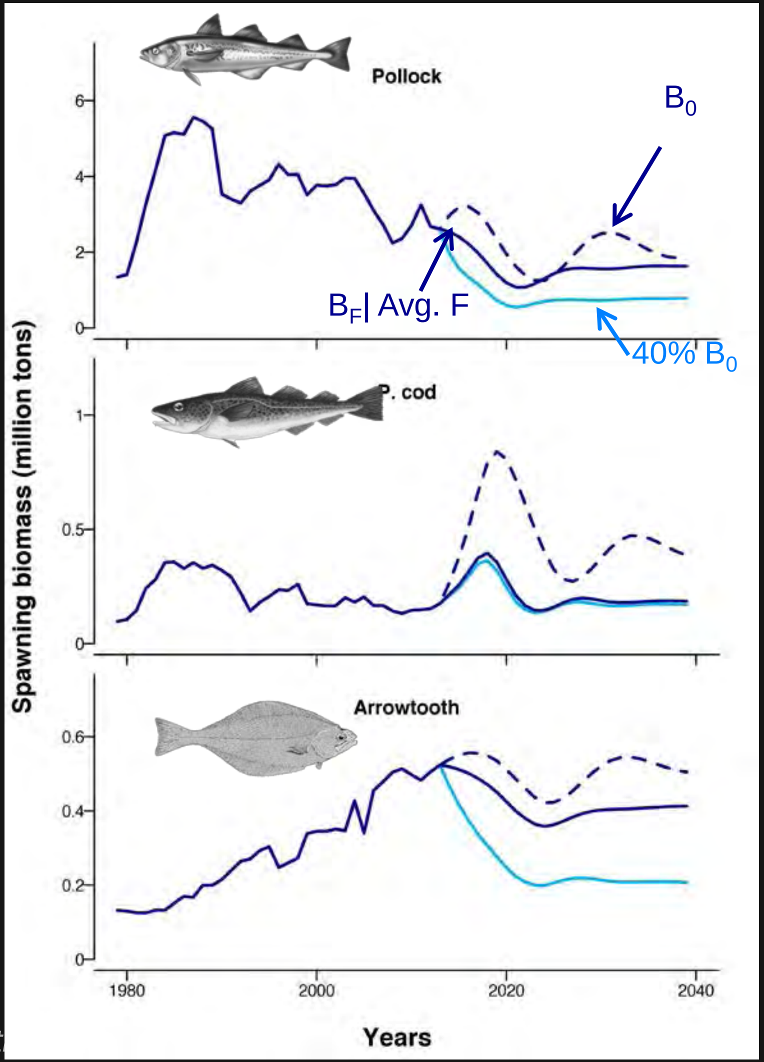

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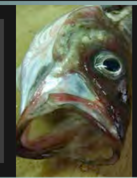


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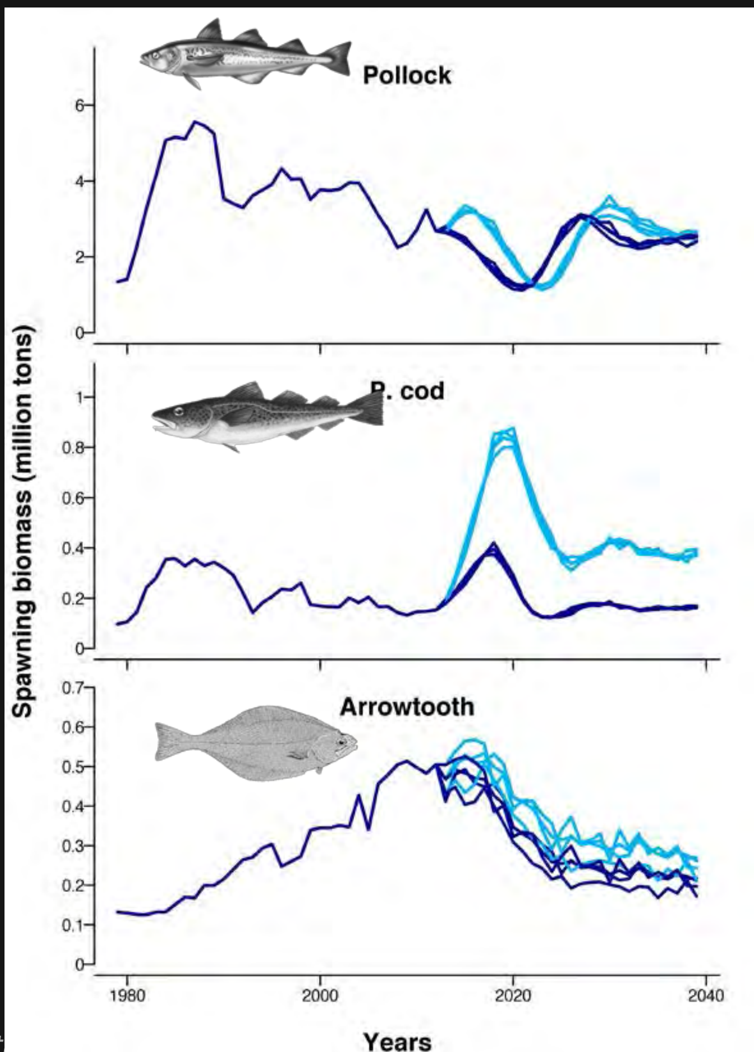

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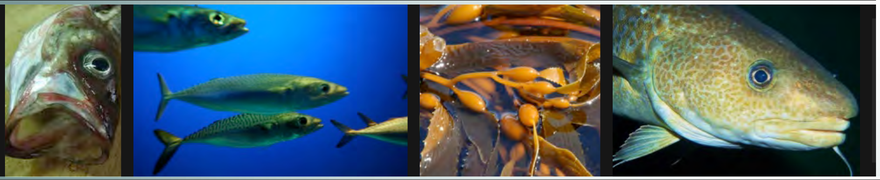

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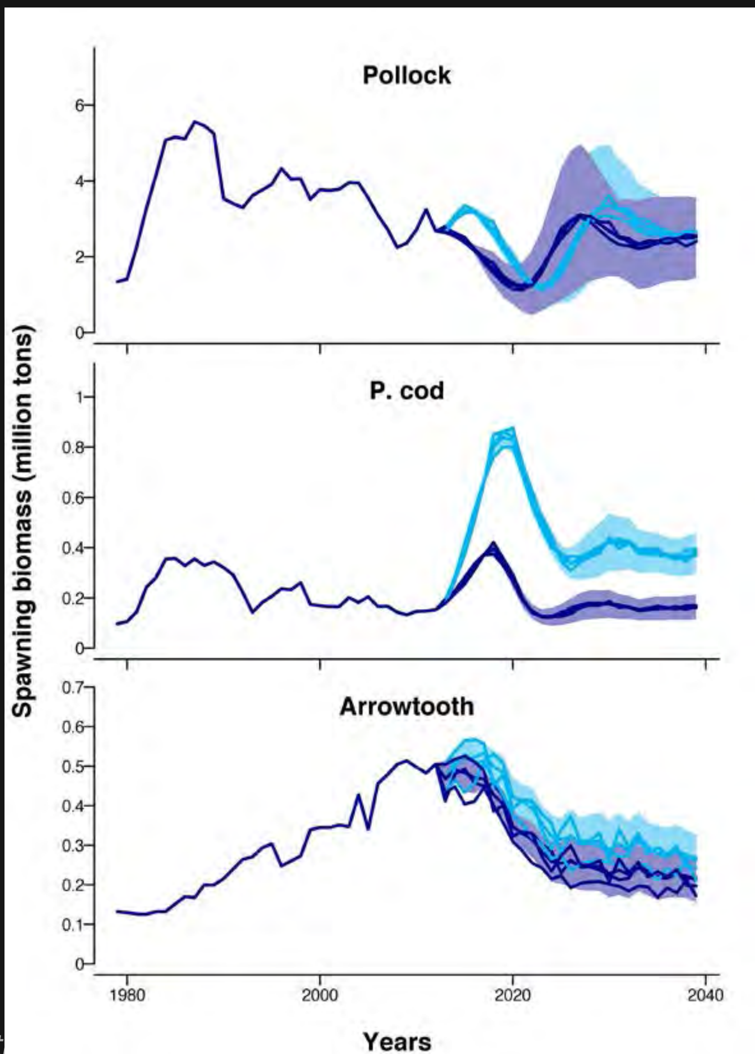

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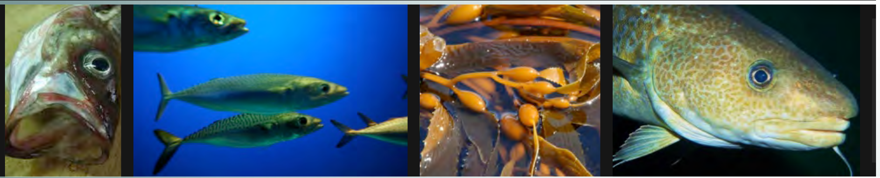

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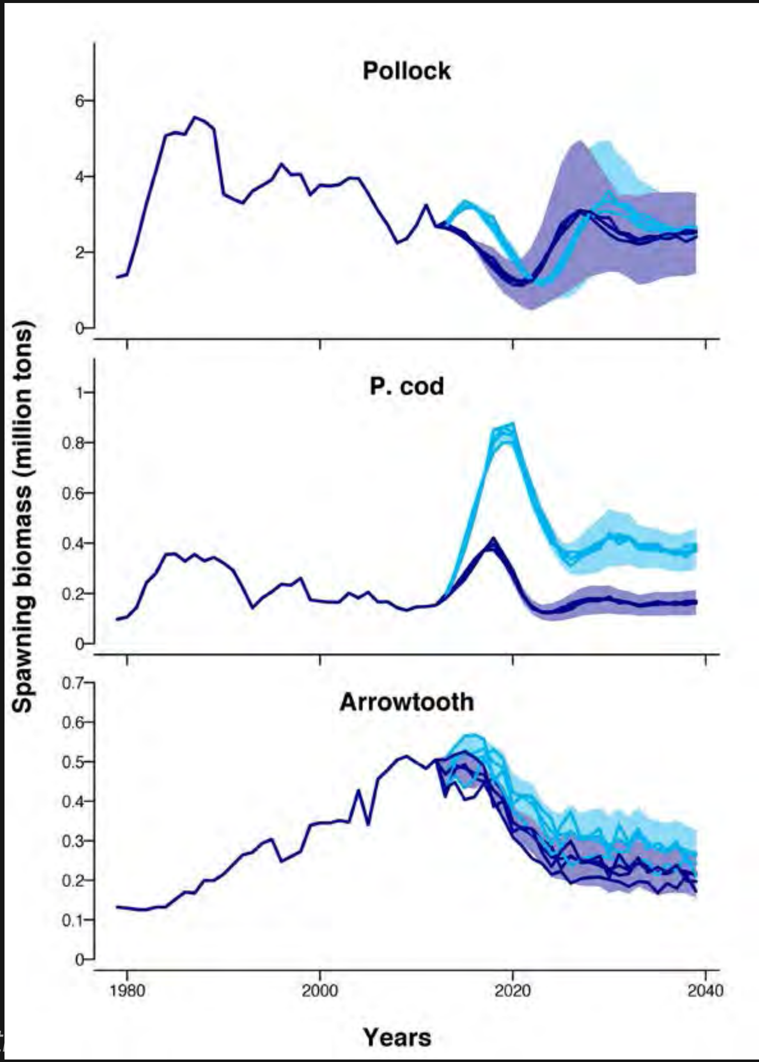

Variation in projected ABC:

1. Temp. effects on Wt & M2

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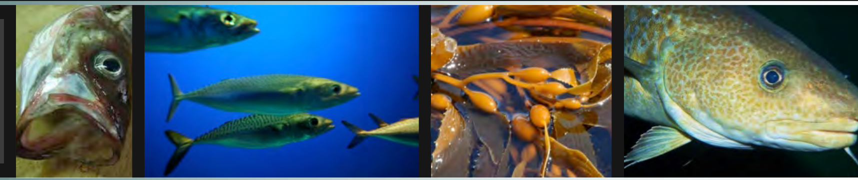

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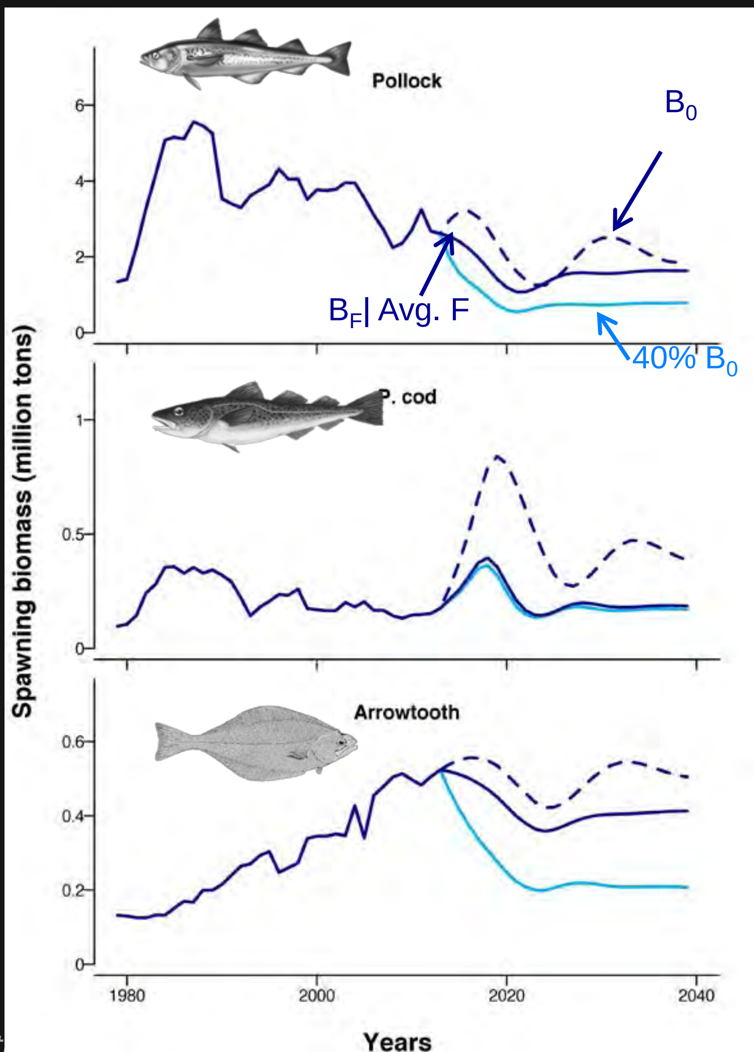

Variation in projected ABC:

1. Temp. effects on Wt & M2
2. Control rule effects on B_0

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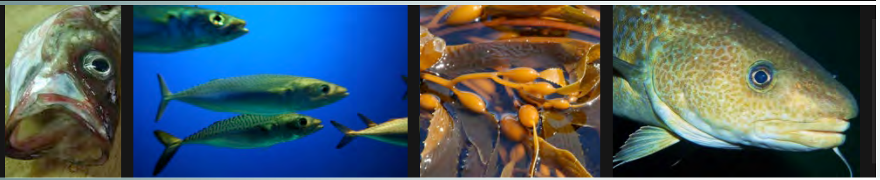
Biological Ref. Points



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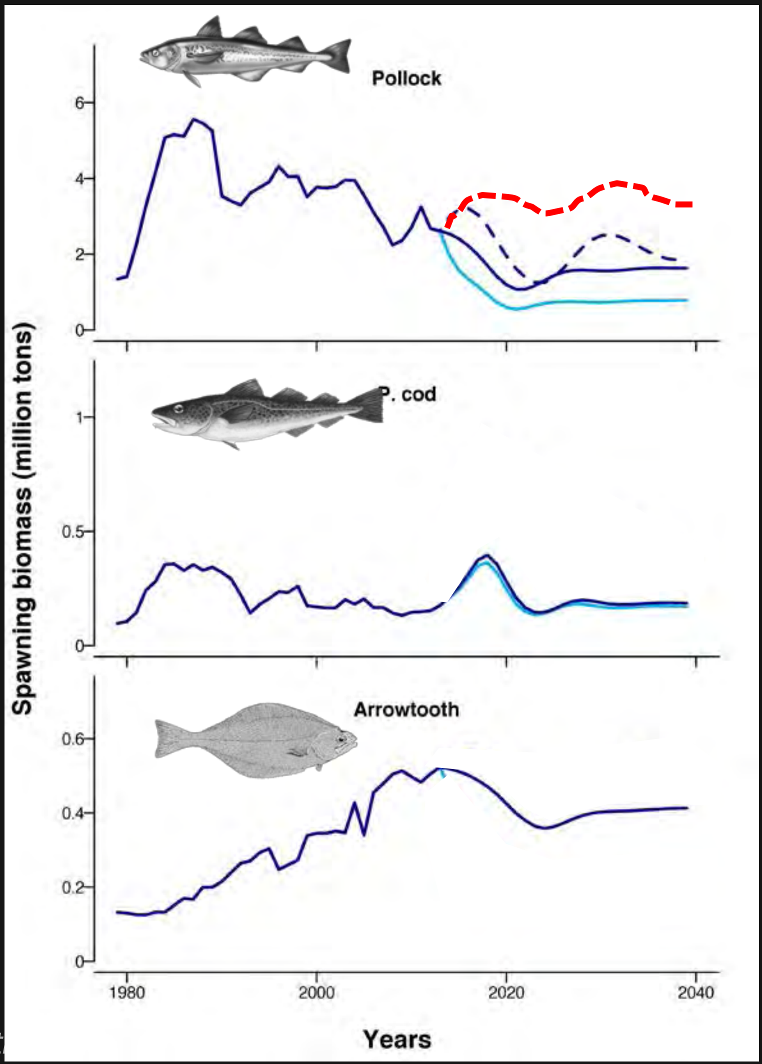

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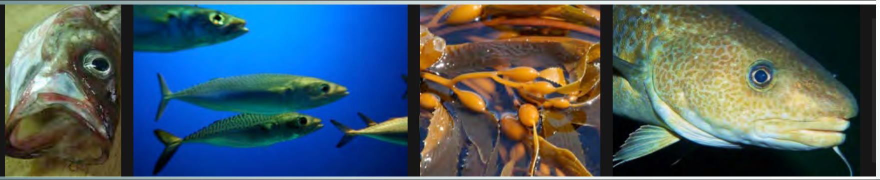
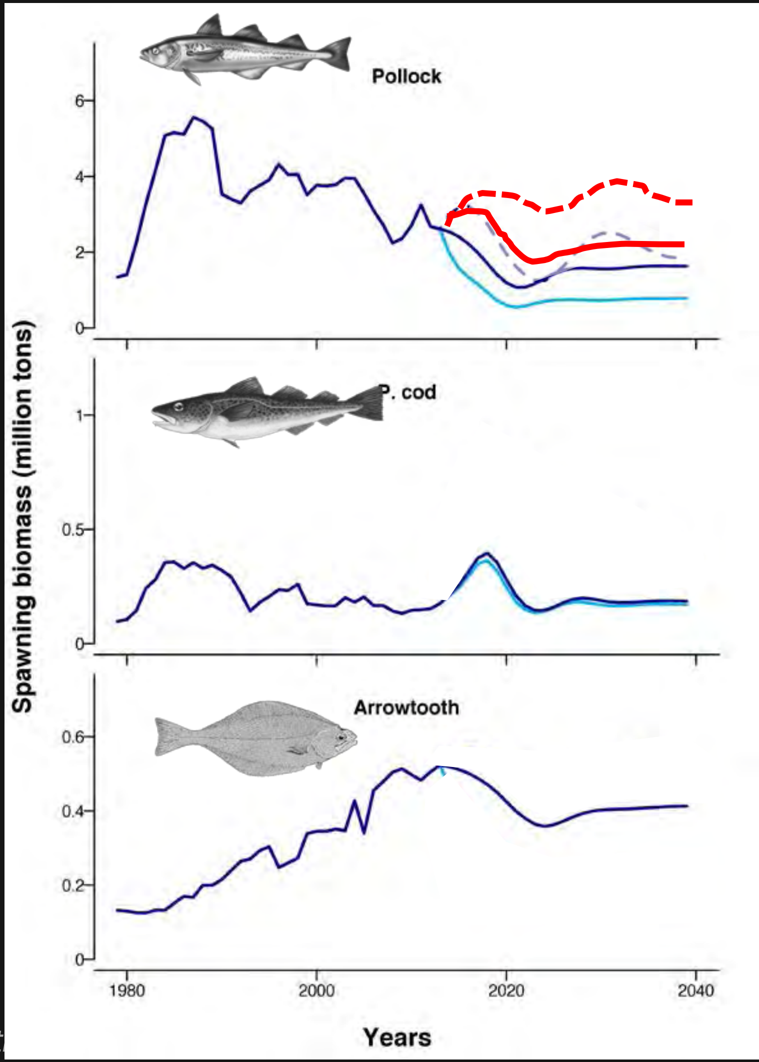
Biological Ref. Points



Multi-Species Model



Variation in projected ABC:

1. Temp. effects on Wt & M2
2. Control rule effects on B_0

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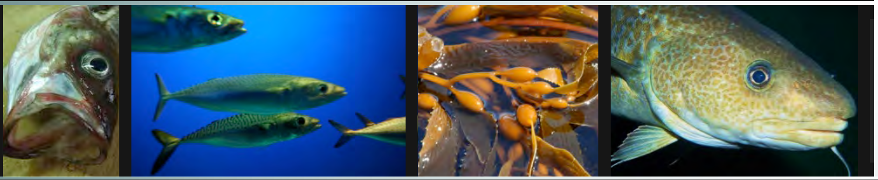
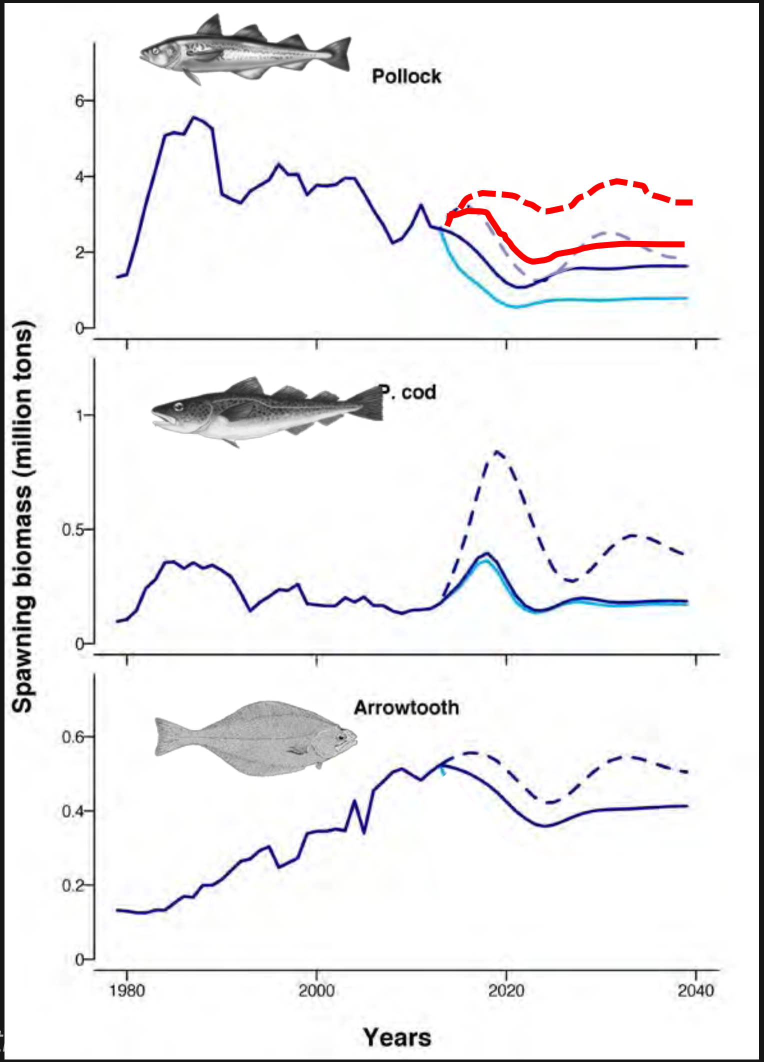


Multi-Species Model

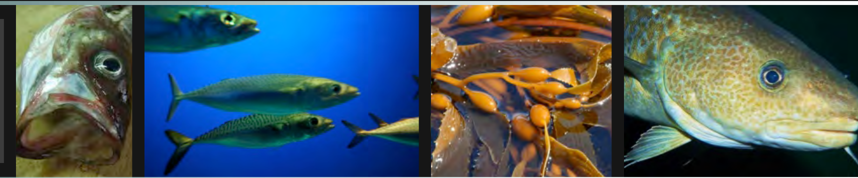


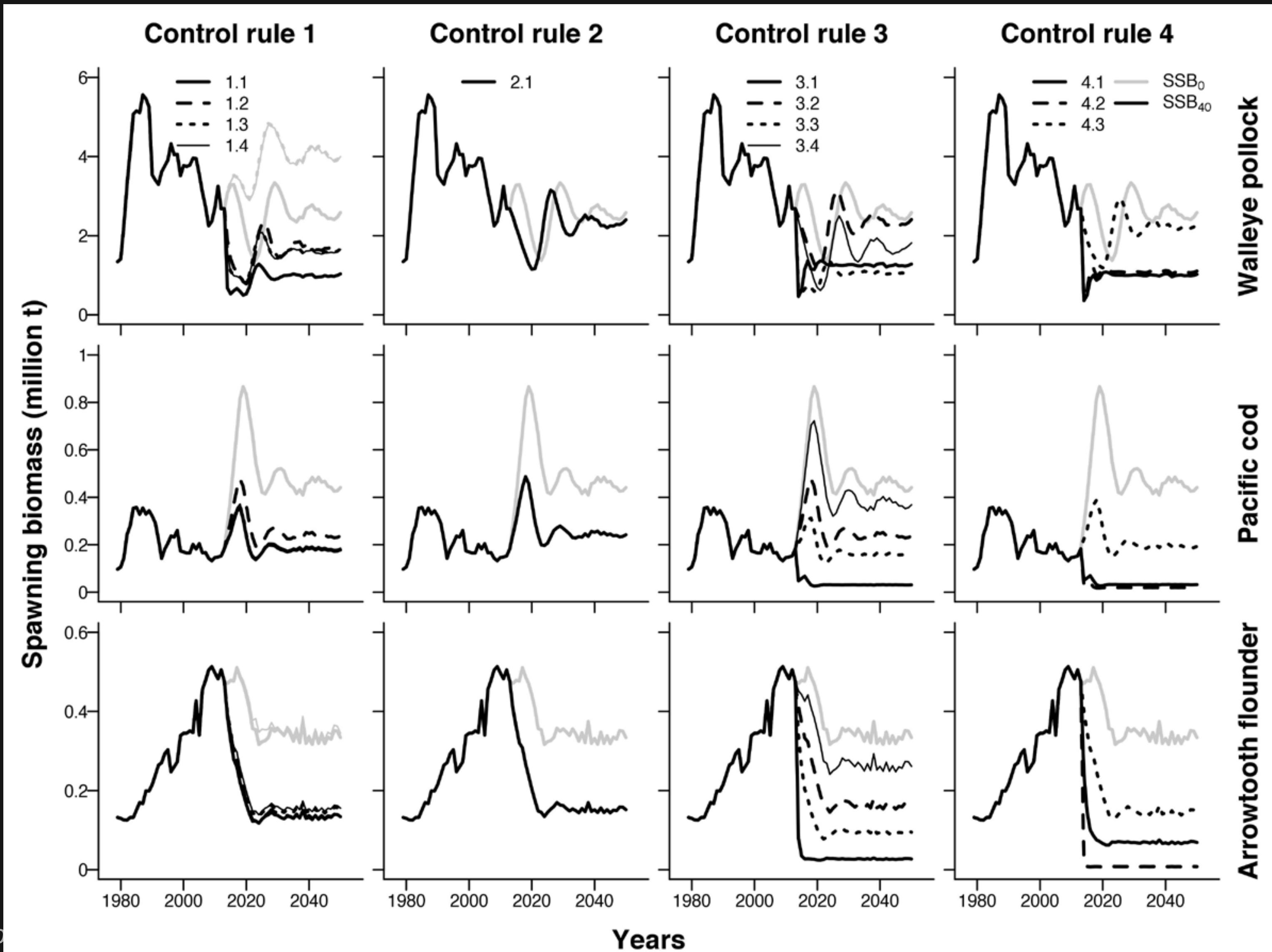
Variation in projected ABC:

1. Temp. effects on Wt & M2

2. Control rule effects on B_0

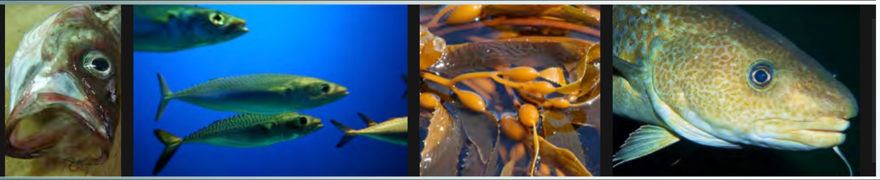
Biological Ref. Points



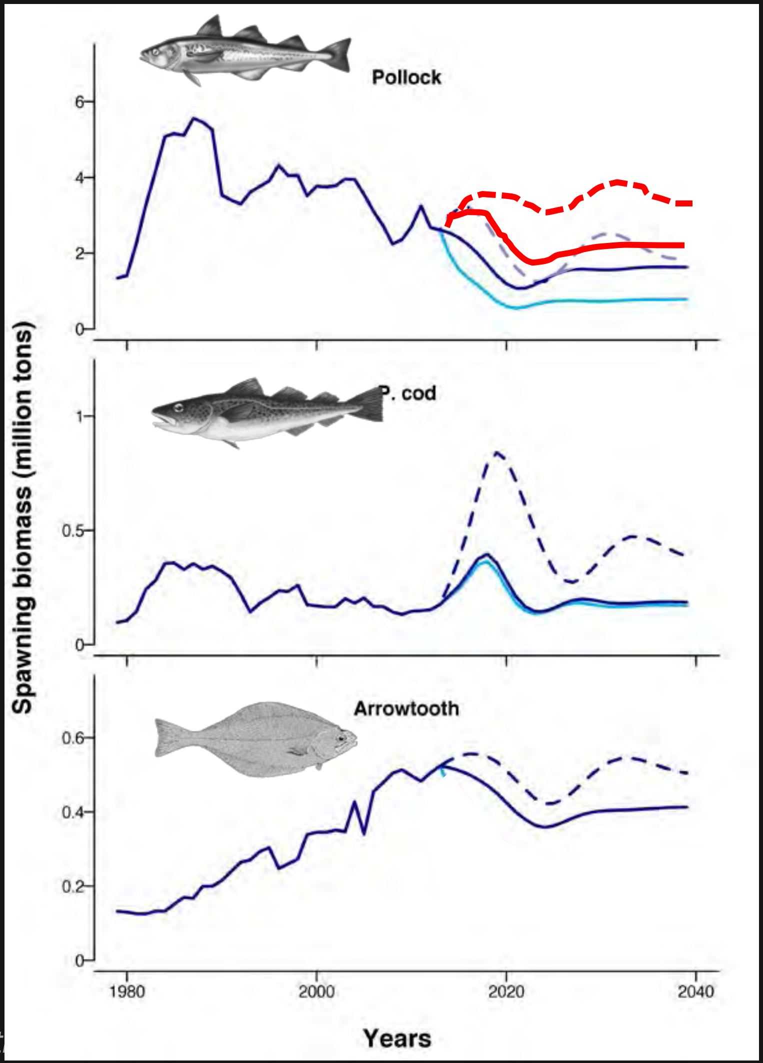


kirstin.ho

Biological Ref. Points



Multi-Species Model

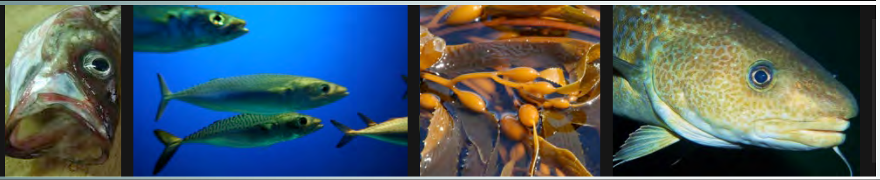


Variation in projected ABC:

1. Temp. effects on Wt & M2
2. Control rule effects on B_0
3. R/S function

kirst

MSMt Multispecies



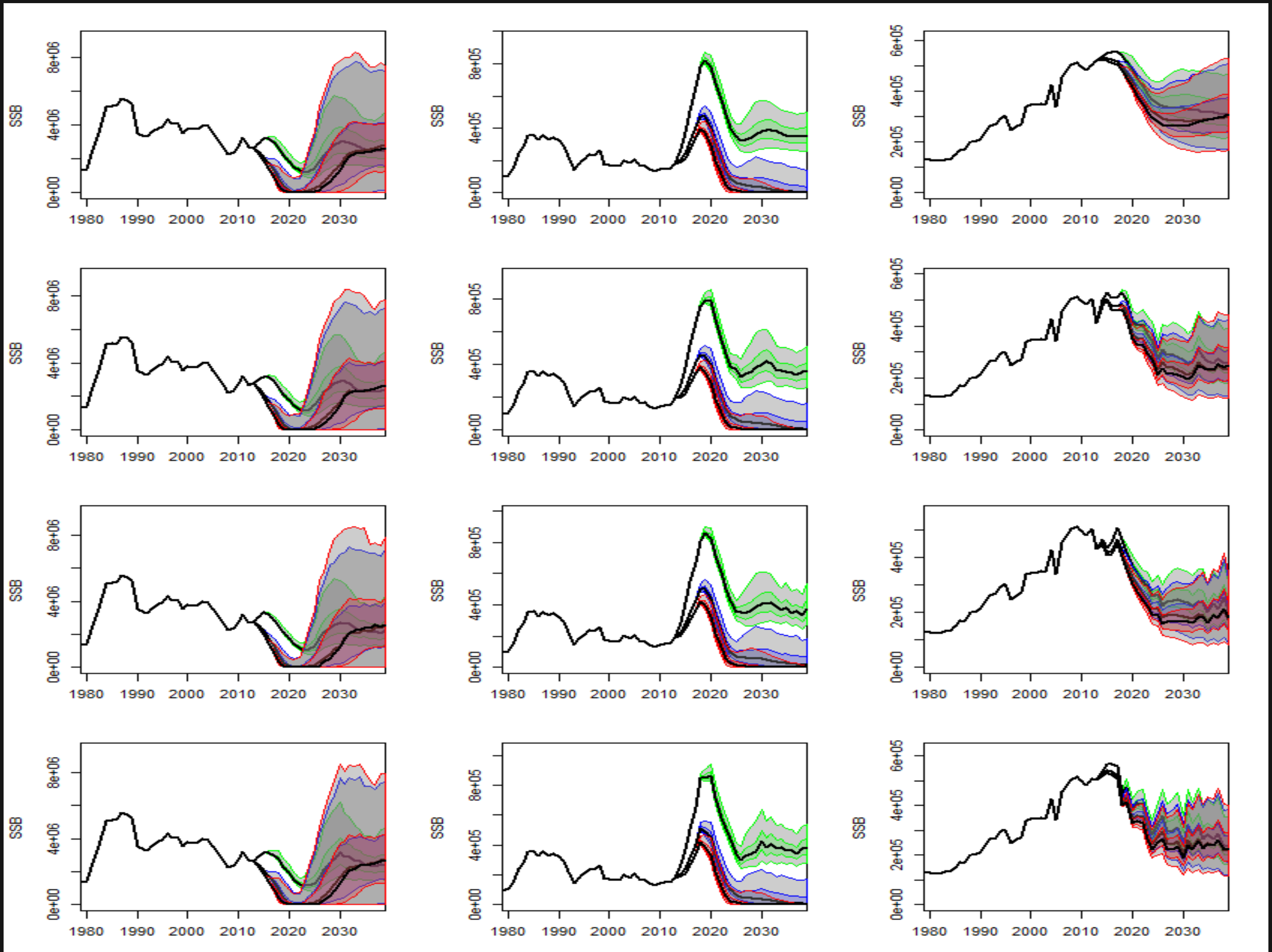
Pollock | P. cod | Arrowtooth

Avg Temp

ECHOG

CCMA

MIROC



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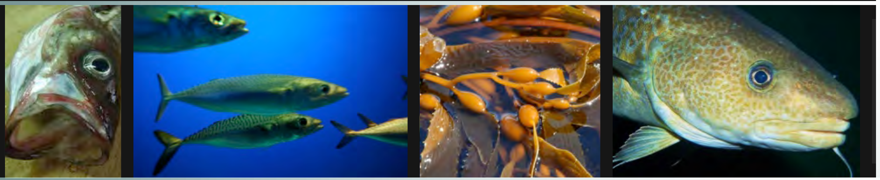
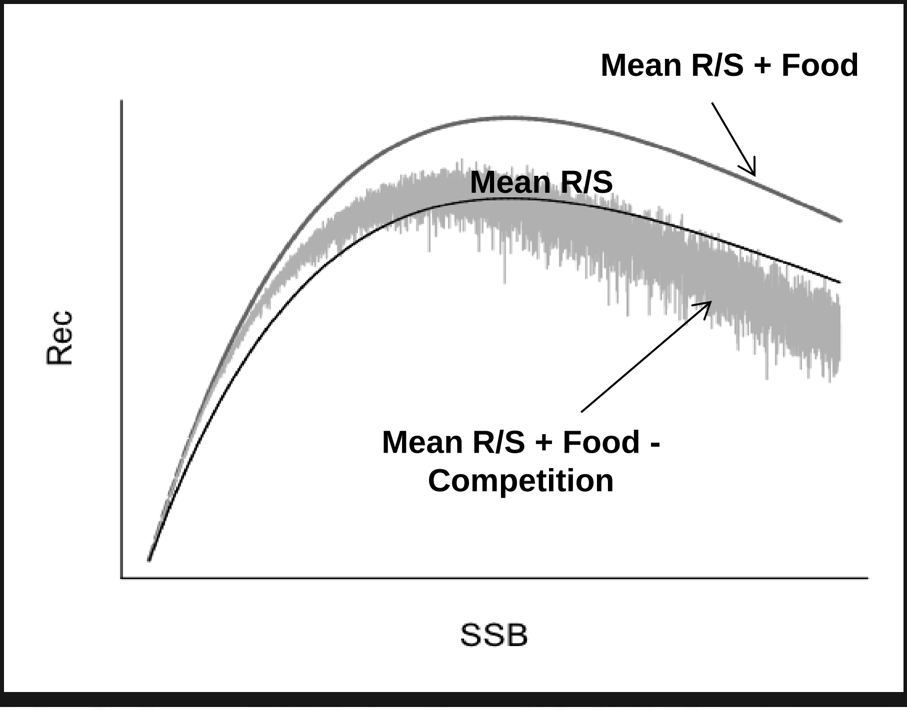
From Ianelli et al. *submitted*

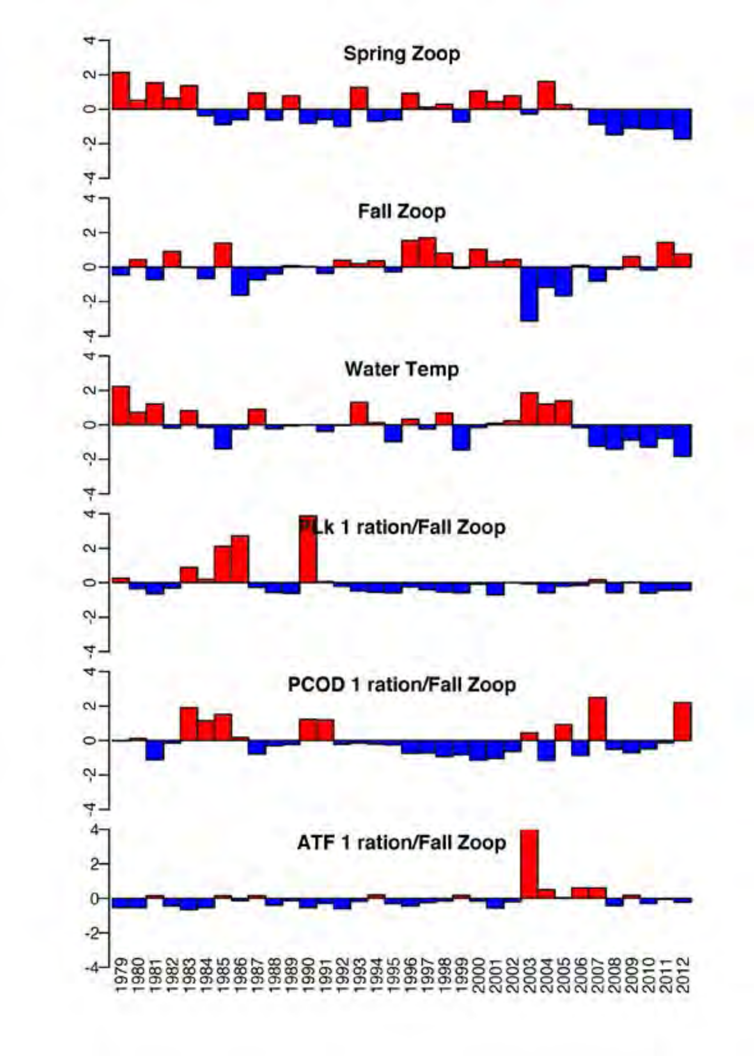
Recruitment estimation





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

Future recruitment



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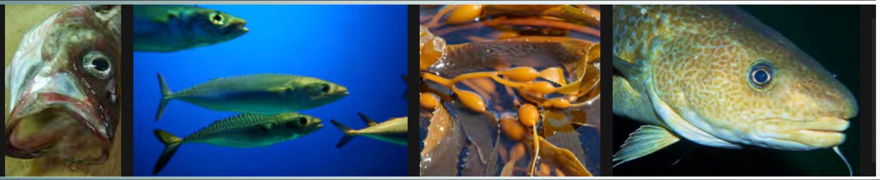
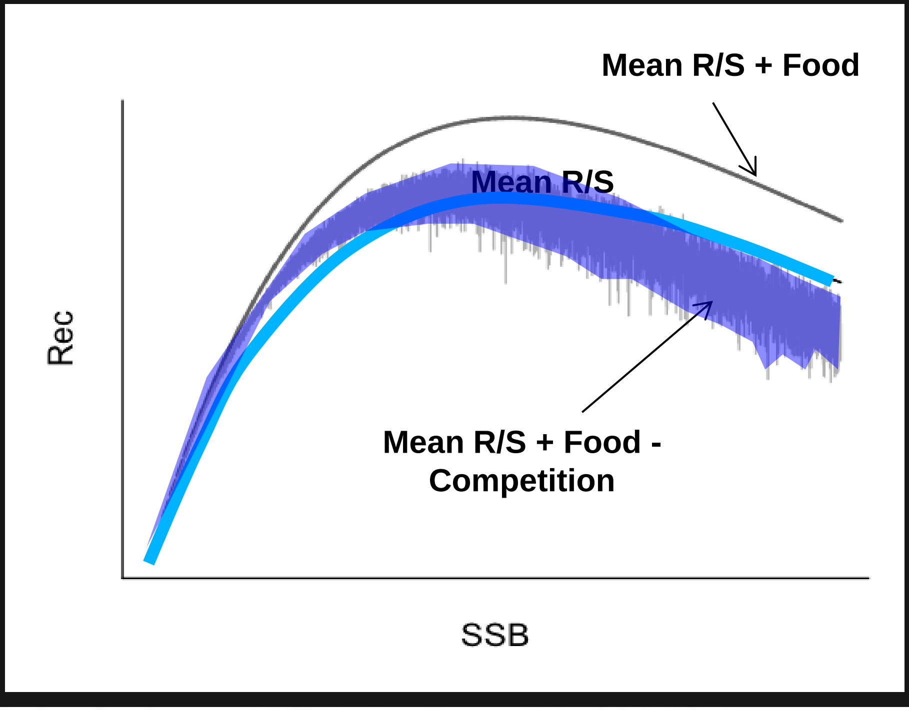


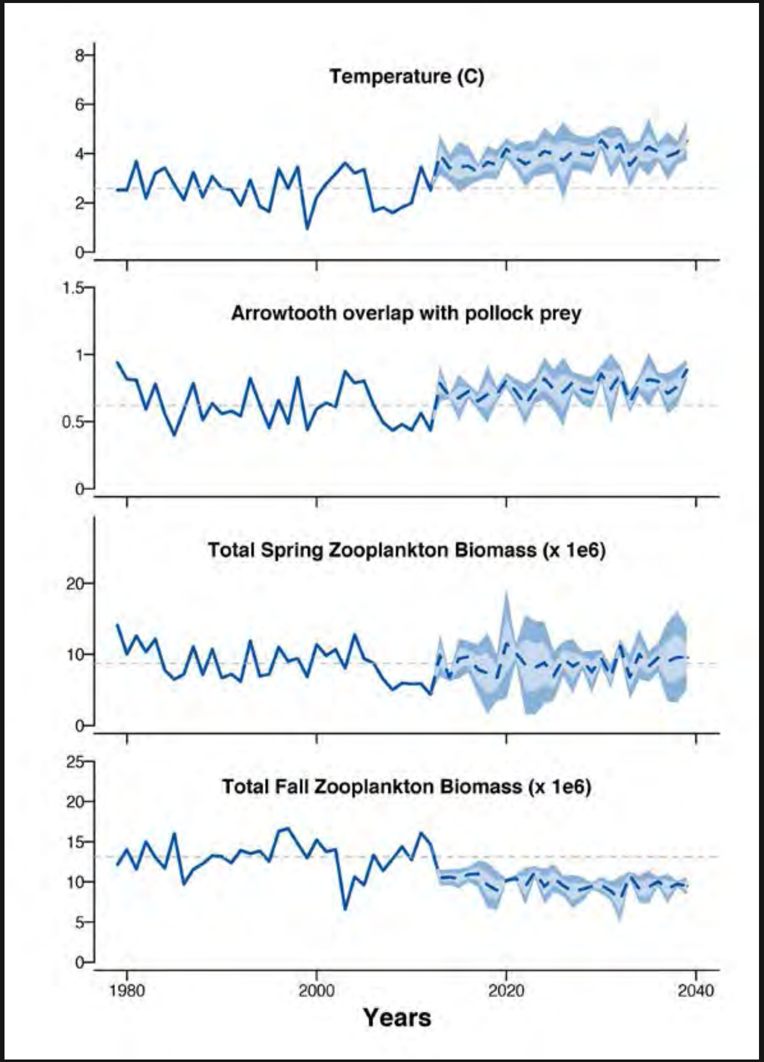
Recruitment projection

Environmental covariates



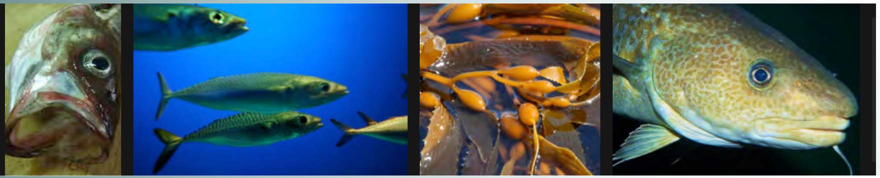
$$\log\left(R_{p,v}^{fut}\right) = \log\left(\alpha_{R,p} \cdot SSB_{p,v-1}\right) - \beta_{R,p} \cdot SSB_{p,v-1} + \beta_{Z,p}^{spr} \cdot Z_v^{spr} - \beta_{Z,p}^{fall} \cdot \left(\delta_{p1,v}^{fut} / Z_v^{fall} \right)$$

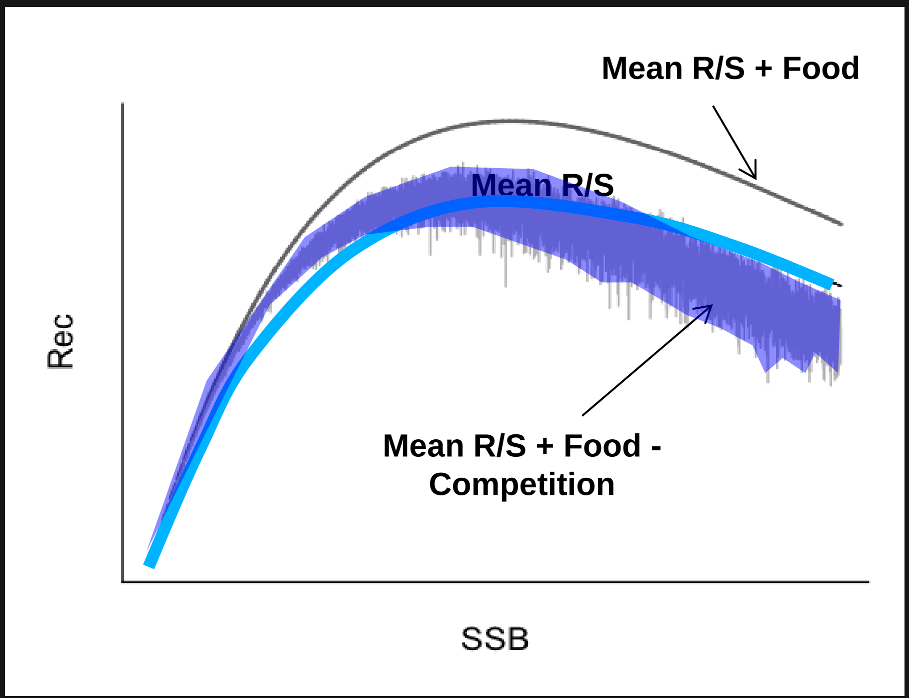
Future recruitment



kirstin.holsman@noaa.gov

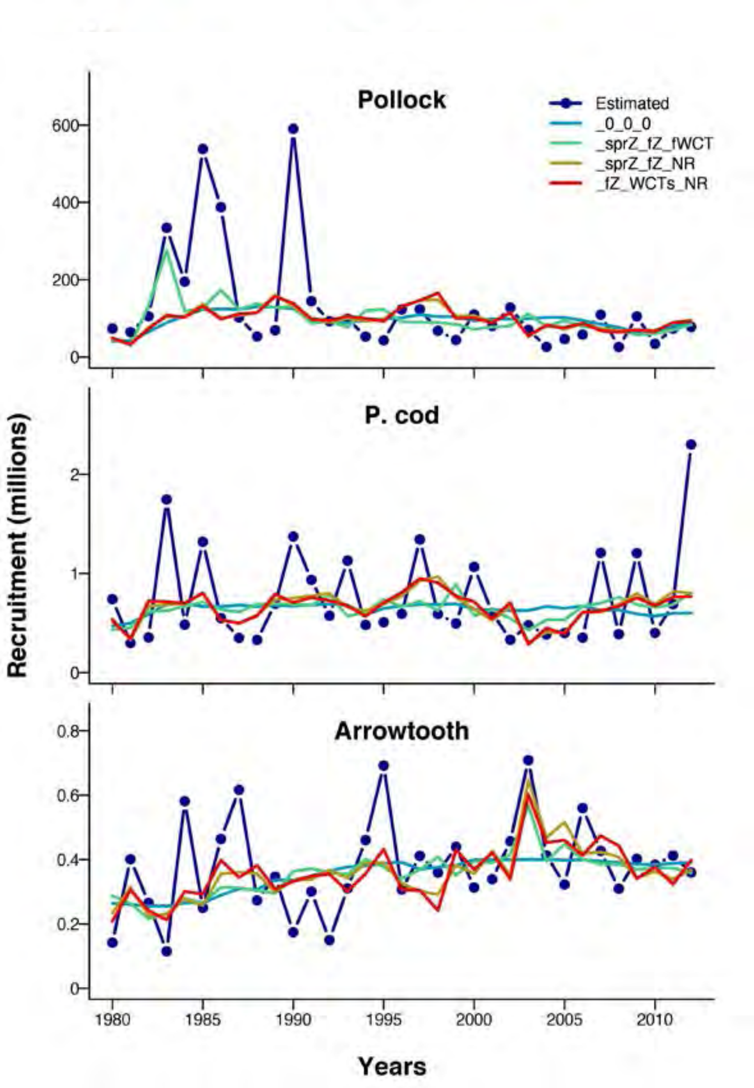
Recruitment projection





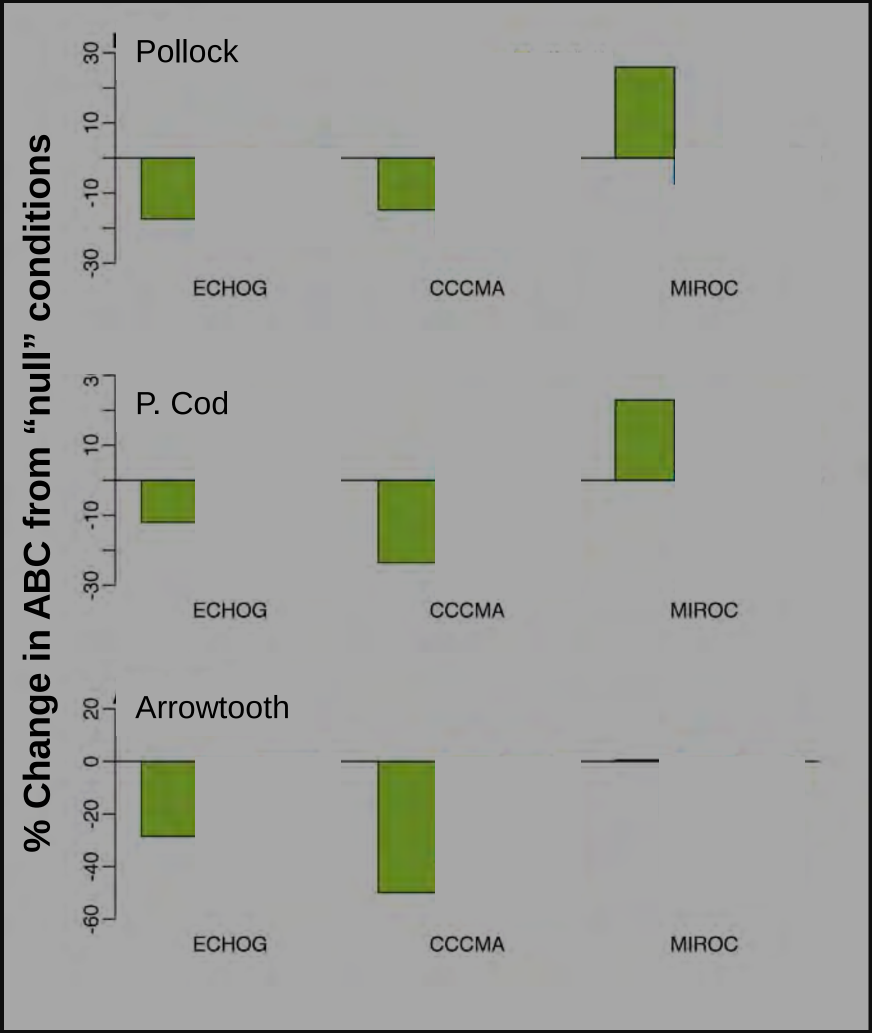
$$\log\left(R_{p,v}^{fut}\right) = \log\left(\alpha_{R,p} \cdot SSB_{p,v-1}\right) - \beta_{R,p} \cdot SSB_{p,v-1} + \beta_{Z,p}^{spr} \cdot Z_v^{spr} - \beta_{Z,p}^{fall} \cdot \left(\delta_{p1,v}^{fut} \Big/ Z_v^{fall} \right)$$

Future recruitment

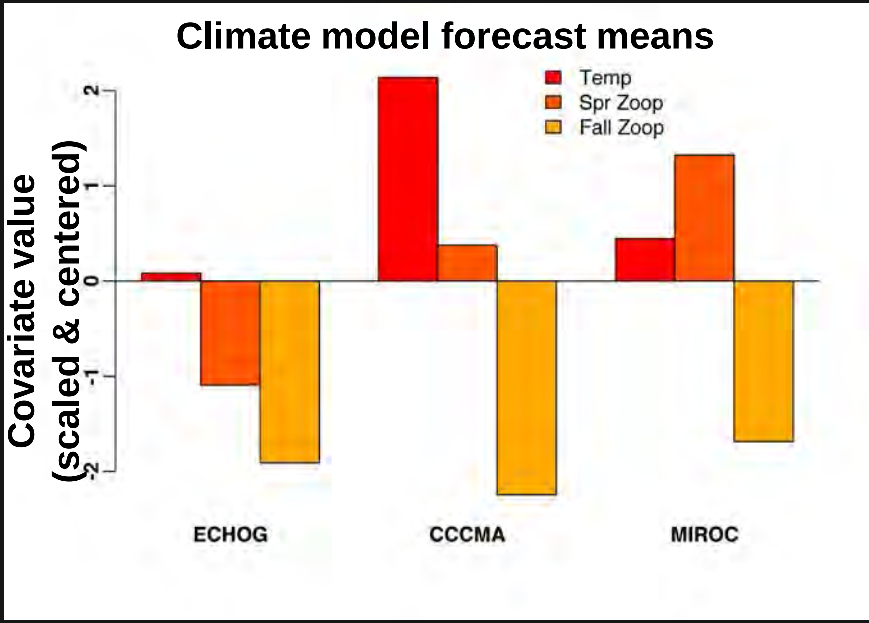


kirstin.holsman@noaa.gov

MSMt Projections



Bottom-up only (single species with covariates)



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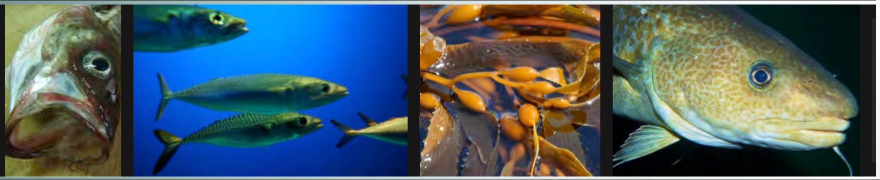
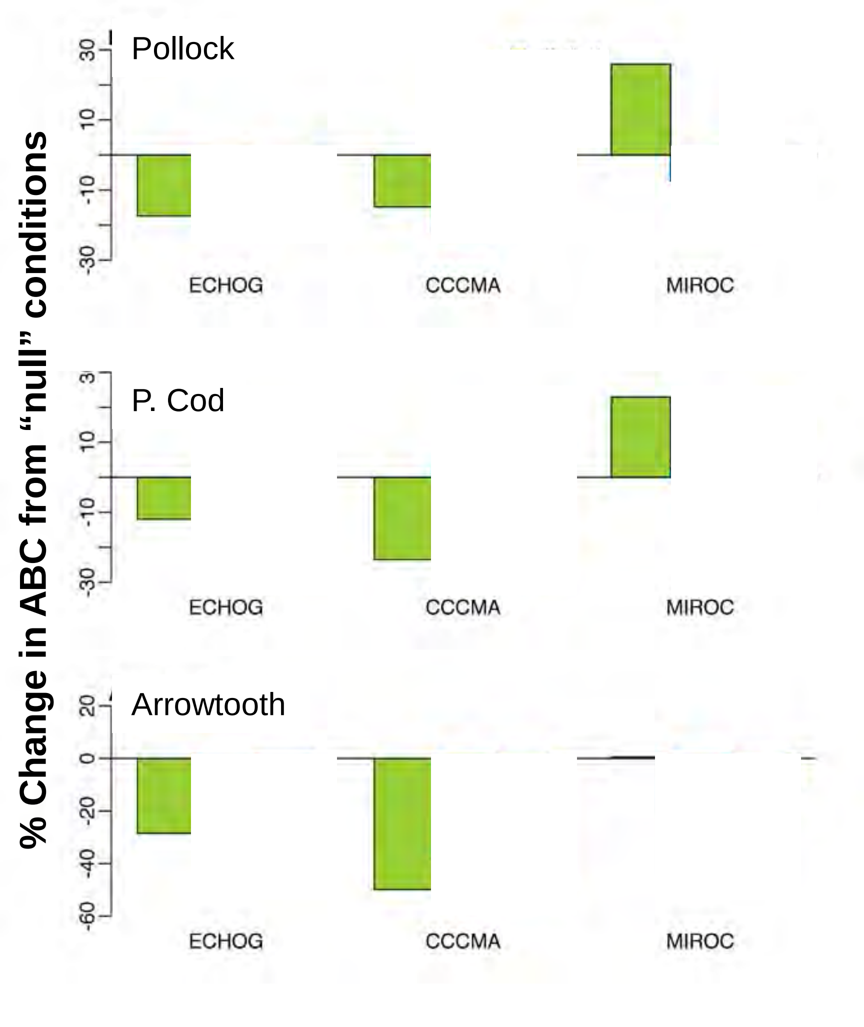
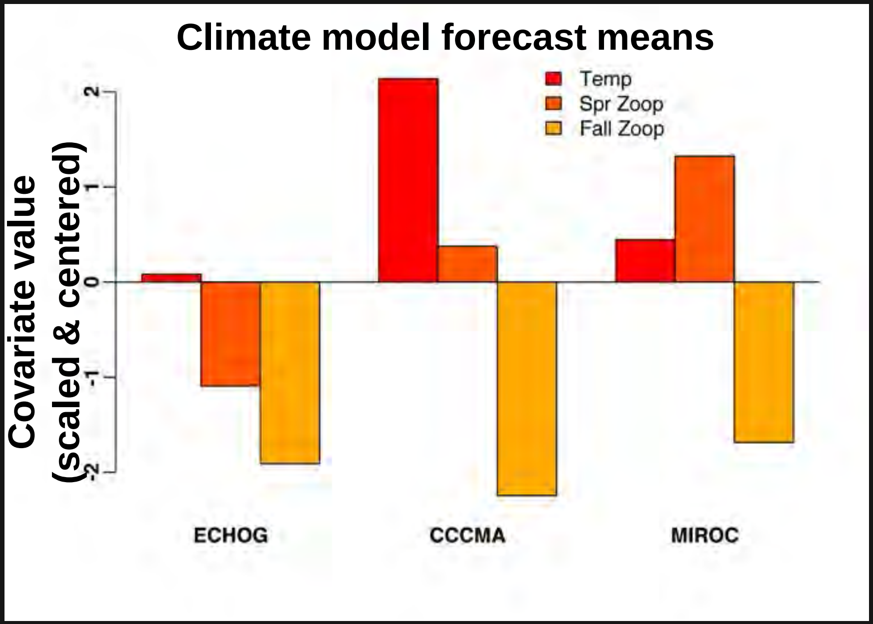
MSMt Projections



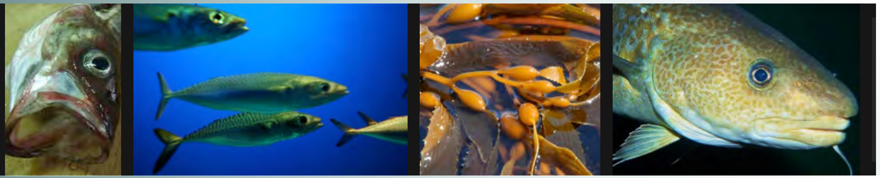


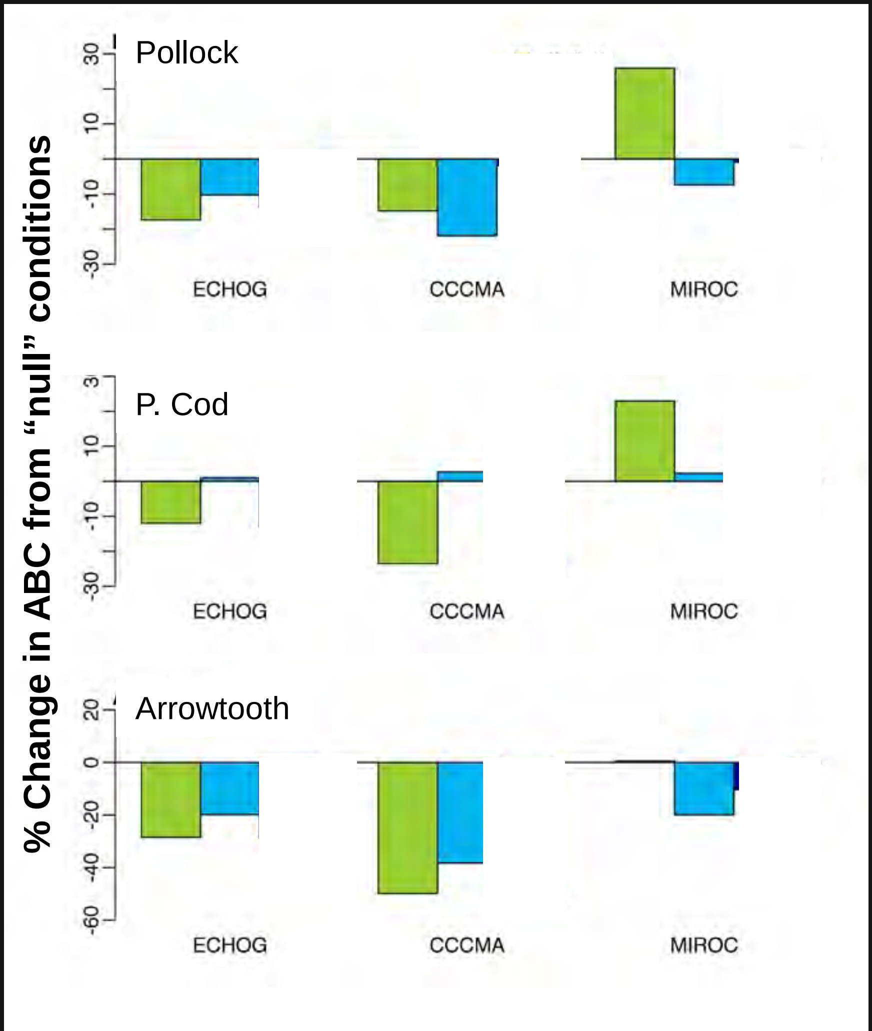
Bottom-up only (single species with covariates)



kirstin.holsman@noaa.gov

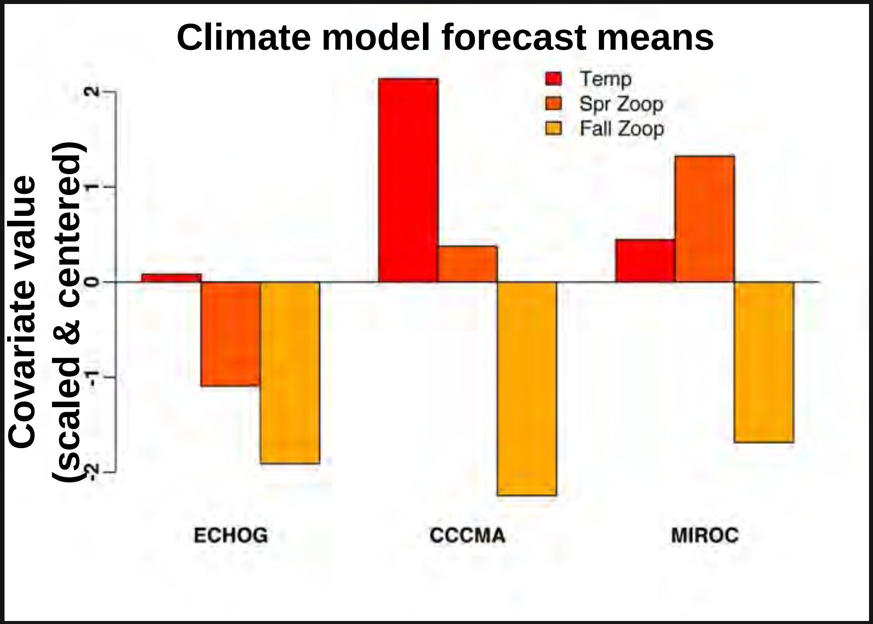
MSMt Projections





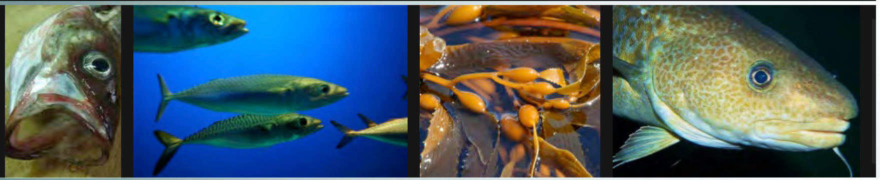
Bottom-up only (single species with covariates)

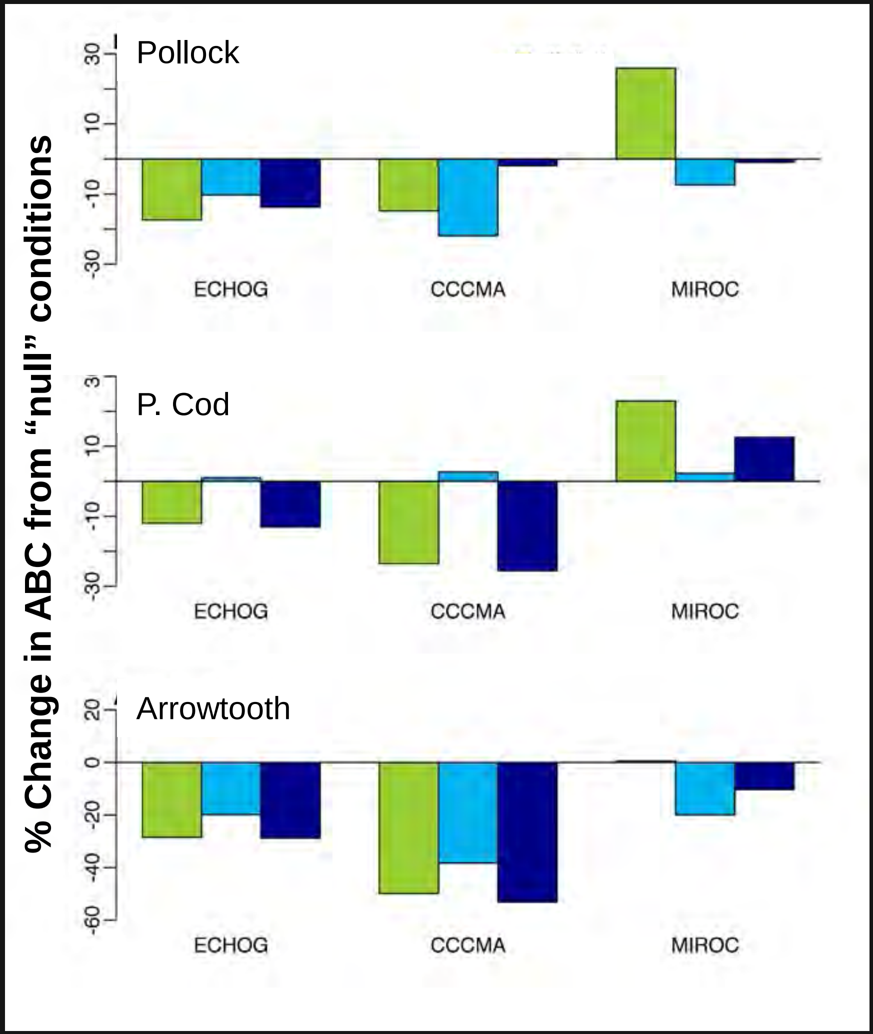
Top-down only (multi-species without covariates)



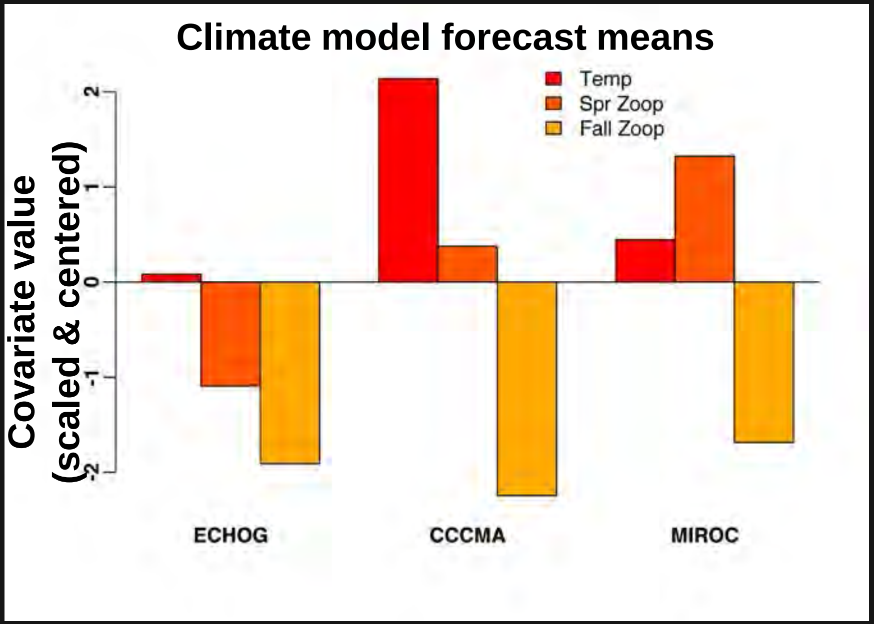
kirstin.holsman@noaa.gov

MSMt Projections





- Bottom-up only (single species with covariates)
- Top-down only (multi-species without covariates)
- Top-down & bottom-up (multi-species with cov.)



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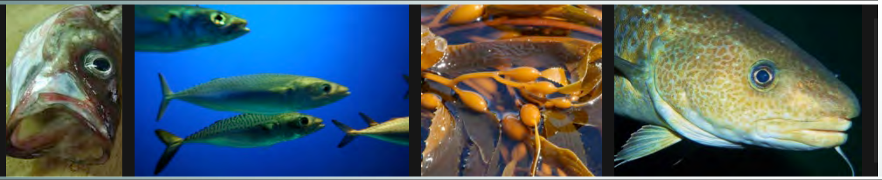
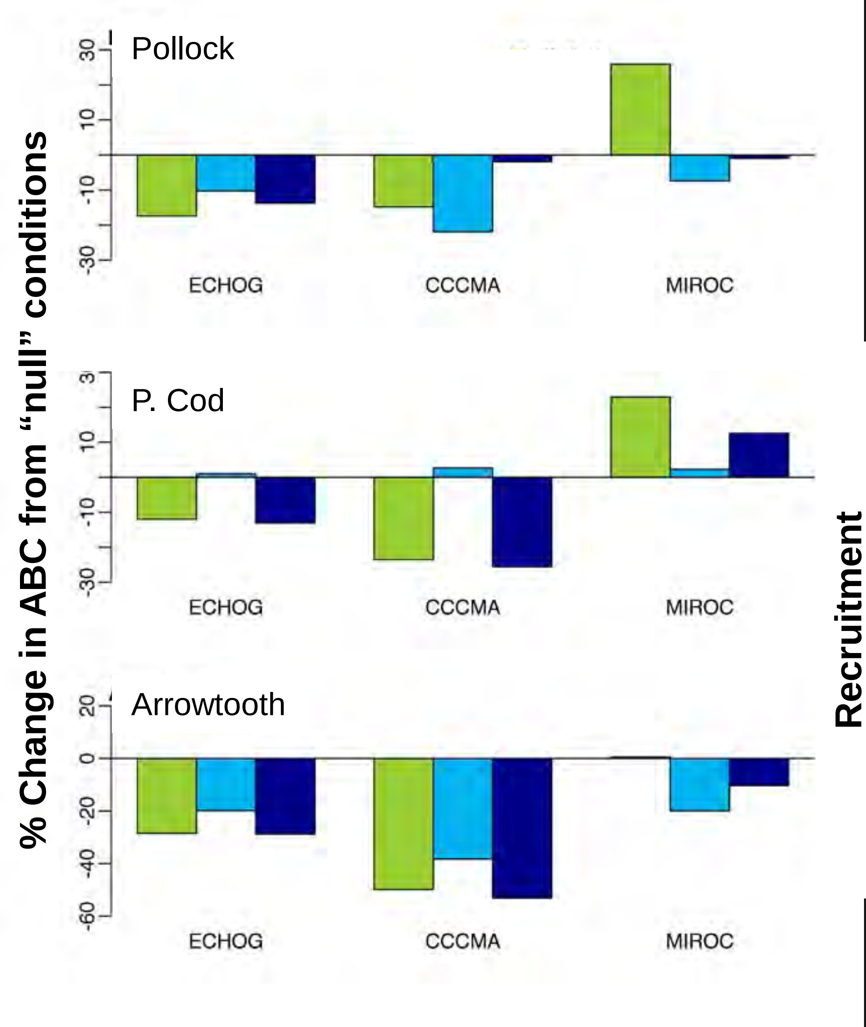
MSMt Projections

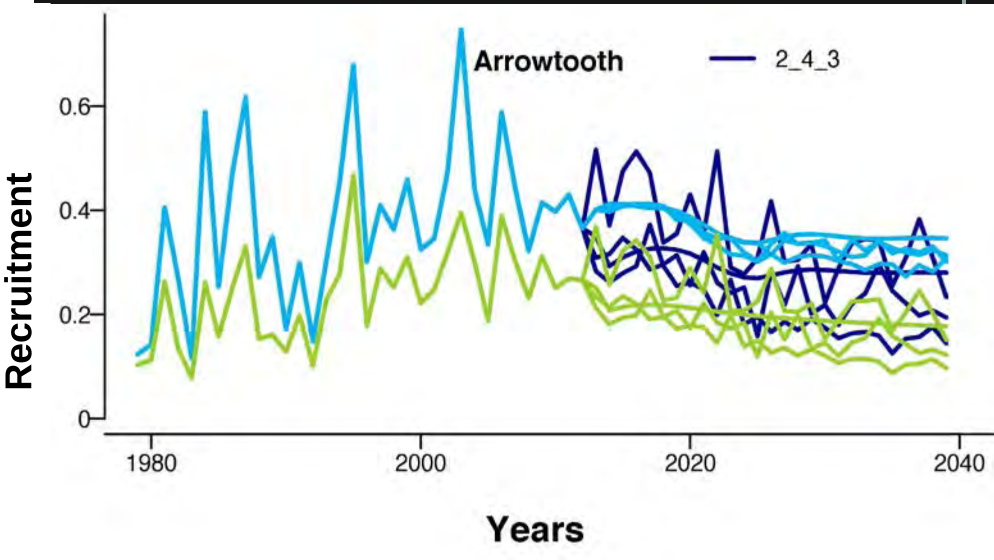




Bottom-up only (single species with covariates)

Top-down only (multi-species without covariates)

Top-down & bottom-up (multi-species with cov.)



kirstin.holsman@noaa.gov

MSMt Single species

Introduction > MSMt: Methods > MSMt: Estimation > MSMt: BRPs > MSMt: R/S > MSMt: Projections

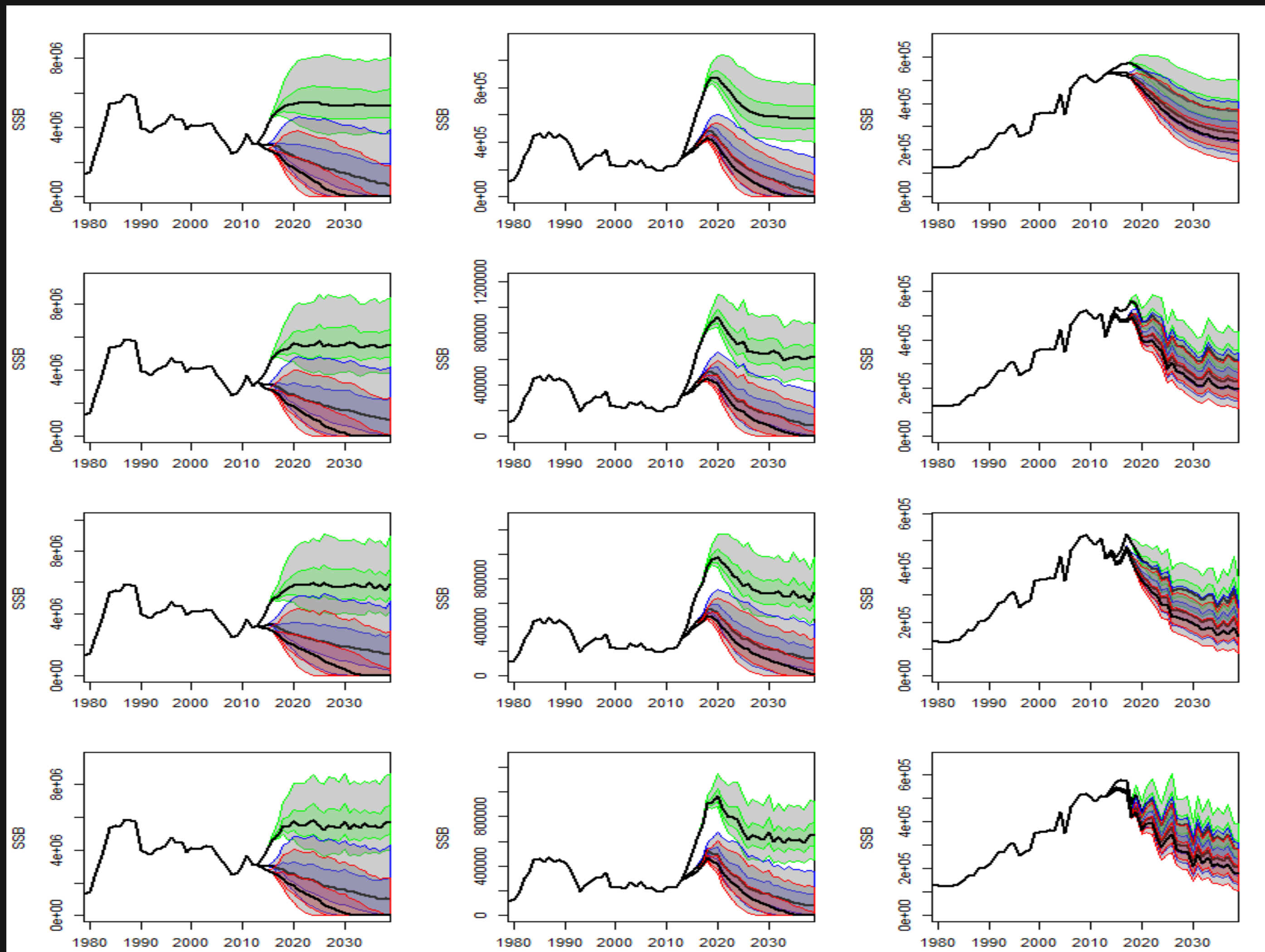
Pollock | P. cod | Arrowtooth

Avg Temp

ECHOG

CCMA

MIROC



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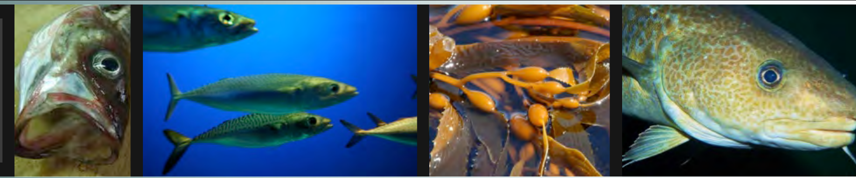
From Ianelli et al. *submitted*

MSMt Multispecies



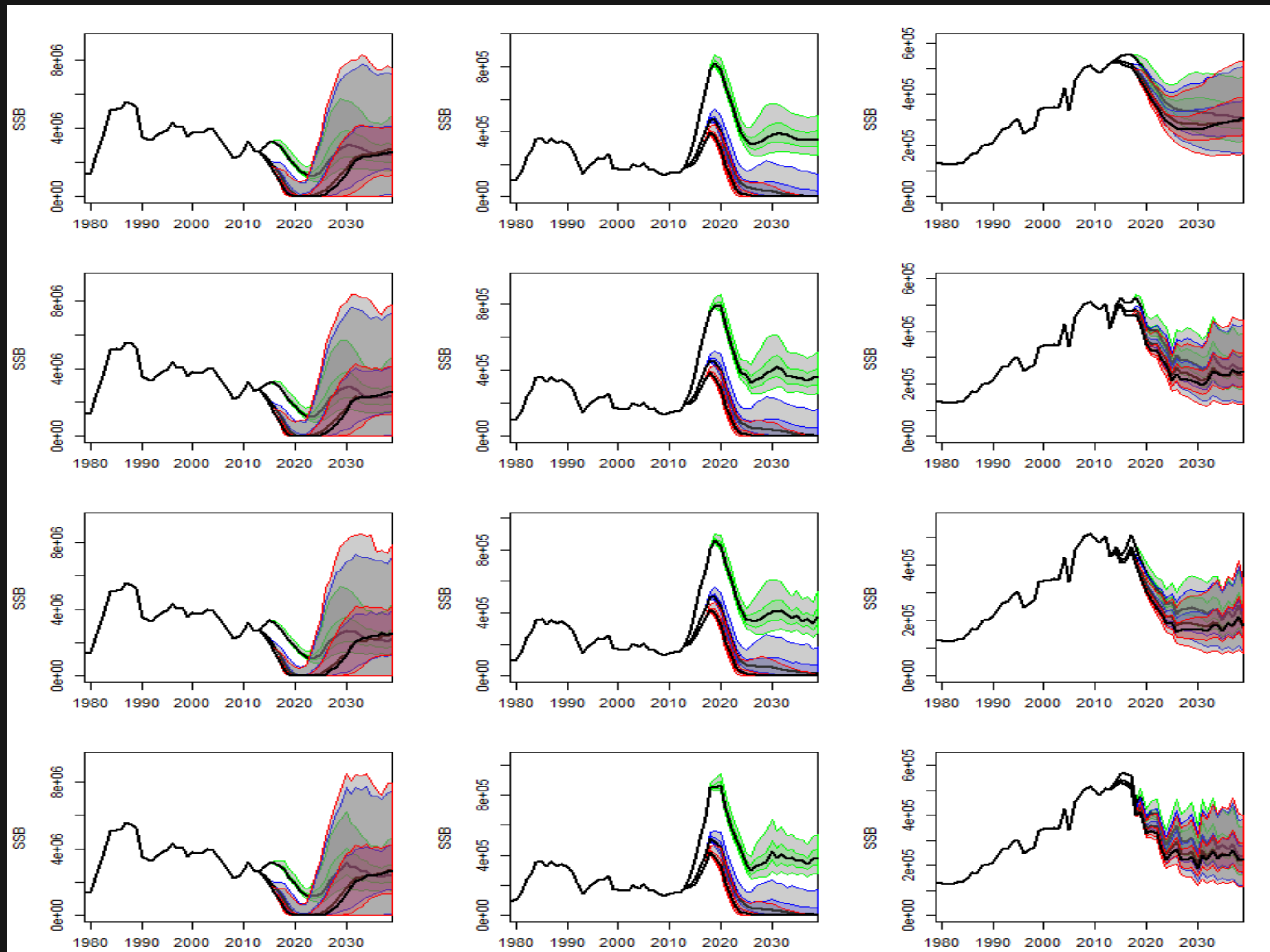
Pollock | P. cod | Arrowtooth

Avg Temp

ECHOG

CCMA

MIROC



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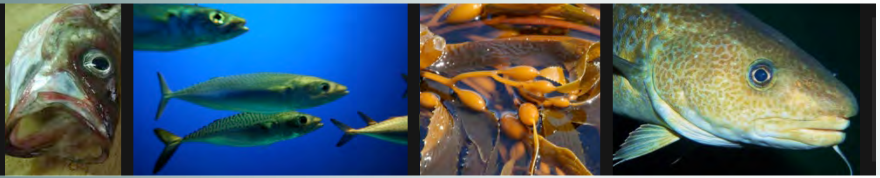
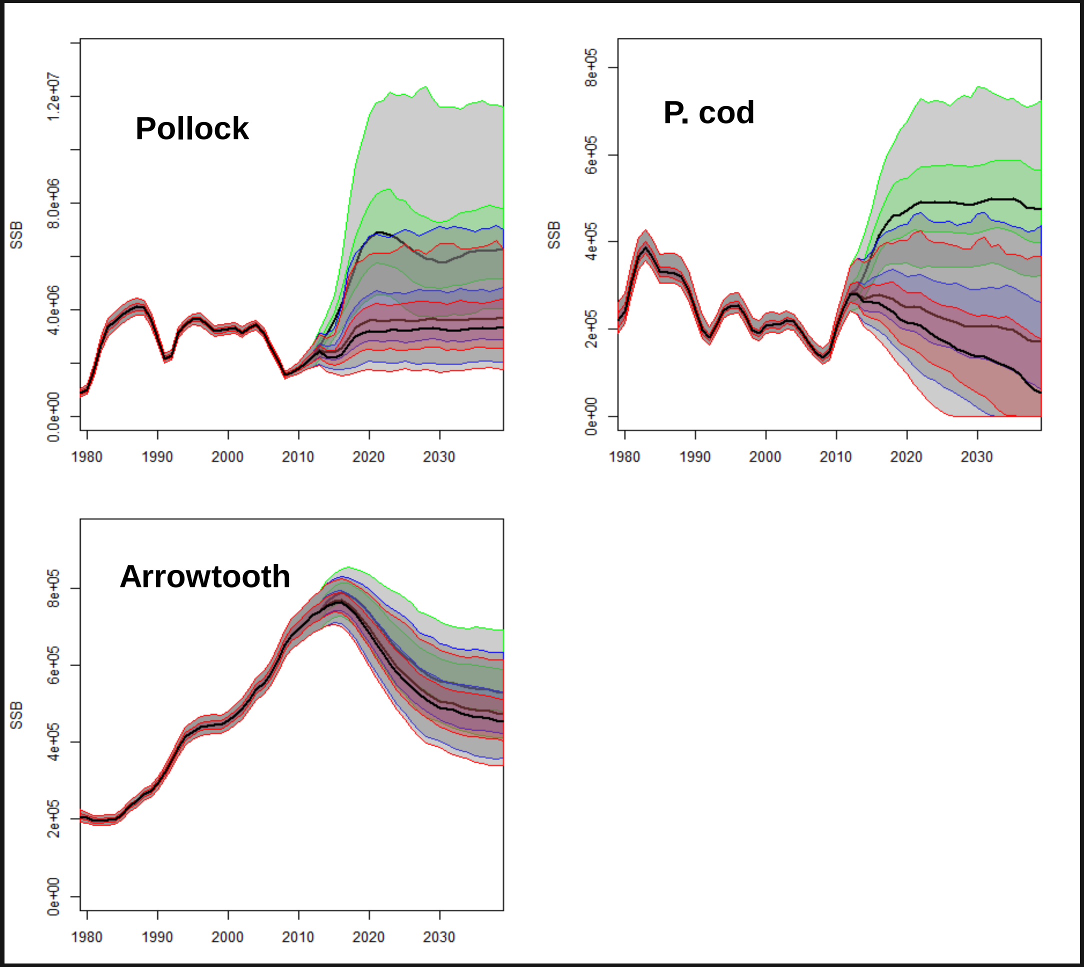
From Ianelli et al. *submitted*

Single species models





From Ianelli et al. *submitted*

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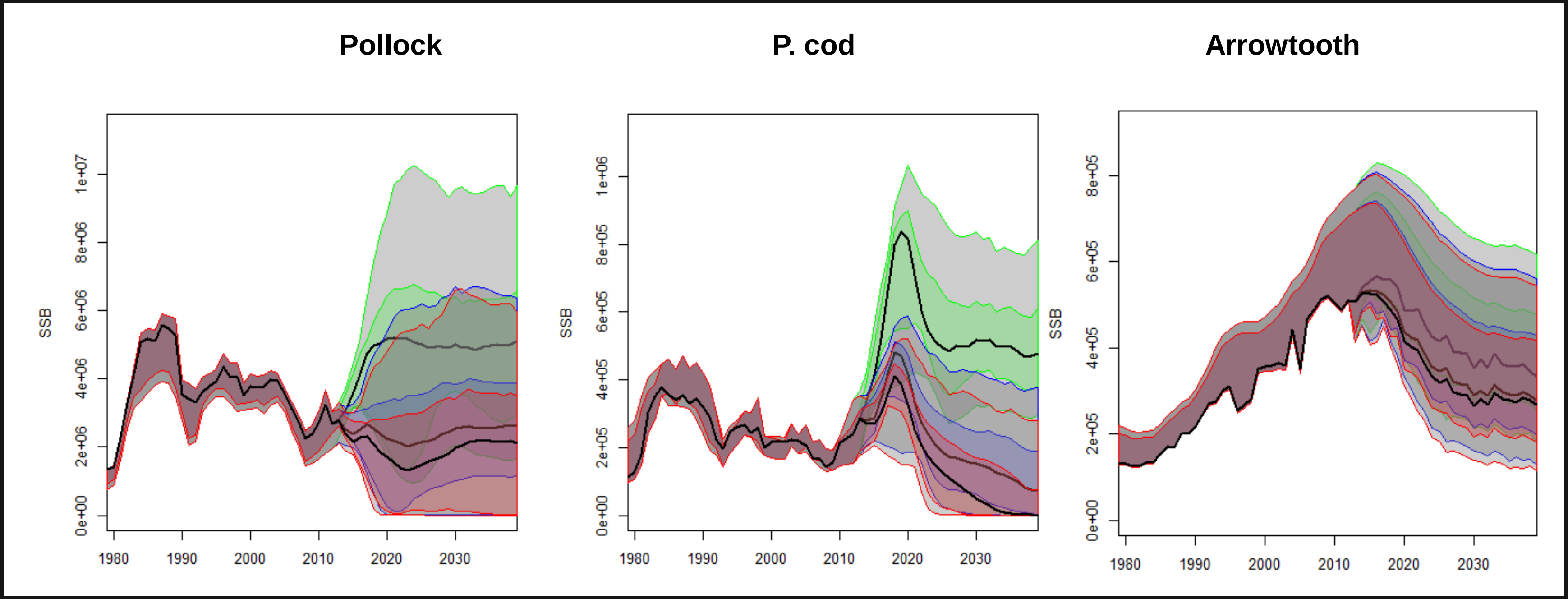
Blended forecasts



From Ianelli et al. *submitted*

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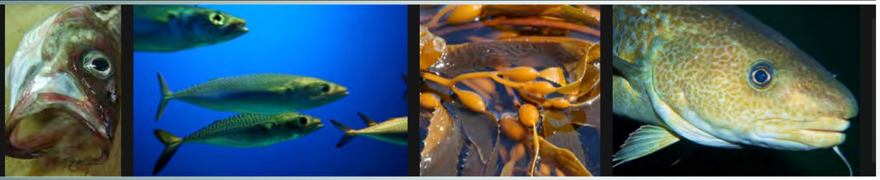
Thanks!



"Behind these numbers lies, of course, an infinity of movements and of destinies."

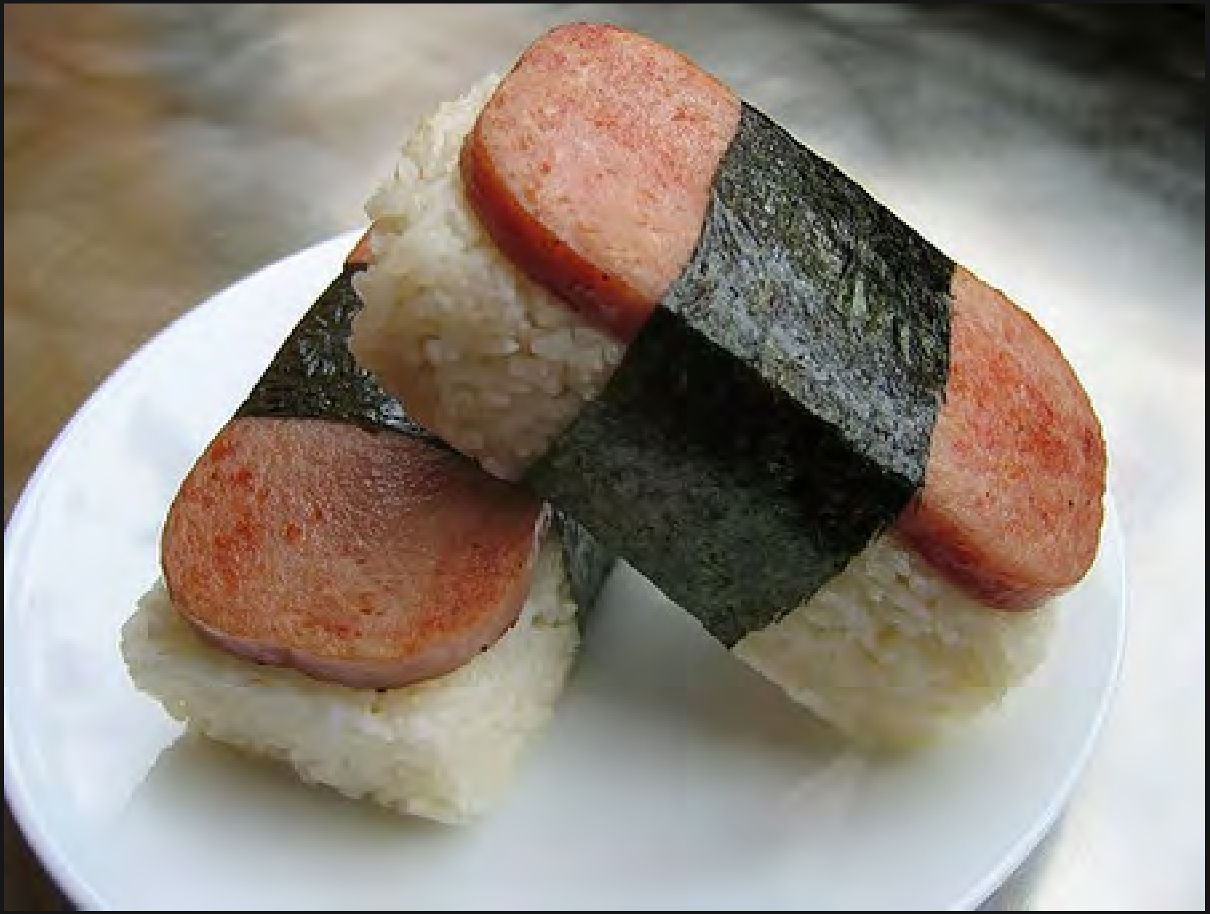
– von Bertalanffy 1938

…and of people!

Kerim Aydin, Jim Ianelli, Brain Knoth, Troy Buckley, Matt Baker, William Stockhausen, Sarah Gaichas, P.Sean McDonald, Ivonne Ortiz, Stephanie Zador, Al Hermann, Ivonne Ortiz, André Punt, Nick Bond, Paul Spencer, Ingrid Spies

kirstin.holsman@noaa.gov

SPAM MUSUBI



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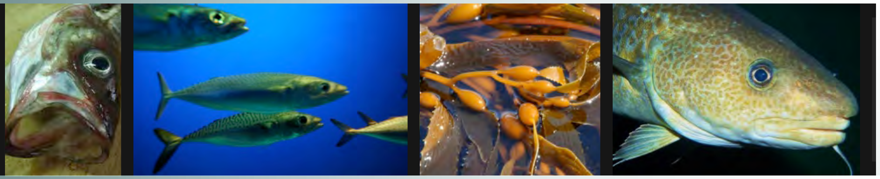
CONCLUSIONS



Preliminary results!

- Climate projections of upper trophic level response should include bottom-up and top-down dynamics
- ABC of pollock may only slightly decline (?)
  (2 of 3 models suggest no change over current conditions)
- ABC for P. cod may decline 10-20%
- ABC for arrowtooth may decline 30-50%
- Fisheries lose out: all ABCs declined under future climate conditions (except cod in the MIROC)

kirstin.holsman@noaa.gov