UNIVERSITY OF BERGEN

Funded by The Research Council of Norway

BOATSv2:

model development, evaluation and uncertainty

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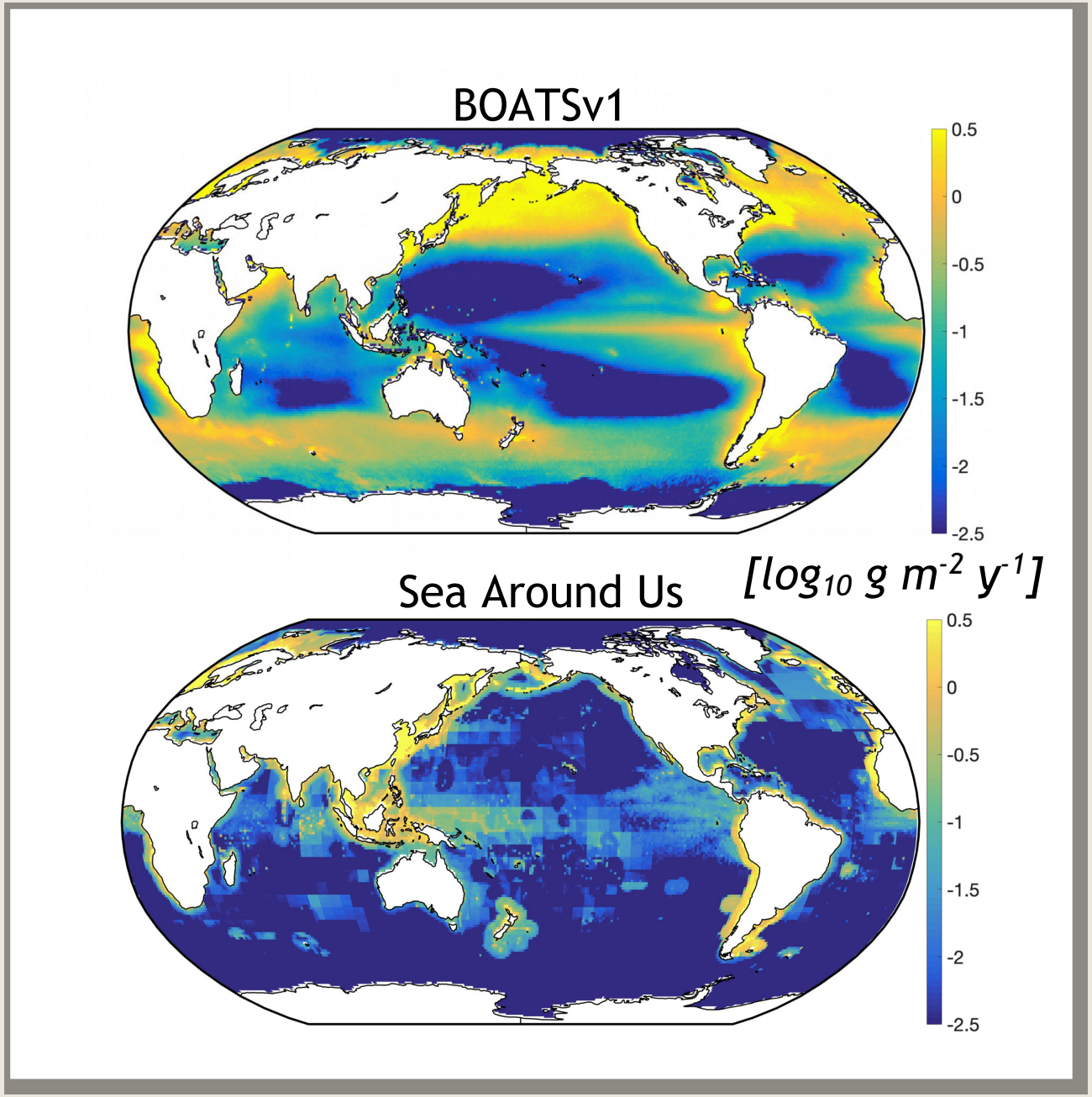
ISIMIP-PROCLIAS workshop, Potsdam 23/4 2024

BOATS upgrade

- Poor performance in the open ocean
- Separate benthic and pelagic pathways
- Iron limitation in HNLC regions
- Spatially varying economic forcings (catchability, fishing cost)



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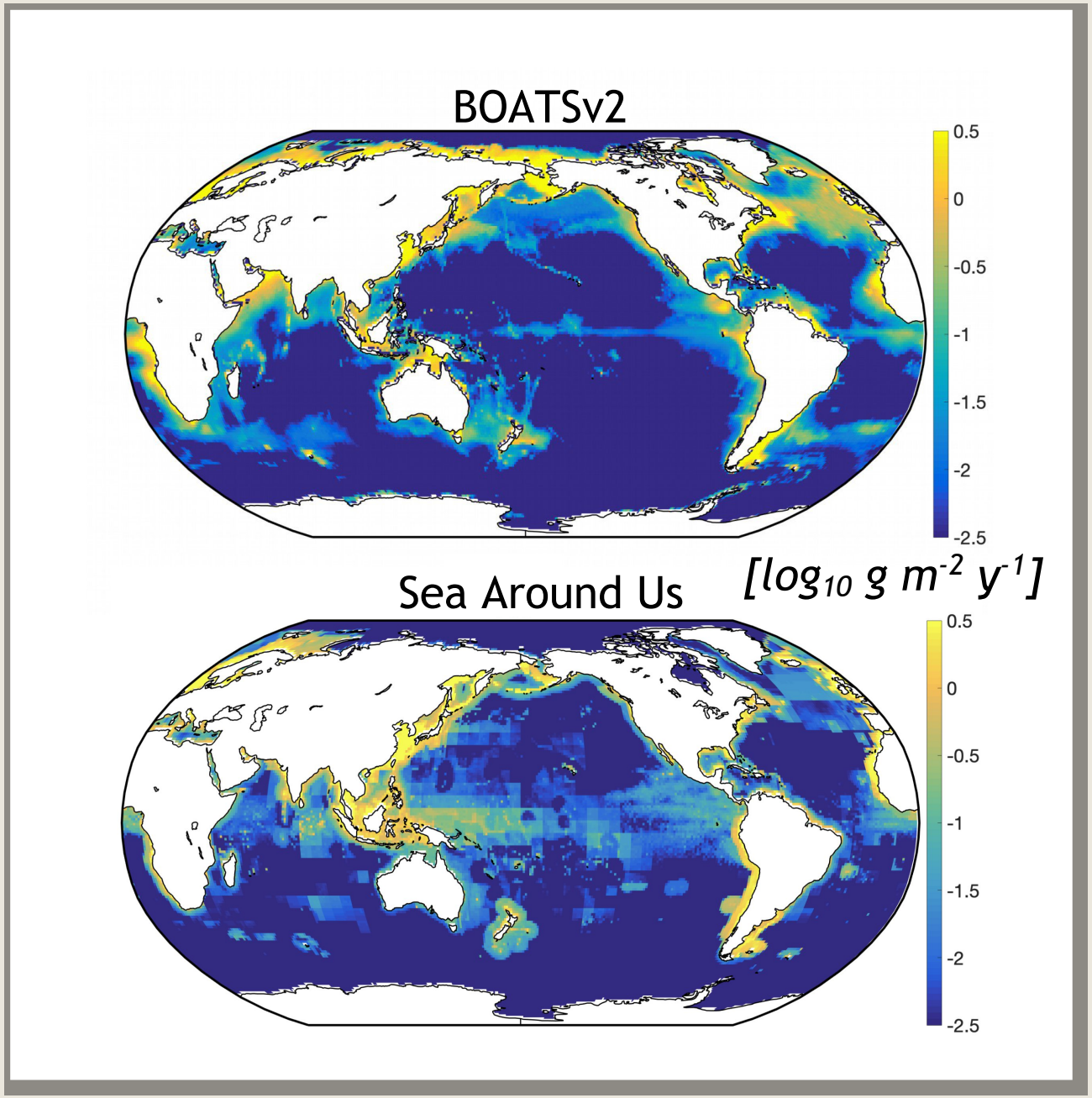
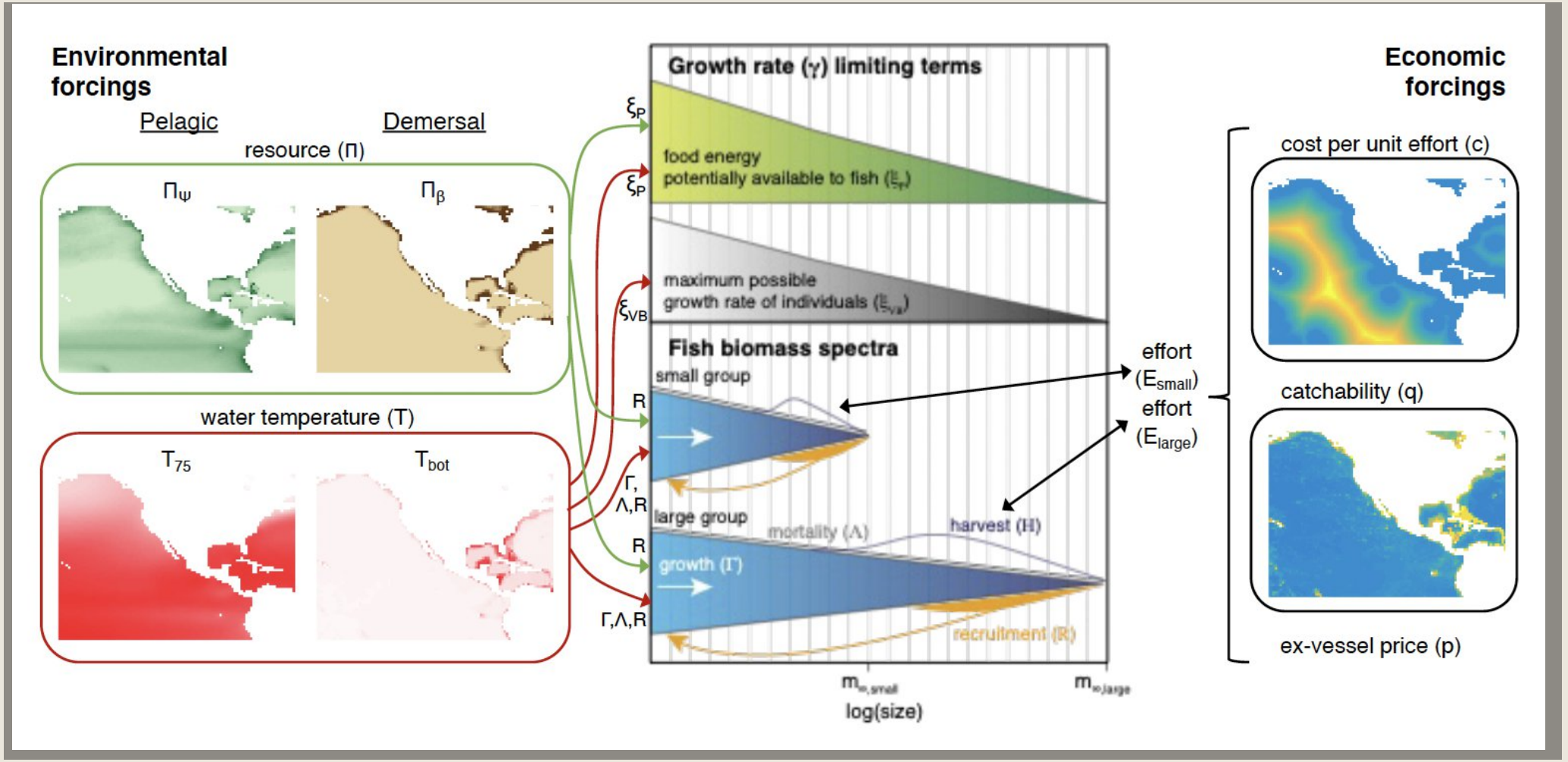


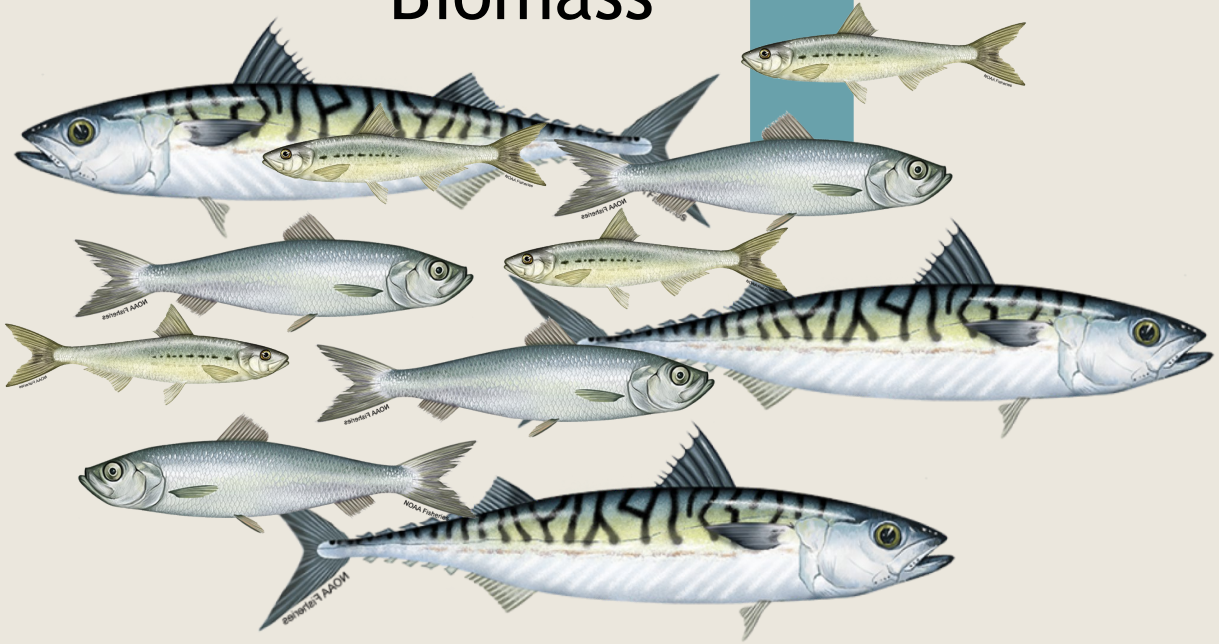
- Model evaluation
- Observational constraints
- Uncertainty estimates
- Fishing scenario uncertainty

BOATS

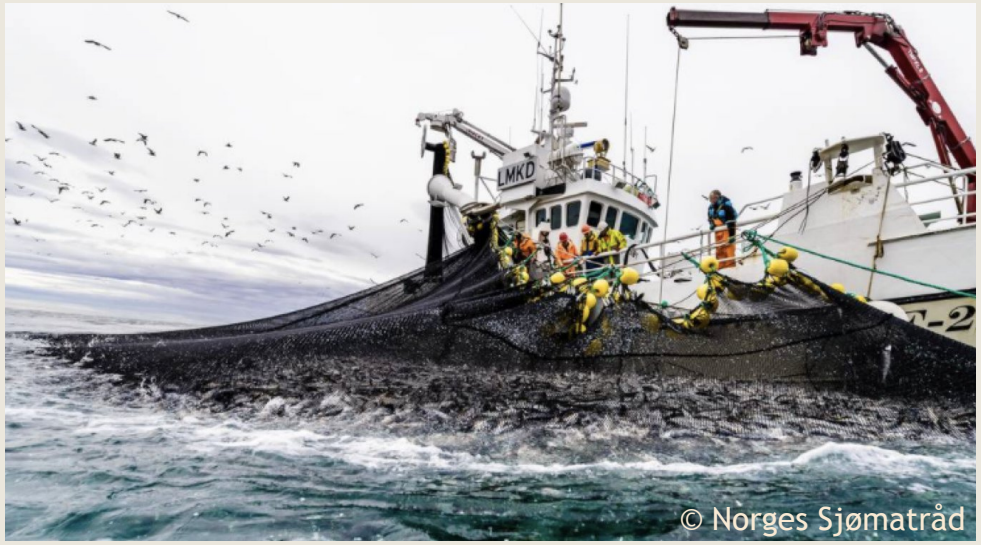

Environmental forcings
Pelagic
Demersal
resource (Π)
Π_ψ
Π_β
water temperature (T)
T_{75}
T_{bot}
ξ_P
ξ_P
ξ_{VB}
R
Γ, Λ, R
R
Γ,Λ,R
Growth rate (γ) limiting terms
food energy potentially available to fish (ξ_γ)
maximum possible growth rate of individuals (ξ_{VB})
Fish biomass spectra
small group
large group
mortality (Λ)
harvest (H)
growth (Γ)
recruitment (R)
$m_{\infty,small}$
$m_{\infty,large}$
log(size)
effort (E_{small})
effort (E_{large})
Economic forcings
cost per unit effort (c)
catchability (q)
ex-vessel price (p)

Observations needed

Biomass



Catch



Main observational constraints

1. Sea Around Us + Watson: **Global peak catch**
   $70 \leq C_{max} \leq 150$ Mt y^{-1}
2. Sea Around Us: **Demersal-pelagic catch ratio** at peak
   $0.8 \leq C_{dem}/C_{pel} \leq 1.8$
3. RAM Legacy Database: **Catch-to-biomass ratio** (25 LME averages)
   Distribution match with data
4. Sea Around Us: **Relative size abundance**
   $0.3\ C_{small} < C_{medium}$
   $0.1\ C_{small} < C_{large} < 0.8\ C_{small}$

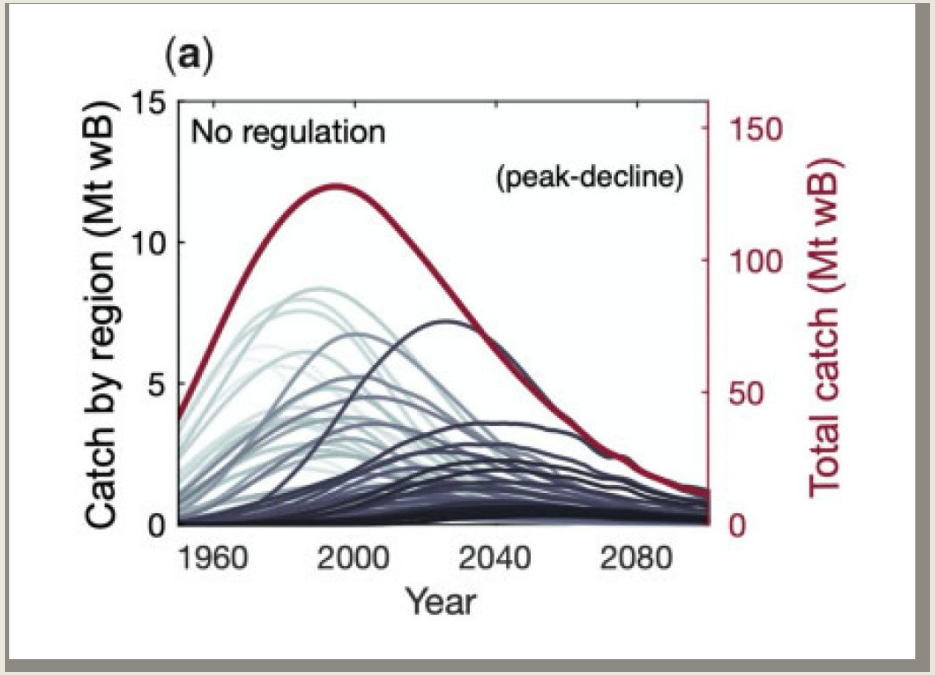
The peak catch as tuning criteria

- A given catch can be aquired by many combinations of ecological and socioeconomic factors
- But the highest possible catch, C_{max}, is an ecosystem feature
- Humanity has unintentionally sampled C_{max} in many regions through heavy fishing
- We can get C_{max} in BOATS by increasing catchability over time

= pC = pqEB

$$\frac{dE_k}{dt} = K_e \frac{\text{revenue}_k - \text{cost}_k}{E_k}$$

= cE



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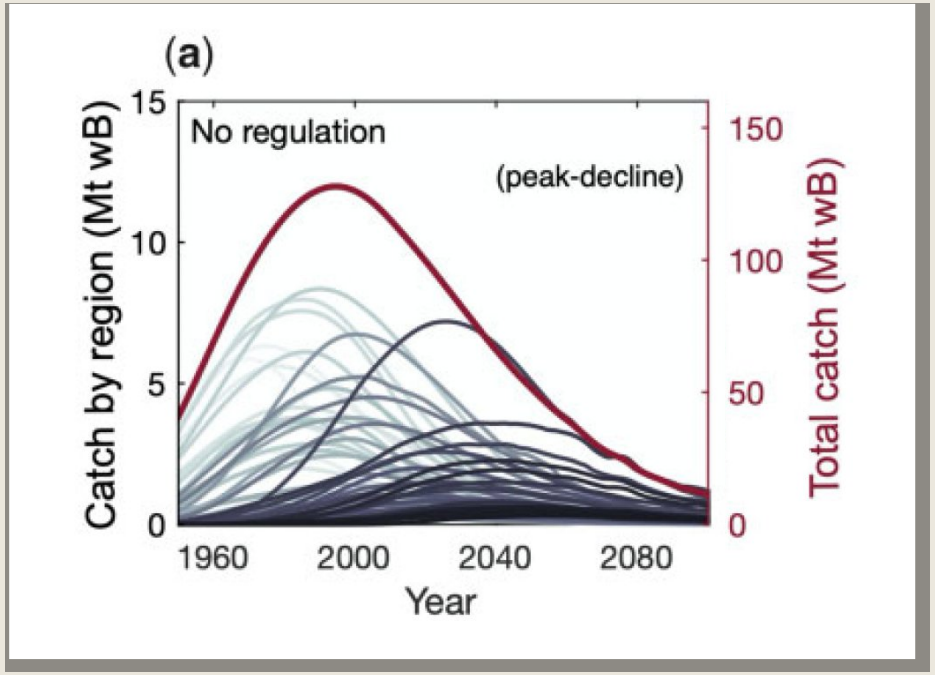
- Humanity has unintentionally sampled C_{max} in many regions through heavy fishing
- We can get C_{max} in BOATS by increasing catchability over time
- Parameters that reproduce observed C_{max} are more realistic
- We can use the peaks (global and regional) as tuning constraints!



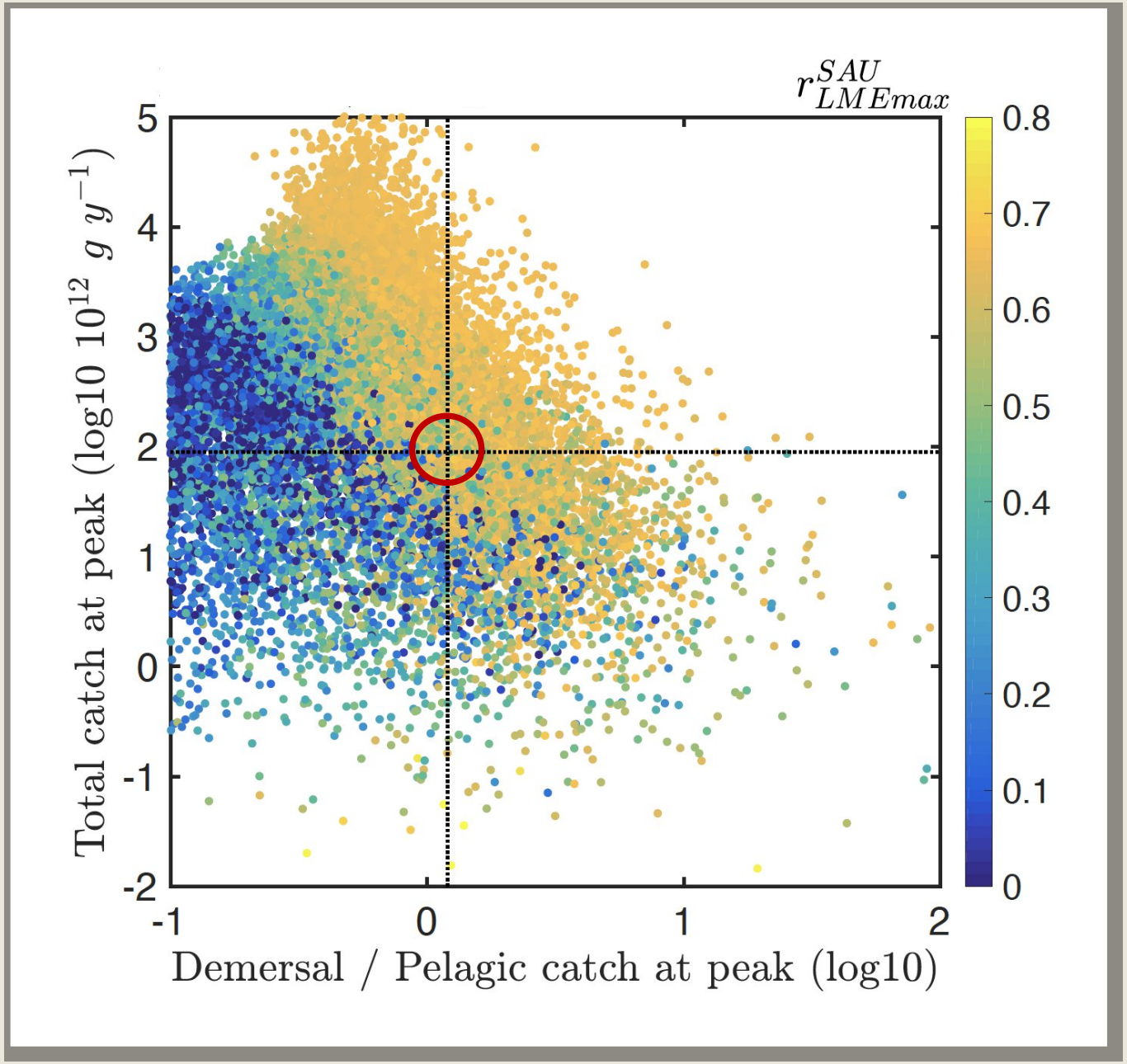
Uncertain parameters

- BOATS has ~ 30 ecological parameters
- 11 of them uncertain enough to use range of possible values

Parameter	Name
$\omega_{a,A}$	Growth activation energy
$\omega_{a,\lambda}$	Mortality activation energy
b	Allometric scaling exponent
A_0	Allometric growth constant
h	Allometric mortality scaling
ζ_1	Mortality constant
α	Trophic efficiency
β	Predator to prey mass ratio
s_e	Egg survival fraction
$e_{m_{\Theta,k}}$	Selectivity position scaling
$log_{10}(m_\beta)$	Mean benthic size

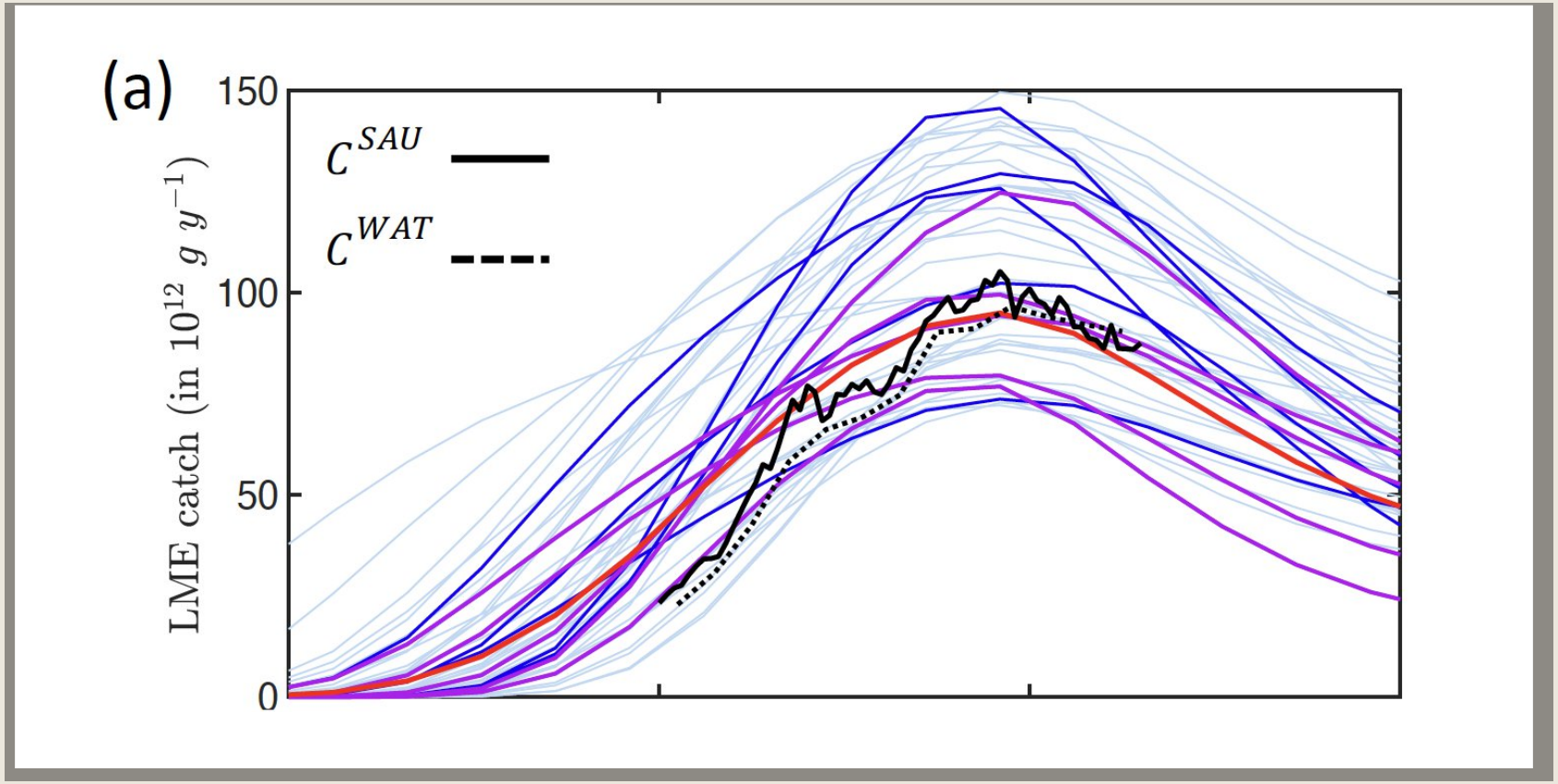
The Monte Carlo approach

- Draw random combinations from a range of possible parameter values
- Do this 20 000 times and run simulations with increasing catchability for each parameter set…
- …then discard combinations that don't recreate the observational constraints

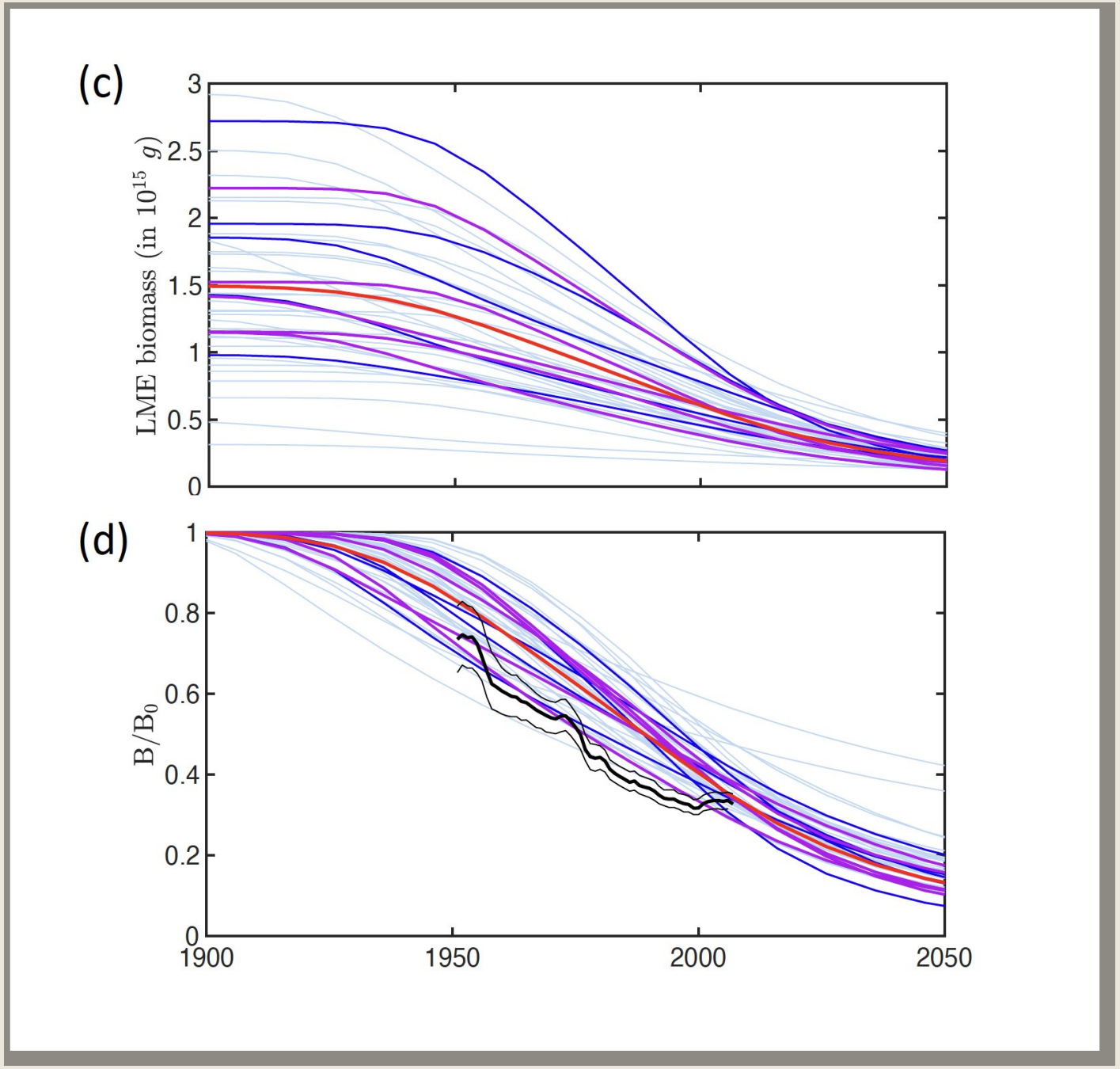


Filtering

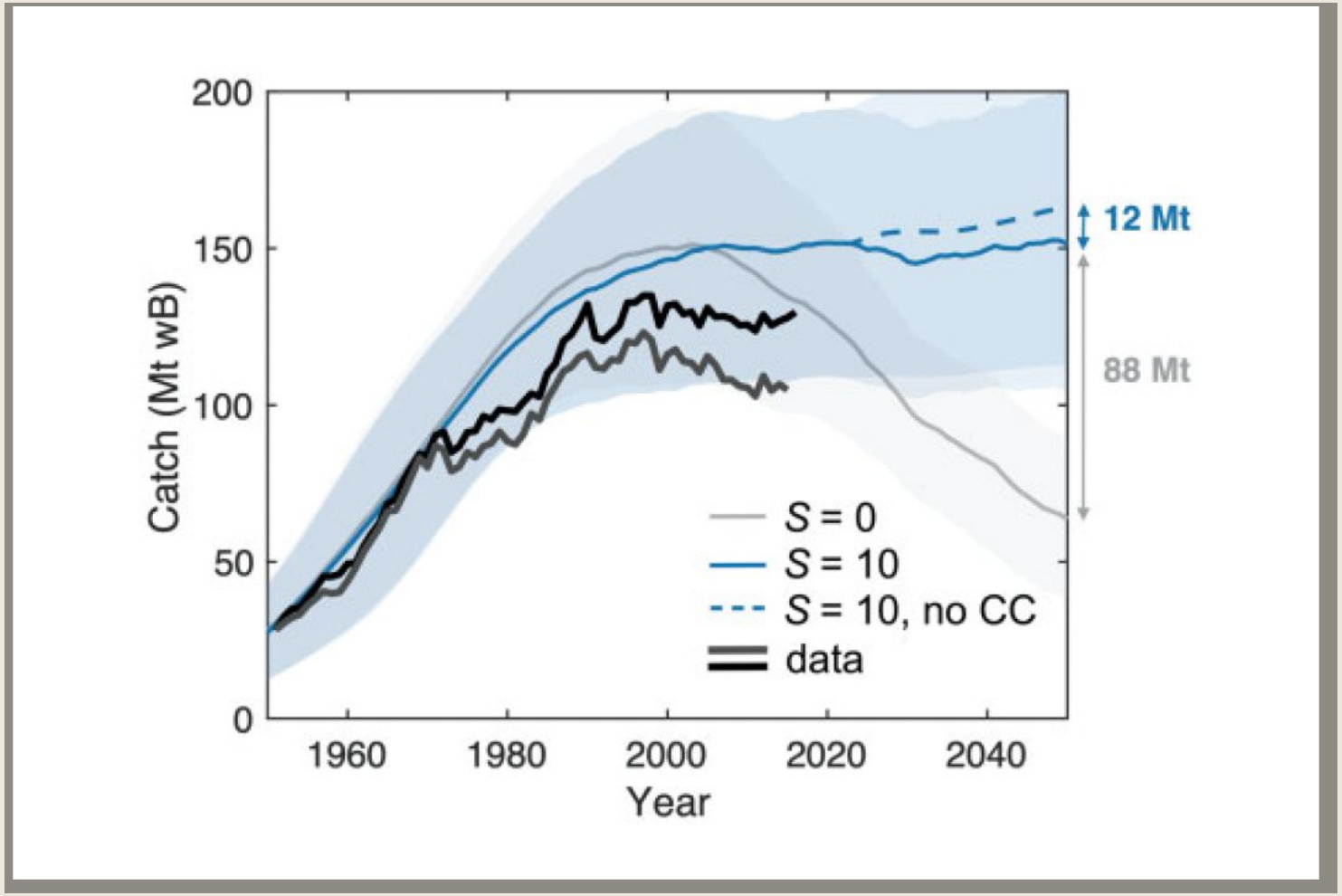
1. Global catch: 12% of simulations
2. + $C_{demersal}$ / $C_{pelagic}$: 3% of simulations
3. + Catch / Biomass: 0.8 % of simulations
4. Size abundance: 0.2 % (42 simulations)



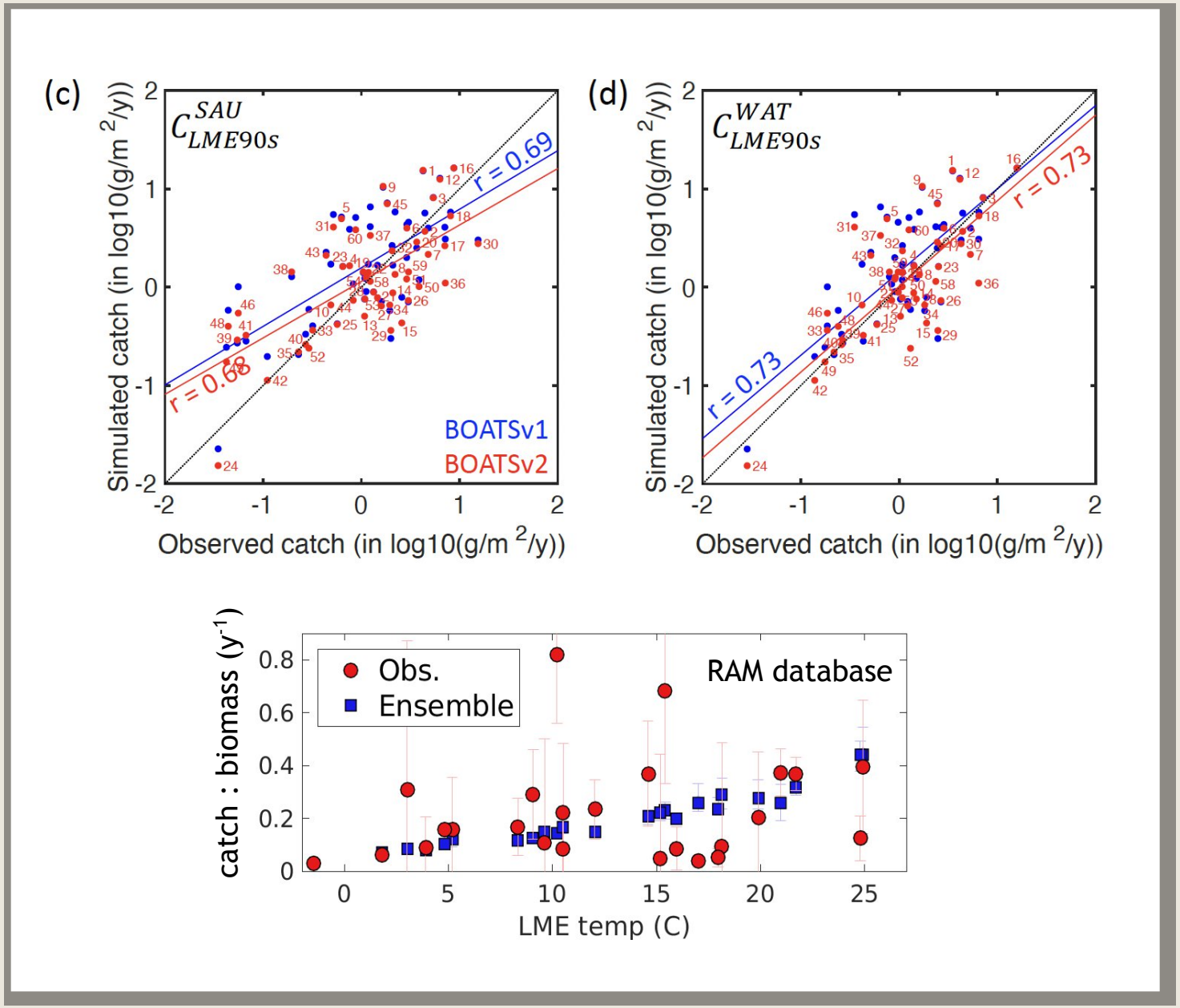
Biomass


(c)
LME biomass (in 10^{15} g)
3
2.5
2
1.5
1
0.5
0
(d)
B/B$_0$
1
0.8
0.6
0.4
0.2
0
1900
1950
2000
2050

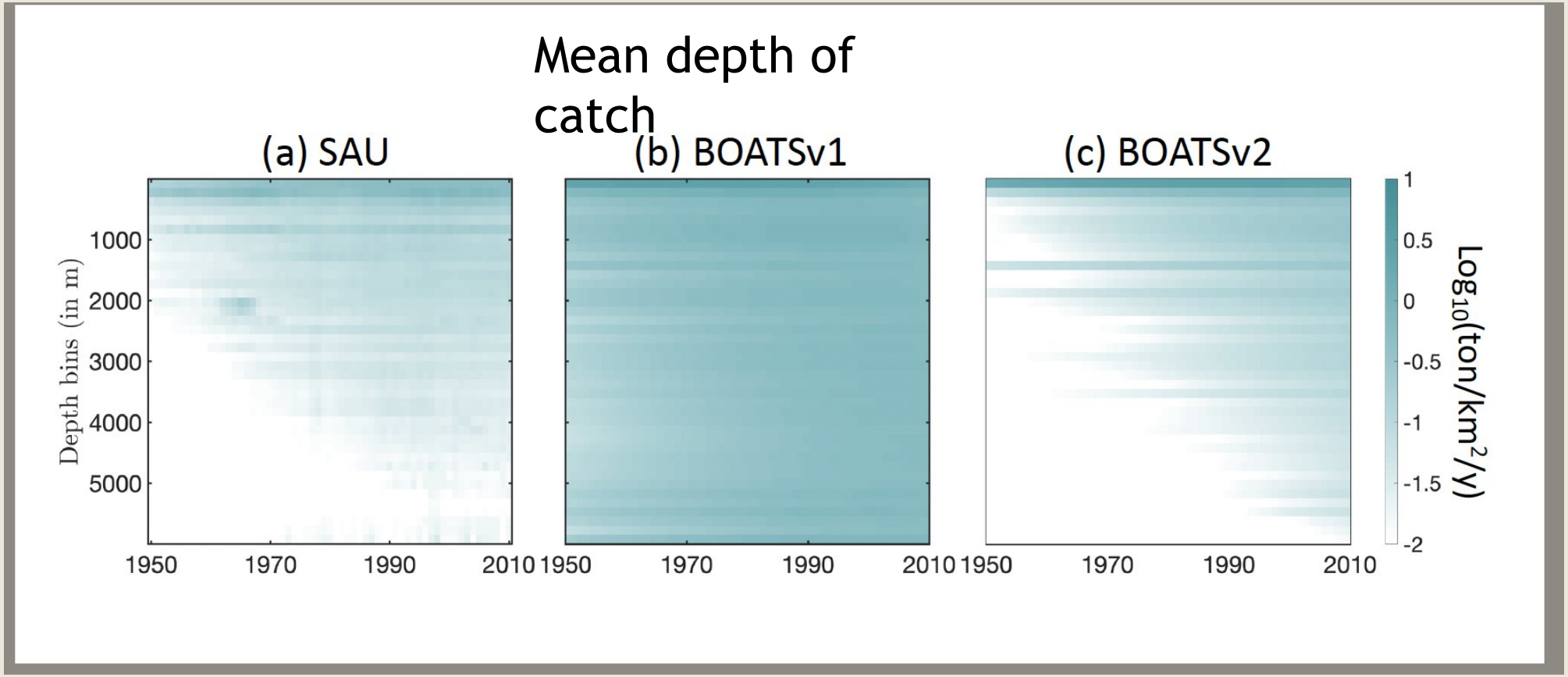
Uncertainty ranges



Performance

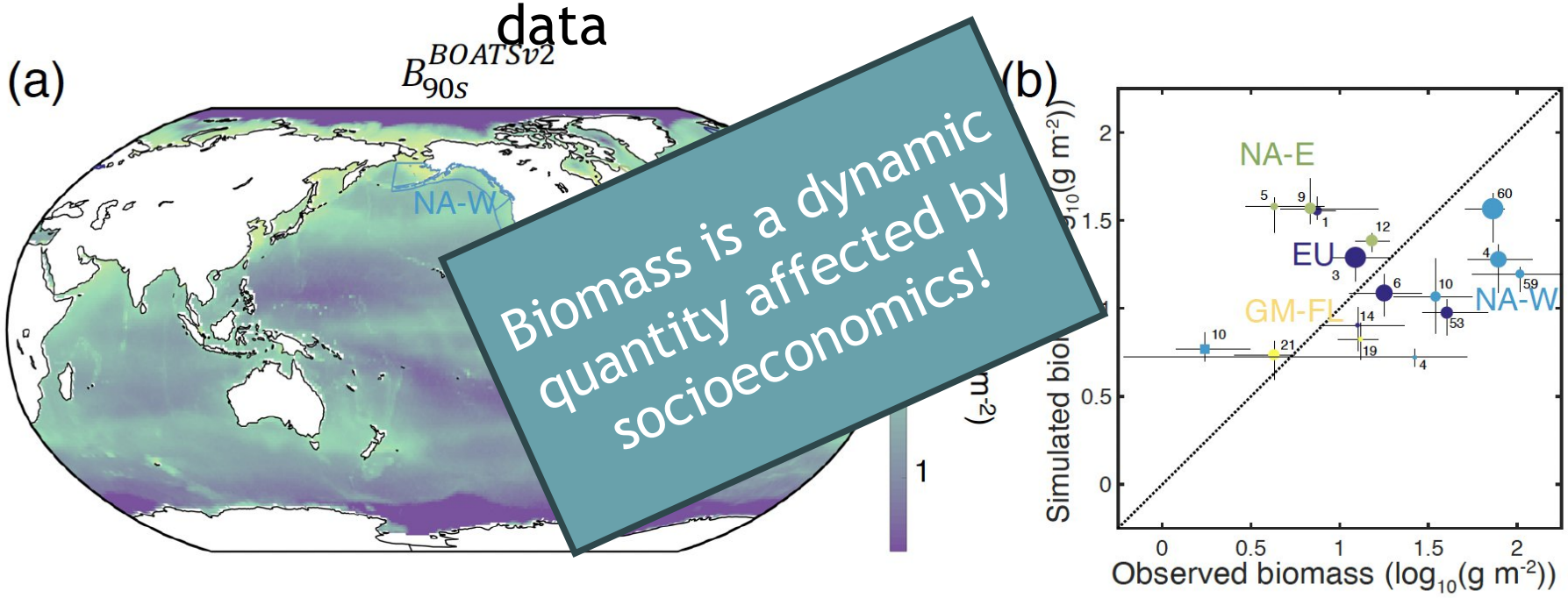


Additional constraints



Additional constraints

Trawl and survey biomass data



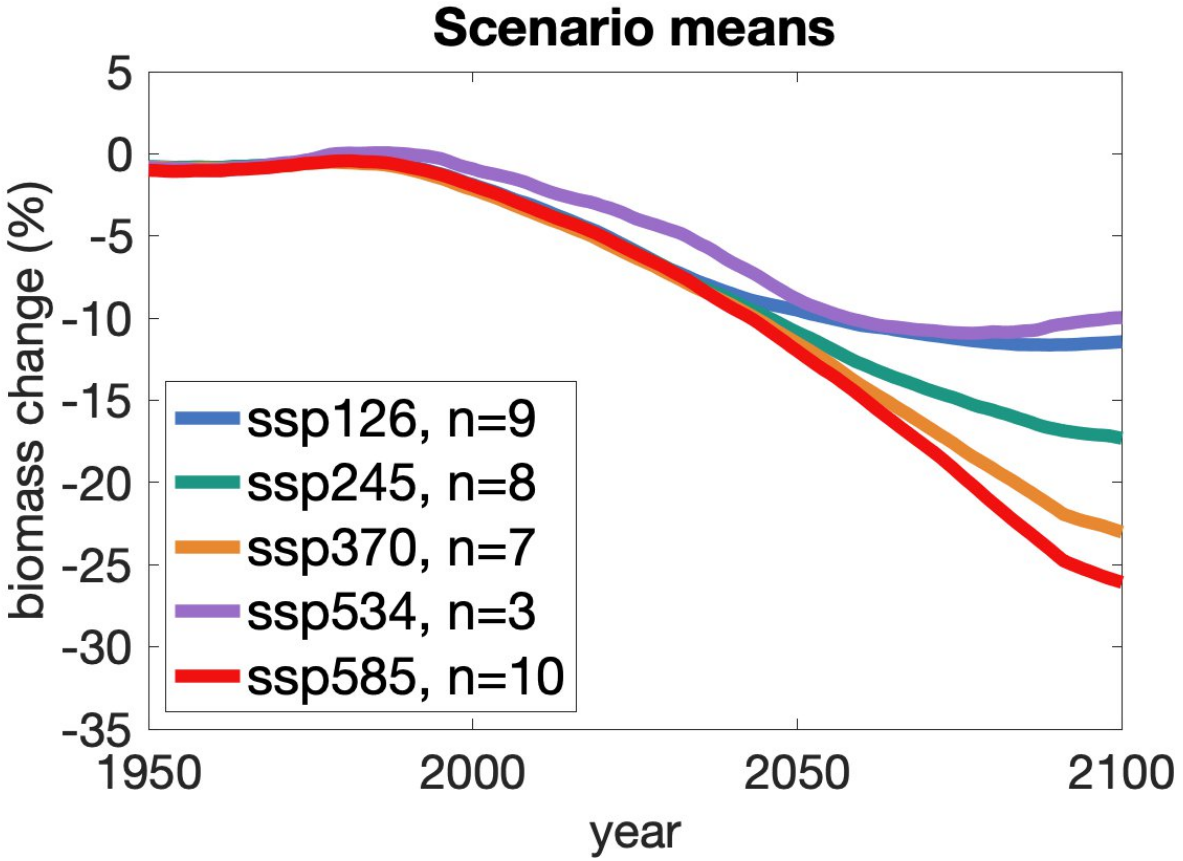
Biomass is a dynamic quantity affected by socioeconomics!

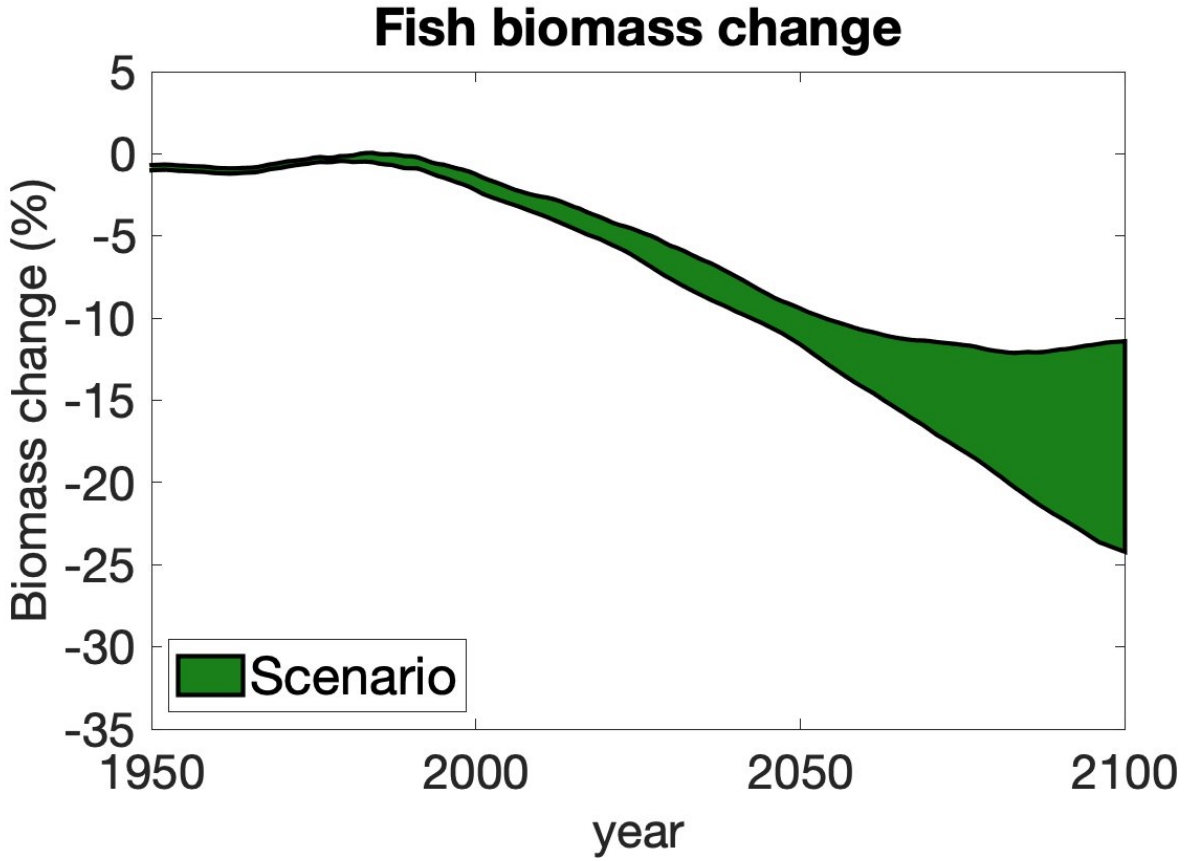
Acoustic biomass data…?

Uncertainty

- from the ESMs used to force the MEM?
- from MEM structure and parameterization?

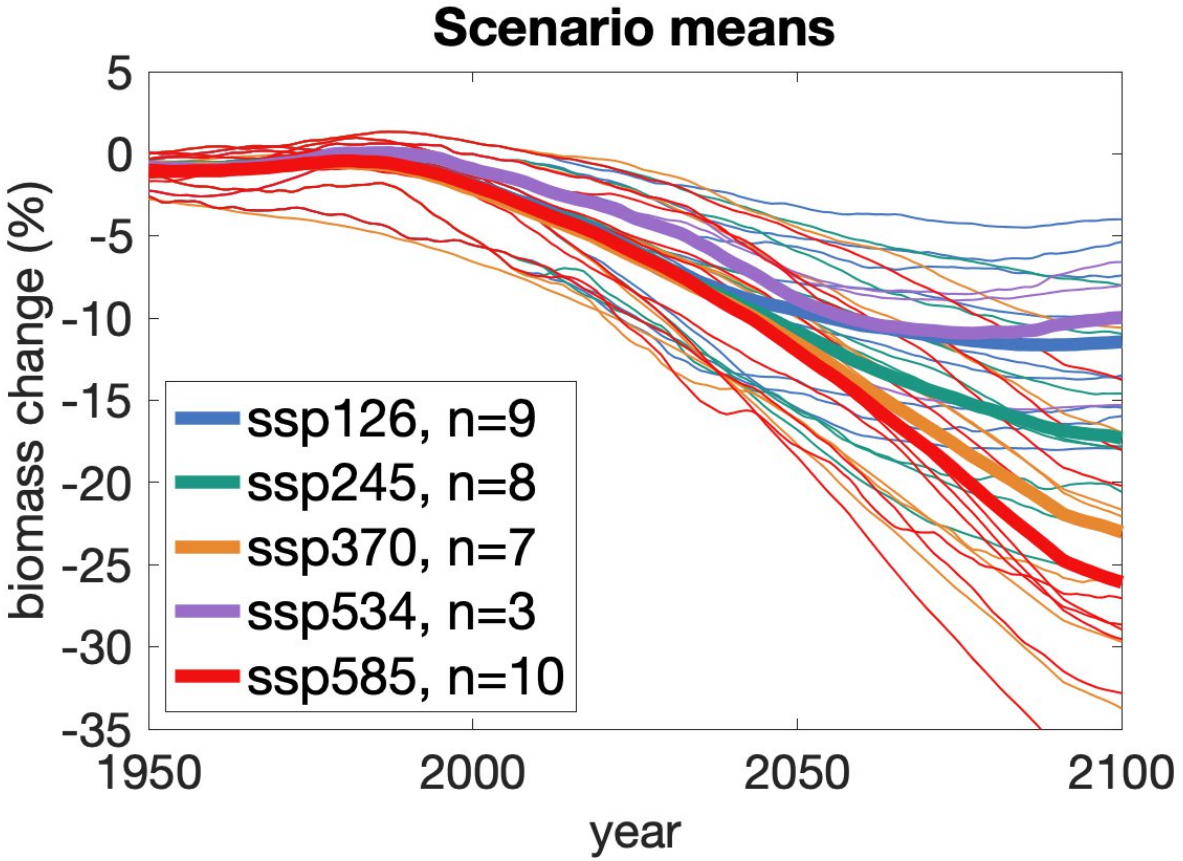
Scenario uncertainty

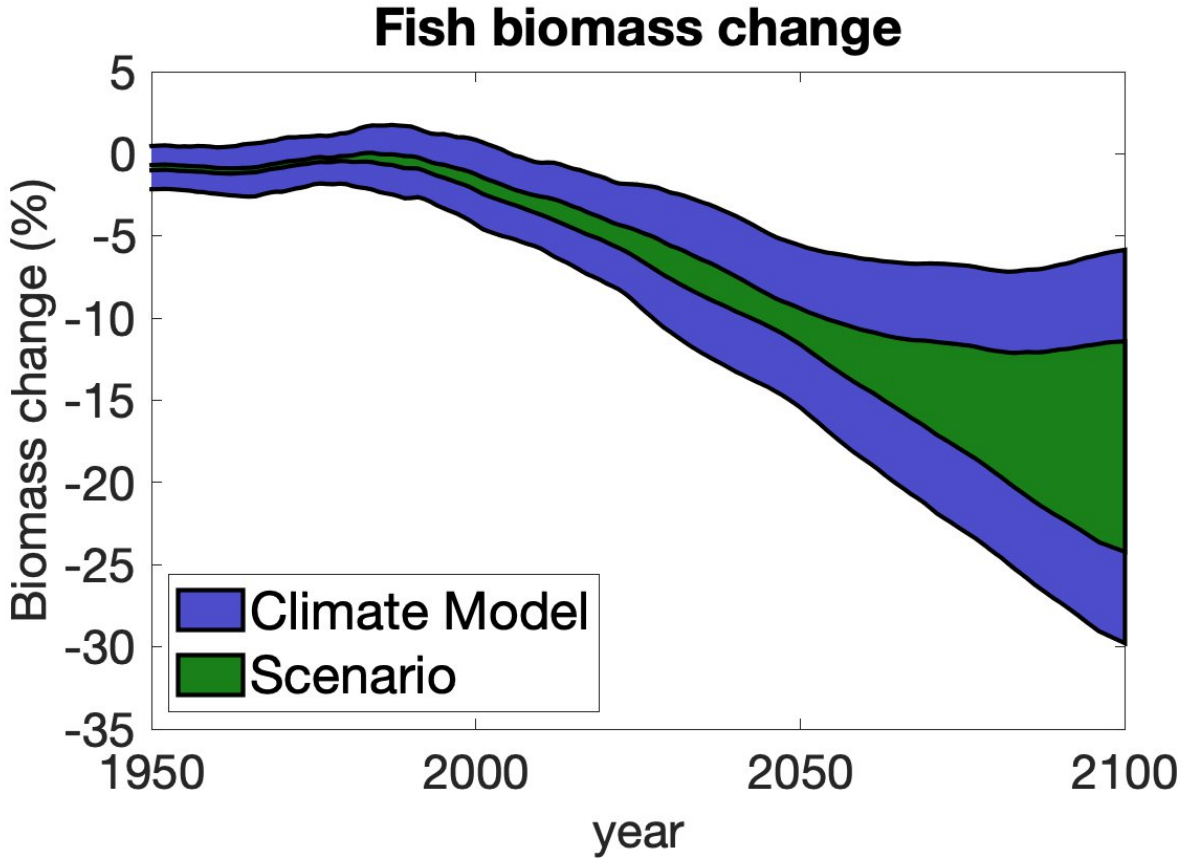




Uncertainty = Scenario

Structural uncertainty

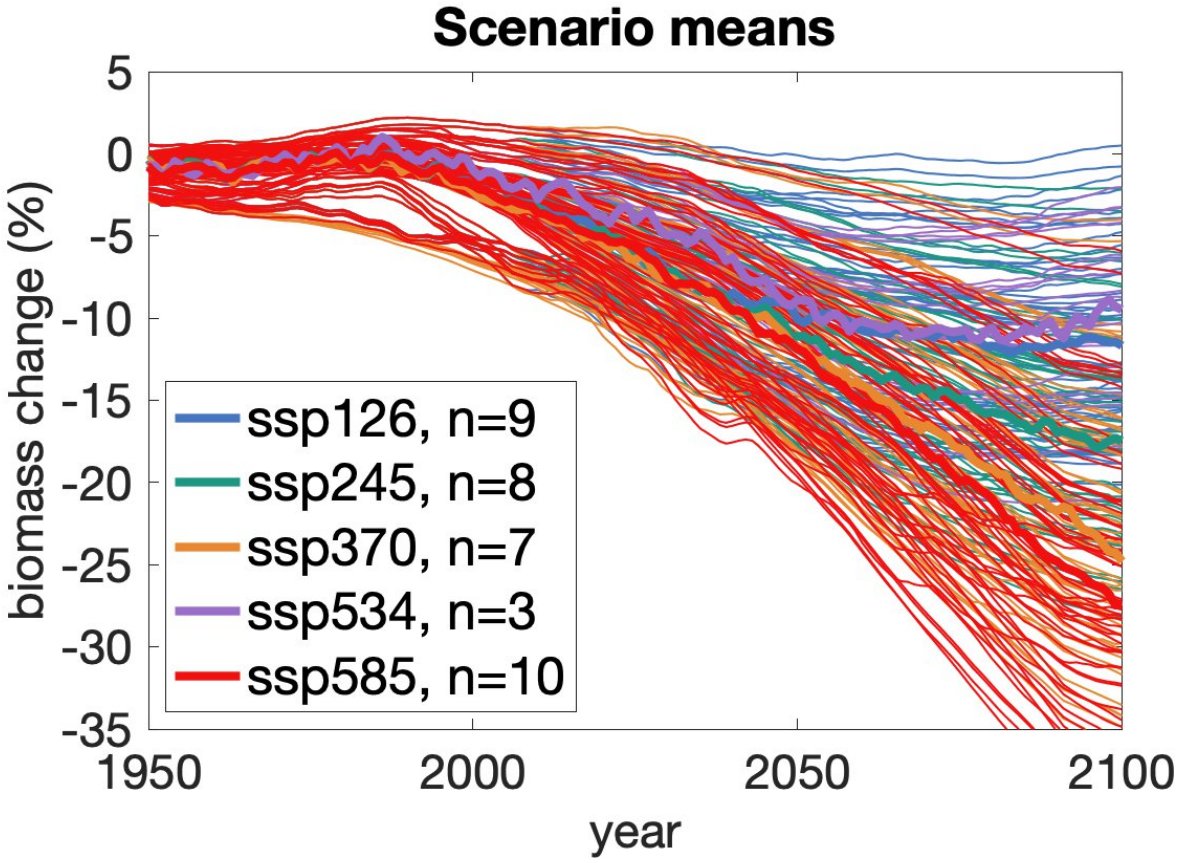


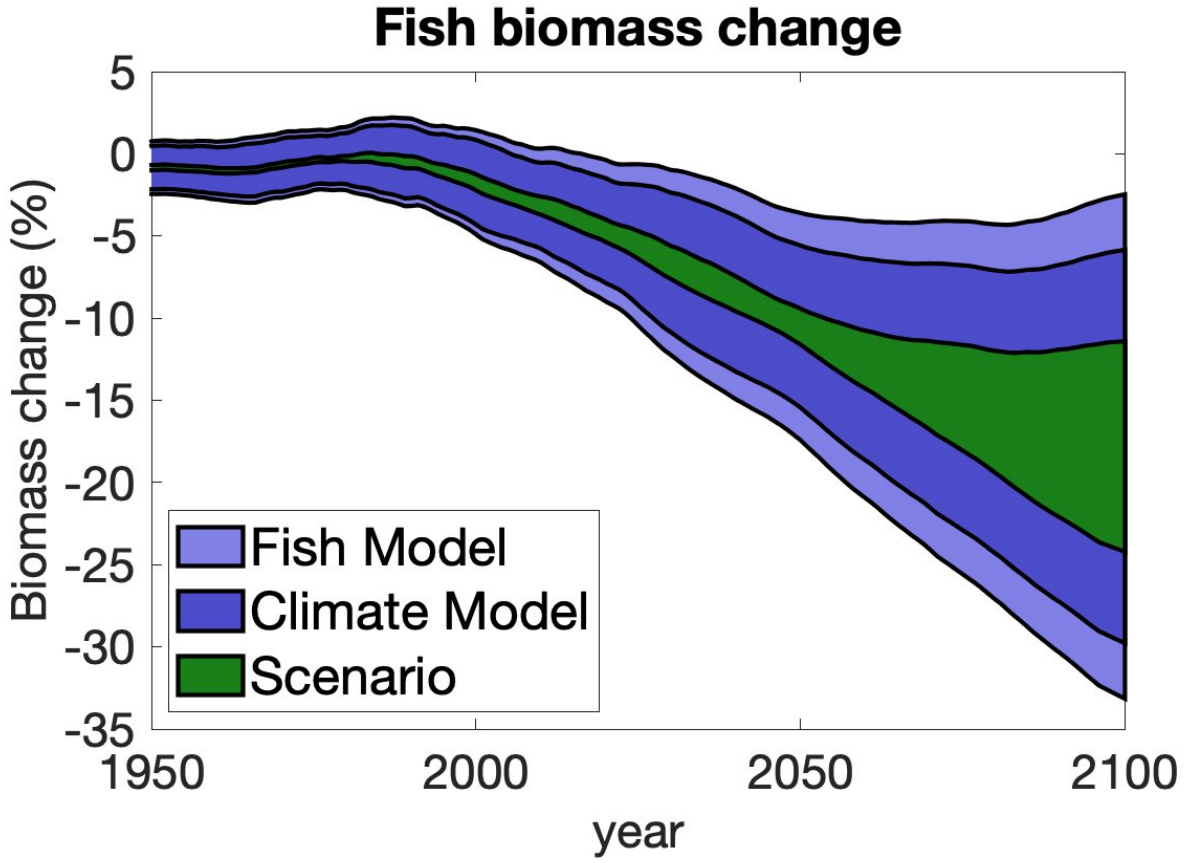


Uncertainty = Scenario + Earth System Model

climate biogeochemistry

Parameter uncertainty



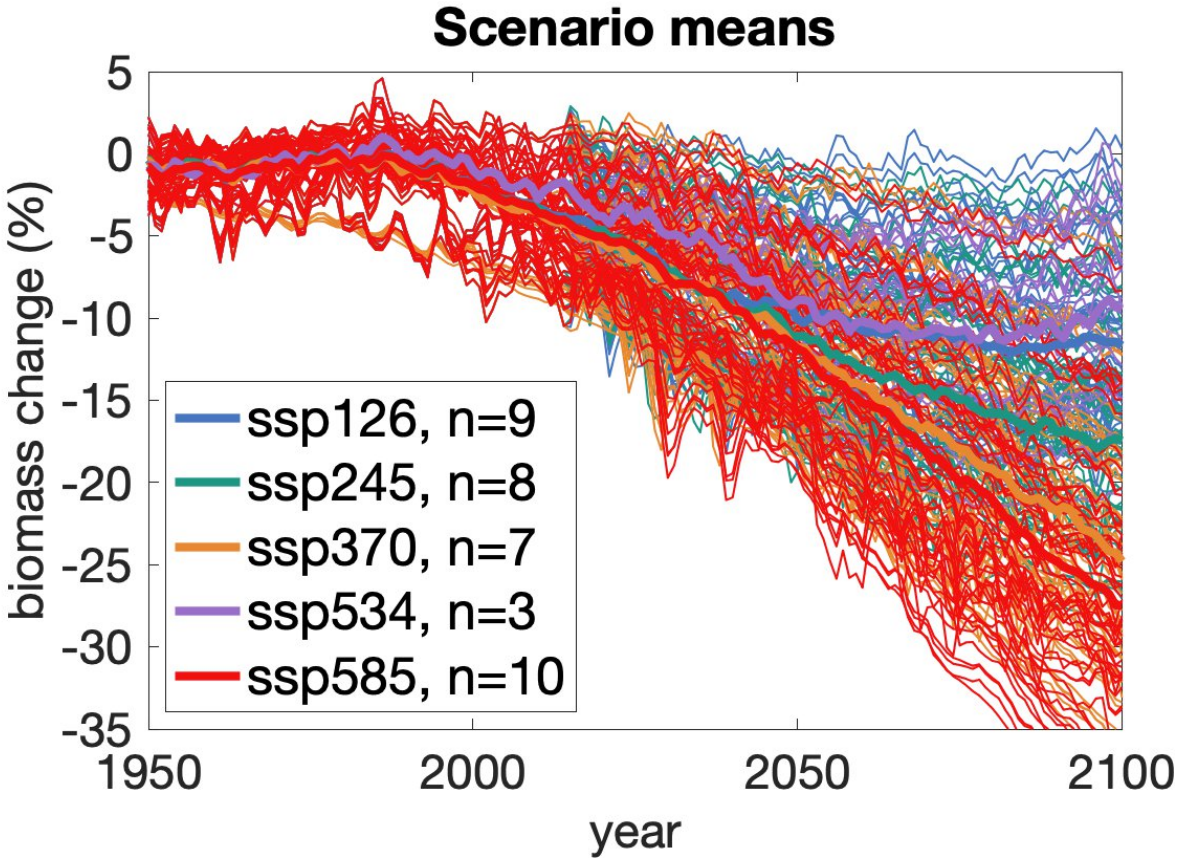


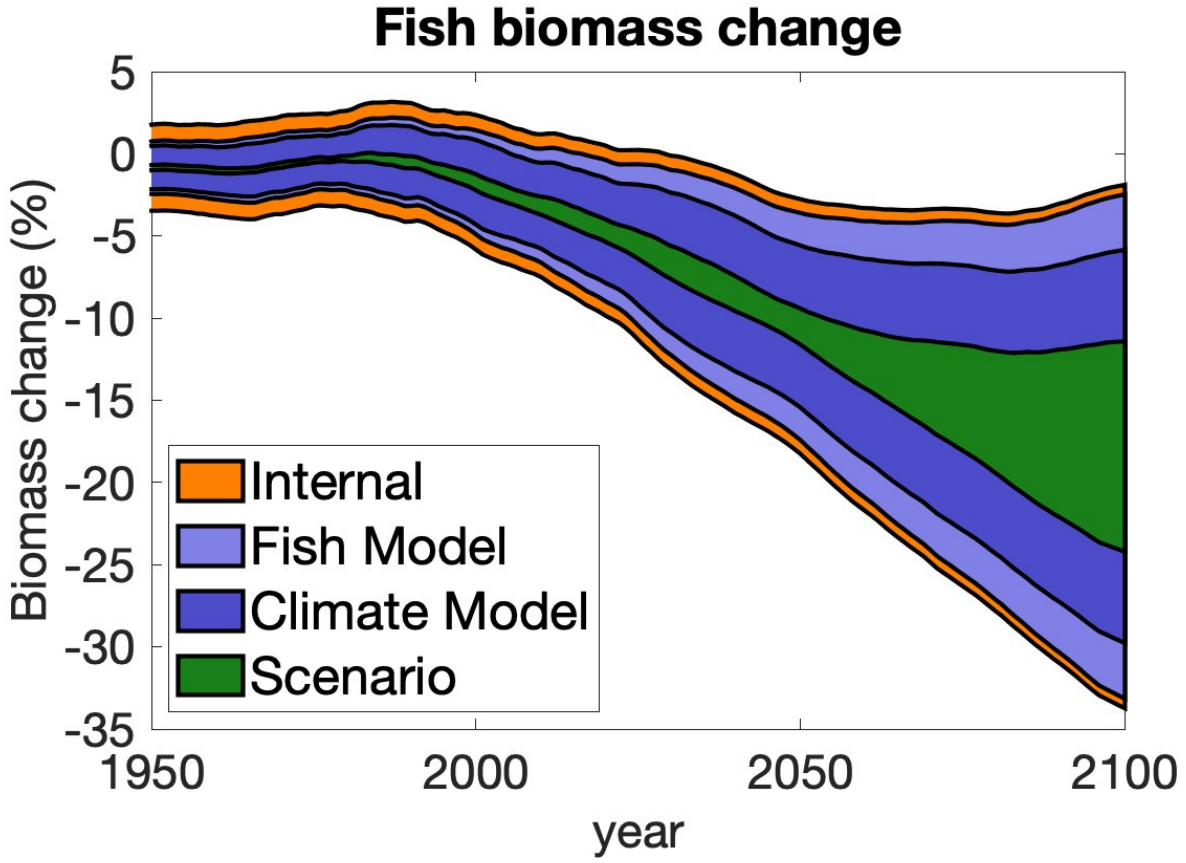
Uncertainty = Scenario + Earth System Model + Fish Model

structure

parameters

Internal variability



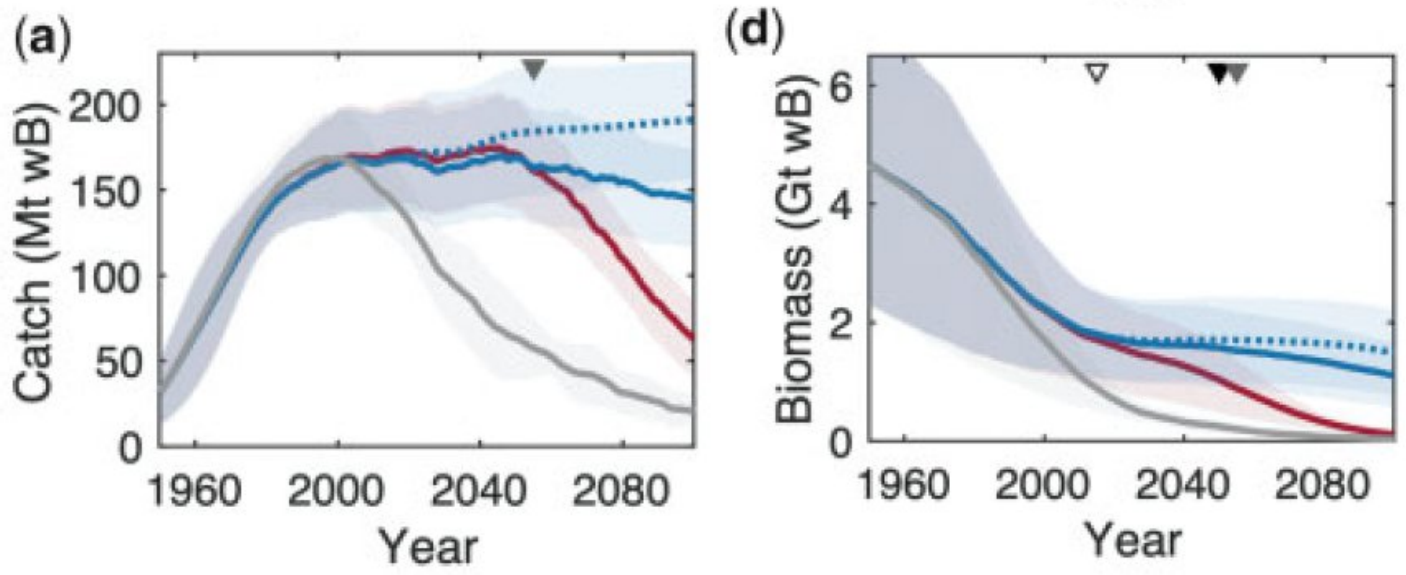


Uncertainty = Scenario + Earth System Model + Fish Model + Internal

… and fishing scenario uncertainty?

$$\frac{\mathrm{d}E_k}{\mathrm{d}t} = K_e \frac{\text{revenue}_k - \text{cost}_k}{E_k}$$

Management towards fishing target



Perfect MSY management

Weak MSY management

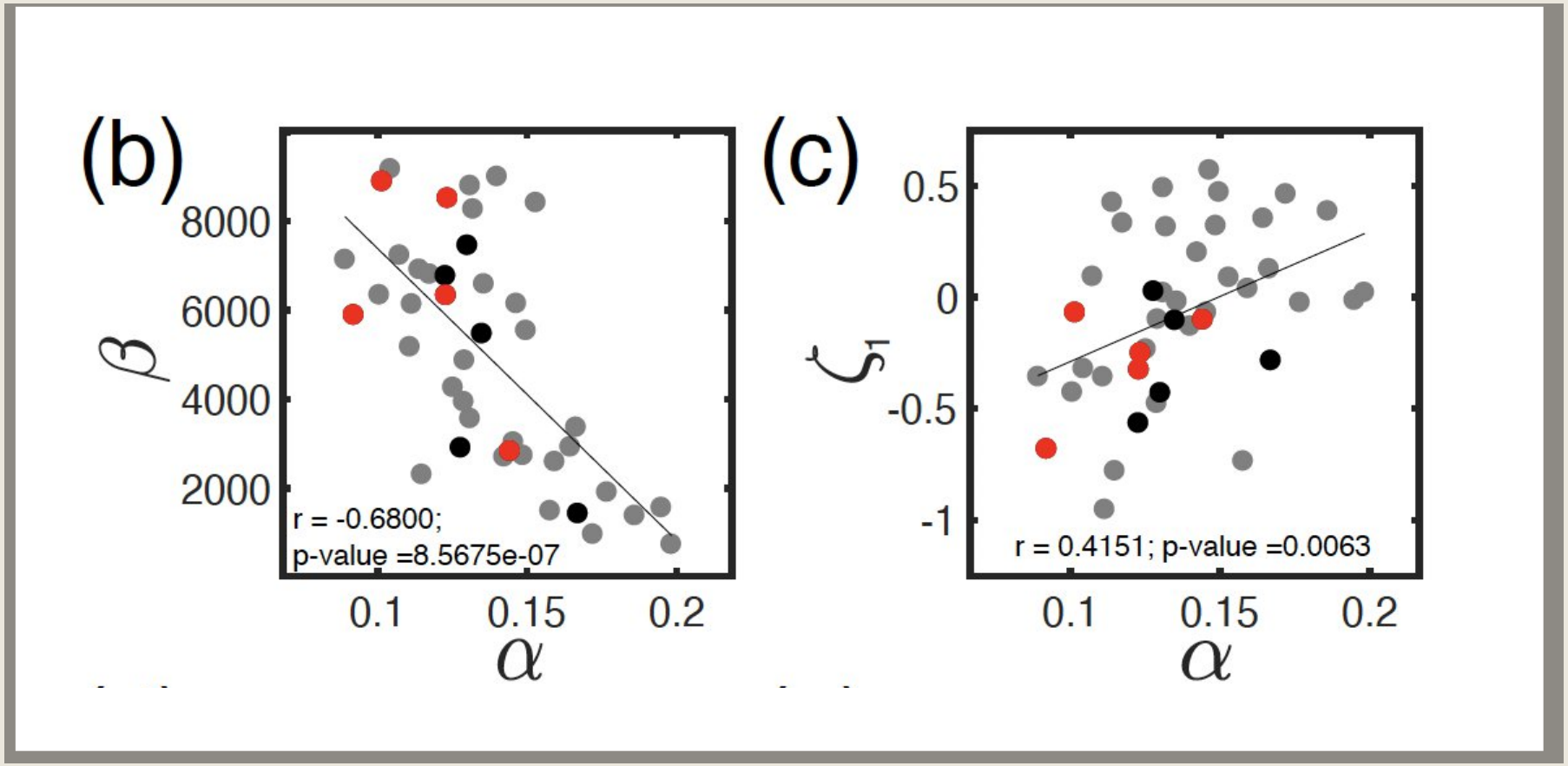
No management

Scherrer and Galbraith, ICES-JMS (2020)

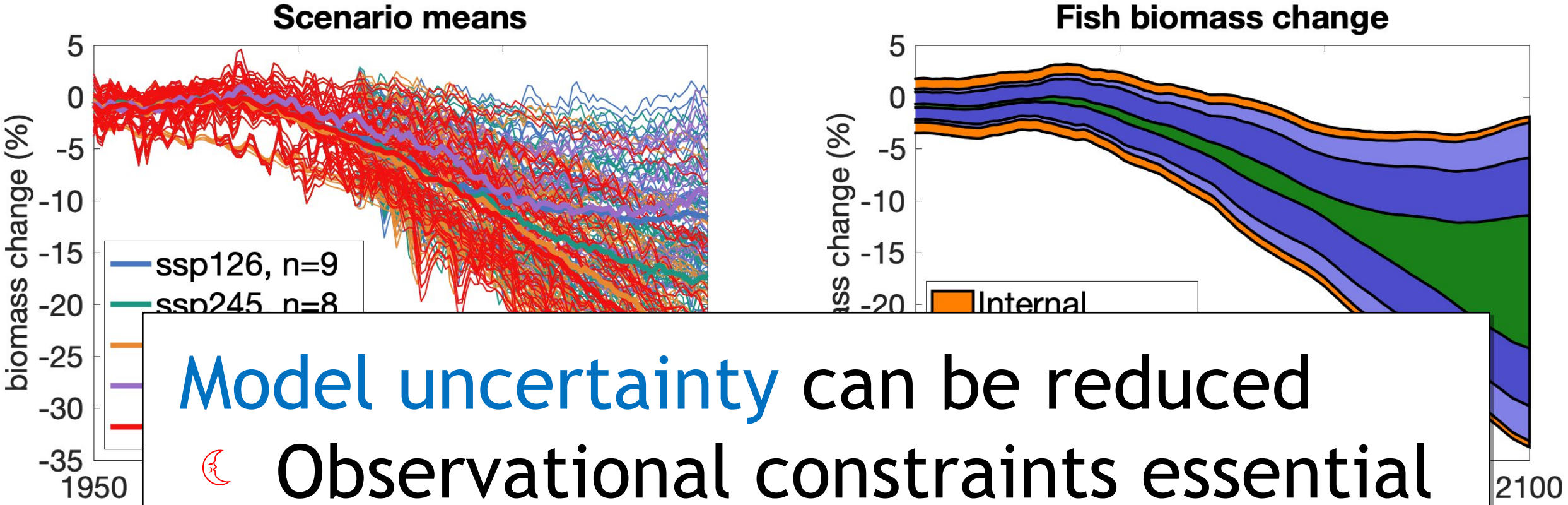
Summary

- Parameter uncertainty is huge without observational constraints
- Global biomass and catch datasets can greatly reduce parameter uncertainty
- Peak catch is an ecosystem characteristic useful for parametrization
- Monte Carlo approach yields estimate of parameter uncertainty
- Complemetary observations (depth of catch, trawl surveys, acoustic data) can continue to improve model skill
- Scenario uncertainty for fishing is large but can be assessed by end-member scenarios

Compensation in parameters



Internal variability



Model uncertainty can be reduced

- Observational constraints essential

Uncertainty = Scenario + Earth System Model + Fish Model + Internal

Fishing effort