Incorporating seasonal climate forecasts into a harvest control rule for Pacific sardine

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Why Pacific Sardine

- Recruitment dependent on SST
- SST used in current harvest control rule

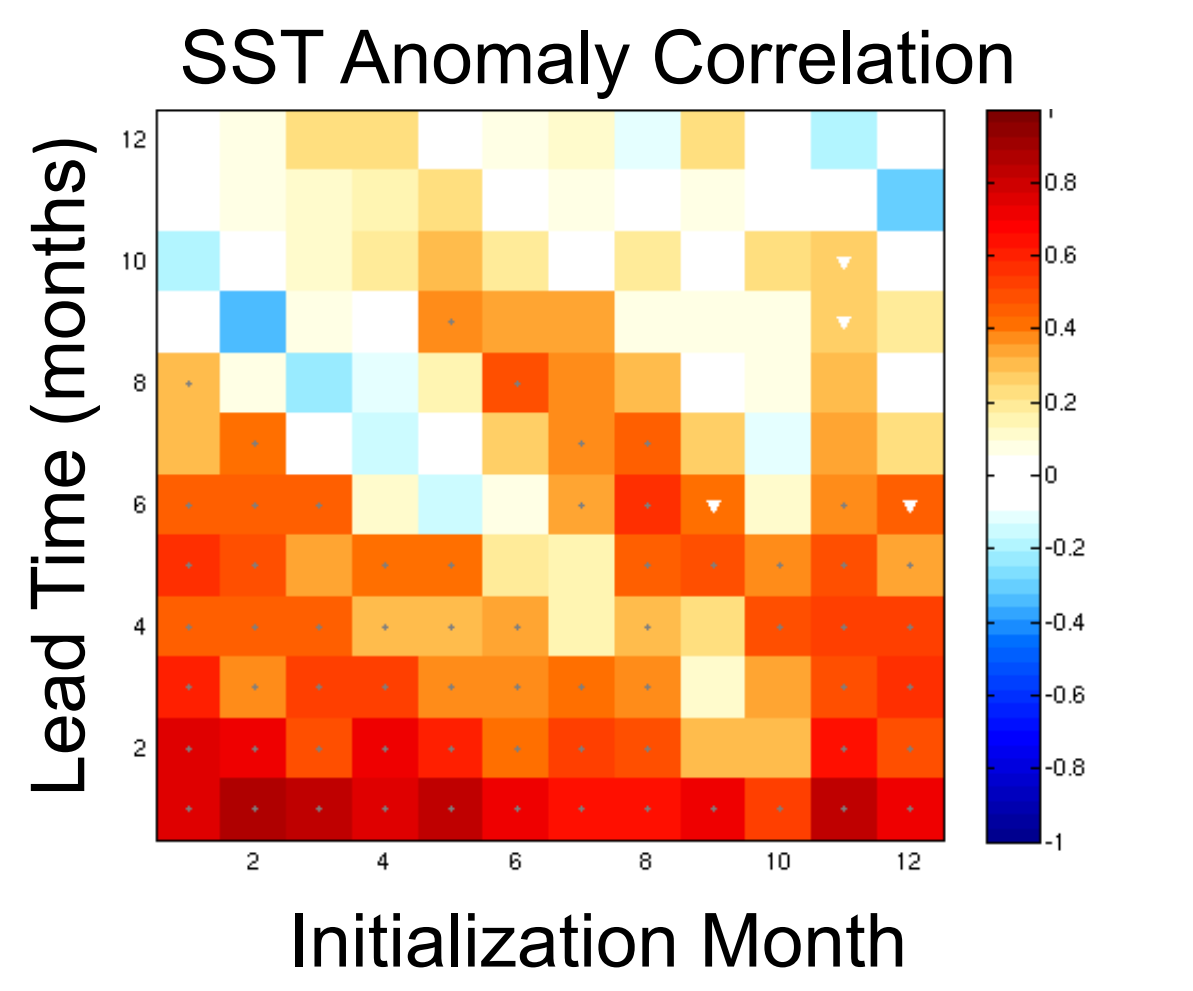
Objective

Assess if incorporation of future environmental information improves effectiveness of pacific sardine harvest control rule

Performance metrics:

- average and variability of catch
- average and variability of stock biomass
- probability of catch falling below threshold
- probability of stock biomass falling below threshold

Future environmental information = monthly SST forecast from GFDL CM 2.5-FLOR for CalCOFI Region



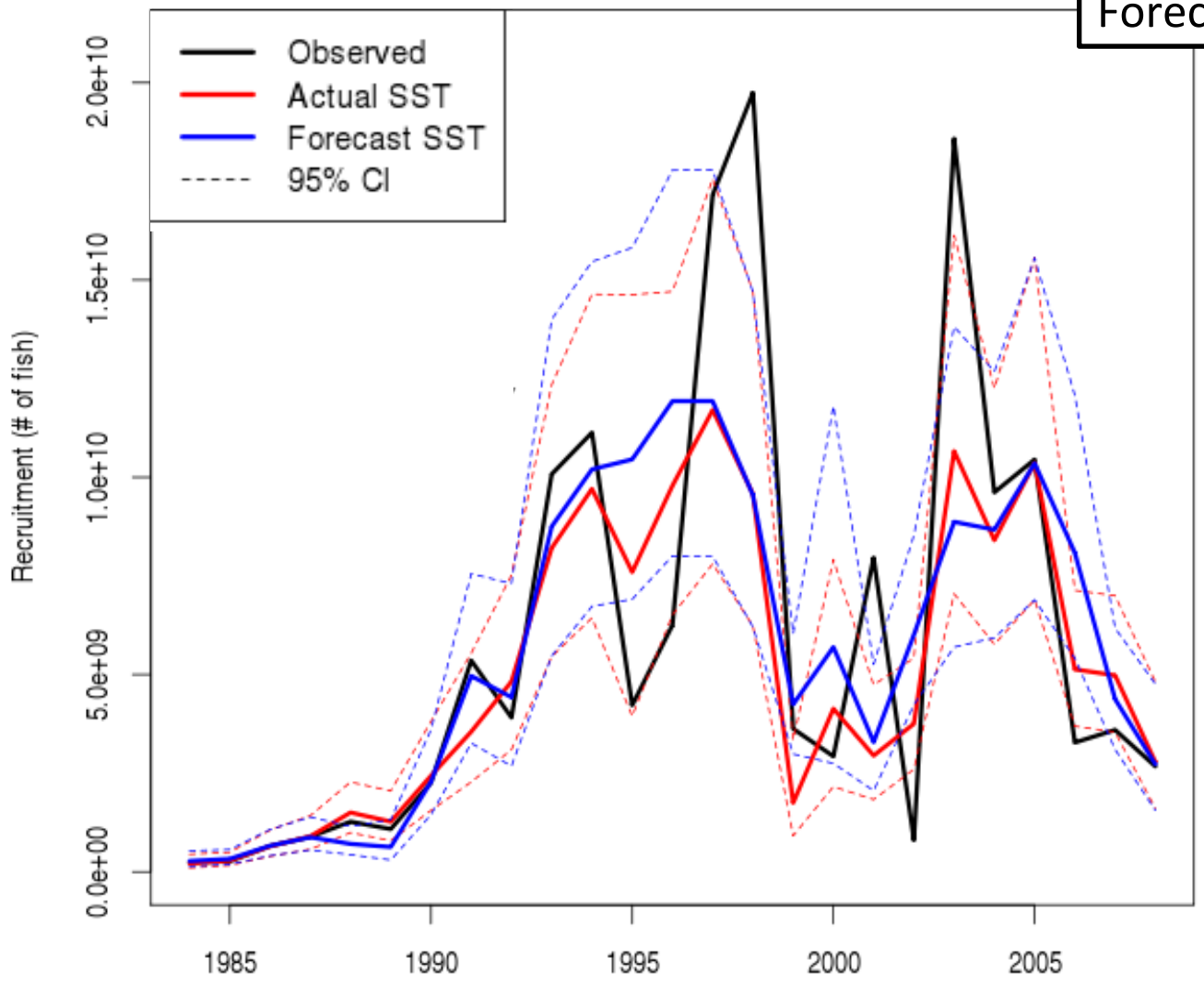
Population Dynamics Model

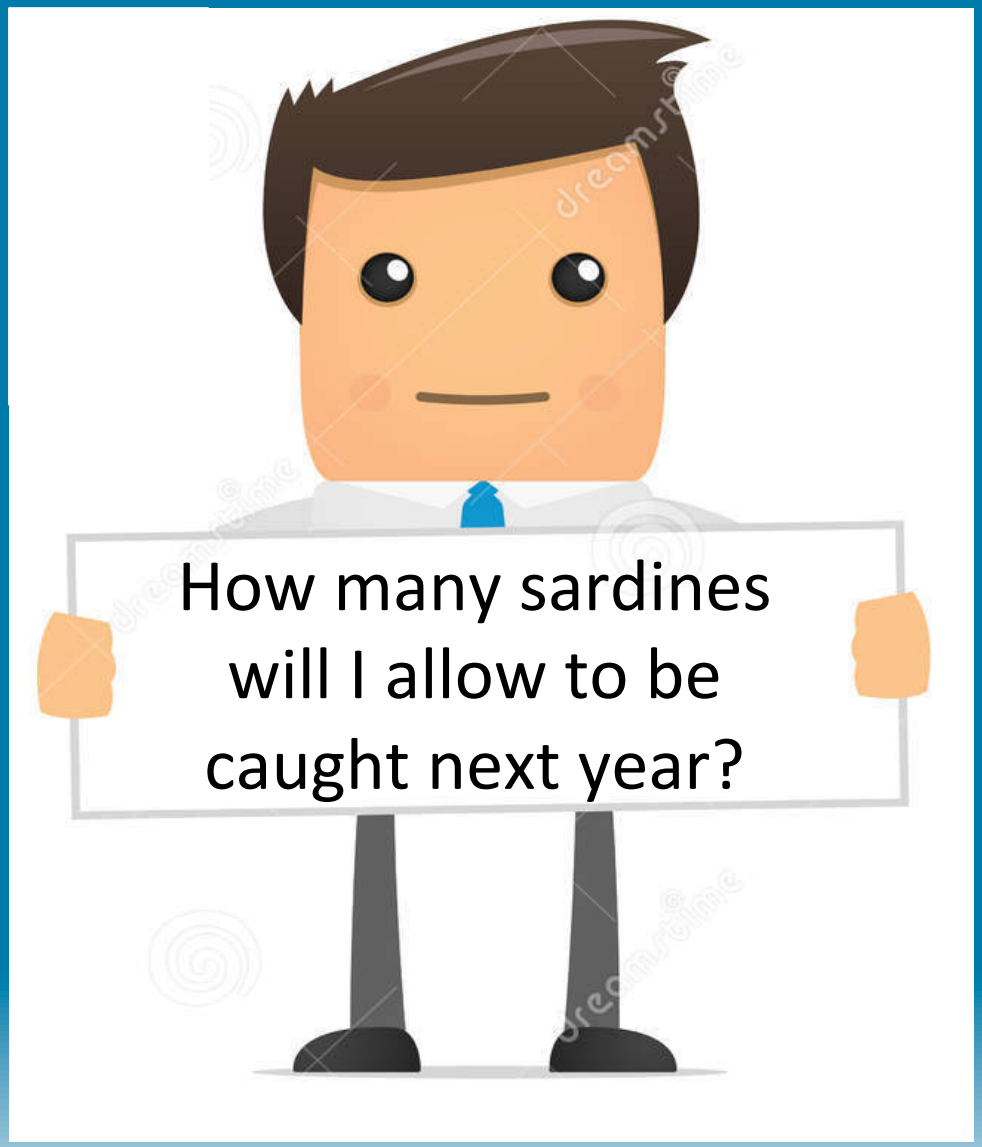
- Age-structured
- Constant natural mortality
- Single fishing fleet
- Age specific selectivity
- Age 0 recruitment – Ricker environmentally explicit stock recruitment - non-linear SST effect

Hindcast of Recruits

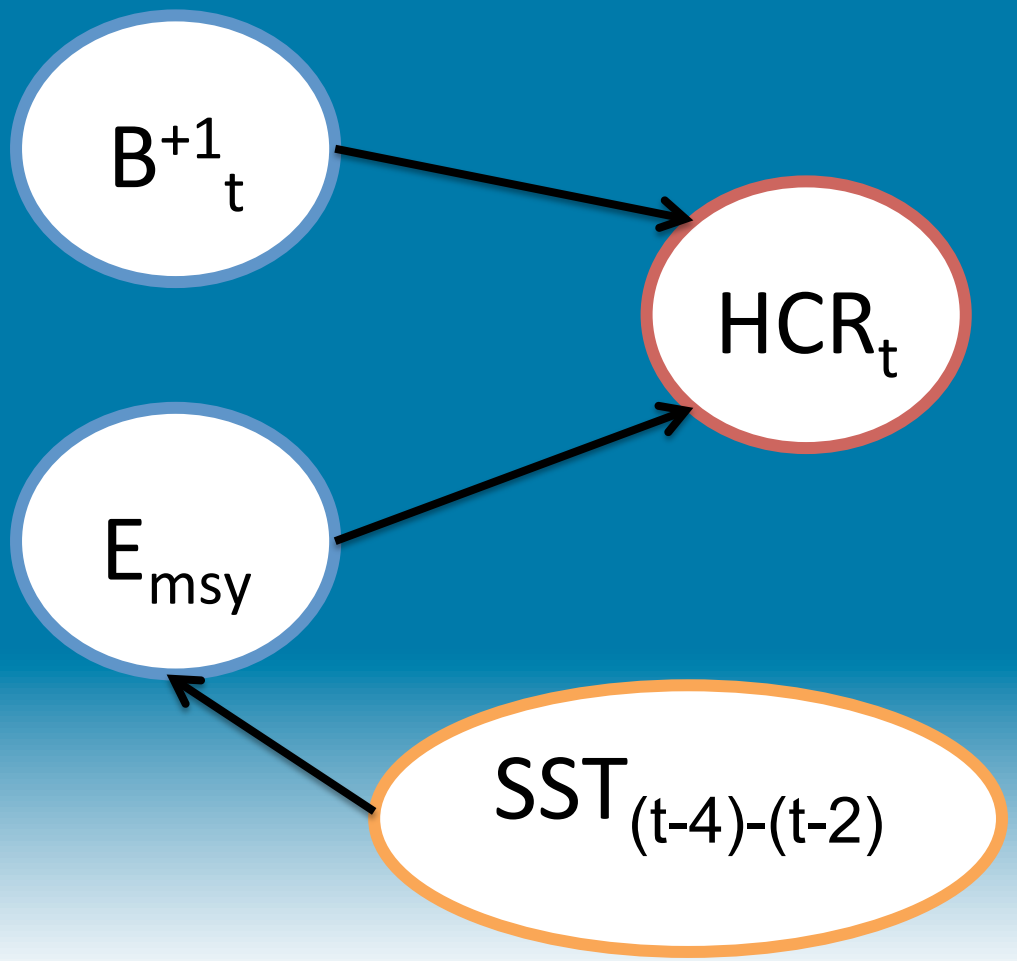
Actual SST Correlation = 0.85

Forecast SST Correlation = 0.73




How many sardines
will I allow to be
caught next year?

Set a Harvest Control Rule, depends on estimate of biomass (age 1+) and E_{msy}

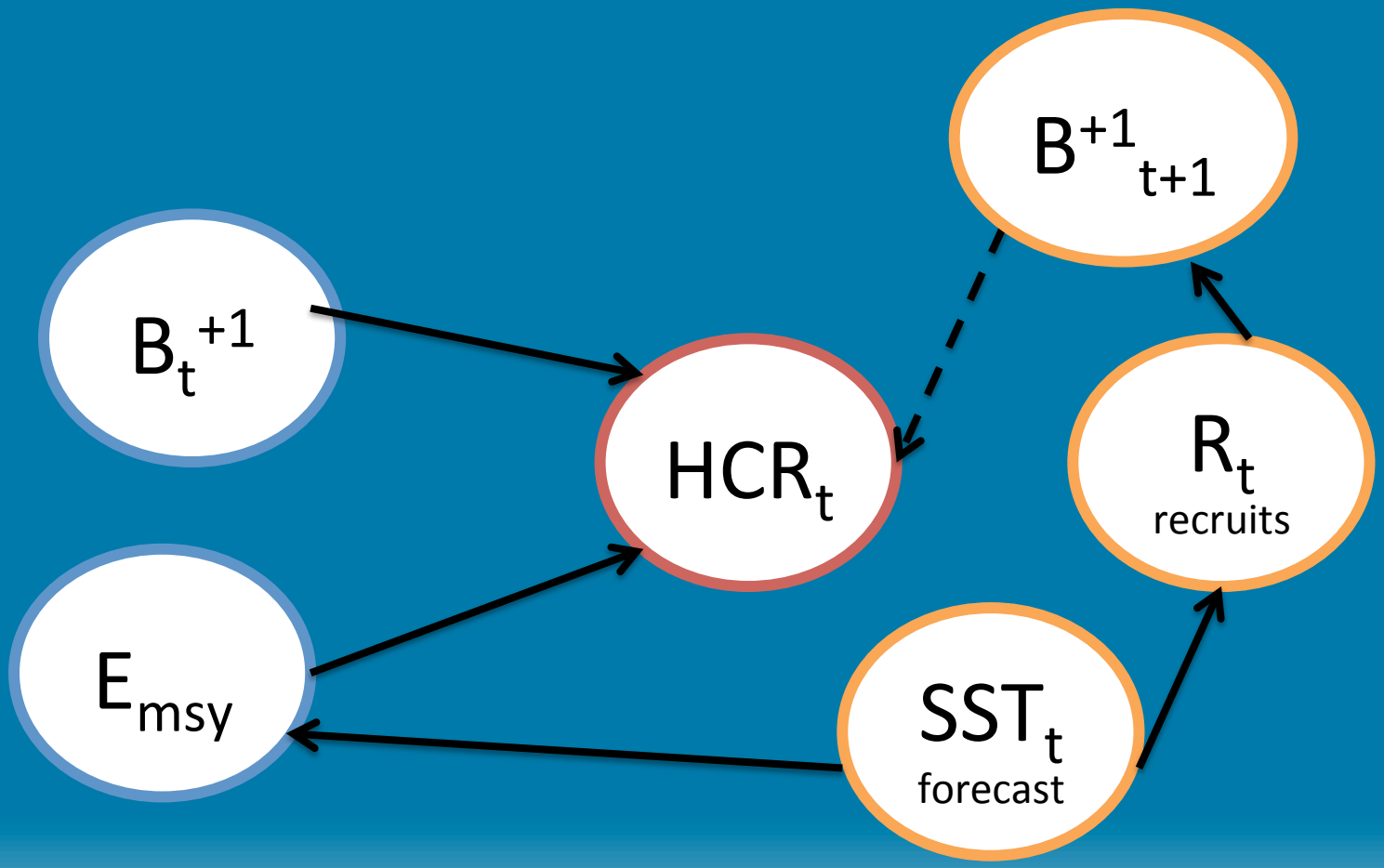


Harvest Control Rules:

Status quo: $HCR_t = B^{+1}_t * Emsy_{(t-4)-(t-2)}$

Future Emsy: $HCR_t = B^{+1}_t * Emsy_{(t-2)-(t)}$

Additional Harvest Control Rule:

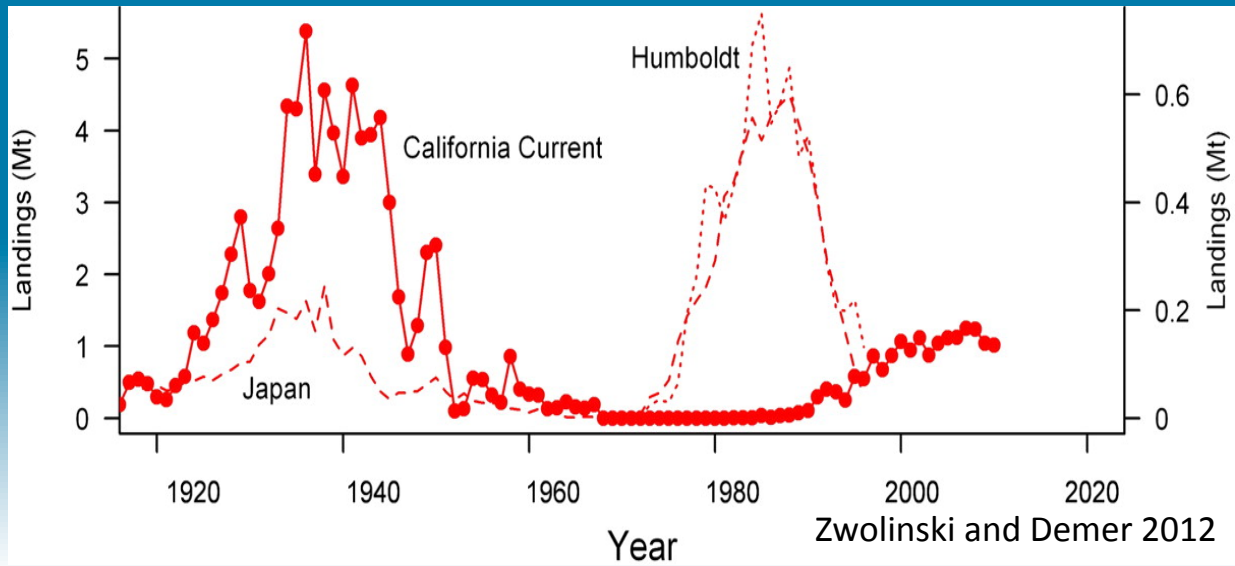


Harvest Control Rules:

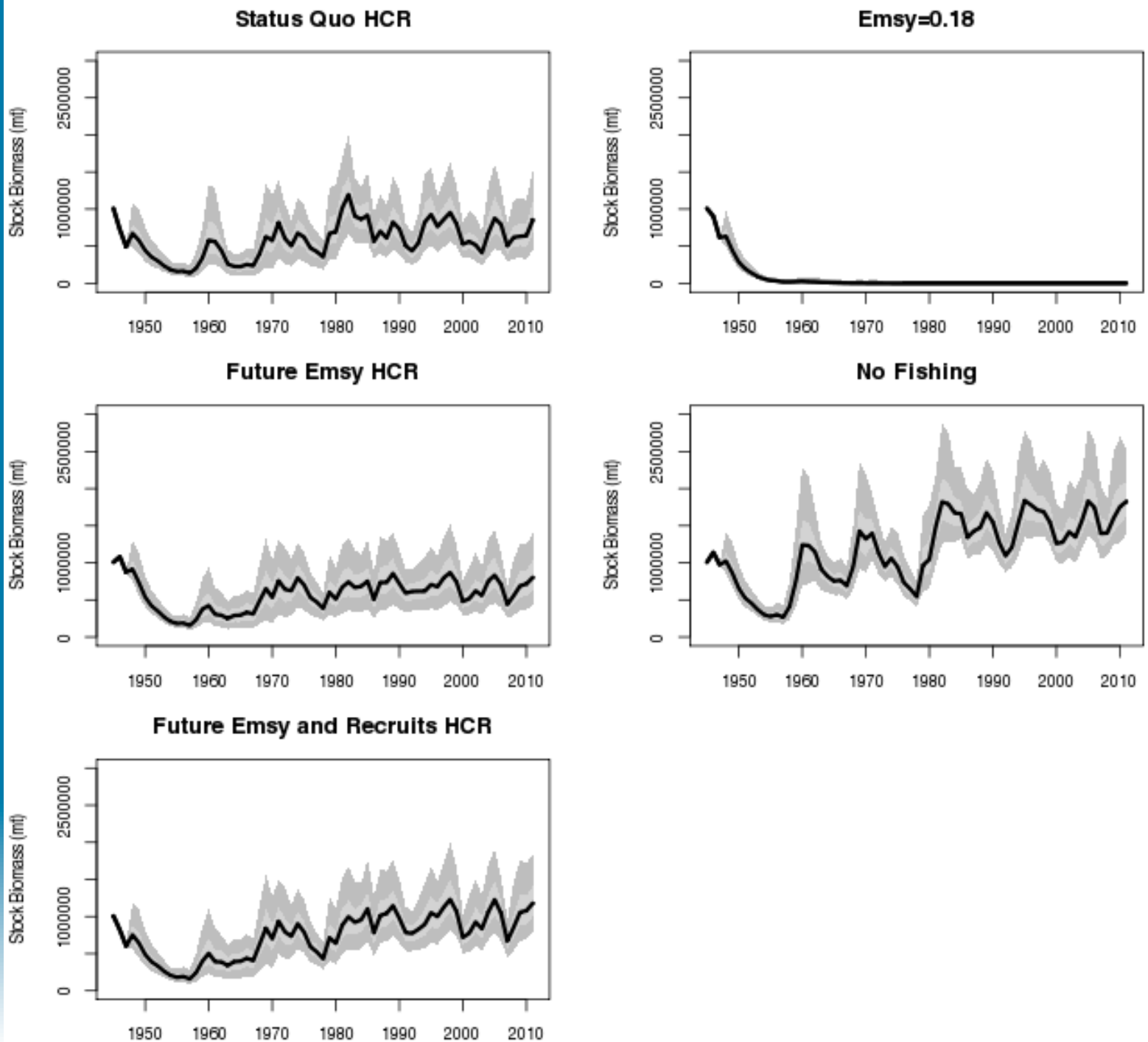
1. Status quo
2. Emsy adjusted for future temp
3. HCR based on current and future biomass
4. Environmentally independent E_{msy}=0.18

HCR Evaluation Framework

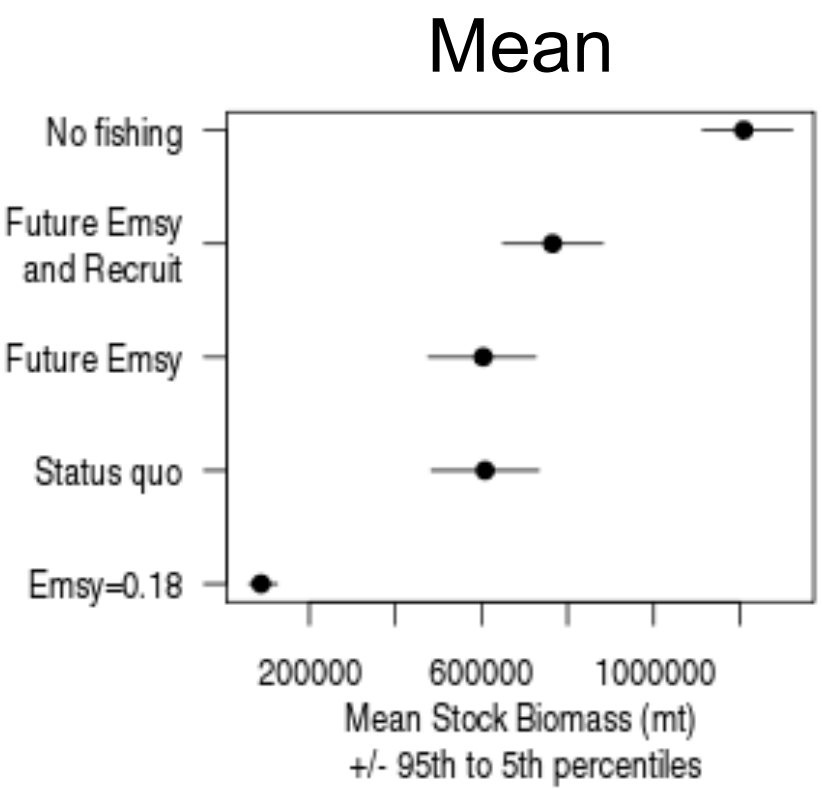
- Assessed value of PERFECT future information
- Used Scripps Pier SST as input
- Long simulation with extreme SST conditions (67 yrs x1000 runs)
- Random recruitment error
- 1945 initial abundance estimates (MacCall 1979)

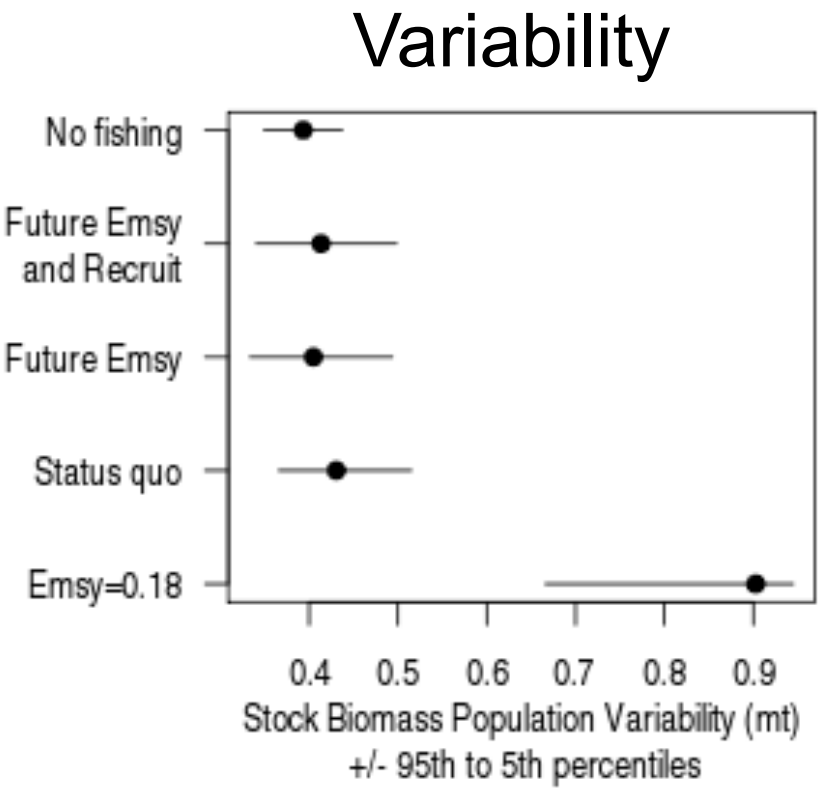


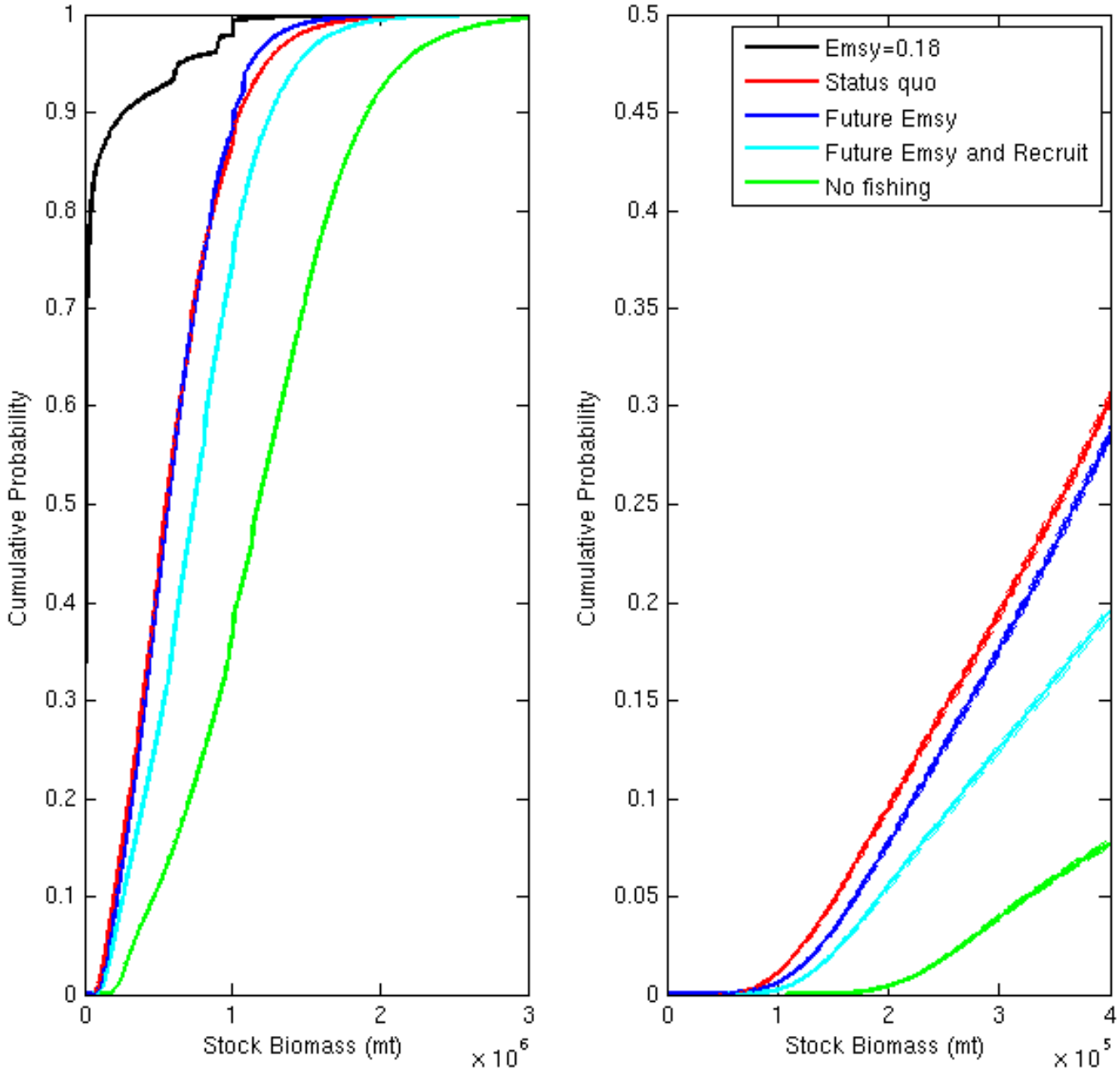
Zwolinski and Demer 2012


Status Quo HCR
Emsy=0.18
Future Emsy HCR
No Fishing
Future Emsy and Recruits HCR
Stock Biomass (mt)
0
1000000
2500000
1950
1960
1970
1980
1990
2000
2010

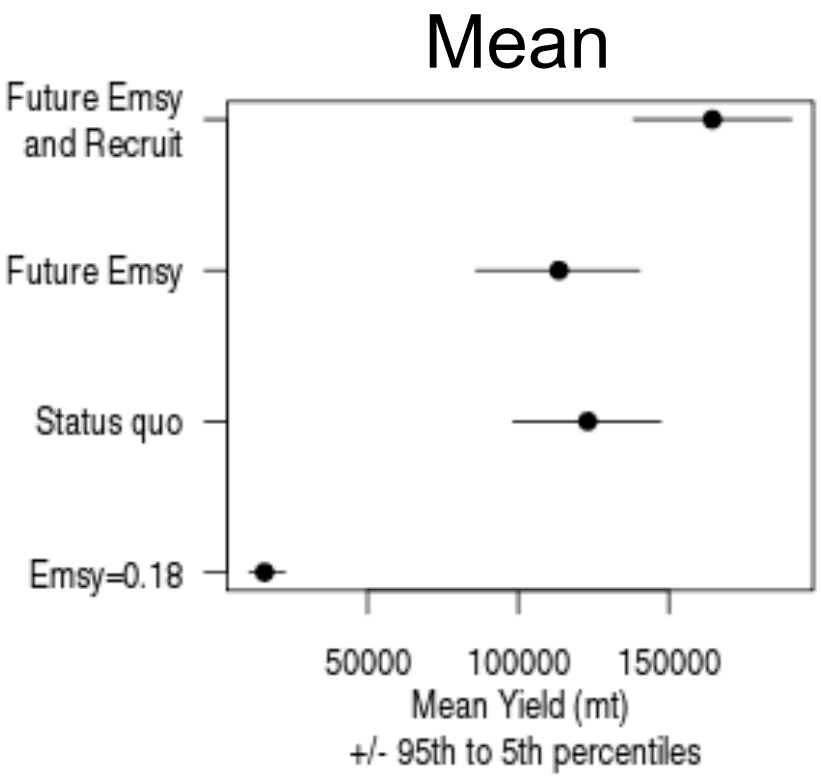
Stock Biomass Performance Metrics

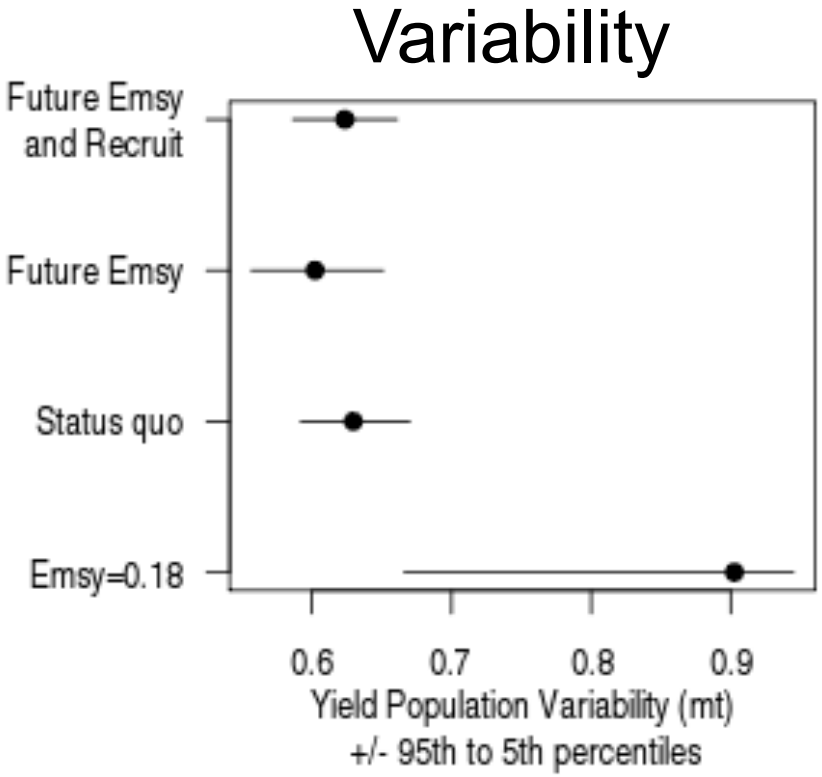


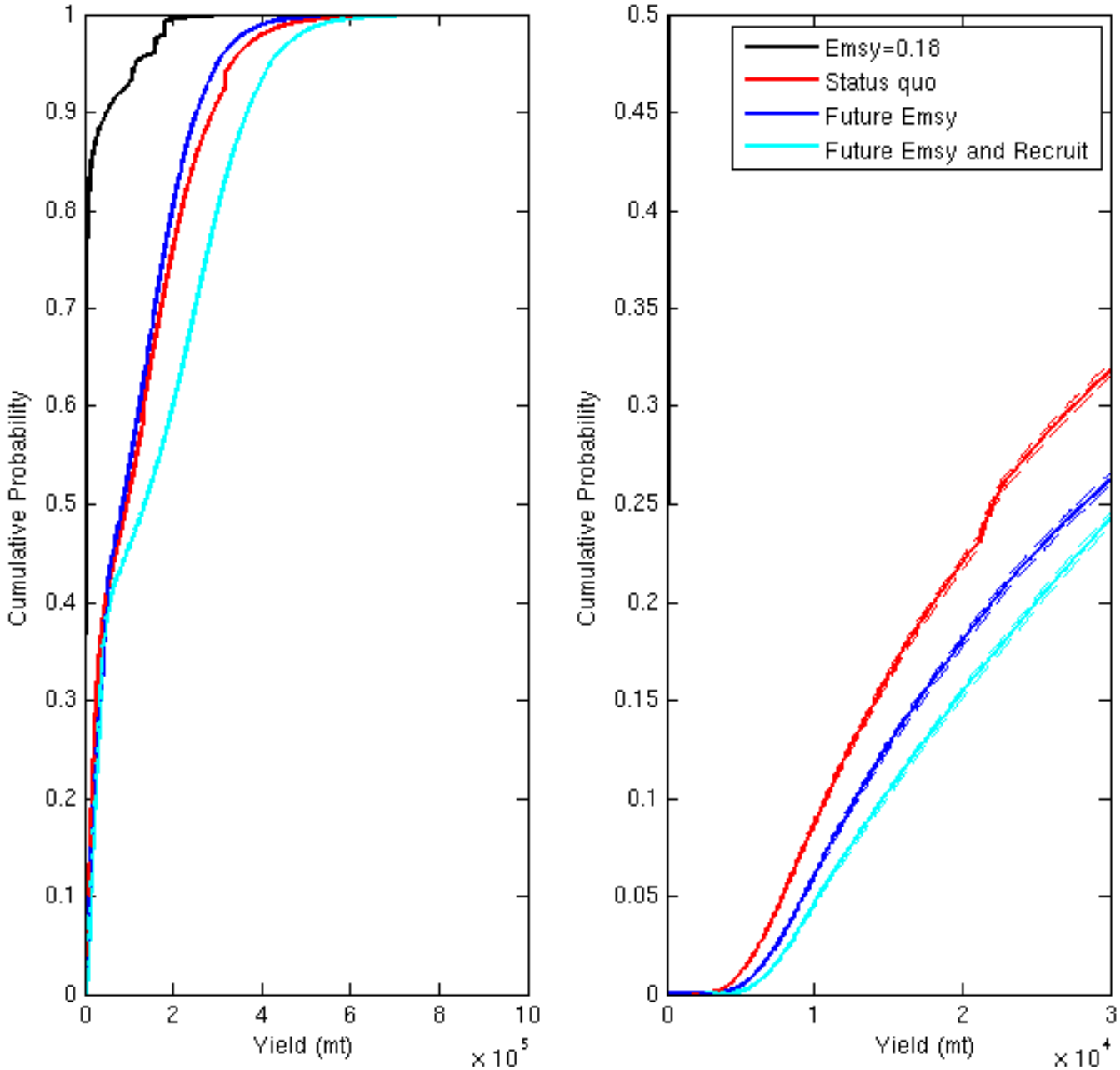



Cumulative Probability
Stock Biomass (mt)
× 10^6
Cumulative Probability
Stock Biomass (mt)
× 10^5
Emsy=0.18
Status quo
Future Emsy
Future Emsy and Recruit
No fishing

Yield Performance Metrics

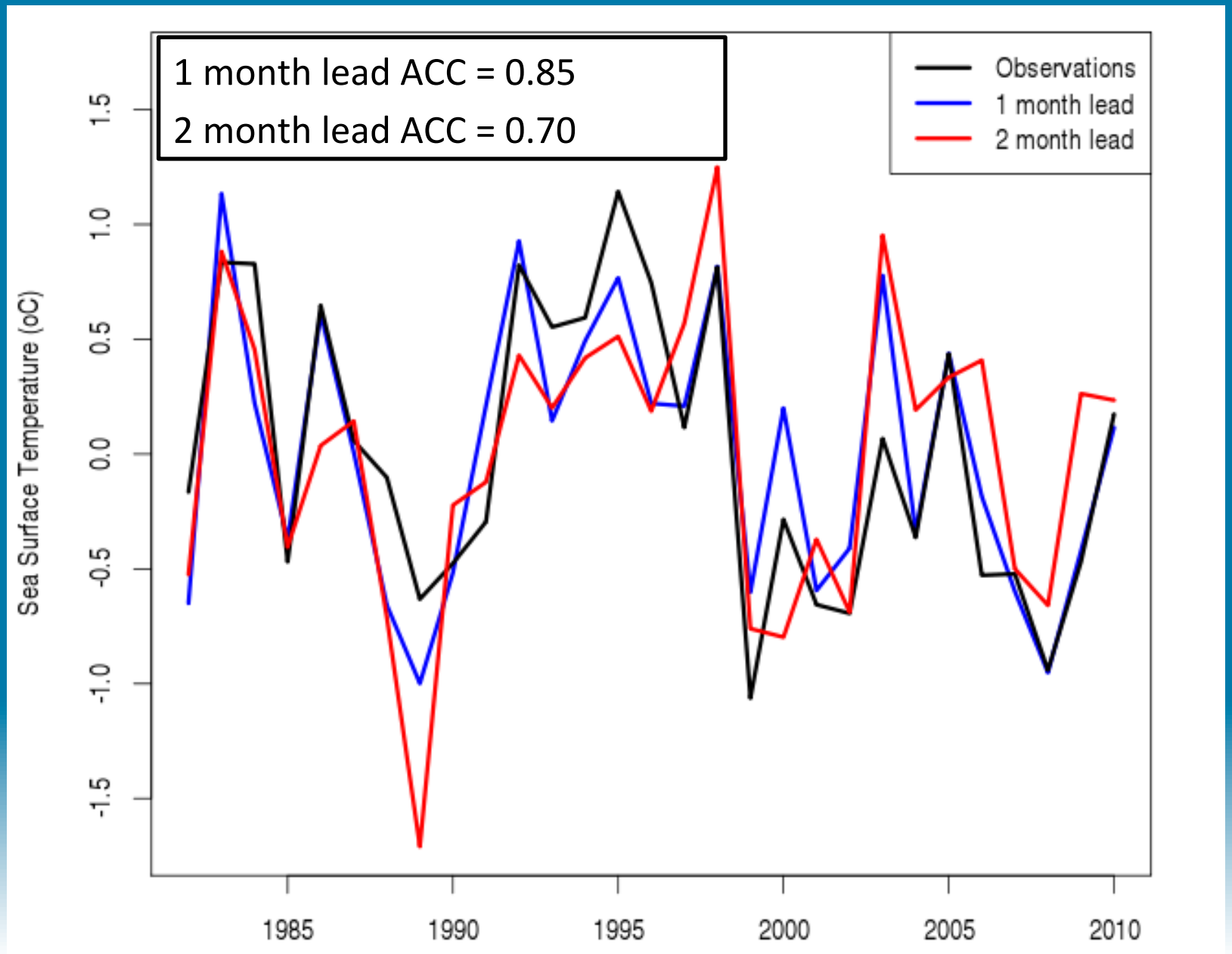




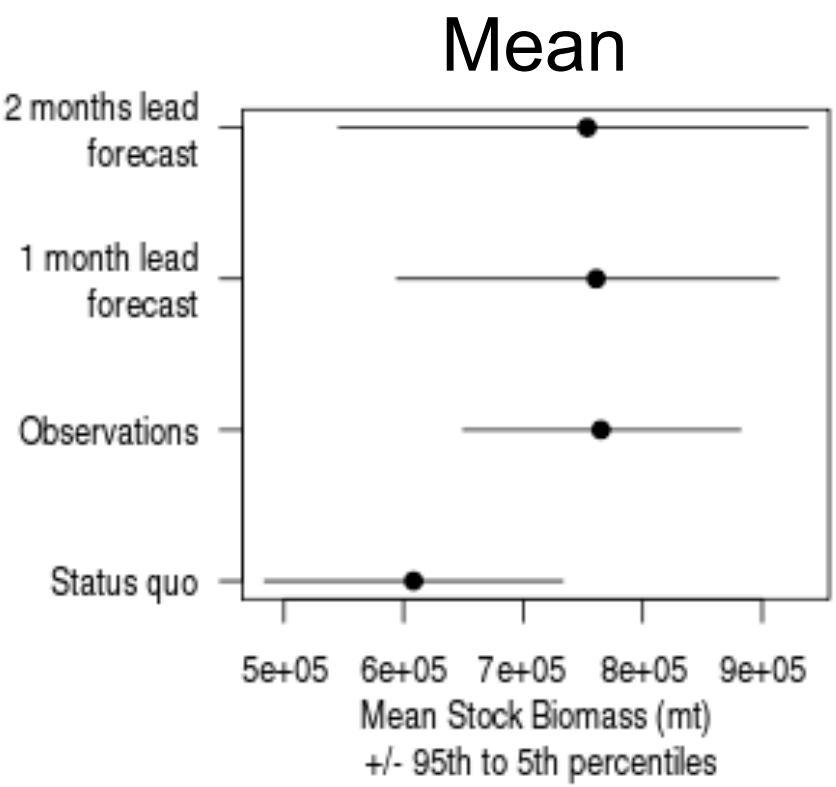

Cumulative Probability
Yield (mt)
× 10^5
Cumulative Probability
Yield (mt)
× 10^4
Emsy=0.18
Status quo
Future Emsy
Future Emsy and Recruit

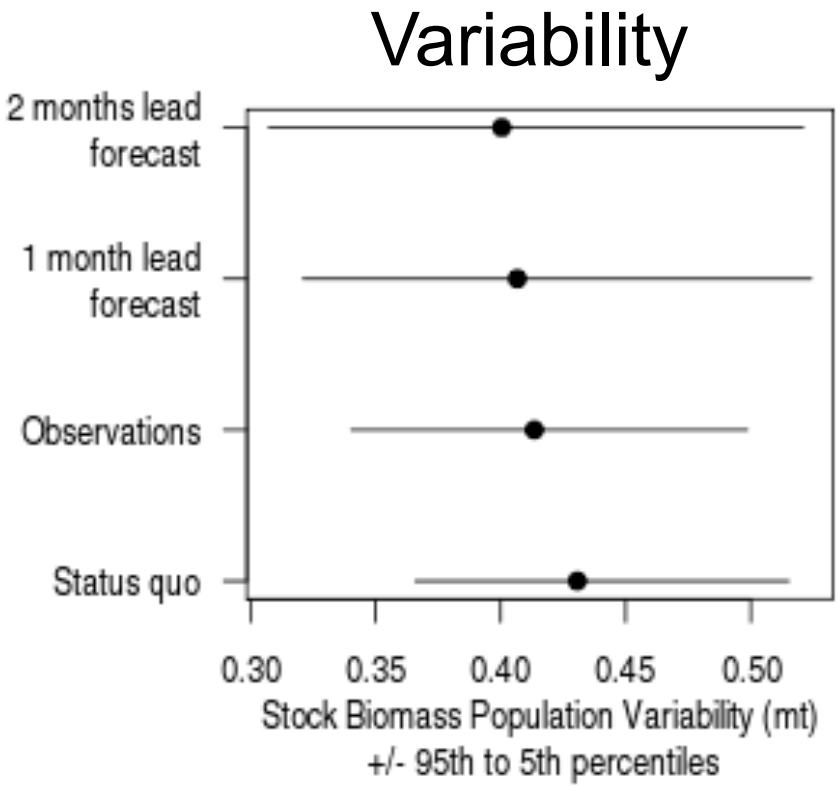
- Incorporation of **perfect** future SST information:
  - through Emsy, slightly reduces variability in catch and stock biomass
  - through stock biomass, increases long-term catch and stock biomass
  - Reduces probability of stock biomass and yield falling below threshold value
- An environmentally explicit HCR may prevent a 1950's-like collapse

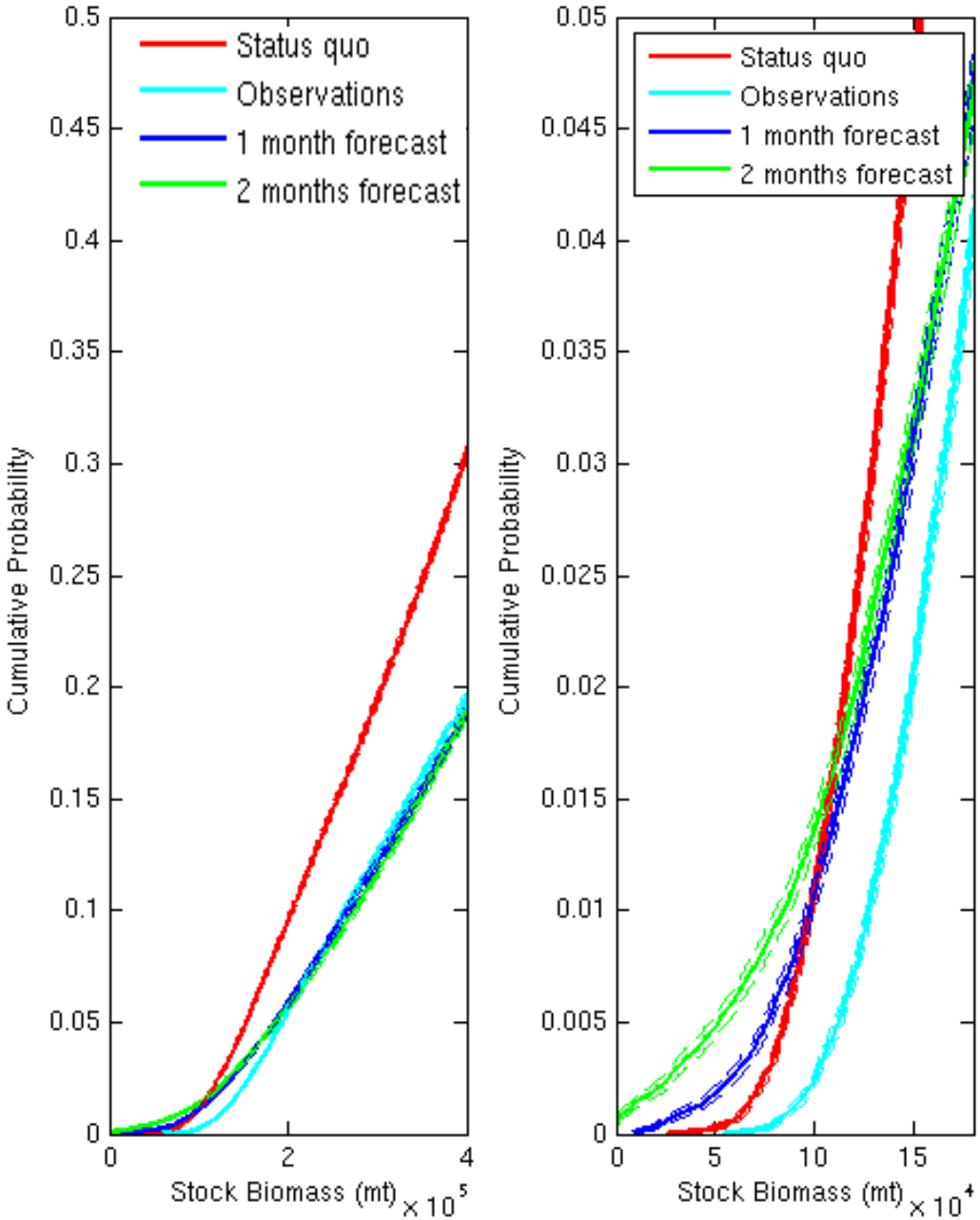
When we introduce forecast error…



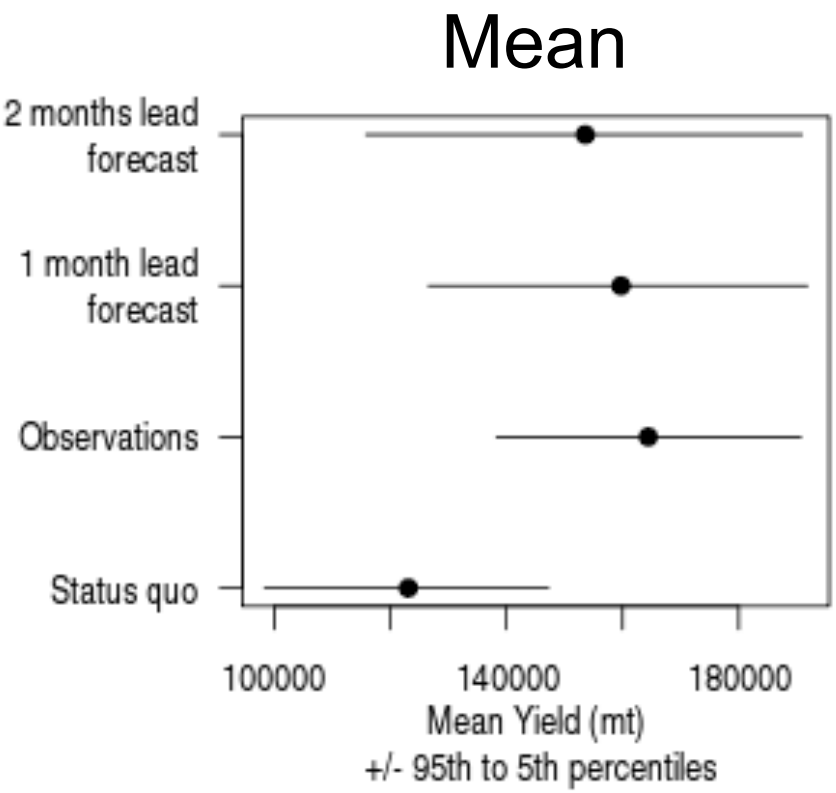
Stock Biomass Performance Metrics

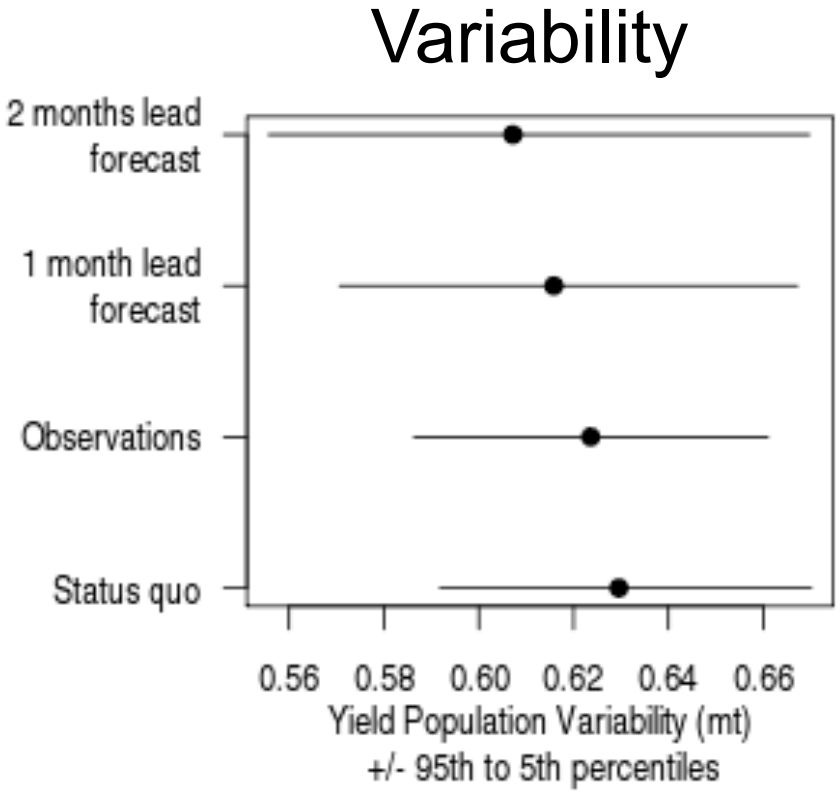


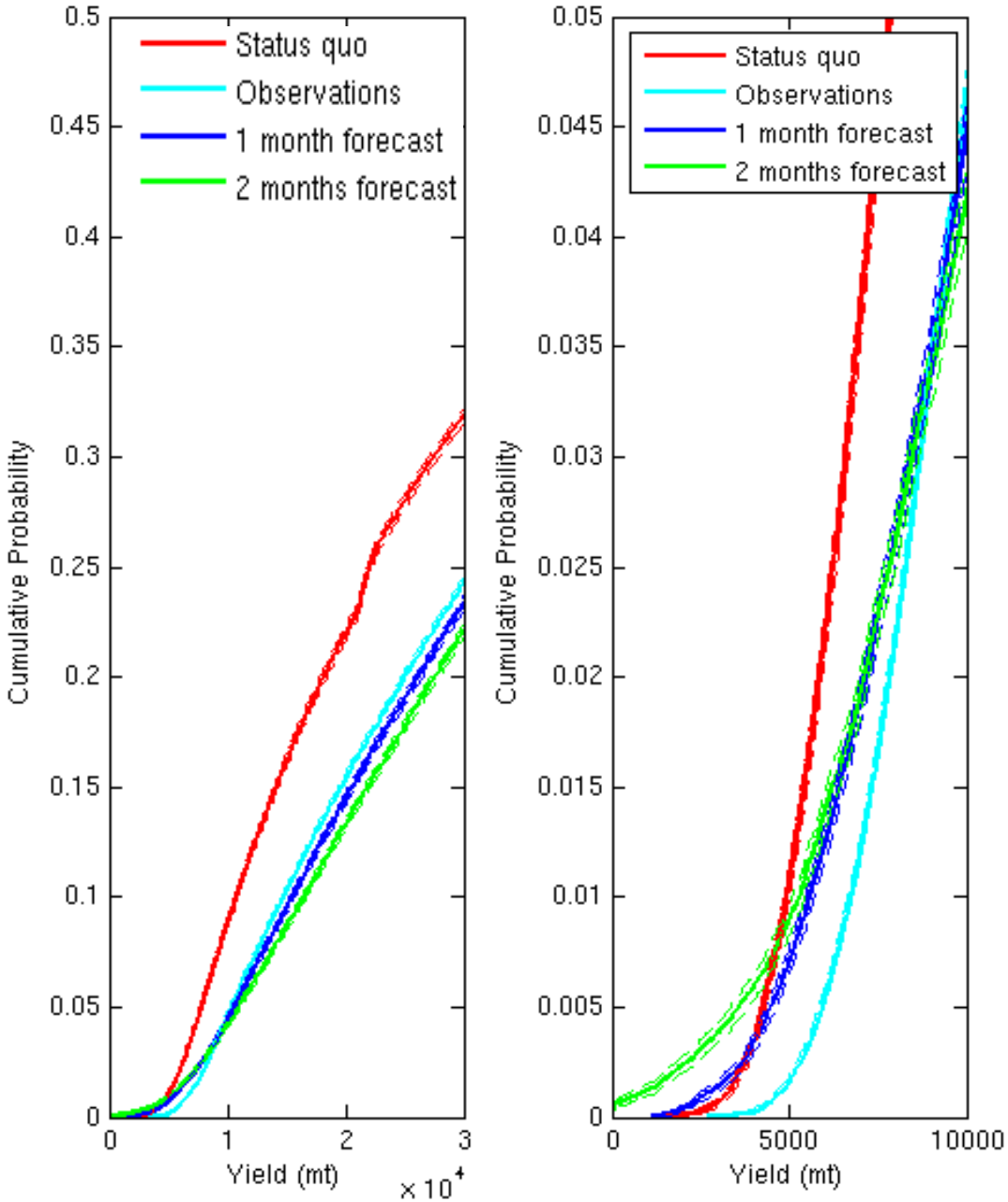



Status quo
Observations
1 month forecast
2 months forecast
Cumulative Probability
Stock Biomass (mt)
× 10^5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
2
4
Status quo
Observations
1 month forecast
2 months forecast
Cumulative Probability
Stock Biomass (mt)
× 10^4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0
5
10
15

Yield Performance Metrics



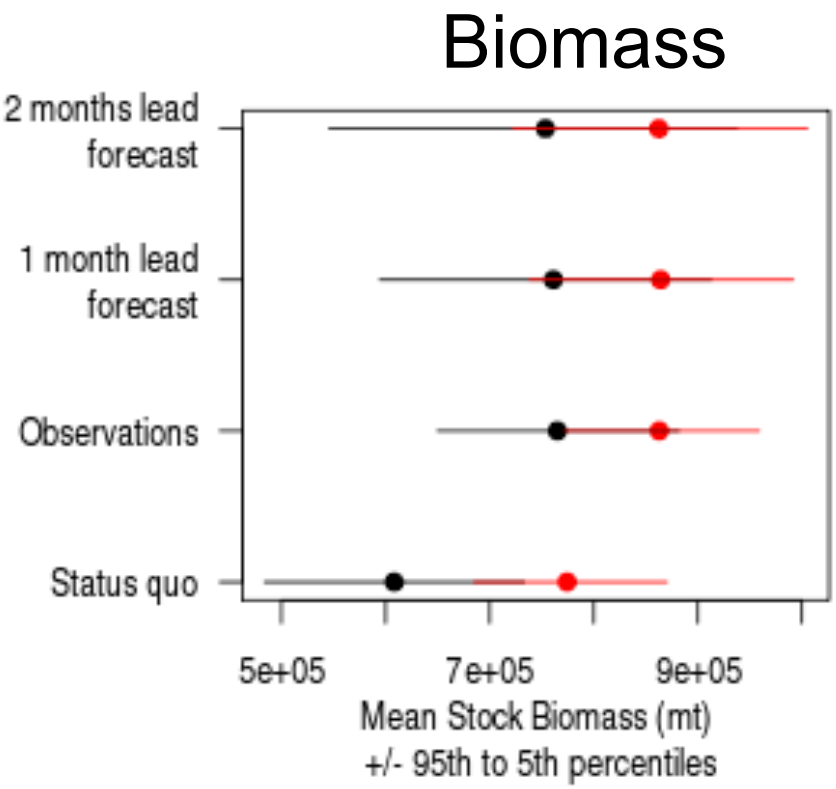


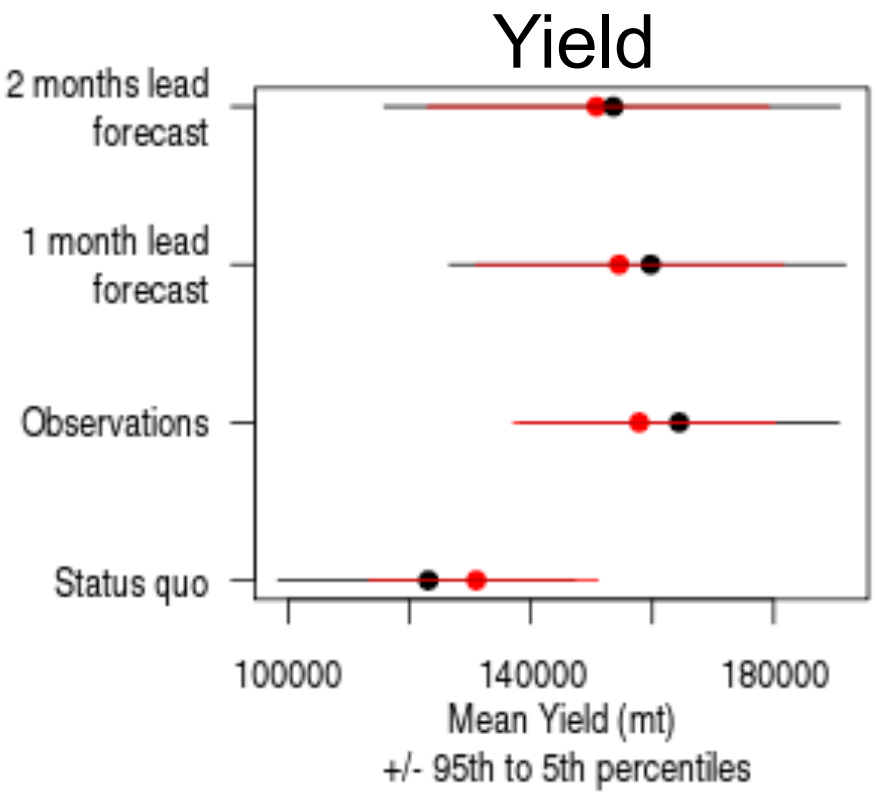

Status quo
Observations
1 month forecast
2 months forecast
Cumulative Probability
Yield (mt)
× 10^4
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
1
2
3
Status quo
Observations
1 month forecast
2 months forecast
Cumulative Probability
Yield (mt)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0
5000
10000

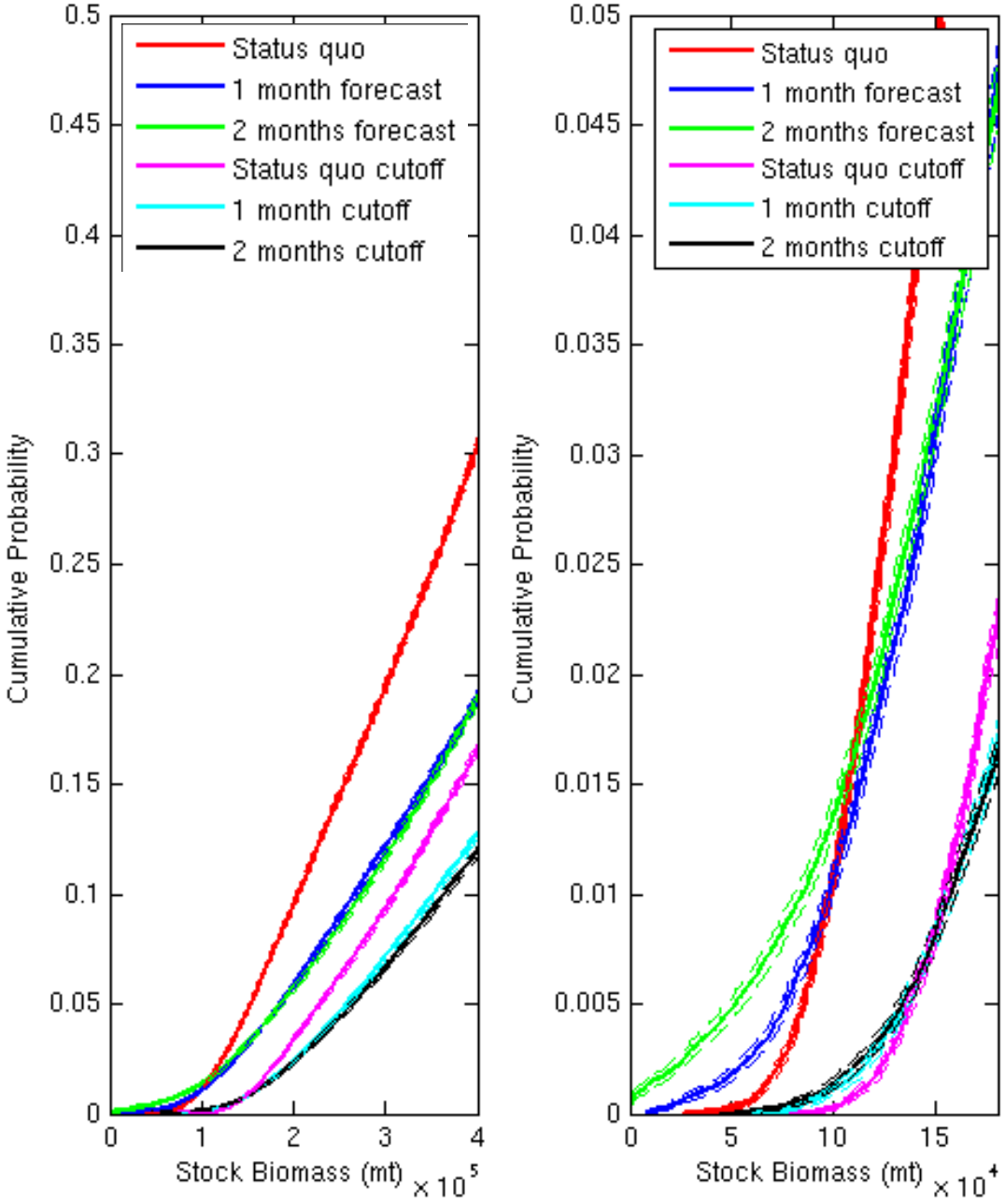
- Incorporation of uncertain future SST information increases the probability of “high risk, low probability” events

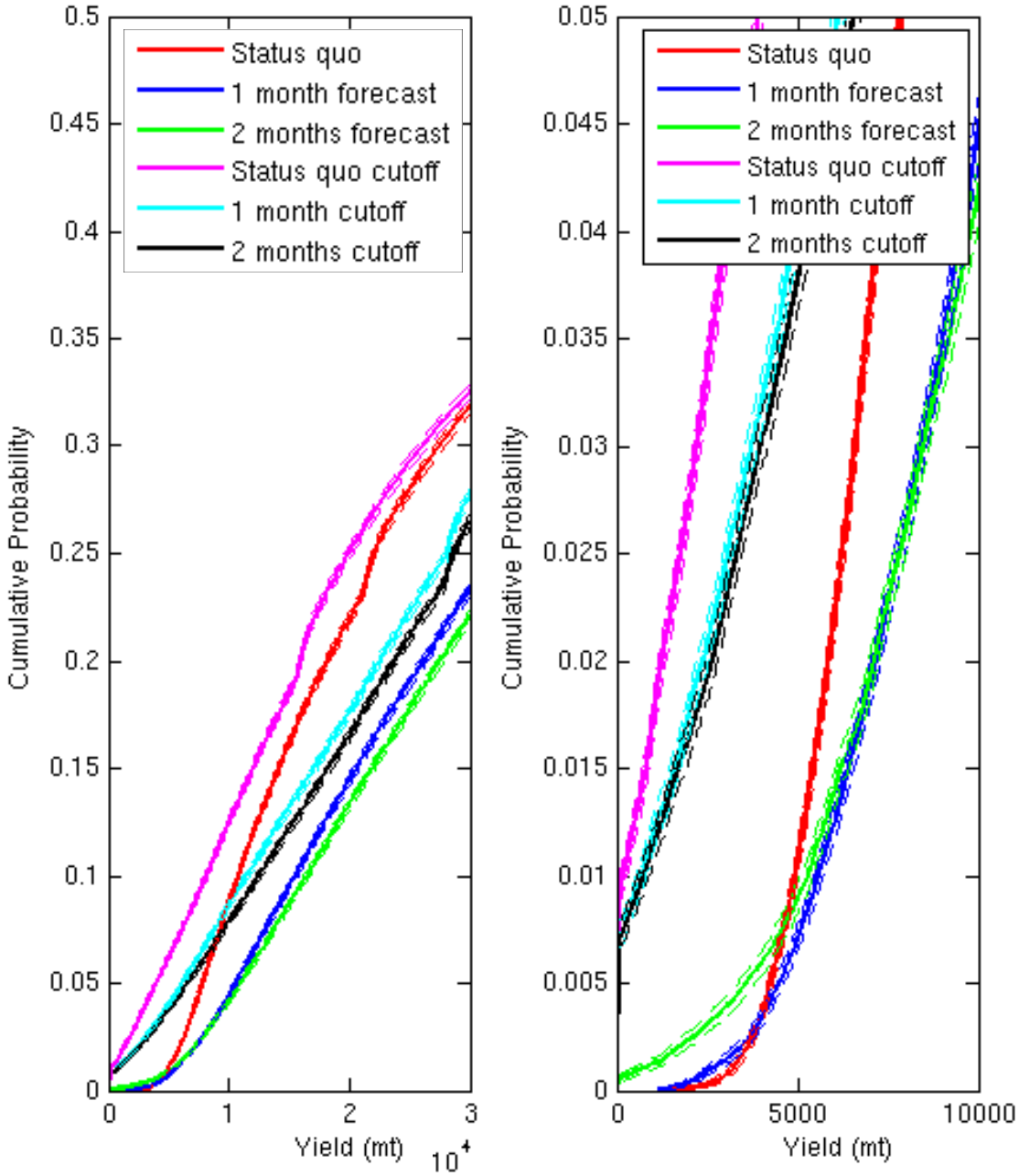
- Introduce harvest cutoff of 150,000 mt

Performance Metrics






Status quo
1 month forecast
2 months forecast
Status quo cutoff
1 month cutoff
2 months cutoff
Cumulative Probability
Stock Biomass (mt)
× 10^5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0
1
2
3
4
Status quo
1 month forecast
2 months forecast
Status quo cutoff
1 month cutoff
2 months cutoff
Cumulative Probability
Stock Biomass (mt)
× 10^4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0
5
10
15


Status quo
1 month forecast
2 months forecast
Status quo cutoff
1 month cutoff
2 months cutoff
Cumulative Probability
Yield (mt)
10^4
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
1
2
3
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
5000
10000

Conclusions

- Integrating future stock biomass information into HCR:
  - Increases mean long-term biomass and yield
  - Long-term variability remains comparable
  - Lower probability of yield and stock biomass falling below threshold
- HCR should include biomass cutoff to safeguard from increased probability of biomass falling to extremely low levels
- Results lead time dependent

Thank you

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