Using nonstationary stock assessment models to diagnose meaningful ecosystem indicators

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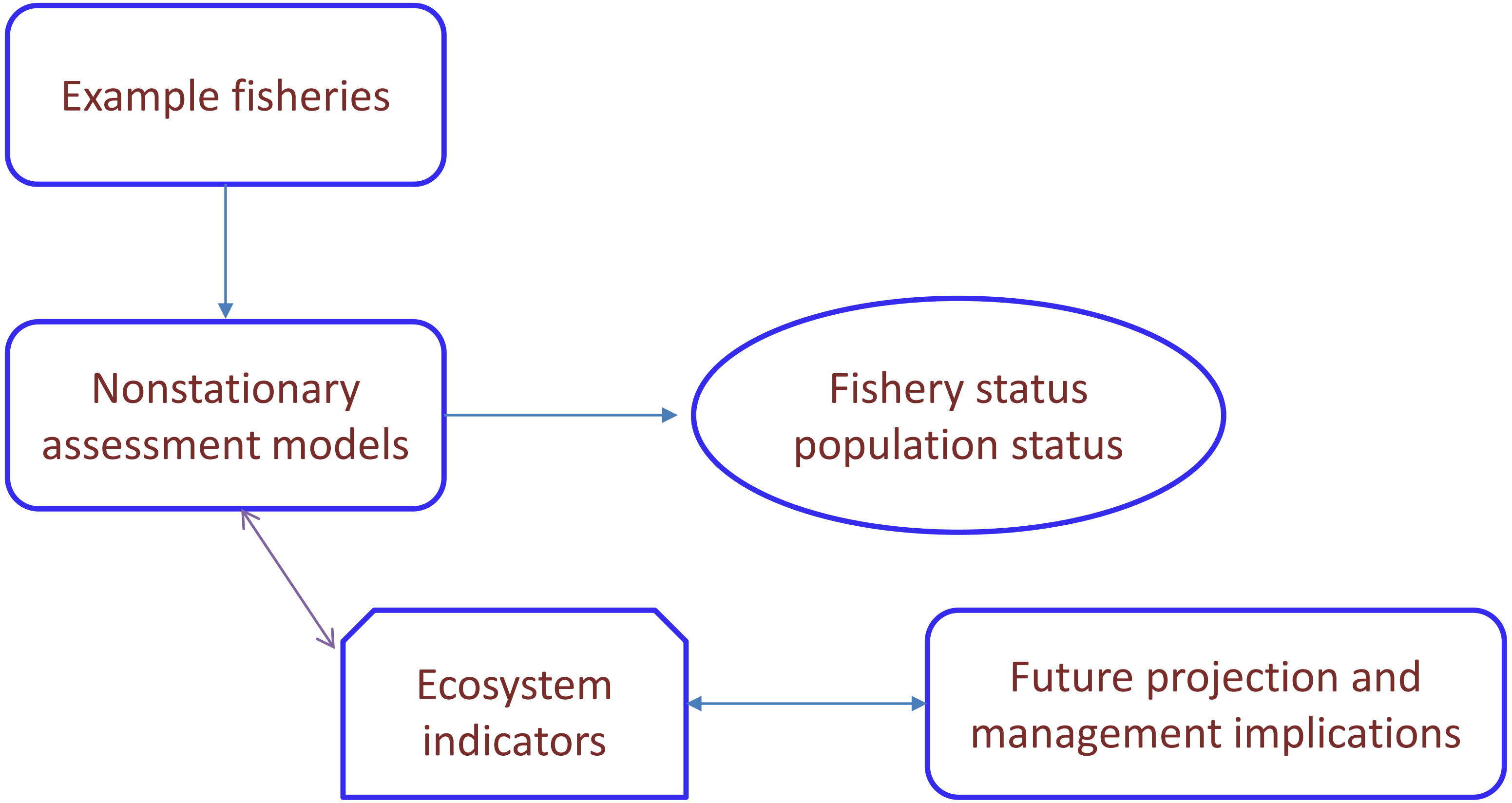
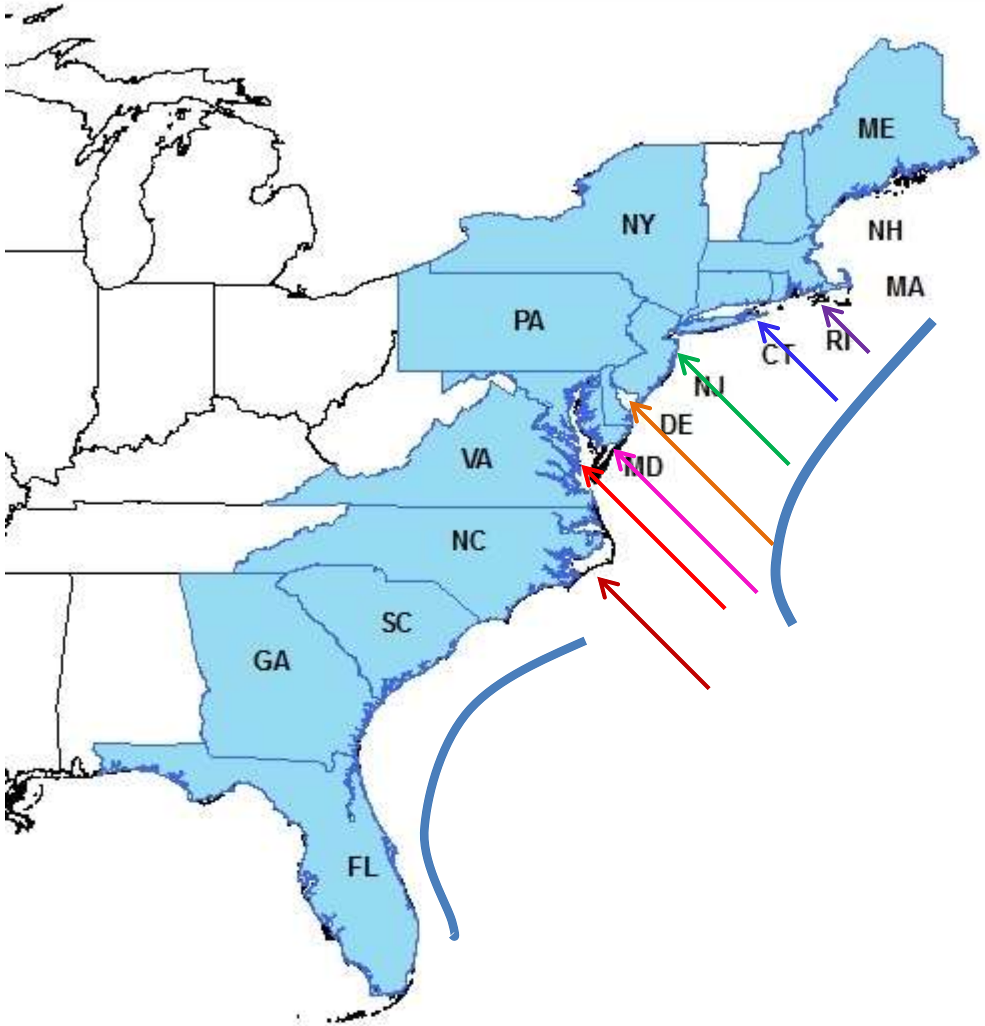
Background

- Rationale of nonstationarity in spatial and temporal dynamics
  - Species interaction (example weakfish related studies ASMFC 2006; NEFSC 2009)
  - Environmental impact
  - Intrinsic biological processes
- A strategy of ecosystem considerations ~ unclear driving factors or inconsistent correlations
  - **Inconsistent abundance indices in trends**
  - **Likely changed population productivity, key life-history processes, and spatial distribution**
- Challenges in using nonstationary stock assessment models for management purposes

Outline


Example fisheries
Nonstationary assessment models
Fishery status population status
Ecosystem indicators
Future projection and management implications

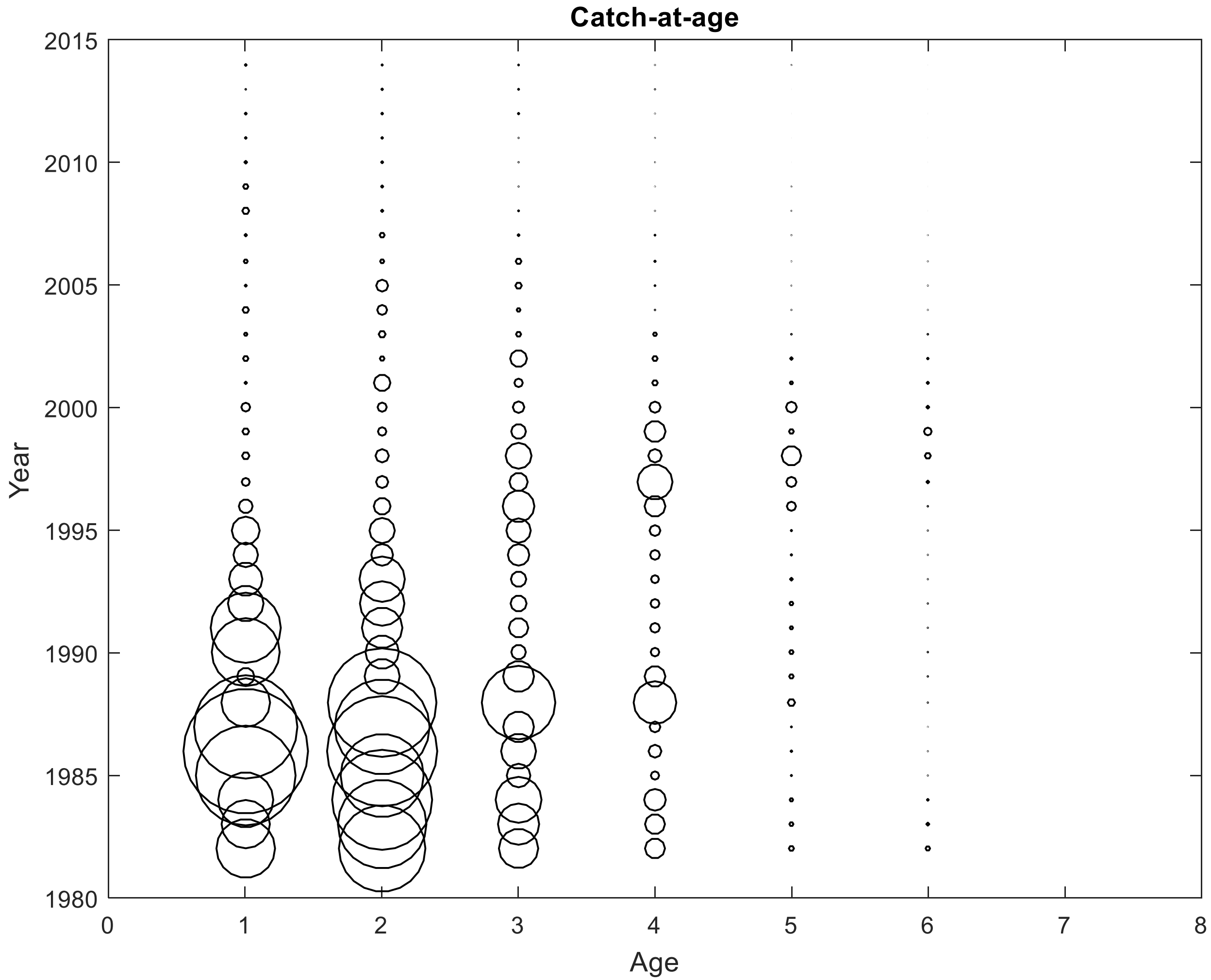
Atlantic weakfish fishery



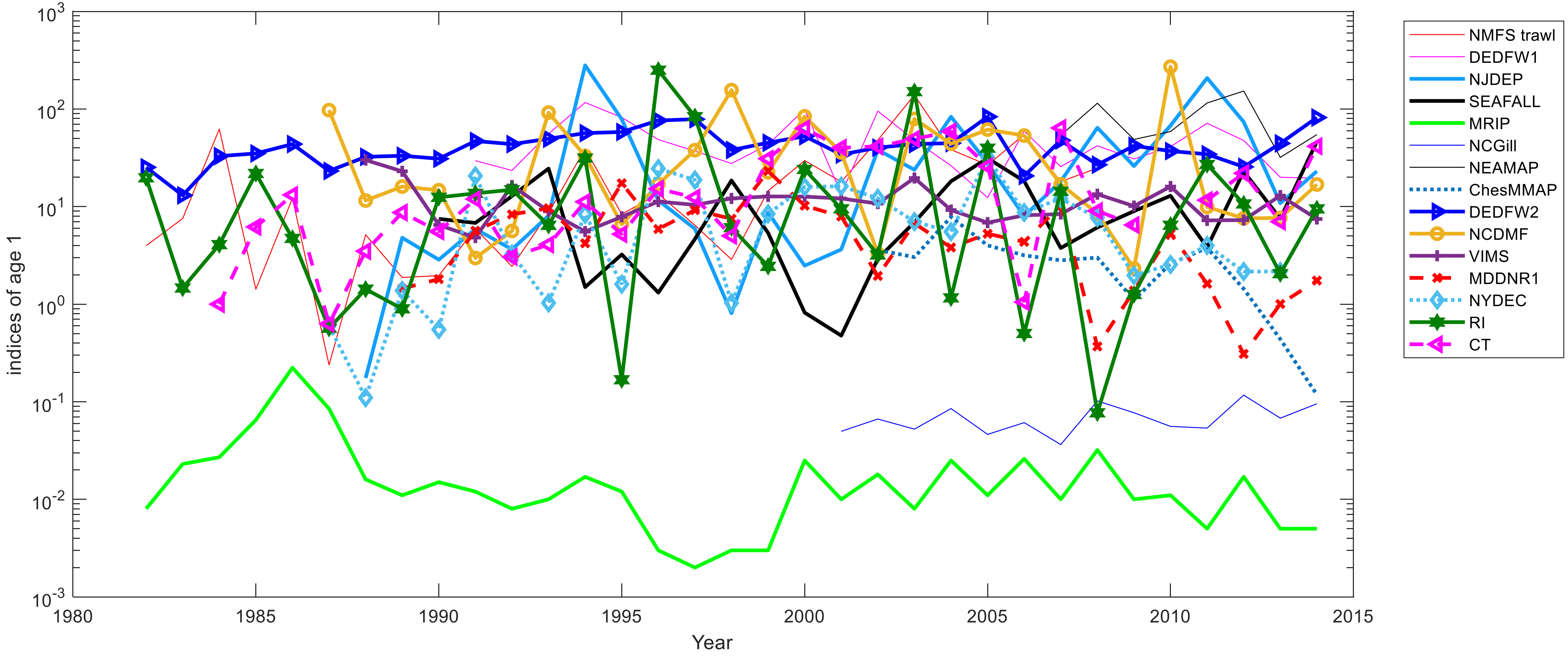
Data

- Catch (recreational + commercial + discarding)
- Relative abundance indices
  - Age 1+ (age structured; 6 by 2007 and 8 in 2019)
  - YOY (7 age 0 indices in year t, used to calibrate age 1 in year t+1)

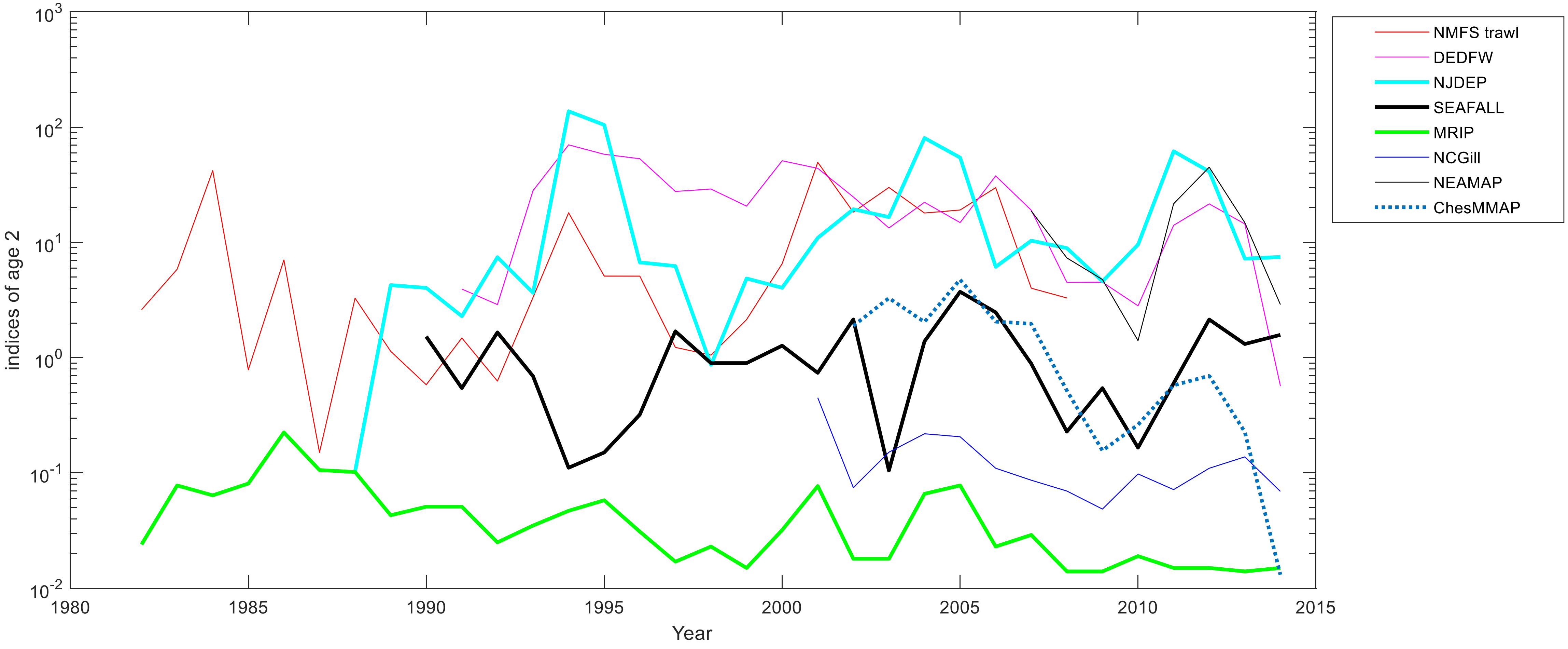
Data - Catch


Catch-at-age
Year
Age
2015
2010
2005
2000
1995
1990
1985
1980
0
1
2
3
4
5
6
7
8

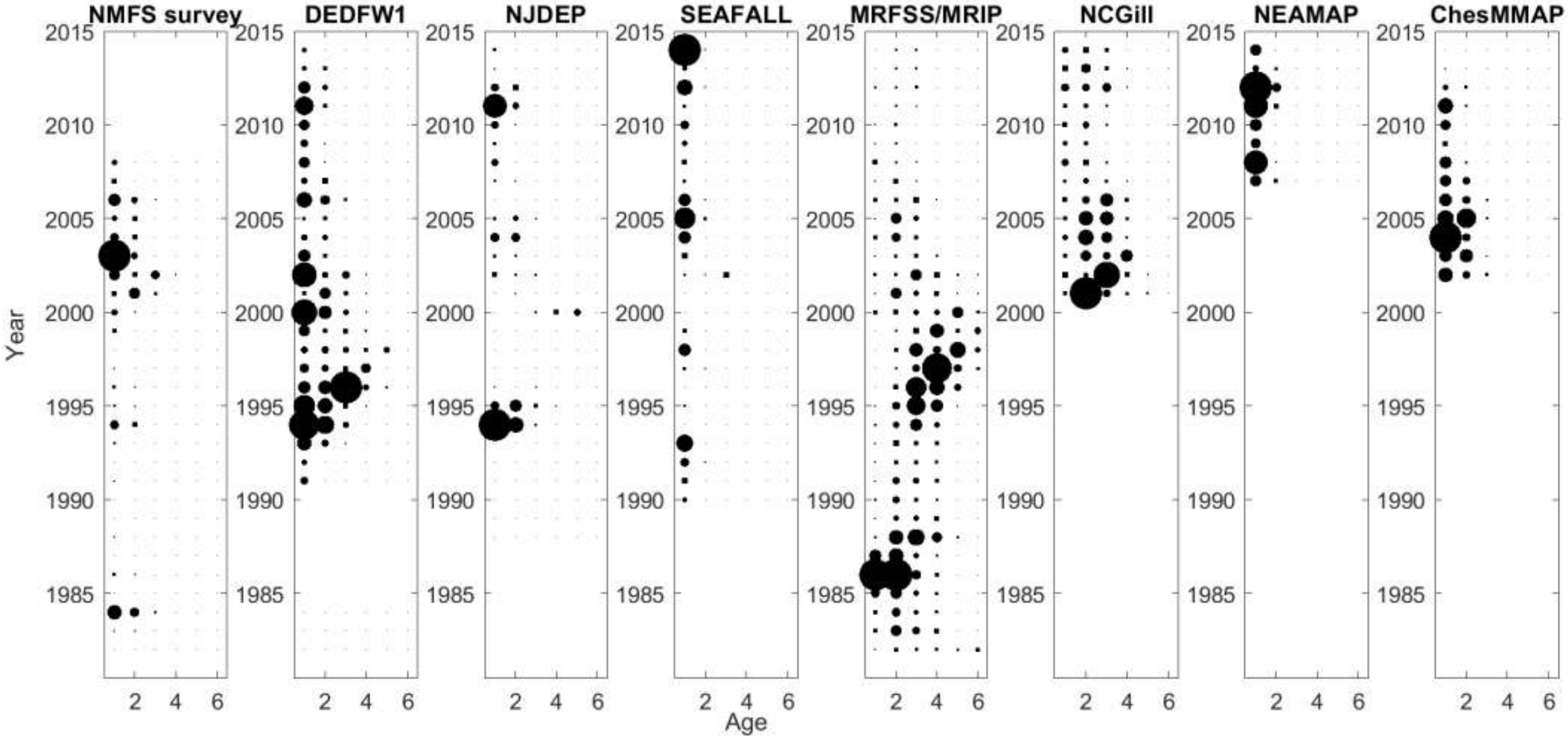
Data – relative abundance indices



Data - relative abundance indices



Data - relative abundance indices

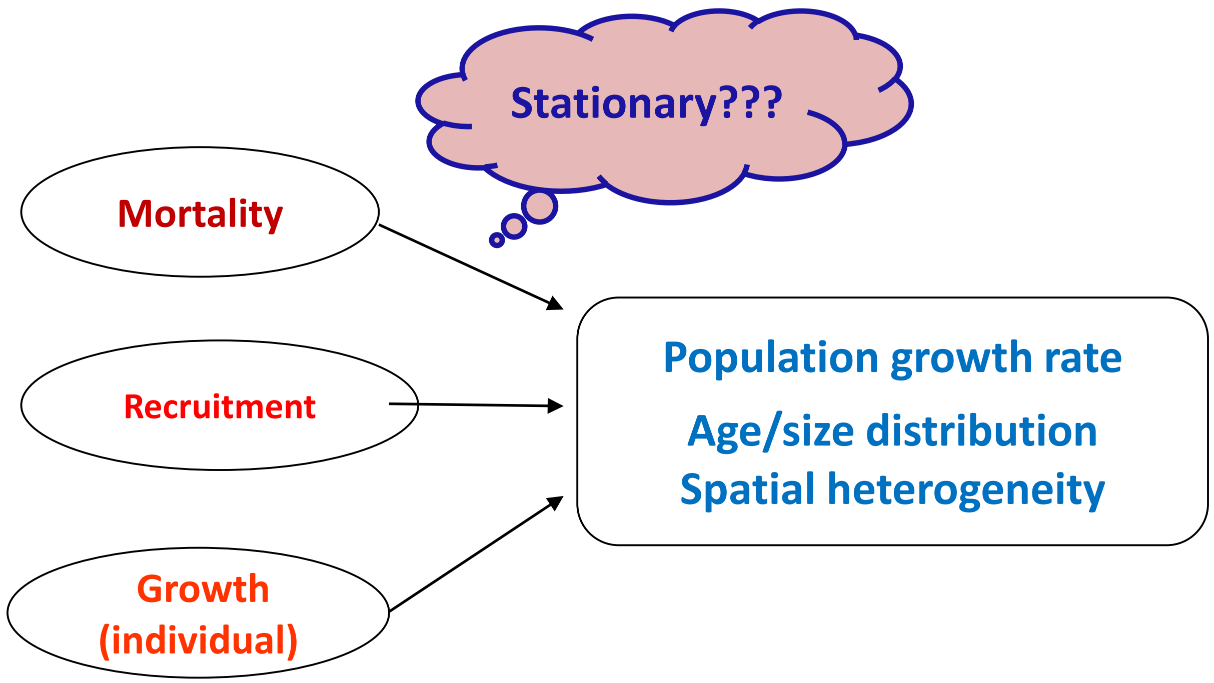


Relative abundance indices correlations (after standardization)

NMFS	MRFSS	SEAMAP	RI	NJ	DE	MD	NC
1	-0.117	0.201	0.212	0.139	0.179	-0.254	-0.716
	1	-0.383	-0.091	0.321	0.688	0.074	0.495
		1	0.152	-0.053	-0.159	-0.195	0.153
			1	0.293	0.213	-0.158	0.180
				1	0.259	-0.172	-0.168
					1	-0.334	0.544
						1	0.155
							1

Nonstationary population dynamics

- How to reflect/model nonstationary dynamics in age structured models?



SCA models to start

Need to develop new nonstationary models which can test the hypotheses of nonstationary spatial dynamics? Also changes in M

$$Ln(N_{a+1,y+1}) = Ln(N_{a,y}e^{-F_{a,y}-M})$$

$$Ln(C_{a,y}) = Ln[\frac{F_{a,y}}{F_{a,y}+M}N_{a,y}(1-e^{-F_{a,y}-M})]+\varepsilon_C$$

$$F_{a,y} = F_y S_a$$

$$Ln(I_{j,a,y}) = Ln(q_{j,a}N_{a,y})+\varepsilon_{j,1}$$

$$N_{a=1,y} = R_y$$

New models to test spatial asynchrony hypotheses

Models on spatial nonstationarity	
M1	Statistical catch-at-age model (SCA) {Assume surveys are independent and represent population trend}
M2S	A random effect SCA model (RSCA) {Assume survey areas as random factors}
M3S	A Conditional Autoregressive (CAR) SCA model (CARSCA) {Assume neighboring areas have similar trends and influence each other}
M4S	A spatial hierarchical SCA model with variance a function of the distance (SHSCA) {Assume trends of all the areas are correlated, with the correlation larger if the distance closer }

Jiao et al 2016.

New models to test M hypotheses

Models on M temporal changes	
M1	SCA with constant known M
M2M	SCA with M unknown with white noise
M3M	SCA with age-specific M unknown with white noise
M4M	SCA with M_y unknown and follow random walk process
M5M	SCA with age-specific M unknown and follow random walk process

Jiao et al 2012.

Method - models

1. Statistical catch-at-age model (SCA) with natural mortality (M) fixed, and all survey indices (Is) independent and proportional to total population size (N) (**M1**);
2. SCA with M changing over time and following a random walk process (**M2 = M4M**);
3. SCA with M fixed, but Is represent spatial asynchrony of the population distribution (**M3 = M2S**);
4. SCA model with M changing over time and following a random walk process, and Is represent spatial asynchrony of the population distribution (**M4 = hybrid of M4M and M2S**).

* SCA with M changing over time and estimated through a change point models (M2C);

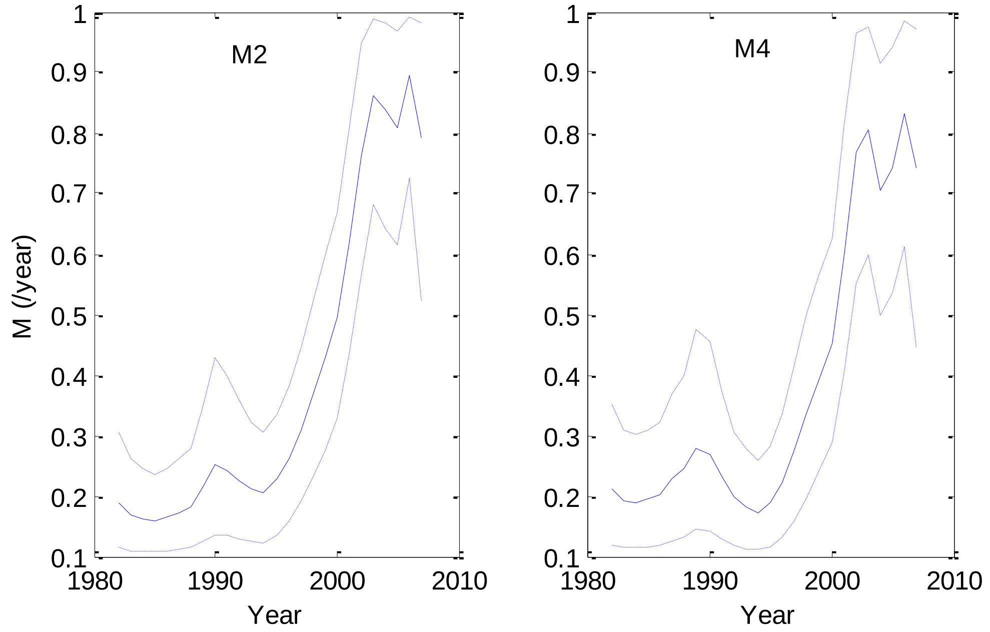
* SCA model with M changing over time and estimated through a change point models, and Is represent spatial asynchrony of the population distribution (M4C).

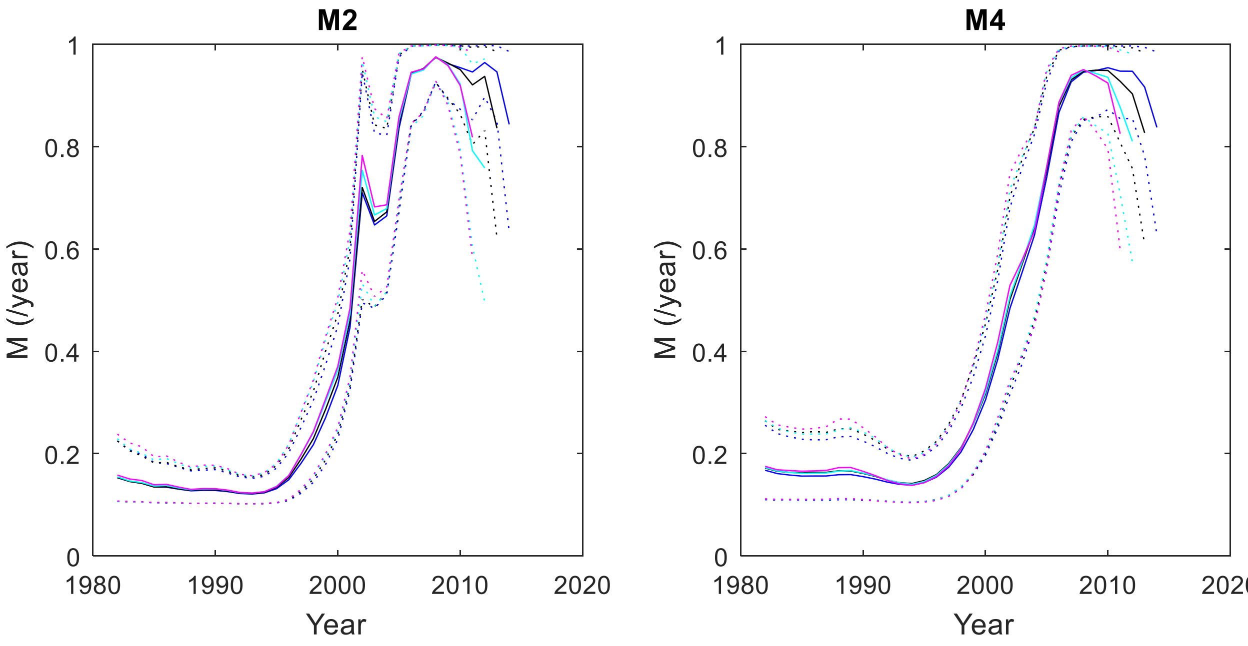
References: Jiao et al. (2012; 2016) ICES J. Mar Sci. ASMFC 2015, 2019.

Estimation approach and model comparison

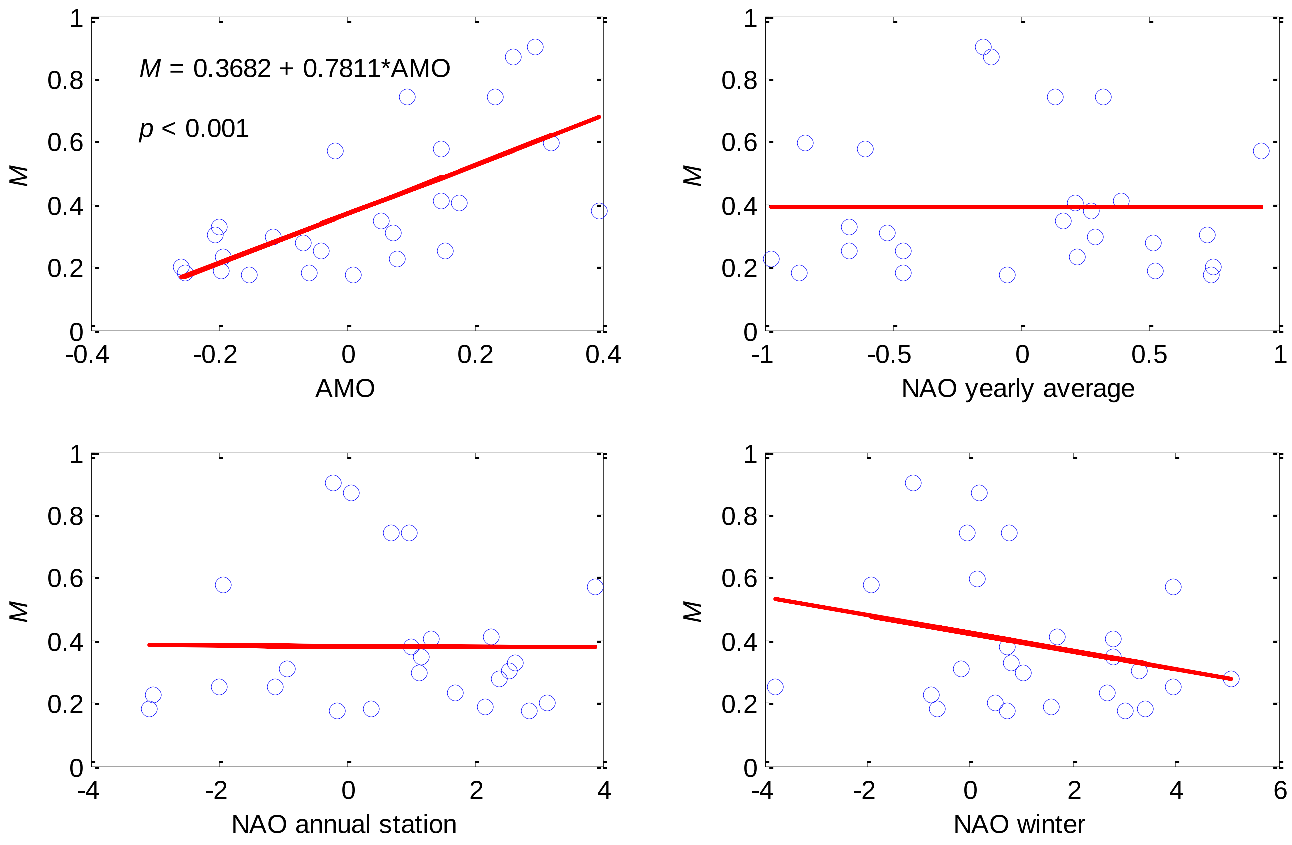
- Estimation approach
  - Bayesian approach
- Model comparison and posterior model selection
  - Deviance Information Criterion (DIC)
  - Retrospective error
  - Predictive ability
    - Predictive probability
    - The better the predictive ability the closer p_a value to 0.5

Results – M


M2
M4
M (/year)
Year
1980
1990
2000
2010
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

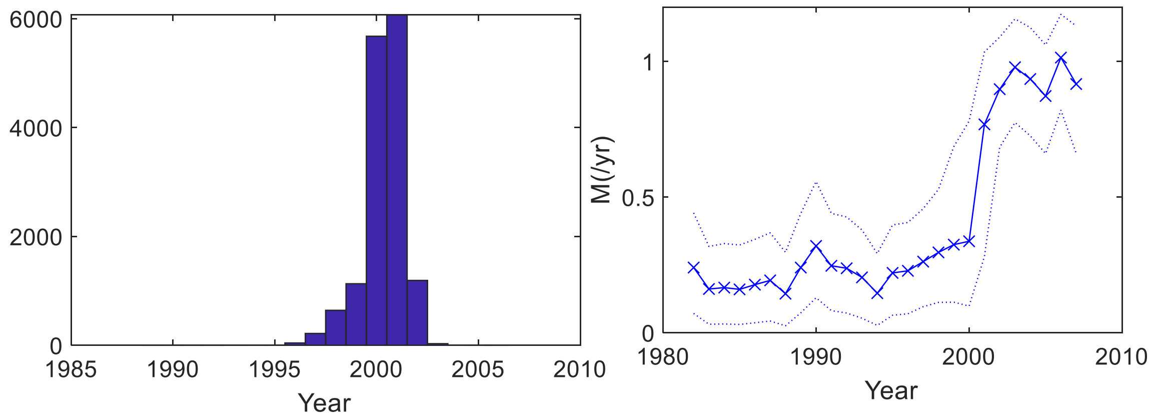

M2
M4
M (/year)
Year
1980
1990
2000
2010
2020
0
0.2
0.4
0.6
0.8
1

Results – M

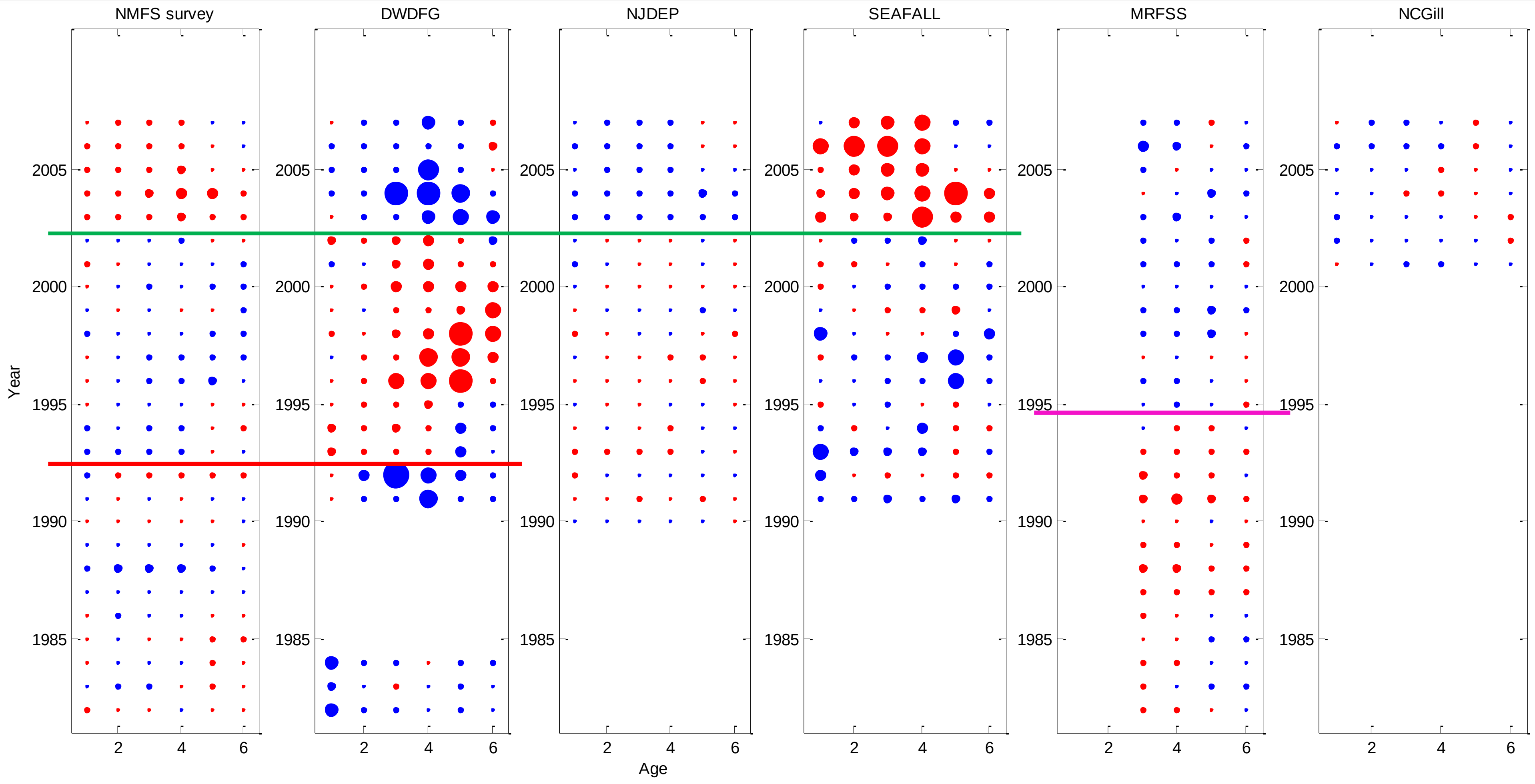


Models to change nonstationary models to stationary models

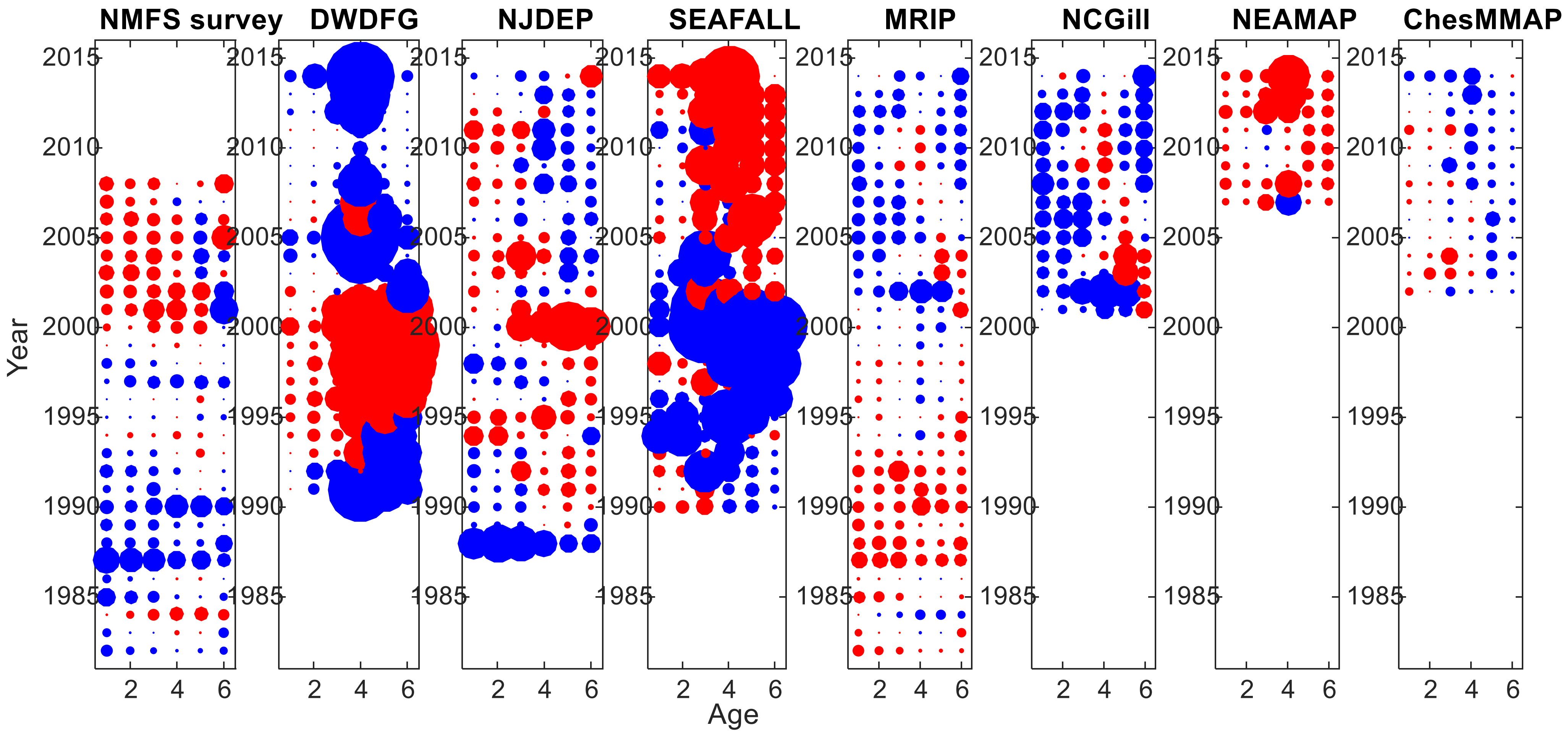
1. Include environmental factors in the models
2. Based on the pattern to recognize trends and shift



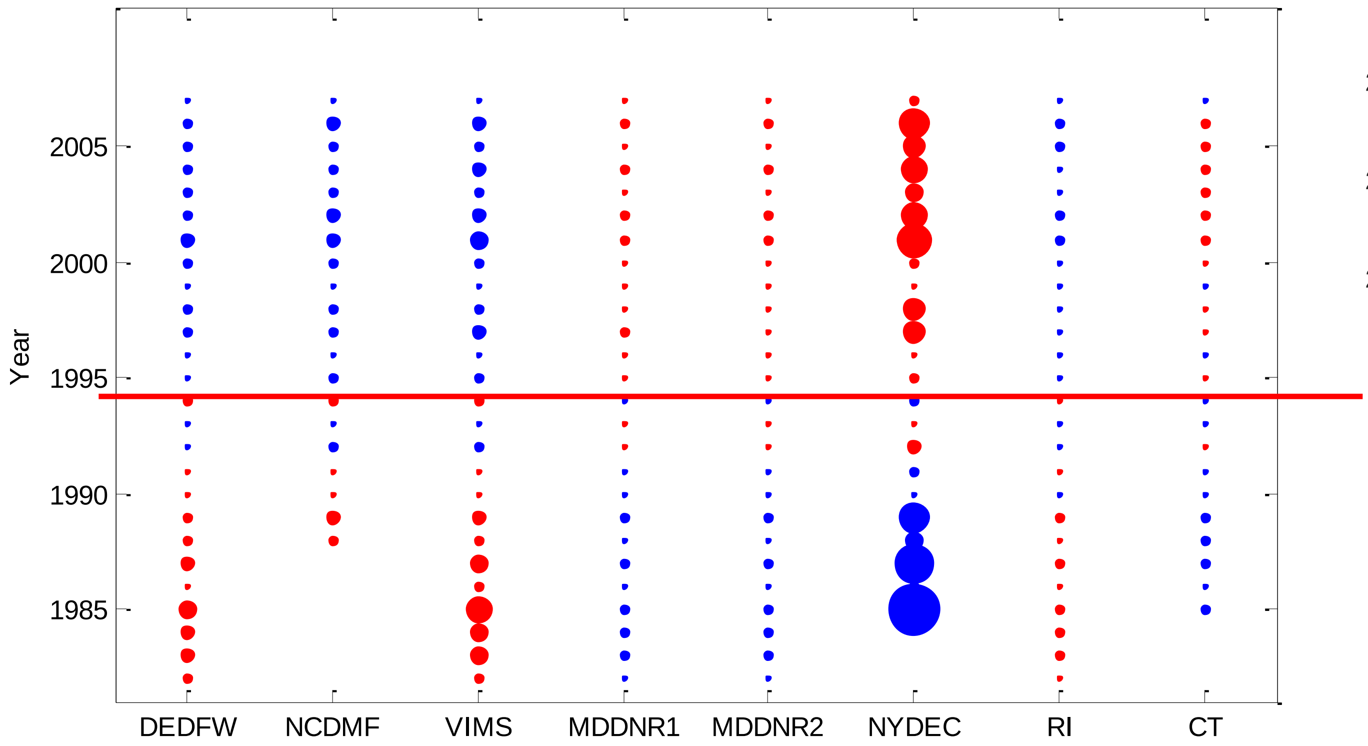
Results (spatial synchrony/asynchrony)

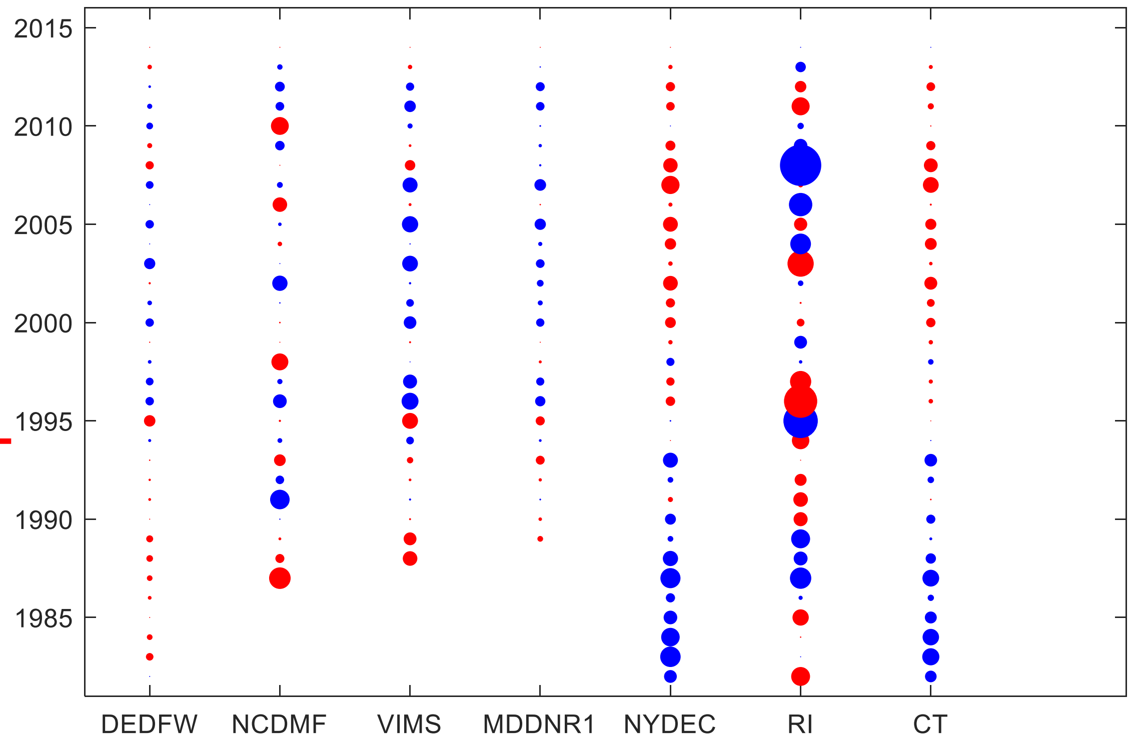


Results – (spatial synchrony/asynchrony)

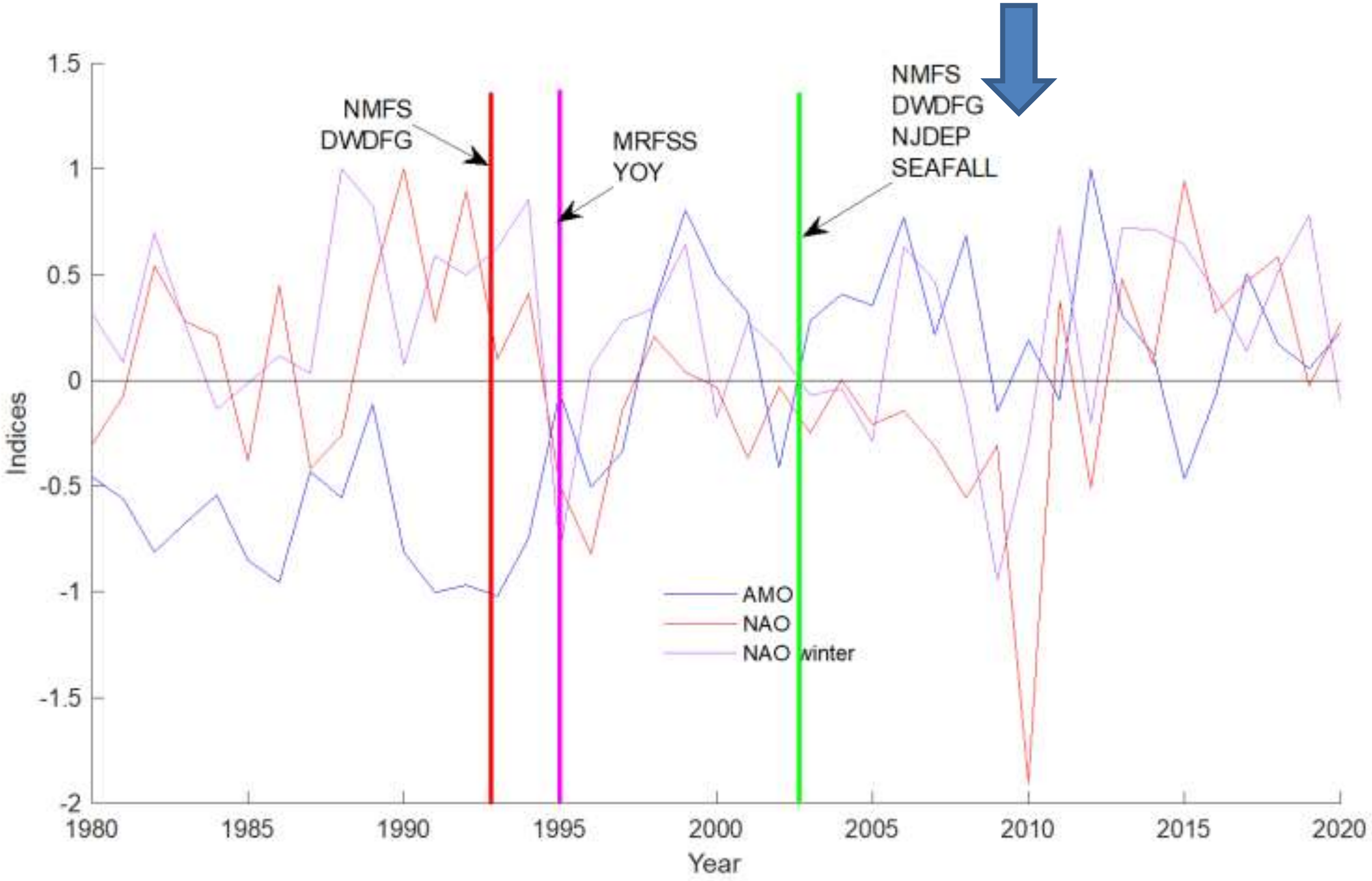


Results (spatial synchrony/asynchrony)

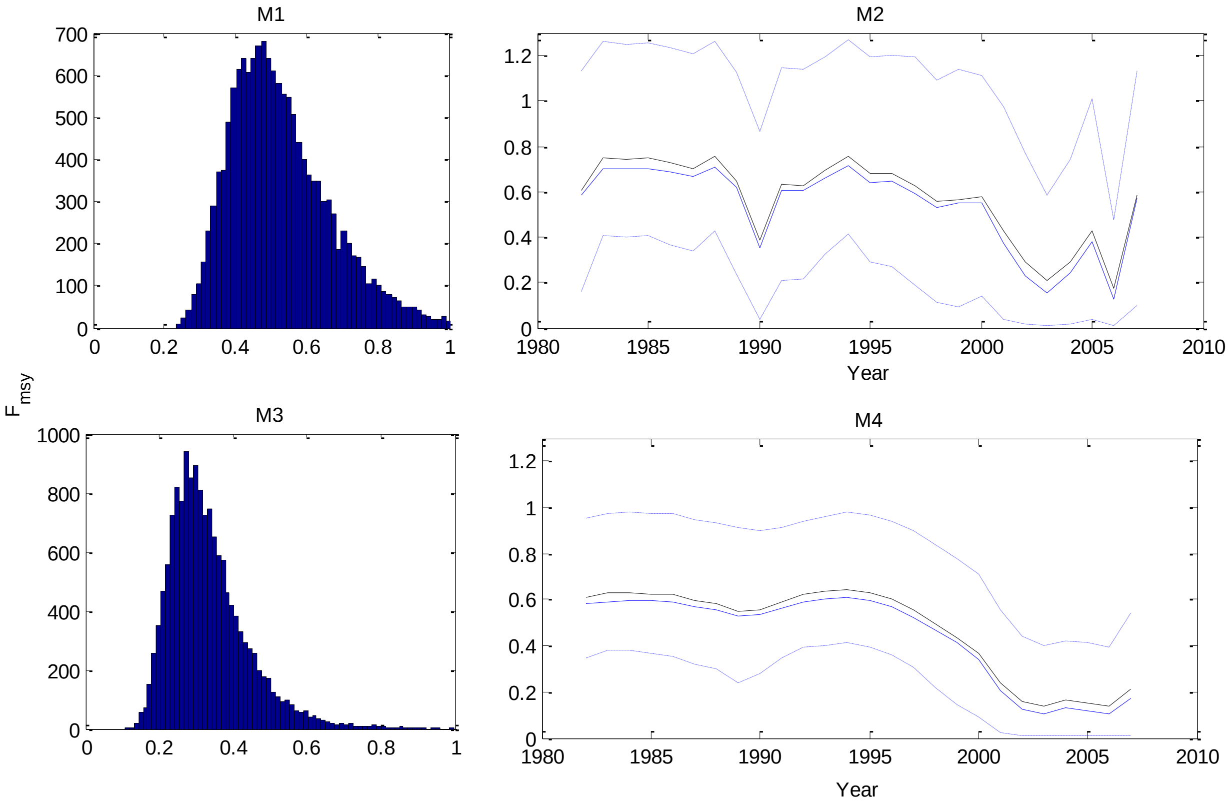


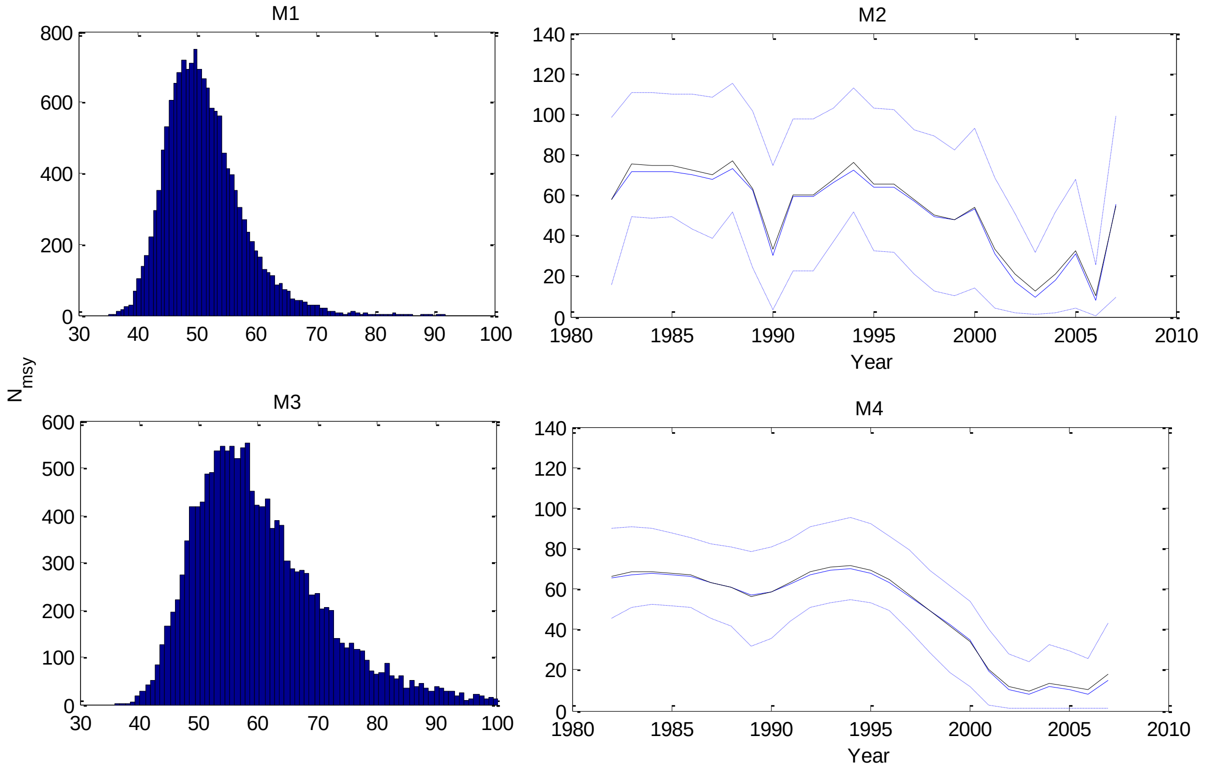


Results (Environmental indicators)

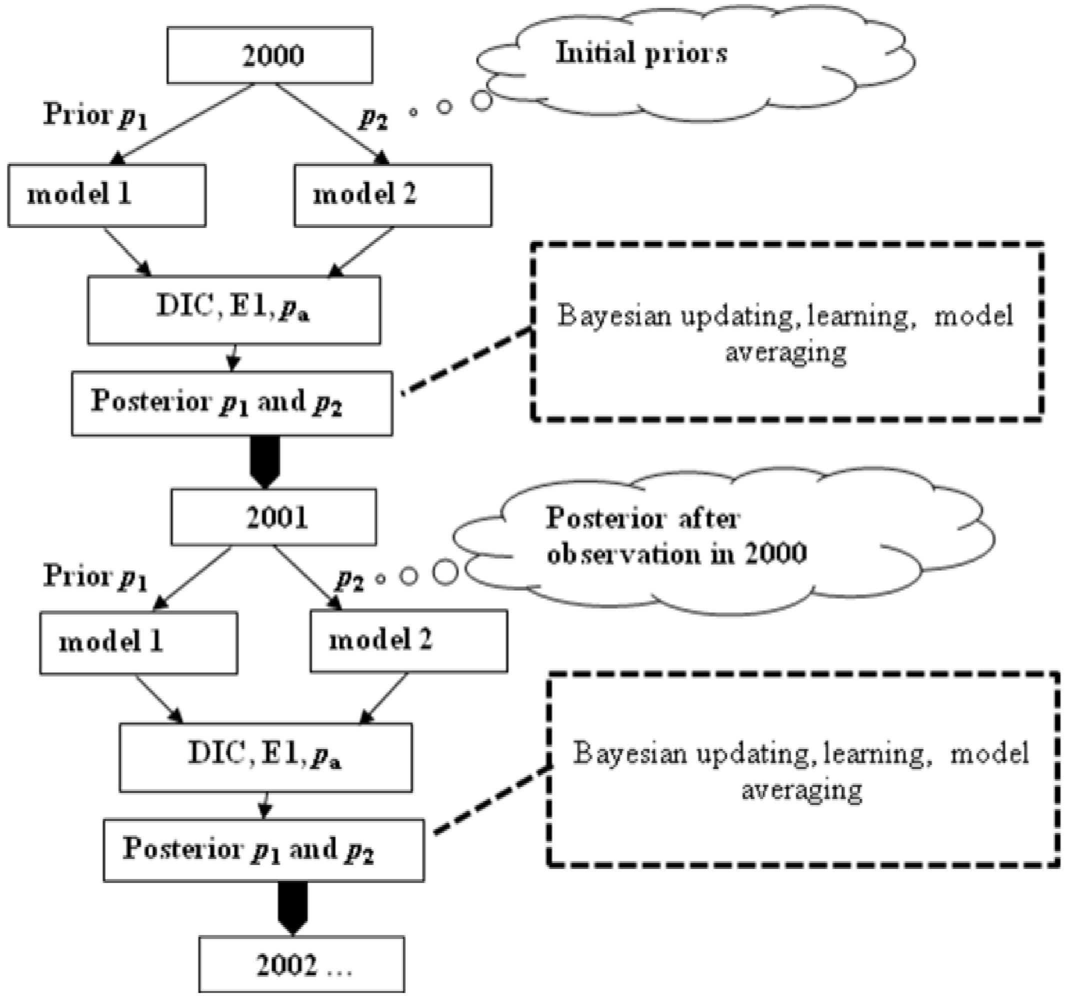


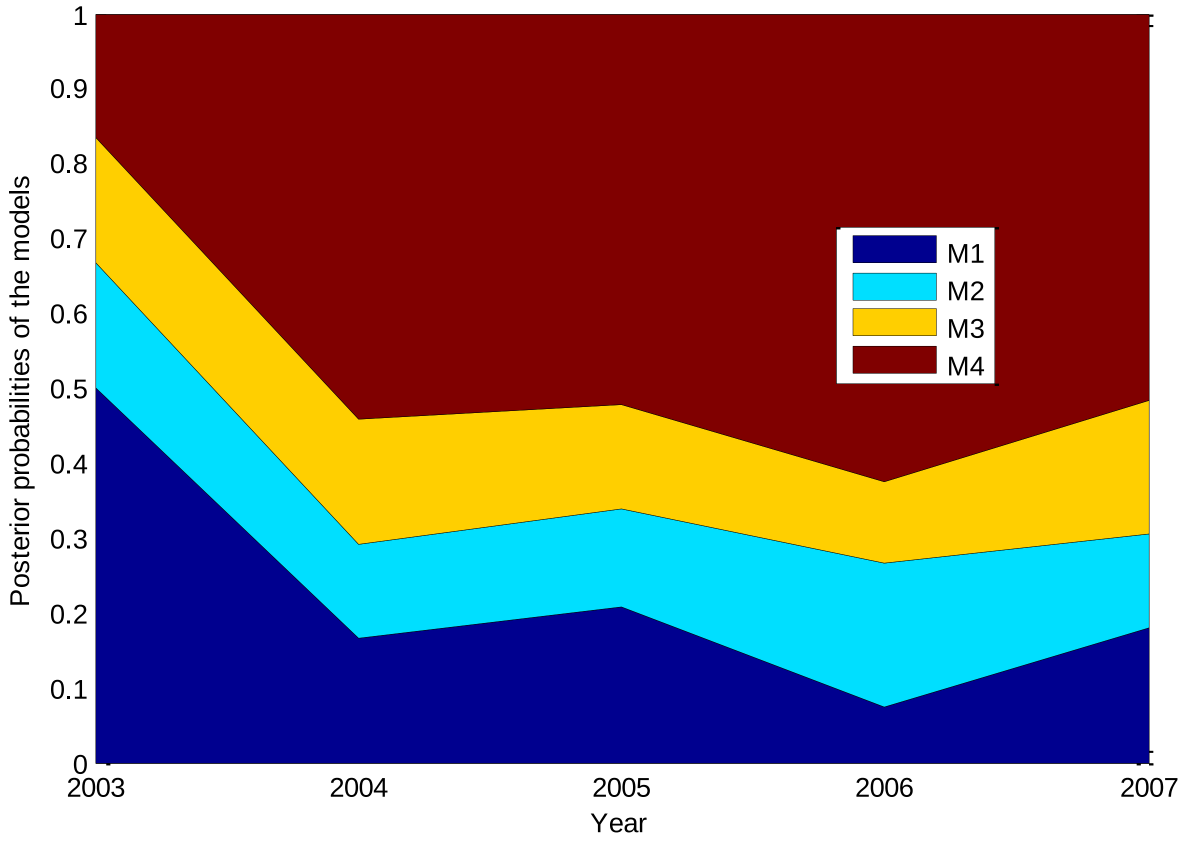
Results (BRPs)



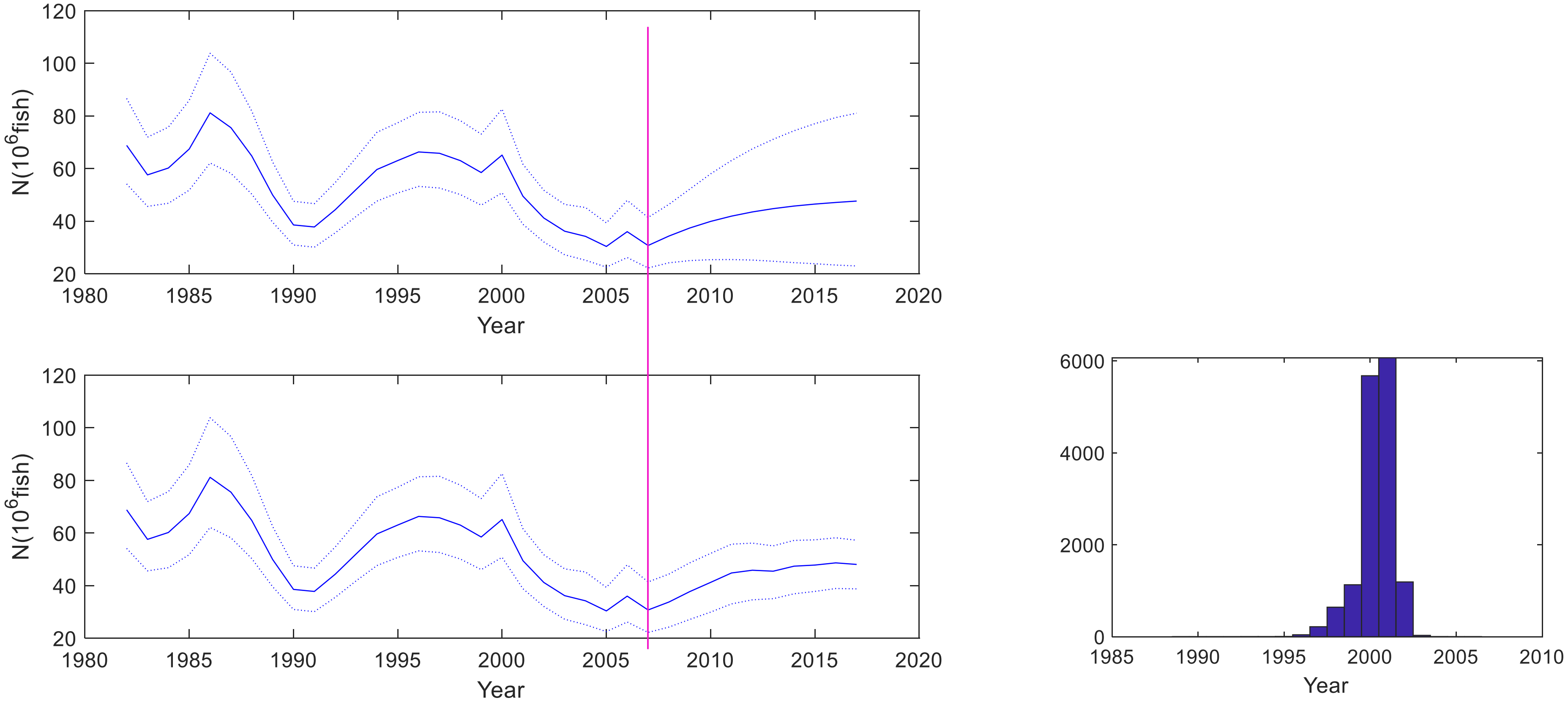


Results (posterior probabilities of the models)





Results (projection for management purposes)



Implications of this study

- ❑ Incorporate spatial asynchrony reflected in different surveys is necessary for fisheries stock assessment
- ❑ Nonstationarity can be important in stock assessment when considering the ecosystem effect
  - – We recommend nonstationary SCA models in stock assessment, at least testing such hypotheses
  - – Strategies should be considered when projecting population by changing the nonstationary models to stationary models if possible for management purposes

Implications of this study

For this case study:

- ❑ Weakfish have asynchronous spatial dynamics
  - less influenced by neighboring areas
  - but rather than the unique geographic locations, such as Chesapeake Bay, Delaware Bay, inshore and offshore
  - Can be linked to climate oscillation indices
- ❑ The variation of *M* over time is supported by the data, and further found to be correlated with AMO
  - How AMO and NAO inform M and spatial dynamics can be considered for future management purposes
  - Pattern recognition can be considered/modeled when including nonstationary processes in the models

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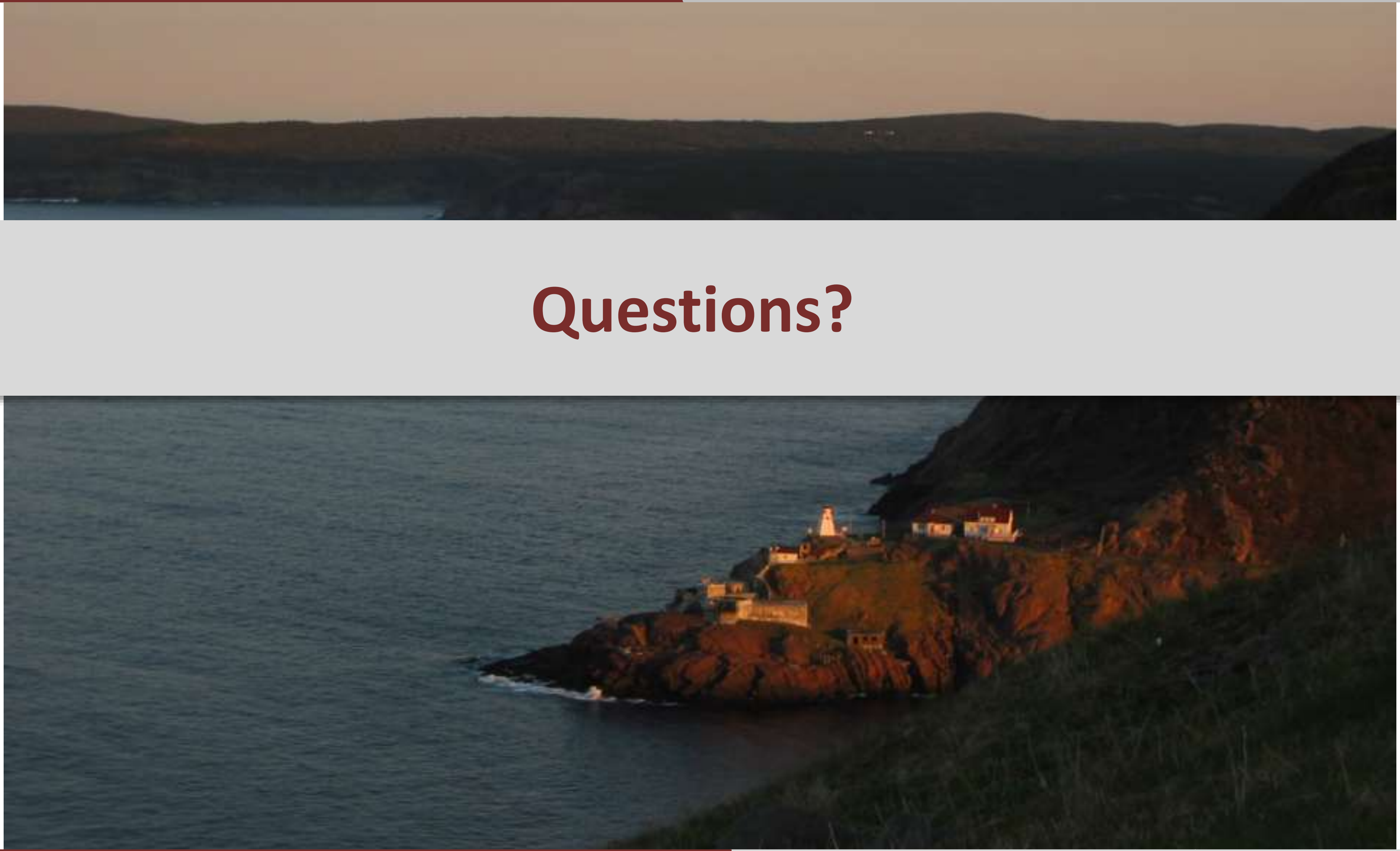

Questions?