

Nonlinear Dynamics and Co-predictability of the Georges Bank Fish Community

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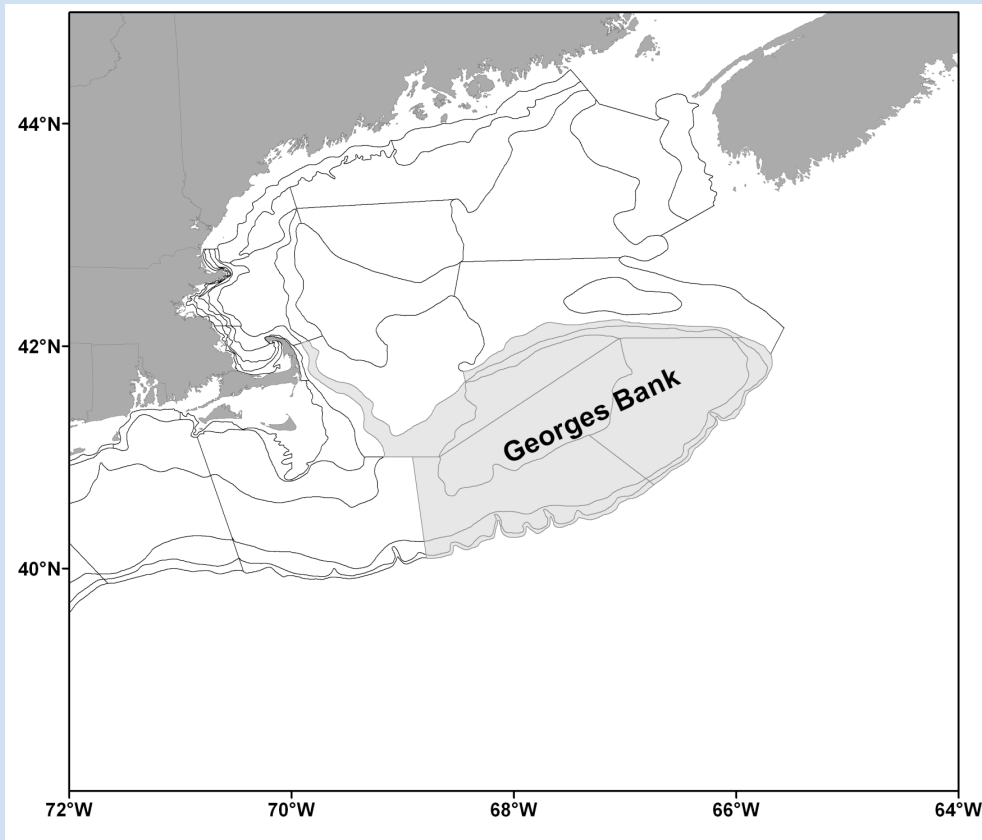
Introduction:

- Nonlinear processes, ecological interactions and environmental forcing cause variability in marine ecosystems
- Recognition of these led to call for development of strategies for EBFM, such as through IEA, and Modeling
- Model uncertainty remains a dominant problem
- However, nonlinear models (simplex projection and s-map) can be helpful to identify the critical elements of system complexity

Objectives:

- Explore the dynamical features of a 26 fish species system on Georges Bank (GB)
- Using co-predictability to examine the dynamical associations among system components
- Exploring the patterns of co-predictability to determine functional groupings of species to be useful in specifying management units

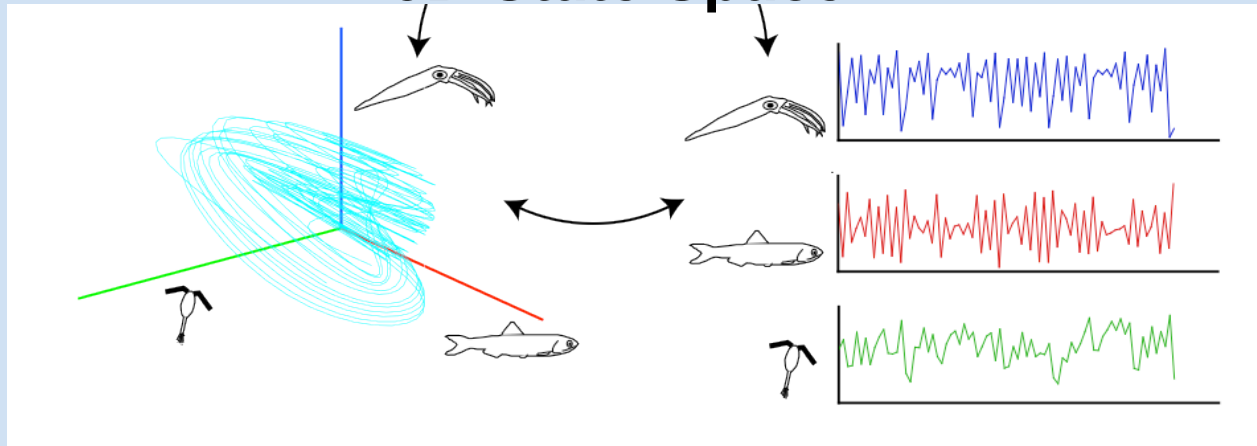
Methods:



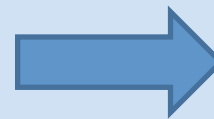
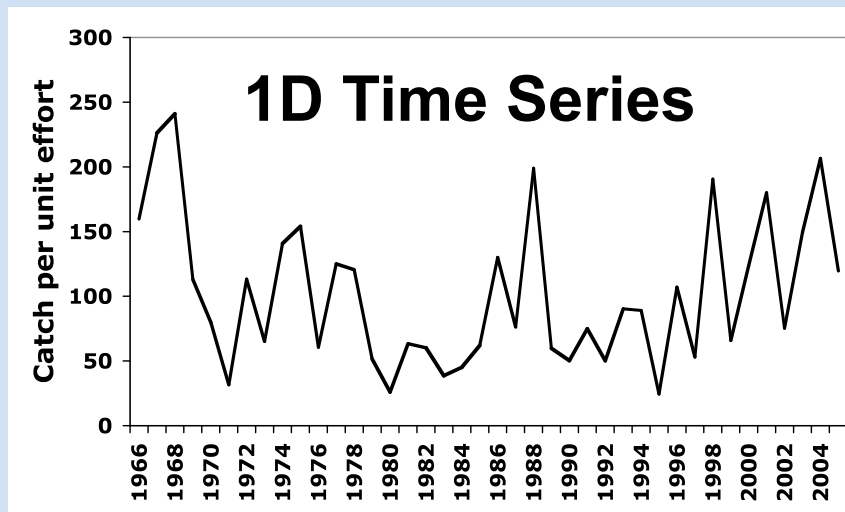
- NEFSC multispecies Bottom Trawl Survey (1963-2008)
- Random sampling design with 11 strata on Georges Bank
- Biomass of 26 fish species adjusted for catch-ability and expanded to the GB area

Nonlinear approaches

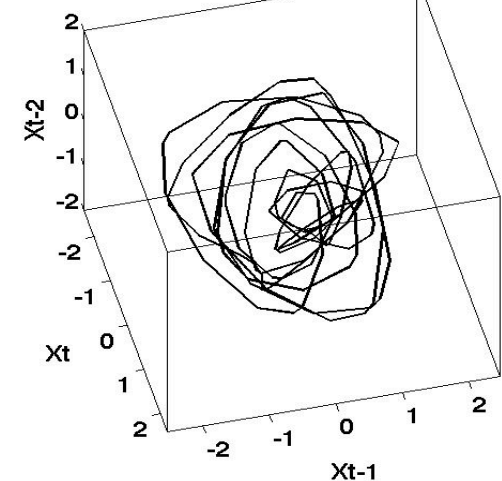
3D State Space



- **State Space Reconstruction (Takens 1981)**



3D Phase Space



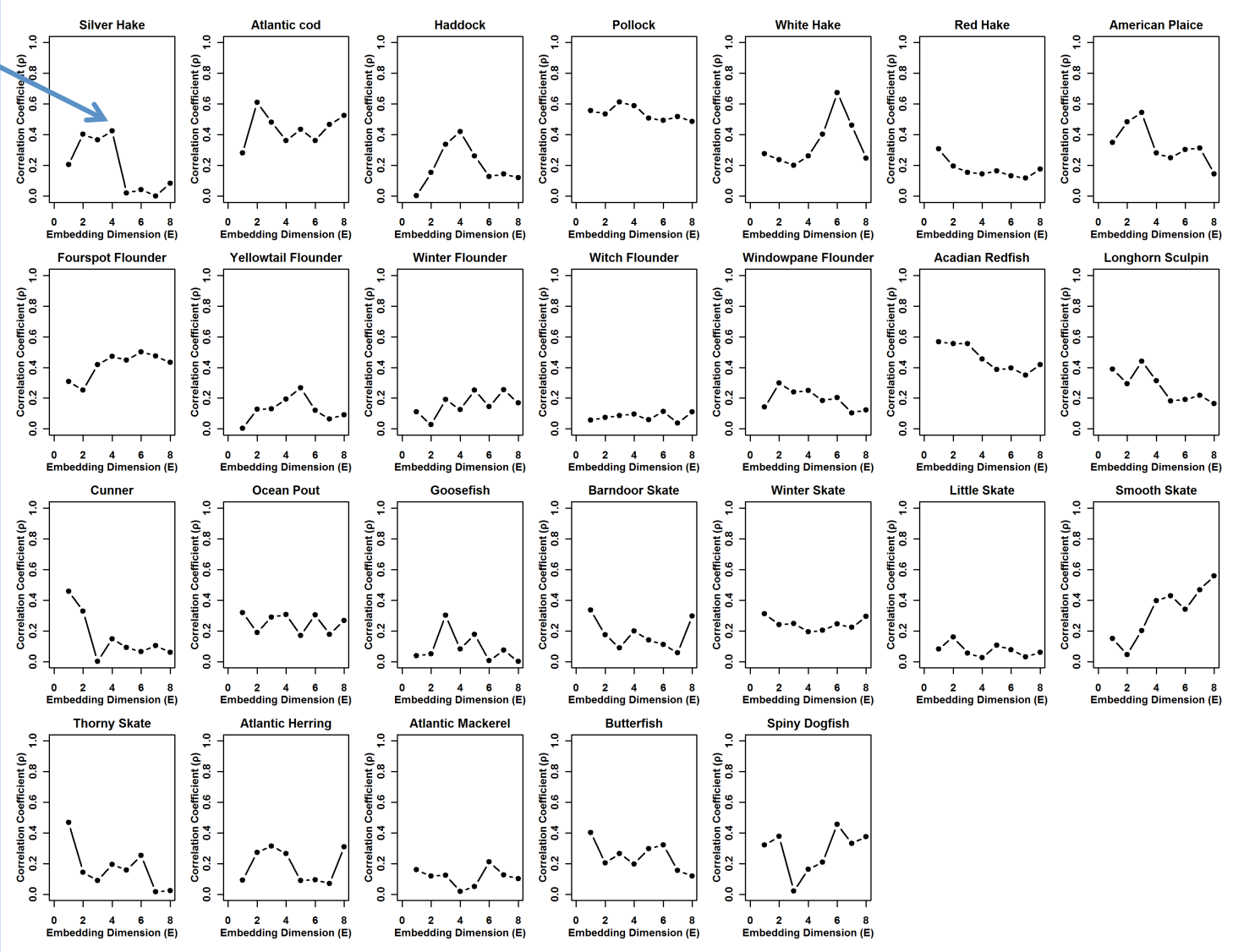
Modeling approaches

- Simplex projection model calculates dimensionality (i.e., complexity) of model (Sugihara & May 1990)
- S-map model determine whether a linear or nonlinear model is “best” (Sugihara 1994)
- Taking the concept of co-predictability (Engle & Granger 1987) to examine dynamical associations between fish species in the Georges Bank system.

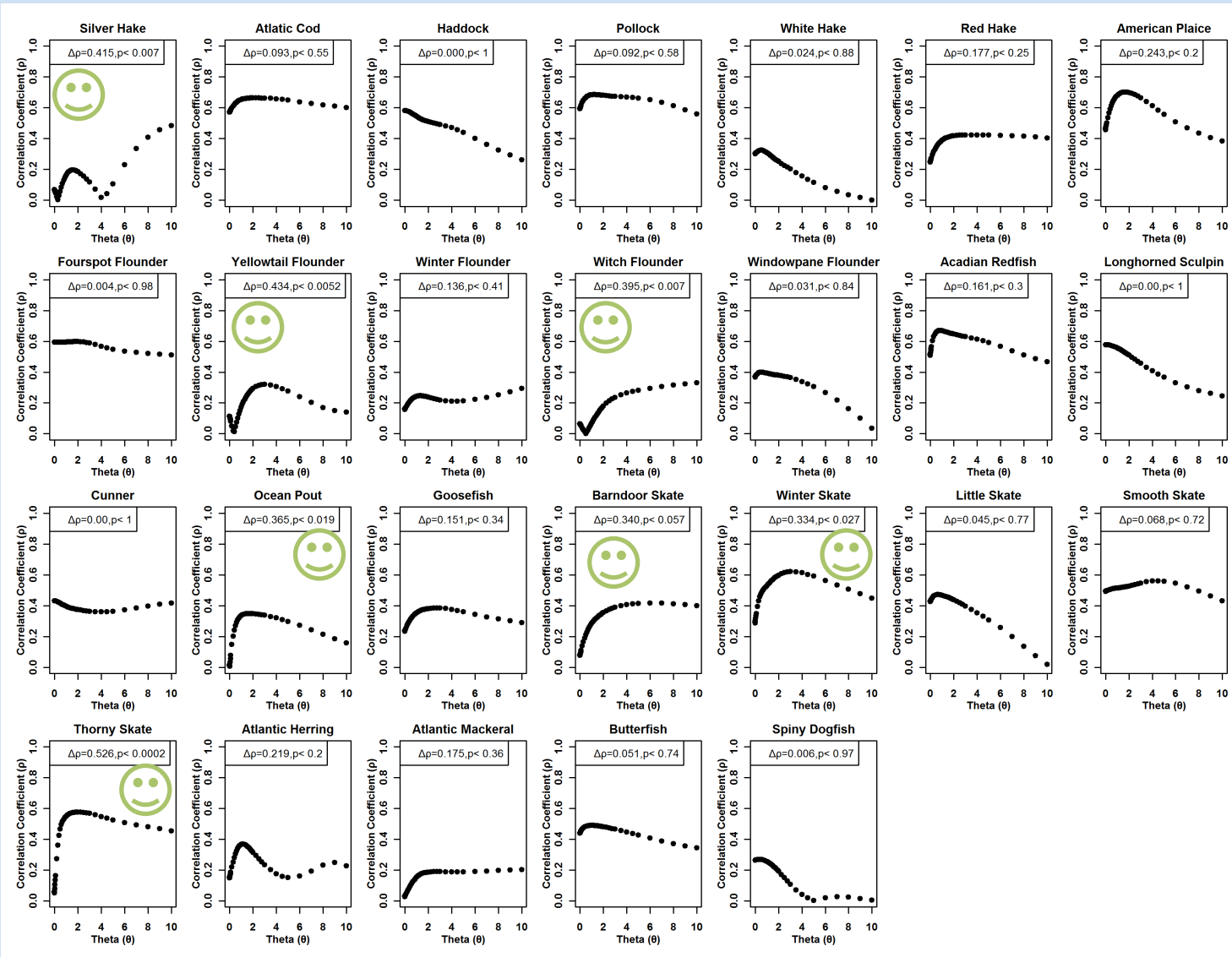
Model predictive skill

- “Best” model chosen by cross-validation or out-of-sample forecast skill i.e. observed versus predicted values
- Model forecast skill = deterministic section + noise
- Modeling philosophy: Correlation does not necessarily imply causation. Likewise, **in a nonlinear system, lack of correlation does not imply lack of causation.**

Results:



Determining the best embedding dimension

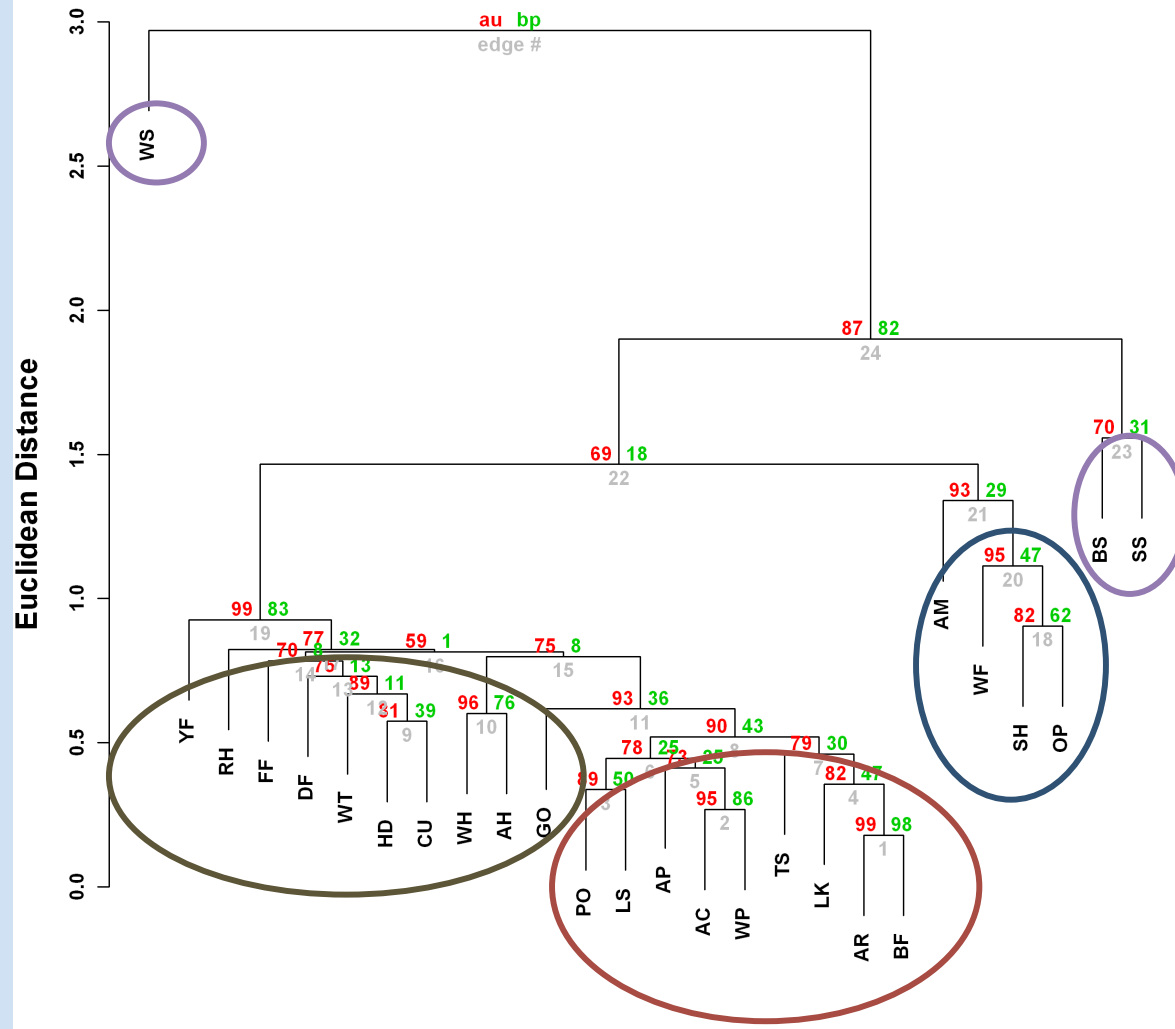


Detecting nonlinear signals in the time series of 26 fish species

Table 2 Dynamic features (with standard deviation in parentheses) of the Georges Bank fish community by taxonomic aggregates

Group	Simplex		S-map				
	Best E	Mean E	Mean ρ at best E	Best θ	Mean θ	Mean ρ at best θ	Mean $\Delta\rho$
Flatfish	2-7	4.8 (1.9)	0.33(0.16)	0.5-10	2.95(3.6)	0.44(0.17)	0.13(0.16)
Gadids	1-4	2.7(1.2)	0.44(0.15)	0.05-10	2.93(3.7)	0.52(0.14)	0.13(0.15)
Other Ground	1-3	1.8(1.1)	0.37(0.08)	0-1.3	0.52(0.54)	0.48(0.14)	0.11(0.16)
Pelagic	1-6	3.3(2.5)	0.31(0.1)	1-10	4.03(5.2)	0.35(0.15)	0.15(0.09)
Skate	1-8	2.6(3.1)	0.37(0.15)	0-4.5	1.44(1.9)	0.53(0.08)	0.13(0.23)
Dogfish	6	6	0.46	0	0	0.27	0

Cluster Dendrogram of the GB Fish Community



Distance: euclidean
Cluster method: average

Conclusions:

- Clear nonlinearity exists for most fish species in the GB fish community
- The low dimensionality imply the system can be modeled with relative small # of critical components
- Co-predictability is helpful for defining the dynamically equivalent groups to be useful for management purpose
- Traditional functional grouping need to consider the dynamic features of system components

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