A predictive modeling approach for single stocks, fish community and fisheries ecosystems

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FATE
Fisheries and the Environment

Challenge in Assessment and Management of Fisheries Resources

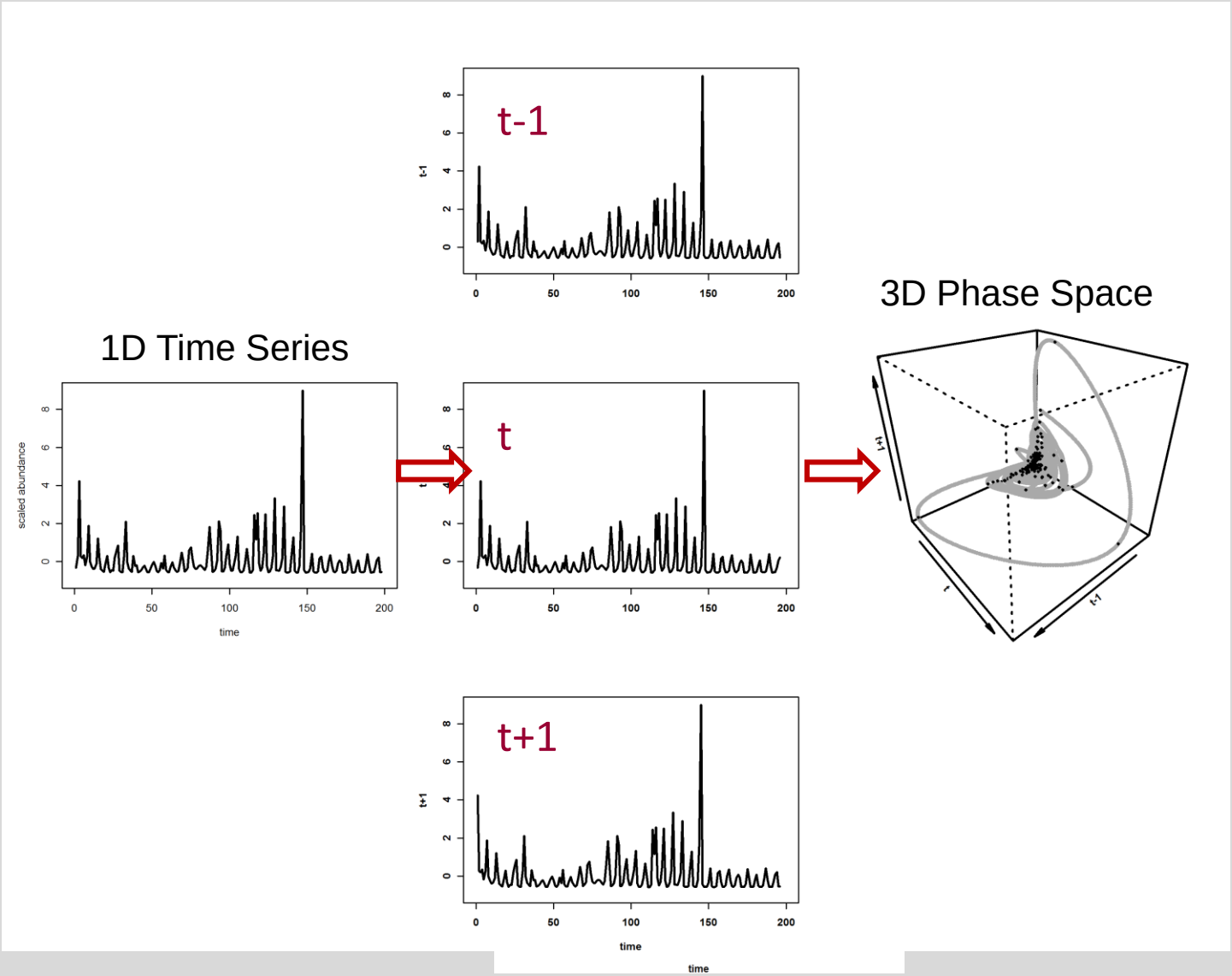
- An important aspect of assessment is the determination of current stock status, exploitation rate (F) and stock size (SSB).
- A lack of perfect knowledge of biological processes affects stock assessment and estimation of reference points.
- Sources of uncertainty: measurement error, process error, model error, estimation error and implementation error.

A New Approach to the Challenge

- A predictive understanding of the dynamics of populations is key to fisheries science.
- The need to specify model structure incorporating ecological processes remains a major source of uncertainty to better predictions of fish stocks.
- Nonparametric methods, such as nonlinear time series (NLTS) models (Sugihara & May 1990, Sugihara 1994) have potentials to avoid these uncertainties.

State Space Reconstruction

Lagged coordinates embedding (Takens 1981)



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Nonlinear dynamic features and co-predictability of the Georges Bank fish community

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Full length article

Forecasting dynamics of red snapper (*Lutjanus campechanus*) in the U.S. Gulf of Mexico

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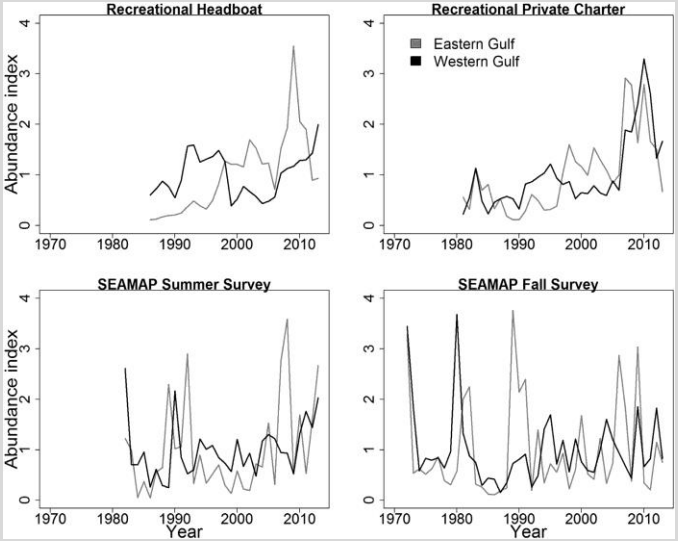
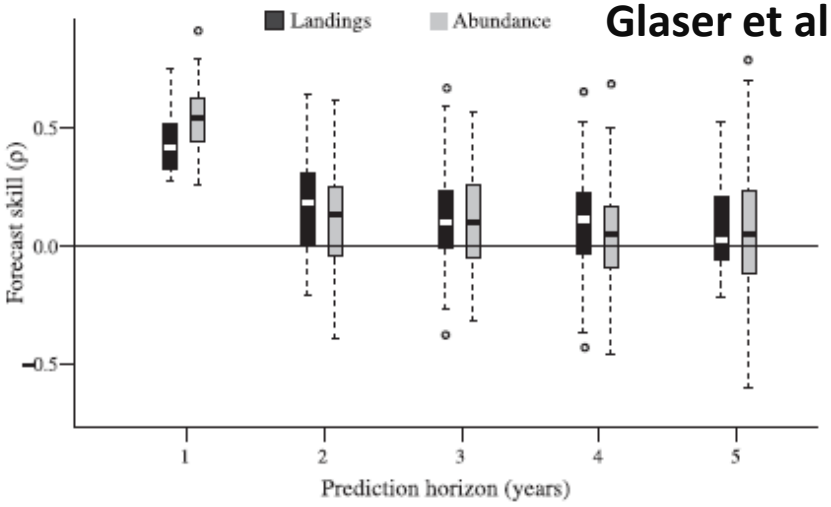
NLTS to Red Snapper in the Gulf of Mexico

- Fisheries of red snapper appear complex, for example, a debate on either two stocks (Cowan 2011), or one stock (Gold et al. 1997).
- External drivers hypothesized to relate to the dynamics of red snapper, but remain largely untested (Cowan et al. 2010).

- Examine stock structure of Gulf red snapper
- Forecast near-term dynamics of red snapper
- Explore dynamics of red snapper in response to ecosystem indicators

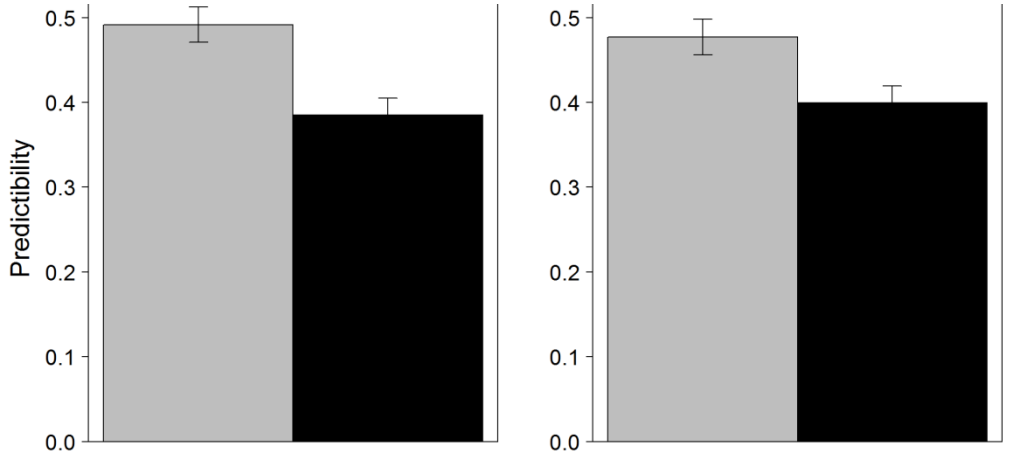


Performance of NLTS on Gulf red snapper



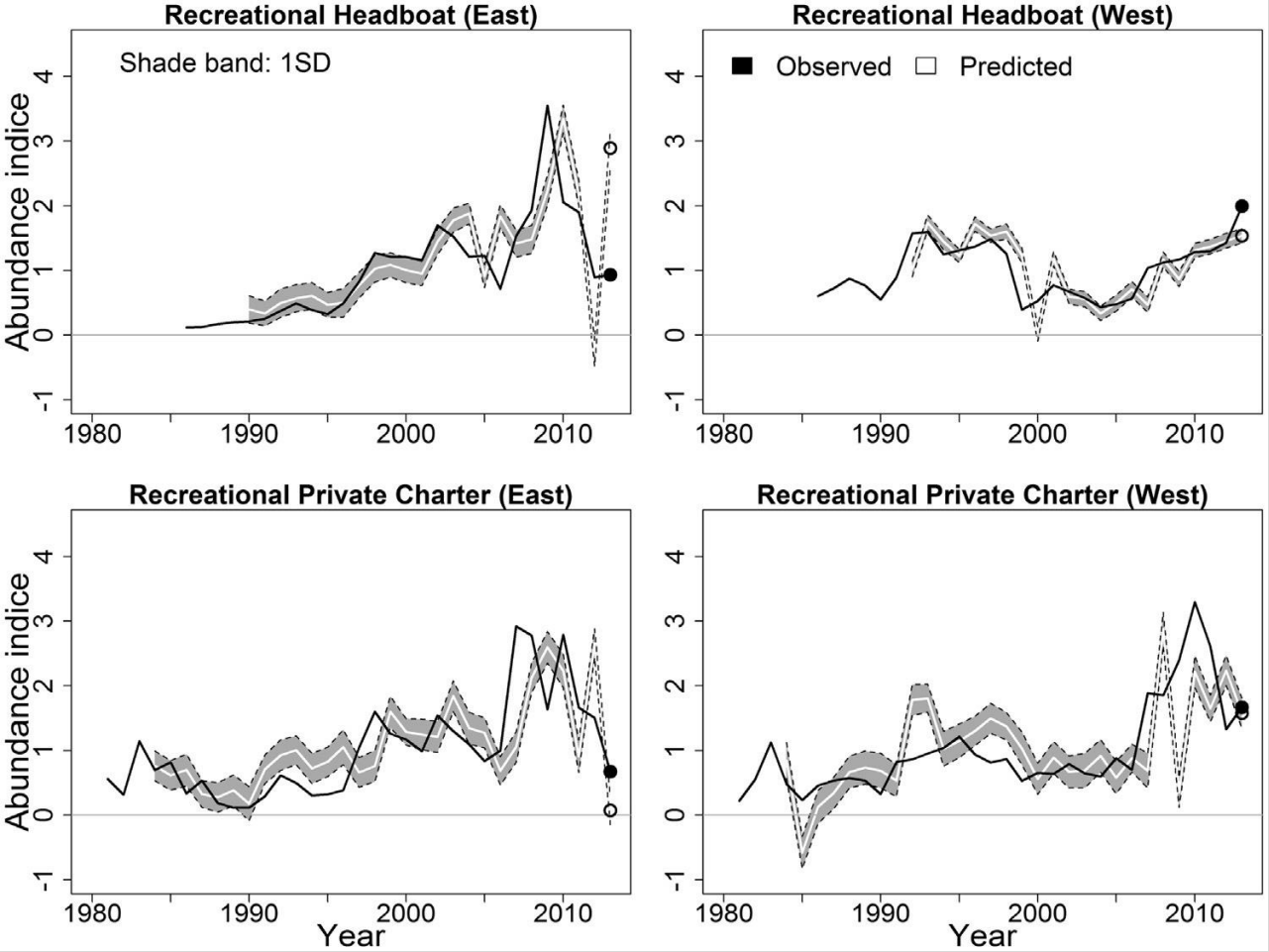
Glaser et al. 2014

Figure 5 Trends in *forecast skill* (ρ) as the time horizon (prediction time, t_p) over which forecasts are made increases.



- Dynamics of red snapper seem different in the eastern and western Gulf

NLTS near-term forecasts



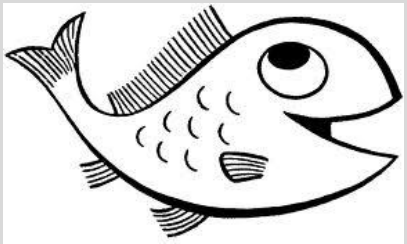
Liu et al. (2017)

NLTS to Fish Community on Georges Bank

- Understanding ecosystem structure and function is highly needed to develop successful ecosystem-based management plans and to conduct effective ecosystem comparisons in the ocean.

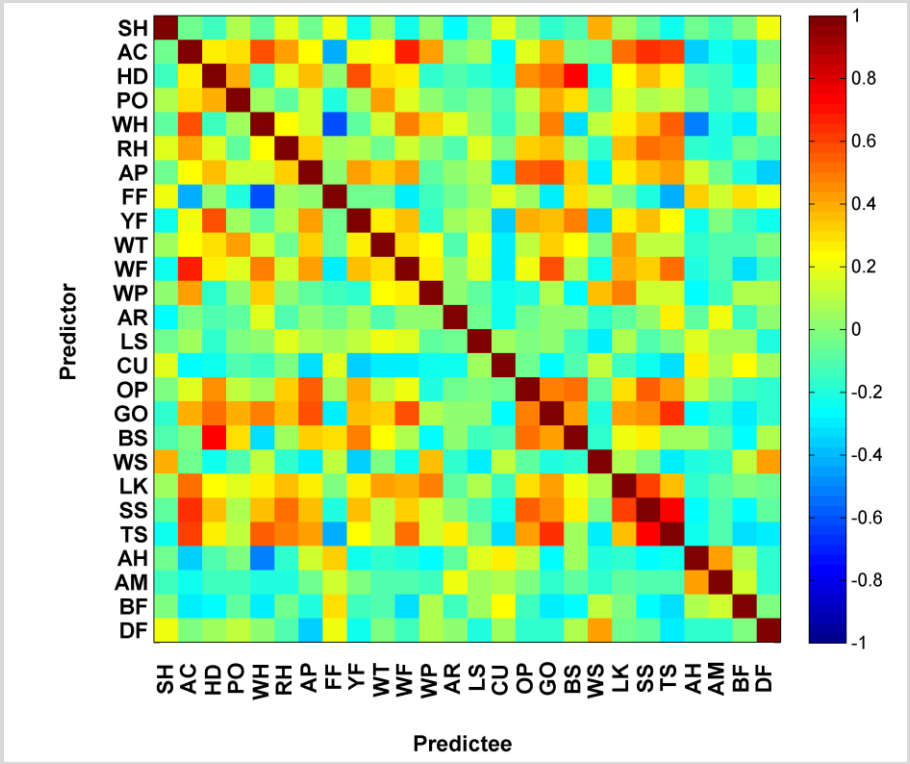
Group	Gadids	Flatfish	Groundfish	Skates	Pelagics
	Atlantic cod	Yellowtail Flounder	Ocean Pout	Little Skate	Atlantic Mackerel
	Haddock	Winter Flounder	Goosefish	Winter Skate	Butterfish
	Pollock	American Plaice	Longhorn Sculpin	Thorny Skate	Atlantic Herring
	Silver Hake	Fourspot Flounder	Cunner	Barndoor Skate	
	Red Hake	Witch Flounder	Atlantic Wolffish	Smooth Skate	
	White Hake	Windowpane Flounder	Acadian Redfish		

- Explore dynamic features of fish species
- Examine dynamic associations of fish species
- Identify functional groups in fish community

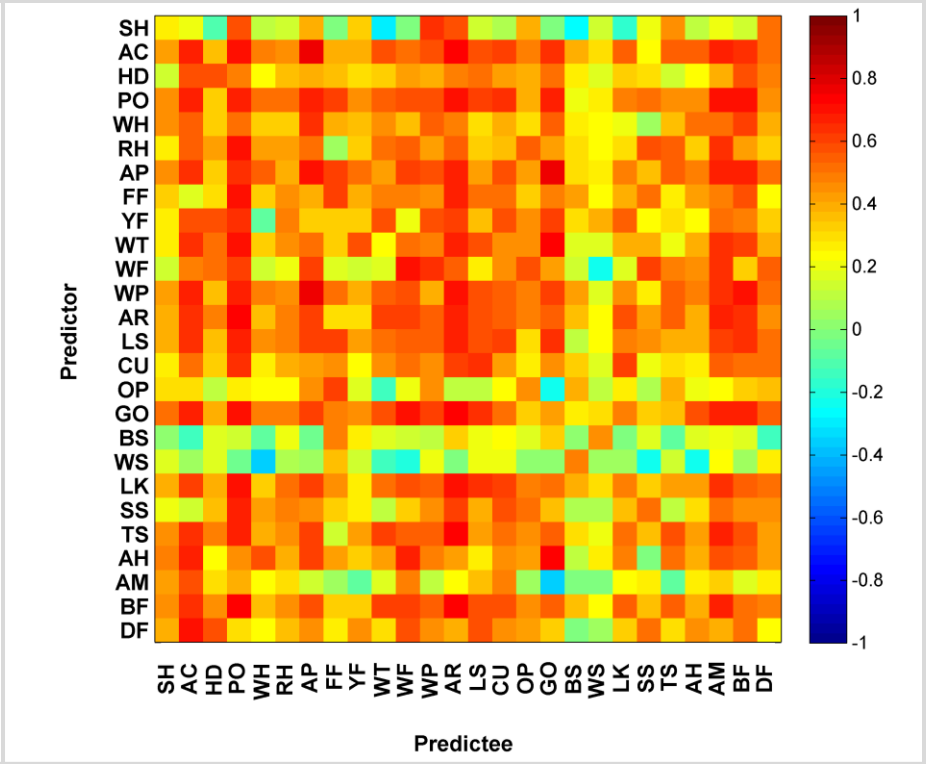


Linear vs. Nonlinear

Correlation



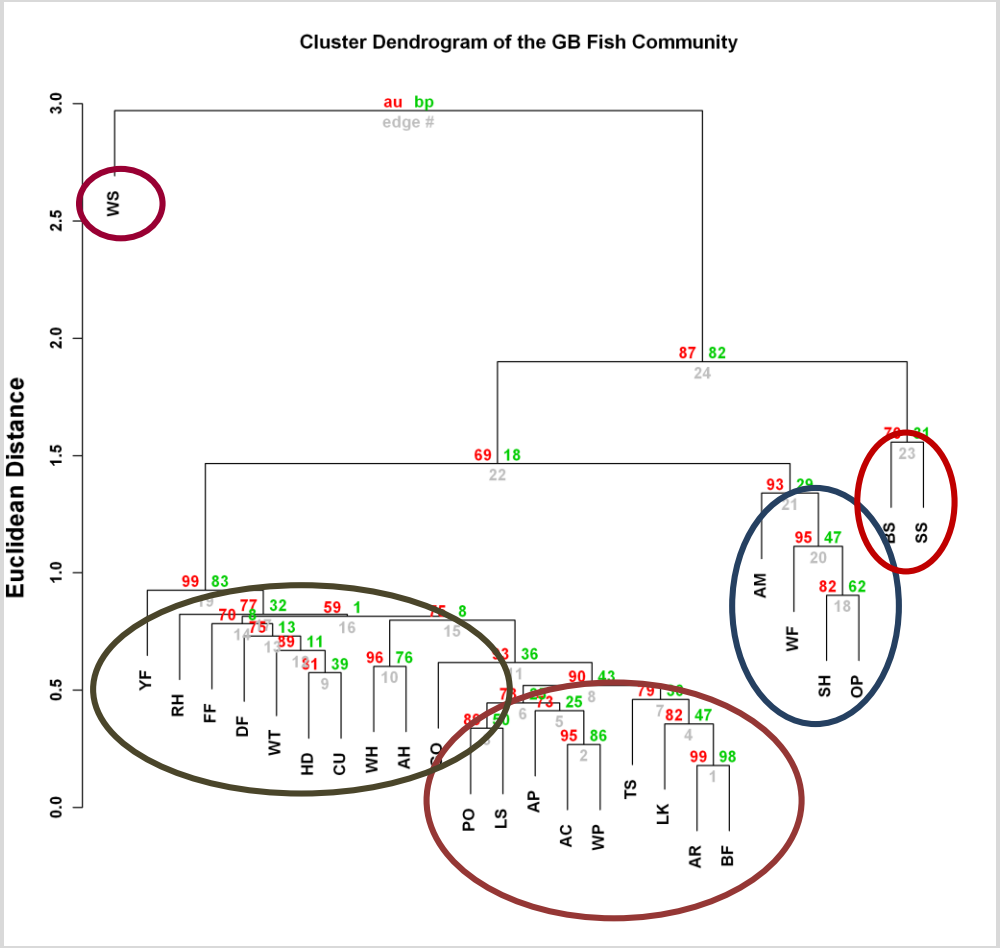
Co-prediction



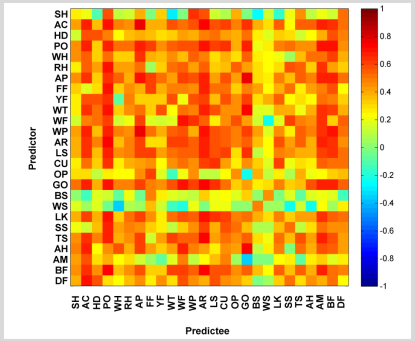
Liu et al. (2012)

- In nonlinear systems, lack of correlation does not imply lack of causation.

Functional groups identified based on dynamical features



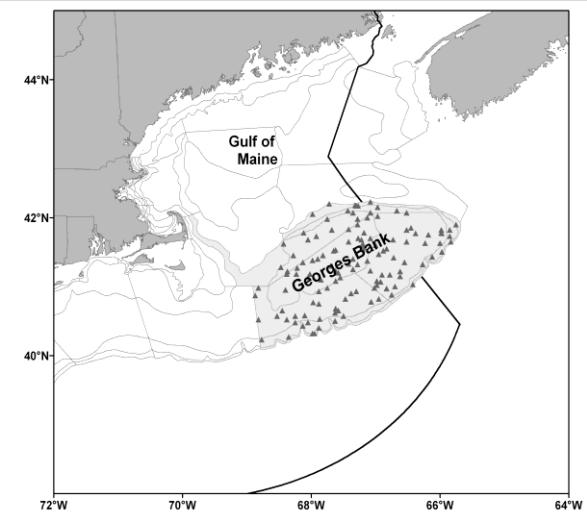
- Nonlinear dynamics occurred in fish community
- High levels of dynamic interactions between fish species
- A new approach defining functional groups among of the system components



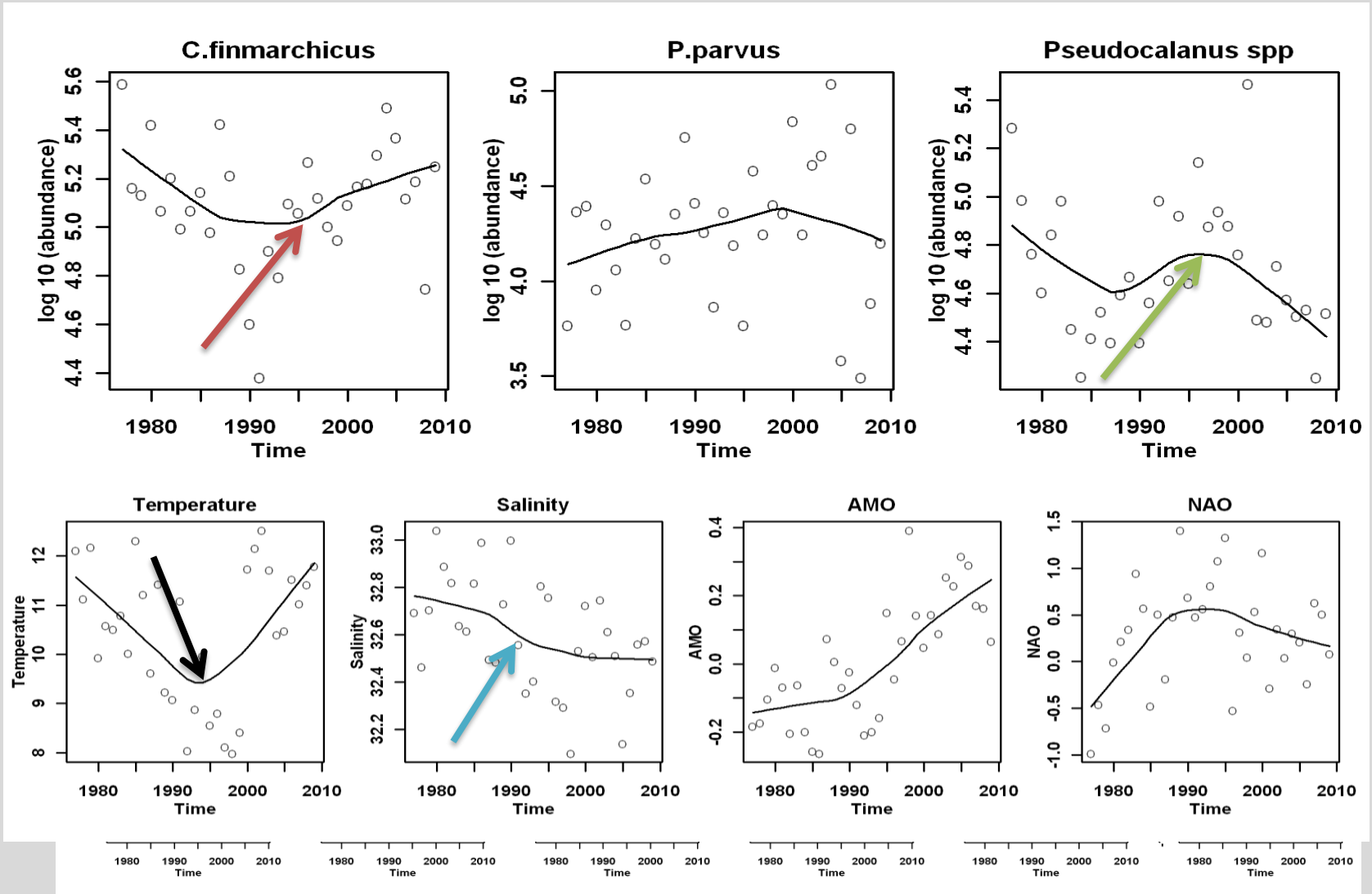
NLTS to Fisheries Ecosystems

- Dynamics of low trophic levels strongly influence fisheries production.
- A major ecosystem shift occurred on Georges Bank and adjacent regions between the 1980s and the 1990s (Pershing et al. 2005, Mountain & Kane 2010).
- Standard models may be unable to capture the underlying complexity of ecological processes.

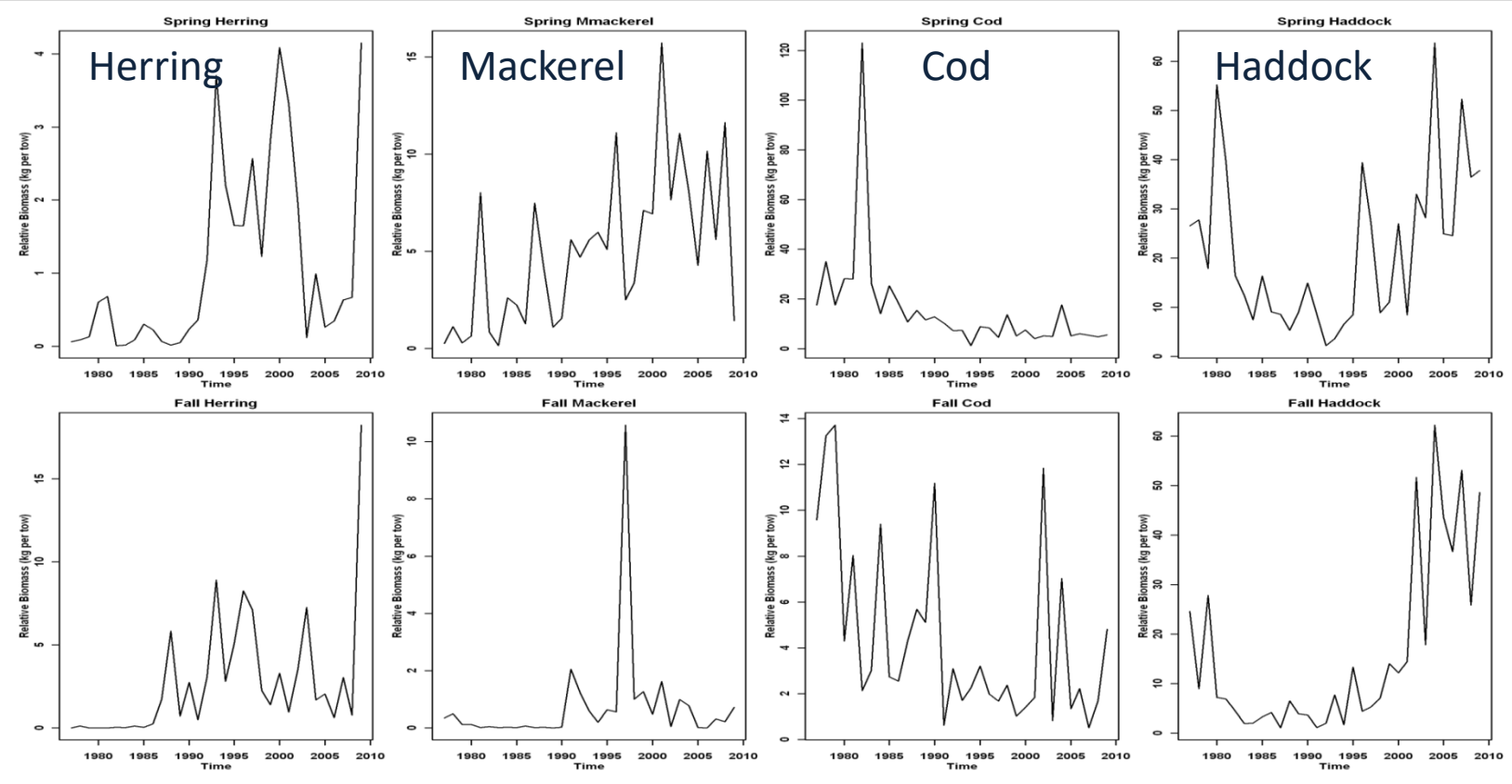
- Examine dynamic interactions among zooplankton, fish and environmental variables.
- Explore mechanisms regulating dynamics across adjacent trophic levels.



Copepods and the Environment

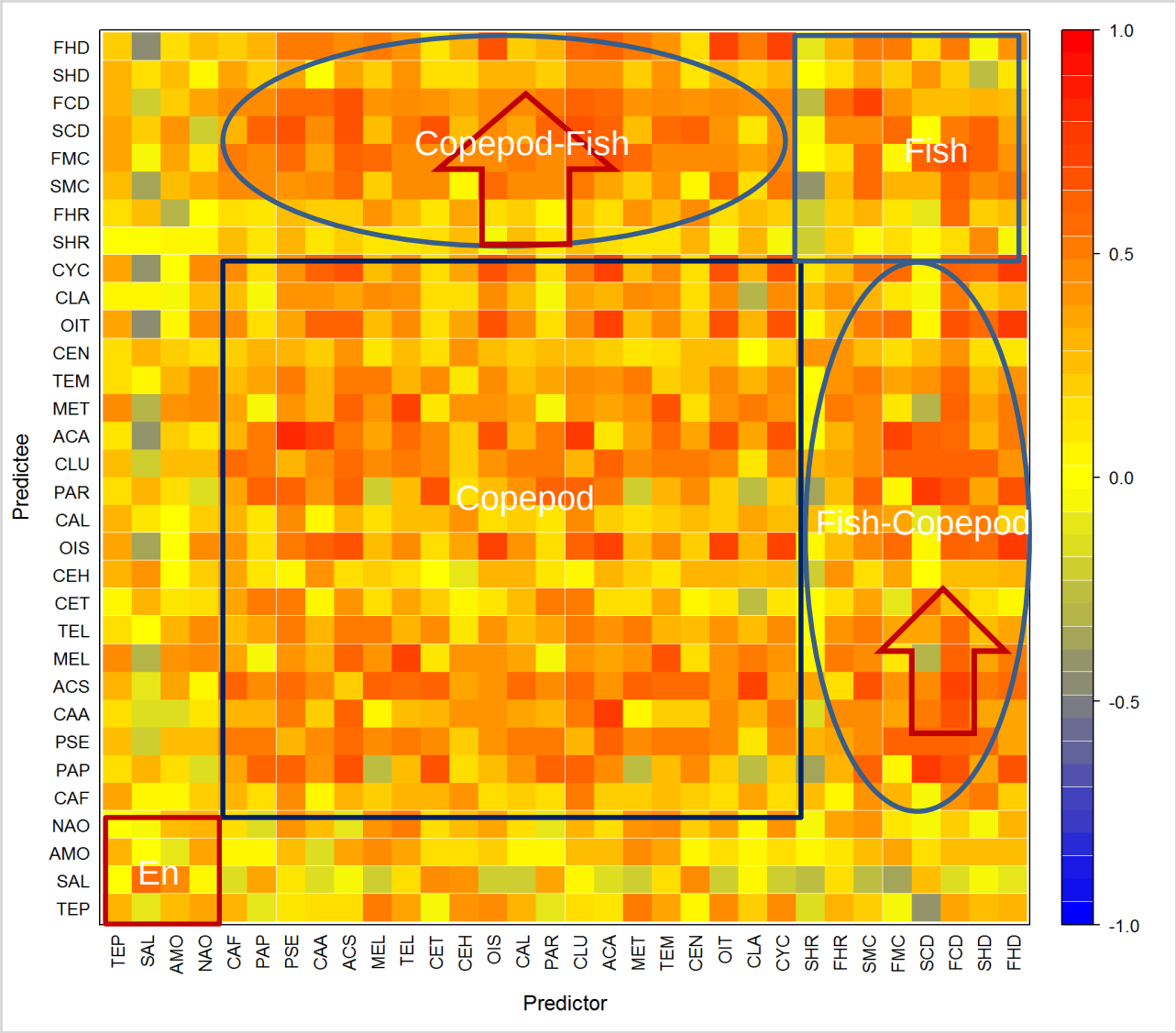


Dynamics of fish populations



- Atlantic cod and haddock on Georges Banks decreased in abundance during 1980s
- Pelagic species (i.e. herring and mackerel) increased at the same period

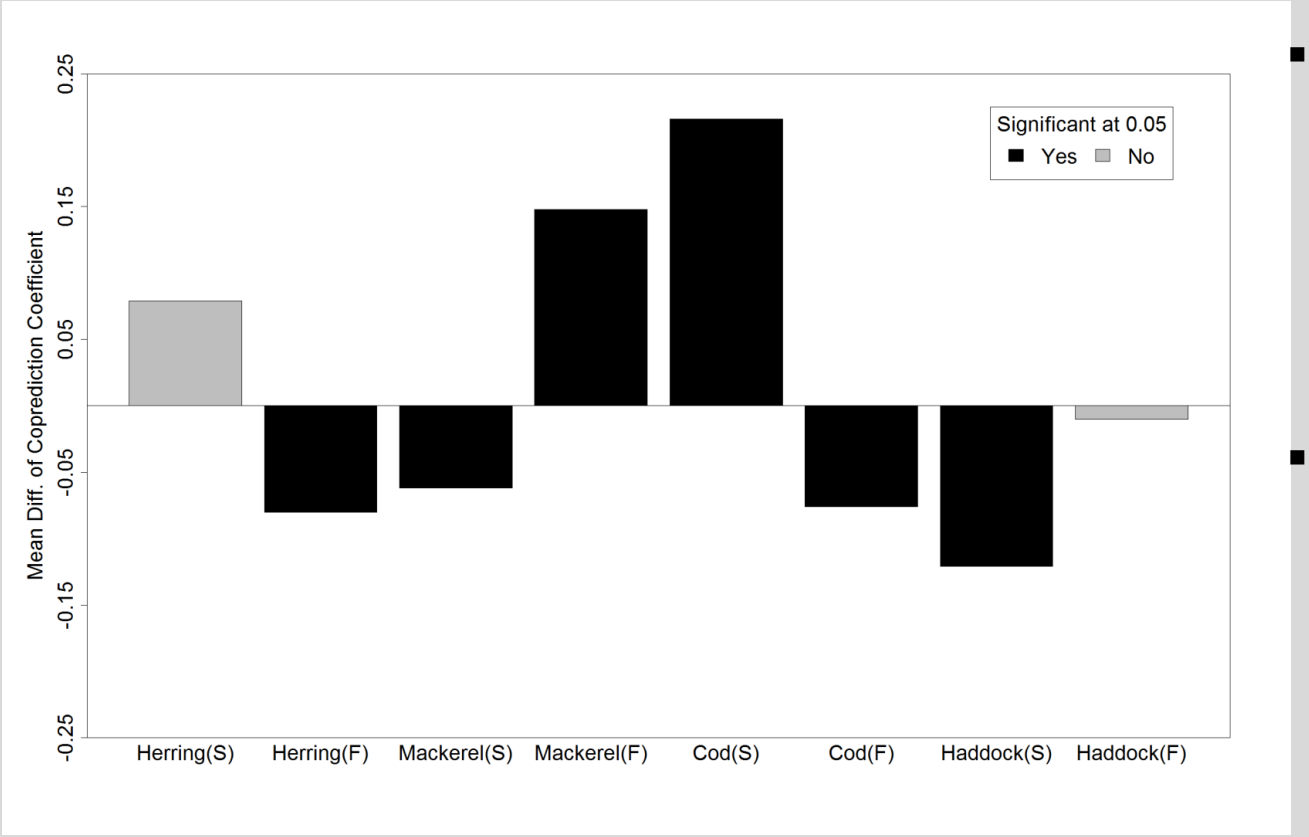
Interactions of copepods, fish and the environment



- NLTS provides bilateral predictions between copepods → fish and fish → copepods

Liu et al. (2014)

Bottom-up vs Top-down
-NLTS detecting driving mechanisms



- Difference of NLTS co-predictions between copepods → fish and fish → copepods indicates either bottom-up or top-down processes
- A new approach detecting driving mechanisms of ecosystem dynamics

Liu et al. (2014)

NLTS applications in Fisheries Research

- Examining stock structure and making short-term predictions on indices of fish stocks
- Identifying groups of dynamically coupled ecosystem components
- Detecting driving mechanisms of ecosystem dynamics
- Potential to be applied to ecosystem-based assessments and management of fisheries resources

Thank You