Climate Variation and Salmon Production

Comparing climate indices for predicting salmon marine survival in the Northern California Current ecosystem

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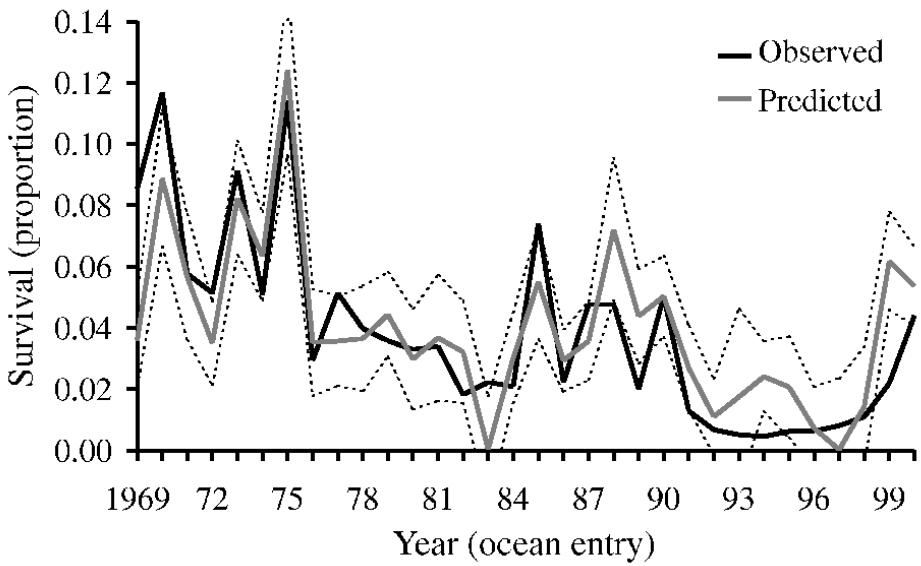
Acknowledgements

- Cheryl Morgan helped with data and figures

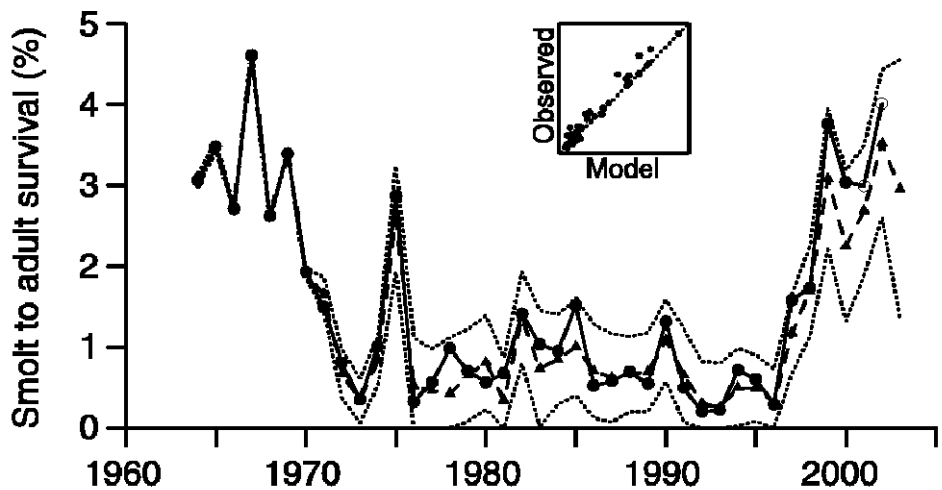
- Funding for data collection and analysis was provided in part by:
  - NOAA Fisheries and the Environment (FATE) program
  - U.S. GLOBEC program through the NOAA Coastal Ocean Program
  - Bonneville Power Administration

Background

- Long-term regional and local physical climate indices are useful for explaining salmon marine survival



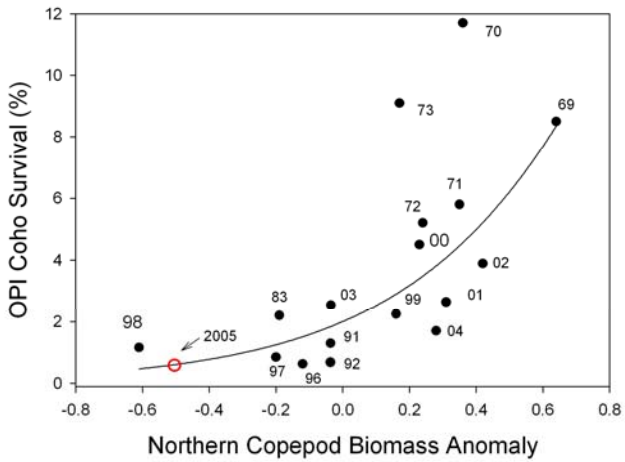
From Logerwell et al. (2003)

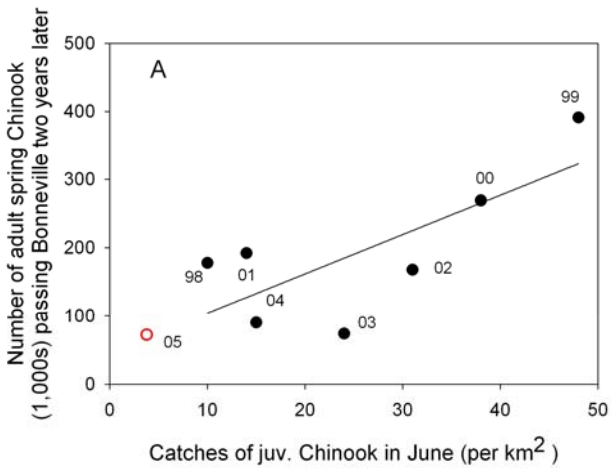


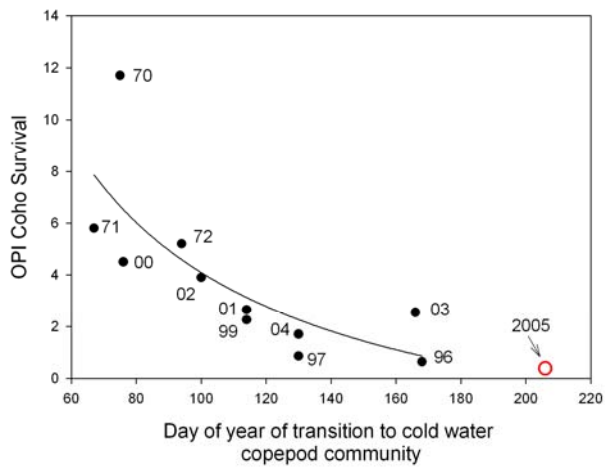
From Scheuerell & Williams (2005)

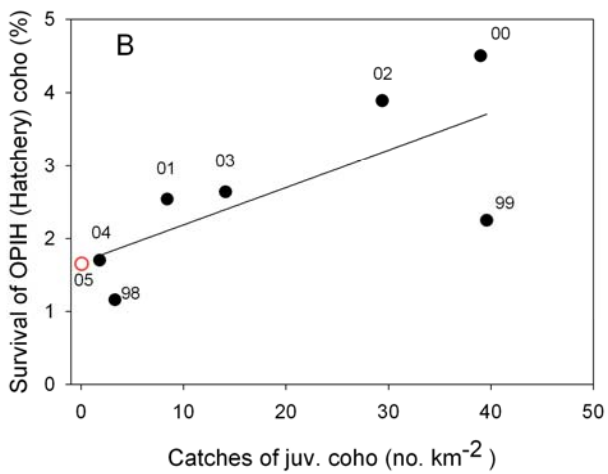
Motivation

- Recent measurements of biological ecosystem properties show strong short-term relationships with salmon marine survival









Key Question

- How good are recent biological indicators relative to long-term results for physical indicators?
  - Short time series (6-10 years)
  - Statistical comparisons difficult due to time-series autocorrelation
  - Complex systems and regime-shift theories suggest that short-term correlations may not hold for long-term, so a secondary question is:
  - How stable are relationships over time?

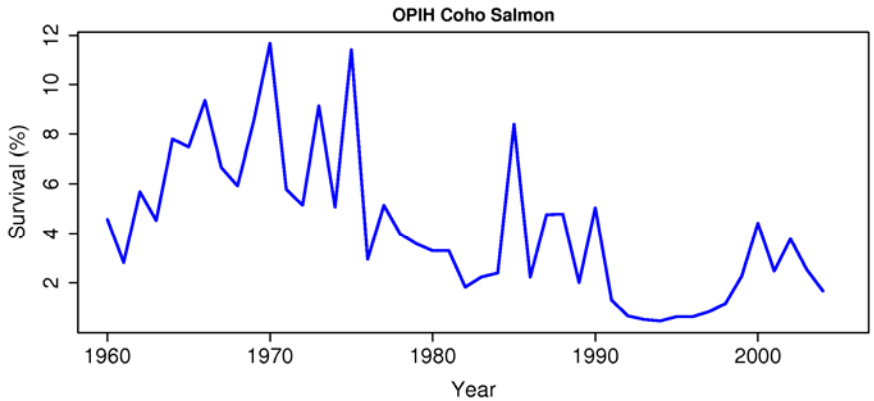
Methods

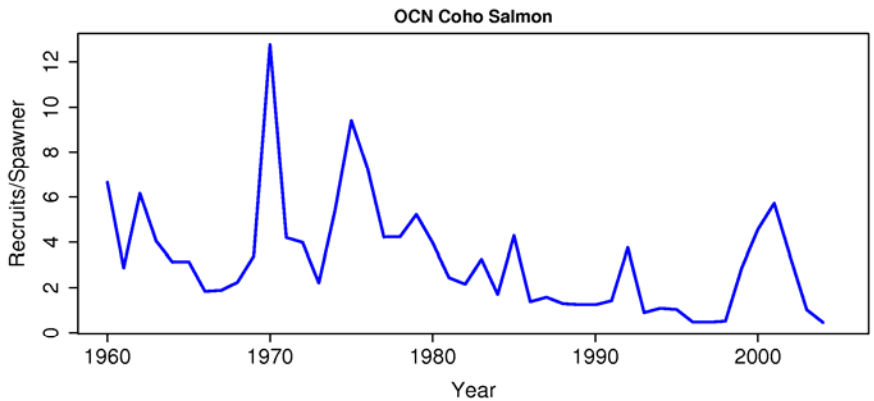
- Data Series
  - Salmon Survival Indices
  - Ecological Indicators (Physics and Biology)

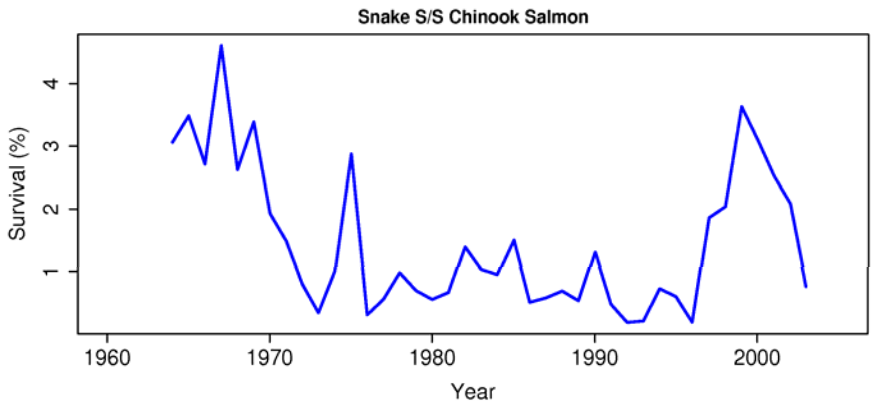
- Analysis
  - Data Series Screening
  - Generalized Additive Models (GAMs)
  - Effect of Series Length
  - Adaptive Multivariate Forecast Technique

Ocean Survival Indices: 3 Stocks

- Oregon Production Index hatchery (OPIH) coho salmon marine survival
- Oregon Coastal Natural (OCN) coho salmon recruits per spawner
- Snake River Spring-Summer (SSS) Chinook salmon marine survival

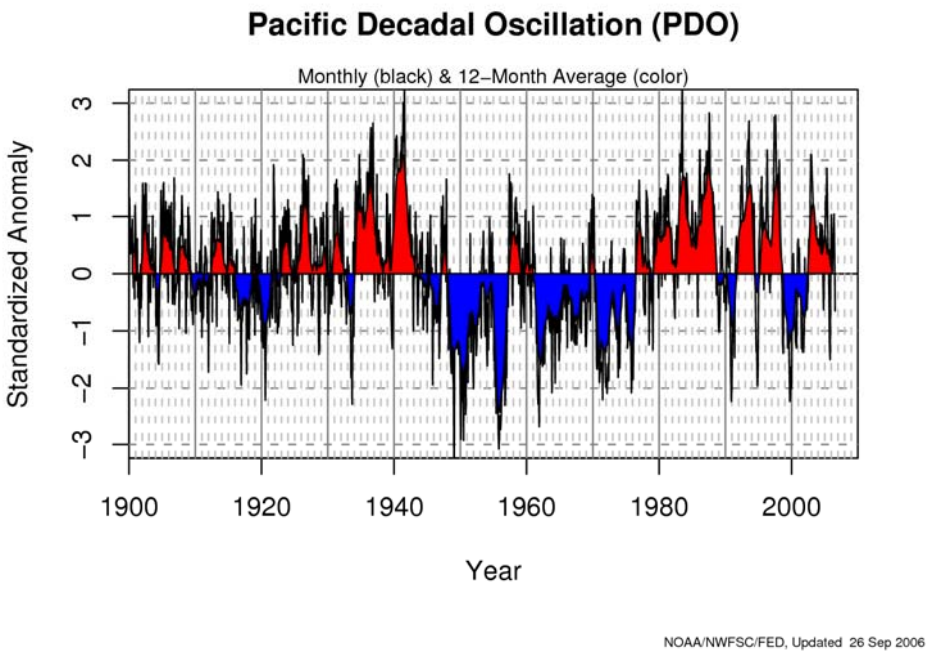


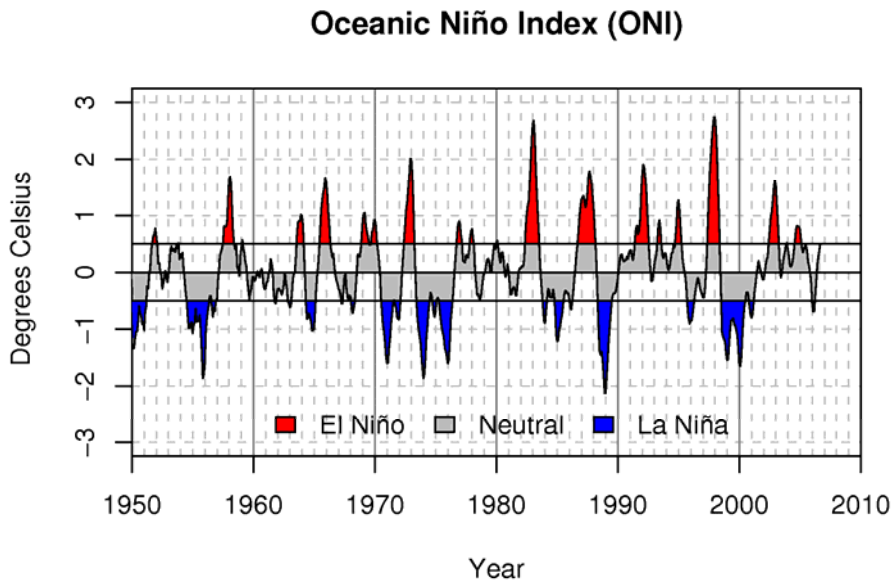




Ecological Indicators--Physics

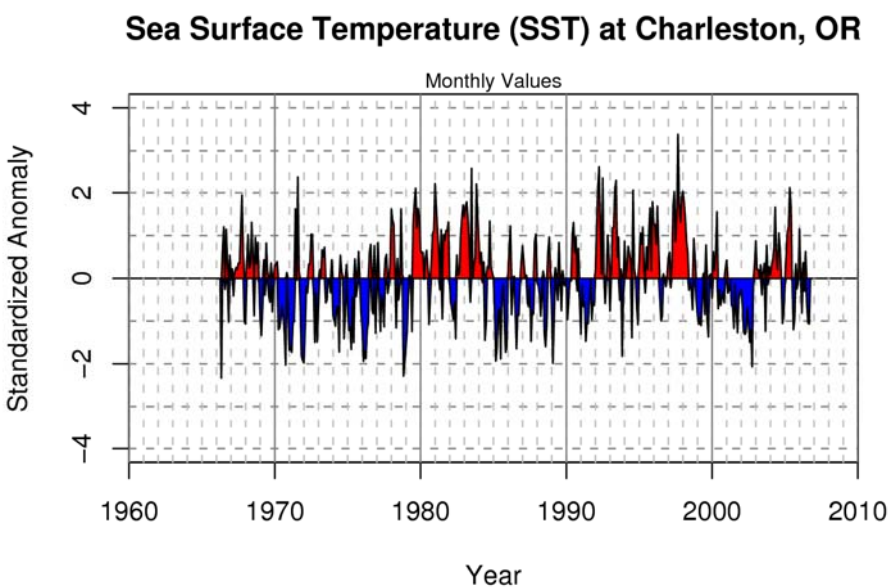
- Regional Climate Indicators
  - Pacific Decadal Oscillation (PDO)
  - Oceanic Niño Index (ONI)



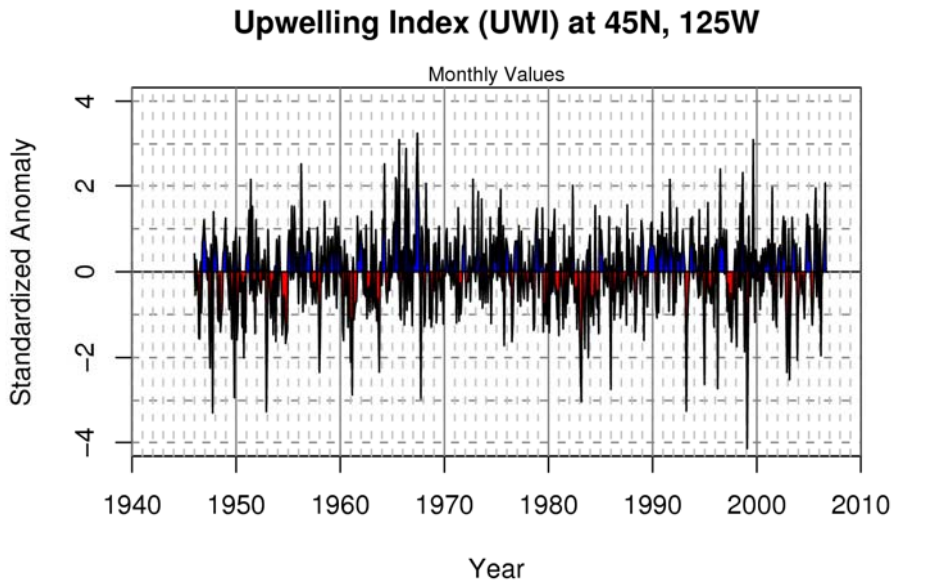


Ecological Indicators--Physics

- Local Climate Indicators
  - Sea Surface Temperature (SST)
  - Upwelling Index (UWI)
  - Spring Transition Date
  - Columbia River Flow



NOAA/NWFSC/FED, Updated 26 Sep 2006



NOAA/NWFSC/FED, Updated 26 Sep 2006

Ecological Indicators--Biology

- Zooplankton Indices
  - Copepod Biodiversity
  - Northern Copepod Anomaly
  - Copepod Spring Transition
- Predator/Competitor Indices
  - Pacific Hake Abundance
  - Forage Fish Abundance
- Juvenile Salmon Abundance
  - Ocean Yearling Chinook Index
  - Ocean Yearling Coho Index
  - Columbia River Coho Jack Index

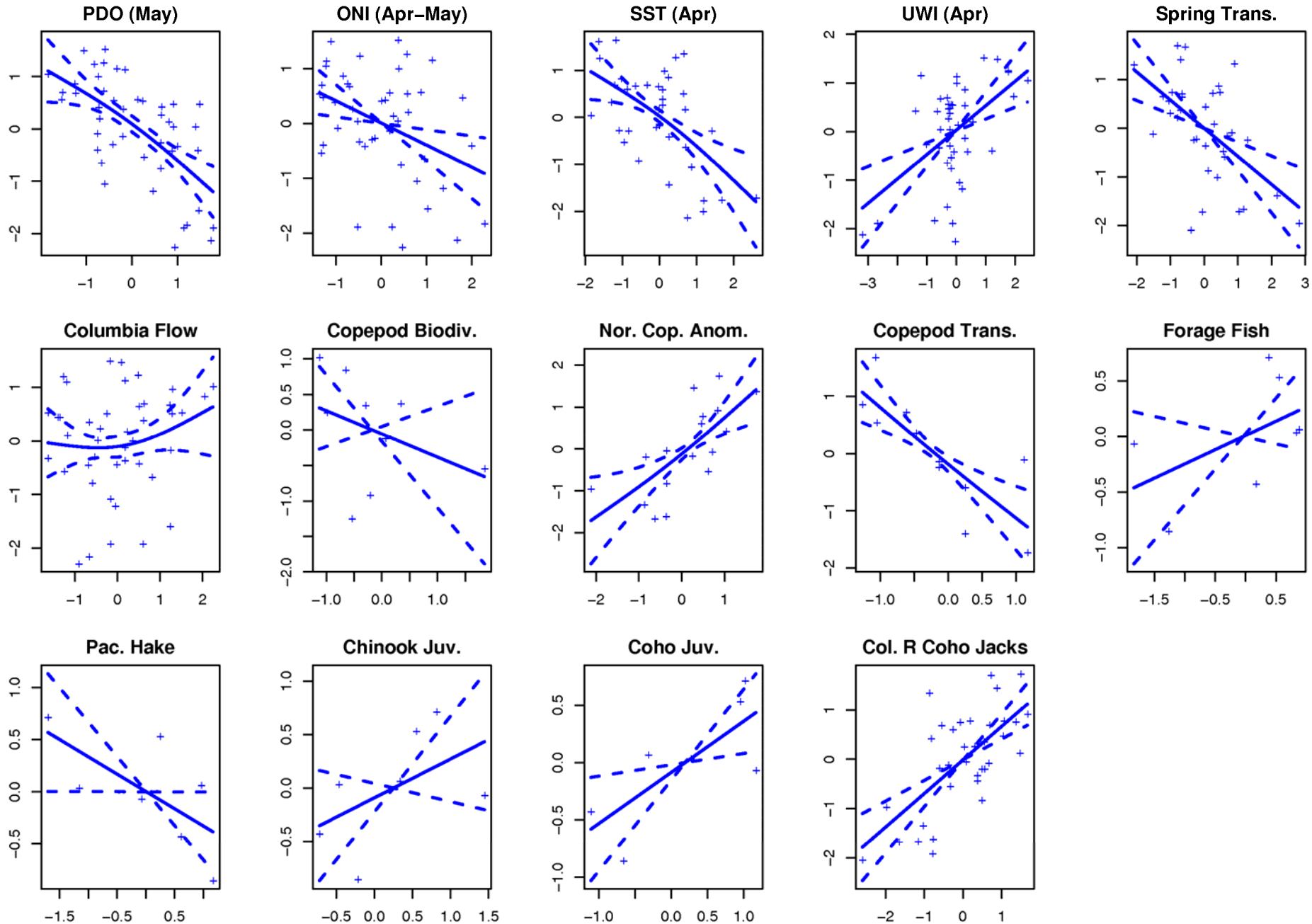
Analysis

- Standardized data series
  - Log-transformed survival and abundance data
  - Transformed all series to standard normal deviates
- Generalized Additive Models (GAMs)
  - Fit regressions to full data series
  - 3 stocks X 82 data series
- Selected monthly data
  - For each physical indicator, selected one or two months with best GAM fit
  - 14 predictor indices (6 physical, 8 biological)
- Short-term models for selected series
  - Fit GAMs to moving 10-year segments of data

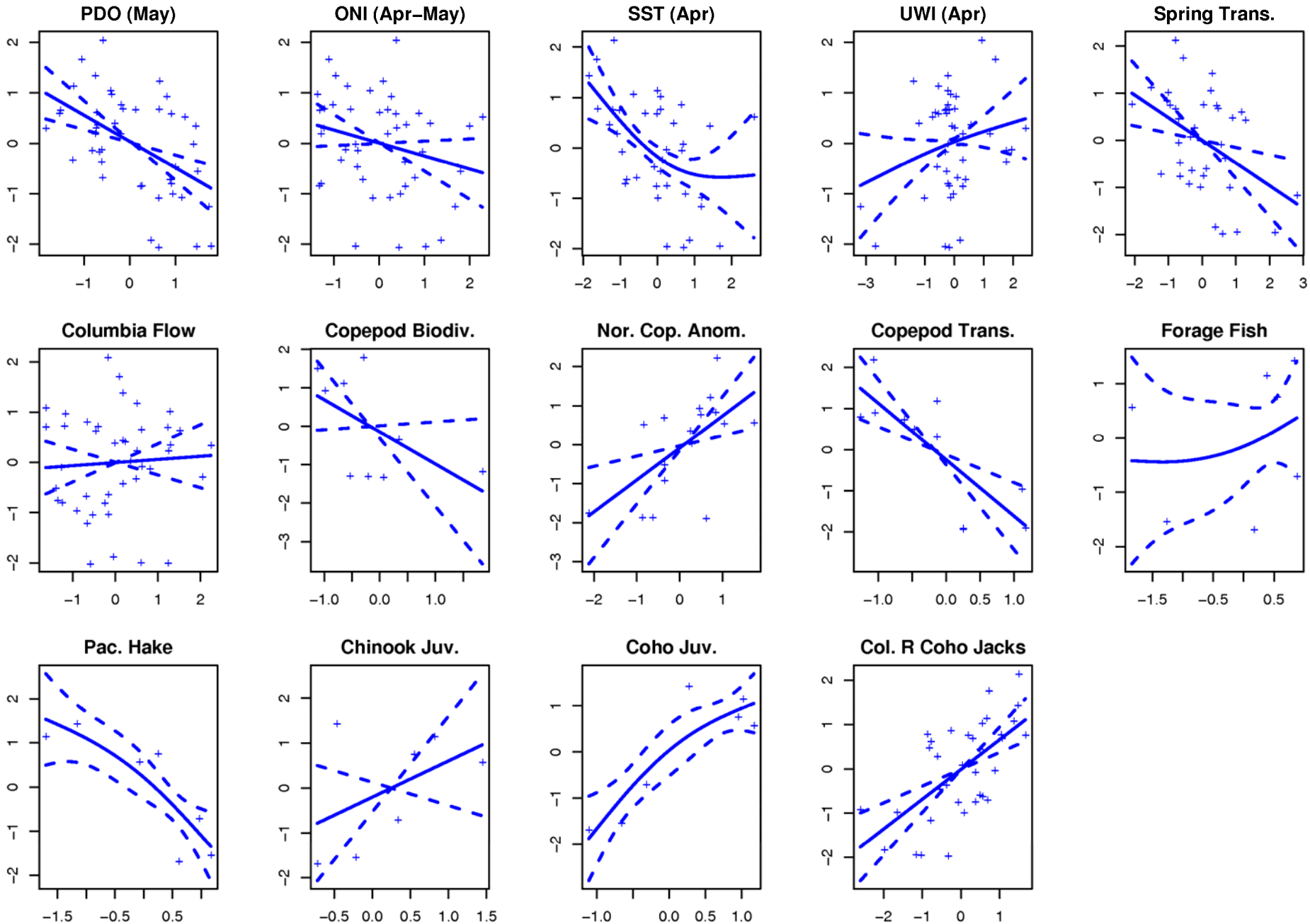
Results

- Three stocks:
  - OPIH coho
  - OCN coho
  - SSS Chinook
- Model comparison—full data sets
- Patterns of predictive ability for 10-year models

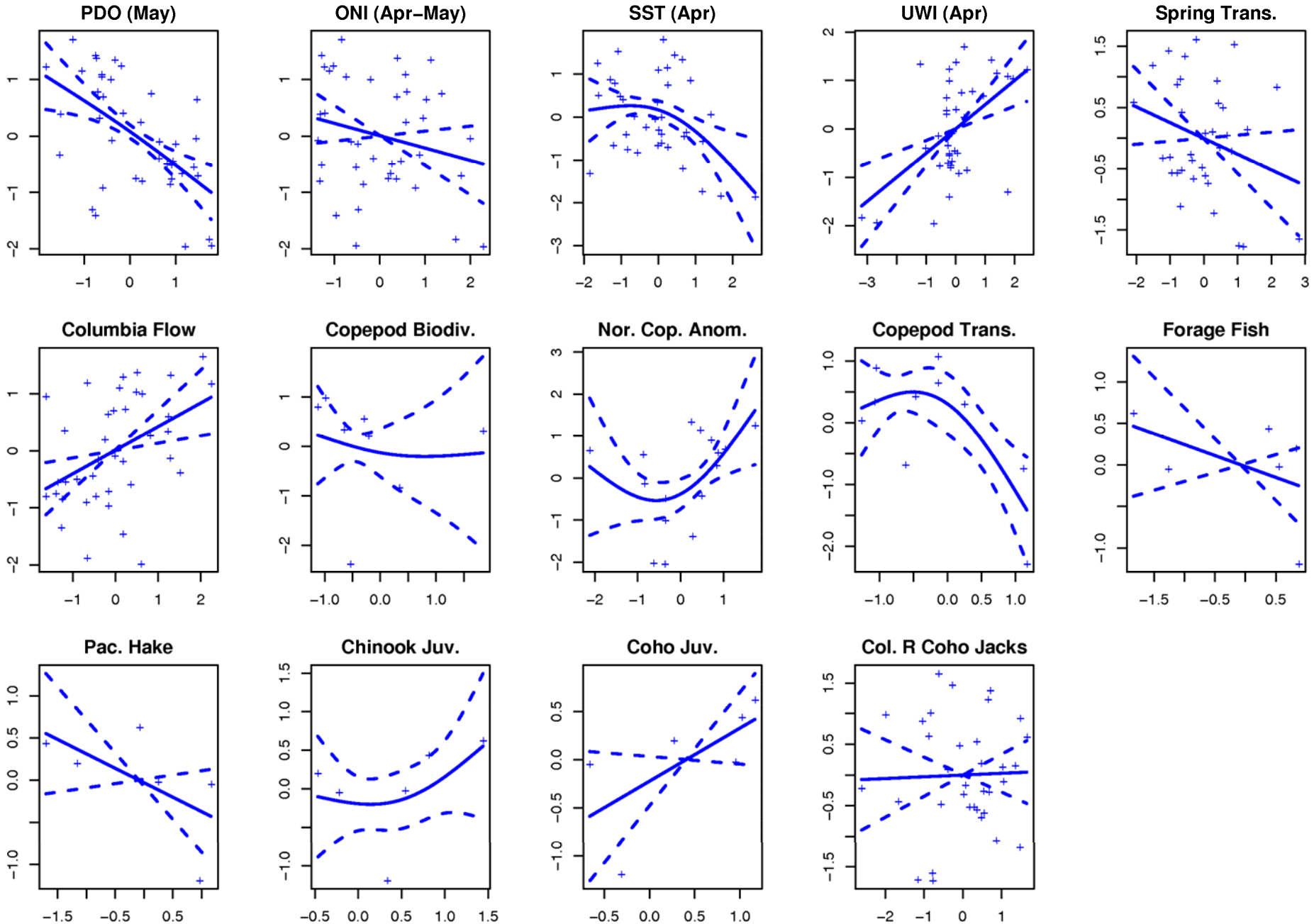
OPIH Coho—Full Data Set



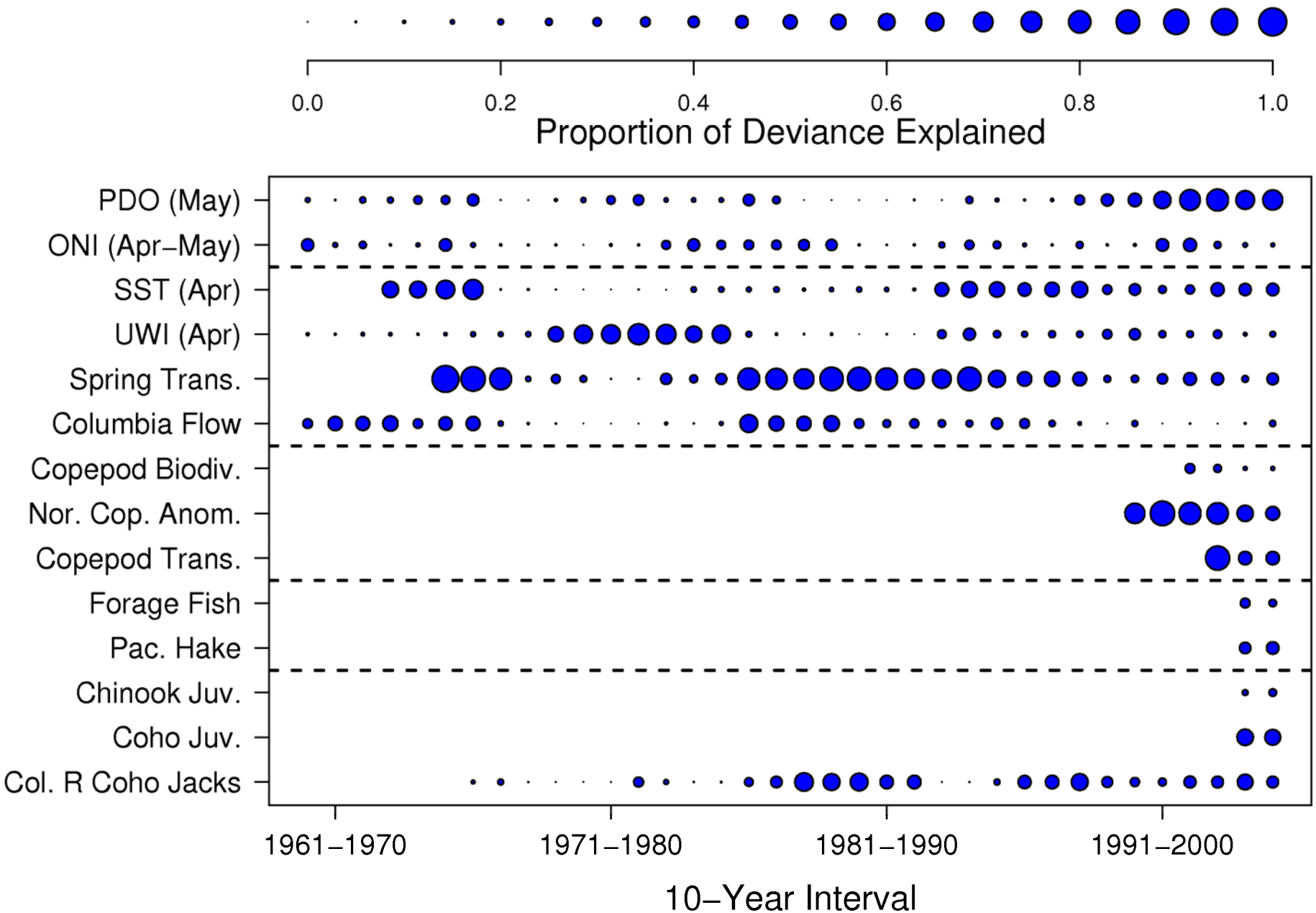
OCN Coho—Full Data Set



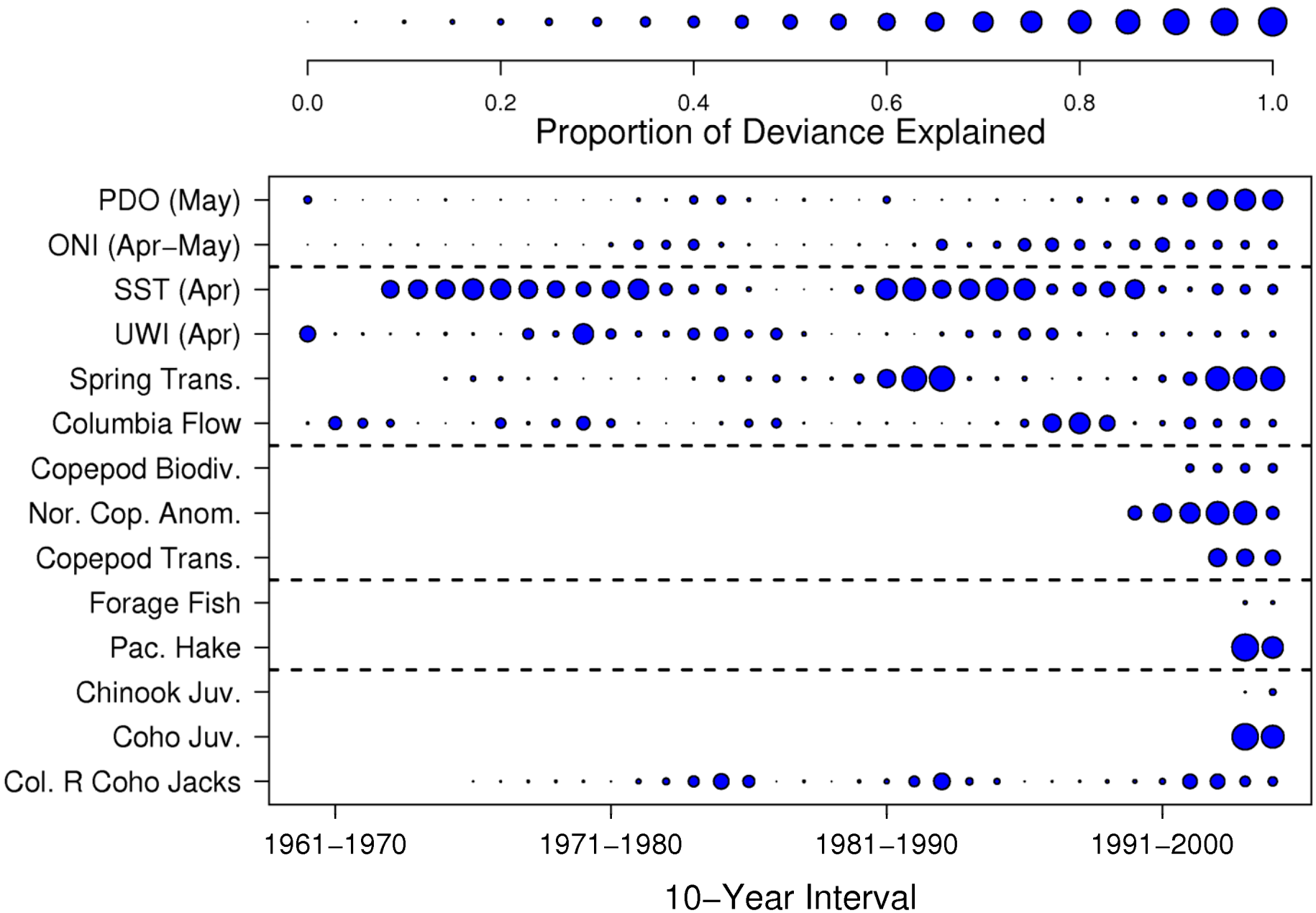
SSS Chinook—Full Data Set



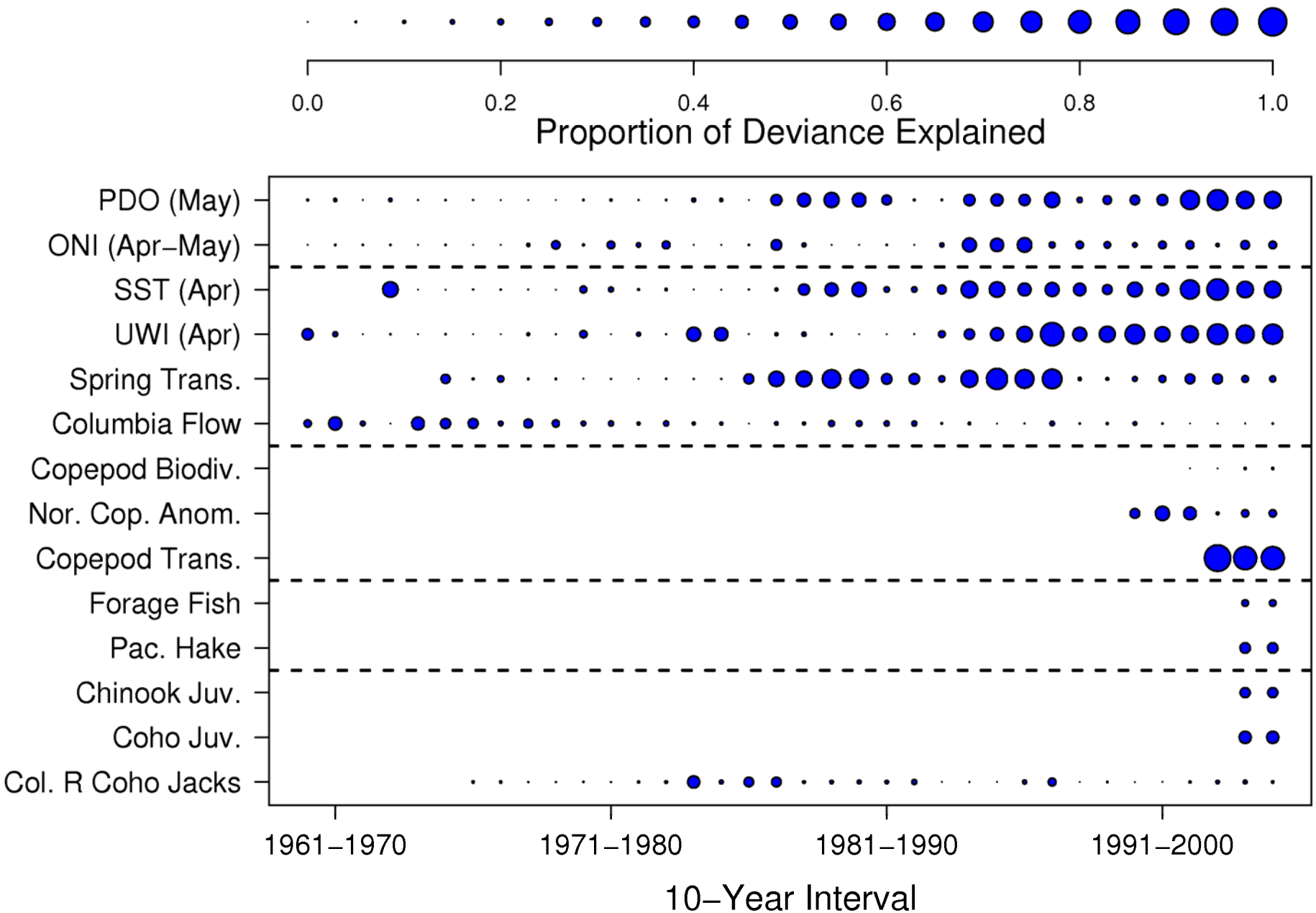
OPIH Coho—10-year Segments



OCN Coho—10-year Segments



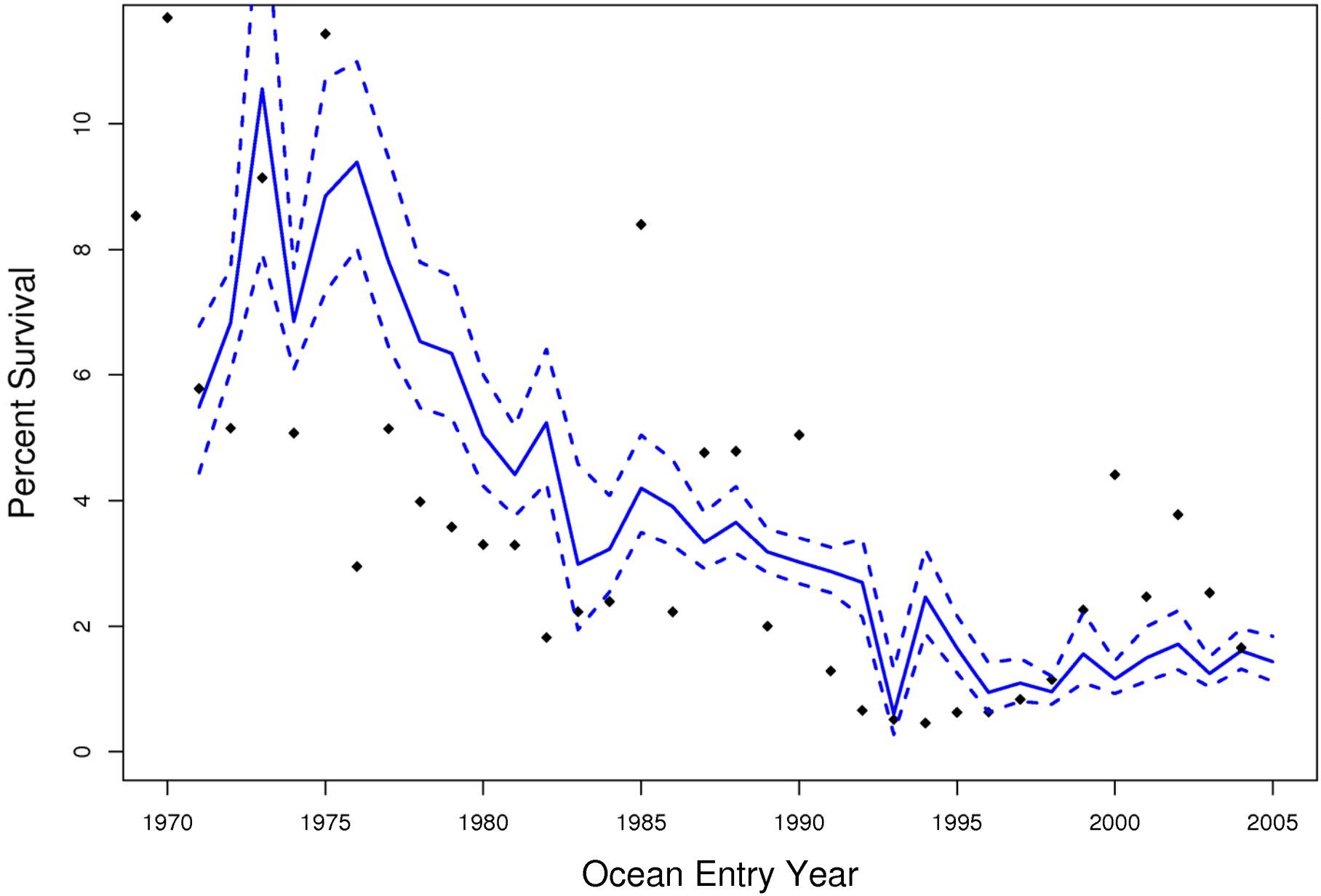
SSS Chinook—10-year Segments



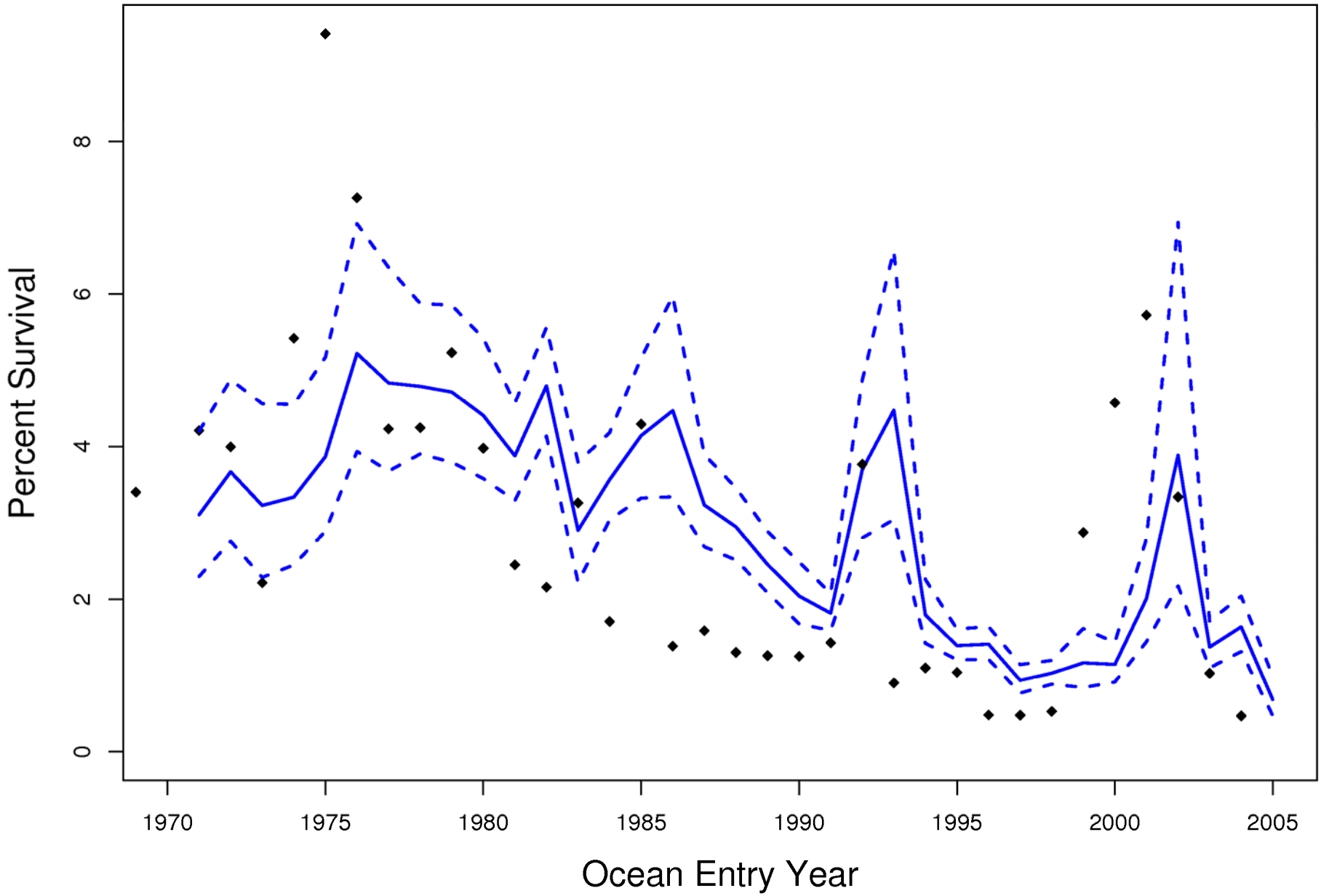
Adaptive Multivariate Forecast

- Variable performance of univariate predictors suggests an *adaptive* forecasting strategy
  - Assume that predictors that worked well in recent past will work best for next year
- Simple approach:
  - Weighted average of all 10-year predictors
  - Weight proportional to mean 1-step-ahead forecast skill over most recent 5 years
- Results
  - 1-step-ahead combined forecasts for each 10-year period
    - That is, use each 10-year period to forecast 11th year

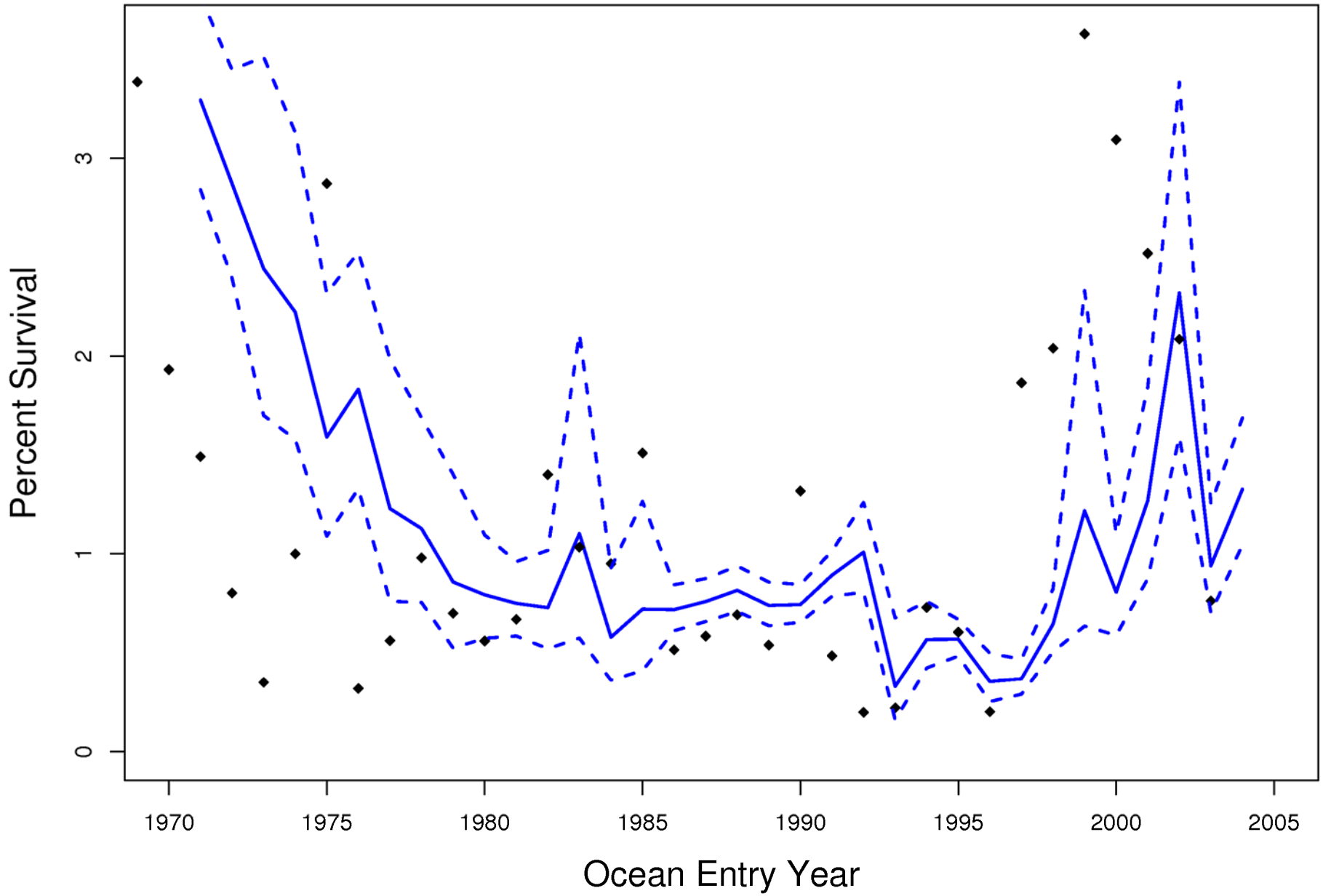
OPIH Forecast



OCN Forecast



SSS Forecast



Summary

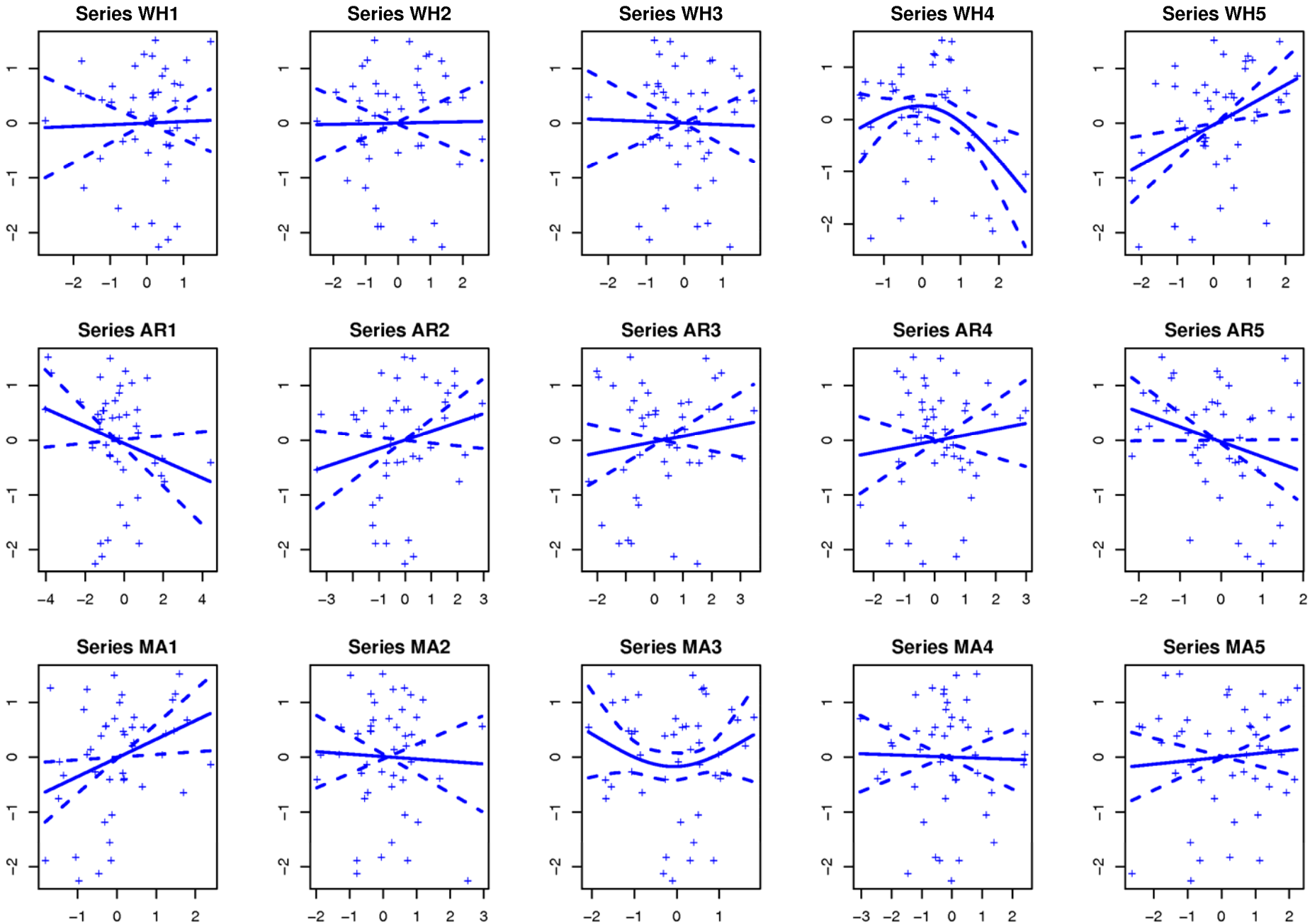
- Predictive skill of physical climate indices varies over time.
- This may be due to climate regime shifts or other influences on ecosystem structure.
- Some biological indicators give good predictions over recent time, but will the relationships last?
  - Maybe—more direct causal links may mean more stable relationships.
- Adaptive multivariate forecasting techniques show some potential, but need a more complete evaluation.

Appendix

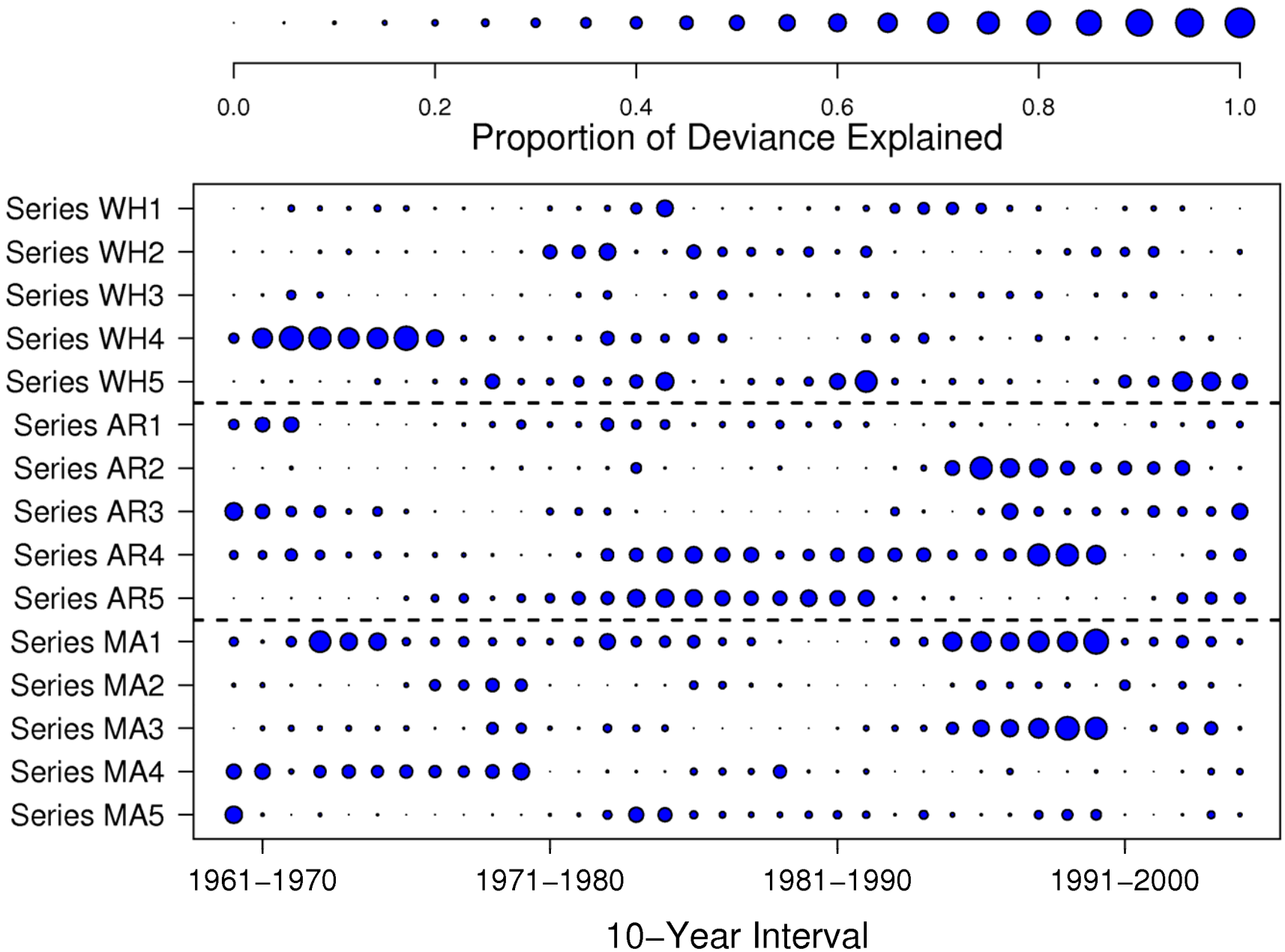
Randomization Trials

- Motivation
  - No legitimate way to calculate confidence intervals for short time series
- Methods
  - Used 3 sets of random indices in 10-year segment GAM models for OPIH coho
    - Gaussian white noise
    - Autoregressive noise—AR(1)
    - Moving average noise—MA(1)
- Results

OPIH Coho vs Random Indices



OPIH Coho vs Random Indices



OPIH Coho Forecast