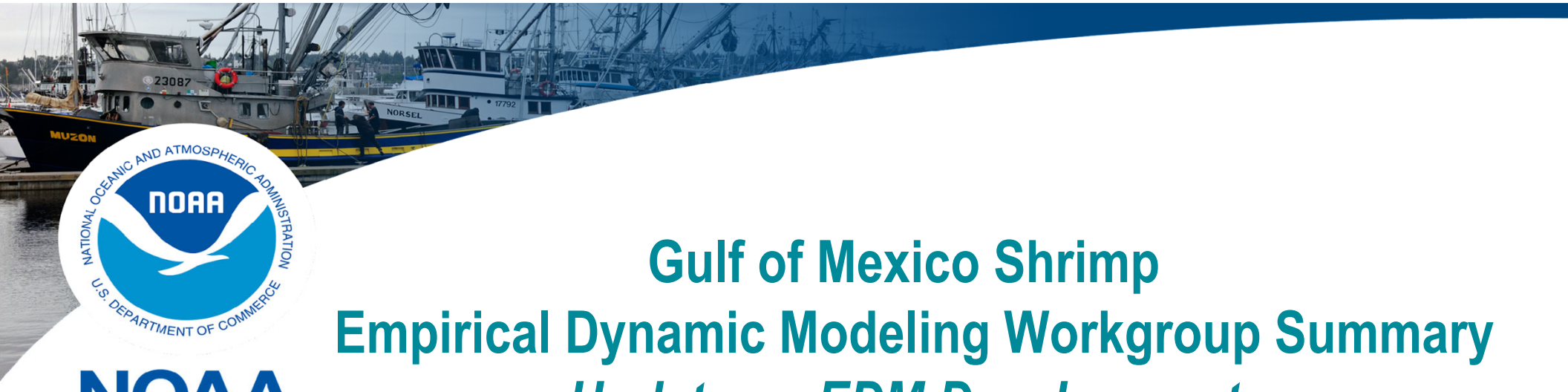


Gulf of Mexico Shrimp
Empirical Dynamic Modeling Workgroup Summary
Update on EDM Development

NOAA Fisheries
Southeast Fisheries Science Center
Gulf Fisheries Branch - Sustainable Fisheries Division

March 2023

Workgroup Purpose

- This workgroup is convened following a request to the Southeast Fishery Science Center from the Gulf Council following their April 2022 Meeting.
- *"… the Council thinks that the continued engagement of the aforementioned groups* [SSC members, Council staff, and shrimp industry representatives] *during the development of the shrimp EDMs is preferable, as there were numerous logistical and ground truthing questions regarding operations of the shrimp industry and data utilization that could assist in a more robust result that can be employed by management, versus waiting to the end to be engaged. Specifically, the various AP and SSC members can provide technical insight, historical institutional knowledge, management expertise, and on-the-water perspectives that will improve the quality and the buy-in of the resulting analytical tools."*

Meeting Summary

- Met 3 times August-October 2022

- Participants

Jim Nance
Leann Bosarge
Steve Bosarge
Glen Delaney
Nathan Putman
Benny Gallaway
John Froeschke
Matt Freeman
Dave Chagaris
Corky Perret
Lew Bullock

Workshop Briefing

- Provided an overview of EDM theory and examples in fisheries applications.

- Provided an overview of current Gulf of Mexico Shrimp EDM methods, results, and proposed next steps for Gulf of Mexico Shrimp EDM work.

Workshop Meeting Objectives

- Brief workgroup members on Empirical Dynamic Models (EDM) and Gulf of Mexico Shrimp EDM results.
- Receive input from workgroup members and discuss future model development.
- Receive input from workgroup participants and discuss utility of Shrimp EDM to inform management.

Environmental drivers and other species have their own dynamics – not really ‘noise’

Feedbacks between the focal stock and other parts of ecosystem may be important

But we don’t have data for everything - Need a method that will allow us to implicitly account for these!

Empirical Dynamic Modeling: an example

Three-species model with type-2 functional response

Z – pr
Y – gr
X – pr

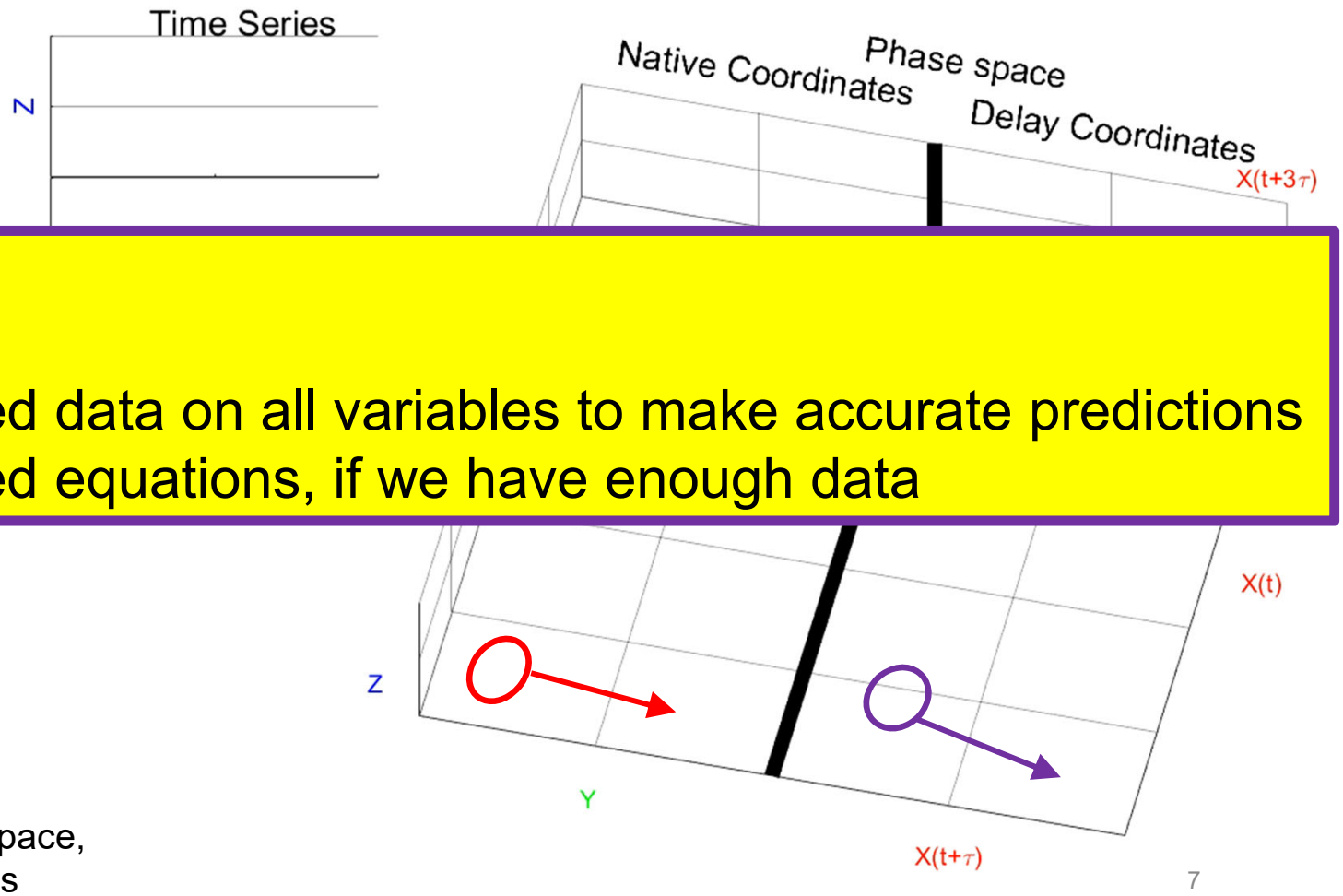
Trace nearby
obtain discre

$$x_{t+1} = F[x_t, y_t, z_t]$$

Analogous model in 'delay coordinates'

$$x_{t+1} = \tilde{F}\,[x_t, \ldots, x_{t-E}]$$

Dynamics equivalent to full state space, based only on observed time series



EDM:

1. Don't need data on all variables to make accurate predictions
2. Don't need equations, if we have enough data

Finding reference points and control rules from EDM

1. MSY
2. Optimal control rules
   - -numerically intensive,
   - -statistically challenging

2a. Harvest control rules

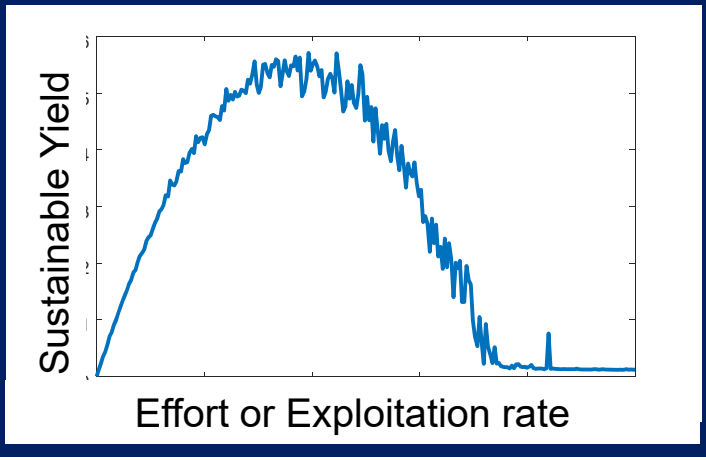
Steady state yield and MSY

Standard approach

Fit assessment model

Fix harvest rate, run to equilibrium, find sustainable yield

Vary harvest rate to find maximum sustainable yield



EDM approach

Fit EDM model with abundance and landings
(or landings and effort)

Fix harvest rate, run to equilibrium, find sustainable yield

Vary harvest rate to find maximum sustainable yield

Applications to brown and white shrimp

Background of EDM development for Gulf shrimp

- Previously we developed spatial hierarchical models using only SEAMAP and in situ environmental data (manuscript in publication)
- Previously we concluded using SEAMAP summer index as the first version model potentially used for index-based management
- To facilitate the interpretation and exploring harvest policies using simpler models, we investigate the aggregated Gulf-mean SEAMAP and fishery catch data for EDM forecasts
- Additionally, environmental variables (temperature, oxygen, salinity) and Louisiana recruitment indices (statewide, westside, eastside) are investigated at the aggregated Gulf-mean scale, together with catch data

Current models

GP-EDM used to predict average annual CPUE in SEAMAP survey.

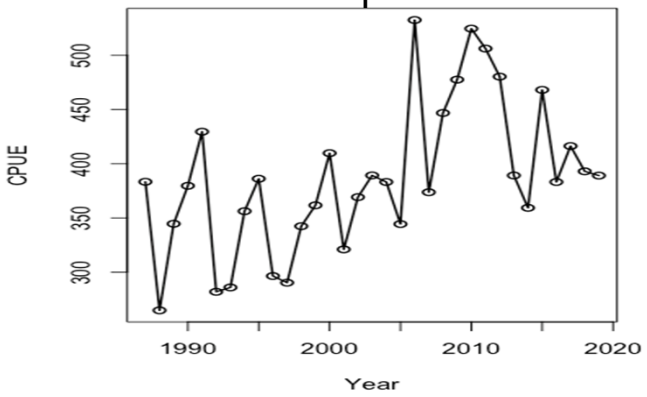
Models include lags of CPUE and catch

Prediction accuracy assessed with leave-one-out forecasts

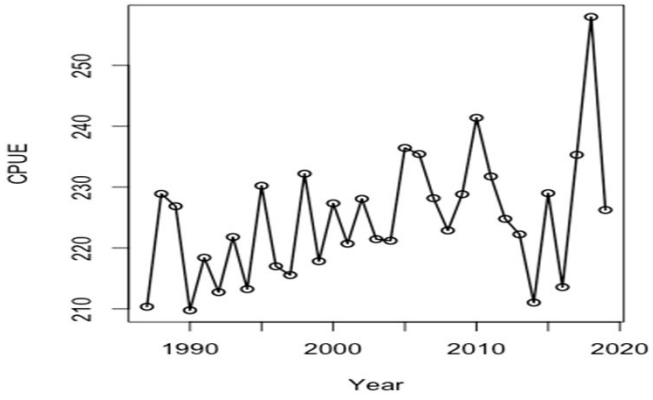
Also tested temperature, salinity, and dissolved oxygen and Louisiana recruitment index as inputs

SEAMAP data
(annual average)

Brown shrimp

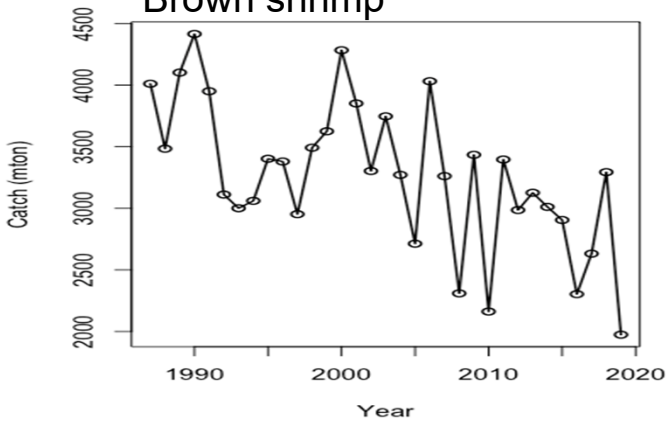


White shrimp

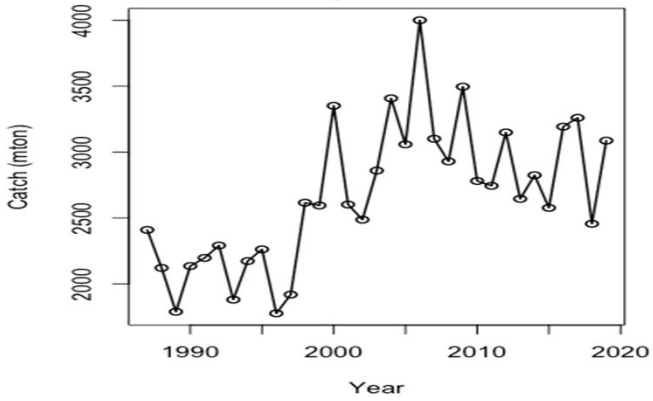


Catch data
(annual average)

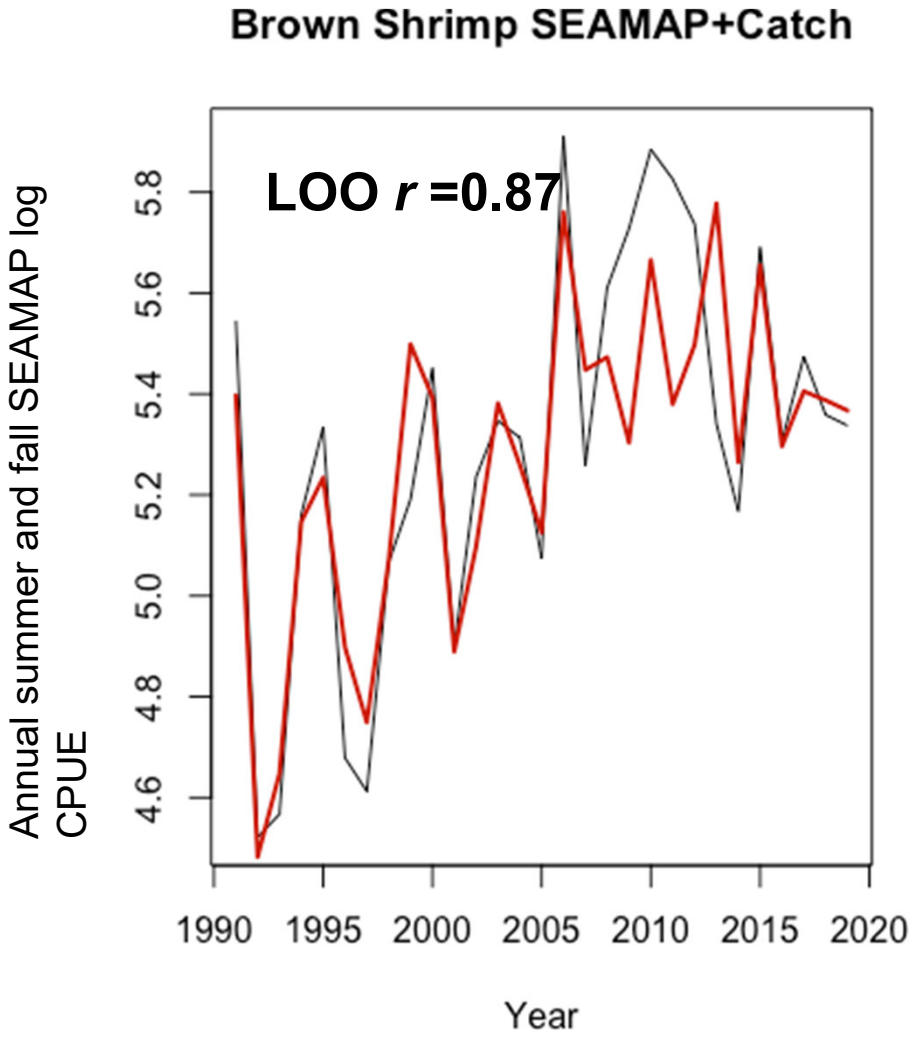
Brown shrimp

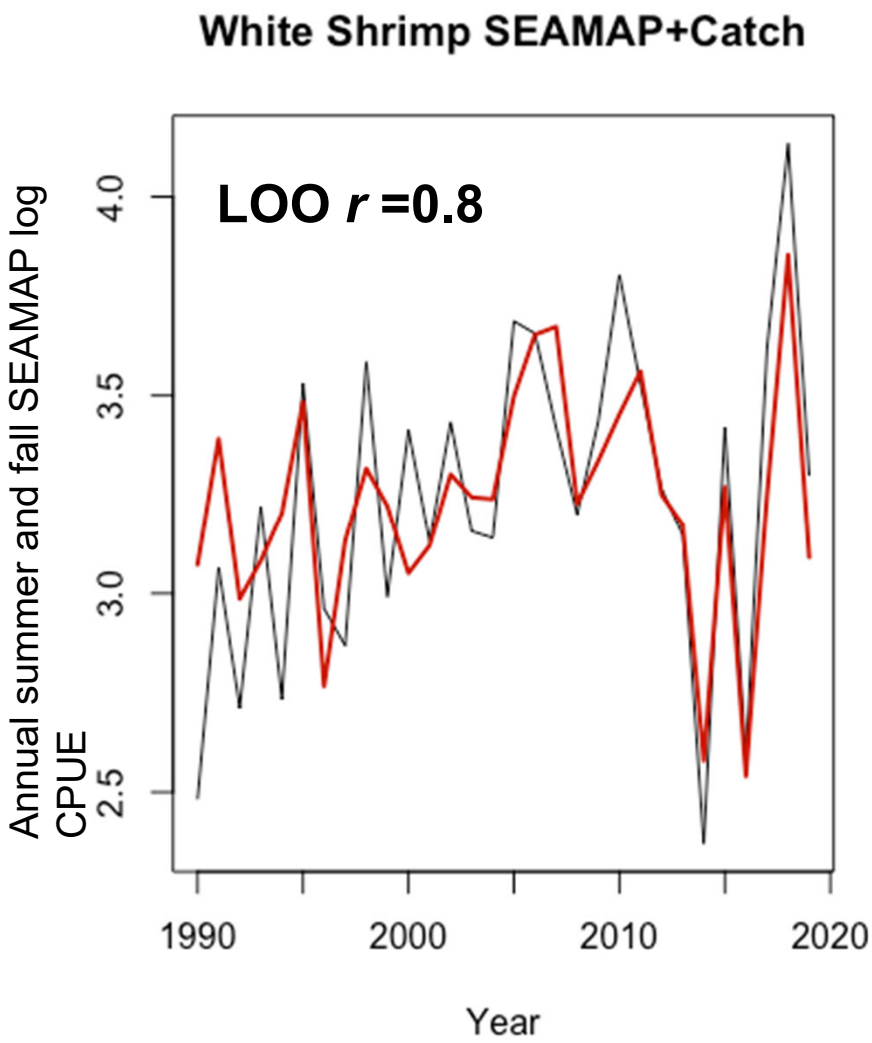


White shrimp



EDM out-of-sample forecasting



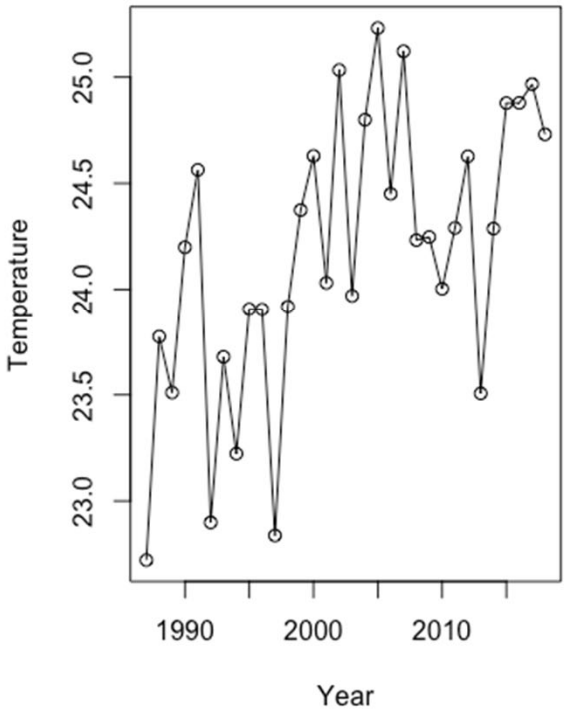


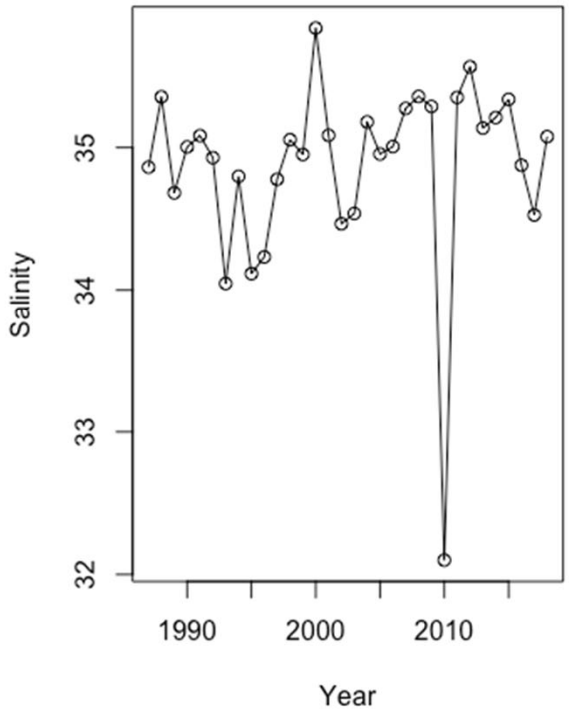
Exploration of predictors other than SEAMAP and catch data

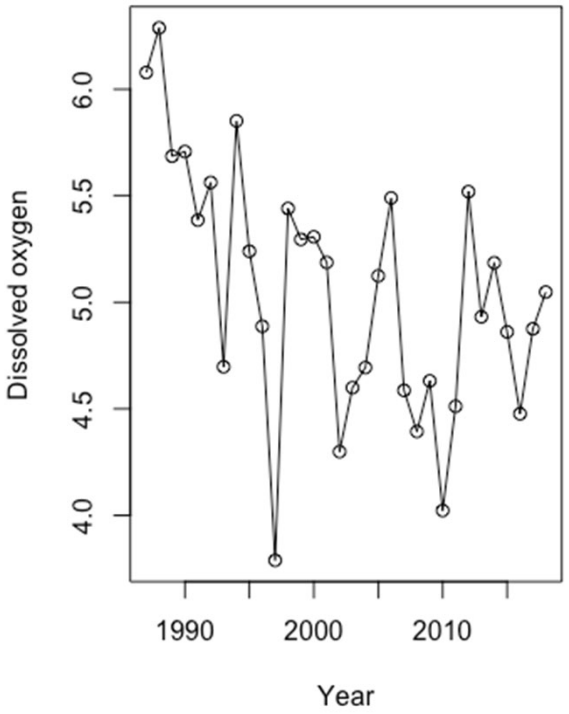
- Environmental variables (bottom temperature, oxygen, salinity)

- Louisiana recruitment indices.

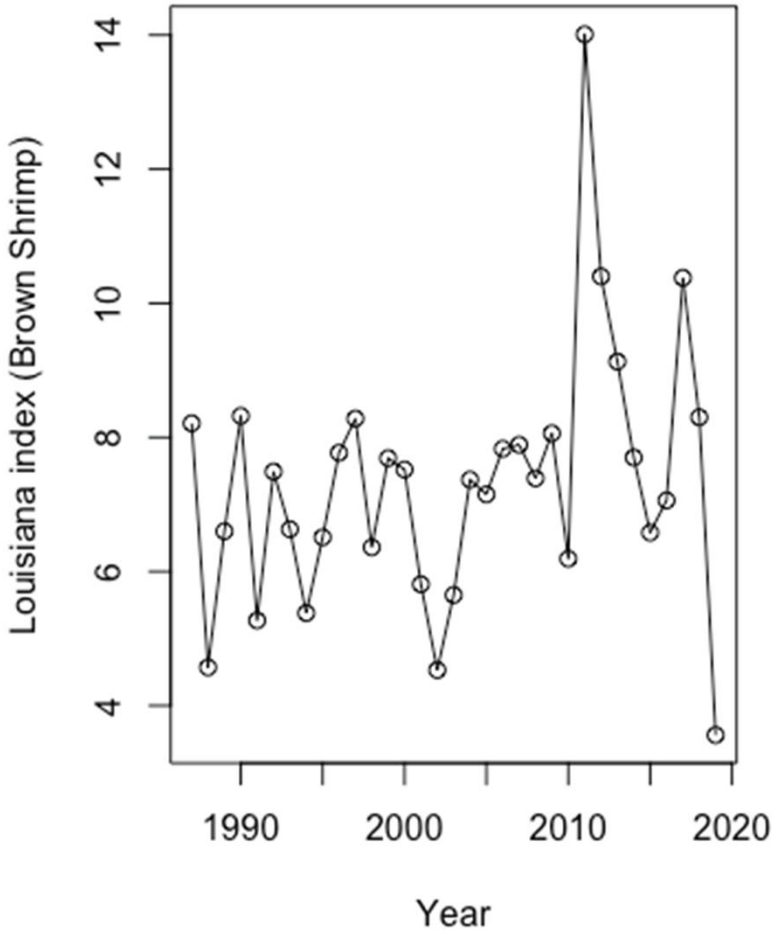
Gulf-mean environmental data

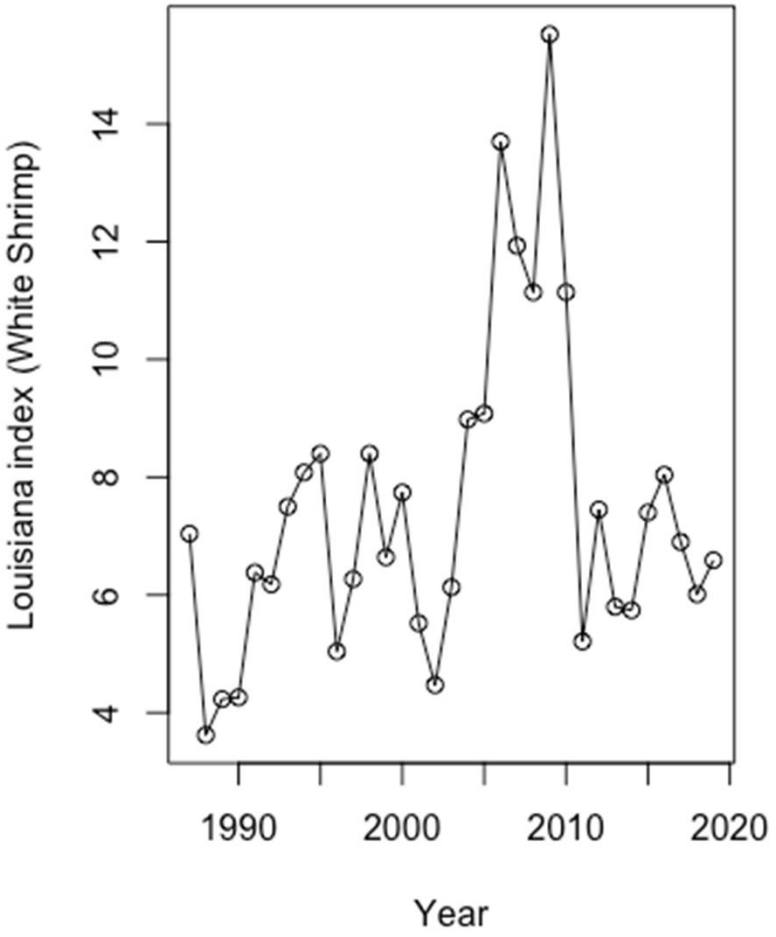




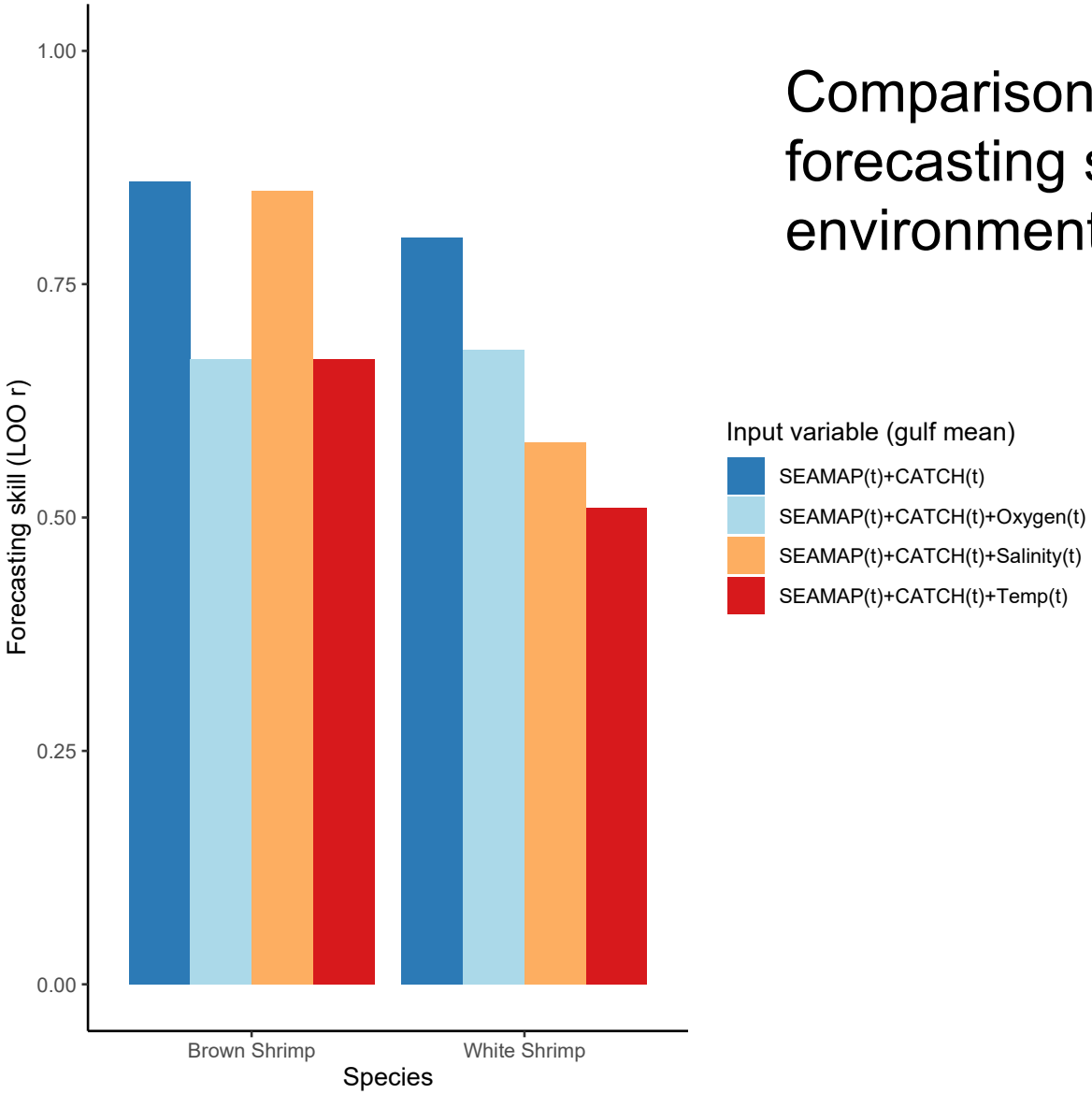


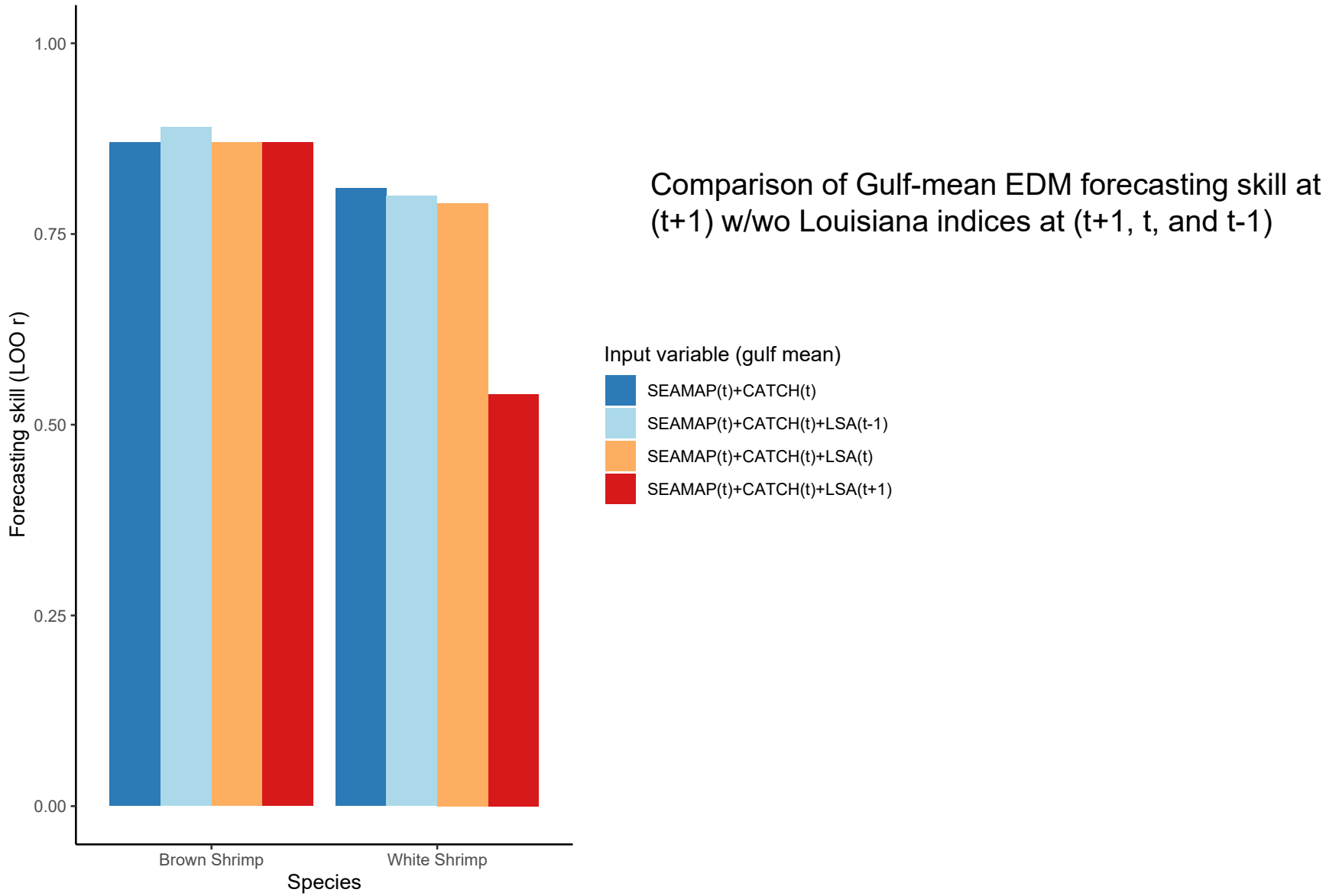
Louisiana survey indices





Comparison of Gulf-mean EDM forecasting skill w/wo environmental variables




Comparison of Gulf-mean EDM forecasting skill at (t+1) w/wo Louisiana indices at (t+1, t, and t-1)
Forecasting skill (LOO r)
1.00
0.75
0.50
0.25
0.00
Brown Shrimp
White Shrimp
Species
Input variable (gulf mean)
SEAMAP(t)+CATCH(t)
SEAMAP(t)+CATCH(t)+LSA(t-1)
SEAMAP(t)+CATCH(t)+LSA(t)
SEAMAP(t)+CATCH(t)+LSA(t+1)

Predicting abundance

Models using SEAMAP and fishery catch data, in general, **outperform** the models including environmental variables (bottom temperature, oxygen, salinity)

Models using SEAMAP and fishery catch data, in general, **perform equally well** with the models including Louisiana recruitment indices.

This **DOES NOT** mean that these other variables are irrelevant! Just means that the information they provide is already contained in the lags of shrimp.

EDM predictions are 2-3x more accurate than production model- because of lags (1-d EDM is about same as production model).

Can do same post-hoc calculations we'd do with a production model (e.g. stock status, etc)-- Use best-fitted EDM to produce benchmarks for constant catch/effort policy.

Summary

Using EDM:

Estimate model of changes in abundance index using catch, SEAMAP

-Prediction accuracy is pretty good ($r>0.8$)

EDM more closely describes what we see in the data, because of the **lags**

(1-d model & production model are about the same)

Use fitted function to determine MSY

Can also evaluate other harvest control rules (e.g. hockey stick, etc)

Summary Workshop Meeting Objectives

- Brief meeting participants on Shrimp Fishery Management Plan and stock assessment requirements.

- Brief meeting participants on Gulf of Mexico Shrimp SEDAR research track assessment planning.

Shrimp Management Strategy Evaluation

- Build off of previous workshops to delve into potential management strategies
- Utilize this information to define scope of SEDAR87 Research Track Assessment
- Define possible models at data scoping call in July based on assessment requirements and available data by species

Shrimp SEDAR Research Track Assessment Planning

- Two meetings including SEFSC, SEDAR, SERO and SSC Chair
  - Identify Data Providers – *done*
  - Potential SEDAR Participants by Stage – *in progress*
    - Work with Council and SERO to appoint – *in progress*
  - Construct a conceptual model along with the data provision and review
  - Data Scoping, Beginning July 2023
  - Stage 2- Data Workshop, September 2023
    - Format and content of data workshops (multiple species considerations)

Background on Management Strategy Evaluation

Management Strategy Evaluation (MSE) – process designed to develop management procedures (MPs) that are robust to uncertainty

1. Identify fishery-specific, stakeholder-defined management objectives
2. Identify relevant uncertainties over which MP should be robust
3. Develop operating models, 'true' states of nature, and condition operating models
4. Identify management procedures that are responsive to stock dynamics (feedback loop)
5. Simulation exercise; summarize and present resulting performance statistics

SEFSC MSE Specialist: Cassidy.Peterson@noaa.gov

Ongoing MSE work at SEFSC

- Dolphin in the South Atlantic
- Stakeholder Workshops
  - South Florida (Oct 2022)
  - Mid-Atlantic (Jan 2023)
  - S New England (Nov 2022)
- Goals
  - Identify conceptual management objectives for the dolphin fishery
  - Identify uncertainties in the stock and fishery
  - Identify participants for continued involvement in the MSE process
  - Introduce the concept of management procedures and management strategy evaluation
- Subsequent MSE analysis

Vision for Gulf of Mexico Shrimp MSE

- SEFSC/SEDAR plans to utilize a portion of the SEDAR87 Data Workshop September 18-22, 2023 for a Stakeholder Working Group in Mobile, AL
  - This would contain some appointed fishermen
  - Open to the public
- Additional Stakeholder Workshops in next fiscal year (2-3 additional)
  - Spread throughout the Gulf of Mexico, targeting primary shrimp ports
  - Working on funding sources for this project
- Goals
  - Define management objectives, available data, and possible model frameworks
  - Develop model for management that fulfills these objectives
- Seeking participants
  - Contact Molly.Stevens@noaa.gov or Cassidy.Peterson@noaa.gov
  - Working to set up registration forms and formal logistics in coming months

Questions?

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