SEDAR 87

Shrimp Stock Assessment History and Future Modeling Approaches

SEFSC Gulf Branch

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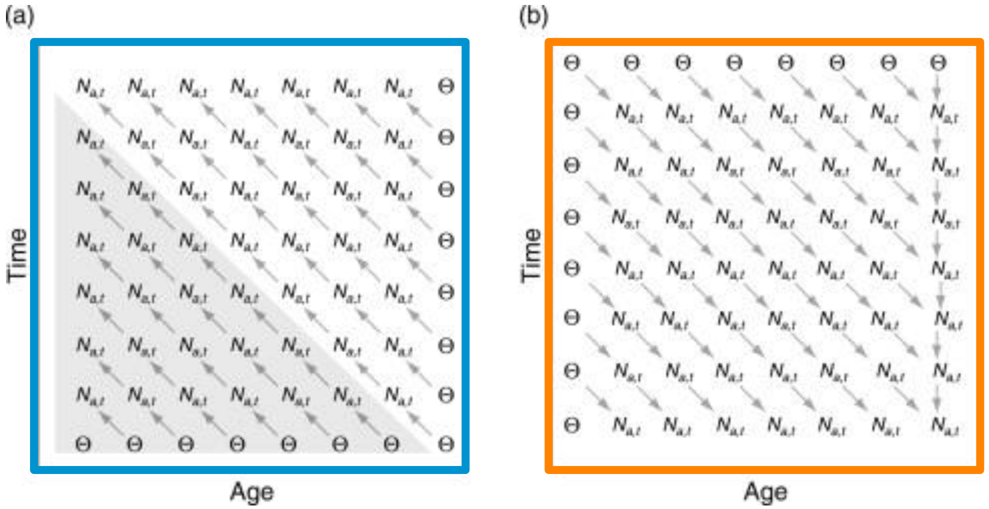
GoM Shrimp Assessments - A brief history

- Virtual Population Analysis (VPA)
  - Nichols 1984; Nichols 1986; Nance 1989; Nance 2008
  - 2009 : internal review – *"the current VPA model cannot be considered to produce a reliable indicator of current shrimp abundance"* – new fisheries models should be investigated
- Stock Synthesis (SS)
  - Hart 2010, 2012, 2017
  - 2019 internal review – *"analytical staff have found several concerning issues that must be addressed before developing new shrimp assessment models"* – move all stocks into a research track



Martell 2008

- Both age structured models – neither adequate for modeling shrimp dynamics

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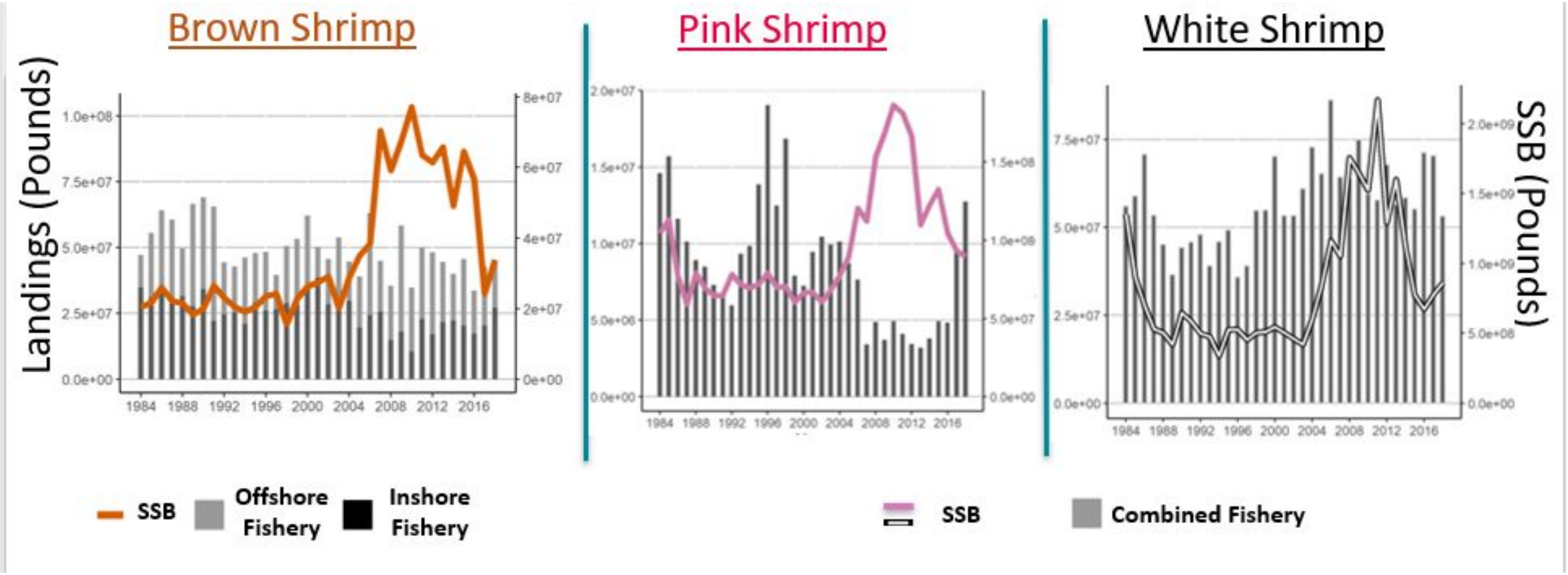
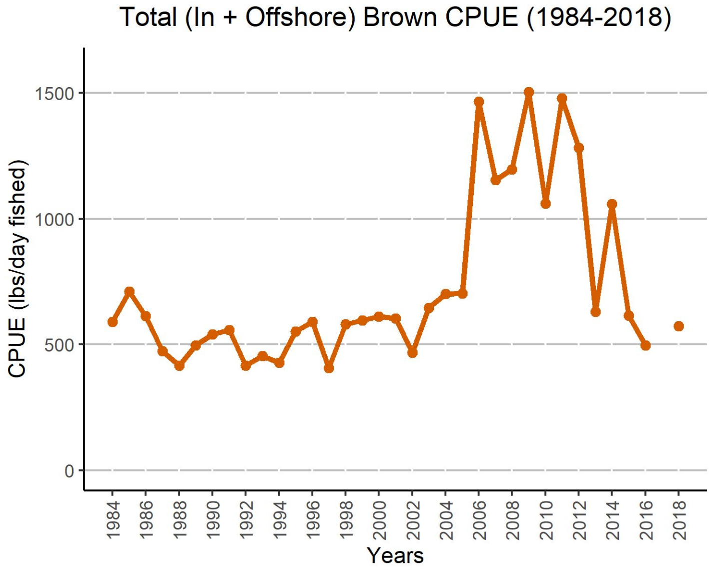
Age structured models

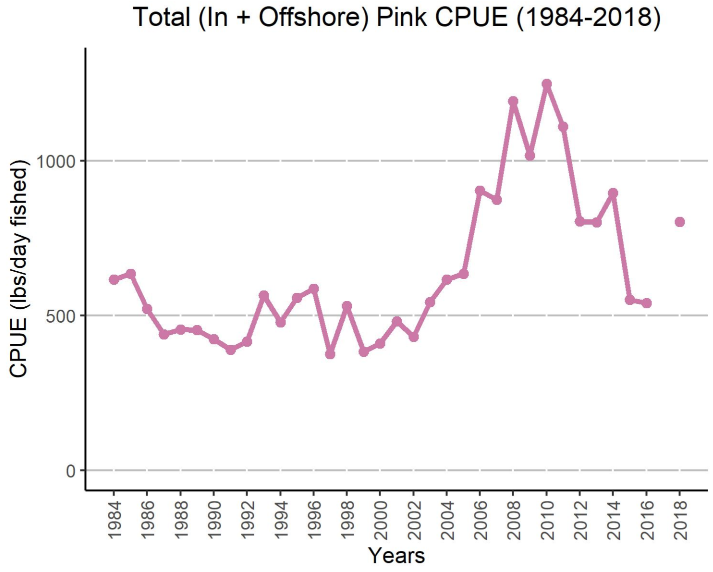
- Why age structured models are not adequate…
  - Shrimp are short lived
  - Age data is lacking
  - Growth is environmentally driven and time-varying (data lacking)
  - Recruitment success largely determined by environmental factors rather than a stock-recruit relationship – *“failure to incorporate environmental signals in SS when the recruitment dynamics are environmentally driven leads to bias in estimates of SSB, R, and F”* (Cao et al. 2016)
  - Lag time is too long to acquire and process the necessary fisheries data to populate an integrated age structured model like SS

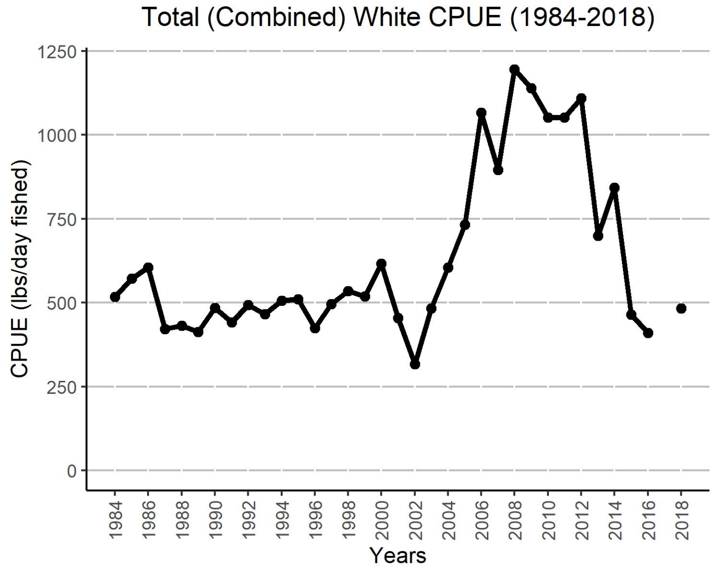
Specific issues with Shrimp SS models

- Model instability, convergence issues
- Insufficient fishery independent data to support monthly models
- Poor diagnostics
- Conflicting indices
- Biomass estimates driven by fishery dependent CPUE
- No apparent relation between catch and biomass


Brown Shrimp
Pink Shrimp
White Shrimp
Landings (Pounds)
SSB (Pounds)
SSB
Offshore Fishery
Inshore Fishery
SSB
Combined Fishery


Total (In + Offshore) Brown CPUE (1984-2018)
CPUE (lbs/day fished)
Years


Total (In + Offshore) Pink CPUE (1984-2018)
CPUE (lbs/day fished)
Years


Total (Combined) White CPUE (1984-2018)
CPUE (lbs/day fished)
Years

Shrimp Management

- Issues with established benchmarks for all three stocks (Amendment 15 & 17B)
- Need for more timely and nimble management advice due to species life history

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Research Track Assessment

- Opportunity to explore and test alternative models
  - JABBA : **J**ust **A**nother **B**ayesian **B**iomass **A**ssessment
  - EDM: **E**mpirical **D**ynamic **M**odeling
  - VAST: **V**ector **A**utoregressive **S**patio-**T**emporal Model

- Simplified dynamics
- Allows us to explore environmental drivers of abundance and nonlinear dynamics

JABBA (Winker et al. 2018)

- Bayesian State-Space Surplus Production Model
  - Assume all individuals in the population are more or less equals – not differentiated by age/size
  - Approximate changes in biomass as a function of the biomass of the preceding year, surplus production and removal by the fishery
  - Can account for both process and observation error
  - Growth, reproduction, M and associated density-dependent processes are inseparably captured in the interplay of the 2 major parameters
    - Intrinsic rate of population increase *r*
    - Carrying capacity *K*
  - Bayesian framework can reduce uncertainties by using reasonably informative priors

JABBA

- **Data requirements**
  - Catch (year and catch by weight aggregated across fleets)
  - CPUE (multiple allowed)
- **Discussion points**
  - Catch time series start year
  - Indices for inclusion
  - Developing priors for *r (intrinsic rate of population increase), K (carrying capacity)* and *φ (initial biomass depletion at the start of the available catch time series)*
    - Incorporate information available from meta-analyses and published literature on historical stock levels and population demographics

EDM (Munch et al. 2017, Tsai et al. 2023)

- Does not assume any set of equations governing the system but recovers the dynamics from time series data
- Framework for analysis and prediction of nonlinear dynamical systems
- Has been shown to outperform parametric models in complex marine systems
- Especially useful for forecasting short-lived species for which long time series of data are available
- May allow for estimation of reference points including MSY and optimal control rules

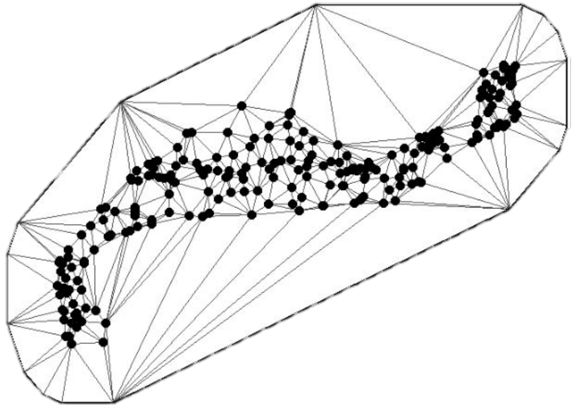
EDM

- **Data requirements**
  - Long time series of data to map the state space of nonlinear systems
  - Can include environmental, economic, and fishery dependent variables that may influence shrimp abundance and landings
  - Do not necessarily need data on all variables to make accurate predictions; can generate analogous model of abundance indices in delay coordinates
- **Discussion points**
  - Top environmental drivers influencing shrimp abundance
  - Top economic drivers influencing shrimping effort and landings
  - Spatial and temporal scale of available indices by species
    - All other data streams must be provided on these scales

VAST (Thorson and Barnett 2017)

- A generalized linear mixed-effects modelling platform that incorporates the functionality of vector autoregression (i.e., each variable in the system is modeled as a function of its past values, as well as the past values of all other variables in the system)
- Assimilates biomass, count, and/or encounter data to estimate population density across space and time for multiple categories (e.g., length classes, surveys) simultaneously
- Habitat variables (e.g., depth, bottom substrate type, temperature and salinity) can be integrated as covariates to evaluate whether their inclusion helps explain the distribution of the species
- This can potentially lead to more precise estimates of abundance, especially when the underlying population distribution is largely dependent on habitat variables

VAST



- Index-standardization
  - "controls for" the effect of catchability covariates – i.e., filters out these components of covariation
  - "conditions upon" the effect of habitat covariates – i.e., uses information about habitat covariates to improve performance when predicting population density

VAST

- **Data requirements**
  - Fishery independent survey data (biomass data, count data and encounter/non-encounter data)
  - Spatially explicit time series of factors that might influence shrimp distribution and/or catchability (e.g., water temperature, salinity, depth, and substrate type)
  - Can include multiple species/size/survey* categories
- **Discussion points**
  - Ecology of the different species
  - Upper/lower tolerance levels of environmental drivers (by species/size class)
  - Spatial and temporal scale at which these drivers impact shrimp populations
  - Identifying covariates as affecting catchability vs. density

*requires that both gears sample nearby locations in the same year, where differences in the survey response at these “calibration samples” can inform the difference in catchability among gears

Terms of Reference

- **Effort and Landings**

5. Provide commercial catch statistics for each stock where possible. Document species-specific issues.
   - Provide maps io fishery effort and harvest by sector and/or gear by species, where possible.
   - Provide estimates of uncertainty around each set of landings and effort estimates.

Terms of Reference

- **Indices**

4. Provide measures of population abundance that are appropriate for stock assessment.
    - Consider all available and relevant fishery-dependent and -independent data sources
    - Document all programs evaluated; address program objectives, methods, coverage, sampling intensity, and other relevant characteristics.
    - Provide maps of fishery and independent survey coverage, where possible.
    - Develop fishery and survey CPUE indices by appropriate strata (e.g., area) and include measures of precision and accuracy.
    - Provide appropriate measures of uncertainty for the abundance indices to be used in stock assessment models.
    - Document pros and cons of available indices regarding their ability to represent abundance.
    - For recommended indices, document any known or suspected temporal patterns in catchability not accounted for by standardization.
    - Provide appropriate measures of uncertainty for the abundance indices.

Terms of Reference

- **Economics and Other Social Sciences**

7. Integrate economists into the stock assessment model development process in order to explore models that can address questions such as benefits of seasonal/spatial closures, impacts of fuel prices on total effort, and ex-vessel prices of different market categories, if possible.
    - Detail the early 2000 industry consolidation and impacts of ex-vessel price on effort

Terms of Reference

- **Environment and Industry**

3. Create a conceptual model based on feedback from a variety of industry representatives in the Data Workshop to capture their institutional knowledge.

6. Describe any known evidence regarding ecosystem, climate, species interactions, habitat considerations, species range modifications and/or episodic events that would reasonably be expected to affect shrimp population dynamics, and the effectiveness of reference points.

   - Provide species envelopes, i.e. minimum and maximum values of environmental boundaries (e.g. depth, temperature, substrate, relief) based on observations of occurrence.
   - Develop hypotheses to link the ecosystem and climatic events identified in addressing this TOR to population and fishery parameters that can be evaluated and modeled.

Terms of Reference

- **General TORs**

1. Gather data through 2022 (where possible) for Gulf of Mexico White, Pink, and Brown shrimp.

2. Review, discuss, and tabulate available life history information for each stock being assessed.
   - Evaluate growth data where available. Determine the adequacy of available life history information for different types of assessment or population model
   - Evaluate and discuss the sources of uncertainty and error, and data limitations (such as temporal and spatial coverage) for each data source.

8. Provide recommendations for future research in areas such as sampling, fishery monitoring, and stock assessment.

9. Prepare a Data Workshop report providing complete documentation of workshop actions and decisions in accordance with project schedule deadlines.

Lead Analyst and Data Expert Roles

Please refer your questions to the appropriate people:

Lead Analysts are here to answer modeling and data stratification/formatting questions

Workgroups contain Data Experts and are here to answer data-related questions

Questions ?

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